Building Information Modelling for the Optimisation of Facilities Management: A Case Study Review

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Abstract
Building Information Modelling (BIM) enables a holistic approach to facility design, construction, and management. However, present BIM implementation largely focuses on just the design and construction phases of the project lifecycle, with design and engineering teams using BIM three-dimensional information to analyse and predict facility performance. Information modelling can assist building operators in making existing data collection, and asset management processes, more efficient, and can improve maintenance procedures, allowing whole-life costing evaluation. Moreover, the incorporation of operational information within the model, from the earliest stages of design, facilitates end users, who commission/own, manage, and maintain a large stock of buildings, though all lifecycle stages, to optimise future decisions concerning asset management and maintenance. To understand the opportunities of using BIM in assisting building operators to make decisions about lifetime management and maintenance, an educational-based case study is used to review Birmingham City University's (BCU) use of BIM in the development of the multi-disciplinary Birmingham Institute of Art and Design (BIAD). The study considers the necessary levels of detail at each stage of the project lifecycle, and the supply chain's adaptive journey of collaborating within a BIM environment. Qualitative data gained through stakeholder interviews and thematic mapping of associated documents and model structures; highlight several core areas of consideration to facilitate BIM-enabled Facilities Management. This paper discusses a number of successes and challenges, in addition to offering lessons learned for future BIM adoption.

Keywords: Information modelling, operation and maintenance, lifecycle

1 Introduction

The UK Construction sector has long been critiqued for failing to produce built assets that are on time, within budget, and that successfully meet the standards and requirements defined by the user (Latham, 1994; Egan, 1997; Egan, 1998). In 2011, the UK Government decided to address these challenges by mandating Building Information Modelling (BIM) as a route to increase the efficiencies and reduced related costs. By the year 2016, 'fully collaborative 3D BIM' will be required as a method of producing product and asset information for all publicly funded projects (HM Government, 2011). These initial targets have evolved to specify an expected reduction in costs, through the use of BIM, of 33% by 2025 (HM Government, 2013); a target, however, that does not clarify if the critical savings should be made in the initial Capital Expenditure (CAPEX) phase, or post-handover during the Operational Expenditure (OPEX) phase.

If we consider that 85% of all lifecycle costs are accumulated during the operational phase of an asset (Korpela & Miettinen, 2013), it makes sense to shift focus on using information models throughout the operation and maintenance phases in order to support total project cost reduction. However, adopting advanced information modelling techniques within these phases requires an understanding of the process and interactions of stakeholders, as well as detailed requirements for relevant asset data.

Facilities Management (FM) involves many stakeholders responsible for a variety of tasks ranging from the *hard* maintenance issues, such as physical maintenance of a door (Olomolaiye, et al., 2004), to the *soft* maintenance issues, such as managing the organisation of occupant functions, or space efficiencies (Olomolaiye, et al., 2004; Arayici, et al., 2012) It is argued that using information modelling techniques allows owners and operators to mitigate lifecycle costs (Rundell, 2006); optimise resource efficiencies (Schuh, et al., 2014) and develop an integrated approach to capturing and reusing knowledge and information about building components and systems (Motawa & Almarshad, 2013). The more appropriate information is available to Facilities Management – both semantically and syntactically – at the right time and in the right format, the greater the opportunity for the refinement of processes throughout the operational phase of an asset's life.

Despite much commentary concerning the potential benefits of BIM for Facilities Management, there is little evidence of its successful use on projects throughout the lifecycle of a built asset. Using the case study of Birmingham City University's City Centre Campus redevelopment, this research aims to collate a more informative representation of how information modelling is adopted in the design and construction stages to support proactive and preventative maintenance during the occupancy and operation stage. Specifically, the first phase Parkside Building development project was chosen as the focus of this study, to learn how BIM strategies can be used to strengthen approaches to the management of large stocks of building, owned and operated by a single FM team.

2 The Parkside Building Development

Birmingham City University (BCU) – one of the UK's largest universities – serves over 25,000 students. Pressure is constantly placed onto the board and associated decision-makers to continually strive for better; more advanced facilities containing the latest, 'state-of-the-art' technologies. For the university to maintain its status as an innovative institution, which puts its students at the forefront of business decisions, the University committed to an order of capital works valuing at £180million to modernize a number of assets spaced around the city that were unfit for purpose, whilst also adding two brand new facilities within the heart of the city centre campus (Fillingham, et al., 2014).

The first phase in this two-phase project – the 'Parkside Building Development' – included the design and construction of the Birmingham Institute of Art and Design (BIAD), and a new Student Centre to provide additional teaching and administrative facilities. Various media spaces, such as TV, Radio and 'green-screen' studios, as well as workshops for rapid prototyping, woodwork and ceramics (Hall, 2015), posed specific challenges for the services and operative systems design, however the building was completed on time, in June 2013, and was awarded BREEAM's 'Excellent' rating, and an EPC rating of 'B' (Fillingham, et al., 2014).

At the start of the project, the University's client team stated their goal for a solution that would enable them to better manage the building throughout its operational life. The in-house Estates team has structured its operational information in a rudimentary, paper-based file system for many years. BIM provided them with an opportunity to develop their existing methods of data collection, whilst consolidating and re-aligning their processes used to manage and maintain their data structures.

In addition to delivering a 'state-of-the-art' custom built asset, the strategy for hand-over required a 'data-rich' as-built model, containing sufficient number objects to establish a link between all project Operation and Maintenance (O&M) documents and corresponding object geometry. The University's Estates team required a single source of information in the form of an electronic O&M database that would enable them to move from a typically reactive maintenance program to more effective predictive and preventative maintenance.

3 Research Methodology

The goal of this study is to investigate how the adoption of information management strategies allowed the Parkside project team to introduce innovative methods of delivering and maintaining the assets; with an intention to identify areas of change and lessons learned to inform future projects. Semi-structured interviews were conducted with members of the BCU Facilities Management Team, the Lead Architect, Structural Engineers, Mechanical and Electrical Engineers, the Quantity Surveyor and the Lead Contractor; to document each of the stakeholder's learning journey, as well as the recognized benefits, challenges and lessons learned. The interview questions were structured to reflect the process development of the RIBA Plan of Work[1] stages from concept and design development, to construction, commissioning and handover (Royal Institute of British Architects, 2013). The questions addressed key tasks in adopting the 'state-of-the-art' to itemise how the BIM implementation potentially changed the stakeholders' perceptions and their work. Concept mapping was used to analyze the responses and identify research themes relating to the phenomenon of information management within FM. Ideas were pinpointed to further understand the challenges in using BIM to optimise the operational management of assets.

4 Process Analysis

The intent to adopt BIM was three years ahead of the publication of the UK Government's BIM Strategy, which subsequently acted as a catalyst for the wider adoption within the UK construction sector (Fillingham, et al., 2014). Before the design commenced, a set of workshops helped the team discuss the client's intentions for the built asset, and also learn more about each other's daily tasks and objectives. Understanding better about the teams' comparative strengths and weaknesses was a critical starting point for the project, and it aided the teams to collaborate more effectively to deliver a well-coordinated project, compared to more fragmented and traditional discipline-based practice.

BCU's request for a BIM-platform at the time was met with hesitation and skepticism. Although it potentially meant that down the line, the University might encounter difficulties in retaining the data in the proprietary model format, BCU felt it was vital that the model was developed in a stable and familiar environment. The use of digital technologies and information modelling were seen as 'project unknowns', particularly in the long-term asset data use after the handover, which was a major factor for altering the mindset and the environment within which the project progressed.

Procured as a two-stage, Design and Build contract, the original design team was replaced at the technical design stage, or Stage E of the 2012 RIBA Plan of Work, thus progressing to a contractor-led construction phase. Although offering certain advantages for cost and program management, the transitional hand-over from design into construction lead to some unwanted rework and realignment. The process of design and construction through to hand-over and operation is discussed in the following sections.

4.1 Pre-Handover Development

The University's intention to use BIM within FM was clear at the initial design stages. Despite this, however, when methods for creating and sharing information needed to be standardized, particularly when the initial BIM protocols were written, confusion over processes led to numerous misunderstandings between stakeholder groups; resulting in complex information coordination issues. Lack of any initial formal guidance to appropriately set up a project, resulted in constant process iterations. To clarify the work process, the client requested that the design team continually meet to discuss the protocol and collaboratively refine the project execution plans. Throughout the majority of the design and development phase, all team members were involved in an iterative process of formalizing creation and exchange requirements.

Developing a project design within the digitally enabled BIM environment brought opportunities to relatively quickly advance existing practices, both within the project team

[1] http://www.ribaplanofwork.com/

and beyond the bounds of the supply team, i.e. outwardly to the University community. Weekly meetings gathered the representatives of each core stakeholder group to review the design. The participants used the model to discuss and refine specific design elements, check for 'clash detection', or simulate specific operational activities. An extranet system was created to facilitate a 'Common Data Environment', allowing easy access to the same raw modelling data for all parties. Although the idea of a common data environment is not new (British Standard Institute, 2007), a single coordinated location for the project information meant structuring the data in such a manner that allowed objects and associated classifications to be more easily itemized. Single discipline model files were issued and uploaded to the extranet prior to the weekly review meetings so that they may be coordinated, and the clash analysis could be prepared, ready for discussion.

Figure 1. Federated model files used to find areas of 'clash' within proposed design scheme **(Draper, 2015).**

Figure 1 illustrates the collision areas when the federated arcitectural and mechanical model files were coordinated for review. Ability to directly alter and amend these 'clash' areas during the collaborative design review session, drastically reduced the post-meeting rework time and advanced quality assurance procedures. Using the coordinated model allowed the project team to reiterate the client's intentions for post-handover use and align the work to date with the driver of BIM for FM.

The model was continually used, from the conceptual design to the construction documentation to inform and discuss with the University stakeholders. Although traditional practice consultation of the affected parties is necessary with larger design schemes, Lead Architect, James Hall, commented that it was "probably the biggest exercise in stakeholder engagement that we've ever done as a practice" (Hall, J., 2013). Rendered images and animated walk-through were created from the federated model files, providing a combined visual representation of the structural, architectural, mechanical, electrical, and landscape design solutions of the proposed design scheme. Both staff members and students were invited to virtually inhabit the designed spaces and provide relevant feedback before any site works commenced. With the significant offerings of Virtual Reality in creating an immersive user experience, the question remains whether the model could have been used to achieve more extensive advantage throughout the developmental process.

As the project transitioned into the construction phase, the design team passed the model ownership and management to the Lead Contractor for both Phase 1 and Phase 2 of the City Centre Campus Development. At this stage, the University Client Team felt it was necessary to extend their internal BIM-capability, and employed the BIM Manager, who was placed within the Estates and Facilities department. The University saw this appointment as crucial to continue with the 'good management practices' established in the initial stages of the Parkside project. From this stage, the BIM Manager monitored all BIM deliverables, ensuring that the supply chain maintained the required level of adoption that is ensuring that developed models and all associated documentation, were at an appropriate level of detail to the associated stage. The BIM Manager's responsibility was therefore critical in terms of aligning model deliverables to the University FM Team's standard, as demanded for all future operations.

However, the model handover from the design to the construction team was particularly contentious. In preparation for tender, the Lead Contractor sought guidance from an external consultant, who helped with their tender documentation development in advancing their capability and understanding of BIM. Discussions regarding the model quality assurance led the Lead Contractor to be critical of the adopted modelling methods and information classification used in the design phase. Once the contract had been awarded, the protocols were entirely rewritten to support the contractor's perspective. Although this decision aligned with a mandated, consistent and controlled process for construction, revising the protocols caused some friction with the new design team. In addition, to meet the construction protocols standards, a large proportion of the design model had to be significantly reworked as well, resulting in an unwanted delay.

When commenting on the design model handover, members of the construction team made it evident that bringing them into the project at an earlier stage, would have increased the awareness of existing protocols and allowed for more effective collaboration between the two teams.

Reviewing the construction schedule within the 3D model prior to site works helped the supply teams understand construction-critical elements of the design organize necessary training and prepare off-site. Consequently, there were few coordination issues discussed with the design team, which is overall unusual for projects of this size and complexity with traditional methods of construction.

The model however, was not used to manage the daily works on site. At the time of construction, the contractors had no intention to use digital technologies and information management in the manner that BIM offered. For them, on-site BIM meant additional time-consuming administration, and therefore avoided on the Parkside Building development. When asked about their decision, the contractors admitted they would begin to mandate the BIM use on site, and consequently did so – to an extent – on Phase 2 of the City Centre Campus Development.

4.2 Post-Handover Development

In preparation for handover of the completed Parkside building, the team was also required to deliver the model, ensuring that all raw data held within its structure was not only consistent, but also accurate in terms of the 'as-built' facility. If the model was to be fully used for operational management and maintenance, it was essential that it was an exact digital representation of the as-built conditions. For the client, it was imperative to ensure the model was reliable enabling them to take it forward and advance other University-wide systems.

Validating the model, however, caused great concern for the project team. Being one of the first fully coordinated BIM projects in the UK meant that little guidance from previous projects could be drawn upon concerning how specific areas should correctly define the term 'as-built'. There will always be tolerances that govern the accuracy of the physical built asset, yet to validate the model, it was key for the project team to have a clear process for when and how to update the model to reflect the as-built conditions. Refining the validation requirements proved to be quite a challenging and extensive process that required further work even beyond the completion of construction. The protocol was once again iterated to facilitate this project stage.

Figure 2. Model view of wiring cable trays captured and coordinated (as-built conditions) **(Hall, 2015)**.

To maintain the accuracy of the collated record data for use post-handover, the University introduced a requirement to take photographs to capture the conditions above ceiling tiles and below flooring constructs (figure 2). Subsequent referencing of these photographic files within the model created a simplistic approach to detailing the unknown, without overloading the level of detail of the model; i.e. technicians within the facilities team now have the ability to discern what lies above and below fixed construction units, and analyze the service-maintenance process, without having to physically come to the site.

LiDAR technologies, such as Laser Scanning were considered at the time as a secondary method of validation. The project team – specifically the clients – saw a vast opportunities that LiDAR offered, however, at the time of construction, the complexities of managing the existing program was such that the introduction of a laser scanning surveying would have only increased the number of conflictions on site. For future projects, the University has committed to Laser Scanning surveys as an accurate and reliable method of capturing as-built conditions, and has developed their internal capability of managing the raw data for historical auditing purposes.

4.3 FM Involvement

Birmingham City University made it clear that their main objective was to have usable data that could be transferrable and used for the operational maintenance and management of the asset, after the handover (Fillingham, et al., 2014). It was critical, therefore, that the process of creation incorporated the ideals of facilities management; enabling the end-product to be holistically driven to meet exacting operational requirements. To meet these expectations, the University mandated ‘Soft Landings’, a process originally developed by Building Services Research and Information Association (BSRIA), and consequently mandated by the UK Government; aiming to involve the end-users and operators within the process of design and construction. The next section explores how the process of ‘Soft Landings’ altered the traditional practices of the project team working within the BIM-enabled environment.

4.3.1 A ‘Soft Landings’ Approach

The ultimate goal for the University was to have a built facility that was designed to the specification and completed within time, and on budget. Construction projects are renowned for being overly complex and laden with tensions stemming from the lack of communication between parties. By mandating a process that incorporated stakeholder groups, otherwise left out of the design process – such as the individual members of the facilities maintenance team – from the earliest phase of the lifecycle, BCU was ensuring that their completed asset not only learned from past failings, but lived up to the expectation of the user; Soft Landings truly providing a route to the end.

End-of-stage review meetings meant that lessons learned from both University teaching staff and facilities management operatives could be captured and fed into further developments. Experiential knowledge, such as understanding how a cleaner might maneuver around plant rooms or what access the maintenance may need to replace a component. Obtaining such knowledge at regular intervals throughout the design process improved the final solution from an FM perspective.

When it came to quantifying the process, by which the model was going to be used, the facilities team was consulted for an opportunity to test various software platforms and output scenarios. Although the commercial software, used to support the BIM model, changed several times during the project, 'Soft Landings' facilitated the trialing of the end-process, which meant that the final focus was on how to get the best from the model. Figure 3 illustrates a model view of the Parkside Building's plant room with a complex layout requiring ongoing maintenance and management. Without this resolute perspective of 'operation', the success of the model throughout the whole life would prematurely be reduced.

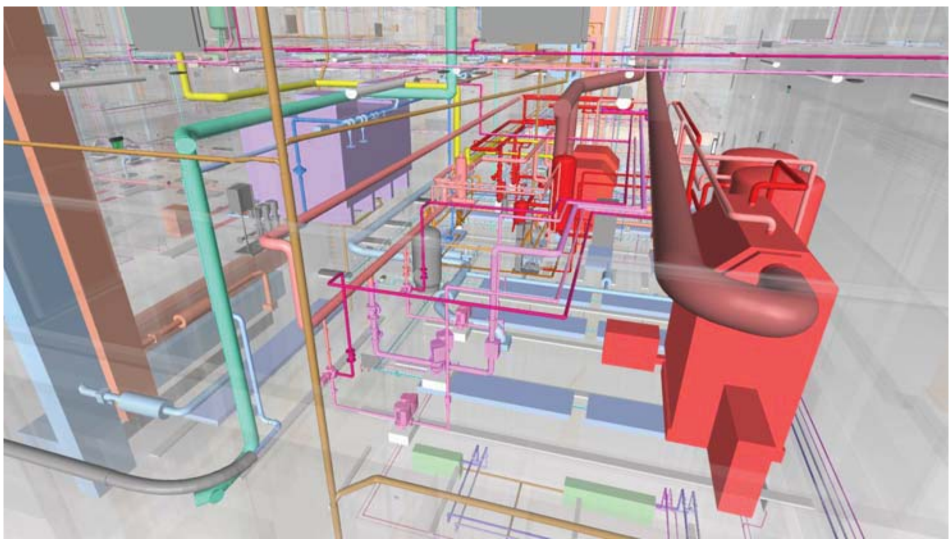

Figure 3. Model views used by the Estates department for training and maintenance preparation **(Draper, 2015)**.

Preparing the models for operation was a process of continual trial and error. Configuring the data meant that 'lists' of required element parameters had to be written and distributed to all suppliers. The intent was that all capable suppliers submit the digital 'asset' in a model format with all associated parameters written into the data structure. This unfortunately, was not as successful as originally planned because many suppliers were unable to produce a digital model to the level of detail required by the client. This also meant the University's BIM Manager had to take ownership of both modelling and coordinating much of the information while the asset 'lists' underwent a series of changes and developments. Iterative learning offered the client team an opportunity to critically evaluate exactly what their intention was for the asset information.

'Soft Landings' was still a key part of comprehensively preparing for handover and the facility's operational life. Bringing the expertise and experiential knowledge from the University's facilities team altered many stakeholder perspectives, and enabled the designers to critique the solution with a heightened set of priorities. Although many lessons have been learnt, it will take three years of supported occupancy to interpret and evaluate BIM from an operational point of view.

5 Challenges and Insight

Lessons learned in the context of complex and innovative projects, such as the Parkside Building project, aim to inform project stakeholders further about the best practices to maximise process efficiency in the future.

5.1 Strategies and Protocols

Understanding the daily and long-term responsibilities of the design, construction and operation teams helps to create a defined set of information and process requirements. Productivity can be increased through the managed manipulation of project data, without overly complicating the processes because of assumed BIM potential beyond what is normally expected.

Although the principle protocols for Phase 1 of the Parkside Building project were created with initial trepidation, continually revisiting of the content, i.e. exploring if the principles remained relevant and strategic for the project at that specific stage, meant that the complete project team had a greater awareness of the how, what, when and who of project details. Considering that there was limited experience of BIM preceding this project, the advancement of understanding, through application, led to a set of individuals who could accurately create and reuse information, as per the client's specification; despite it initially being an unfamiliar environment. Learning from Phase 1 has been drawn upon for the specification of the protocols and BIM deliverables for Phase 2 of the development, further advancing the methods of data exchange and overall project progression.

5.2 Collaboration

Information modelling facilitates an evolution of working strategies and project delivery approaches. Despite the advancement of state-of-the-art technologies pushing innovative methods in construction ever further, there is still a requirement for individuals to work together as a team. Maintaining a 'forthcoming' attitude can have a greater influence on the success of a project. Informed clients, who are aware of their information goals and the processes by which they could be achieved, offer greater opportunities for developing an open and collaborative-driven method of working. Only by ensuring early stakeholder involvement, and by allowing processes to be cross-influenced by the experience of others, will the greatest benefit from working with BIM be realized.

5.3 Common Data Environment

A core area of BIM as a process, is the advanced utilisation of information; i.e. data, structured in a way that is syntactically accessible to all parties, and semantically usable as a basis for more intelligent decision-making. Developing precise methods for the creation and exchange of data, within the earliest stages of strategic conception and definition process, eases the transition of information throughout development. All stakeholders having access to common knowledge, as in the case of BCU, meant that discussions were undertaken more freely and issues were resolved far quicker; allowing more time to discuss the design issues. For example, disabling automatic extraction of layers, levels and elements caused much frustration because expectations of model exchange were not defined. Both the designers and consultants were further required to develop an information exchange method to facilitate each party's work without extracting capabilities within the model-space.

It is essential to ensure flexibility in the design to allow for future conflicts to be resolved with less concern. The changing landscape of technology and the fast-passed process of innovation hold the potential for restricting the usability of data in the future. Making decisions with an awareness to limitations of software, or possible changes in 'open-format' standards, allows for a smoother transition into future solutions, and extends the longevity of value that can be gained from the model and its information.

5.4 Quantifying Cost

Digitally investigating elements for their cost relationships, allowed the Quantity Surveyors a greater appreciation of the capital demands of the project at a far earlier stage in its development. Quick access to initial designs, meant more accurate rudimentary analyses could be carried out, and feedback comments and improvements could be passed directly to the designers. The opportunity to challenge specific elements of the proposed scheme gave the entire project team a more commercial outlook, and facilitated continual evaluation of the necessity of items; resulting in the reduction of abortive work. Insightful conversations about quantities and costs were informed through the modelling interface, which led to a greater sense of ownership, ultimately improving the project outcome.

Initially the model was seen as a burden, with stakeholders feeling a sense of hesitation due to a lack of trust of the information – stemming from inexperience. However, as the project developed, and as the capability and trust of stakeholders advanced, the core activity was facilitated by the model, with traditional paper-based methods maintained as a 'sense-check'.

5.5 Thermal Modelling

One of the main flaws of BIM discovered during this project was the inability to integrate the thermal modelling analysis within the federated model. This links back to the discipline within the modeling process itself, where certain information was unable to be translated from the mandated software platform, into the thermal analysis software. The team found it quite disappointing, especially after dedicating a large amount of time enhancing the quality of the model, that they were again later required to largely restructure, to enable a construction software with a different classification system to read and manipulate it. To create a truly holistic modelling capability, a solution is needed from the industry to answer the question of how best to integrate the technical modelling, with the specialist strategies for environmental and performance analysis.

5.6 Model Validation

Discussions regularly took place to progressively re-evaluate the protocol parameters, developing them at each stage. A lack of discipline within the modelling itself often caused unnecessary confusion; since elements were not as robust as they sometimes needed to be, which caused inherent issues during later stages. Clear confidence in the content of the model was essential for the team's willingness to continue to work collaboratively. Model accuracy is still a challenge if the industry is to achieve the necessary confidence in the modelling process itself. By capturing knowledge and experiences from each discipline, and by feeding them back into the structure, the robustness of the protocol documents ensured that a 'single truth' was managed by all.

5.7 Designing for FM

Creating information with the perspective of whole life operational use of the model enabled the client team to evaluate their systematic process for managing their portfolio of assets. Testing the capability of BIM in terms of incorporation and classification of information led to the development of intelligent solutions for the 'in-use' phase of the asset; i.e. moving away from the stagnated repository of information. Understanding the base-level metrics required by the facilities maintenance technicians and using them to develop a strategy and a set of outputs resulted in a comprehensive deliverable of both physical asset and digital tool.

6 Summary and Conclusions

When considering the demands of facilities management, in terms of both the technical requirement for undertaking the work, such as the specific technicalities of maintaining a ventilation unit, and the information requirements for that work, a flexible approach to developing ideas and priorities is beneficial. Building Information Modelling offers an opportunity to explore the ideals of, and application within, facilities management, and simulate innovative practices without any negative implication on either cost or time.

The advanced use of information, created and exchanged in a timely manner, not only allows facilities management to be brought to the forefront of design decisions, but also does so in a way that forces disparate parties to collaborate, discover, and share. Although Birmingham City University's Parkside Building project facilitated iterative learning, the individual stakeholder groups were given a unique opportunity to test their appreciation for the whole-life in a supportive environment. Disciplines that would usually work within their own bounds, not comprehending the on-going operation of a facility when in-use, were obligated to alter their perspective of delivery, and start with the end in mind.

The journey of discovering precisely how the potential for direct learning could be supported within the model-space is an incomplete one. BCU's client team has since emphasized their desire to further explore how their technicians can use this volume of generated data to support daily on-site activities. With the facility in operation and live data continually being captured – whether through rudimentary processes such as pen on paper, or advanced input within the model database – the future for further optimisation is one of occasion and thrilling opportunity.

This case study has highlighted the opportunities for innovative project development within the field of construction, when mandating and utilising the process of BIM for Facilities Management. Through the exploration of a single project, it has concluded that although there are numerous benefits from BIM such as heightened collaboration and advanced awareness of long-term processes, there are still areas for progression and refinement. BIM for FM is a subject matter that has only recently begun to be explored. It is clear, however, that only by learning from a range of case examples will FM be able to develop future state-of-the-art solutions to achieve the long-term saving requirements of our assets.

7 References

Arayici, Y., Onyenobi, T. & Egbu, C., (2012). Building Information Modelling (BIM) for Facilities Management (FM): The Mediacity Case Study Approach. *International Journal of 3-D Information Modelling.* 1(1). p.55-73.

British Standards Institute, (2007). BS 1192-2:2007. *Collaborative production of architectural, engineering and construction information - Code of practice.* Switzerland: ISO Copywrite Office.

Egan, J., (1997). *Accelerating Change.* London: Strategic Forum for Construction.

Egan, J., (1998). *Rethinking Construction.* London: Construction Task Force.

Fillingham, V., Malone, A. & Gulliver, S. R., (2014). *Birmingham City University City Centre Campus Development.* London: Faithful+Gould.

Hall, J., (2015). *BIM O&M Case Study: Birmingham City University Associated Architects*. [Online] Available at: http://www.theb1m.com/videos/birmingham-city-university-bim-o-amp-m-case-study [Accessed 10 06 2015].

HM Government, (2011). *Government Construction Strategy.* London: HM Gov. Cabinet Office.

HM Government, (2013). Construction 2025. *Industrial Strategy: government and industry in partnership*. London: HM Gov. Cabinet Office.

Korpela, J. & Miettinen, R., (2013). *BIM in Facility Management and Maintenance: The Case of Kaisa Library of Helsinki University.* Finland: Institute of Behavioural Sciences, CRADLE, University of Helsinki.

Latham, M., (1994). *Constructing the Team.* London: Department of the Environment.

Motawa, I. & Almarshad, A., (2013). A knowledge-based BIM system for building maintenance. *Automation in Construction.* (29). p.173-182.

Olomolaiye, A., Liyanage, C. L., Egbu, C. O. & Kashiwagi, D., (2004). *Knowledge management for improved performance in facilities management.* s.l., In Proceedings of International Construction Conference of the Royal Institute of Chartered COBRA.

Royal Institute of British Architects, (2013). *The RIBA Plan of Work,* London: RIBA.

Rundell, R., (2006). *How can BIM benefit facilities management?.* [Online] Available at: http://www.cadalyst.com/cad/building-design/1-2-3-revit-bim-and-fm-3432 [Accessed 29 05 2015].

Schuh, G., Schmitt, R., Kuhn, T. & Hienzsch, M., (2014). *"Low-Cost" Tools Through Life Cycle Observation.* In Proceedings of 21st CIRP Conference on Life Cycle Engineering. p.526-530.