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AN EVALUATION OF BUILDING INFORMATION MODELLING AND ITS IMPACT ON DESIGN

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Abstract. As BIM adoption increases the challenge of transitioning to a three-dimensional workflow is faced by a growing number of designers. Such a transition requires a fundamental transformation in how designers think due to the fact that, "with BIM, buildings are modeled rather than drawn" (Levy, 2012). This way of working requires an open and coordinated approach to design and construction, and it is important that those new to the process understand what to expect and appreciate the challenges that may be encountered. As such, this paper will provide an overview of some of the important issues to be considered by those implementing BIM in practice, with a particular focus on the design stage. This will be done via a review of literature and qualitative analysis of a project case study, offering observations from a real project.

1. Introduction

Design professionals within the UK are currently faced with a dilemma, to continue using the same methods to produce architectural drawings and construction information as they have for the last few decades, or to make the transition to BIM. The choice for those involved with central government work is straightforward, as they will need to make the transition to be eligible to work on future projects. For others, especially those within smaller practices, the choice is more difficult. The various benefits and challenges need to be considered to ensure that a move towards BIM will produce benefits for the practice in terms of productivity and client satisfaction. The latest results from the National BIM Report (NBS, 2014) show that adoption levels in the UK are steadily increasing; hence it would suggest that more practices of all sizes are beginning to embrace BIM.

With adoption levels likely to increase further over the coming years, there are a number of pertinent issues to be considered and challenges to be overcome. Therefore, the aim of this paper is to analyse some of the issues occurring at the design stage, such as collaboration, communication and the impact of technology, and relate these to a real scenario. The research was based on a literature review and synthesis, supplemented by the use of a case study project, providing a context (Cohen *et al* 2007: 253) to support the theory.

The paper will begin by providing a brief overview of the history of design communication. This will be followed by a discussion on changes to the traditional design process brought about by BIM, such as a greater focus on collaboration and the impact on creativity. A case study will relate the literature findings to a real project, outlining some of the issues those new to BIM may expect to encounter. The paper will conclude with a discussion around the key findings.

2. Use of Models in the Design Process

Although many in the UK regard BIM as a new phenomenon, the concept has been around for a number of years and been successfully implemented in other parts of the world, e.g. the United States (US) and Scandinavia. Indeed, the early origins of BIM can be traced back to the 1960's when Englebart authored a report that included a notional example of how advancements could be made in the architectural design process by developing new working methods in conjunction with potential advancements in computing technology (Englebart, 1962: 4-6). Eastman and his colleagues at Carnegie-Mellon University built upon this concept in the 1970's with the development of their "Building Description System"

(Eastman, 1975), which in essence was a computing program containing many "now-routine BIM notions". (Eastman *et al*, 2008)

At the time of Englebart's writings pen and ink drawings produced using drawing boards were the main method of design communication, later followed by two-dimensional computerised draughting. Architectural models, in the physical form, were also an early method of presenting designs and testing structural concepts (Dunn, 2010).

Currently, models of a different kind are being used to transform the design process and construction sector in general. BIM compatible software is facilitating the digitalisation of the construction industry, with three-dimensional models becoming more widely used. These models are becoming the main instrument from which all other sources of information required to plan, construct, operate and maintain a building are generated (Harty & Laing, 2011).

Although these building information models consist of an abundance of detailed information, parallels can still be drawn with early architectural models, as the general principles of conveying concepts and testing performance remain the same. In essence, BIM "is about how we share data, use data and present data, in forms that are meaningful to the intended recipients." (Harty, 2013: 28) Similarly, physical models were an early method of presenting data on building projects. "The model has been an important method of communication in the understanding of architecture for over 500 years." (Dunn, 2010: 18) This is something that is likely to continue, albeit via a BIM platform, as adoption rates increase.

3. Collaborative Design

Abbasnejad and Izadi Moud (2013: 287), refer to BIM "as a new way of technical communication in construction". It "changes *how* data is shared" (Deutsch, 2011: 95) and lends itself to collaborative working, something that is becoming increasingly required in the built environment sector (Matthews, 2013: 213).

This differs from current processes, where team members tend to work in isolation (Salmon, 2013: 96), at least up until the detailed design stage. Even in the subsequent stages of the process, communication between construction team members and designers is often less than ideal. Deliberations that do take place are often to identify how the structure or services can be incorporated within the already designed building or facility. Once the technical design process is complete and statutory approvals received, the drawings are provided to the main contractor, who in many cases makes changes to the approved scheme as the project progresses. This has implications for the management of the building, as the lack of communication means that the stamped approved drawings that the client possesses are often quite different to the 'as built' building.

3.1. WORKFLOW CHANGE & DESIGN IMPACT

Collaborative working should facilitate changes in workflow for professionals. Levy (2012) outlines, "BIM is a design environment that requires that the designer reevaluate the practice of architecture." This requires a paradigm shift for design professionals, as they are required to move away from a way of working where they develop the majority of decisions, up to the detailed design stage, in isolation.

The changes in workflow outlined above are being recognised in publications such as the BIM Overlay to the RIBA Outline Plan of Work (RIBA, 2012) and PAS 1192-2 (BSI, 2013). This more collaborative and joined up methodology is also commonly referred to as Integrated Project Delivery (IPD). There is no doubt that such a workflow will bring benefits, however it is likely to have implications for current fee structures and contractual relationships. With the entire design and construction team being involved earlier in the design process, it will place an onus on all members of that team to commit to coordinated and collaborative working.

BIM could improve design, as it supports "integration of construction knowledge earlier in the design process" (Eastman *et al*, 2008: 22). This has associated benefits, for instance, simulations and analysis of building performance can take place at the modelling stage (Nicholson *et al*, 2013: 50), allowing a more considered approach to decision making rather than having to make them instantaneously whilst on site. But changing to the BIM workflow and embracing the collaborative ethos brought about as a result of this is not without its challenges. Deutsch (2011: 94-111) highlights a number of potential issues, some of which include; legal aspects, issues with *interoperability*, building *trust* and *communication*. All of these need to be considered and overcome if a collaborative workflow is to prosper.

4. BIM and Creativity

Whilst facilitating a workflow which should assist with technical design decisions, arguments exist which raise questions about the impact of BIM on creativity. Holzer (2011: 477) suggests that a more collaborative approach resulting from the BIM process could be viewed with apprehension among designers, outlining;

"*Architects typically assume that their capability to explore in early stage design is constrained by consultants who only want to model and analyse as few options as possible.*"

Holzer (2011: 466) also brought forth the notion, "that a technology-centric view on BIM...will inevitably lead to fundamental problems in understanding BIM as a method for conceiving buildings in the first place." An interview undertaken with an architect who is vastly experienced in BIM implementation also suggested BIM could "hamper creativity in the design process" if the user of the software was not able to sufficiently master it (Simoni, 2013).

Both the above are important issues that need to be considered by practices implementing BIM working methods. It would be unthinkable and unacceptable for any design to be compromised by the tool used to create it, thus it is essential that proper training and support be provided to those individuals with practices who will be using the software on a daily basis. However, it is important that designers understand BIM as a process and retain the ability to use their judgement to select the correct tool for the task in hand. For instance, in the early conceptual stages of a project, many designers will find a sketch or hand drawing a more appropriate method of conceiving and refining ideas as opposed to using BIM tools. The BIM process should be seen as enabling the use of appropriate tools for diverse tasks rather than being viewed as restrictive. It is incumbent on the designer to realise this and not feel that every task needs to be driven by technology or software. The statement relating to possible apprehension among architects due to increased collaboration could be considered as more of an issue of mind-set, and should be overcome by committing to the new coordinated approach to design in which everyone works together for the common good.

The discussion would suggest that understanding the process, mastering the tools and retaining the ability to select the most appropriate method to undertake specific tasks (which may be non BIM related) is key to maintaining creativity within the design process. However, any designer, no matter how skilled or experienced, will go through a learning curve and require time to familiarise themselves with the technology and adjust to the process before being able to utilise it to its full potential. Once the technology is mastered there is no reason for creativity to be affected, and as technology develops it could be argued that BIM will enhance creativity and allow for increased innovation, with concepts such as 3D printing being used in conjunction with building information models to create bespoke building elements.

5. Research Method

The aim of this paper is to provide an overview of some of the benefits and challenges that may be faced by those new to BIM and wanting to implement it in practice at the design stage. As such, a case study approach was selected to provide an overview of the challenges facing firms moving from a two-dimensional to a three-dimensional design environment and implementing BIM on real projects. A co-author of the paper worked in the role of BIM Manager on the case study project, and the information provided in the case study is based on direct observations during the scheme design and recorded afterwards for inclusion within this paper. It could be considered an 'illustrative' study, with qualitative analysis allowing for a first hand account of the challenges and benefits experienced from the architectural firm's perspective in implementing BIM.

6. Case Study

Northern Irish based Hamilton Architects are a long established, award winning practice, working in a variety of sectors and specialising in the design of sports stadia. Historically, as with most practices, they predominantly utilised a two-dimensional Computer Aided Design (CAD) based workflow. However, over the last three years the practice has adjusted to the requirement of providing BIM for architectural services. After training their staff and implementing BIM Level 2 (RIBA, 2012: 4) on projects of different scales, Hamilton Architects began to notice the benefits and challenges BIM workflows had on, for example, design and communication during the different stages of a project. One such project is the redevelopment of Windsor Park in Belfast (Figure 1).

This case study was selected as it closely aligns with the research objectives and provides valuable information on the challenges faced by a practice implementing BIM. The following discussion provides the background to the project, highlights some of the aforementioned challenges as well as the benefits derived from BIM implementation.

It should be noted that at the time of writing construction work on site is ongoing.

Figure 1: Proposed Windsor Park Redevelopment Scheme. Source: Hamilton Architects

6.1. PROJECT BACKGROUND

Outlined in the project delivery objectives and the scope of works for the project was the requirement for a building information model. This model (Figure 2) would be handed over to the contractor and their integrated supply team for further contractor's design, and delivery of the project to operation. The procurement strategy was Design and Build which involved a requirement of detailed proposals from the design team up to stage D of the RIBA Outline Plan of Work (RIBA, 2007), with further detail added in the scope of works up to stage E for the architects only. This involved further detailing the 'equal or approved' architectural specification allowing a more rigorous employer's works information package prior to handing over to the contractor.

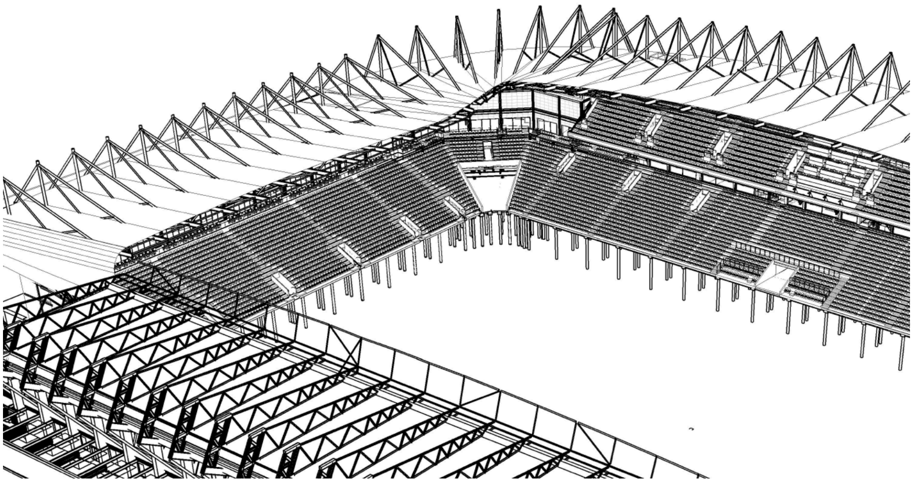

Figure 2: Architectural Model. Source: Hamilton Architects

The project illustrated how manufacturers' data can be incorporated within a building information model, but also raised challenges based on the European Union (EU) Procurement regulations. This is discussed in greater detail later in the paper. The Industry Foundation Class (IFC) file format was used for the stadium seats, with manufacturer's data and costs linked to the model. For a scheme such as this the BIM workflow can allow overall cost of the stadium seating to be easily calculated, as well as facilitating feasibility cost analysis for increasing or decreasing stadium capacity.

The model also enabled clash detection between the structural and architectural designs, helping to identify potential issues in advance of the project commencing on site. The ability to better analyse possible health and safety concerns was also an important by-product from the model. Simulation in 'virtual reality' proved useful for the identification of everyday hazards, with potentially dangerous physical realities highlighted in the model thus allowing the communication of safety risks through a virtual world. Some of the remaining benefits and challenges are outlined in more detail in the remainder of the case study.

6.2. CREATIVITY

The project highlighted interesting points regarding design and creativity. As already outlined, the design team received a document outlining the project deliverables and their descriptions, essentially a set of employer information requirements, one of which was a building information model. Creativity, the design of the stadium in terms of aesthetics and functionality in this instance, was solely left to the design team to develop in whatever way and using whatever methods they saw fit. In this project those methods saw initial concepts and designs conceived via the use of sketches and software packages that the architectural team felt more comfortable with (at the time they were new to BIM compatible software programs). This allowed spaces to be defined and the two most explored architectural components of stadia, the facade and roof, to be designed. BIM software was only used after this initial conceptual stage had been completed. Whilst the initial conceptual work was happening, not only was geometric data being shared within the design environment, but information was being added to the model (wall and floor build ups, doors, windows etc.) creating a more efficient and design effective process as a whole.

The above discussion supports the assertion in an earlier part of the paper that outlined the importance of the designer to retain the ability to select the most appropriate tool for the task being undertaken. Whilst understanding that conceptual design using BIM can be beneficial and lead to a more efficient workflow, this was not the case on this particular project and sketches were viewed as the most efficient way of processing thought to paper.

6.3. ANALYSIS OF BIM IMPLEMENTATION

Overall benefits included:

- Coordination - Revit software was used for the respective architectural and structural engineering designs and for interference checking. This made it easier to identify clashes between the architectural and structural components, which were not so easily identified in the traditional drawing platform.

- Communication - Dropbox was used as a ‘common data environment’ to share models between the architectural and structural engineering teams, with email communication taking place to record what had been sent and received. Real-time coordination in 3D allowed quick and effective discussions between all parties involved in the project. This was achieved by projecting the model onto a TV screen during design team meetings.

- Basic human error –This is a common trait when coordinating a team working on separate 2D drawings. This problem was overcome by working on a constantly updated and coordinated central model that was accessible and modifiable by the design team. This meant that any person in the office who made a change to the model could synchronise with others, therefore allowing fast and effective communication of constant changing designs and details. However, development of a shared model requires the discipline of a team. This was the BIM manager's task who managed, for example, drawing (or modelling), sharing, filing and backup standards.

- Quantifying – Although only briefly required in this project, quantifying areas was as simple as 2D platforms with the added bonus of quantifying volumes as well as elements in the model. For example, the geometry of the terracing units not only produced plans, sections and elevations; it also contained the volume of the overall concrete required for construction. This could then be extracted into information as outlined below.

- Information – Every element of the model (such as the seats) held information that could be processed into some form of a spreadsheet or easily accessible and readable data using tools within Revit, which was the software used by the design team. This saved time later in the project for analysis purposes.

- Visualisation – perceptions from the architectural team suggests that a great deal of time was saved (compared to the traditional workflow) in preparing visualisations for public presentations and client meetings during the course of design.

As well as the benefits discussed above, there were also challenges to be overcome throughout the project. One of the main challenges was changing the way the team approached drawing and design development, something that can initially be difficult to grasp for firms that are predominantly 2D in their method of working.

A second challenge encountered with BIM on this particular scheme was due to the method of procurement. As already outlined, the Design and Build procurement method required the development of the design up to the stage of planning submission, with some additional input (from the architects only) at the detailed design stage. Therefore complete collaboration could not be achieved between the architectural and structural engineering teams for the model due to the fact that the contractor effectively could change the geometry of the design through their technical design stages (by influences for example of technical structural detailing, M&E modelling and achieving building control approval). This particular situation raised concerns as to what level of detail the building information model should progress to.

Additional questions raised during the course of modelling the stadium for this particular procurement strategy were:

- What level of detail should the model have at each design stage?

- How can the lead designer discipline his or herself to develop the model's geometry so that it was adaptive and considered reasonably easy for making changes by the contractor's design team?

- What elements of the specification can be included in the model? For example, the seats were a chosen percentage of what could be specified within the EU Procurement rules. The rules will not allow a project with a budget over the EU Procurement threshold to include a specification that labels suppliers directly. The remainder of the specification therefore needed to be labelled 'equal or approved' for the contractor to ultimately tender to a competitive market of suppliers (allowing an equal and rational use of public funds). How does the designer leave the model 'blank' for the suppliers to provide their input?

- At what level is it considered reasonable for the architect's information model and the structural engineer's information model to be collaborated to a level of detail expected within the scope of works, despite not reaching completed design?

6.4. DISCUSSION

The benefits and challenges of BIM implementation on this particular project have raised interesting points regarding collaboration. The Design and Build procurement route limited collaboration to a certain extent, and there were challenges with the production of detailed specifications due to the EU Procurement rules. The use of a 'performance based' approach could possibly be a way of overcoming such issues, with the model containing information on the desired performance criteria as opposed to specifying specific manufacturers or suppliers.

There were also initial challenges in determining the most appropriate method of sharing the model and information between the architectural and structural engineering teams, and all of the associated issues that go along with this such as naming conventions. This is an inevitable issue that those new to implementing BIM will face, however the use of existing standards and protocols such as BS1192 (BSI, 2007), PAS1192-2 (BSI, 2013), PAS1192-3 (BSI, 2014) and The BIM Protocol (Construction Industry Council, 2013) will undoubtedly assist with understanding the requirements and processes involved. As well as the challenges, the case study also highlighted numerous benefits related to the collaborative approach; most notably the ability to view clashes between the models and more effective communication.

The link between BIM, design and creativity is an important concept. The benefits derived from utilising more traditional architectural skills in the case study project highlights how BIM and these traditional design skills can be utilised and work in harmony to produce the desired outcome. It is essential that designers do not become obsessed by the technology to the point where they lose focus and are unable to decide on the most appropriate design technique for the task being undertaken.

Taking all of the above into consideration, it is clear that there are still challenges regarding BIM implementation. However, many of these challenges should easily be overcome as the BIM workflow is increasingly adopted and understood by those within the design and construction sector. The project case study highlighted many benefits from the process, most notably a coherent understanding between all parties during the development of the design.

7. CONCLUSION

The digital revolution within the construction sector is well underway. Although there are still challenges, BIM is increasingly being recognised as a superior method of creating, understanding and analysing buildings. This paper has considered some of the important issues for designers about to embark on their BIM journey. It has also provided examples of the benefits and challenges relating to the collaborative workflow and creativity process from implementing BIM in practice.

In terms of the new process influences on this project, the efficiency of the design team in production and most notably the ease of communication between parties were the two major benefits of the BIM process. Although this may not necessarily mean the design was ‘better’, the benefits of the process certainly allowed more time to design with more effect from the designers’ viewpoint.

Those designers who embrace the BIM concept and become familiar with the software, protocols and procedures will have a competitive edge and be ideally situated to deliver the change that is required. However, it is essential that a holistic approach be taken and that the technology does not become an obsession to the point where traditional design skills are completely discounted. The case study in the paper has demonstrated that there is a place for both in the process of design and it is important that this is not lost sight of. Whilst being careful not to downplay the challenges, the appetite for change within the industry is undoubtedly present. This, along with the many positive benefits of BIM already witnessed in practice, means that uptake is only likely to increase over the coming years.

Acknowledgements

This paper has been developed from coursework submitted to the University of Salford as part of the MSc. BIM and Integrated Design programme. Thanks are expressed to Hamilton Architects for allowing the use of the project case study and associated images.

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