SECM/15/117

Building Information Modelling Implementation in Practice: Lessons learned from a housing project in the Netherlands

A.A. Aibinu[1]*

[1]University of Melbourne, Australia
*E-Mail: aaibinu@unimelb.edu.au, TP: +61 3 8344 6811

Abstract: Real-world implementations of BIM can serve as use cases to demonstrate BIM implementation strategy in practice. This paper presents the findings from a case study of BIM implementation on a housing project in the Netherlands. It describes how BIM approach was used to facilitate the delivery of the project. The benefits and challenges encountered are discussed. The role of BIM process management, BIM activities and key enabling technologies are examined as well as the impact of procurement on BIM implementation. The paper highlights how BIM activities was structured to deliver the project faster (time), cheaper (cost) and better (quality and performance). The analysis is based on project documents and interview with those involved in managing the BIM process. One of the major implications of the findings is that: BIM implementation is a set of interrelated activities and processes. Organisations seeking to work using BIM approach need to actively engage with the process and, in an ongoing basis, learn from their experiences as well as improve based on the lessons learned.

Keywords: Building Information Modelling (BIM), Case study, housing project, BIM implementation.

1. Introduction

The delivery of building and infrastructure projects are generally complex. These projects are often executed in a non-collaborative way. Because of lack of integration and collaboration, project information are often difficult to generate, transmit, reuse, coordinate and so manage thereby leading to inefficiencies, low productivity, delays and project cost blowout and poor value for money outcomes. In addition to that, the accuracy of project information generated and communicated are often less reliable and where reliable they are difficult to access due to lack of team and process integration.

Building Information Modelling (BIM) promises to eliminate the problem associated with the traditional approach to project coordination and management. The drive toward the adoption and implementation of BIM on projects is gaining momentum. In Finland, United Kingdom, Norway, Singapore, and many other countries, BIM has become a mandatory requirement for government projects by a set date. BIM policies and BIM guides has also proliferated globally.

Although there is a lot of talk about the benefits of Building Information Modelling (BIM) as well as growing interest in BIM implementation across architecture, engineering and construction (AEC) industry in many countries, a widespread lack of understanding about how BIM can be implemented in practice remains one of the significant barriers to the widespread adoption of BIM by organizations and on projects. There is anecdotal evidence to suggest that where BIM has been adopted by company, its implementation is still fraught with many difficulties and challenges.

Real-world case example of BIM implementation would provide useful way of understanding the BIM process, benefits, challenges and the implementation in practice. Lessons learned could help others who might wish to implement BIM on their projects.

The purpose of the research reported in this paper was to understand the actual implementation of BIM in practice using a case study. The research is part of a larger study looking at best practices for efficient adoption and effective deployment of BIM. This paper presents some preliminary findings. It describes how BIM approach was used to facilitate the delivery of a housing project in the Netherlands. The benefits and challenges encountered are discussed. The role of BIM process management, BIM activities and key enabling technologies are highlighted.

2. What is BIM?

Building Information Modelling (BIM) can be described as an intelligent model-based process of creating and managing building and infrastructure project information during design, construction and operations phase using three-dimensional, real time, dynamic building modelling software to decrease wasted time and resources. BIM can help integrate project delivery process, the product (the built form or the facility), and people (the supply chain).

BIM facilitates simultaneous work by multiple design disciplines. BIM can eliminate project coordination difficulties and information management problems [1]. It provides a platform for integrated information exchange through a single model. This means that BIM is not just defined by a 3D graphical model; it also includes the capability to transmit and reuse the information embedded in the model. Depending on the data embedded, a model can be 3D graphical model, 4D time model or 5D cost model. With further information stored, BIM can be modelled to include other dimensions such as sustainability aspects (including energy), safety etc. Thus, BIM maturity can be at various levels namely: manual 2D, computer-aided 2D, 3D CAD drawings, intelligent 3D, collaboration which involves sharing of object-based models between two or more disciplines, and integration which involves integration of several multi-disciplinary models using model servers of other network such as cloud computing. GIS information can also be linked to the model. Arguably, when developed and used in its multi-dimensional form, building information model may be referred to as built environment information model. Thus BIM approach offers many promises.

3. BIM benefits and promises

The use of BIM can lead to faster, cheaper and better buildings which are environmentally sustainable. BIM-enabled project delivery can facilitate integration of project team as well as integrate design, construction and operations of a building. BIM can bring cost and time savings on projects because of (a) the high quality of design documentation and well-coordinated project team (b) the ability to facilitate exchange of information between the various design disciplines thereby reduce design errors and omissions with significant reduction in design time (c) the use of BIM to collate the various components of designs authored with BIM tools in order to identify clashes early during the design stage. Information enriched BIM can improve communication between the project team members and can facilitate agile response to project stakeholders' concerns or suggestions during design and construction of facilities. BIM can enable the project team and the owner to visualize the design. Visualization can support design decisions regarding choice of alternative materials, technology and building systems for the facility.

Advanced level of BIM implementation can also help the owner and the design team understand the newly proposed facility in relation to existing facilities, and road network in a precinct, town or city. The impact of the newly proposed facility on neighbourhood infrastructure can be interrogated and potentially improve sustainability of cities and the built environment. BIM information can be used for facility management during operations. For example, upon project completion, the coordinated construction models developed by the builder can become as-built models incorporated with electronic specifications, catalogues, maintenance manuals, testing and commissioning documents that are passed on to the client and facility managers for the purpose of asset operations and maintenance, and later for refurbishment when required.

Despite the promises of BIM, it appears that real-world adoption is still very patchy in many countries and high-level of BIM maturity is still evolving. There is lack of consistent evidence to show that there is widespread adoption of BIM. Case study of real world BIM implementation could help reduce uncertainties around BIM process and its implementation.

4. Research methodology

The research is exploratory using a case study. It made use of qualitative research approach with semi-structured interviews and document review. As part of the larger study, the BIM managers responsible for managing the project were interviewed. In the rest of this paper, the implementation of BIM on the housing project is described and examined.

5. Project description and context

5.1 The Project, the main parties and why BIM was used

The housing project consists of rental apartments for single and two-person households. The complex has nine storeys containing 40 apartments, with five apartments on each floor spread over eight floors. The client (hereafter referred to as 'the owner') is a housing association in partnership with a property development company. The contractor (hereafter referred to as 'the builder') is a design, build, maintain and manage company with over 500million Euros turnover in 2013. The builders are also into property development business. On the project, BIM was not a contractual requirement. The use of BIM was the builders' choice and part of the tender proposal to the owner with the goal of using BIM to help the owner achieve their requirements, the most important being to achieve the lowest 'economic cost'. Thus the value statement is about a better building delivered at the lowest cost. Overall, by using BIM, the builders hoped to eliminate design errors, reduce clashes and deliver the project faster, cheaper and better.

5.2 Project organisational structure, roles and responsibilities and the procurement approach

The project delivery method was design and build (D&B) procurement. The designers were engaged by the owners to define the scope of the project whereby the design was developed from conceptual design (LOD100) to schematic design (LOD200) stage. The Level of Development (LOD) describes the dimensional, spatial, quantitative, qualitative, and other data included in a design model [2]. It indicates the level of design information in the design at various stages. For the sake of clarity, Figure 1 and Figure 2 show a balcony in LOD 300 and LOD 400 respectively. Based on the LOD200, the project was tendered and the builder was selected. The designers engaged by the owner to define the project scope at LOD100 and LOD200 were novated to work for the builder after the tender process. Figure 3 shows the project organisational structure.

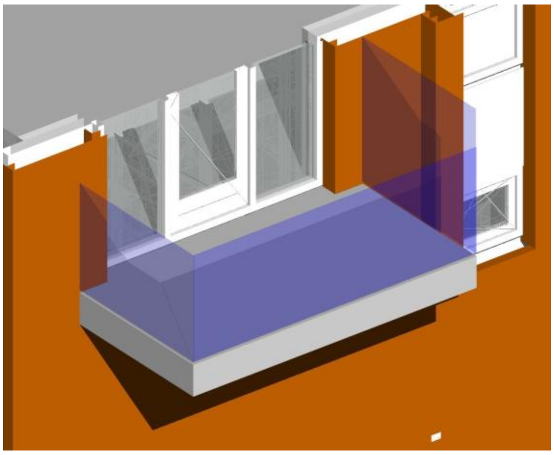

Figure 1: Balcony at LOD 300
(Source: Made available to the author by the interviewee)

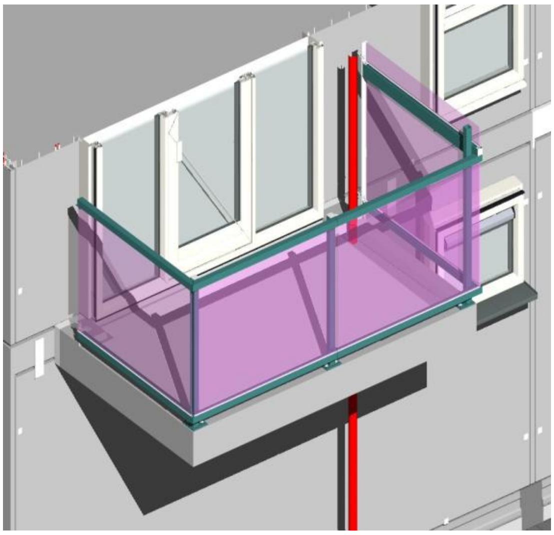

Figure 2: Balcony at LOD 400
(Source: Made available to the author by the interviewee)

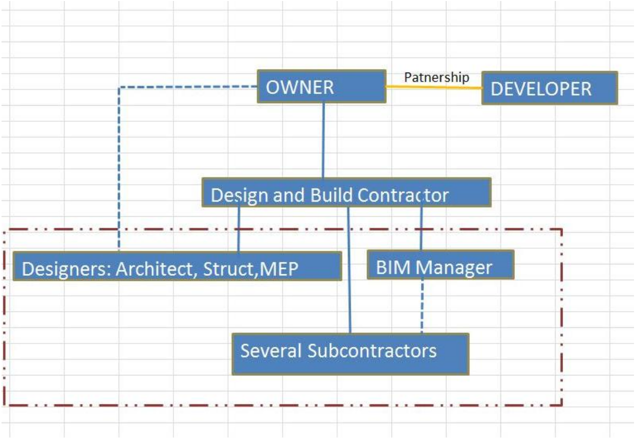

Figure 3: Project organisational structure [Design and Build]

Ideally, the collaborative platform offered by BIM tools and process need to be leveraged by using Integrated Project Delivery (IPD) system [3]. This is because engineering and construction projects delivery process is a social-technical system involving interaction between people and technical aspects. The way interaction occurs between project team members is critical for success. IPD is a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction [4]. With BIM and IPD, a project can be defined and coordinated to a much higher level before the commencement of construction on site [5]. Although design and build (D&B) method is not the ideal arena for reaping the full benefit of BIM, the use of D&B on the project do exhibit some features of collaborative and integrated project delivery (IPD).

6. The use of BIM features and integrated project delivery

6.1 Virtual Design and Construction (VDC) method

As recommended by the American Institute of Architects [4], the use BIM and features of IPD, was adopted in what can be referred to as 'Virtual Design and Construction' (VDC). The method integrated the project stakeholders. Models were created by the various designers and participants and the project was built virtually with many design coordination activities and many design revisions. The re-visioning was enabled by the use of 3D models and intelligent computer programs which facilitated information exchange between the parties.

The Centre for Integrated Facility Engineering (CIFE) at Stanford University pioneered the VDC. According to CIFE, VDC is the use of multi-disciplinary performance models of design-construction projects, including the Product (i.e. facilities), Work Processes and Organization of the design - construction - operation in order to support business objectives. With VDC, practitioners can build symbolic models of the project, project organization and process (P-O-P) early before a large commitment of time or money is made to a project. VDC supports the description, explanation, evaluation, prediction, alternative formulation, negotiation and decisions about a project's scope, organization and schedule with virtual methods [6]. The virtual models can be used to simulate the complexities of the construction project delivery as well as identify and analyse the pitfalls that the project team may encounter and how they can be addressed virtually before start of construction work [6]. Thus VDC involves simulation, analysis, visualization, and constructability inputs at the early stage of project development. Forecast of project cash flow can be conducted early with high accuracy. Overall, VDC should reduce project risk and speed up project completion time because key project participants are involved from the earliest practicable moment. The approach can also improve decision-making because of the influx of knowledge and expertise of all key participants.

In this project, the design and build (D&B) procurement overlaid with IPD features allowed the builder to take the advantages of BIM despite BIM not being a contractual requirement. Several subcontractors were engaged early to provide their input into the design.

6.2 BIM managers, MEP engineers and subcontractors roles

The BIM managers were engaged by the builder after the award of the project. They were responsible for managing the BIM process from LOD300, LOD350 to LOD400 phases as well as the calculation of the construction costs at the various stages of the design. They worked with the services engineers i.e. mechanical, electrical and plumbing (MEP), to model the final design of the project (LOD 300). The LOD 300 models form the basis of clash detection, cost calculation, and formed the basis of the subcontractors LOD400 models. The BIM managers worked with several subcontractors to develop the LOD400 prior to working drawings development. The team jointly produced an excellent model for the construction of the complex. It is important to note that the subcontractors were selected based on price and their experience with BIM.

7. BIM management and BIM use

7.1 BIM management process

To ensure the success of BIM implementation, an initial project workshop was conducted. The purpose was to ensure that all the parties understood the project as well as agree to the way of working and how BIM would be used. All parties had to sign the BIM execution document as a part of the contract. Thus the BIM process was supported by BIM protocols and BIM management plan right from the early stage of the workshop. The BIM management plan contains parties' agreements regarding technology, definition of required training levels, BIM goals, process and responsibilities as well as deliverables and timelines etc. After the initial workshop, parties stayed in contact using online project platform. All the parties got the right information at the right time. The BIM activities were structured into six phases with sub activities within each phase as shown in Table 1 to Table 6. During the process, there were several meetings in order to monitor the progress.

7.2 BIM use

BIM was used for the following: clash detection, preparation of working drawings, design visualization, quantities take-off, cost calculation, and exchange of information.

The BIM managers were responsible for the quantity take-off and costing as the design evolved from LOD300 to LOD400. The quantities were automatically extracted from the model therefore more accurate. The quantities also formed basis for developing the construction programme. He programme was separately done and was not live-linked to the model. The federated model was used to produce unambiguous working drawings which formed the basis for actual construction of the building on site. It also made it possible for the parties to visualize and analyse the building prior to construction.

Table 1: Phase 1 of BIM Implementation Activities
(Project document sharing and explanations and BIM specification phase)

Step	Activity
1.1	Transfer of documents to all parties
1.2	Presentation of BIM methodology
1.3	Preparation of the online platform (common data environment for the project)
1.4	Providing the BIM execution plan to all parties
1.5	Verifying and agreeing on the execution plan

Table 2: Phase 2 of BIM Implementation Activities
(Drafting 3D BIM model - LOD 300)

Step	Activity
2.1	Preparation of the 3D architectural and structural models
2.2	Import 3D models (structural) in IFC
2.3	Clash detection (architectual and structural)
2.4	Revising the 3D models (architectual and structural) as result of the clash detection report
2.5	Transfering the cordinated 3D architectual and structural models to MEP engineers
2.6	Preparation 3D MEP models
2.7	Clash detection of 3D architectual and structural models with MEP models
2.8	Revising the 3D models (architectual, structural and MEP) as result of the clash detection report
2.9	Verifying LOD300 models (architectual, structural and MEP)

Table 3: Phase 3 of BIM Implementation Activities
(Preparation of the Budget)

Step	Activity
3.1	Preparation of budget using model based estimating method
3.2	Discuss / review budget
3.3	Establish working budget and possible changes in the design

Table 4: Phase 4 of BIM Implementation Activities
(Drafting 3D BIM model for subcontractors - LOD400

Step	Activity
4.1	Sharing the verifed 3D models (LOD 300) with the subcontractors
4.2	Identifying and clarifying key constraints based on subcontractors input
4.3	Preparation 3D subcontractors models
4.4	Clash detection of 3D modells (architectual, structural, and MEP) with subcontractors models.
4.5	Revising the 3D models of the subcontractors as a result of the clash detection report
4.6	Verifying LOD400 models (with fabrication, assembly and detailing information embeded)

Table 5: Phase 5 of BIM Implementation Activities
(Phase 5: Working drawings)

Step	Activity
5.1	Identifying required information for working drawings
5.2	Establishing the required working drawings
5.3	Processing the possible design changes of subcontractors model into a final LOD400 model
5.4	Preparation working drawings out of LOD400 model
5.5	Control of the working drawings
5.6	Revising the working drawings
5.7	Verifying the working drawings

Table 6: Phase 6 of BIM Implementation Activities
(Phase 6: Overall/general activities during all the phases)

Step	Activity
6.1	Consultation with the owner
6.2	Verifying and recording of all processes
6.3	Collaboration among all the parties involved
6.4	Specific explanation of the BIM methodology by the BIM manager
6.5	Opening abnd mantaining of the project comon data environment.
6.6	Evaluation of the project

8. Information sharing, Technology, and Model coordination

A project website was hosted on the servers of the BIM managers and was used as a common data environment (CDE) and platform for sharing project information. The platform served as a single source of information for the project. Although it was not possible for models to be viewed directly on the platform during the modelling phase, the website served as a platform for gathering, managing and transmitting documents as well as all 3D graphical models and non-graphical data for the project team. This facilitated collaboration between the team members. It also helped avoid duplication and mistakes. All parties were required to upload their updated model every Friday. All project team members used their own software but shared information using IFC (industry foundation classes). About 8 different softwares were used on the projects.

The BIM process involved frequent coordination of 3D models from the various design disciplines and from several subcontractors. Thus the building was virtually built through collaboration between the owner, builder, the BIM manager, the various designers (architectural, structural and services) and several subcontractors. All models were federated by the BIM managers and subjected to clash detection to identify errors and clashes in the models and the process.

9. BIM challenges and how they were resolved

Some of the challenges encountered include: late delivery of documents by the owner, architect and other parties; many changes in the design phase; coordination of many different models due to the number of parties involved including the several subcontractors; exchange of BIM models with IFC (software were not compatible), tight schedule, different expectations from different parties. The BIM maturities and knowledge of the parties are divergent. The initial workshop conducted at the early stage of the project helped secured commitment of all the parties to BIM method. Frequent model coordination helped to detect errors and clashes early.

10. Outcome of BIM use

In this project, parties did not recreate their own information at every phase. Information created at an earlier phase was reused in the subsequent phases. This eliminated inefficiencies by reducing wasted time and effort. For example, the LOD200 model created by the owner’s designers at the early stage was used as the basis for LOD300 model produced by builder while the LOD300 model formed the basis for the subcontractors’ model (LOD400). Thus the implementation of BIM resulted in federated 3D model (architectural, structural and MEP) at LOD300; and subcontractors model at LOD400) on the basis of which unambiguous drawings, working drawings, design visualization, clash report, cost estimates, planning, document management, were prepared and carried out. It also supported construction works on site.

In terms of design errors, up to 590 clashes between architectural, structural and services elements were identified and resolved prior to construction. 84% of the clashes were detected at the LOD 300 while 16% at LOD400 involving several subcontractors models. Overall, the project time was shortened by 40%. Parties, especially the owner was very satisfied because of the quality of the building delivered. The BIM process on the project provided a good learning experience for all the parties involved.

11. Conclusions

A description of real-world implementation of BIM in a housing project has been presented. BIM implementation is a learning process for adopters. The experience from this project shows that BIM implementation is a set of interrelated activities and processes enabled by digital technology including common data environment (CDE) and collaborative procurement. The role of BIM leader (or BIM manager) as well as the management of the BIM process is critical for successful implementation of BIM. The case study described also suggests that the success of BIM would depend on the BIM maturity and commitment of all parties involved. The use of open BIM where parties can share information about their model while working with their preferred software is crucial.

Acknowledgements

The author would like to thank the company who provided the information (including the images in figure 1 and figure 2) as well as participated in the face-to-face interview forming the basis of this paper.

References

[1]. Autodesk, *Building Information Modeling, 2011* [Online].Available: http://usa.autodesk.com/building-information-modeling/about-bim/ [visited 10th July 2014].

[2]. AIA, *Building Information Modeling and Digital Data Exhibit, AIA G201™–2013, (available at:* www.aia.org/digitaldocs, visited June 2014).

[3]. Loke, T.K. 'The Potential of Lifecycle Approach Through 5D'. In Rickers, U and Krolitzki, S (Eds.), *Proceedings of the 2012 Lake Constance 5D-Comference*. Dusseldolf: VDI Verlag, pp. 63 – 77, 2012.

[4]. AIA National & AIA California Council, The American Institute of Architects. *Integrated Project Delivery: A Guide*. 2007 Version 1 [*available at:* http://www.aia.org/contractdocs/aias077630, visited June 2014].

[5]. Aibinu, A.A., de Jong, P, Wamelink, H. and Koutamanis, A. 'Using Effort Distribution Analysis to Evaluate the Performance of Building Information Modeling Process'. In Raymond Issa R. and Ian Flood (eds.), *Proceedings of the 2014 International Conference on Computing in Civil and Building Engineering. **ICCCBE**[2014]. Walt Disney World, Orlando, Florida, USA. June 23-25*, pp. 73 -80, *2014.*

[6]. Khanzode, A., Fischer, M., Reed, D. and Ballard, G., '*A Guide to Applying the Principles of Virtual Design & Construction (VDC) to the Lean Project Delivery Process'*. CIFE Working Paper #093. Stanford University, 2006.