DESIGN VISUALISATION AND DOCUMENTATION WITH BUILDING INFORMATION MODELLING – A CASE STUDY

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Abstract. Building Information Modelling (BIM) is an emerging technology in the architecture/engineering/construction industry. This paper presents a case study of the implementation of BIM at the pre-contract stage of a small scale in-door swimming pool project in Hong Kong. It aims at reviewing the workflow between consultants and the impacts on design visualisation, drawing documentation and bills of quantities. A practicable approach to transform designers’ traditional 2D drawings to BIM with the support from a BIM manager is unveiled. In addition to the results, this paper also highlights some issues such as hardware requirements, the shortfalls of the BIM tool and the supply and demand of skilled BIM personnel. There are other unanswered questions to be addressed in the near future.

1. Introduction

Computer-Aided Design (CAD) is an essential tool for the production of drawings in the construction industry. Since the introduction of CAD some 20 years ago, there have been a number of studies on the downstream applications of CAD drawings (Tse and Wong, 2004). However, the majority of these applications have not been widely adopted. The core problem is that CAD has been mainly used as a digital drafting board rather than as a design tool. The upstream CAD data remains mainly in the form of 2D geometry data, compiled by entity-based CAD software such as AutoCAD and MicroStation. The whole building model is therefore simply represented by raw graphic entities or primitives (e.g. lines and arcs), which cannot provide rich semantic meaning about the building. Although several kinds of building information can be encapsulated using layering, linetypes, colour, blocks and extended data, this would unavoidably increase the drafting time or involve a lengthy post-drafting standardisation process.

Hence, entity-based CAD software apparently is not the appropriate agent for forming building models with rich semantic meaning. On the market, there is another line of CAD products referred to as object-based or object-oriented CAD modelling. These products construct a building model consisting of parametric objects such as walls, columns and windows. Nemetschek Allplan and GraphiSoft ArchiCAD, introduced in 1980 and 1984 respectively, were notable as the pioneers in object-based modelling in
the construction industry (Nemetschek, 2006; Graphisoft 2006). As reflected by the selling records in 1994 (DSC, 2000), majority of practitioners did not opt for object-based modelling in the 1980s. One of the major reasons for that was due to the huge gap between what was available and what was required in hardware and software capability. Object-based modelling, by nature, is considerably more sophisticated than entity-based modelling. It requires more floating point calculations, faster graphic displays, and more memory and storage. Given the use Intel 80286/80386/80486 microprocessors and the same level of investment, the development as well as the application of object-based modelling was at a comparative disadvantage (Tse et al, 2005). As pointed out by Eastman (1999), many limitations in developing and using CAD have gradually disappeared due to technological advances and the decreasing cost of systems. As a result, the development of object-based modelling has been expanding since the early 1990s. Bentley and Autodesk, who had already captured a large share of the market in entity-based modelling, began developing object-based models and subsequently launched the Bentley MicroStation Triforma and Autodesk Architecture Desktop in 1996 and 1998, respectively (Bentley, 2006; Autodesk, 2006).

In 2000, Revit Technology Corporation launched a new parametric model called Revit, which was acquired by Autodesk for a price of US$133 million two years later (Graves, 2002). Revit seemed to be a new product and the acquisition was remarkable in such a short period of time, but the company was actually founded by ex-members of the engineering team who created the Pro/Engineer parametric CAD model for the manufacturing industry in 1989 (Monster, 2004). This move is considered as a sustainable business strategy to Autodesk as BIM is believed to be the next generation of design tool. Autodesk Architecture Desktop is merely rooted in AutoCAD platform which might has limitations on future scalability. In 2002, Bentley revamped the MicroStation Triforma into a new line of products called Bentley Building Information Modelling, which include sub-modules in Architecture, HVAC and Structure (Bentley, 2006). Gehry Partners in the United State also spun off Gehry Technologies which sell and provide technical support for a new solution called Digital Project (DP). DP was built on a mature Mechanical CAD system – CATIA Computer Aided Three-Dimensional Interactive Application) which has been in use in the automobile and aerospace industries. The evolvement was a result of Gehry Partners Architects’ experience and expertise in using CATIA on a number of signature buildings such as the MIT Stata Center, Guggenheim Museum in Bilbao, and the Walt Disney Concert Hall (Gehry Technologies, 2006). These projects proved the possibility to design, document and build complex freeform buildings, which would be difficult to achieve using traditional 2D architecture CAD software. Nemetscheck issued the AllPlan 2006 in year 2006 (Nemetscheck, 2006) and Graphisoft shipped the latest version of ArchiCAD version 10 in September 2006 (Graphisoft, 2006).

This object-based CAD software is now commonly known as Building Information Modelling (BIM). Virtual Building, Parametric Modelling and Model-Based Design also refer to the same line of products. BIM is currently an emerging and revolutionizing technology in the construction industry, recognised by both local practitioners and overseas experts (AIAB, 2005). The study presented in this paper evaluates the impacts of BIM on
architecture visualisation and documentation in a small scale in-door swimming pool project in Hong Kong. The information and images presented were collected from the client and consultants at the pre-contract stage.

2. Project Description

The project is a 2-storey in-door swimming pool which is an extension to an existing secondary school in Hong Kong. It is situated on top of a cut slope where the bed rock profile varies from 3.9m to 26.8m below the existing ground level. The foundation is comprised of 76 mini-piles and each pile penetrate 3.3 meters below the rock surface (Fig. 1). The filtration plant room is integrated with part of the substructure. The tie-beams are arranged to support the bearing structure of the swimming pool cubical (Fig. 2). The ground floor consists of a 6-lane pool measured 15m x 50m, a male and a female changing room, an external basketball court and associated performance stage and planters (Fig. 3). The upper floor is designated as a store. Another basketball court on the roof is accessible through an external staircase and a walkway connecting the existing school (Fig. 4). The pool is equipped with some “green” features including solar chimneys, reflector panels and photovoltaic panels (Fig. 5). The design was awarded a “Merit in Environmental Design” in the research and planning category by the Professional Green Building Council (PGBC, 2006). The construction commenced in November 2006 and is expected to be completed in September 2007.
3. BIM Implementation Framework and Tool

The implementation of BIM in this project is lead by the Project Manager (PM) and a BIM Manager rather than the design consultants. The design was developed by the architect, structural engineer and building services engineer using traditional 2D CAD drawings. The softcopy and hardcopy drawings were given to the BIM Manager to create the model. This approach is particularly suitable on the current situation where most design consultants are still working on 2D drawings. A similar arrangement was also adopted in another BIM project in HK and discussed by Tse et al (2006).

As mentioned earlier, several BIM tools are available on the market. This project uses Autodesk Revit as the modelling tool. After the acquisition of Revit by Autodesk, it was further developed into three separate modules for the three main design disciplines, namely Revit Building, Revit Structure and the recently launched Revit Systems (Autodesk, 2006). Revit Building 9
is used to build an integrated architecture and structure model in this project. Building services have not been incorporated, since Revit Systems was not released in the pre-contract stage.

4. Deliverables in this Project

A number of deliverables are stated by BIM software vendors (Autodesk, 2006; Graphisoft, 2006; Nemetschek, 2006). The following sub-sections discuss the real benefits according to the experience gained.

4.1 EFFECTIVE & EFFICIENT VISUALISATION

The modeling process started from early design stage. There were a number of design review meetings between the consultants and the board of directors of the school. Instead of just showing the 2D views and rendering, the directors were presented with different 3D views, 3D sections and walkthrough animations from the virtual models. They commented on different schemes and advised on changes. The modifications were subsequently made in the consultants’ offices and the updated models were presented in the next meeting. This process continued throughout the design stage. Since most of the school directors were unfamiliar with the spatial concept offered by 2D plans/sections/elevations, the use of BIM had enhanced the effectiveness and efficiency of this communication process. For example, the client clearly understand the reasons for high foundation cost due to the varying rock profile and heavy substructure (Fig. 2). The headroom in the swimming pool (Fig. 8) and the appearance of the environmental features (Fig. 9) were also improved.

4.2 ACCURATE DRAWING DOCUMENTATION

Discrepancies between drawings, e.g. the location of a window on plan being not correctly reflected in elevation, are not uncommon in 2D drawing presentation. These errors are often picked up at the post-contract stage when the design is constructed in reality. In this project, the construction was simulated virtually at the pre-contract stage. The majority of the drawing discrepancies as a result were identified. During the modelling process, the BIM Manager communicated these discrepancies to the design consultants by issuing query sheets. The consultants responded to the queries and made
the corresponding changes on the 2D drawings. The model was then updated according to the clarified information. In order to meet the project completion date, about two-thirds of the queries had been dealt with before tendering. The remaining discrepancies are being rectified at post-contract stage. Nevertheless, the tender drawings were hence more accurate.

4.3 ENHANCED BILLS OF QUANTITIES (BQ)

One of the main objectives of using BIM is to facilitate the production of bills of quantities faster and more accurately. Since all the architecture and structural components were input to scale, the material quantities generated by the BIM tool saved much measurement time (Fig. 10). However, the BIM Manager should take into account the standard method of measurement (SMM) when creating a model. For example, the Hong Kong SMM for Builder Works (HKIS, 1979) stipulates that the concrete quantity of a floor slab is counted over the beams and columns. This requirement should be followed in the model (Fig. 11) or otherwise the quantity cannot be used in the BQ.

5. Areas for Improvement

The above achievements were not gained without pain. When modeling the design, a lot of effort was put on creating new families of objects from stretch (e.g. roof fencing, solar chimney, special cat ladders, taper beams, flag poles, etc.) because these were not available in the BIM tool by default. Modelling of new families demands a high level of solid modelling skills. Due to the practice different between US and HK, modification of the parametric properties of several built-in objects was also required to suit the local standards. For example, the width of a door in the model is the width of the opening and not the net clearance as defined by the local statutory requirement. As a result, the default door schedule cannot be used for submission proposes. There is a need for the development of new objects and local customisation of the BIM tool.

A major benefit of BIM is that all the views and schedules come from a single database. Any change in a view/schedule is therefore instantly and automatically updated in all other views/schedules. Under the current BIM implementation framework, however, the design consultants did not directly use and benefited from this advantage. Also, the function of BIM as a design
tool is not fully utilised. A better alternative is that the consultants evolve their design using BIM and the BIM Manager is responsible for managing the master model. Further research is needed to investigate the best BIM practice model.

In view of large quantity of 3D geometry and data in a single project file, it is not difficult to understand that the implementation of BIM requires high-end hardware support. The hardware included a typical mid-range personal computer with 2.8G CPU, 1.5G RAM, and an on-board display card connected with a 17” LCD monitor. The performance was considered to be acceptable for this small scale project. The same configuration was tested on a large scale project but the results were unsatisfactory. It is suggested that a workstation computer with at least 3.4G CPU, 4G RAM, and a specialist CAD/CAM graphic card supporting dual or even quad 20” or larger LCD monitors be used. Given the increasing capability and decreasing cost of hardware, this should not be the key obstacle to the uptake of BIM.

6. Conclusions

A case study illustrating the implementation of BIM in a small scale in-door swimming pool project in Hong Kong has been presented in this paper. The aims are to discuss the workflow between different consultants and the impacts on design visualisation, drawing documentation and bills of quantities at pre-contract stage. Currently the local industry has a shortage of experienced BIM managers and modelers as BIM management is still a new profession. Ideally, a BIM manager should possess not only the technical skills but also a wide range of knowledge including architecture, construction, building services as well as quantity surveying. Existing CAD draftsmen need to be re-trained as the operation of BIM is substantially different from traditional 2D CAD drafting. The supply from academic institutions has yet to materialise as BIM has not been formally included in the curriculums of most undergraduate and sub-degree programmes in Hong Kong. In the near future, more extension courses should be organised to meet the demand in the short term. Changing the mindset of people who are accustomed to the de-facto practice is a more challenging task. One may simply do not want to change their practice. In a recent BIM seminar, a respondent expressed that BIM might not welcome by some contractors who earn profits from drawing discrepancies and coordination problems. Some design consultants also suggested to review existing fee structures due to the implementation of BIM. Other unanswered questions such as the provision of BIM in contract clauses and the metric of BIM will be reviewed in the near future.

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