THE NEED FOR AN INTEGRATED COST MODELLING FRAMEWORK FOR BUILDING INFORMATION MODELLING

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ABSTRACT

Building Information Modelling (BIM), a revolutionary concept in the construction industry, produces an object-oriented, intelligent and parametric digital representation of the construction facility, which requires a collaborative participation of members of the design team members. These emphasize that BIM has characteristics of sustainable procurement strategies. Open BIM standards developed by buildingSMART International, are the most popular data standards for BIM to share digital construction information within the design team and beyond throughout the life cycle of the project. Other proprietary BIM standards are also extensively used, but they often have limitations on sharing information across all stakeholders. Even though BIM conceptually is an integrated approach for all project team members, not all functions are performed within the common platform. Project participants use their domain specific tools often with proprietary standards, and share the results translated to common standards. BIM enables a live information model with which all project participants can actively interact. This enables minimizing of errors and early clash detection, paving the way to sustainable project delivery methods. However, Quantity Surveying functions within a BIM based project delivery was found to be least interactive. This has hindered the real benefits receivable from a BIM implementation. Since, a cost model will provide critical information required for decision making at various stages, an up-to-date cost model is critical for a BIM based project delivery. While a variety of software tools is used for this purpose, a standardized method is not found to share cost information effectively with BIM. This study aims to develop a suitable framework for cost modelling for a BIM implementation in order to help develop BIM standards for cost modelling. This paper contains the preliminary findings of an ongoing research.

Keywords: *Building Information Modelling; Cost Modelling; Open BIM Standard; Quantity Surveying.*

1. INTRODUCTION

Procurement of a construction facility deals with design, construction and operation stages where sustainability is a major requirement. Building Information Modelling (BIM), an upcoming modern day concept, is capable of sharing information between the project team members and across the software applications which are commonly used in the procurement process of the construction facility (buildingSMART, 2013a), emphasizing the characteristics of a sustainable procurement strategy.

Although conceptually BIM is a fully integrated approach where all the functions are performed in a common platform, there are major limitations in practical implementation. Mitchell (2012) quite clearly points out that for BIM to be truly successful in providing better buildings all of the dimensions are to be embraced. Hence this research aims to develop a suitable framework for one of the major activities in procuring a construction facility; cost modelling. It should be noted that this paper is based on the preliminary findings of an ongoing research.

2. BUILDING INFORMATION MODELLING (BIM)

The BIM is a "revolutionary concept of using computer simulation in the construction industry" (RICS, 2012) which has already attracted the attention in Architecture, Engineering and Construction/

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Facility Management (AEC/FM) field (Zhiliang *et al.*, 2010a). Moreover, Zhiliang *et al.* (2010b) pointed out that BIM is designed in a way that it is capable of facilitating information sharing in a construction project, among the stakeholders in different phases in order to make better decisions.

To date, in most of the design firms, the main focus on (BIM) implementation has been simply about the way the parametric 3D modelling software works (Mitchell, 2012). However in 2007, U.S. General Services Administration (GSA) emphasised that 3D models alone are not BIM models as geometric representation is only a part of the BIM concept, and its true concept and true intention is represented by the "I" in BIM; information.

As defined by Associated General Contractors of Georgia (AGC) in 2013,

> BIM is the development and use of a computer software model to simulate the construction and operation of a facility. The resulting model, a Building Information Model, is a data-rich, object-oriented, intelligent and parametric digital representation of the facility, from which views and data appropriate to various users' needs can be extracted and analyzed to generate information that can be used to make decisions and improve the process of delivering the facility. (para.2)

Moreover, Hamil (2012) highlights that the problem of silo working and badly coordinated documentation in the construction industry will be greatly reduced through the adoption of BIM, and for this to be achieved, interoperability is critical. But, Bernstein and Pittman (2004) clearly points out that poor software interoperability has long been regarded as an obstacle to industry efficiency in general and to BIM adoption in particular. Among different levels of interoperability, interoperability through open standards is considered to be the most applicable (Hamil, 2012).

2.1. OPEN BIM

Amid the various data standards for BIM, Industry Foundation Classes (IFC) is a non-proprietary open standard published by International Alliance for Interoperability (IAI), to define AEC objects consisting properties and/or geometry (Mitchell, 2013). The importance of IFC standards in the BIM process is highlighted as it is a standard for sharing of digital construction information throughout the whole life cycle of a building project, globally, across the disciplines in the AEC/FM industry (buildingSMART, 2013b).

This open standard is adopted by Open BIM; an initiative of the neutral, non-profit buildingSMART alliance and several developers of BIM based software (Johnson, 2012). Furthermore, Johnson (2012) explains that Open BIM aims to accelerate the adoption of BIM in the AEC industry by providing common definitions, requirements, and branding for building projects, helping to overcome the challenges that can impede the collaboration among architects, engineers, contractors, and project owners that is so vital to an effective BIM workflow.

No matter what the scale of the project is, according to buildingSMART (2013c), the current AEC/FM industry is facing the following key collaboration issues.

- Lack of real coordination workflow
- Lost information during data conversion
- Interpretation issues of data from other party
- Limited utilization of building data created by others
- Missing follow-up of design changes between the trades
- Lack of overall coordination environment for multiple trades
- Lack of detailed model for construction

The open standards are believed to be capable of providing solutions for the above collaboration issues. It is because open workflows provide different trades with the option to use the best tools for their own purpose without losing the benefits of model-based collaboration, provides integrity and ownership of BIM project data and transparency of workflow is available.

The official definition of Open BIM is defined by buildingSMART (2013c) as follows.

> Open BIM is a universal approach to the collaborative design, realization and operation of buildings based on open standards and workflows. Open BIM is an initiative of buildingSMART and several leading software vendors using the open buildingSMART Data Model.

3. COST MODELLING

Among the critical activities for any construction project, cost modelling is a vital task to be performed throughout the lifecycle of a building project (Zhiliang *et al.*, 2010b), especially from inception to completion of project. As defined by Ferry *et al.* (1996, p.110),

> Cost modelling is the symbolic representation of a system, expressing the content of that system in terms of the factors which influence its cost. In other words, the model attempts to represent the significant cost items of a cash flow, building or component in a form which will allow analysis and prediction of cost to be undertaken. Such a model must allow for the evaluation of changes in such factors as the design variables, construction methods, timing of events, etc.

Though quantities of the building project can be extracted from BIM model, the estimating process is currently not an automatic process in BIM environment as "work must be performed which identifies and maps the objects in the CAD model to a format which traditional estimators are comfortable with" (Hannon, 2007). According to Bailey (2010), even in USA, though progress has being made with the use of the “OmniClass” coding system, at this stage “published documentation only provides a level of codes suitable for conceptual and early schematic models and estimates”. It should be noted that thus far 5D modelling is performed through the combination of BIM authoring software combined with 3rd party software for measurement and estimating (Boon *et al.,* 2011).

4. CURRENT PRACTICE OF COST MODELLING IN BIM ENVIRONMENT

4.1. INDUSTRY FOUNDATION CLASSES (IFC) USE CASES

According to background research, IFC standard has been applied in various use cases with regard to construction cost estimation by various researches (Zhiliang *et al.,* 2010a). Here cost estimation consists traditionally of the application of appropriate unit rates to the measured finished quantities of the proposed structure (Ashworth, 1994). Faraj *et al.,* (2000) had developed a web and IFC based construction computer integrated environment named WISPER (Web-based IFC Shared Project Environment), in which the IFC based object-oriented database can assist estimators. Through this application, estimators can retrieve quantities of elements, grouped together based on their type, in Ms Excel spreadsheet. Then the estimators have to cost the element groups in the spreadsheet to obtain a cost summary of the project. IFC - compliant lifecycle cost prototype tool developed by Fu *et al.,* (2004), is capable of calculating and demonstrating a breakdown of the overall life cycle cost of the building, after assigning all the building elements for the certain construction type. Tanyera and Aouada (2005) had proposed a web-based 4D planning prototype tool comprising of a basic cost estimator, which can automatically calculate main building elements and their quantities by using the submitted IFC file. In order to calculate the total material cost, the estimator has to fill the unit costs of the building elements.

4.2. COST ESTIMATION SOFTWARE

Apart from the above use cases, several BIM based costing software has been developed by various vendors. The following table shows a summary of the widely used costing software.

Table 1: Costing Software Details

Costing Software	How it Works	Source
MS Excel	This is the simplest method to quantity takeoff within Revit. Here, accurate quantities are extracted from the Revit BIM, output as a text file. Then these data are imported to an Excel spreadsheet file, which used by the Quantity Surveyors for pricing of items.	BIM Wiki (2013)
Success Estimator	Using Success Estimator internally cost baselines for Revit projects can be quickly developed and can deliver optimal designs that is within the clients' budget. Here, the API links between Revit and Success Estimator have to establish successfully. This also has the capability to produce quick cost estimates on small, fast-track projects. Through the accurate costs extracted from the Success Estimator, the QS can develop more realistic cost estimates.	US COST (2013)
Innovaya	Innovaya Design Estimating is a cost estimating software tool to automatically generate an estimate for the entire project. The program integrates Autodesk Revit seamlessly with RS Means Assembly Database, and it uses Sage Timberline Estimating, to calculate project costs instantly and accurately based on City Cost Index in North America, while providing powerful, flexible, and fully customizable estimating reporting capabilities. Quantities can be extracted based on building element types and dimensions. This also can detect the design changes from the Revit model and automatically update the quantities.	Innovaya (2013)
CostX	This is useful for integrating data-centric applications such as specification management and cost estimating with BIM. These approaches typically use the Open Database Connectivity (ODBC) database to access the attribute information in the building model, and then use exported 2D or 3D CAD file to access the dimensional data. For accurate estimation of cost and variations as they occur, CostX features bi-directional ties for design solutions, including ODBC based integration between CostX and Revit. These ties automatically detect the changes and graphically display the results, which allow to easily seeing the areas that have changed and quickly cost the model.	Exactal (2013)
Vico Office Suite	Vico Cost Planner is a powerful model-based cost estimating solution. Based on the concept of Target Cost Planning, Vico Cost Planner provides an environment for an evolving cost estimate that readily compares one version to another and any version to the original Target Cost Plan. Vico Cost Explorer is the first model-based budgeting application that allows the extended project team to visually understand which aspects of the project are contributing to changes in cost. Pouring over rows and rows of spreadsheet data is a thing of the past.	Vico Software (2013)
Tocoman iLink	Tocoman iLink is a plug-in to a building modelling application. It is used to calculate quantities either from designers or contractor's building models. These quantities can be used as such or with the Tocoman Express product, in estimating and scheduling applications.	Tocoman Group (2010)

4.3. MAJOR CHARACTERISTICS OF CURRENT PRACTICE OF COST MODELLING IN BIM ENVIRONMENT

After reviewing the IFC use cases and BIM based costing software, the major characteristics of the current practice, it is quite clear that all those except MS Excel comprise of the following characteristics (Zhiliang *et al.*, 2010a).

- Operating in 3D-based platform obtained either from independent developing or professional BIM based design software.
- Capable of extracting input data from IFC file.
- Since there is no enforced specification, the software follows the coding system developed by the industry association.
- Applicable for estimating from conceptual design to detail design.
- The quantity extraction is not subjected to uniform calculation rules but is based on object types and their dimension.
- Cost estimation is based on the cost items generated by the professional and experienced cost estimators.

Through the literature, it was identified that the current practice has several problems and it does not clear the path to confiscate the obstacle of the interoperability inefficiencies to adopt BIM (Mendez, 2006).

5. KEY REQUIREMENTS OF COST MODELLING IN BIM ENVIRONMENT

Through the literature search, the main requirements of cost modelling in the BIM environment were identified. Since Zhe (2009) suggested a comprehensive list of requirements, those were adapted in this research.

Table 2: Key Requirements of Cost Modelling in BIM Environment

No	Key Requirements	Description
1	Automatically import design result	The estimators can make use of the design result of IFC data automatically. There is no need to manually identify the drawing and to establish the model which could eliminate manual reworks, increase speed and improve productivity.
2	Interactive 3D visualization	Users can enjoy the best performance of 3D building model navigation and object details examination. The 3D building elements and cost items are highly interactive and selectable. Support interactive data modifications.
3	Intelligent match	Building elements can be automatically linked to cost items through the intelligent judgment of the building element's properties. This feature reduces a great deal of effort of estimators.
4	Intelligent change management	If the design is changed, the next generation Construction Cost Estimation software can display changed, new, and deleted objects, and automatically update the quantities. The cost estimating can be easily adjusted. This feature helps the estimators to deal with the design change efficiently.
5	Export the standard cost estimating data	Export the standard IFC data file which include building element's dimensions, construction process and cost items data so that the downstream software, such as construction management software, information reuse software can directly use the data.

6. OPEN BIM DEVELOPMENTS

In order to achieve the above key requirements of cost modelling in the BIM environment, cost modelling software should be capable of implementing IFC interoperability, for which the vendors have to enable their software to read and write IFC format. This can be achieved through Information Delivery Manual (IDM) which defines the information exchanges between users, and Model View Definitions (MVDs) which define the implementations in software (buildingSMART, 2013d).

When user requirements for a data exchange are defined in an IDM and a solution that meets those requirements, through the use of software, is defined in a MVD, software vendors implement support for one or more specific MVDs in their software applications. After completing the implementations, the end user can use the data exchange defined in the IDM in their businesses (buildingSMART, 2013d).

According to the IFC Solution Factory (2013), it focuses on supporting the development and certification of IFC based data exchange in end user processes and software used in the worldwide construction industry. In order to accomplish this MVDs are developed by buildingSMART and other international organizations and they are made available for any software company to build support in their software. In addition, IFC Solution factory intents to provide information about software that has been certified for correct support of these MVDs.

Among various MVDS, Architectural Design to Quantity Takeoff for Cost Estimating, under the other international organizations MVDs, is the only MVD in the status of candidate for cost modelling. This MVD has completed its conceptual design which attempts to define a subset of the data created in architectural design software, which is useful for quantity take-off purposes. The basic idea behind this view is that design team members provide design object quantities which can be used as 'underlying quantities' that drive the calculation of 'construction quantities'. Designers think in terms of spaces, building elements and their functional properties. Quantity take-off focuses on assemblies, items, and the resources required constructing these assemblies (IFC Solution Factory, 2013).

The MVD development is based on the internationally agreed exchange levels of Quantity Take-Off (QTO) information. These levels are as shown below.

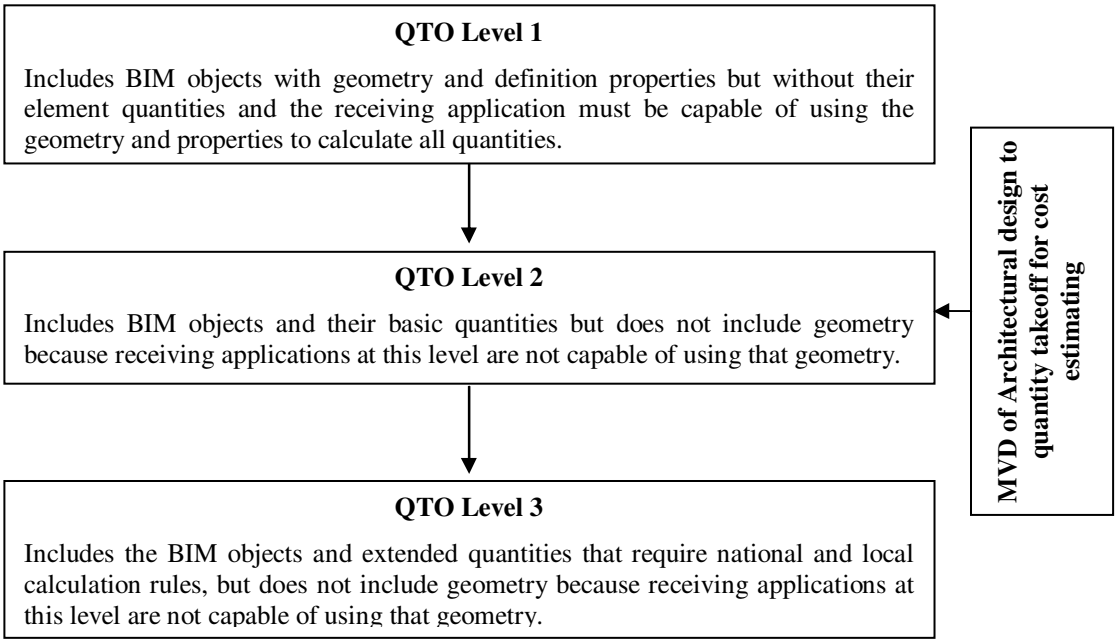

Figure 1: Levels of Exchange of QTO Information

In the scope definition of this MVD, it is clearly stated that most important cost modelling parameters like cost information and construction type libraries are not considered in this view.

7. CONCLUSIONS

As the conclusion of the literature findings of the ongoing research, it can be identified that in order to achieve the key requirements of the cost modelling in the BIM environment, interoperability through open standards is critical. It is mainly because; the main collaboration issues prevailing in the AEC projects should be addressed through the best practical approach, which is the open standard. Furthermore, the current Open BIM developments on cost estimation are not at a level where they could solve the issue of not having an integrated cost model in the BIM environment. Hence, developing a framework for integrated cost model comprising of the above mentioned key requirements in the BIM model is appearing to be a key requirement.

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