FRAMEWORK DESIGN FOR BIM-BASED CONSTRUCTION COST ESTIMATING SOFTWARE

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ABSTRACT

This paper mainly focuses on establishing a framework for BIM-based Construction Cost Estimating (CCE) software based on Chinese standards. The characteristics of the existing major CCE software in China and the key requirements of the next generation CCE software were identified based on investigations and interviews. Furthermore, the characteristics of major BIM-based CCE software of foreign vendors were reviewed and their feasibility to be used in China was analyzed. The framework of BIM-based CCE software subject to Chinese standards was proposed and corresponding functions were systematically analyzed. The framework laid a solid foundation for developing the next generation CCE software.

Keywords: BIM, IFC, Construction Cost Estimating, Software Framework

1. INTRODUCTION

Construction Cost Estimating (CCE) is a vital step for construction enterprises whose efficiency and accuracy are of great value for advancing their economic benefits and cutting down the labor intensity. With the development of computer technology, CCE software have been developed and applied to assist the estimating work more efficiently. However, there is still great room for improvement for the estimators who still have to spend a lot of time on accomplishing the estimating task right now.

Building Information Modeling (BIM) shares information between project team members and across the software applications which are commonly used for design, construction, procurement, maintenance and operations (Building Smart, 2008). Industry Foundation Classes (IFC) is the major standard of BIM which is proposed by International Alliance for Interoperability (IAI) in order to share construction and facility management data across various applications used in the building domain (IFC wiki, 2009). Up to now IFC has been applied in the construction cost estimating by some researchers. Ihsan Faraj et.al developed the WISPER (Web-based IFC Shared Project Environment), which built an IFC-based object-oriented database to help users realize the network integration and sharing of the design, budget, schedule and other information in construction projects (Ihsan Faraj et.al, 2002). Charlie Fu et.al developed an system for the life-cycle cost assessment which could automatically extract cost estimating data from the design results of IFC files, and then transfers the data to a pre-existing component of life-cycle cost assessment (Charlie Fu et.al, 2004). Sheryl Staub-French et.al developed an IFC-based cost

estimating system, which could directly use the results of IFC files and then automatically apply corresponding quota to accomplish cost estimating according to the component geometries and properties (Sheryl Staub-French et.al, 2003). Nobuyoshi Yabuki et.al applied the IFC standard in the cost estimating of earthwork and accomplished the cost estimating function according to the 4D model (Nobuyoshi Yabuki et.al, 2005). Theoretical study shows that the estimating result obtained from BIM-based CCE software tends to be more efficient and accurate. Especially when the design is changed, it could be easily updated and the efficiency would be improved by an order of magnitude (Fuchun Yang et.al, 2005). Real life case studies indicated that BIM-based CCE software can increase the efficiency of the estimating process by more than 300% (Innovaya, 2010).

At present, several BIM-based CCE software have been developed to improve the efficiency of estimators. However, due to the localization of specifications, those software cannot be applied widely to all countries and regions. Consequently, this paper aims to provide a foundation for developing BIM-based CCE software by analyzing the CCE software home and abroad and the feasibility of the BIM technology.

2. CHARACTERISTICS OF THE EXISTING MAJOR CCE SOFTWARE IN CHINA

CCE can be divided into two types, i.e. quantity take-off and project valuation. Time spent by estimators on quantity take-off varies by projects, but approximately around 50% to 80% of the time needed to create a cost estimating (AIA and Rick Rundell, 2006). Therefore, reducing the time of the quantity take-off is the key to improve the efficiency of CCE.

With development of the information technology, the history of developing quantity take-off software in China could be divided into three phases (Zhe Lou, 2009). In early 1990s, quantity take-off software based on the spreadsheet was developed. After 1995, 2D-based quantity take-off software was developed. After 2000, with the development of 3D visualization technology, 3D-based quantity take-off software was developed. Right now, it is in the third phase. Because of the importance of quantity take-off, it often represents the key development phase of the whole CCE software. It is believed that BIM-based take-off will be the key feature of the next generation CCE software.

Due to the work mode, quantity take-off software and project valuation software have been separately used so far. In this paper, the authors summarized the characteristics of the existing major CCE software in China including the quantity take-off software and project valuation software, as collectively shown in Table 1.

Table 1: Characteristics of the existing major CCE software in China (Zhe Lou, 2009)

No.	Aspects	Characteristics
1	Operating platform	AutoCAD-based platform or 3D-based platform obtained from independent developing.
2	Way of design result inputting	Manual modeling and digitizing the architect's paper drawings, dwg file inputting, or Excel file inputting.
3	Specification	Support quota specification for each region and “Code of Valuation with Bill Quantity of Construction Works (GB50500-2003 or GB50500-2008)”.
4	Way of quantity take-off	Support the quota and BQ calculation rules.
5	Valuation mode	Support the quota method and the BQ method, covering the quota of most provinces and cities nationwide scale.
6	Application scope	Detailed estimating.

Note: BQ is short for Bill Quantity

Overall, compared to CCE software in the second phase, the current CCE software has three main advantages. First, they give rise to quick data-input mode and more simple and intuitive user operation. Second, because of the precise mathematical model, it can calculate more accurately and faster. Third, it can take advantage of the design result partly which have further improved the CCE efficiency (Zhe Lou, 2009).

3. THE KEY REQUIREMENTS OF THE NEXT GENERATION CCE SOFTWARE

In order to establish the key requirements of the next generation CCE software, the authors have done the following works. First, interviews with the estimators of five typical construction enterprises were carried out. Based on the interviews, the authors established the application problems of the existing CCE software. Second, literature search was conducted. From the literature, the authors identified the problems of the existing software and some requirements of the next generation CCE software. Based on the above studies together with BIM technology review, the authors established the key requirements of the next generation CCE software, as shown in Table 2.

Table 2: The key requirements of the next generation CCE software (Zhe Lou, 2009)

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 CCE 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.

4. ANALYSIS OF MAJOR BIM-BASED CCE SOFTWARE'S FEASIBILITY USED IN CHINA FROM FOREIGN VENDORS

This paper has reviewed 7 BIM-based CCE software of American vendors, which are widely used. They are Innovaya Viusal Estimating, Success Design Exchange (U.S.Cost, 2010), Timberline Extended (Sage, 2010; AECCAFE, 2002), MC2 ICE (MC2, 2010), Winest DesignEst Pro (Winest, 2010), Tokmo Production System (Tokmo, 2010) and Vico Estimator 2009 (Vico, 2010). Table 3 collectively illustrates the major characteristics of the 7 BIM-based CCE software.

On the whole, while not considering the local specification, these BIM-based CCE software can meet most of the key requirements of the next generation CCE. For example, with CAD Integrator, Sage's Timberline Extended can open an IFC data file created by an IFC-compliant CAD program during the design phase. The IFC data file contains common building objects, with their design and dimensional information. Then CAD Integrator reads the IFC data straight into items and assembles the takeoff, instantly creating a cost estimating in Timberline Estimating. No manual entry of quantity values or use of a digitizer is required (AECCAFE, 2002). With the Innovaya Composer, Innovaya Visual Estimating can directly use the design result for cost estimating and export the estimating data to INV file which can be directly used by all Innovaya visual applications, such as construction simulating tool (Innovaya, 2010). However in-depth analysis of the BIM-based CCE software indicates these software have to address the following issues so that they can be used in China.

The first is the coding system. The basis of CCE is coding system. At present, UNIFORMAT II and MASTERFORMAT are widely used in the American AEC industry. However, there are two methods being used

for CCE for tendering in China. One is called BQ method, and the corresponding coding system is "Code of Valuation with Bill Quantity of Construction Works (GB50500-2003 or GB50500-2008)". The other is called quota method, and the corresponding coding system includes the national quota coding system "National Unified Basic Quota of Construction Works in China" and the local coding system, such as "Valuation Quota of Construction Works in Beijing". The coding system in different country is quite different. For example, MASTERFORMAT divides the construction project into 16 parts and every part is constituted by a number of chapters (Yilin Yi and Ling Yan, 2009). While the coding system "Code of Valuation with Bill Quantity of Construction Works (GB50500-2008)" firstly divides into five parts based on the different work packages. These work packages are construction, decoration, installation, municipal, landscape and mining projects. Then, a number of division-items are included in each work package.

Table 3: Characteristics of major BIM-based CCE software from foreign vendors

No.	Aspects	Characteristics
1	Operating platform	3D-based platform obtained from independent developing or depending on the professional BIM-based design software, such as Autodesk Revit Architecture.
2	Way of design result inputting	Read IFC data file etc.
3	Specification	There is no enforced specification. Generally the software follow the coding system developed by the industry association, such as American Construction Specifications Institute (CSI) or large consulting firms, such as RS Means.
4	Way of quantity take-off	There are no uniform calculation rules. The quantities are extracted based on object types and their dimensions. The quantities can be organized and saved by different classifications such as UNIFORMAT II or MASTERFORMAT.
5	Valuation mode	There is no uniform pricing standard. Cost estimating is based on the cost items generated by the professional consulting firms or the construction enterprise.
6	Application scope	From the conceptual estimating to the detailed estimating.

The second is the quantity take-off method. In USA, there are no unified calculation rules. However, in China, no matter the quota method or the BQ method, there are standard calculation rules which have to be followed by estimators. Besides object types and their dimensions, the quantities are extracted also based on the object division- items information, such as construction technology and construction method etc.

The third is the valuation basis. There is no unified valuation quota of construction works in USA and the cost of the construction project is determined by the market. While in China, valuation is based on the national or local quota such as "Valuation Quota of Construction Works in Beijing". Although the contractors are supposed to use their own comprehensive unit price based on the internal quota and the market information to calculate the cost, they normally have to calculate the cost by using the public quota right now.

It means that a lot of works have to be done before these foreign software can be used in China, such as the embedding of the coding system, database preparation and quantity take-off function adjustment etc. Obviously, these work will led to a complex and costly process to modify the software. Therefore, even if only from the technical point of view, it would be best to develop BIM-based CCE software which is suited to conditions of China rather than to localize the BIM-based CCE software from foreign vendors.

5. FRAMEWORK DESIGN FOR THE NEXT GENERATION CCE SOFTWARE

5.1 FRAMEWORK MODEL OF THE NEXT GENERATION CCE SOFTWARE

Based on the above-stated key requirements of the next generation CCE software and the overlap of the functions of the existing CCE software in China, the authors have established the framework model of the next generation CCE software, as shown in Fig 1. Two parts are included in the model, which are management platform of BIM data and module of CCE sub-system. The former is used to store BIM data and provide interface to access the da-

ta. The latter provides the users with CCE application functions (Zhiliang Ma and Yili Zhao, 2008). The purposes of adopting such a framework are to isolate basic BIM data from application functions and to do appropriate encapsulation to BIM data. The rationale behind this is that the management platform of BIM data is bestowed with universality, and thus can be applied to develop other BIM-based application software, such as the Energy-Efficient Design Software (Yili Zhao, 2008).

With this framework model, users can directly use the design result which is in the form of an IFC data file through the Management platform of BIM data and then complete the CCE through the Model of CCE sub-system. Finally, the estimating data can be exported in IFC format through the Management platform of BIM data again, so that downstream software can directly use it. More details of the model of CCE sub-system will be introduced in the following.

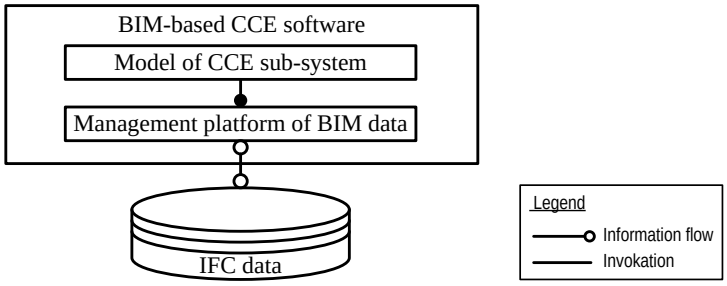

Fig 1: Framework model of next generation CCE software (Zhe Lou, 2009)

5.2 MODEL OF CCE SUB-SYSTEM

As shown in Fig 2. Five categories of functions are contained in the model based on BQ-method, namely the categories of project settings, BQ-item settings, quantity take-off, project valuation and report generation and management module. Both the major functions included in the categories and their work-flow are also shown in the Fig 2. Specifically, based on the project settings, the software can help the users to use the design information contained in the IFC data mostly. For example, if the building element contains the necessary information identified in the specification, the software will automatically map the building element to BQ-items and quota. However, some construction information such as construction methods, site work etc. may be not included in the design result, so it also need to do manually settings. Then, it can automatically calculate the quantity based on the calculate methods. Finally, with the corresponding functions contained in project valuation and report generation and management, the CCE could be completed and the estimating data could be generated into report which can be previewed, printed etc. It is worth of emphasizing that the model can be expanded to support the realization of quota method.

Further details of each category of functions are specified in Table 4.

6. CONCLUSION AND FUTURE WORK

Based on the investigations and interviews of the CCE software home and broad and review of the BIM technology, this paper proposes the framework of the next generation CCE software for China. The framework takes full advantage of the BIM technology and meets the key requirements of the next generation CCE software. This framework laid a solid foundation for developing the next generation CCE software.

At present, the software is under development, in which, C++ is employed as programming language, IFC Engine DLL as the import and export interface for the IFC data, Open Inventor as the graphics support software and the Rational Database (RDB) for data management. Further research results will be reported when they become available.

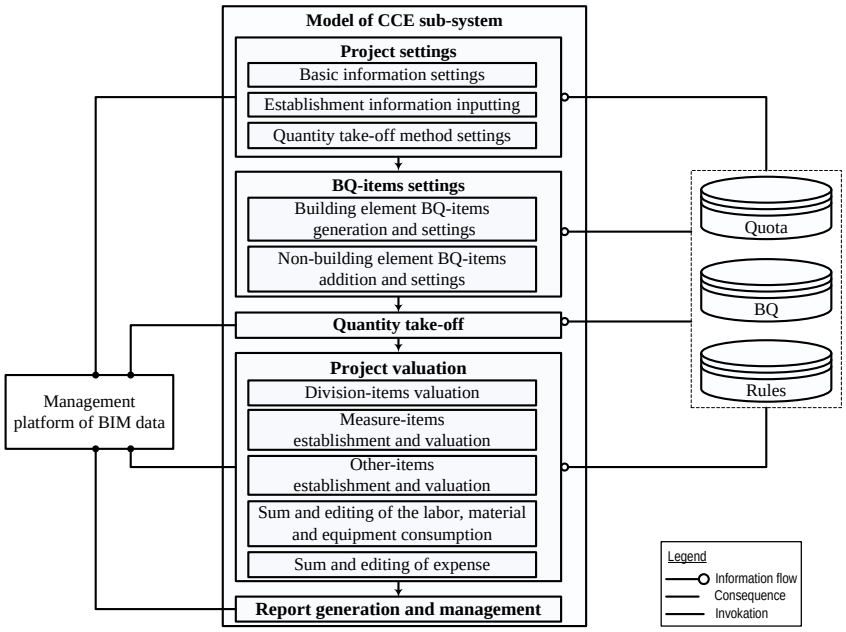

Fig 2: Model of CCE sub-system

Table 4: Major functions of CCE software

No.	Functions		Details
1	Project settings	Basic information settings	Determine method for CCE calculation rules etc.
		Establishment information inputting	Input and check the establishment information, such as the name of the tendering person, establishment time, etc.
		Quantity take-off method settings	Quantity take-off methods are customized and are reusable for multiple projects
2	BQ-items settings	Building element BQ-items generation and settings	Generate building element BQ-items and set their construction information.
		Non-building element BQ-items generation and settings	Add non-building element BQ-items manually such as the earth backfill and set its project characters, work scope and quantity, etc.
3	Quantity take-off		Automatic quantity take-off based on the calculate methods and the cost items.
4	Project valuation	Division-items valuation	Value the division-items.
		Measure-items establishment and valuation	Value and establish the measure-items.
		Other-items establishment and valuation	Value and establish the other-items.
		Sum and editing of the labor, material and equipment consumption	Summarize the total labor, material and equipment consumption and screen the major material.
		Sum and editing of expense	Summarize the expense such as the total labor and equipment fees, etc. In addition, complete the fees and taxes establishment and valuation.
5	Report generation and management		Generate the standard report according to the relevant standards. The report can be previewed, printed and exported as report in excel.

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