A Methodology of Open BIM-based Quantity take-off for Schematic Estimation of the Frame Work in Early Design Stage

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ABSTRACT: Recently AEC industry has required construction automation according to becoming large and complex. Thus BIM-based construction project is increased and used in whole fields of AEC industry. Quantity take-off and estimation fields are important factor for decision-making in conceptual and schematic design stages of construction projects. The purpose of this study improves reliability of the estimation through QTO based on Open BIM. Scope and method to apply QTO is to select conceptual design stage through LoD(Level of Detail) in AEC field and to extract information from BIM model through analysis of IFC structure. This study proceeds three step to make BIM model and check the model quality and calculate QTO. The methodology of QTO using IFC is to verify of result in this study and expects utilizing in design stage of construction projects. The result from this study is expected to decrease the risk factor and time of estimation in the project early phase through improving reliability of schematic estimation.

Keywords: Open BIM, IFC(Industry Foundation Classes), QTO(Quantity take-off), Schematic Estimation, LoD(Level of Detail).

1. INTRODUCTION

Cost estimate in construction projects is an important factor for decision-making in both early phase and detailed design phase. The construction phase based on QTO can function for procurement and prediction construction cost. In Korea, estimate work based on 2D drawing has generated problems of difference from QTO according to workers' mistake and know-how. In addition, 2D-based estimation are obtained uncertainty factors of estimation depending on lack of information due to becoming larger and more complex than any other project of the construction project itself [1]. Accordingly, in the construction project increases the requirement for securing reliability of accurate QTO and cost estimation.

Reliability of the estimation is needed by exact quantity information of buildings. The inaccurate information of QTO brings about error of estimation because schematic estimation in the early phase process multiplies the quantity by unit cost. To solve 2D-based QTO task problems, research of 3D based QTO has been active [2]. However, various problems in 3D based QTO were later than the cost estimation, as an extension of work on your business; a lot of methods have been proposed as sided opinions.

This study presented methodology of connecting BIM data properties (volume, area) with unit cost. The scope of this study is that the schematic estimation which has been made in the design phase of the work focus on the building's frame work. It accounts for more than 50% of the total cost to the project making it an important early work task. The schematic estimation of frame work through analysis of the productivity is helpful to select design alternatives in the early design phase. Moreover, it is more useful to make a construction plan. The QTO prototype system developed in this study has schematic estimation modules for reinforced concrete work and steel frame work.

The methodology of research is,

1. Deriving the critical point and implications through analysis of cases and researches of QTO/cost estimation.

2. Suggesting Open BIM-based QTO process through BIM modeling, physical quality check, data quality verification for cost estimation and QTO for schematic estimation of the frame work.

3. Presenting the methodology of extraction quantity information in IFC model and linkage between quantity information and calculation method of schematic estimation.

2. Preliminary research

2.1 Schematic Estimation

The cost estimation for each design phases can be defined as follows; conceptual estimation in planning phase, schematic estimation in schematic design phases, and detailed estimation in design development phase, respectively [3]. The purpose of schematic estimation according to its definition is feasibility study and economical evaluation through prediction of rough investment.

Schematic estimation in the basic approaches of domestic production can divide largely into two.

- Statistical and empirical approaches, each approach with a construction cost of running the data through an analysis of how to calculate the construction cost per square meter.

- Method of cost per unit area based on the calculation costs through analysis of the floor plan cost per unit area

The method of this study is to extract architectural elements' quantity through BIM data. Difficulty elements of authoring are to extract from the volume per unit area used for construction costs. This induced, schematic estimation reliability increases.

2.2 Analysis of advanced research

QTO and estimation field have developed an automated system since 1990s and changed from 2D-based automatic system into 3D-based automatic system. From analyzing the major studies in Korea, some Implication could be found; Automatic system applying for the methodology of object-oriented in 3D model [4], Recipe-based Methodology of connecting 3D model with cost [1], Methodology of QTO using IFC 3D model [2] and so on. From analyzing the major overseas studies, some Implication could be found; The methodology of cost estimation of factors impact on Energy performance assessment factors affected using IFC model [5], Algorithm and development of database in object-oriented software for estimation task [6], and The methodology of estimation assumption for high-performance building through cost of building functional [3] and so on.

On-going researches trend has been studied methodology of 3D-based object-oriented and increased studies on linkages among various tasks about CM-Cost, Energy-Cost and so on.

Table 1. Analysis of the research trends

Trend	Keyword	Research contents
Automation QTO	Object-oriented	Automation estimation system applying element information in 3D model [4]
	Recipe	The research of Recipe-based QTO [1]
	IFC model	Development of QTO application in IFC 3D model [2]
	Schedule-Cost	Development of modules for QTO according to the schedule(Lee J.C., 2004)
Automation estimation	Automation based on method of construction	Automation based on method of construction using 3D model [8]
	Energy-Cost	Cost estimation of factors impact on Energy performance assessment factor affected using IFC model [5]
	Automation estimation for high-performance building	Estimation assumption for high-performance building through cost of building functional [3]
Efficiency of estimation	Automation Finishing work	The methodology of 3D automated modeling for BIM-based QTO [9]
	Build a DB for automation estimation	Algorithm and development of database in object-oriented software for estimation task [6]

2.3 Implication

The previous researches of 3D-based QTO and estimation were constructed on one's own data model for QTO/Estimation for the reason that it was not performed the task through 3D model. QTO/Estimation increases accuracy and speed compared to the existing system.

However, it has a weakness of making on one's own data model for QTO. Therefore, this study proposes the integration model using QTO task and estimation task through the concept of Open BIM. The concept of the IFC model can be progressed in the entire task of the building life cycle, as long as worker inputs the necessary data for the task; design, construction, facility management. Thus, in this study suggests methodology

of QTO for the schematic estimation due to IFC model in early design phase.

3. QTO process and BIM modeling

3.1 Open BIM-based QTO process

BIM-based estimation needs BIM model and database of unit cost information. Reliability of estimates require accuracy of the QTO result and high quality BIM model has a decisive effect on accuracy of the QTO. In this chapter proposes Open BIM-based QTO process and suggests the method of modeling for schematic estimation.

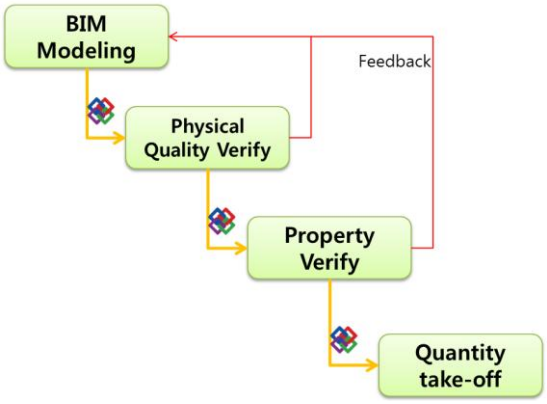

Figure 1. Open BIM-based QTO process

The QTO process is comprised of four steps; BIM modeling, physical quality verify, property verify, Quantity take-off. First step is BIM modeling which is made by BIM authoring tools supporting IFC format. Physical quality of BIM model is verified by commercial software, *SMC(Solibri Model Checker)*. Through this step can ensure accuracy of quantity information.

Verification of property is constructed with extracting of structural elements and checking the construction code in order to extend the estimation work. BIM model to be gone through verification of physical/data quality is calculated the quantity for schematic estimation of the frame work.

3.1 Analysis of LoD for Modeling

To make model for suitable project phases is demanded the modeling for each step on the level of detail. LoD means level of detail of model. Definition of LoD through the analysis of domestic and international BIM guides and manuals is the level of detail of the model in order to achieve the project's BIM utilization purpose; furthermore it suggests the purpose and scope to take advantage of model data at each step. Table 2 is contents of LoD in the guide of domestic and international.

Table 2. Analysis of LoD in the guide of domestic and international

	AIA Document E202: Building Information Modeling Protocol Exhibit [10]	BIM Standards & Production Technology [11]	Singapore BIM Guide [12]
LOD1 (Conceptual Design)	➢ Non-geometric data or line work, areas, volumes, zones, etc.		➢ Building massing studies. ➢ Indicative dimensions, area, volume, location and orientation
LOD2 (Schematic Design)	➢ Generic elements shown in three dimensions. ✓ maximum size ✓ purpose	➢ Approximate dimensions, shape, location, orientation and quantity.	➢ Approximate dimensions, shape, location, orientation and quantity. ➢ Non-geometric properties.
LOD3 DD (Detailed Design)	➢ Specific elements confirmed 3D Object Geometry. ✓ dimensions ✓ capacities ✓ connections	➢ Dimensions, shape, location, orientation and quantity. ➢ Specified elements and equipment.	➢ Accurate dimensions, shape, location, orientation and quantity. ➢ Non-geometric properties
LOD4 (Construction)	➢ Shop drawing/fabrication ✓ purchase ✓ manufacture ✓ install ✓ specified	➢ Modeling to assembly details include quantity, quality, material, texture, color etc.	➢ Complete fabrication and assembly details over and above the Detailed Design stage.
LOD5 (O & M)	➢ As-built-actual	➢ Complete fabrication and assembly details. ➢ Review and complementary of material, dimension of equipment, texture ect.	➢ BIM element is similar in level of detail to the Detailed Design stage. ➢ Updated with changes during Construction stage.

Through Table2, LoD for schematic estimation approves LoD2 is to do basic building elements modeling, it is possible to calculate quantity of the basic building elements. Architectural elements are sorted by structural property in order to calculate quantity of the frame work. Architectural elements are sorted by structural property in order to calculate quantity of the frame work according to MVD for QTO/Estimating in buildingSMART Int'l.

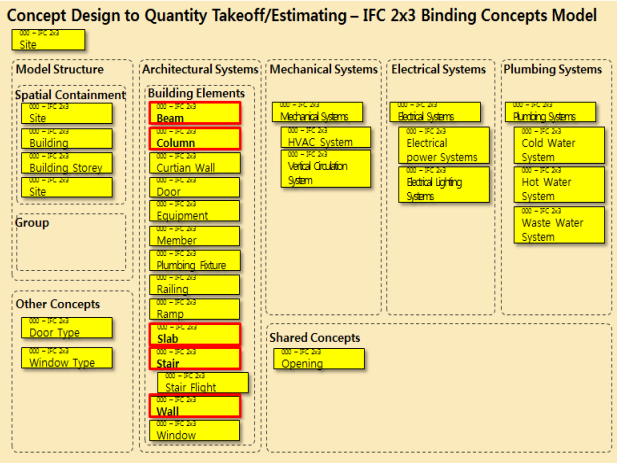

Figure 2. Structural building elements applying the frame work among architectural building elements [13]

Building elements applying the frame work as shown in Figure 2 are bearing wall, column, slab, beam, and stair. The manufactured model due to LoD2 progresses extracting quantity of 5 elements.

3.2 Modeling for the schematic estimation

The sample model is done by *Revit Architecture 2012* using *KBIMS-Library v.0.9* [14] established by *buildingSMART KOREA*. The model is to be inputted the property of the estimation, for the reason that this study is not only QTO but also the schematic estimation. Inputted properties are *LoadBearing* for extracting structural element and *Code of construction classification* for the estimation.

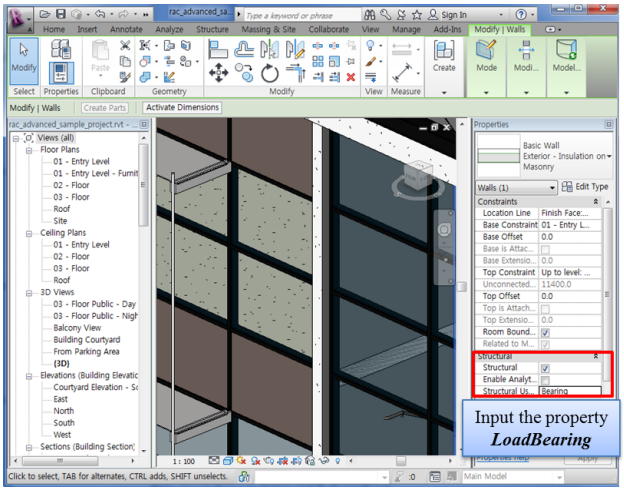

Figure 3. Input *LoadBearing* for extracting element of the frame work in *Revit Architecture 2012*

First, structural property as shown in Figure 3 is possible to select *Bearing* or *Non-Bearing* in wall, thereupon wall fall into two categories, bearing wall and nonbearing wall. It can check that the structural property of the wall is entered as true or false in the IFC file *LoadBearing*. The only true value of the element to extract the *LoadBearing* values are calculated quantity of the frame work through columns, slabs, beams, stair is entered the property in the same way as walls.

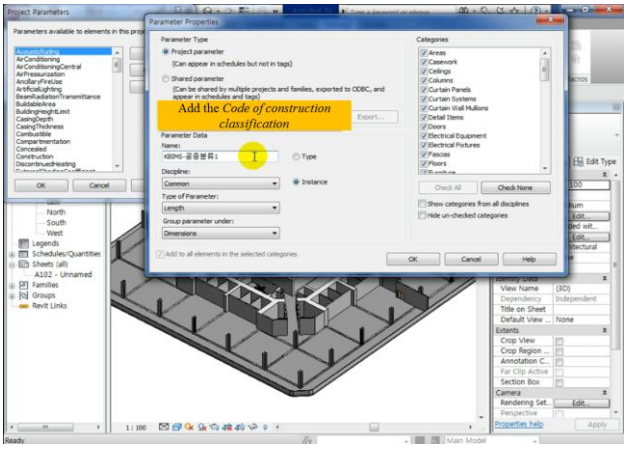

Figure 4. Input the Code of construction classification for the estimation

Second, the method of inputting construction code for the estimation is to add the pset and to enter codes in each element as shown in Figure 4. It is to add pset of 10 for the reason that each element has to need a string of codes. It is to add pset of 10 for the reason that each element has to need several codes; it is referenced by "Construction Code Operating System - Construction Classification" [15] by Korea Public Procurement Service and "Construction Type and Unit Cost apply Actual Cost of the Construction Project in 2012" [16] by Ministry of Land, Transport and Maritime Affairs. Two types of codes can be used by code mapping between construction type and unit cost for the estimation and contributed by standardization of the estimation.

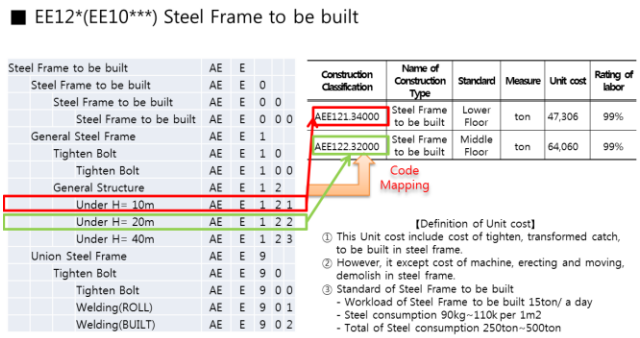

Figure 5. Construction classification / Construction type and Unit

Final model for the schematic estimation of the frame work is made by using *KBIMS-Library* and completed by inputting the structural properties and construction code. The model is verified the physical and data quality by

quality checking software. After completion of quality checking, the model is to be final model for QTO and the estimation.

4. Verification of quality of BIM model and the method of calculating quantity

In this chapter, the method of verifying quality in order to increase accuracy and reliability is presented. The method of verification is divided two types; one is physical quality, the other is data quality. The method of verifying physical quality is proposed by using common software and the Open BIM-based method of verifying data quality is proposed.

4.1 Verification of physical quality for QTO

The model is made by authoring tool verifies the validity of physical quality. Physical quality checking is a minimum requirement for shape representation and intersections among elements can increase the accuracy of quantity. Process of verify progress uses common software such as *SMC(Solibri Model Checker*) through making rule-set depending on domestic design checklist.

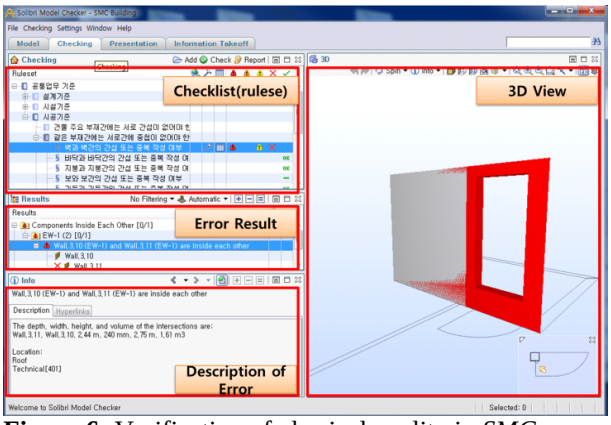

Figure 6. Verification of physical quality in *SMC*

BIM model is undergoing a process modifying in BIM authoring tools according to error facts. After checking the physical quality, it goes through input properties that code of construction type in BIM data.

4.2 Verification of data quality for QTO

The QTO prototype system separated into two modules have been developed. Verification of data quality is used to check whether or not required data is inputted, detect the error of input data. First, it detects the error, when structural elements don't have the structural property. Second, check item is verified the error of the construction code which has non-existent code or a wrong code, for the reason that the construction code are used by mapping between element and unit cost.

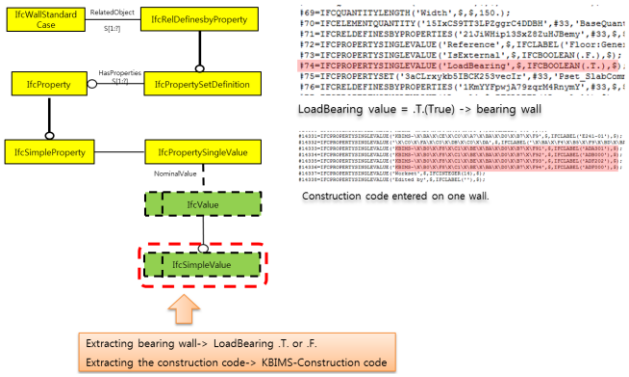

Figure 7. Extraction of frame work and construction code – Example of structural wall volume

Figure 7 shows that it is the method of extracting structural elements and construction codes on one wall. Consequently, it is conducted verification of data quality by this method.

BIM model can be modified by authoring tool through the error r. After completion of physical/data quality checking, BIM model can be conducted QTO.

4.3 Quantity take-off of the frame work

QTO of the frame work is divided into two; one is the r einforced concrete work, and the other one is the steel frame work. Bearing walls, columns, slabs, beams, stairs applicable to QTO of the reinforced concrete work can be extracted quantity from IFC file as shown in Figure 8. Columns, beams applicable to QTO of the steel frame work are extracted its length from IFC file, for the reason that method of shape-steel's quantity multiplies its unit weight by length.

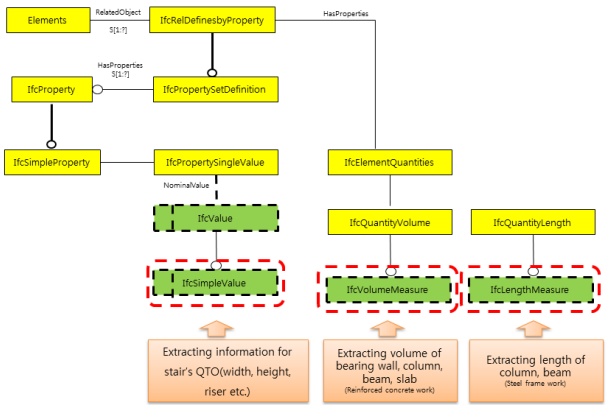

Figure 8. The methodology of extraction of elements' quantity in the frame work

Extracted information as shown in Figure 8 is calculated by method of schematic QTO. The concrete quantity is extracted in BIM model, quantity of the rebar and the form are calculated by the ratio of concrete. The concrete quantity is extracted in BIM model, quantity of the rebar and the form are calculated by the ratio of concrete according to method of using in practice. The method of schematic QTO is as shown in Figure 9.

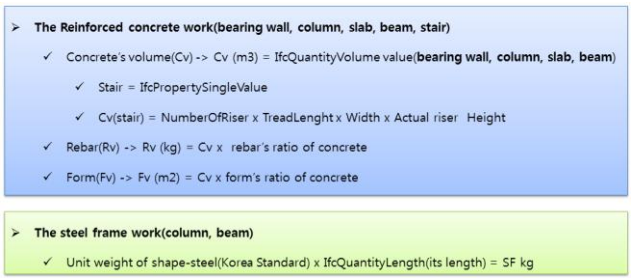

Figure 9. The methodology of QTO(Reinforced concrete work, Steel frame work)

The ratio for calculating quantity can be modified quantity of the rebar and the form rating per concrete quantity and selected shape-steel's type and its size. The model through the quality's verification and set-up calculate ratio is obtained the quantity using IFC.

The value of result in the reinforced concrete work is quantity of concrete, rebar and form of each element. In addition, ratio of rebar and form per concrete is possible to provide basis of calculation. In the steel frame work, it is calculated steel's quantity of columns and beams. Stairs and steel of the quantity of the proposed method are more accurate than another method you can get the value of quantities, the reason that the method follows the estimation of Korea Standard.

5. CONCLUSIONS

This research suggests a solution of QTO for low reliability of estimation manually, and difficulty about huge amounts of data management by building's complication and larger. Specifically, it based on Open BIM for QTO process of schematic estimation by early design stage, and QTO method of the frame work had developed from information to extract IFC model.
The detailed research results are as follows;

I. This study suggests Open BIM-based process of QTO for the schematic estimation which increases reliability. The process is 4 stages; the modeling for the schematic estimation, verification of physical quality for increasing accuracy, verification of data quality for the estimation, the method of QTO through interlocking between extracting quantity and calculation method.

II. The study is proposed that the method of calculating QTO for the schematic estimation of frame work, which is an important factor for decision-making in early phases. The method is Calculate for QTO of reinforced concrete work and steel frame work. Additional methods are selecting structural elements for the frame work and calculating quantity of the rebar and the form through modifying ratio of concrete.

Thus, the methods are helpful not only in increasing accuracy of QTO, but also in quality assurance of IFC model. Moreover the result of QTO can extend schematic estimation task and improve reliability of the estimation. The research result is possible to be used in schematic estimation which applies for feasibility study, EVM (Earned Value Management).

Further research effort will be extended into QTO and estimation in the whole of construction work. Additionally, the schematic estimation system is expected to develop for the IFC-based estimation with more reliability.

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