Development of Quantity Take-off System for Framework Schematic Estimates in Design Stage

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Abstract

Recently AEC industry has demanded construction automation for large and complex construction projects. Thus the demand of adopting BIM for construction projects has increased in the AEC industry. 'Quantity take-off' and 'estimation' are two important features for decision-making during the conceptual and schematic design stages of construction projects. The purpose of this study is to improve the reliability of estimation through QTO based on Open BIM. Scope and method to apply QTO are to be selected in the conceptual design stage through Level of Detail (LOD) in AEC field and to extract information from BIM model through analysis of IFC structure. This study consists of three stages: BIM data generation, model quality check and QTO calculation. QTO prototype system based on IFC is to verify results in this study and expect utilizing system in early design stage of construction projects.

Keywords

Open BIM, Industry Foundation Classes (IFC), Quantity Take-off (QTO), estimates, Level of Detail (LOD).

INTRODUCTION

Cost estimates in construction projects are important for decision-making in conceptual and detail design phases. In the construction phase based on quantity take-off (QTO) can function as procurement and predicting construction cost. In Korea, cost estimation based on 2D drawings has generated problems of different to QTO according to workers' mistake and know-how. In addition, 2D-based estimates obtain uncertainty factors for estimation due to lack of information and becoming larger and complex of the construction project (Choi *et al*., 2006). Accordingly, it increases the requirement of securing the reliability of QTO and cost estimates.

Reliability of the estimation needs exact quantity information of buildings. The inaccurate information of QTO might cause errors in estimation because schematic estimation in the early phase multiplies the quantity by unit cost. To solve 2D-based QTO task problems, research of 3D based QTO has been active (Hwang, 2004). However, various problems in 3D based QTO were later than the cost estimation, as an extension of work on your business, several methods have been proposed as sided opinions. This study presents a

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methodology of connecting BIM data properties (volume, area) with unit cost and develops QTO prototype system.

The scope of this study is 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 percent of the total cost for the project making it an important early work task. The schematic estimation of framework 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 framework.

The methodology of research is,

1. Deriving the critical point and implications through analysis case and research of QTO and cost estimates.
2. Suggesting Open BIM-based QTO process through BIM modelling, physical/data quality verifies for cost estimates.
3. Developing the framework QTO prototype system through the design of interface, algorithm, and database.

PRELIMINARY RESEARCH

SCHEMATIC ESTIMATION

The cost estimation for each design phase can be defined as follows; *conceptual estimation* in planning phase, *schematic estimation* in schematic design phase, and *detailed estimation* in the design development phase, respectively (Prasad *et al.*, 2009). 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 be divided 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. Therefore, schematic estimation reliability increases.

LITERATURE REVIEW

QTO and estimation field have developed an automated system since 1990s and changed 2D-based automatic system into a 3D-based automatic system. From analyzing the major studies in Korea, some implications could be found; Automatic system applying for the methodology of object-oriented in 3D model (Oh, 2001), Recipe-based Methodology of connecting 3D model with cost (Choi *et al*., 2006), Methodology of QTO using IFC 3D model (Hwang, 2004) and so on. From analyzing the major overseas studies, some implications could be found; The methodology of cost estimation of factors impact on energy performance assessment factors affected using the IFC model (Vladmir, 2005), Algorithm and development of a database in object-oriented software for

estimation task (Saeed, 2005), and The methodology of estimation assumption for high-performance building through cost of building functional (Prasad *etal.*, 2009) and so on.

Current research trend has 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 estimates system applying element information in 3D model (Oh, 2001)
	Recipe	The research of Recipe-based QTO (Choi *et al*., 2006)
	IFC model	Development of QTO application in IFC 3D model (Hwang, 2004)
	Schedule-Cost	Development of modules for QTO according to the schedule (Lee, 2004)
Automation estimation	Automation based on method of construction	Automation based on method of construction using 3D model (Kim *et al*., 2007)
	Energy-Cost	Cost estimation of factors impact on Energy performance assessment factor affected using IFC model (Vladmir, 2005)
	Automation estimates for high-performance building	Estimates assumption for high-performance building through cost of building functional (Prasad *et al.*, 2009)
Efficiency of estimates	Automation Finishing work	The methodology of 3D automated modelling for BIM-based QTO (Kim *et al*., 2007)
	Build a DB for automation estimates	Algorithm and development of database in object-oriented software for estimates task (Saeed, 2005),

IMPLICATIONS

The previous research of 3D-based QTO and estimates was constructed on one's own data model for QTO/Estimation because of difficult to do not perform the task through 3D model. It increases the accuracy and speed more than that of in the existing system. However, it had a weakness of making on one's own data model for QTO. Therefore, this study proposes the integration model using QTO task and estimation through the concept of Open BIM. The concept of the IFC model can be progressed whole of the task in building life cycle, if workers input the necessary data for the task; design, construct, and facility management. Thus, this study applied a methodology of QTO for estimation through IFC model of the design phase.

BIM MODELLING AND QTO PROTOTYPE SYSTEM

QTO PROCESS

BIM-based estimation needs 3D BIM model and database of unit cost. Making precise BIM models can increase the accuracy of QTO. Mapping quantity and unit cost need to input some properties in the BIM model thus, chapter 3 shows BIM modelling for

schematic estimates and QTO prototype system using the BIM model. Figure 1 shows the QTO process in this study.

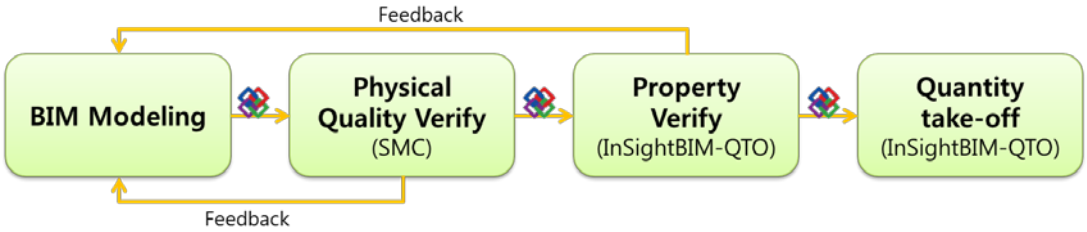


Figure 1. Process of Quantity take-off

BIM MODELLING FOR SCHEMATIC ESTIMATES

BIM model for schematic estimates is produced to focus on architectural work (more than 30 percent per total cost) through analysis of total cost of the construction project. Moreover, it is to focus on framework occupy a large portion of architecture work. The element of architectural work is that scope of detail is LoD3, elements are beam, column, wall, slab according to "Information Requirements for Model-based Quantities Definition of Base Quantities" defined by buildingSMART (IFC, 2012).

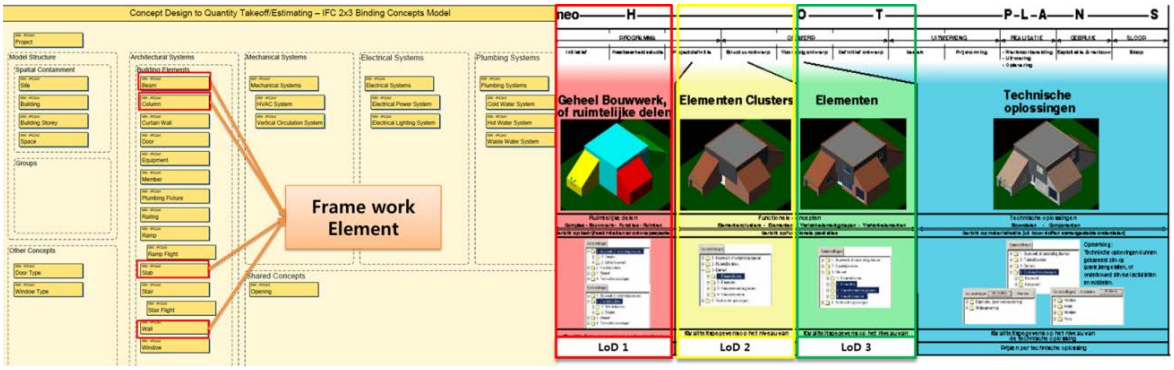


Figure 2. Architectural elements / Level of detail (LoD) (Hubert and Liebich)

This model verifies the validity of physical quality. Physical quality checking is the minimum requirement for shape representation. Intersection between elements can be increased accuracy of quantity. The process of verifying progress using common software, SMC (Solibri Model Checker) through making rule-set depending on domestic design checklist. BIM model is undergoing a process modifying in BIM authoring tools according to error facts.

After physical quality checking, it goes through input properties that code of construction type in BIM model. Properties are used by mapping element and unit cost. Construction classification used construction type code of Korea Public Procurement Service and unit cost was applied "Construction type and unit cost for previous bid price of construction in 2011" (Construction code operation system, 2012).

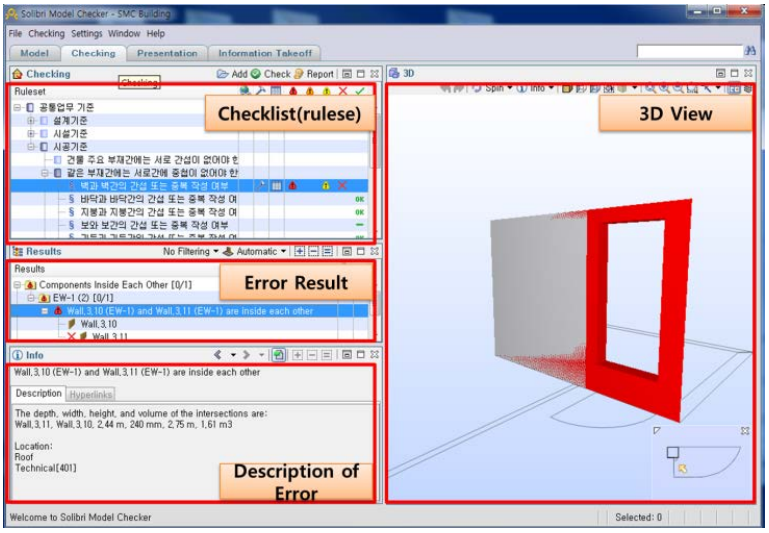


Figure 3. Physical quality verifies using SMC

■ EE12*(EE10***) Steel Frame to be built

Steel Frame to be built	AE	E				
Steel Frame to be built	AE	E	0			
Steel Frame to be built	AE	E	0	0		
Steel Frame to be built	AE	E	0	0	0	
General Steel Frame	AE	E	1			
Tighten Bolt	AE	E	1	0		
Tighten Bolt	AE	E	1	0	0	
General Structure	AE	E	1	2		
Under H= 10m	AE	E	1	2	1	
Under H= 20m	AE	E	1	2	2	
Under H= 40m	AE	E	1	2	3	
Union Steel Frame	AE	E	9			
Tighten Bolt	AE	E	9	0		
Tighten Bolt	AE	E	9	0	0	
Welding(ROLL)	AE	E	9	0	1	
Welding(BUILT)	AE	E	9	0	2	

Construction Classification	Name of Construction Type	Standard	Measure	Unit cost	Rating of labor
AEE121.34000	Steel Frame to be built	Lower Floor	ton	47,306	99%
AEE122.32000	Steel Frame to be built	Middle Floor	ton	64,060	99%

Mapping

【Definition of Unit cost】
① This Unit cost include cost of tighten, transformed catch, to be built in steel frame.
② However, it except cost of machine, erecting and moving, demolish in steel frame.
③ Standard of Steel Frame to be built
- Workload of Steel Frame to be built 15ton/ a day
- Steel consumption 90kg~110k per 1m2
- Total of Steel consumption 250ton~500ton

Figure 4. Construction classification / Construction type and Unit cost (Construction code operation system, 2012)

BIM modelling is completed model for schematic estimates input construction type code of LoD3 in BIM model.

ALGORITHM FOR SCHEMATIC ESTIMATES OF FRAME WORK

After BIM data is made by the requirement for estimation and input method, it is necessary to analyze IFC structure for bringing on input data. Figure 5 is the algorithm for extracting the volume in IFC structure according to its definition through analysis of IFC data.

This algorithm can be extracting construction type code and structural elements and therefore it is possible to calculate the quantity of frame work element.

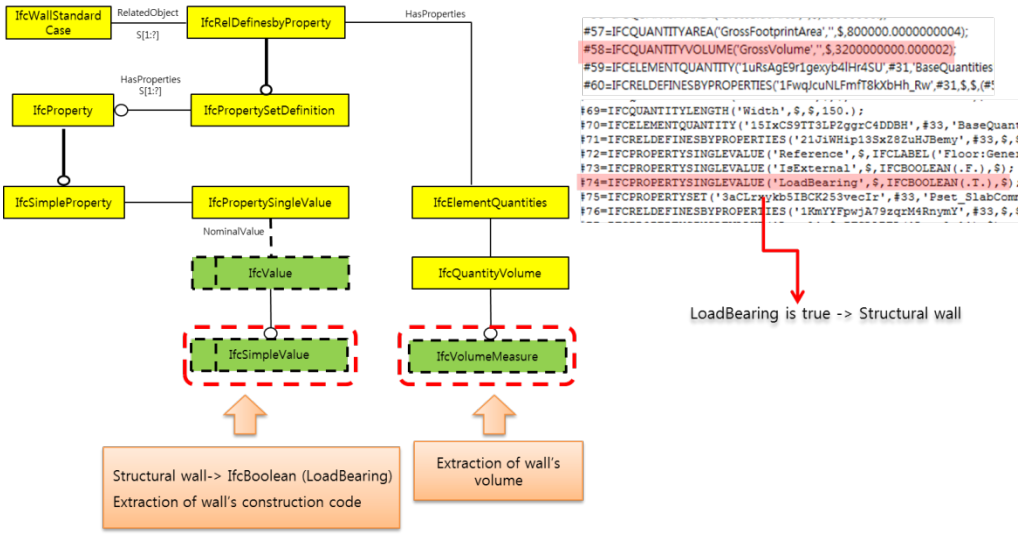


Figure 5. Extraction of framework and construction code – Example of structural wall volume

QTO PROTOTYPE SYSTEM - INSIGHTBIM-QTO

Two kinds of modules were developed by the authors. One is InSightBIM-QTO Pre-Check for data quality checking, the other is InSightBIM-QTO Calculate for calculating the quantity of framework. Pre-check module can verify data quality-checking whether code is true by checking the input data error. It makes reports about the error list and is exported as MS Excel file format.

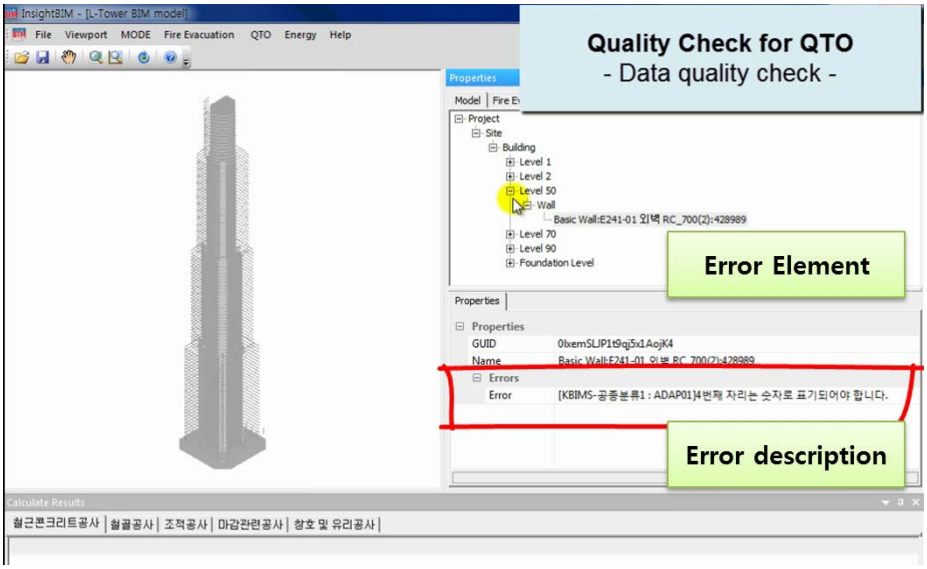


Figure 4. Pre-check module in InSightBIM-QTO

Modified BIM model according to error report is completed modelling work for schematic estimates and QTO through data quality checking. The complete BIM model calculates quantity of reinforced concrete work and steel framework. Concrete quantity is extracted from BIM model, other things (rebar, forms) are rebar, forms rating per concrete quantity because of schematic estimates.

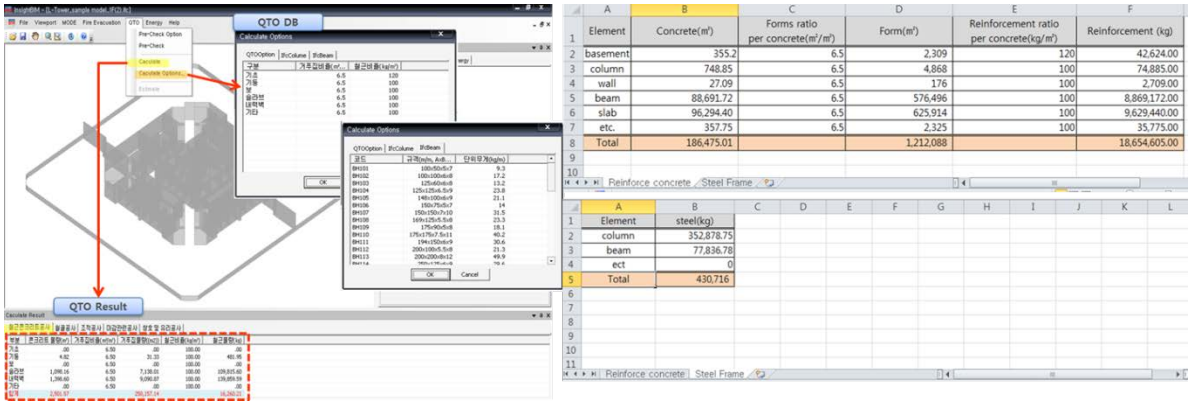
In Steel frame work, calculation method of shape steel (shape: H,I,O) is multiplying unit weight by length, unit weight is possible to select the type and size. Figure 7 shows the calculation methods of quantity for schematic estimates.

- QTO of Reinforce concrete
  - ✓ Concrete(Cv) -> Cv (m3) = IfcQuantityVolume value
  - ✓ Reinforcement(Rv) -> Rv (kg) = Cv x reinforcement ratio per concrete
  - ✓ Forms(Fv) -> Fv (m2) = Cv x forms ratio per concrete

- QTO of Steel Frame
  - ✓ Specific weight(shape steel - H,I) x IfcQuantityLength value = SF kg

Figure 7. Methodology of QTO (Reinforced concrete, Steel frame)

Calculate Option function can be selected rebar, forms rating per concrete quantity and shape steel. It was completed previous step (physical/data quality check, set-up ratio option) for QTO. Finally it calculates the quantity of BIM model. The QTO result is confirmed in interface and exported reports in MS Excel format.



Element	Concrete(m³)	Forms ratio per concrete(m²/m³)	Form(m²)	Reinforcement ratio per concrete(kg/m³)	Reinforcement (kg)
basement	355.2	6.5	2,309	120	42,624.00
column	748.85	6.5	4,868	100	74,885.00
wall	27.09	6.5	176	100	2,709.00
beam	88,691.72	6.5	576,496	100	8,869,172.00
slab	96,294.40	6.5	625,914	100	9,629,440.00
etc.	357.75	6.5	2,325	100	35,775.00
Total	186,475.01		1,212,088		18,654,605.00

Reinforce concrete | Steel Frame

Element	steel(kg)
column	352,878.75
beam	77,836.78
ect	0
Total	430,716

Reinforce concrete | Steel Frame

Figure 8. QTO result interface / QTO result export as MS Excel

CONCLUSION

This study proposes the methodology of QTO for solving problems of existing QTO systems based on 2D/3D drawing. The problems are low reliability of the estimation and difficulty in controlling big data for the estimation. Thus, the authors suggest IFC-based QTO methodology. The details of this study;

1) IFC-based method of QTO for the schematic estimation which increases the reliability. The methods are extracting information for the estimation in IFC model, verifying physical/data quality check, and calculating quantities of elements.
2) The authors developed QTO prototype system for the schematic estimation of the framework. This system evaluates data quality of IFC model, and it calculates schematic QTO of reinforced concrete work and steel frame work.

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 can be used in schematic estimation which applies to feasibility study, and Earned Value Management (EVM).

Further research efforts can 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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