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Open BIM-based quantity take-off system for schematic estimation of building frame in early design stage ☆

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Abstract

Since construction projects are large and complex, it is especially important to provide concurrent construction process to BIM models with construction automation. In particular, the schematic Quantity Take-Off (QTO) estimation on the BIM models is a strategy, which can be used to assist decision making in just minutes, because 70–80% of construction costs are determined by designers' decisions in the early design stage [1]. This paper suggests a QTO process and a QTO prototype system within the building frame of Open BIM to improve the low reliability of estimation in the early design stage. The research consists of the following four steps: (1) analyzing Level of Detail (LOD) at the early design stage to apply to the QTO process and system, (2) BIM modeling for Open BIM based QTO, (3) checking the quality of the BIM model based on the checklist for applying to QTO and improving constructability, and (4) developing and verifying a QTO prototype system. The proposed QTO system is useful for improving the reliability of schematic estimation through decreasing risk factors and shortening time required.

Keywords: Industry Foundation Classes (IFC); Level of Detail (LoD); Open BIM (Building Information Modeling); Schematic estimation; Quantity Take-off (QTO)

1. Introduction

Cost estimation in construction projects is an important factor for decision making in both the early phase and the detailed design phase. The construction phase based on QTO can function for procurement and predicting construction costs [2]. In Korea, estimate work based on 2D drawing has generated differences from QTO based on workers' mistakes and know-how. In addition, 2D-based estimation lacks uncertainty factors for estimation [3]. Accordingly, construction project seek more accurate QTO and cost estimation. Reliable estimates require accurate building information. Inaccurate information from QTO produces estimation errors because schematic estimation in the early phase process is multiplied by unit cost. To solve 2D-based QTO task problems, research on 3D based QTO has been active [4]. However, various problems exist in 3D based QTO [4]. However, various problems exist in 3D based QTO.

This study describes methodology connecting BIM data properties (volume, area) with unit cost and develops a QTO prototype system. The scope of this study includes primarily a building frame. This accounts for more than 50% of the total cost of a project. Schematic estimation is helpful to select design alternatives and construction plans. The QTO prototype system developed in this study has schematic estimation modules for reinforced concrete work and steel frame work.

The methodology of the research is:

1) Derive the critical costs through analysis of cases and research on QTO/cost estimation.
2) Suggest an open BIM-based QTO process through BIM modeling, physical quality check and data quality check for

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cost estimation and QTO for schematic estimation of the frame work.
3) Develop and verify the building frame QTO prototype system using information from the IFC model and the linkage between quantity information and the calculation method for schematic estimation.

2. Preliminary research

In this section, we analysis the early research and implementation of the QTO/estimation area based on 3D model. Also we draw an implication and trend in the QTO/estimation through the analysis of software that is widely used at home and abroad. As a result, in Chapter 3 seeks to provide a process to solve the existing limitations and improve the accuracy of the QTO/estimation.

2.1. Definition of schematic estimation

The cost estimation for each design phase can be defined as follows: conceptual estimation in the planning phase, schematic estimation in the schematic design phases, and detailed estimation in the design development phase, respectively [5]. The purpose of schematic estimation is feasibility study and rough cost estimation. In WBDG, schematic estimation may be used to price various design schemes, construction materials and to compare methods. The goal at the end of schematic design is to have a design scheme, program, and estimate that are within budget [6].

Schematic estimation during the basic approaches of domestic production can be approached in two steps.

1) Statistical and empirical approaches to calculate the construction cost per square meter.
2) 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 for schematic estimation. It is difficult to extract the volume per unit area for construction costs. This induced schematic estimation reliability increases.

2.2. Analysis of advanced research

QTO and estimation have used automated systems since the 1990s and have changed from 2D-based automatic systems into 3D-based automatic systems. From analyzing the major studies in Korea, some implication could be found; Automatic system applying for the methodology of object-oriented in 3D model [6], recipe-based methodology of connecting 3D model with cost [3], methodology of QTO using IFC 3D model [4] 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 [7], algorithm and development of database in object-oriented software for estimation task [8], and the methodology of estimation assumption for high-performance building through cost of building functional [5] 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.

Previous research on 3D-based QTO and estimation used a 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, previous research has a weakness of making on one's own data model for QTO. This study proposes an integration model using QTO task and estimation task through the concept of Open BIM. The concept of the IFC model can progress through the entire task of the building life cycle, as long as workers input the necessary data for the task; design, construction, facility management. Thus, this study suggests a methodology for QTO with schematic estimation due to IFC model in the early design phase (Table 1).

2.3. Analysis of QTO/estimation software

Until the early 1980s, technologies for estimation involved QTO and writing by hand. Since the mid-1980s, automated estimation related systems were used. 3D-based models for large construction companies began to be used in the early

Table 1
Analysis of the research trends.

Trend	Keyword	Research contents
Automation QTO	Object-oriented	Automation estimation system applying element information in 3D model [6]
	Recipe	Research on recipe-based QTO [3]
	IFC model	Development of QTO application in IFC 3D model [4]
	Schedule-cost	Development of modules for QTO according to the schedule[9]
Automation estimation	Automation based on method of construction	Automation based on method of construction using 3D model [10]
	Energy-cost	Cost estimation of factors impact on energy performance assessment factor affected using IFC model [7]
	Automation estimation for high-performance building	Estimation assumption for high-performance building through cost of building functional [5]
Efficiency of estimation	Automation finishing work	Methodology of 3D automated modeling for BIM-based QTO [11]
	Build a DB for automation estimation	Algorithm and development of database in object-oriented software for estimation task [8]