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A hybrid conceptual cost estimating model for large building projects

Hyung-Jin Kim [a,*], Yong-Chil Seo [a,1], Chang-Taek Hyun [b,2]

[a] Dept. of Research & Development, Kunwon Engineering, Co., Ltd., Hoe-Rim Building 3rd floor, Nonhyeon-dong 246-1, Gangnam-gu, Seoul (135-010), South Korea
[b] Dept. of Architectural Engineering, University of Seoul, University of Seoul 163 Siripdaero (90 Jeonnong-dong), Dongdaemun-gu, Seoul (130-743), South Korea

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ABSTRACT

Conceptual cost estimating is a challenging task under time and information constraints. This paper presents a practical hybrid conceptual cost estimating model for large building projects, including multiple mixed-use buildings. In this model, two different methods, assembly-based estimating and historical data-based estimating, can be used either together or separately at the work package level whereas a mixed-use building is considered a unique combination of multiple spaces for different uses. Comparing the two estimates reduces the uncertainty associated with using the limited project information in the early phase. The practical use of automated conceptual estimation has been achieved through a comprehensive and realistic approach that accounts for the estimator's role in the automated process, user acceptance of and confidence in the final estimate, and the efficient use of incomplete historical data. A case study using eight large building projects found that the proposed hybrid model can improve the accuracy of and estimators' confidence in the conceptual estimates.

1. Introduction

The conceptual estimate of construction costs is an essential part of project planning. Decisions based on an estimate involve a commitment of resource spending, which may have critical consequences. During the early project stage, cost estimating needs to be performed within a limited time period using limited information [1] in an uncertain environment. Estimating methods at this stage needs to be quick, economical (inexpensive), and reasonably accurate [2]. Various estimating methods and techniques have been proposed, from simple square meter methods to complex intelligent systems. Recently developed approaches tend to use more complex methods and a large volume of data due to the advent of computer technologies and mathematical programming techniques. Current methodologies include regression analysis [3], artificial neural networks [2], fuzzy logic [4], and case-based reasoning (CBR) [5,6]. Various avenues for improved conceptual cost estimating remain to be explored for a better conceptual cost estimating. This study examines the following issues in conceptual estimating for large building projects: the automation of estimating, the estimator's role in estimation, the use of limited project information, and the use of historical data:

- Various estimating models and systems have been developed for single-use buildings, but it is still challenging estimating multiple mixed-use buildings within limited time using un-detailed information in the early project phase;
- It has been observed that complex methodologies and automated systems do not always provide consistency in outputs and process transparency, resulting in misused systems [7]. The estimator's subjective judgment plays a critical role in the estimation of construction costs [8]. Estimators' occupational characteristics and preferences should be considered in automated estimation;
- Conceptual cost estimates are made before design and engineering work are completed or even not started. An efficient conceptual estimating method should consider the effective use of limited information in minimizing uncertainty;
- One of the most common estimating methods in the conceptual phase is using historical data. Many existing models assume that a large amount of complete project cost data is available for the models, but this is not always the case. The efficient and practical use of incomplete historical data needs to be considered.

Focusing on the above issues, this paper discusses the elements that are critical for cost estimating, the efficient methods of estimating large building projects, how to make good use of estimators' judgments in estimation, how to use incomplete historical data efficiently, and how estimate accuracy and estimator confidence can be improved in the conceptual phase, even when using limited or vague project information and incomplete historical data.

The goal of this study is to develop a hybrid conceptual cost estimating model for large building construction projects in order to overcome the difficulties and limitations addressed above. The developed methodology in this paper will be helpful to practitioners interested in the conceptual

* Corresponding author. Tel.: +82 10 4553 2373; fax: +82 2 545 3461.
E-mail addresses: kudos2008@hotmail.com, hyungjinkim93@gmail.com (H-J. Kim), m9732009@kunwoneng.com (Y-C. Seo), cthyun@uos.ac.kr (C-T. Hyun).
[1] Tel.: +82 10 4553 2373; fax: +82 2 545 3461.
[2] Tel.: +82 2 2210 2171; fax: +82 2 2248 0382.

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cost estimating of large building construction projects and to researchers interested in the development of automated cost estimating models and systems.

2. Conceptual cost estimating

2.1. Characteristics of conceptual estimating

The literature offers many classifications for cost estimates. The American Association of Cost Engineers (AACE) lists five types of cost estimates: 1) order-of-magnitude estimate; 2) study estimate; 3) preliminary estimate; 4) definitive estimate; and 5) detailed estimate [9]. Furthermore, depending on its purpose, a construction cost estimate will be a design estimate, bid estimate, or control estimate [10,11]. Construction cost estimates may be classified according to their functions. Conceptual estimates are needed by the owner, contractor, designer, or lending organization for purposes such as the feasibility study of a project, the financial evaluation of alternatives, or the formulation of an initial budget [2].

Conceptual estimating is strategically important because it is an essential part of project planning. However, detailed project information is limited in such an early phase, which causes uncertainty; also, estimating needs to occur within a limited time period. Therefore, the availability of historical data is important, and the estimator's subjective judgment plays a critical role in estimations, while traditional methods are occasionally blamed for estimates' lack of accuracy [12]. The development of an effective conceptual cost estimating model needs to comprehend the characteristics of conceptual estimating: strategic importance; limited and vague information; limited time allowed for estimating; low accuracy; and the dependency on estimators' subjective judgments and historical data.

2.2. Estimating methods

The level of detail in cost estimates varies throughout the different stages of a project. Different estimating methods can be used depending on the available information. Estimate accuracy can be improved as more information becomes available, while the degree of effort required varies depending on the amount of data available and the methodology used. The literature enumerates various classifications of estimating approaches. Generally, the approaches are classified into top-down and bottom-up [13,14]:

- Top-down approach: this is commonly used in the conceptual phase and is sometimes called the "analogous approach." It uses the historical cost data for previous similar projects to estimate the current project. Estimators usually select a similar project from the available historical data and modify it for the current project.
- Bottom-up approach: this approach is commonly applied to individual work items or activities when detailed information is available. The estimator breaks down a project into multiple work items. Individual item costs are estimated based on the amount of resources (materials, labor, and equipment) required to complete each work item and the relevant unit costs or rates. Then, individual item costs are summed up for the total cost.

Meanwhile, Dell'Isola [15] classifies construction cost estimating methods are classified into four types: 1) single-unit rate methods; 2) parametric cost modeling methods; 3) system/elemental cost analysis; and 4) quantity survey. Each method has its own advantages and limitations regarding data requirements, estimate accuracy, and the effort and time required for the estimation:

- Single-unit rate methods are the most common in initial budgeting due to their simplicity. They estimate the overall unit cost per gross square meter using methods including the accommodation method and the functional area method. The accommodation method uses the major measure of a facility (i.e., cost per bed for hospitals). The functional area method specifies the functional space types within a building to account for variations in space types for specific purposes.
- Parametric cost modeling methods commonly apply statistical analyses. These methods usually use a predetermined equation model based on the historical cost data using a regression analysis.
- The system/elemental cost analysis divides a building into elemental components to estimate the cost of each component using historical data on similar projects. The estimate can be modified by different alternates (e.g., construction methods and materials).
- A quantity survey can be performed when detailed design information is available. Quantities and unit costs or rates (for materials, labor, and equipment) are calculated for each of the individual work items and activities.

In the conceptual phase, many estimators use single-unit rate methods or analogy-based decision-making processes. To estimate a new project, a similar previous project is often selected and adjusted based on its recognized similarities or differences, depending on the estimator's own experience and subjective judgment [16]. A lack of historical data or inadequate adjustments could lead to bias, resulting in under- or overestimations. However, it is agreed among practitioners and researchers that estimators' experience and professional knowledge play a critical role in conceptual cost estimating [8].

3. Improvements for better estimating

3.1. Estimation of mixed-use buildings

There is an increasing need to estimate large and complex building projects, such as for city regeneration or urban development. Though there is a variety of cost estimating softwares available in construction [12], most existing models and systems support the cost estimating of single-use buildings. Estimating large projects such as multiple mixed-use buildings involves many difficulties. For example, case-based reasoning (CBR) is perhaps one of the most actively studied methods for the efficient use of historical data in construction cost estimation. The effectiveness of CBR-based methods has been reported for various retrieval methods but mostly for single-use facilities [4,6,17,18]. The most critical step in CBR is case retrieval, in which the similarity of previous cases is determined; estimate accuracy is then attained when similar cases exist in the historical project inventory. However, it is rare to find similar cases with unique combinations of different functional areas for a specific building or a unique combination of mixed-use buildings for large building construction projects. Meanwhile, the functional area method can be effectively used for cost estimating large building projects such as multiple mixed-use buildings by considering the variations in space types within each building.

3.2. Critical elements of cost estimating

In general, the common goal of information systems in business organizations is improving job efficiency [19]. Due to the advent of information technologies, automated cost estimating models and systems save time while avoiding human error in mathematical calculation. It should be noted, though, that computers cannot perform the entire process or make decisions [12]. In conceptual cost estimating, estimators' subjective judgments play a critical role [8], and the availability of historical data is also important. To show what elements are essential in cost estimating and estimation models, Fig. 1, modified from Phaobunjong [20], depicts the estimating process as consisting of five critical elements, listed below:

- Project information: the information about the current project, including project scope and major building characteristics (such as type and use).