AN ECONOMIC EVALUATION SYSTEM FOR BUILDING CONSTRUCTION PROJECTS IN THE CONCEPUTAL PHASE

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ABSTRACT: The conceptual phase of capital projects is of strategic importance - an economic evaluation at this early stage is critical to the owners' decision-making with limited information. The current study developed a comprehensive but practical system that can be used in such an early phase for economic evaluation of capital building construction projects. The system integrates four analytical steps: project planning, construction costs estimation, projection of incomes and expenditures, and economic evaluation. Due to the integration, the system effectively manages the information flow from the planning to the evaluation, in which any changes from the initial plan are fully accounted for multiple alternates. In the system, users predict construction cost using a combined estimating method with historical project data and assembly costs. The system performs the tabulation of all incomes and expenditures based on the automated calculation as well as users' inputs and then the economic evaluation based on project cash flow, which is generated using an automated scheduling method. System performance has been tested in terms of its accuracy and efficiency through case study.

Keywords: Economic Evaluation, Capital Projects, Conceptual Phase, Automation, Historical Database

1. INTRODUCTION

Economic evaluation of facility investment is one of the most critical tasks in the conceptual phase since it involves a commitment of resources spending when a decision is made. The evaluation involves forecasting cash flow considering all capital requirements and revenues [1]. An economic evaluation should include the following analytical steps: 1) project planning; 2) construction cost estimating; 3) projection of all expenditures and revenues; and 4) cash flow analysis and economic evaluation for alternates [2]. However, most existing software programs in construction have been developed separately for cost estimation or for project evaluation while they have different levels of detail in the analysis. Thus, the efficiency of the evaluation task has been limited – it is difficult to manage project information and any revision of

it between the analytical steps, especially more when multiple alternates need to be analyzed. Also, controlling the information and the changes becomes complex if a project includes multiple buildings of mixed-use. The current study develops a comprehensive but practical economic evaluation system to combine the analytical steps so that the information flow can be efficiently managed in an integrated way based the computerized automation, but using limited project information available in an early phase of project planning.

2. EFFICIENCY OF EVALUATION SYSTEM

The essential element of economic evaluation is project cash flow analysis, which requires quantifying all monetary items and specifying the time of their occurrence. Fig. 1 conceptually depicts the information for an

economic evaluation of a capital building construction project. All expenditures and revenues should be accounted for the analysis in forms of quantity and time within the prediction period. For multiple alternates (the initial plan and its revisions), quantifying and scheduling of all the items for each alternate is a challenging task. A practical system, for the use by practitioners, should be able to deal with all the quantity and time information in an integrated way based on automated estimating and scheduling. However, the system should consider the trade-off between automation and flexibility – the efficient use of un-detailed project information supported by the automation, as well as the flexibility, i.e., allowing manual adjustments by users.
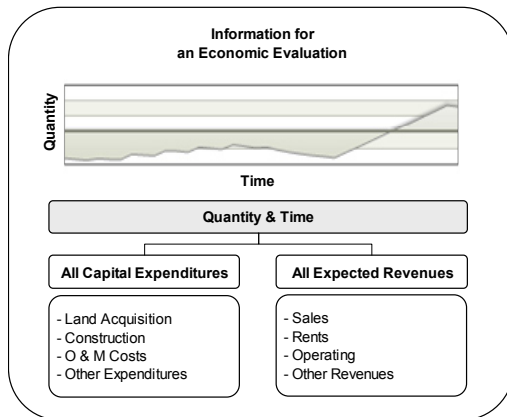

Fig. 1 Information for economic evaluation

3. CONSTRUCTION COST ESTIMATING

3.1. Estimating in the Conceptual Phase

In the conceptual phase, cost estimate with a reasonable accuracy is required within a limited time period while information is limited [3]. Various estimating methods for the conceptual phase have been proposed: simple square foot method, regression analysis, probabilistic estimating, neural network, case-based reasoning, fuzzy models, etc. Meanwhile there are criticisms on some empirical estimating models, e.g., *black box* with no explanation of output [4]. In the conceptual phase, cost estimators commonly use analogy-based estimating methods, i.e., an

estimator selects a similar one from past projects and adjusts it based on similarities and differences perceived by the estimator, which depends on his individual experience or perception. Also, simple square foot or assembly costs methods are preferred by many cost estimators in the conceptual phase [5]. However, under limited project information in the conceptual phase, lack of historical data frequently could lead to the estimator's bias, which could result in under budget or over budget [6].

3.2. Combined Cost Estimating

Estimators usually desire to have their estimates compared with the actual costs of past similar projects, which makes them feel comfortable. Also, many professionals in construction desire to have a list of quantities and costs in a form of cost breakdown structure (CBS), in which the real values are present for different work packages even though the CBS has a low level of detail in an early phase. For instance, a building is decomposed into work elements whereas unit cost of each element can be assessed and the total cost is the sum of the products of the quantities multiplied by their corresponding unit costs.

Considering the points addressed above, the current study proposes a combined estimating method using historical data and assembly costs for the conceptual phase. There are advantages by using both methods simultaneously to determine an estimate in such an early phase. A historical data-based estimate can be made using similar projects data selected based on their similarity to the current project while the similarity is determined by major project information (design parameters). At the same time, an assembly cost-based estimate can be prepared by calculating the required quantity and cost of an *assembly* (a set of material/labor/equipment) for major construction methods selected by estimators for different work packages. Even if using such un-detailed information, the comparison

of the two estimates can reduce the chances of possible under or over estimate and improve estimators' confidence.

3.3. Data for the Combined Cost Estimating

The data for the estimating method described above include historical data for past projects and different types of assembly costs. The historical data, in which the projects (all single-use buildings) are classified by the type of building, provide unit cost as well as duration information. Different types of building should be considered in cost estimating since the type of building has an important effect on the project cost [7]. Each project needs to be indexed by major parameters, i.e., site, size of building (square foot and story), building-to-land ratio, floor space index, etc. These building characteristics are used as the multiple search conditions to find similar projects to estimate the current project. When a building includes multiple uses, the system calculates a weighted average unit cost per area (M^2) to estimate the total cost whereas weights are determined based on the areas of different uses. An *assembly* represents a specific construction method, which involves a set of materials, labors, and equipments. Each assembly has its own pre-determined equations (developed by experienced estimators) to estimate the required quantity for a set of materials, labors, and equipments and its composite unit cost. For instance, if a user selects *concrete* for the superstructure of a building, the program estimates the quantities of materials (concrete, form, steel, etc.), labors (formwork, reinforcing, and concrete placement, finishing), and equipments (concrete pumps) based on the design parameters, i.e., the perimeter of the building, stories, floor area, height, etc.

The historical project data as well as assembly costs can be accumulated or updated by the system administrator, i.e., adding/deleting/modifying the assembly items and their equations – different organizations (estimators) may have different equations. The accuracy of the output can be improved as more data are accumulated in the system.

4. DEVELOPMENT OF THE SYSTEM

4.1. Framework of the System

The system consists of four analytical steps (project planning, construction costs estimation, projection of incomes and expenditures, and economic evaluation) and database. The database in the current system includes historical data (cost and duration) for 301 past projects and 131 different types of assembly (equations and composite unit costs). Fig. 2 shows the overall framework of the system, in which project information flows from *Project Planning* to *Economic Evaluation*. The system is dynamic in terms of that changes in a previous step are automatically reflected in the next steps. Commonly, project planning and cost estimating are performed using estimating software programs while the others separately using economic evaluation software programs. A detailed description of each analytical step and linkage between the steps is provided below.

4.2. Project Planning

In the system, users develop a project plan for one or multiple buildings by specifying major project information, which include project name, location, site area, building area, floor area, gross floor area, building-to-land ratio, floor space index, number of stories, average height, areas of different uses, perimeter of building, area of exterior finish, parking area, etc. Different uses in a building are specified by quantifying the areas of different uses. All of the above information should be available in a schematic plan. The above building characteristics are used as multiple search conditions to find similar projects from the historical database.
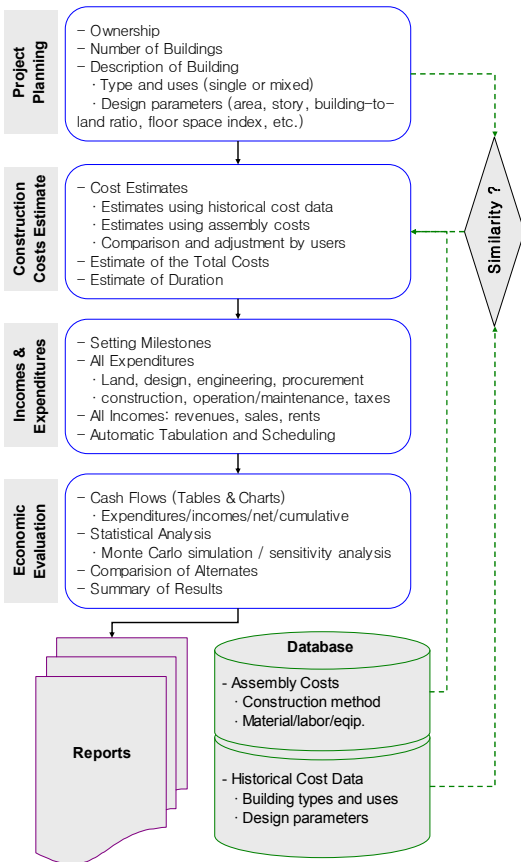
Fig. 2 Framework of the system

4.3. Construction Costs Estimate

The system searches similar projects using the multiple search conditions defined in *Project Planning*. Similarity of a past project to the current project is simply defined as true (matched = 1) or false (not-matched = 0) for a search condition and the sum of similarity scores is given to the project. To estimate the construction cost of the current project, users select projects among the scored projects which are prioritized by the system based on the similarity score. The users' selection of the similar projects represents the implementation of their experience and subjective judgment. To account for the variability of cost due to inflation, adjustments are made whenever historical data are retrieved for the estimation.

In addition, users are able to estimate costs for different work packages using the assembly costs by selecting major construction methods. This method involves calculating the

required quantities of a set of material/labor/equipment and estimating the assembly cost using composite unit costs. Even if using un-detailed information (major design parameters and construction methods), the comparison of the two estimates improves the accuracy as well as the estimators' confidence in the final estimate whereas users may select one between them or modify depending on their subjective judgment.

4.4. Construction Duration

The system predicts construction duration for each building by averaging the durations of the similar projects, which were selected in *Construction Cost Estimate*. When a building includes different uses, its duration per unit area (M^2) is estimated as a weighted average while the weights are determined based on the areas of different uses. However, users may specify the target duration if necessary. This duration information is delivered to the automated scheduling using a generic adjustable S-curve, which is discussed below in detail.

4.5. Expenditures and Incomes

Total project expenditures include land acquisition, architectural and engineering design, construction, field supervision, financing costs, insurance and taxes, inspection and testing, operation and maintenance costs, repair costs, utilities, and other expenses. It should be noted that construction cost is one of the cost elements of the total capital cost and other cost elements are not insignificant [2]. The construction cost estimate is frequently used as the reference for estimating of other various expenditures. The system provides the tabulation of a total forty nine expenditure items (including most of legally required expenditures in Korea), which are automatically calculated using pre-determined equations (developed by experienced professionals), and different types of revenues defined by users. Users may add or

delete individual items and also make changes in the estimates if necessary. Any changes by users are reflected in the cash flow analysis.

4.6. Automated Scheduling

In the system, users define major milestones within the prediction period, such as land acquisition, beginning of construction, completion of construction, initiation of sales or rents, etc. Fig. 3 shows the two automated scheduling methods: 1) scheduling of construction expenditures using a generic adjustable S-curve and 2) scheduling of individual monetary items using one or two milestones. The construction expenditures are planned using a generic S-curve, by converting it to a density function. The curve is the average of percentage complete of all historical projects in the database. This curve can be prolonged or shortened based on the estimated construction duration for the current project. On the other hand, each of the other monetary items (expenses and incomes) has its own default sequence in the system being defined relatively to one or two major milestones. For instance, an expense is expected to occur at a specific time before or after one of the major milestones or periodically with an interval between two milestones. Based on the default sequences and the projected quantities in *Incomes and Expenditures*, the system generates the project cash flow. However, users may adjust the schedule for individual items.
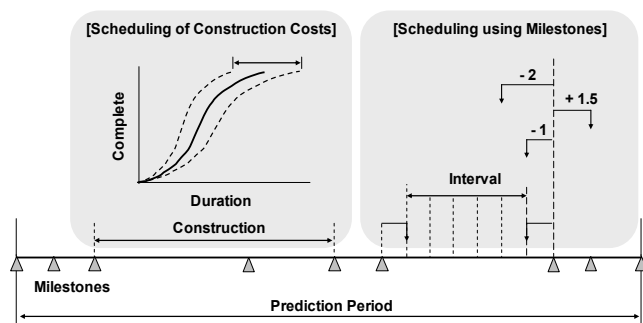

Fig. 3 Automated Scheduling

4.7. Economic Evaluation

The current system develops four types of project cash flows: expenditure, income, net, and cumulative net. Also, four evaluation metrics are calculated: rate of return (ROR); net present value (NPV); internal rate of return (IRR); and payback period (PP). User defined discount rate is used for the evaluation of a long-term project.

4.8. Dealing with Uncertainty

It is a difficult task to forecast the costs and benefits before their realization. Information available in the conceptual phase is limited as well as uncertain. All estimates of costs and benefits involve some degree of uncertainty. Users may execute Monte Carlo simulation for the economic evaluation by specifying range for the estimates with probability distributions. The sensitivity of each monetary item is estimated through the simulation.

4.9. Comparison of Multiple Alternates

In the conceptual phase, multiple alternates are commonly analyzed and compared to select the best economically feasible one. In the system, users are able to generate multiple copies of the initial plan, which are called *revisions*. In each revision, users may modify project plan (i.e., design parameters), as well as certain cost or revenue items in terms of monetary quantity as well as sequences in schedule. Changes made in each revision are automatically reflected to the subsequent analyses by taking advantages of the integrated information flow. As a result, the system provides an efficient comparison of different *revisions* against the initial plan by the evaluation metrics, as well as by the probability distribution of rate of return.

5. CASE STUDY

The system has been tested for its performance. During the test, the system was applied to an urban development project in Seoul. The project includes six buildings of

mixed-use. At the time of the test, the project already had the result of feasibility study and a detailed estimate after the completion of its preliminary design. However, only limited project information available in the conceptual phase was used for the test, i.e., site area, building area, gross floor area, building-to-land ratio, floor space index, number of building, stories, uses, etc. Test result was satisfactory considering that the common accuracy of conceptual estimate is between +75% and -25% [8]. The construction cost estimate showed a difference of -6.5% compared with the detailed estimate. Regarding the total capital costs and rate of return, small differences of +3.5% and -3.4% were found, respectively, compared with the feasibility study, assuming same revenues. The test took only two and a half hours, which is very significant time saving. The system performance may be greater due to its *revision* control features.

6. CONCLUSIONS

The current study developed a comprehensive but practical economic evaluation system for capital building construction projects, which can be used in the conceptual phase. This system has unique aspects: 1) the efficient management of information flow based on the integration of analytical steps; 2) the combined cost estimating method, which enhances the confidence in the final estimate; 3) the automated tabulation and scheduling of cash flow; 4) trade-off between automation and flexibility; and 5) the *revision* features. Regarding the estimating method, the comparison of the two types of estimates was so favored by practitioners during the case study. There are improvements to make for future study: the generic S-curve needs to be developed for different types of building and more historical data and assemblies need to be accumulated, which improve the accuracy of the estimates.

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