APPROXIMATE COST ESTIMATING SYSTEM FOR CONSTRUCTION OF STEEL MILL

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Abstract: Enhancing the accuracy of an approximate cost estimate is a critical issue since the estimate ordinarily predicts the total cost of a project with insufficient project information. In order to facilitate the approximate cost estimate process, this paper proposes a computer-based integrated system that enables the *flexibility* to varying amount and accuracy of available information, higher *accuracy* by using several different adjustment factors at the same time, and *decision supporting feature* by fast manipulation of the profits and contingencies in determining the final bid price. Proposed methodology has been implemented for a steel mill construction company in Korea, and its viability was validated. Findings and practical implications are outlined.

Keywords: approximate estimate, historical database, adjustment factors, information system

1. INTORDUCTION

Preliminary estimating, especially for the design-build contracts, is a critical process predicting the total cost of a project with insufficient project information. In order to enhance the accuracy of a preliminary or an approximate estimate, several methodologies have been developed and utilized.

Approximate cost estimating methods ordinarily utilize parameters, factors, and indices. In addition, the advanced applications including probability and statistics, neural networks (NN), and relational database management systems (RDBMS) have been employed for the purpose of improving the accuracy. Findings of previous studies [1][2][3][4] indicate that the accuracy of the estimate using these advanced applications can be increased up to 20%.

The approxi mate cost estimating method based on historical cost records is a frequently used one as well. When using this method, the quality of the historical cost data from the previously performed projects is a crucial factor determining the quality of the estimate result.

The purpose of this research was to develop an estimating methodology and a computerized system for an engineering and construction firm in Korea, that has abundant experience in planning, designing, procurement, construction, inspection, and test operation of the Pohang and Kwangyang steelworks of the world's second largest steel company. The estimating system developed as a result of this research is integrated with the project management information system (PMIS) of the company in order to obtain quality information in a timely manner.

2. SYSTEM DEVELOPEMENT

The system developed in this research, named CEDA (Capital cost Estimate Data Analysis), uses relational database management systems (RDBMS) that manipulate all relevant estimate data and the historical database as well.

CEDA consists of two subsystems; one for the estimate of construction cost and the other for the estimate of equipment cost. In estimating the cost of construction, the system mainly utilizes the shared historical construction performance database focused on actual labor productivity. For the cost estimate of major equipment to be installed in the steel mill, this system provides an estimator the historical cost records of many similar equipment with the analysis tools so that the estimate of a new equipment cost can be made based on the relationship between its specifications and cost.

2.1 System Characteristics

CEDA has three major distinctive features that facilitate the approximate estimate process. These features include the *flexibility* to varying degree of details and amount of information available, higher *accuracy* obtained by selective application of various adjustment factors, and its *decision supporting feature* enabling fast manipulation of the profits and contingencies in determining the final bid price

Data structure of CEDA employs a hierarchy that defines the types of facility and the kinds of commodity as well. Namely, each record has a commodity classification number and a facility classification number (Physical Breakdown Structure, PBS). Again, each numbering system has own hierarchy that enables composing and decomposing. Only part of the data can be manipulated in a different hierarchy as well. Due to its flexibility, the system can be used not only for an approximate estimate, but also for more detailed estimate, which is dependent upon the amount of information available at the time of estimate.

Even a project being estimated is in its preliminary stage with very limited information, fairly accurate estimate can be produced by only using historical cost data and adjustment factors. Furthermore, detailed estimate is possible with this system when more specific information is available. In other words, several different types of estimate processes are combined in the system, and a user can easily utilize any combination of the processes without predefining the specific methods.

Various types of adjustment are selectively applied to each cost item in order to improve the accuracy and reliability of the estimate result. The adjustment factor database in the system, which provides useful reference information to an estimator, is maintained and updated regularly by the system administrator. In case an estimator needed to make a change in total project cost after reviewing the estimate results, the system allows the estimator to modify the total project cost by changing the adjustment factors already applied. The reapplication of adjustment factors to the estimate data can be made not only by the groups but also individually.

After total cost of project is estimated, the system plays a role of decision support system to help the estimator making a decision on how much profit and contingencies to be included in the final bid price. By using standard classifications for cost account, work section, crew mix, materials, equipment, and so on, it is possible to summarize the direct costs in many different facets. Different types of direct cost summary help determine the indirect costs. Also, the outputs generated from the system take the form of spreadsheet file which gives the estimator additional flexibility.

2.2 Database Structure

The system was developed as a client-server based system using MS SQL Server 7.0 for the database and Visual BASIC 6.0 programming language for controlling applications. As shown in Figure 1, the system has four major areas of database; historical cost database, unit cost database, adjustment factor database, and estimating database.

The historical cost database contains the cost information accumulated from the previously performed projects and provides the starting point of a new estimate. When estimating a new project, selecting one similar project from the historical cost database as a reference project forms the basic

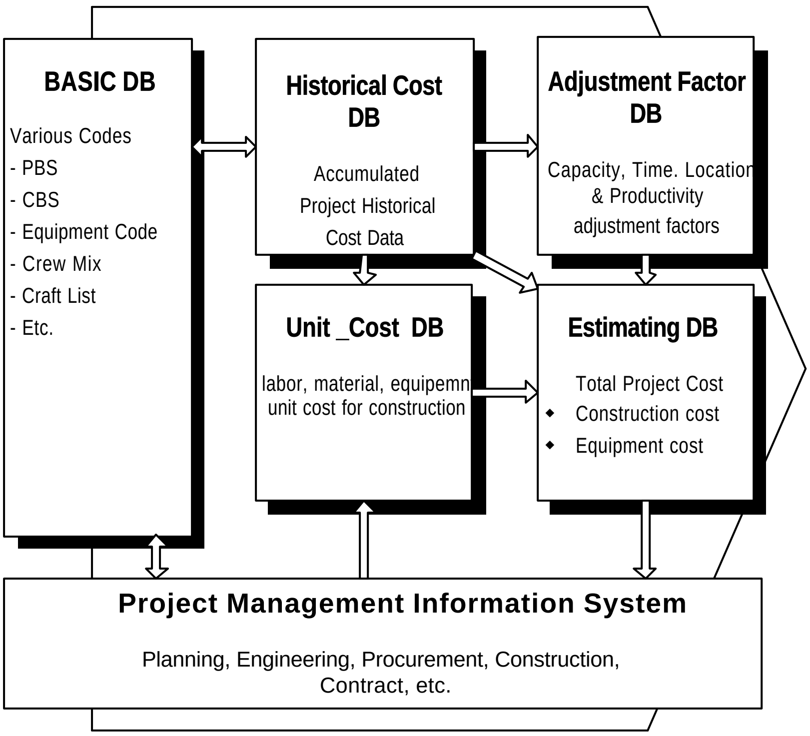

Figure 1. Estimating System Structure

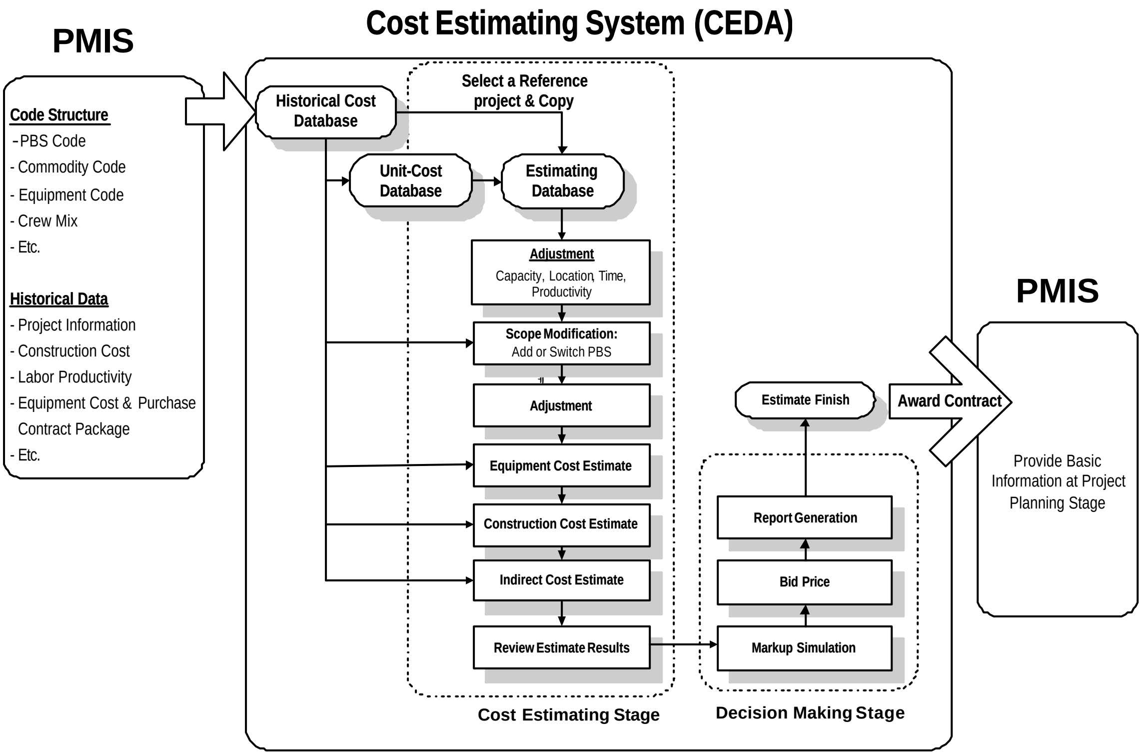

Figure 2. Estimating Process

estimate structure for the new project.

The unit cost database is the database automatically created by CEDA whenever a new project cost estimate is initiated. The labor productivity and the unit costs for construction equipment and materials to be applied to a new project cost estimate are calculated from the selected projects in the historical cost database and stored in the unit cost database.

The adjustment factor database consists of various cost indices and factors. When the cost data from the previous projects are chosen for a new project, the cost adjustment factors are applied in order to incorporate a new project conditions like time and location that a new project is taking place, production capacity of a new plant, and also labor productivity difference.

The last element is the estimating database where actual estimating work is taking place and contains the new project cost estimate data.

2.3 Estimating Process

The first step of estimating is selecting a reference project from the list of previous projects contained in the historical cost database. The scope of the reference project selected should be similar to the scope of new project currently being estimated because its cost components are used to form the basic cost structure of the new project. When the reference project is selected, every cost components of the reference project are copied to the estimating database with the exception of crew productivity and the unit cost for construction labor, materials, and equipment.

The second step is creating a unit cost database and applying it to the estimating database. The unit cost database, which is formed whenever a new project is estimated, contains the weighted average value of the unit cost for construction materials and equipment to be applied to a new project. The unit costs are calculated from the selective projects in the historical database. Also, the unit cost database calculates the average crew workdays for unit quantity of work based on the productivity information accumulated in the historical cost database. The crew workday information and the average crew cost, calculated with a current labor craft rates provided by the estimator, are applied to the labor cost in a new project estimate.

When the unit cost database is formed and applied to the estimating database, the next step is adjustment. The various adjustment processes are explained in the following section 2.4.

Until the completion of the adjustment processes, the structure of the cost components constituting the project being estimated has been kept unchanged from the scope of the reference project copied from the historical cost database. After the four different types of adjustment are made to the estimating data, an estimator can work at more detailed data level to modify the project cost structure.

The system allows the estimator to make changes in estimating database not only by the individual data but also by the groups. Since the system provides the interface that is similar to the one the commercial spreadsheet program has, making changes in individual estimating data can be done easily. When the scope of new project being estimated includes new cost items that were not the part of the reference project, the estimator should estimate the cost of them from the scratch and add to the estimating database. On the other hand, if a group of data from the previous project, other than the reference project, is useable for the new project estimate, the estimator can copy the bundle of data from the historical database and add them to the estimating database. This modification of the cost estimate copying and pasting bundle of data can be made at all three levels of PBS. In case that a group of data are copied from the other project in the historical cost database, the same adjustment factors that were used at the prior adjustment stage are applied to the data.

As mentioned before, the estimating system developed consists of two subsystems. One for the construction related items and the other for the equipment to be installed in the steel mill.

The system provides the estimator the cost records of previous projects sorted and displayed by various criteria and formats to be used as a reference for the detailed estimate of construction cost.

For detailed equipment cost estimate, a number of equipment records including their specifications and purchase contract package information are provided as a reference. When specific price and vendor information is not available, the provided tool for analyzing the relationship between specifications and costs of the similar equipment helps the estimator in estimating the cost of new equipment. Also, cost indices of various and more detailed equipment categories are provided for the time adjustment of equipment cost in case the previous equipment cost record is used in a new estimate. After finishing the estimate of direct cost including construction and equipment costs, the indirect costs are estimated.

Determination of the amount of profit and contingencies to be included in the bid is closer to the process of decision making rather than estimating. The system applies the amount of profit and contingences determined by the human judgement based on specific project conditions and circumstances to the bid price.

Various types of reports, both for in-hour and external use, are generated from the system. The output takes the form of spreadsheet file in order to give the estimator additional flexibility. The flowchart showing the estimating process is shown in Figure 2.

2.4 Adjustment Factors

After the estimating database are formed using the previous cost data, the adjustment process is followed. The adjustment is a crucial process, especially in conceptual or preliminary estimate based on the historical cost records, because it incorporates the characteristics and conditions of the project being estimated, such as time and location that a new project is taking place, production capacity of a new steel mill, and also labor productivity difference occurred by the project location, in the new estimate. Also, application of appropriate adjustment factors improves the accuracy and reliability of estimate result.

There are 4 types of adjustments in the estimating system developed. The selective applications of 4 types of adjustments are shown in Table 1.

Production capacity adjustment is made using the power factor model. Power factor model is based on that the costs of similar plants or pieces of equipment of different sizes vary with the size, which is raised to some power. The determination of cost-capacity factor in the power factor model is important to the success of the model. When there is not enough historical data to analyse the relationship between the size and cost, the frequent value for the cost-capacity factor is 0.6, so this relationship is often referred to the six-tenth factor rule.

Even though the original purpose of this model was for application to an individual piece of equipment, it can be applied to the entire plant since Chilton [7] has shown that it is applicable not only to the cost of individual pieces of equipment but also to the entire plant cost. The estimating system offers the default cost-capacity factor value of 0.6 in production capacity adjustment of the entire plant cost along with the option of assigning the value the estimator prefers based on his/her experience. Also, when estimating the cost of an individual equipment to be installed in the steel mill, the estimator is provided with the previous cost history of many similar equipment and regression analysis tools for calculating the appropriate cost-capacity factor. The system analyses the relationship between its specifications and costs to determine the appropriate cost-capacity factors to be used.

The use of cost information from a previous project to forecast the cost of a proposed project will not be reliable unless an adjustment is made proportional to the difference in time between the two projects. In general, the time adjustment is made using the index represents the relative inflation or deflation of costs with respect to time. Time Adjustment factor database consists of various countries' construction related cost indices, where available, or Producer Price Indices (PPI). Time adjustment is made to the each unit cost of labor,

Table 1. Types of Adjustment and Their Selective Application

Cost \ Adjustment		Capacity	Time	Location	Productivity
Construction Cost	Material	Qty.	Unit Cost	Unit Cost	N/A
	Labor	Qty.	Unit Cost	N/A	Production Rate
	Equipment	Qty.	Unit Cost	Unit Cost	N/A
Equipment Cost		Unit Cost & Installation Qty.	Unit Cost	Unit Cost	N/A

material, equipment, and also the major equipment to be installed.

Location adjustment is made using the location factor, which is used to convert a base project cost from one geographic location to another by reflecting the relative difference in cost between two locations. With the growing tendency toward globalization, the interest in the international location factors have been increased, and several location factors have been presented by researchers [8][9][10]. The system adopted the location factor presented by McConvile [8], and provides the estimator the option of using the value other than presented since the considerable judgment is required for its proper application.

Differences in productivity caused by various factors are reflected by the productivity adjustment. Productivity adjustment of the estimating system affects only the labor cost because it is applied to the crew workdays. Labor productivity difference between countries, which has been well recognized by researchers and practitioners, are quantified with productivity factor. The productivity factor presented by Humphreys [11] and McConvile [8] are adopted by the system and presented to the estimator for adjustment. Like the other adjustment factors, the estimator has an option of not using the value presented by the system and uses for reference.

3. CONCLUSIONS

The purpose of this research was to develop an estimating system based on the relational database management systems (RDBMS) containing the historical data from the previously performed projects. Three distinctive features of CEDA are its adaptability to varying degree and amount of information available to the estimator, increased accuracy from historical cost data and selective application of various adjustment factors, and its flexibility and decision supporting feature enabling fast manipulation of the profits and contingencies in the final bid price.

CEDA dramatically reduces the time required for making an approximate estimate without sacrificing the accuracy at all. Also, by utilizing the previous cost data, this system enables the estimator to have the objective and detailed supporting data backing up the approximate estimate result. The critical factor for determining the usability and viability of the system is the accumulation of the quality data in the historical cost database.

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