AN APPROXIMATE COST ESTIMATING MODEL FOR CONSTRUCTION PROJECTS

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ABSTRACT: The sudden changes in the construction market and the progressively intensifying price wars have amplified the importance of the construction cost estimation in the initial and planning phases of construction projects. However the methodologies and process of estimating construction cost in the planning and design phase are not standardized in the domestic market, in contrast to the markets of more developed countries. Therefore this paper proposes a new approximate estimation model to be used from the initial stages of construction projects. This methodology that extracts, modifies and synthesizes comparable elements of previous cases. This will introduce the foundation for the implementation of systems with improved usability and applicability.

Keywords: Approximate Cost Estimating Model, Case Based Reasoning(CBR), Construction Phase

1. INTRODUCTION

Rapid changes in the market and escalating competition have resulted in the increased importance of the planning phase and the nucleus of the planning phase is the estimation of cost. Due to the lack of information during the initial phase, the accuracy of cost estimation becomes the biggest variable in the success of the project. The task in the design phase is to come up with an efficient answer to the problem within the bounds of the estimated cost. The cost of construction is, once again, a significant factor in this phase. However the lack of a reliable and efficient method of estimating construction cost creates a lot of difficulties.

The construction industry is experience-orientated only when knowledge and information gleaned from past experience is taken into consideration, can a business be planned (Yau, 1998). However, unlike in other industries such as manufacturing, in the construction industry, company activities are centered on projects. And because projects are pursued in parallel, it is difficult to share knowledge and information obtained from previous projects.

Therefore in order to increase accuracy, there are many projects under way to estimate construction cost using data from previous projects. However, considering the fact that systematically organized data is severely lacking, there is a need to analyze previous project data more efficiently in order for it to correspond to the new project.

Thus the purpose of this research is to present an Approximate Cost Estimating Model that can be used from the inception of construction projects when information is lacking. In order to do this, the construction project process will be defined, a housing structural construction prototype will be presented, and to aid comprehension.

Research method and procedure are as follows:

1) Define the construction project phases and the required estimation of cost at each phase.

2) Investigate the types of existing Approximate Cost Estimating Models through examination of literature, and identify problems.

3) Establish a suitable methodology for construction projects and present a new Approximate Cost Estimating Model.

4) Present a public housing structural construction prototype, and establish a system architecture taking into consideration the construction cost estimating process.

2. COST ESTIMATION

2.1 Process of Cost Estimation

The processes preceding construction are the three stages of Feasibility & Conceptual Design, Preliminary Design and Design Development & Construction Documentation. The estimates made in each stage differ in how they are approached and in their accuracy. For example, in the beginning stage a rough estimate is preferred over an exact estimate. On the other hand, the estimate made right before the construction phase is a systematic and detailed estimate that incorporates a certain level of error in its calculations in order for construction to proceed without problems. This type of estimate, complex as it may be, warrants a thorough item-by-item analysis. This paper takes into consideration this

type of construction cost estimates and the relationships in design information when defining the types of different estimates in each phase. The estimate in the conceptual and preliminary design phase is defined as approximate estimation, and the estimate in the design development and construction documentation phase as detailed estimation and definitive estimation.

The purpose of research in this paper is the approximate cost estimating used in the preliminary phases of construction projects, namely, in the Feasibility & Conceptual Design, and the Preliminary Design phases. The reason for the focus on the preliminary stages is due to the fact that although the accuracy in estimating the required cost in those phases are crucial in determining the success of the project, tools and processes for accurate estimation are at present, severely lacking.

From the owner point of view, the objective is to plan, design and construct a structure of satisfactory quality and functionality within the allocated budget and time frame. From the contractor's point of view, the primary interest is to maximize profits within the owner's budget whilst offering the lowest construction costs when compared with the competition. The estimates are made from the given information in each design phase and this, in turn, is used in the decision making process for the bidding and execution of the project. Therefore the estimates in each phase are important. Decisions made in the beginning stages of a project are especially important as they affect project or construction cost estimates more than in the subsequent stages (Hendrickson and Au 1989). In order for construction projects to be proceeded reasonably, cost checks must be implemented at every stage, starting from the initial stages. In this paper, a Approximate Cost Estimating Model is proposed so that it may be used in the initial stages of construction projects where information is lacking.

2.2 Problems of Current Approximate Cost Estimation

The reason behind making estimates is to facilitate construction decision-making. Therefore even at the approximate estimation level, a reliable process should exist. In the case of domestic construction companies, due to the recent changes in project procurement, they have taken to using approximate estimates in the preliminary design phase to make decisions concerning, for instance, bidding and contracting. The deepening of competition in recent years has meant that expected profits have been reduced. Therefore recent approximate estimates in the preliminary design phase are, in many cases, requested to have comparatively smaller margins of error. In general, decision making with approximate estimates with a margin of error of 15% is challenging. Moreover, even if the project is accepted, there is the problem of the risk of exceeding construction budget.

The traditionally typical method of approximate estimation is to use the functional area cost. Functional area cost utilizes the total construction cost derived from the quantity of materials multiplied by unit cost. Therefore in estimates for new projects, the following problems arise: the lack of measures to counter changes made in materials, and obscure process that using the construction cost indicator for consider time valuation. This increases the margin of error, which reduces the level of reliability, and, in turn, hinders responsiveness to changes in environment.

If there are many previous examples of similar projects, then a construction cost estimate relational function can be derived from statistical analysis. However considering that current projects favor more complex structures, there is a risk of not having sufficient enough samples for a meaningful interpretation. Even in the example of multi-housing residential buildings where there is a substantial amount of past experience, the margin of error of approximate estimates is rising due to the recent changes in the market and environment (Son, 2006).

3. APPROXIMATE COST ESTIMATING MODDEL

3.1 Definition of Cost Estimating Model

A cost model can be defined as an expression of semiotic analysis of a system that explains how factors are influenced by cost (Ferry and Brandon, 1984). And in order to develop a model that satisfies this definition, one must examine each stage in the construction process and decide on the approximate estimation method for each. The following Figure 1 is a summary of the various definitions found in the literature review, of construction project processes and the preferred estimation methods.

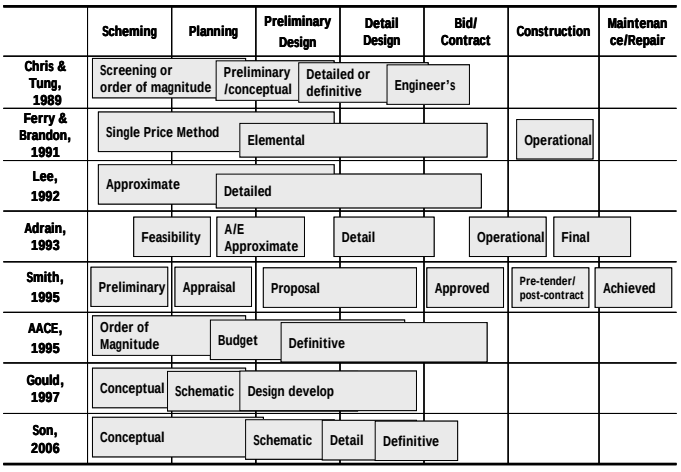

Figure 1. Projects Process of Construction Project & Cost Estimating

What can be seen from the summary is that the level of estimation required in each stage is different, and that this, in turn, can alter the applied methodology. Only when an appropriate methodology is applied can a reliable cost model be created.

3.2 Cost Estimation Method

Table 1. Cost Estimation Method

Researcher	Method
Allsop (1980)	Linked the unit costs and unit from estimating program to obtain cash flow
Jamieson (1980)	Simplified this process by the application of a cost curve using an average rate of markup
Berny & Howes (1982)	Suggested the integrated model of polynomial and exponential curve for expenditure forecast
Stotller (1992)	Applies a CBR system for cost and sales prediction under uncertainty
Fleemming (1994)	Proposed the SEED model with a goal to support the tasks at early phases of building design
Lee (1995)	Describes a CBR system that develops forecasts for cash flow account
Soibelman (1999)	Developed a model that aim to assist engineers in the conceptual of the structural design

In order for an estimation model to be efficient, an appropriate methodology for deriving a value must be the basis. A methodology must not only be accurate, it must take in consideration load of works. Thus, to spend too much time and effort on an approximate estimation is against the very nature of an approximate estimation. Examples of the efforts made in estimation are summarized in Table 1.

The methodology used in approximate estimates can be largely classified into four groups. The first methodology is unit-based and derives construction cost from determining the unit price and multiplying each element in the unit area, capacity, and installation facility. The second is a statistical methodology and normally uses standard work division substitution rule. The third is to use Artificial Intelligence which allows diverse approaches. The final methodology uses quantity variability as a basis to derive the construction cost. The aforementioned methodologies can be used individually or used in combination. The types of methodologies and their pros and cons are summarized in Table 2.

3.3 Artificial Intelligence(AI)

Artificial Intelligence (AI) is the realization of the human skills as a computer program, namely the human abilities of learning, deduction, judgment and the comprehension of natural language. The tools of AI share a common goal of enhancing computer intelligence and making it more human-like.

The reason for AI use in Approximate Cost Estimating Models is twofold. The amount of data can be too much for people to manage directly, and there can be a lack of previous examples needed to make rational decisions. Both circumstances occur in the construction industry. The type and number of items used in a construction project is considerable and it is unreasonable to expect it to be checked one by one by hand. Furthermore, the types of projects are diversifying and new endeavors are becoming ever more common, making the use of previous, similar projects increasingly irrelevant. Due to this, efforts are being made to introduce AI in approximate cost estimating. Representative examples are Neural Networks (NNs), Expert Systems (ESs), Case Based Reasoning (CBR).

AI is a skill used in order to do human work, but more efficiently and logically. However due to the inherent characteristics in the construction projects, AI use may create the opposite effect of making approximate cost

Table 2. Classification of Cost Method

	Parametric Method	**Statistical Method**	**AI Utilized Method**	**Quantity Variation Analysis Method**
Type	-Unit-based method -The physical dimensions method(AACE)	-Regression analysis method -Monte Carlo Simulation	-Neural Networks (NNs) -Expert Systems (ESs) -Case Based Reasoning (CBR)	-Quantity Based Active Schematic Estimating Model(Q-BASE, Son) -『D company』 proximate Estimation System
Pros	-Speed, Simplicity	-Possible to reduce margin of error due to mathematical model	-More reliable than Regression analysis method -CBR offers ease in creating and maintaining obvious model	-Ability to evaluate reliability -Responsive to change
Cons	-Risk of Error -Inappropriate for complex projects	-Difficult to consider time effect -Linear relationship reliability problem	-Possibility of becoming a black box in the Inference phase	-A lot of time and effort required -Only applicable to similar projects due to material estimates being based on Regression analysis

estimating irrational.

Utilizing NNs to create databases of the substantial number of items and processes in the construction industry is difficult. Moreover having a "black box" in cost estimating is potentially very dangerous. This is because verification of results can be a factor in raising the reliability of the approximate estimation model. In the case of ESs, defining the rules is the most important factor, but formulating rules for all the items and processes in a construction project is very demanding. Moreover, there are processes vague enough to make the creation of rules problematic. CBR input and output (as well as the case base itself) are more readable than that of a NN application. If previous cases are selected carefully and stored in the case base, a CBR application does not require training before it can be put to use, thereby saving much of the training time required by NN application. Therefore, using CBR in approximate cost estimating is an effective way to apply.

4. CASE BASED REASONING (CBR)

Academics have defined Case Based Reasoning (CBR) in different ways. However, all the definitions have simply used different vocabulary and are essentially the same. CBR is an experience-based methodology that uses corresponding previous experiences in order to solve problems.

The process of solving a problem using CBR is remarkably similar to that of a human. Figure 2 shows the essence of the process involved in CBR, and is commonly referred to as 4RE. Brief explanations are included at every stage (Admodt, 1994).

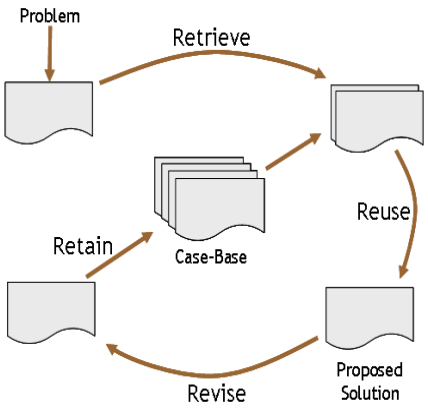

Figure 2. 4REs (Admodt, 1994)

(1) REtrieval

Past cases similar to new problems retrieved from case DB. The principle problem here is how to match the similarities.

(2) REuse

In order to produce a result for the pending problem, the data and knowledge from previous similar cases are reused.

(3) REvise

The differences between the current problem and the retrieved case are analyzed, and if needed, the solution plan is appropriately modified.

(4) REtrain

The solved problem is stored in the database to be reused in future problems.

CBR searches past cases and selects cases that can be used as a reference in solving current problems. The problem solving utilized in previous cases are then modified in order to be appropriate in solving the current problem. Figure 3 expresses this structurally.

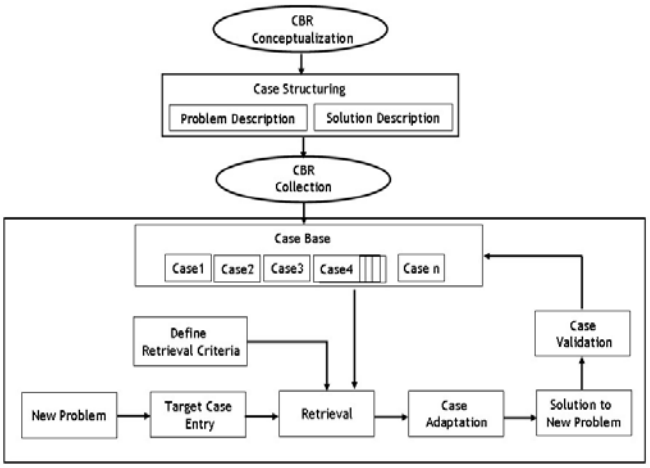

Figure 3. General CBR Development Methodology (Yau, 1998)

5. PROTOTYPE OF SYSTEM ARCHITECTURE

In this paper, the estimates dealt with are approximate estimates used in planning and preliminary design, and the object is a public housing construction project. The Prototype of System Architecture is comprised of the Handlers part including the system logic or rule set and database, the Client part that handles the solution generation for the problem solving, and the Manager part that system for the expansion and management of the case database. Each part is linked to one another in order to be able to operate. Figure 4 illustrates the order of operation and relationship of part in System Architecture.

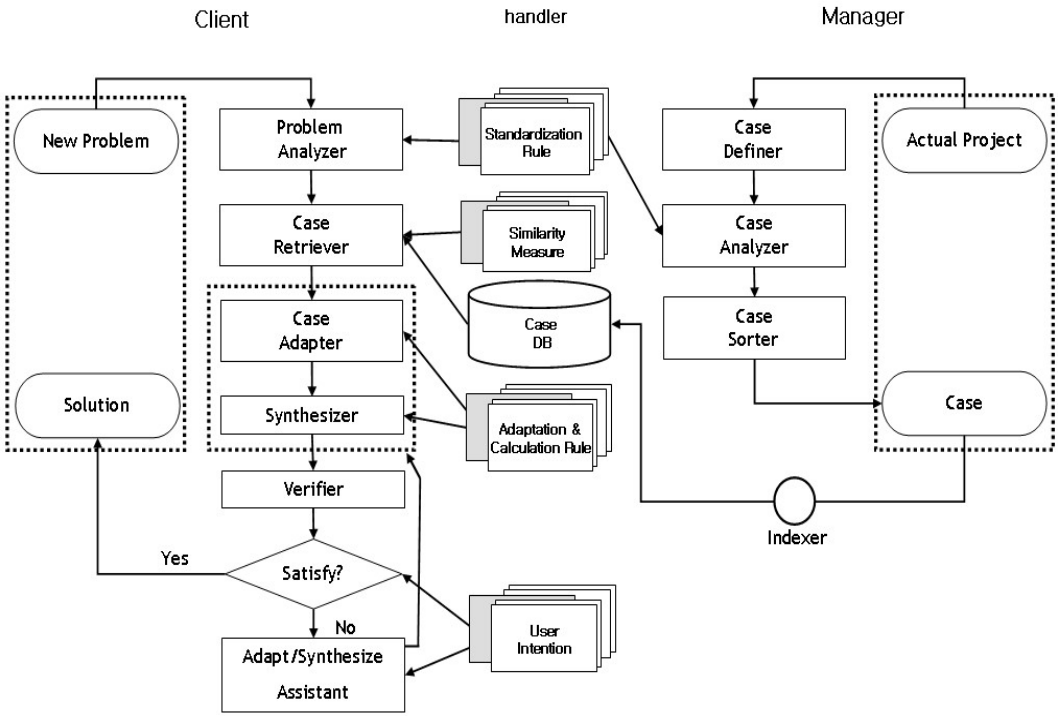

Figure 4. System Architecture

(1) Standardization Rule

The standardization rule specifies the standard by which the cases are partitioned, and is used in the partitioning of units smaller than the minimum unit. In the case of residential buildings, the unit of the detailed breakdown of materials is a building. A building is composed of certain forms. Figure 5 shows examples of the various building forms.

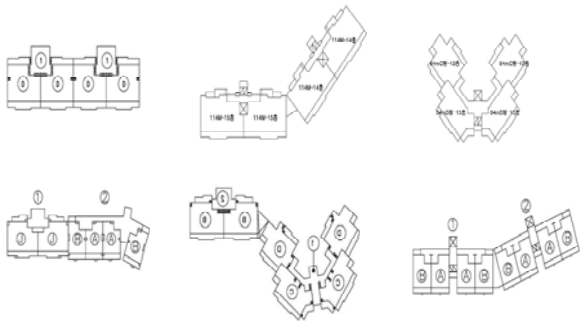

Figure 5. Shape of Buildings

In order to efficiently organize the different combination of forms, this research has assigned the unit "Type" to a building. Type is a set of households that use the public core in any one building, and generally conforms to the same measurement plan. If there is one Type in a single building, then it is a Single Case. If there is more than one Type, then it is a Multiple Case. In a Multiple Case, one or more corners or walls are shared between Types.

In this case, if data is entered, the Standardization Rule is applied in the partitioning by Type and after that, goes through the Synthesis Multi-case-snippets process to produce a result.

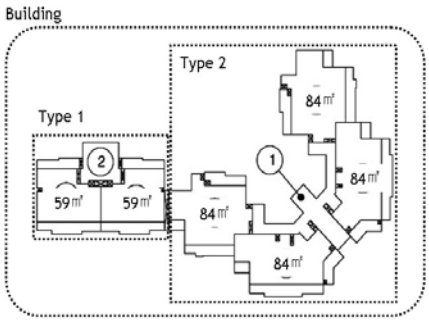

Figure 6. Sorting Types

(2) Case Database

The Database is comprised of a Quantity of Materials DB and a Per Item cost DB. The database is maintained and expanded by a professional administrator. The per item cost is entered into the database at the point the new project is planned, and the database is constructed using the direct costs during the project in order to aid the user in making decisions.

(3) Similarity Measure

Measurement of similarity is done by defining the influential elements in construction cost and comparing these to one another. These elements are defined as influence factors, and in order to identify these influence

factors, previous research and interview-based studies were conducted to construct a construction cost influence factor pool divided into three parts; characteristic of construction factors, construction management factors, and economic and social factors Consultations with professionals, examination of the importance of influence factors, inter-relationships analysis, etc, should be carried out before deciding on the final influence factors.

(4) Adaptation & Calculation Rule

Case selection depends on extraction using the system's similarity measurement, and on user selection. The model proposed in this paper makes both of this possible, and the Adaptation Rule takes into consideration all the possibilities in such a case and produces a rational result. The synthesis calculation is split into two parts; the first calculation is within the Multiple Cases and the second calculation calculates the structural construction cost for the entire project. The first calculation considers the variables for the synthesis between Types, and the second considers the combination of the building and the data alignment.

(5) User Intention

The estimating model can be used differently depending on the user's goal or stage in the project. In the planning phase where information is lacking, the variables can be considered to change the extraction of cases. In the preliminary design phase, it can be used to verify the changes in construction cost for various alternatives.

8. CONCLUSIONS

This paper proposes a new approximate estimation model to be used from the initial stages of construction projects. The use of AI in approximate estimations in the construction industry is clearly beneficial due to the complexity and the considerable number of item types involved. Owing to the significant influence that experience plays in new projects, Case Based Reasoning (CBR) is deemed to be the most appropriate AI for use in construction projects. However, there is the possibility of a quantitative and qualitative lack in the data used in the initial setup of CBR which could severely limit its use in the present market where the recent trend is that of increasingly novel and innovative projects. Therefore this paper proposes a new approximate estimation model that tackles the problems of the CBR method.

A new methodology that extracts, modifies and synthesizes comparable elements of previous cases is proposed in this paper. The prototype of system architecture was developed to be comprised of the Handlers part including the system logic or rule set and database, the Client part domain in charge of producing solutions to the problems, and the Manager part domain maintaining and expanding the case database.

In this research the approximate estimating model was limited to system architecture. Therefore additional research into implementation in the case study and verification process of a project may be performed. Another possible area of research is implementation for indirect costs. Additional verification for the use of the model in various circumstances is also needed.

This research will introduce the foundation for the implementation of systems with improved usability and applicability, and will provide the opportunity for the increase in importance and value of approximate estimations systems in the construction industry.

ACKNOWLEDGEMENTS

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