Construction Conceptual Cost Estimates Using Evolutionary Fuzzy Neural Inference Model

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ABSTRACT:
The conceptual estimate plays an essential role in project feasibility study. In practice, it is performed based on estimators' experiences. However, due to the inaccuracy of cost estimate, budgeting and cost control are planned inefficiently. In order to increase the estimate accuracy, this study employed the Evolutionary Fuzzy Neural Inference Model (EFNIM) to develop an Evolutionary Construction Conceptual Cost Estimate Model (ECCCEM).
The ECCCEM is designed for owners and planners to perform order of magnitude estimates and conceptual estimates. The impact factors of cost estimate are identified through literature review and interview with experts. Applying the EFNIM, the evolutional construction conceptual cost estimate model is established. Furthermore, for automating the developed model, this study integrates the Evolutionary Fuzzy Neural Inference System (EFNIS) with the developed model to construct a web-based cost estimate system. This system can assist managers to estimate the project costs accurately for different purposes.

KEYWORDS: Conceptual Estimate, Fuzzy Theory (FT), Genetic Algorithm (GA), Neural Network (NN), Order of Magnitude Estimate.

1. INTRODUCTION

Cost estimate of engineering is the foundation of all project-related engineering. It is based on planning, designing, bidding, and even construction. For owners and planning authorities, the data of cost estimated can be the evaluation base of feasibility of project, design with content and cost control during engineering execution. Based on the analysis of curve of management control of engineering, design of prototype and initial phase of design play an influential role during project.

The estimate of cost is based on owner's need and geographical condition, and is, therefore, taken as a foundation for feasibility evaluation and design plan. In practice, at the stage of engineering initial plan and design, there are two ways to estimate cost, one is Rough Estimate and the other is Sketchy Estimate Method. The former uses Experimental Judgment, which requires experienced experts. With their experiences, engineering cost can be calculated subjectively. Whereas, even though the experts are experienced, the different standards in assessing may be hard to judge the precision of cost estimate. Further, a common way used in sketchy estimate is Factor Estimate. It uses past cases and chooses some engineering items with obvious cost percentage as base, then adjust engineering cost based on the ground of standard items and scales of other items [1]. Is it possible to present features of project and obtain a reasonable cost if calculation is resulted from key engineering items? These are still much more to be discussed. With the problems of Rough and Sketchy Estimates, an incompletion of data at initial stage, there is still a huge tolerance between estimate cost and actual one. It is estimated that the tolerance of Rough Estimate is ±25%, while Sketchy Estimate ±15% [2]. Hence, because of this tremendous tolerance, it is obvious that budget cannot be arranged and taken as a way to control cost for project based on the data from cost estimate.

The current way to estimate price is differentiated from stage. Based on engineering and construction cost, a rough estimate at conceptual planning stage is basic research of existing area and customer's initial demand. Initial stage is to last conceptual planning stage, put it into practice, process initial design, and calculate a rough cost based on the result of design. Therefore, it is hard to distinguish engineering stage between Rough Estimate and Sketchy Estimate. However, it is still a continuous operation. It is essential to consider the continuity of price estimate and estimate price based on Rough and Sketchy Estimates so as to build up a model for price estimate of information integration at varied stages.

Moreover, time is rather short compared with schedule of initial design and planning with the stage of engineering execution. Thus, in order that cost can be estimated along with price estimate, a development of system for engineering cost will help establish a mechanism of rapid price estimate. To sum up, this research will develop an integrated estimation system, which consists of Rough and Sketchy Estimates, thereby the operation of engineering cost can satisfy needs, cost and time three dimensions [6].

2. RESEARCH OBJECTIVE

The objectives of this research are stated as below:

(1)Discussion of problems resulted from the method of engineering cost estimate

This research is to use the most commonly used Rough and Sketchy Estimate, analyzing their problems and developing a basis of price estimate model for Rough and Sketchy Estimate.

(2) Establishing a cost estimate model of construction engineering with information integration.

As the current way to estimate engineering cost is too simple. In order that Rough and Sketchy Estimate can fit the continuity of project development and effectively integrate it, this research will take Evolutionary Fuzzy Neural Inference Model (EFNIM) as core of price estimate model so as to improve mentioned simple way of estimate, thereby fully utilizing experts' experience and historical cases and considering the continuity of price estimate in order to establish a model of cost estimate with information integration. On the basis of stages, this model can be divided into two parts:

(a)Rough Estimate Model for construction engineering cost

At stage of conceptual planning design, Rough Estimate is established based on the status of existing area and initial idea of project so as to assess the land price for engineering.

(b)Sketchy Estimate Model for construction engineering cost

To continue the project Architecture and integration of design content established during the designing stage, build up Sketchy Estimate Model, assess land price for each engineering item, and then sum up to the final land price of engineering.

(c)Developing an estimate system for construction engineering

With the objective to set up a rapid price estimate mechanism, this research will discuss the infrastructure of designing plan, cost estimate system of construction engineering, and apply it to price estimate personnel. By using this kind of systemic operation, a reasonable cost can be calculated within a short time.

3. EFNIM MODEL

3.1 Architecture of EFNIM

EFNIM is configured under the structure of Fuzzy Theory, Neural Network and Genetic Algorithms. Its configuration is as Fig. 1. With these combined, advantages can be integrated while defects can be made up. In this model, Fuzzy Theory (FT) deals with inaccuracy and similar theories, while Neural Network (NN) is used for a maximum of learning curve; furthermore, Genetic Algorithms (GA) optimizes the whole model.

The purpose to build this model is on the base of Intelligence Theory model. Therefore, the development of model is based on the theoretical Process of simulated human brain combined with fuzzy theory. FT and NN are a compensated technology, the combination of which can effectively gain the features of human brain, thereby offering the development of IA an effective approach. In Fig.1 the Fuzzy Inference Engine and Fuzzy Rule in the traditional FT are replaced by NN, and the use of which is to overcome the attainment of Fuzzy Rule, decision of integrated algorithms so as to help system equip with learning ability. It is acknowledged that the combination of FT and NN is – The origin of nerve with fuzzy input and output. It is also a neural network with fuzzy input and output. To make the study easier, we call the origin of nerves with Fuzzy input and output as FNN.

Compared with traditional FT, though FNN can simulate the features and process of human inference, there are still some difficulties in terms of proper topology and selection of parameters. Besides, it may increase the difficulty and time based on the appropriateness of the selection of MFs (Membership Functions). Hence, GA could be an effective way to help resolve the defects of FNN.

As a result, EFNIM will use GA to simultaneously search for the most suitable mode of subsidiary function, and the best topology and coefficient of FNN.

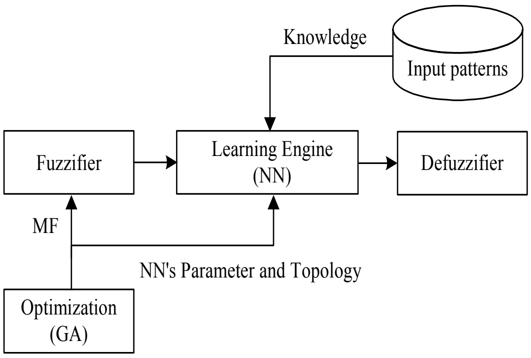

Figure 1. Architecture of EFNIM

3.2 Features and Limitations of EFNIM

EFNIM is inherited from the features and limitations of FT, NN and GA. It includes [3]:

(1)Features of EFNIM

a.It has an uncertainty, unclearness, and ability of partial unknown questions during the resolving process.

b.It has an ability of self-adjustment and learning in different environments.

c.It has ability to solve highly complicated problems.

d.It has fault tolerance.

e.It can find out the reflective relationship in input variable factors and output variable factors.

f.It can find out highly similar inference.

g.It can accumulate knowledge and experience.

(2)Limitation of EFNIM

a.It need training materials.

b.Training material should be correct and equally spread.

c.Solution should be a similar number.

4. ESTABLISHMENT OF COST ESTIMATE FOR CONSTRUCTION ENGINEERING

The model of cost estimate in this research can be divided into Rough Estimate and Sketchy Estimate. Rough Estimate means that during engineering planning, before designing, customers would develop a cost estimate model based on engineering objective, geographical information and initial idea. Sketchy Estimate means after initial design, customers could get an estimate of engineering total cost based on the assessment of engineering cost, and sum up each engineering cost.

4.1Evaluation of Current Cost Estimate

There are 3 features in Rough and Sketchy Estimates:

(1)Experience-Oriented

Rough and Sketchy Estimates are different from Detailed estimate. Detailed estimate is used after engineering drawing and specification are completed, whereas Rough and Sketchy estimate are used merely based on a simple idea or an initial design. Thus, when information is insufficient, all that calculating personnel can do is to use their experience to assess the cost. With lots of experience notwithstanding, their estimate of cost may still have high tolerance based on their subjective judgment and different experience level.

(2)Method Too Simple

The current methods of cost estimates are related to analyze the relation between factors and cost, complete engineering projects and cost referring to some exemplary engineering items and predict cost via linear approaches. For instance, Factor estimate is based on engineering items with obvious cost scale, by which adjusts the basic items and relationship for scales of other items so as to procure cost estimate. However, the composition of engineering cost is complex, and is it possible that cost estimate can represent features of case based on obvious cost scale? Is the relationship between factor and cost a linear relationship? Thus, with a simple estimate approach, it is hard to get a precious cost estimate.

(3)Historical Cases as Basis

Historical cases can be regarded as basis during cost estimate. Thus, the success of cost estimate relies on the collection of historical cases, analysis and confirmation of engineering items needed for estimate.

4.2Feasibility Analysis of EFNIM

This chapter will refer to the evaluation for the features or estimate methodology based on the infrastructure and features of EFNIM.

(1) Experience-oriented

EFNIM can use neural network to learn from cases and obtain the membership functions.

Therefore, it can help sort out calculating personnel with insufficient experience and varied subjective judging criteria, which resulted into a tolerance of cost estimate.

(2) Method Too Simple

EFNIM takes FNN as it's inference engine, and uses GA to process FNN network by the best search in the entire area. It can effectively describe the relationship between the reasons for affecting cost estimate and engineering cost. It can simultaneously represent the impact on the cost estimate resulted from the relationship among factors.

(3) Historical Cases as Basis

Cost estimate model developed through EFNIM can reflect features of different cases onto the network architecture searched through the course of learning from abundant and represent-able historical cases. When facing different case, it can stand for its features and assess a reasonable cost.

4.3 Cost Estimate Model of Construction Engineering

4.3.1 Establishment of Model Architecture

The cost estimate models in this study are Rough Estimate and Sketchy Estimate as Fig.2. The rough estimate model drafted in the figure is based on engineering land price from related parameters. Sketchy estimates in the initial design stage are Engineering of hypothesis, engineering of foundation, engineering of structure, engineering of installation, electromechanical and equipment engineering, engineering of miscellany and indirect engineering, which can calculate the land price for each engineering and procure the sum of engineering land price according to the parameters for each model.

4.3.2 Influential Factors for Models

Stage	Model		Estimated Cost Model
Stage of Conceptual Planning	Rough Cost Estimate Model		Land Price of Engineering
Initial Stage of Designing	Sketchy Cost Estimate Model	Model of Hypothesis Engineering	Land Price of All Engineering
		Model of Foundation Engineering	
		Model of Structure Engineering	
		Model of Installation Engineering	
		Model of Electro-mechanical and Equipment Engineering	
		Model of Miscellany Engineering	
		Model of Indirect Engineering	

Through analysis of literature review, brainstorming, influence diagram, hierarchy of objective techniques and summary of influential factors for rough and sketchy cost estimates are:

4.4Integration of Engineering Cost Cases

(1)Collection of CasesThe case resource is from an A-level plant in Taipei. This case mainly focused on the case of residential cluster for construction engineering. The period was from 1997 to 2001 and main location is in northern area of Taiwan. Land price for each

Ping is between \$40,000 to \$100,000 NTD. Considering the uniformity and completion of data, there are altogether 28 cases about RC.

(2) Pre-treat for Cases Data

In response to the cost model request upon data type of cases, there are some pre-works for case data. Including input variables – quantitative factor and qualitative factor, qualitative and

quantitative factors simultaneously, output variables– conversion of land price and normalization of land price. After historical cases are treated through input and output variables, they are able to be applied to training, the testing of cost estimate.

Figure 2. Cost Estimate Model of Construction Engineering

(3) Case Decision of Training and Testing

28 historical cases about RC were collected in this study and 26 out of them were chosen for the training cases of EFNIM. 2 out of them were chosen as testing cases. Under the condition of sufficient and presentable data of training cases, the network architecture of cost estimate will be able to calculate precise cost in response to different cases. Whereas, testing cases represents different cases out of collected data and tests. Cost estimate model are able to calculate a precise cost in response to different cases types. Hence, this study will choose the price of engineering land as base and pick up case 18 and 24 for testing. The land price of engineering in case 18 is \$63,308NT, while in case 24 is \$70, 873NT.

4.5Design of Cost Estimate

(1) Rough Cost Estimate Model

It is based on the influential factor of Rough Estimate Model in Fig. 1.There are 10 input variables in rough estimate model while one output variable, which is land price of engineering.

(2) Sketchy Cost Estimate Model

Based on the influential factors of Sketchy Cost Estimate in Fig. 2, we assumed that there are 4 input variables of engineering cost estimate model and output variables are assumed as engineering land price; 7 input variables of fundamental engineering cost estimate model and output variables mean the land price of fundamental engineering. There are 8 inputs and 1 output (land price of structure engineering) of structure engineering. There are 9 Inputs and 1 output (Land price of installation engineering) of installation engineering. There are 8 input variables of electromechanical equipments and output variables mean the land price of electromechanical equipment engineering. There are 5 inputs and 4 outputs of miscellany and indirect engineering and output mean the land price of engineering of miscellany and indirect engineering.

4.6 Training and Testing of Estimate Model

4.6.1 Criteria of Model Evaluation

During initial stage of rough estimate, the tolerance is around ± 25%, and during sketchy estimate, the tolerance is around ± 15%. Based on the difference of estimate stage, during rough and sketchy stages, it may not be reasonable to demand for an accurate cost under the condition of limited time, budget and information. Thus, it is necessary to consider the need of accuracy during planning and initial designing stages and enhance the accuracy reasonably. In this study, we set the tolerance of land price of engineering during rough estimate stage to be within ± 15%, while within ±10% during conceptual planning stage, with the view of enhancing the accuracy of cost estimate reasonably.

4.6.2 Training and Testing of Rough Cost Estimate Model

(1) Training and Testing of Rough Estimate Model

Based on the training cases 26 with EFNIM, proceeding the model training and executing the result as shown on Table 1. This result demonstrates that the cost tolerance through rough estimate model is within ±15%, which indicates an accuracy to predict cost.

Table 1. Comparison of Testing Case for Output Land Price by Rough Estimate Model

Model	Case	Inferred Land price (NTD/Ping)	Targeted Land price (NTD/Ping)	Tolerance (%)
Rough Estimate	18	63992	63308	-0.468
	24	71861	70843	1.832

4.6.3 Training and Testing of Sketchy Estimate Model

(1) Training and Testing of Sketchy Model

Based on the use of EFNIS, after the search and training for 6000 generations for engineering model from 7 groups. Used case 18 and 24 to demonstrate the engineering cost estimate model by items and the inferred output result is shown as Table 2. After calculation, the tolerance in case 18 and 24 are 7.812% and 2.058%, which is indeed within ±10%. Thus, based on this result, the establishment of Sketchy Cost Estimate Model in this study can definitely assess the accuracy of engineering land price by items.

Table 2. Comparison of Output Land Price Cost from Testing Cases through Sketchy Cost Estimate Model

Model	Case	Inferred Land Price (NTD/Ping)	Desired Land Price (NTD/Ping)	Tolerance (%)
Cost Estimate of Hypothesis Engineering	18	1413	1501	-5.878
	24	1998	1936	3.205
Cost Estimate of Foundation Engineering	18	7878	7735	1.848
	24	6381	6180	3.255
Cost Estimate of Structure Engineering	18	18049	17351	4.021
	24	18465	20224	-8.701
Cost Estimate of Installation Engineering	18	23555	23243	1.341
	24	21350	21548	-0.922
Cost Estimate of Electro-mechanical and Equipment Engineering	18	10995	11129	-1.196
	24	14512	14687	-1.189
Cost Estimate of Miscellany Engineering	18	2787	2632	5.874
	24	3193	2757	15.823
Cost Estimate of Indirect Engineering	18	3687	4337	-14.988
	24	5878	6902	-14.833
Land Price of Engineering	18	68253	63308	7.812
	24	72301	70843	2.058

5. SKETCHY COST ESTIMATE SYSTEM IN CONSTRUCTION ENGINEERING

This study takes EFNIM as a core and EFNIS as a basis to build up sketchy cost estimate system in construction engineering and develop it based on evaluating the demand of operational personnel. The functional module in this system contains: case management, case conversion, case calculation, price index management and module for user's management, while in the mean time integrating the use of EFNIS.

6. CONCLUSIONS

In this thesis, we will summarize the above-mentioned process of study and achievement of study as follows:

(1)This study considers the phase of engineering life cycle and the stance of customers and consultants so as to design and integrate the rough cost estimate for prototype stage and sketchy cost estimate for initial design stage, thereby establishing an engineering cost estimate model with data linkage and cross-phase.

(2)This study combines the construction engineering cost estimate model in EFNIM, which effectively obtains experience from historical cases, summarizes regulation for cost estimate, and solves traditional cost estimate approach that only infers cost with some important engineering items. This study also improves the impact on subjective judgment by human.

(3)With the application of EFNIM, this study enhances the accuracy of price estimate effectively, and decreases the tolerance of rough cost estimate down to ±15%, while for sketchy cost estimate down to within ±10%.

(4)Based on the design of cost estimate model of construction engineering, this study takes EFNIS as its base and develops a cost estimate system for construction engineering. Considering the demand for price estimate process, the whole system is presented with internet pages, which is not limited by stand-alone system, thereby being able to offer many people of proceeding cost estimate process from far distance.

(5)Through the cost estimate model and system established by this study, the designing authority could calculate the engineering cost based on project contents proposed by customers. Customer could then assess the feasibility based on the proposed project contents and cost from related authority. A concrete project content and estimated cost could be established in time, as well as cost and requirement could fit the need.

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