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Predicting Effectiveness of Construction Project Management: Decision-Support Tool for Competitive Bidding

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Abstract

This article presents construction project management effectiveness modeling from the construction management organization perspective. The paper reports on construction project performance data collected from construction management companies in Lithuania and the USA. Construction project management effectiveness model (CPMEM) was established by applying artificial neural networks (ANN) methodology. Twelve key determinants factors that influence project management effectiveness in terms of construction cost variation were identified covering areas related to the project manager, project team, project planning, organization and control. The CPMEM can be used during the competitive bidding process to evaluate management risk of a construction project and predict construction cost variation.

Keywords

Construction Project Management, Effectiveness Modeling, Artificial Neural Networks.

1. Introduction

Construction projects are delivered under conditions of risk in the competitive market environment. There are external risks (economic, political, financial and environmental) and internal risks based on project management issues, i.e. projects manager's and his team competency, experience, strategic and tactic decisions made during construction project delivery. The opportunity to improve organizational performance through more effective project management could provide substantial savings for construction management company.

Project management effectiveness depends on certain factors of project management system. The literature review revealed a substantial volume of work on measuring or identifying the factors or conditions contributing to the effectiveness of construction projects. There are three main trends of previous research on construction project success factors:

- key factors identification for construction project success (Jaselskis et al. 1991; Sanvido et al. 1992; Chua et al. 1997, Chua et al. 1999);

- identification of key success factors for a particular group of construction projects, e.g. BOT, design-build, public-private partnerships (Tiong 1996; Molenaar et al. 2001; Chan et al. 2001, Zhang 2005, Shen et al. 2005);
- analysis of a particular factor impact on construction project success (Faniran et al. 1999; Cheng et al. 2000; Bower et al. 2002; Ford 2002).

Some writers were attempting to develop predictive models while others focused on generating a list of practices. Predictive models developed to identify the key factors and to measure their impact on overall project success were using regression and correlation techniques, factor analysis, Monte-Carlo simulation, experts and multicriteria decision-making support methods. Essentially in these approaches the functional relationships between the input factors and project outcome is assumed and tested against the data. The relationships are modified and retested until the models that best fit the data are found.

When developing construction project management effectiveness model (CPMEM) referred to here, the writers attempted to cull the best aspects of artificial neural networks (ANN) methodology. The neural network approach does not require an a priori assumption of the functional relationship. Artificial neural networks are very useful because of their functional mapping properties and the ability to learn from examples. Networks have been compared with many other functional approximation systems and found to be competitive in terms of accuracy (Haykin 1999). This and the ability to learn from examples allow modeling the complex construction project management system where behavioral rules are not known in detail and are difficult to analyze correctly.

2. Development of Construction Project Management Effectiveness Model by Applying Neural Networks

Construction project management effectiveness modeling by applying neural networks consists of the following stages:

- selection of the variables of the construction project management effectiveness neural network model (CPMEM);
- selection and preparation of training data for the CPMEM;
- designing and training the construction project management effectiveness neural network;
- evaluation of the importance of a particular input factor to the CPMEM output by applying a sensitivity analysis technique;
- identification of the key construction project management effectiveness factors and modification of the CPMEM;
- determining the validation range of the CPMEM practical applications.

Construction project management effectiveness factors are the input variables of the CPMEM. The framework for the list of construction management effectiveness factors covering areas related to project manager, project team, project planning, organisation and control was selected from the research conducted by Jeselskis and Ashley (1991). However, the actuality of each construction management factor was retested by interviewing construction management practitioners and the approach was modified according to the interviewers opinion (Table 1). The output variable of this model is the construction project management effectiveness in terms of construction cost variation. The construction project cost variation was calculated by equation:

$$Q = \frac{PI - FI}{PI} \cdot 100\% \qquad (1)$$

where PI - predicted construction project cost; FI - actual construction project cost.

The present study is based on a set of data obtained in a questionnaire survey on construction project management effectiveness factors from construction management organizations in Lithuania and the USA. Twelve Lithuanian companies presented information on 32 completed construction projects. The average size for the projects is 4.3 million Litas and the mean duration is 7 months. 27 US construction management companies presented information on 54 completed construction projects with the average size of 30.1 million USD and the mean duration of 14 months. The neural network model was trained with 76 project samples and retested with 10 project samples. The construction project management effectiveness neural network model had been developed using *NEURAL NETWORKS TOOLBOX* by *MATLAB*.

Table 1: Construction Project Management Effectiveness Factors

Category	Project management factor	Measure	Order of priority	Key factor
Project manager (PM)	PM meetings	Number/month	7	✓
	PM time devoted	Hours/day	16	
	PM site visits	Number/month	2	✓
	PM subordinates	Number	10	✓
	PM levels to craftsmen	Number	8	✓
	PM education level	Years	11	✓
	PM construction experience	Years	27	
	PM project management experience	Years	15	

Table 1: Construction Project Management Effectiveness Factors (continued)

Category	Project management factor	Measure	Order of priority	Key factor
	PM scope experience	Number of projects	12	✓
	PM technical experience	Number of projects	13	
	PM scope experience other than as PM	Number of projects	9	✓
	PM technical experience other than PM	Number of projects	14	✓
Project team	Team turnover	% per year	26	
	Monetary incentives	% of total constr. cost	1	✓
Planning	Design complete at construction start	%	21	
	Activities in execution plan	Number	19	
	Budget contingency	%	18	
	Independent constructability analysis	% of total constr. cost	5	✓
	Modularization	% of total constr. cost	4	✓
Organization and control	Progress inspection	Number/month	23	
	Quality inspection	Number/month	22	
	Safety inspection	Number/month	17	
	Control system budget	% of total constr. cost	3	✓
	Design control meetings	Number/month	20	
	Construction control meetings	Number/month	24	
	Schedule updates	Number/month	6	✓
	Budget updates	Number/month	25	

A neural network works best when all its inputs and outputs vary within the range 0 and 1. Preparation of the training data and statistical computations had been performed by applying *Microsoft Excel.* The input data - project management factors - was classified into six groups and the output data - the percentage of the construction cost variation in loss or profit - was classified into five groups (Table 2).

Table 2: Classification of Project Cost Variation

Range of predicted project cost variation Q	Class description	Predicted neural network output
Q > +10%	Very good	00001
+3% < Q ≤ +10%	Good	00010
–3% ≤ Q ≤ +3%	Average	00100
–10% ≤ Q < –3%	Poor	01000
Q< –10%	Very poor	10000

The number of neurons in the input and output layer was decided by the number of input and output variables of the construction project management effectiveness neural network. Thus, the input layer had 27 neurons and the output layer had 5 neurons, representing five classes of the construction cost variation. The number of hidden layers was determined during the neural network training. The neural network was trained to solve the classification task by applying resilient backpropagation learning algorithm. The network performance in this study was measured by the modified reguliarization error function. The interpretation of the network output is based on the Bayesian posterior probability: the construction project cost variation belongs to the class represented by the output layer neuron of the highest output value. The classification error was calculated by equation:

$$CE_{RMS} = \sqrt{\frac{1}{q}\sum_{p}\left(T_p - P_p\right)^2} \quad (2)$$

where T_p – actual class of project cost variation; P_p– class of project cost variation predicted by neural network; p – construction project index; q – number of examples for testing.

All construction management effectiveness factors were incorporated into the model at the first stage of model development. The initial network model comprised 27 neurons in the input layer with 9 neurons in the hidden layer and 5 neurons in the output layer. In order to understand the importance of a particular input to the network output, a sensitivity analysis technique was applied. Insignificant factors were trimmed from the network gradually by eliminating the least important factors, respectively to the results of sensitivity analysis. In this stage of model development 12 key determining construction management effectiveness factors were identified (Table 1). The final neural network model was built with 12 neurons in the input layer, 4 neurons in hidden layer and 5 neurons in the output layer.

The established CPMEM represents the input-output functional relationships reflected by the specific characteristics of the training data set. The model was validated by 10 project samples, 2 for each class. All testing samples were classified correctly. Thus, the model is valid within this particular range of training data. However, the analogical model can be developed by applying training data of any group of construction projects or construction management organizations.

3. Decision-Support Tool for Competitive Bidding

Authors of the paper established the construction project management effectiveness model and developed the application algorithm of that model for competitive bidding process (Figure 1). The range of potential construction project cost variation can be evaluated by applying CPMEM on the specific project, project team and construction company.

Case study: The request for bidding proposal was issued by the private company to manage the construction of industrial project of 20 million USD on a fixed price contract basis. Construction company X prepared bidding material for that project. Company's X estimated total bid price was 20.7 million USD, 10 % profit margin was included. According to the market analysis the competitive bids might fall into the range of 20-21 million USD. What would be the company's X bidding decision?

Solution: The estimated construction cost was 18.82 million USD. The predicted cost variation was calculated within the range of –3 % and +3 % by applying CPMEM construction projects management effectiveness neural network model. If the worst happened, the construction cost would increase by 3 % up to 19.38 million USD and the markup would reduce to 6.8%. If the target markup for that project procurement was 10%, the company should re-estimate the bid price up to 21.32 million USD. Though, that price would not be competitive.

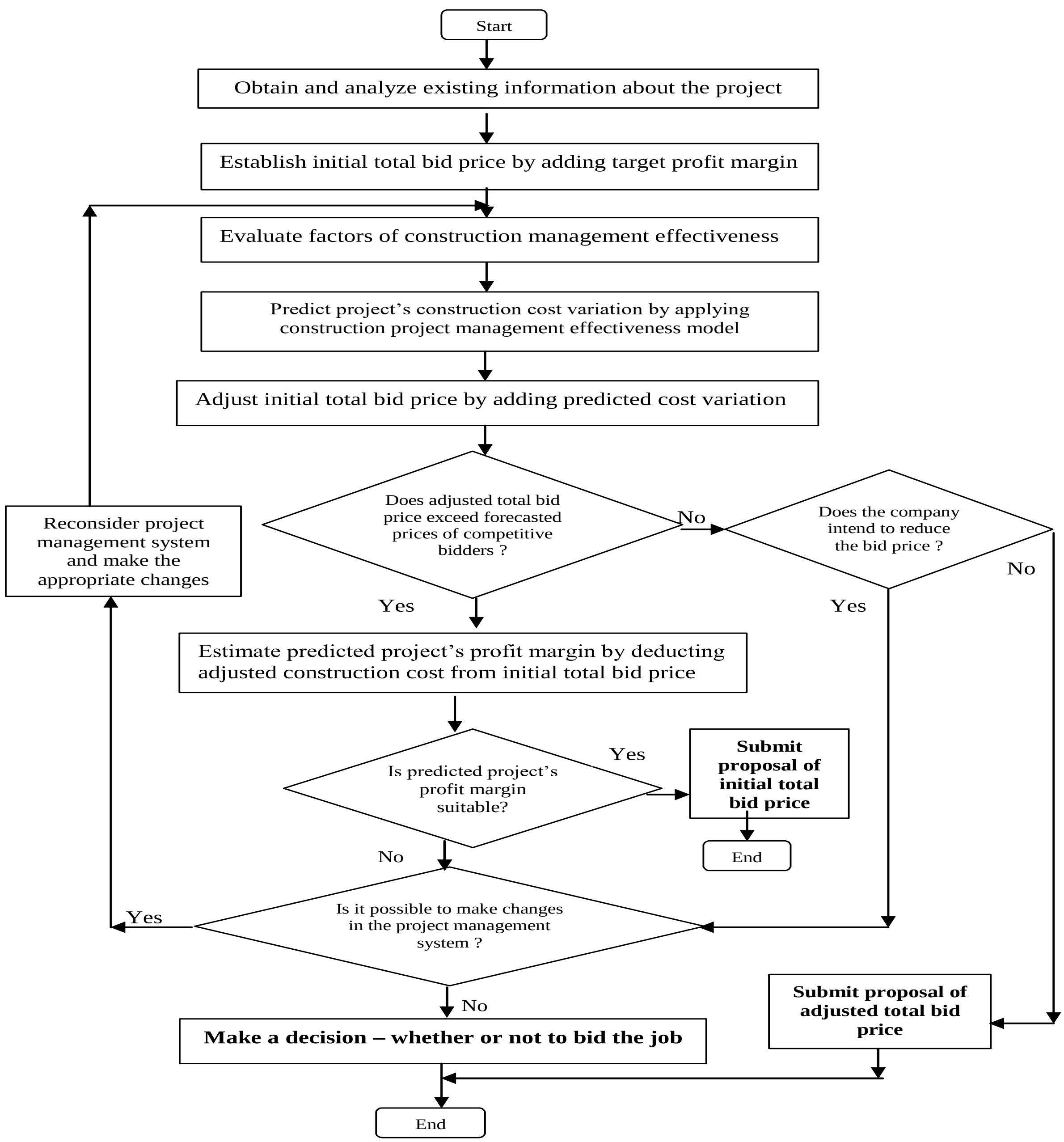

Figure 1: Construction Project Management Effectiveness Prediction Algorithm

The managers decided to replace two members of the project team by more qualified professionals and not to hire outside consultants, i.e. reevaluated the CPMEM factors of project team monetary incentives and independent constructability analysis. By applying CPMEM model for the second time, the predicted cost variation was calculated within the range of +3% and +10%. In that case there was a possibility of at least 3% construction cost reduction, i.e. 0.56 million USD (18.82*0.03=0.56). Thus, adjusted bid price was calculated at 20.08 million USD [(18.82-0.56)*1.1] =20.08.

X Company must make a decision – whether to submit the bid price of 20.08 million USD, which seems competitive enough, or keep trying to reduce it by strengthening the other aspects of project management system, thus resources can be deployed even more effectively. By applying the construction project management effectiveness neural network model, managers of construction company can indicate how much importance each factor has for a particular project outcome, find the best possible arrangement of construction management effectiveness factors and examine the construction cost variation tendencies.

4. Conclusions

The paper presents a new methodology for construction project management effectiveness modeling by applying artificial neural networks. The approach of artificial neural networks allows the CPMEM to be built and to determine the key determinants from a host of possible management factors that affect project effectiveness in terms of construction cost variation. The established neural network model can be used during the competitive bidding process to evaluate management risk of a construction project and predict construction cost variation. The model allows the construction project managers to focus on the key success factors and reduce the level of construction risk. The model can serve as a framework for further development of construction management decision support systems.

5. References

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