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A Two-Stage Model to Support Go/No-Go Decision Making in the International Construction Market

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Abstract

In recent years, many construction companies have attempted to expand their businesses into the overseas market. However, a number of them face difficulties in ensuring that their international construction projects are profitable, mainly because they don't have an in-depth knowledge of their company's capabilities and the likely risk level associated with projects. This study proposes a go/no-go decision support model for construction companies. The proposed model simultaneously considers the capabilities of a construction firm, the project risk level, and the firm's business philosophy or attitude. The creation of the model can be classified into two stages. Stage 1 includes two evaluation models, namely, a corporate competency assessment model and a project risk assessment model. These models are created by an artificial neural network (ANN), and the input and target values are derived from a questionnaire. Stage 2 is a fuzzy inference model whose aim is to support go/no-go decision making. These models have two linguistic input values; one is a net competency value derived from risk score and competency factors, and the other is the company's business philosophy, which indicates corporate management tendencies. It is expected that the proposed decision support model will support companies in identifying strategies that will facilitate project customization and profit objectives by utilizing the company's qualified capabilities, complying with their business philosophies, and outlining their risk factors.

Keywords: Fuzzy logic; artificial neural network; risk factors; competency factors.

1. Introduction

1.1. *Research Background*

In recent years, many construction companies have expanded their business activities into the international market. However, a number of them face difficulties in terms of being profitable in the international construction market, largely due to market uncertainty and risk. This has led several construction companies to start analyzing international construction risk and their company's capabilities in order to facilitate more effective decision making. However, the standard decision-making processes do not accurately reflect companies' capabilities and the level of risk they face. To address this issue, the current study proposes a go/no-go decision support model that considers the capabilities of a construction firm, the level of risk associated with its projects, and the company business philosophy. This model is created with the help of artificial neural networks and fuzzy logic.

There is currently considerable progress in the construction industry regarding the implementation of construction management strategies using fuzzy logic and neural networks. Specifically, the duration of construction in overseas projects is measured using a fuzzy set theory [1], and fuzzy logic is used to evaluate the rate of cost overrun risk [2]. Based on a genetic algorithm, construction times and costs are traded off to ascertain the optimal trade-off point using the fuzzy set theory[3], and the prediction of financial contingency is progressed by means of artificial neural networks [4].

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While neural networks and fuzzy logic are applicable to many areas of construction, they have been used widely in many other industries. In the case of international construction in particular, companies must assess risk and capability in the engineering phase before the project commences. In essence, any decision models defined based on fuzzy logic and ANNs should be able to predict project go/no-go opinions. Therefore, the proposed model is expected to identify strategies that will meet profit targets based on a company's qualified capabilities and possible risk factors, as well as its business philosophy.

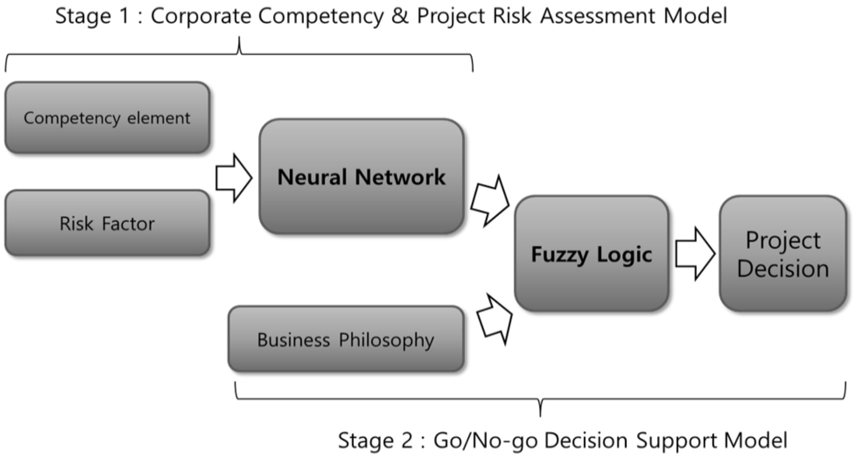
1.2. *Research Framework*

In general, the decision model will support go/no-go decision making in accordance with the attitude of the company in relation to its competence and the risk attached to the project. The model incorporates two stages, as shown Figure 1.

Stage 1 comprises two neural network (NN) models, namely, a corporate competency assessment model and a project risk assessment model. The competency assessment model quantifies the ability of the company by evaluating eight competency factors. The project risk assessment model is developed in the same way and can quantify the project's total risk by evaluating twelve risk factors. These two models are developed using a neural network.

Stage 2 is a fuzzy inference model that supports go/no-go decision making by considering the attitude of the company. This model is created by fuzzy logic using two input values. One is the net competency value that differentiates between corporate competency and project risk, both of which are evaluated in Stage 1 based on linguistic values. The other is the attitude of the company (business philosophy), which consists of five linguistic values: very stable, stable, normal, challenge, very challenge.

Figure 1. Two-stage of the decision support model



2. Research Methodology

2.1. *Artificial Neural Network Model*

Artificial neural networks (ANNs) are a series of machine learning models that were inspired by biological neural networks [5]. They are used to approximate algorithms that can be made using a number of inputs. Typically, an ANN is a system of interconnected "neurons" (nodes) between which information is exchanged. These connections have numeric weights that can be trained based on experience (data).

For our model, the corporate competency assessment model and the project risk assessment model were created using ANNs. Since the models' input consists of a large number of indicators (eight competency factors and twelve risk factors) and it is hard to ascertain the relationship between indicators and target values (one is the company's capability and the other is the project total risk), an artificial neural network was used.

2.2. *Fuzzy Inference System*

In effect, fuzzy logic reduces the ambiguity and uncertainty of human judgment. It is essentially a form of many-valued logic, in which the values of variables may be any real number between 0 and 1. Fuzzy logic can deal with the concept of partial truth, where the truth value ranges between true and false [6]. It is applied in many areas, such as vehicles, electronics, and computers, but is particularly convenient for the construction industry in terms of managing costs and schedules [1, 3, 4, 7].

In stage 2, the go/no-go decision model is created using a fuzzy inference system. This model uses two inputs, one of which is the attitude of company. Since company attitude is hard to quantify exactly, it can be seen as a form of linguistic variable. This is why a fuzzy inference system is appropriate for designing the model.

3. Stage 1: Corporate Competency and Project Risk Assessment Model

3.1. *Corporate Competency Model*

The competency assessment model quantifies the ability of the company by evaluating eight competency categories comprising 27 indicators. These indicators were derived from literature reviews and interviews with experts.

Using the 27 indicators, a questionnaire was developed to ascertain the evaluations for each indicator and the level of competitiveness of the companies. Fifty-nine companies were selected for the questionnaire and these indicators were measured on 5-point Likert scale.

For the corporate competency assessment model, the competency indicators were grouped into eight categories and used to input the data, while corporate competency level was used to target the data.

Table 1: Categories of competency factors

Large categories	Small categories (# of competency indicators)
Construction specialized technical strength	Construction technical strength (2)
	Project management (6)
Overseas project experience	Overseas project performance (2)
	Potential for market growth (5)
Overseas project manpower	International labor transfer and expertise (3)
	Organization growth (3)
Financial stability	Financial stability (3)
	Company sustainability (3)

Based on 59 samples, the corporate competency assessment model was created using Matlab's ANN tool box. Of the 59 samples, 41 (70%) were used for the training model, nine (15%) were used for validation, and nine (15%) were used for testing. This model has two hidden layers and seven hidden nodes. Generally, the number of hidden nodes is decided based on 70%~90% of the number of input nodes [8].

Table 2: Corporate competency assessment model's specification

Set	Number of samples	MSE	R value
Training	41	30.0624	0.9389
Validation	9	41.5291	0.8782
Testing	9	50.2212	0.8432

The output of the corporate competency assessment model represents the level of corporate competency, and the competency score ranges from 0 to 100. A zero score indicates that the company has no overseas business capability or competitiveness

3.2. *Project Risk Assessment Model*

The project risk assessment model quantifies the risk of the project by evaluating 77 risk factors. A survey was conducted to establish the project risk level using 77 factors on a 5-point Likert scale. In the project risk assessment model, the risk factors were grouped into 12 categories and used to input the data, while the project risk level was used to target the data.

Table 3: Categories of risk factors

Large categories	Small categories (# of risk factors)
Host country condition (county level)	Political and administration risk (4)
	Macro-economic risk (5)
Project execution environment (project level)	Owner risk (6)
	Bid and contract risk (12)
	Procurement risk (6)
	Physical risk (4)
	Socio-environmental risk (4)
Project execution capability (corporate level)	Prime contractor risk (9)
	Organization risk (6)
	Construction management risk (11)
	Localization risk (4)
	Construction technical risk (6)

The project risk assessment model is created based on 83 samples. Of the 83 samples, 59 (70%) are used to train the model, 12 (15%) are used for validation, and 12 (15%) are used for testing (Table 4). This model has two hidden layers and 10 hidden nodes (83% of the number of input nodes).

Table 4: Project risk assessment model's specification

Set	Number of samples	MSE	R value
Training	59	111.8594	0.8813
Validation	12	152.8483	0.8214
Testing	12	171.4361	0.7931

The output of the project risk assessment model represents the level of project risk, and the project risk score ranges from 0 to 100. A zero score means that there is no risk attached to the project.

4. Stage 2: Go/No-Go Decision Support Model

4.1. *Fuzzy Input Variable*

The fuzzy input variables comprise two values. One is a net competency value that is calculated as corporate competency scores and project risk scores, which are the results of the stage 1 model. The other value is business philosophy, which indicates the tendencies of corporate management. These two values will be fuzzy input values.

For defuzzification, a centroid method will be used, which usually involves applying a fuzzy frame. The fuzzy inference system type is "mamdani" because the training data set is small, and risk and competency require professional knowledge to make fuzzy rules

4.2. *Net Competency Value*

The net competency value is the difference between corporate competency and project risk score. It is important to note that because these two scores are scaled differently, an indirect comparison is applied; specifically, this is a comparison using sections.

Each input score is divided into five sections, for example, 0–20, 20–40, 40–60, 60–80, and 80–100. Each section is then labeled with numerical numbers from one to five. The net competency value is the difference between the numerical numbers for each section of the input. Thus, the range of net competency values is from -4 to 4, because the maximum value is 5 and the minimum value is 1. Subsequently, the value is categorized into five sections corresponding to different fuzzy numbers (Table 5).

In effect, each section represents five scenarios of net competency. In scenario 1, competency is very high and project risk is very low. In contrast, competency is very low in scenario 5, and project risk is very high. In this study, these five linguistic variables are quantified based on trapezoidal and triangular fuzzy numbers, as shown in Table 5.

Table 5: Categories and fuzzy numbers of the net competency values

Category (linguistic variables)	Net competency value (differences in input variables)	Trapezoidal and triangular fuzzy number
Scenario 1	-4, -3	(0, 0, 10, 30)
Scenario 2	-2, -1	(10, 30, 50)
Scenario 3	0	(30, 50, 70)
Scenario 4	1, 2	(50, 70, 90)
Scenario 5	3, 4	(70, 90, 100, 100)

4.3. *Business Philosophy*

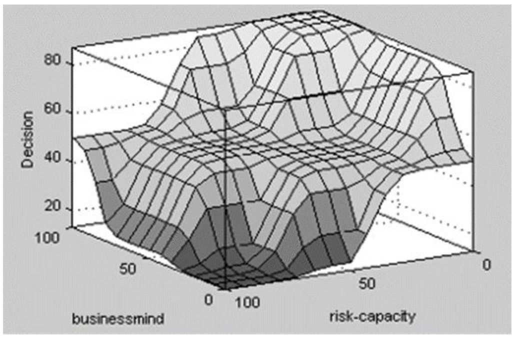
The second fuzzy input variable defines the company's business philosophy. All companies have their own particular management tendencies; for example, some relish the global challenge, others prioritize stable growth, etc. For this reason, business philosophy is defined using linguistic terms such as very stable, stable, normal, challenge, and very challenge. The membership function of business philosophy is the same as that of net competency value.

4.4. *Results of the Fuzzy Inference System*

The fuzzy output variable indicates a project decision consisting of three linguistic terms: no, consider, and go. The membership function is defined using a Gaussian function. Using these input and output variables, IF-Then rules are determined. For example, one of the rules indicates that if the net competency value is scenario 1 and the business philosophy is very stable, then the decision is consider.

Through these fuzzy rules, the go/no-go decision support model's result is as shown below in Figure 2. It can be seen that the decision values are divided into three sections ranging from 13.2 to 86.8, and the three sections represent 13.2 ~ 37.7 / 37.7 ~ 62.3 / 62.3 ~ 86.8. Thus, each range matches the three terms, no, consider, and go.

Figure 2: Fuzzy output surface



5. Conclusion

This study proposes a two-stage model to support go/no-go decision making for construction companies. Stage 1 comprises the creation of two models, namely, a corporate competency assessment model and a project risk assessment model. These models can evaluate company capability and project risk level by using ANNs. Stage 2 is a fuzzy inference model, which can support go/no-go decision making using two linguistic input values; one is a net competency value based on the risk score and competency factors, and the other is business philosophy, which indicates the tendency of corporate management.

However, the study has some limitations. First, the input and target values used in ANN models are based on surveys, so they are unable to produce a fully exact statement on corporate competence and total risk levels. Also, the number of samples here was insufficient to create ANN models. Generally, to establish the net competency value, instead of a direct comparison to identify the differences between corporate competency and project risk scores, an indirect comparison is conducted based on linguistic values.

In further research, input/target values are required that contain not just survey data but also actual numerical data such as profit rate, bid data, and so on. Therefore, the values should be able to explain corporate competence and project risk levels more precisely. Moreover, a more accurate and sophisticated go/no-go decision tool can be developed through a direct correlation analysis of the results of two ANN models.

Acknowledgments

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