Development of a decision support system (DSS) for the contractors decision to bid: regression analysis and neural network solutions

Development of a decision support system (DSS) for the contractor's decision to bid: regression analysis and neural networks solutions

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Abstract

The decision whether to bid or not for a project is extremely important to contractors; besides the issues of resource allocation, the preparation of a bona fide tender commits the organisation to considerable expenditure, which is only recovered if the bid is successful. There is, therefore, a potential financial benefit to be realised through the adoption of an effective and systematic approach to the decision to bid process.

Artificial neural network and regression techniques are used to produce a rational and optimal model for the bid/no-bid decision process. While the regression model is ultimately rejected, the selected back-propagation network, comprising 21 input nodes, 3 hidden layers and 4 output nodes is used to support a DSS for the decision to bid process. The results obtained demonstrate that the model functions effectively in predicting the decision process.

Key words: bidding, construction, decision support system, decision to bid, neural networks

INTRODUCTION

There has been a plethora of research activity into the application of neural networks to decision-making and problem solving within the construction industry (For example: Emsley et al. 2002; Lam et al. 2000, Boussabaine et al. 1999; Lie and Love, 1999; Sinha and McKim 1999, Hegazy and Ayed, 1998; Sonmez and Rowings, 1998; Chao and Skibniewski, 1994). Generally, these studies have been focused on demonstrating the feasibility and usability of neural networks within the domain.

This paper presents the results of a research project which focused on developing and implementing a neural networks system as a Decision Support System (DSS) for the decision to bid process. Its aim is to develop and validate a generalised (rational and optimal) model of the decision to bid process.

BACKGROUND

Importance of the decision process

The bid/no-bid decision is both complex and dynamic, involving many factors (Shash, 1993), while the selection of the most appropriate projects for which to bid is fundamental to a successful commercial strategy. What evidence there is, however, suggests that this decision is usually determined by subjective rather than objective information (Fellows and Langford, 1980; Ahmad and Minkarah, 1988; Shash, 1998). This decision is extremely important to the contractor, as, beside the resource issues, the preparation of a bona fide tender commits the organisation to considerable expenditure, which is only recovered if the bid is successful. Fellows and Langford (1980) estimate this to be 0.25% of annual turnover for an average bid or alternatively as 1% of the projected contract sum for each bid submitted. These statistics demonstrate the potential financial benefit that, in addition to achieving strategic objectives, can be realized by organisations through adopting an effective and systematic approach to decision-making when deciding whether or not to bid for a project. However, to date research into bidding has primarily been directed to the bid mark-up problem (for example: Friedman, 1956; Gates, 1967; Willenbrock, 1972; Fine, 1975; Carr, 1982; Moselhi *et al*. 1991; Dozzi and AbouRizk, 1996; Li and Love, 1999; Chua and Li, 2000; Dulaimi and Shan, 2002; Marzouk and Moselhi, 2003).

Factors influencing the decision to bid

Literature related to the bidding decision process was investigated and analysed to identify those factors that were thought to influence the decision-making process (Lowe et al. 2004, Lowe and Parvar, 2004; Parvar, *et al*., 2000). Initially, literature concerning the construction industry, based on primary data, was analysed (Ahmad and Minkarah, 1988; Eastham, 1987; Odusote and Fellows, 1992; Shash, 1993; Wanous et al. 2000; Ward and Chapman, 1988), then the prescriptive and descriptive literature (The Chartered Institute of Building, 1997; Fellow and Longford, 1980; Kwakye, 1994; McCaffer and Baldwin, 1995; Marsh, 1987; Park and Chapin, 1992; Skitmore, 1989; Skitmore, 1991; Smith, 1995; Thorpe and McCaffer, 1991), based on secondary data and/or the opinion of the authors, was considered.

The bid/no-bid decision output

Ansoff (1965) suggested the following classification of bid opportunity decision outcomes:

- Unconditionally accept the invitation to tender
- Provisionally accept the project and prioritise as follows:
    - Remove another project from the reserve list and replace it with the current project
    - Add it to a reserve list
- Reject the opportunity to bid

Alternatively, Fellows and Langford (1980) suggested the following five possible outcomes: returning the documents; submitting a ‘cover price’; providing detailed estimates and tender conversion; preparing a tender based on approximate estimates; or reworking the tender. However, according to Skitmore (1989) the usual options are simply acceptance or rejection of the opportunity, although rejection does not mean that the contractor does not submit a bid.

Previous decision to bid models

Eastham (1987) developed a model of the decision to bid process with relevant weightings for different items. A main feature of the model is that it is based on 90% subjective and 10% objective decisions to establish the desirability of the project. Ahmad (1990) presents a deterministic worth-evaluation model of the bid/no-bid decision problem, where individual factor ‘worths’ are weighted and combined additively to generate an overall score based on the subjective assessment of the project and the objectives of the firm. A parametric approach to modelling the bid/no-bid decision-making process is provided by Wanous *et al*. (2000), based upon the findings of six semi-structured interviews and a formal questionnaire survey of Syrian contractors.

Following a comprehensive literature review and both semi-structured and unstructured interviews with the bid/no-bid decision-makers within a UK main contracting organisation, Lowe et al. 2004 used functional decomposition to develop a conceptual view of the relationships between the factors identified as influencing the decision outcome. These factors were organised to represent a model of the relationships within the decision to bid process. The model was validated and further refined through consultation with representatives from the collaborating construction company. The validated conceptual model (the factors and their related hierarchical group) is presented in Table 1.

Table 1: The factors and their related hierarchical groups

Opportunities

1. Economic contribution of the project
2. Strategic and marketing (non-monetary) contribution of the project
3. Competitive analysis of the tender environment
4. Feasibility of alternative design to reduce cost

Resources

5. Resources to tender for the project
6. Internal resources (managerial and technical) to support the implementation of the project
7. Financial resources to support the implementation of the project
8. External resources (plant, materials and subcontractors) to support the implementation of the project

Project Relationships

9. The current relationship with the client
10. The current relationship with the client’s professional advisors

Project Procedures

11. Form of contract
12. Contract conditions
13. Tendering procedure

Project Characteristics

14. Competency - project type
15. Competency - project size

16. Competency - location
17. Experience

Risks

18. The risks involved due to the nature of the project
19. Financial capability of the client
20. The speed of payment of the client

Competitive advantage

21. Lowest Cost

A pro-forma to assess the above 21 factors for the decision to bid was devised, which elicits a numeric assessment of the factors on a four-point scale. The pro-forma was used to collect data from 115 historical projects of a UK construction company. These data were used to develop logistic regression models (Lowe and Parvar, 2004) and linear regression and neural network models (Lowe et al. 2004). While demonstrating an acceptable degree of accuracy in representing the data collected, the models have the limitation of only representing the responses of a single organisation. Further research was, therefore, recommended to use the bid opportunity assessment pro-forma and neural networks modelling techniques to develop a generalised decision support system for the contractors' decision to bid.

EMPIRICAL STUDY

Data generation

A rational and optimal model of the decision bid process was developed where each decision to bid option is represented by a set of patterns of relationships. These are depicted in tabular format in appendix A.

In total 476 vectors were generated to represent these patterns. The representative data set consisted of: 200 vectors where the opportunity to bid was rejected (Reject); 32 vectors that were classified as added to a reserve list (Reserve); 32 vectors that were classified as replacing another project with the current project in a reserve list (Replace); and 212 vectors where the opportunity to bid was accepted (Accept). These decision outcome sets were coded as 1, 2, 3 and 4 respectively to enable statistical analysis.

Analysis

Models of the decision to bid process were produced using the items of the bid opportunity assessment pro-forma as predictors. Regression analyses were undertaken using the Statistical Package for the Social Sciences (SPSS for Windows, release 10.0.7), while neural networks were generated using NeuralWorks Professional II Plus, from NeuralWare Inc.

FINDINGS

Modelling the decision to bid process

Linear Regression

Linear regression analysis can be used to model the linear approximation of a problem domain. If this modelling approach is successful, it can contribute to furthering our understanding of the factors involved in the decision-making process, their interactions, and their contribution to a given outcome or outcomes.

Real life problems, however, are not generally linearly related. In the cases where a linear approximation of a problem domain can provide an acceptable degree of accuracy for modelling, which enables the estimation and prediction of the likely outcomes in the domain, then linear regressions analysis would be a valid approach. Linear regression models, due to their ease of use, wide spread usage, have created knowledge and awareness of their underlying concepts and the ease of visualization of relationships between the variables and the decision outcome, are the preferred option in these cases.

Linear regression analysis was used to develop several predictive models to depict the relationships between the 21 factors and the decision to bid options. Table 2 summarizes the results of the best model, developed by entering all 21 factors into the model, and selected using the backward method. The model with the highest coefficient of determination, in comparison with the other regression models generated, has an adjusted coefficient of determination of .917 indicating that the model accounts for 91.7% of the variance. The model's summary statistics are presented in table 2, while table 3 shows its predictive power. The overall classification accuracy of the model was 84.5%.

Table 2: Regression Model Summary and Coefficients

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
9	.959	.920	.917	.40499

	Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
(Constant)	-.297	.110		-2.696	.007
Economic contribution	.523	.053	.390	9.847	.000
Competitive analyses of the tender	-.251	.055	-.204	-4.584	.000
Resources to tender	.547	.069	.443	7.902	.000
Contract conditions	-.471	.104	-.363	-4.519	.000
Tendering procedure	.452	.076	.349	5.926	.000
Location	.370	.074	.306	4.971	.000
Risks owing to nature of the project	-.141	.023	-.108	-6.112	.000
Speed of payment	.712	.088	.610	8.065	.000
Financial capability	-.335	.103	-.286	-3.248	.001
External resources	-.193	.065	-.154	-2.962	.003
Competitive advantage for lowest cost	-9.601E-02	.036	-.074	-2.661	.008
Managerial and technical	.201	.078	.155	2.582	.010

resources					
Relationships professionals	-.200	.093	-.151	-2.157	.031

While the overall predictive power of the model is acceptable, in terms of classifying the acceptance of an opportunity to bid the predictive power of the model was not acceptable. The model was, therefore, rejected.

Table 3: Predictive power of the linear regression network decision to bid prediction model

Observed	Predicted				Percentage Correct
	Accept	**Replace**	**Reserve**	**Reject**	
Accept (n = 212)	168	44	0	0	79.0
Replace (n = 32)	0	32	0	0	100.0
Reserve (n = 32)	0	8	24	0	75.0
Reject (n = 200)	0	0	22	178	89.0
				Overall	84.45

Note: Accept = accept the opportunity to bid, Replace = replace another project with the current project in the reserve list, Reserve = add project to reserve list; Reject = reject the opportunity to bid

Failure of the linear model could be an indication that non-linear relationships exist between the items and the decision to bid options. To model the decision to bid process effectively, a tool that can model non-linear relationships needs to be employed. A neural networks approach, which is capable of modelling both linear and non-linear relationships, was used, therefore, to model the process.

Neural networks approach

Neural networks can be defined as a non-linear function-mapping tool, which maps the relationships between a set of input variables (input vector) to a set of output variables (output vector). The input vector consists of the factors that are required to be considered and assessed during the decision making process for the domain that is being modelled. The output vector represents the desired response set from the model.

A numeric assessment of the 21 input variables of the model, on a scale of 1 to 4, forms the input vector (21 nodes), while the output layer of the neural network consists of 4 nodes:

1. Reject the opportunity to bid.
2. Add to a reserve list.
3. Replace another project with the current project in a reserve list.
4. Accept the opportunity to bid.

The term prototyping is used to refer to a systems development approach, which searches for the optimum network architecture through the development of a number of neural networks systems (prototypes), which differ in the architecture of the hidden layer. These prototypes are then assessed for accuracy of response. A prototype that provides the desired accuracy in respect of Root Mean Square (RMS) of error and/or classification rate is then selected for further development.

The prototyping methodology was employed to search for the optimum network architecture for the neural network for the model of the decision to bid. The learning rule used to train the networks was the modified back-propagation learning rule (Rumelhart, *et al.*, 1986; McClelland and Rumelhart, 1988) called Extended Delta Bar Delta (EDBD) (Minai and Williams, 1990), with the sigmoid transfer function. From the generated data set, 452 vectors were used as a training data set and 24 vectors were used as a test data set for the development of the neural network system.

19 neural network prototypes with different hidden layer architectures, which can manage the information processing to an acceptable degree of accuracy, were developed. The optimum network architecture selected for further development and integration into the DSS consisted of a network with 21 nodes in the input layer, 3 hidden layers (with 20 neurons in the first hidden layer, 20 neurons in the second hidden layer, 20 neurons in the third hidden layer), and 4 nodes in the output layer. The network captures the principal relationships in the training data very well, as indicated by an RMS error of 0.0002 and a classification rate of 100%. Likewise, the model has an excellent generalisation capability as indicated by an RMS error of 0.0001 and a classification rate of 100% for the test data set. The characteristics of the selected model are shown in table 4.

Table 4: Characteristics of the final neural networks model

Model	No. inputs	No. of hidden layers	Nodes in layer			LR	TF	Training		Testing	
			1	2	3			RMS	Class	RMS	Class
9	21	3	20	20	20	EDBD	Seigmoid	0.0002	100%	0.0001	100%

LR: Learning rule; TF: Transfer function; RMS: Root mean square error, EDBD: Extended delta bar delta; Class: Classification rate (%)

A further 22 prototype systems were also developed using Learning Vector Quantization (LVQ), Radial Basis Function (RBF) and General Regression Neural Network (GRNN). While these networks were able to manage the information processing required for modelling the decision to bid successfully, they did not provide any additional benefits when compared to the neural network system developed using the EDBD.

DEVELOPMENT OF THE DSS USER INTERFACE

The C programming language was used to develop, from first principles, a user-friendly interface for the DSS, which incorporates an online help facility that provides information related to the operation of the DSS. Data entry into the system is performed through a set of dialog boxes (an example is shown in Figure 1). Each dialog elicits a numeric assessment related to a sub-set of the input variables. Online help for each dialog provides further information related to each sub-set of input variables (an example is shown in Figure 2). Data entry is validated for each dialog to ensure that the numeric assessment for each factor is within range, before allowing the user to proceed to the next dialog.

Figure 1 Input dialog box for the Opportunities subset of the factors

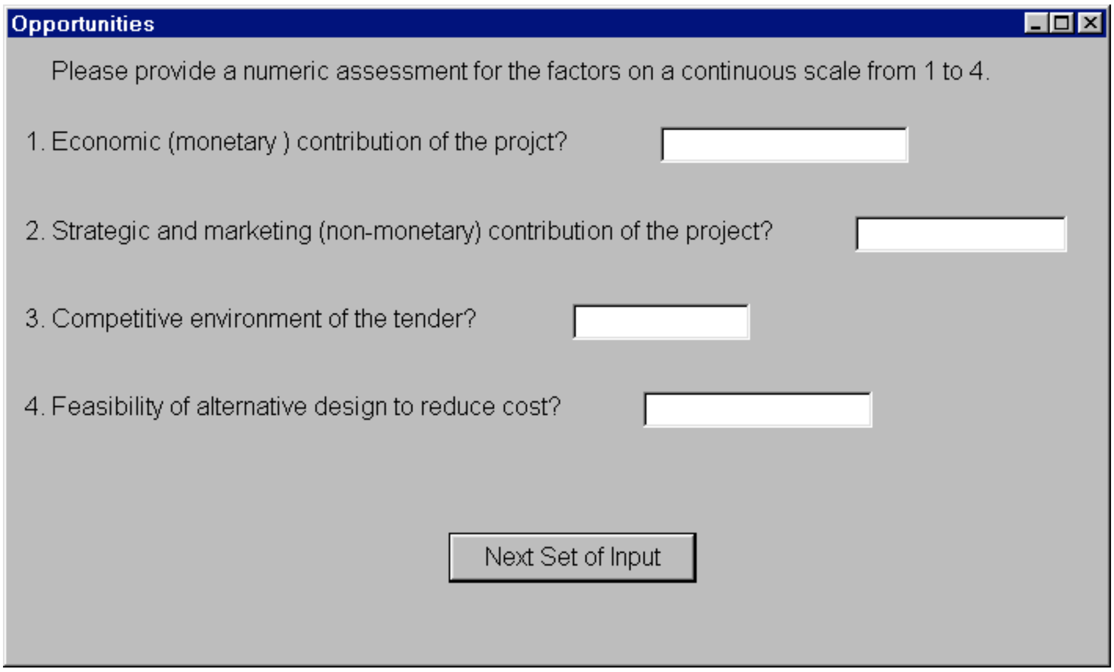
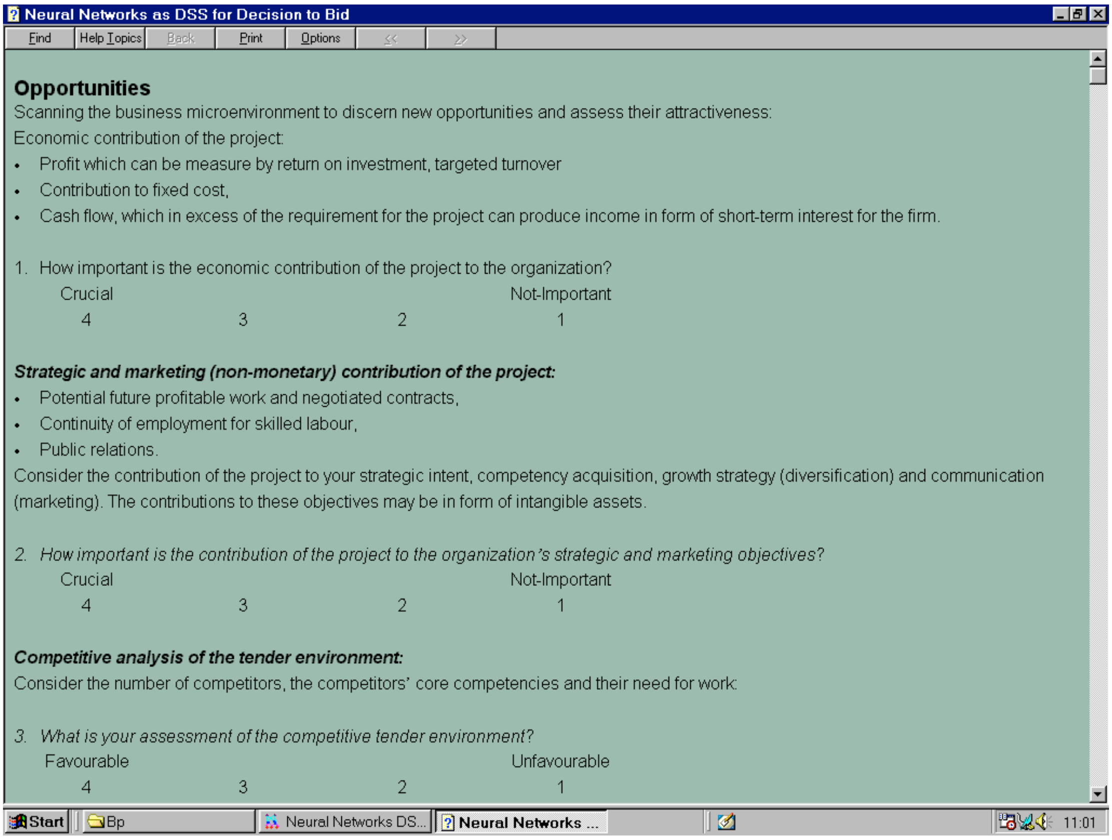
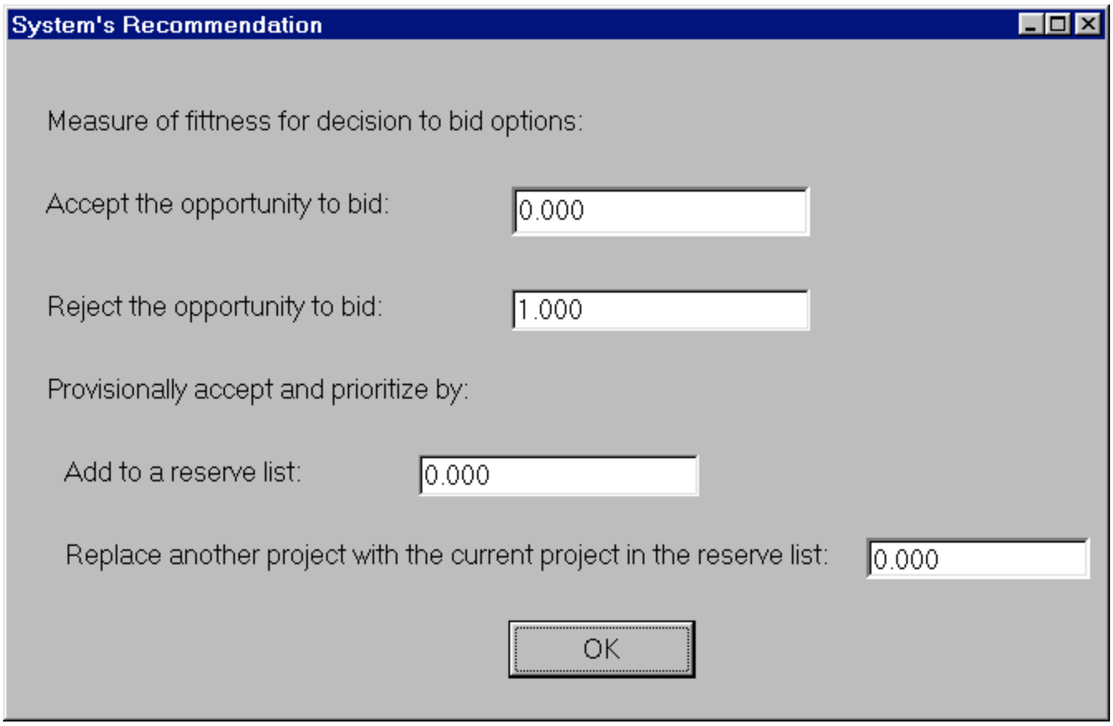


Figure 2 Help information for the Opportunities dialog box data entry



The DSS recommendation is provided in a separate dialog box, which becomes active when the user requests an output. The neural network is recalled at this stage to process the input vector and the result is presented to the user (see Figure 3). The facility to store information to file for each bid opportunity is also provided.

Figure 3 System's recommendation dialog box



The end users of the DSS model have been involved in the development process since the inception of the research project, and throughout the development of the neural network DSS. During field-testing of the DSS, a user group (comprising senior representatives from five contracting organisations) challenged the developed system, and were delighted with the capability of the system, its accuracy and speed of response. Each representative used the DSS to assess the decision to bid for 5 recent bid opportunities (n = 25); the model correctly classified all the decisions to bid.

CONCLUSION

The decision whether or not to bid for a project is a strategic decision requiring the consideration of strategic intent, competency acquisition and the long-term aims and objectives of the organisation. Moreover, the decision is extremely important to contractors; besides the issues of resource allocation, the preparation of a bona fide tender commits the organisation to considerable expenditure, which is only recovered if the bid is successful. Analysis of the literature identified 21 factors considered to influence the decision to bid outcome. Deliberation and assessment of these factors ensures a systematic approach to the decision-making process, which can improve the quality of the decision-making, increase productivity, and assist in achieving the strategic objectives of an organisation. Automation in the form of Decision Support Systems (DSS) can enhance these benefits further.

A rational and optimal model of the decision bid process was developed where each decision to bid option is represented by a set of patterns of relationships. Artificial neural network and regression techniques are used to model 476 vectors generated to represent these patterns. While the regression model is ultimately rejected, the selected back-propagation network, comprising 21 input nodes, 3 hidden layers and 4 output nodes is used to support a generalised DSS for the contractors' decision to bid process. The results obtained demonstrate that the model functions effectively in predicting the decision process.

The uniqueness of the approach adopted to systematize and model the decision to bid process is the development of a conceptual view based on patterns of the relationships between a set of inputs and a set of outputs for a decision domain.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the support from the Engineering and Physical Sciences Research Council and the contribution of Dr Roy Duff during the initial stages of this research.

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Appendix A: Patterns of relationships for the decision to bid options

The pattern set (vectors) which represents accepting the opportunity to bid option is presented in Table 6.

When a project possesses favourable characteristics, according to the factor set, but there are insufficient resources available for bidding, management, and implementation of the project, the project can be classified as replacing another project in the reserve list (The pattern set which represents this option is shown in Table 7). This approach would ensure that the reserve list contains the most favourable projects for the effective and efficient utilization of scarce organizational resources.

Alternatively, when there are shortages of resources for bidding, management, and implementation of a project, but the project is assessed as favourable, the project may be added directly to a reserve list, so that if the resources do become available the most favourable projects can be identified. (The pattern set which represents this option is shown in Table 8).

The pattern set which represents rejecting the opportunity to bid option is presented in Table 9.

Table 6: Accept the opportunity to bid vectors pattern

	1.00	**2.00**	**3.00**	**4.00**
Economic contribution			■	■
Strategic and marketing contribution		■	■	■
Competitive analyses of the tender			■	■
Feasibility of alternative design	■	■	■	■
Resources to tender		■	■	■
Managerial and technical resources		■	■	■
Financial resources		■	■	■
External resources		■	■	■
Relationships project client			■	■
Relationships professionals			■	■
Form of contract			■	■
Contract conditions			■	■
Tendering procedure			■	■
Project type			■	■
Project size			■	■
Location			■	■
Previous experience			■	■
Risks owing to nature of the project	■	■	■	
Financial capability			■	■
Speed of payment			■	■
Competitive advantage for lowest cost		■	■	■

Table 7: Replace with another project in the reserve list vectors pattern

	1.00	**2.00**	**3.00**	**4.00**
Economic contribution				■
Strategic and marketing contribution				■
Competitive analyses of the tender			■	■
Feasibility of alternative design	■	■	■	■
Resources to tender	■			
Managerial and technical resources	■			
Financial resources	■			

External resources	■			
Relationships project client				■
Relationships professionals				■
Form of contract				■
Contract conditions				■
Tendering procedure				■
Project type				■
Project size				■
Location				■
Previous experience			■	■
Risks owing to nature of the project	■	■		
Financial capability				■
Speed of payment				■
Competitive advantage for lowest cost			■	■

Table 8: Add to a reserve list vectors pattern

	1.00	**2.00**	**3.00**	**4.00**
Economic contribution			■	
Strategic and marketing contribution			■	
Competitive analyses of the tender			■	■
Feasibility of alternative design	■	■	■	■
Resources to tender	■			
Managerial and technical resources	■			
Financial resources	■			
External resources	■			
Relationships project client			■	
Relationships professionals			■	
Form of contract			■	
Contract conditions			■	
Tendering procedure			■	
Project type			■	
Project size			■	
Location			■	
Previous experience			■	■
Risks owing to nature of the project	■	■		
Financial capability				■
Speed of payment				■
Competitive advantage for lowest cost			■	■

Table 9: Reject the opportunity to bid vectors pattern

	1.00	2.00	3.00	4.00
Economic contribution				
Strategic and marketing contribution				
Competitive analyses of the tender				
Feasibility of alternative design				
Resources to tender				
Managerial and technical resources				
Financial resources				
External resources				
Relationships project client				
Relationships professionals				
Form of contract				
Contract conditions				
Tendering procedure				
Project type				
Project size				
Location				
Previous experience				
Risks owing to nature of the project				
Financial capability				
Speed of payment				
Competitive advantage for lowest cost				