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A Neural Network Model for Financial Performance Prediction: The Case for Road Works in Bahrain

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Abstract:
In construction projects, there are circumstances when contractors meet financial prequalification criteria but show low financial performance in practice. These cases in Bahraini road works add up to complexity in the contractor selection process. Thus, this study considers data from 72 most recent road works contract projects in Bahrain. Each has the contract amount and the contractor's financial capability record. The use of covariance between these records variable through the Principal Component Analysis reduces them into manageable variables. The resulting variables used to train an Artificial Neural Network ANN to construct criteria-performance mapping. The ANN finds the nonlinear correlation between the FP and contractors' capabilities. The ANN model predicts the FP so decision-makers can efficiently evaluate bidders in the prequalification phase. Then the sensitivity analysis help detects the FP change that corresponds to changes in capabilities. The research findings from the Bahraini case that improvement in some financial capabilities criteria does not reflect equally on the performance of contractors of varying grades.

Keywords:*Artificial neural network, principal component analysis, pre-qualification.*

I. INTRODUCTION

Bidding involves multi-criteria decision-making under uncertainty and analysing large and complex data(Cheng, Wang and Sun, 2012) to select a contractor or supplier(Taylor *et al.*, 2015). It requires setting criteria, and policies(Cheng, Wang and Sun, 2012) to shortlists the bidders to only those legally, technically and financially capable (Bushait and AI-Gobali, 1996). With this in mind, bids are evaluated either the price or quality evaluating and scoring system. The scoring system is used to recommended qualified bidders according to their overall score(Cheng, Wang and Sun, 2012). Otherwise, the widely held method of the lowest price is used (Cheng, Wang and Sun, 2012) after passing though the prequalification process. This research argues that the improvement in contractor selection can enhance throughout the prequalification process. IN addition to upgrading the prequalification system which contributes to cost efficiency that may reach up to the fifth of the local industry annual turnover as in Scotland(Rahman, 2014). Moreover, prequalification affect practices(Nazari *et al.*, 2017) and has a demonstrated relationship with project success(Acheamfour *et al.*, 2019) and risk management(Iyer, Kumar and Singh, 2019). On the other hand, the prequalification is a non-design investigation(Tah, Carr and Howes, 1999) that requires counting for uncertainties and risk assessment when setting the criteria thresholds (Afshar *et al.*, 2017). Besides, one of its limitations is a challenge to investigate the capabilities against the inexact or vagueness qualitative criteria(Li, Nie and Chen, 2007).

This research proposes to explore the effect of key selection factor which is the financial

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capabilities on the financial performance. Especially that the financial capabilities is deliberated as the most important factor of contractors' success following management and strategy factors(Kuwaiti, Ajmal and Hussain, 2018). On the contrary, the larger companies do not show a difference in marketing than smaller ones(Arditi, Polat and Makinde, 2008) despite that they differ in sales(Chan and Au, 2009).

In the light of that, this research proposes a solution for the projects Client "Road Works Projects Management Department" RPMD in Bahrain where they counter poor financial performance by capable contractors. In spite of the companies win contracts exceeding the lowest limits of financial criteria. Likewise, the nature of road works adds more challenge that requires linking contractors with rieht performance indicators(Partnerships, 2003). The research also deals with the effect of ongoing projects since working in several projects with resources fully in use, premium payment needed for any extra work(Fayek, 1998). Otherwise, contractors suffer resource shortage that affects schedules (Nguyen *et al.*, 2018)(Liu *et al.*, 2018) and operations that in return impacts the performance (Simu and Lidelöw, 2019).

In addition, the purpose of this research is to develop aclient decision-making model that adds to the dynamic relationship between the parties in road works projects(Emre and Hastak, 2009) that result in improving cost and schedule outcomes(Ling and Tran, 2012). Likewise, it is important for other parties to consider this nature of correlation in the procurement decision(Chao and Hsiao, 2012)such as bid/no-bid (VanderWeele and Vansteelandt, 2013) and mark-up value(Polat, Baytekin and Eray, 2015) in which financial status plays a main role. As a result, companies avoid business failures and (Cheng and Hoang, 2015)yctpurknab and ultimately find its effect in cost estimation and saving(Rafiei *et al.*, 2018). Especially for contractors, the financial capabilities are of their paramount success factor after management and strategy factors(Kuwaiti, Ajmal and Hussain, 2018).

The research considers that the successful methods in modelling require a combination of antiquity and ease of application (Jato-espino *et al.*, 2014). Therefore, the modelling utilizes ANNs that predict the FP using actual data sets and assessments of earlier contracts. The data includes a list of financial capability criteria related to the contractor's bankruptcy that potentially allows for a high degree of correlation with each other(Altman, 1968) and with the client financial objectives as the "performance targets" (Olander, 2014). Explicitly , eht ecneulfni sevitcejbo dna snoitatcepxe eht ssecorp noitacifilauqerp(Jafari, 2013).

II. Research Method

The aim of the research is attained by finding the correlation between the contractor capability data sets with the value of the FP using the neural network. At that point, sensitivity analysis is done to explain the contractor's performance in Bahrain road works.

A. Data Collection

A team was established to prepare the project assessment reports prepared in Road Projects and Maintenance Directorate RPMD in the Ministry of Works MoW, Municipality Affairs and Urban Planning, in Bahrain. These reports contain evident data about the contractors that confirm they are capable of contracting legally, technically, and financially such as certificates and audited bank statements, etc. For when the lowest bid wins the contract, it is ascertained to be handled by a qualified bidder at the prequalification phase, unless other less popular methods used(Ioannou, Asce and Awwad, 2010) methods used such as the second-lowest, average or below average (Ahmed *et al.*, 2010).

The total attributes collected for contractors are 24 capabilities criteria that potentially affect the FP. They cover a whole range of capabilities from

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small to large local and international contractors to span the whole span of expected inputs(Boussabaine, 1996).

B. Data source

In the prequalification phase in road works in Bahrain, the RPMD enforces the international and local bidders to submit concrete evidence to prove compliance with the requirement of the project for testing compliance with financial criteria. The requirements aim to meet the contracting sequence and schedule, increase competition to track down lower prices, procure the quality project, foster the evolution of indigenous contractors (Lo, Krizek and Hadavi, 2002).

C. Financial Performance Assessment

During the execution of the construction projects, the client representatives check on the performance indicators of contractors in the construction site and keep count for assessment of the FP. The FP assessment is the level of achieving client financial obligations (Huang *et al.*, 2013)which covers the following three main areas:

- Financial Capacity to pay all expenses such as material, labour, etc.
- Availability and appropriateness of the construction equipment, work machinery, and tools.
- Adequacy in the supply of approved materials (materials as per specifications)

The client representative assesses the contractors' performance in several contracts to supervise practices during procurement and works(Alan., 2011). Then, the average FP corresponds to performance along with a cumulative number of Contracts TC. However, there are instances when contractors demonstrate higher and lower FP than average referred to as optimistic and pessimistic FP, respectively.

III. DATA PREPARATION AND ANALYSIS METHODS

The flowchart of the research analysis to select training attributes and designing the neural network number of hidden layers and nodes are summaries in Figure1. Generally, the system tracks variations, especially that the training sample is representative for the Bahraini road works and covers contracts with variation from poor to excellent FP (Simon Haykin, 2014).

This large number of attributes required in prequalification are reduced to only the most important ones or some principle components whichever is fewer(Kulkarni, Londhe and Deo, 2017). The PCA is used to extract these significant variables from the pool of contractor financial capabilities data. Then the ANN model predicts the FP of contractors on these projects. Eventually, the established prediction model is used to measure the sensitivity of FP in each contract case (Adya and Collopy, 1998).

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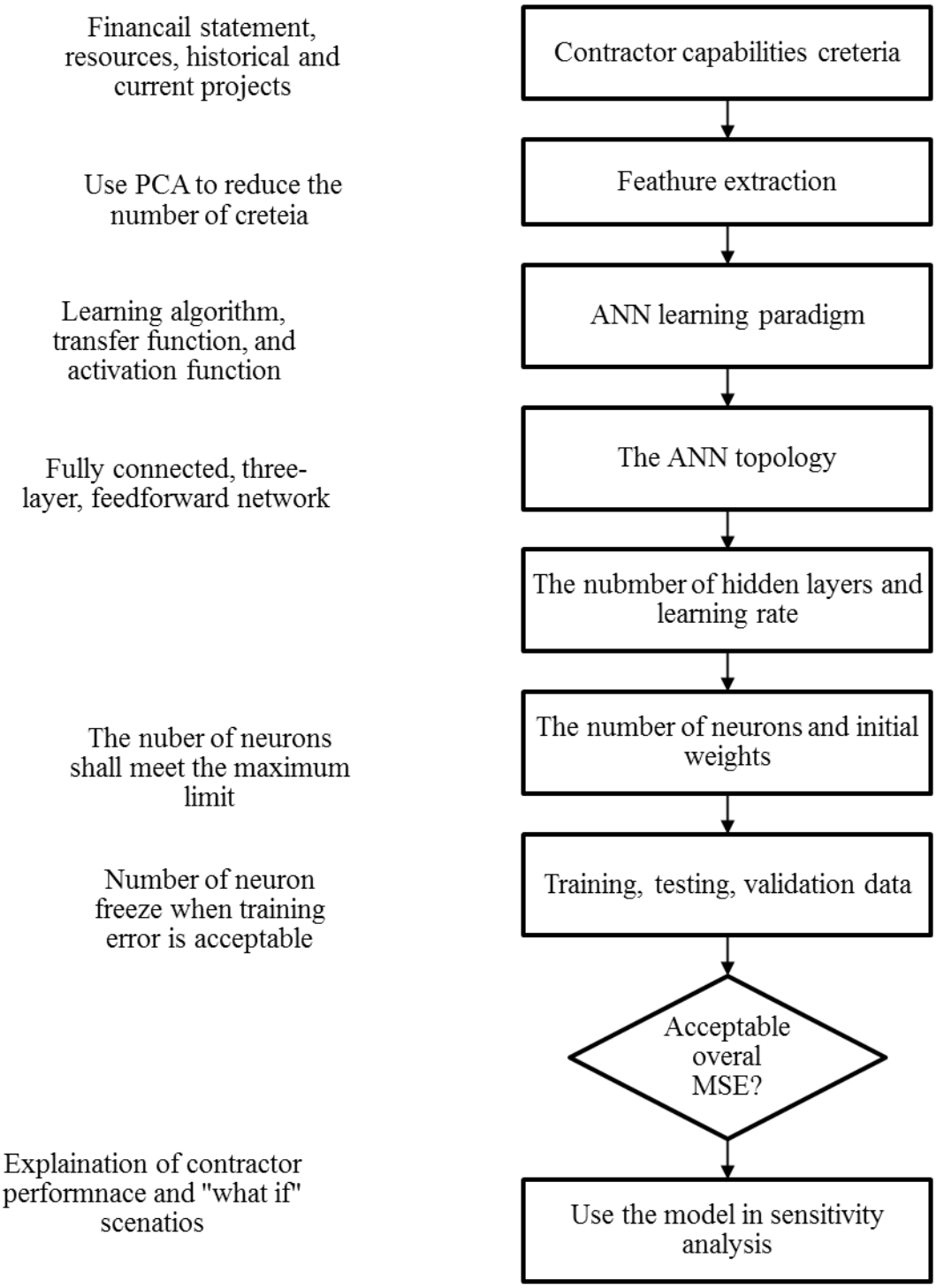

Figure 1. The research flowchart and procedure of the data analysis

IV. Results and Discussion

A. *Principal component analysis*

In general, the use of PCA is suitable for large and complex data to reduce the dimensionality from original variables to new set of variables (Jolliffe, 2002). Several recent applications of dealing with project complexity used this technique (Ahn *et al.*, 2017). Additionally, the complexity and the large number of contractor pre-qualification criteria, the multi-collinearity reveal using PCA (Lam, Hu and Ng, 2005). The measures choosing the right PCs relies on the slope of the screed plot, total variance

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percentage, and size of variance (Jolliffe, 2002).

The total number of PC's is nine components that covered the total 100% of the variance in the dataset as shown in Figure 2. These component numbers are associated with large eigenvalue.

The first PC has positive coefficients for all original variables and highest loading for "the net-worth" and "equity net worth". Next come, the second PC which has the highest positive loading in "largest successful project in past". The third PC, the positive loadings are allocated for "the annual average per work", "working capital" and "annual turnover" while the negative loading is for "the paid-up capital". The fourth PC, both largest loadings are positive which are "the aggregate amount of completed projects" and "the paid-up capital". The fifth PC includes positive loadings for "the largest successful project in past" and "working capital", while negative loading for "the paid-up capital", "annual average per work", and "annual turnover". The sixth PC, contains a positive loading for the aggregate amount of completed projects" while a negative loading for "working capital". Likewise, the seventh PC, one positive loading for "annual average per work" and highest negative is for "annual turnover". Same way, loadings of the eighth PC variables are positive "largest successful project in past" and negative for "the aggregate amount of completed projects". Lastly, the ninth PC positively loads the "cumulative amount of contract projects", and "equity net worth" while negatively loads the "the net-worth".

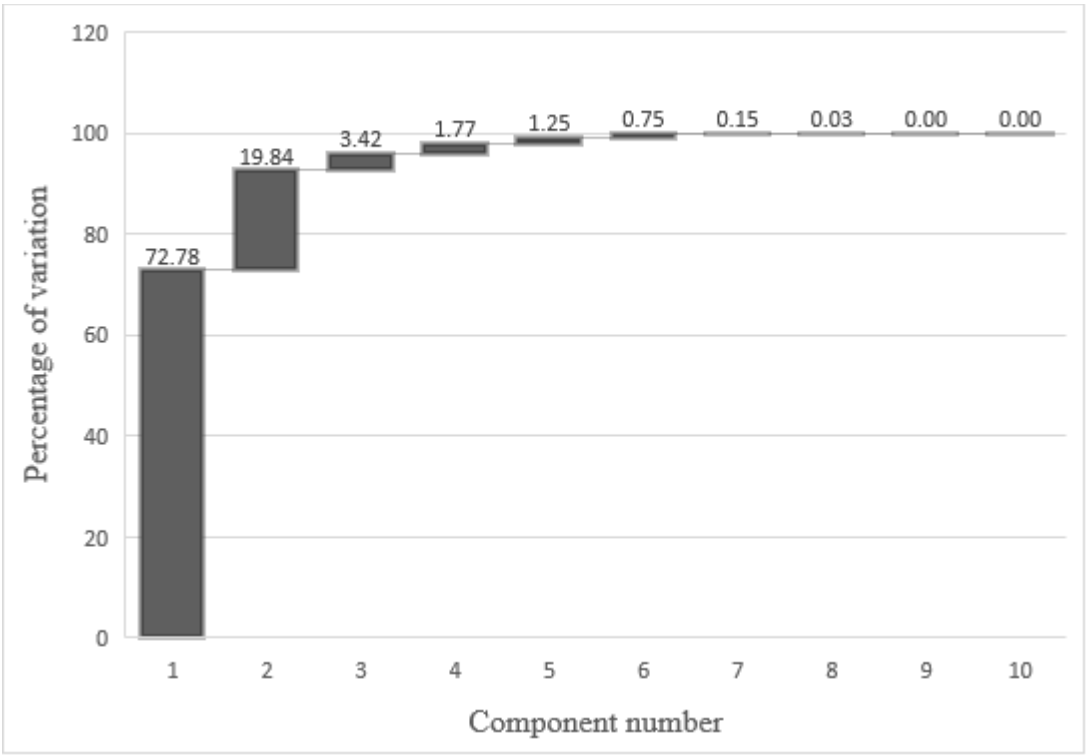

Figure 2. Cumulative percentage of variance and total percentage of variation for the components of financial capabilities components

B. Artificial Neural Network

The ANN models are used to solve challenging problems by processing independent variables resembling the neurons receiving stimuli in the human neural system. Thus, a three-layer feed-forward network trained to learn from the 72 financial capability criteria represented by the nine variables with the FP.

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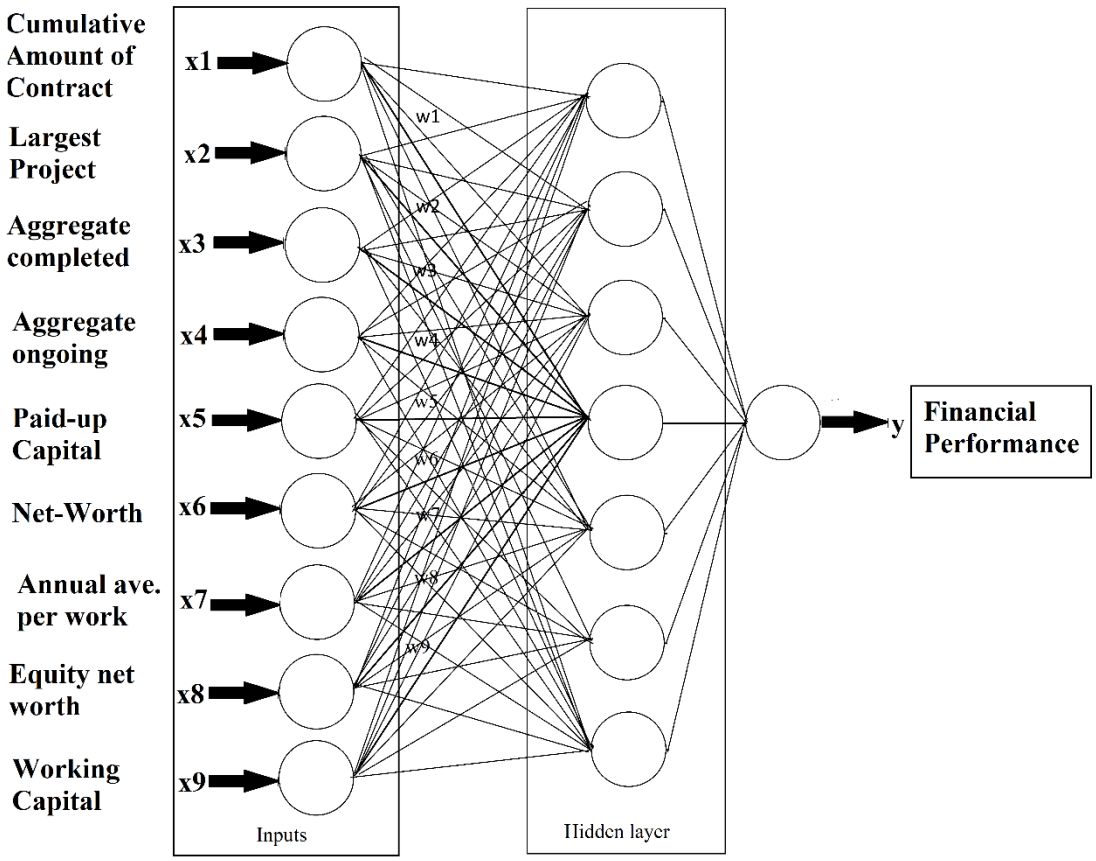

Figure 3 neural network structure

The topology used in this research as input-output mapping transfers the set of inputs $x_i$into output y using inputs weights w_i, biases b_1, b_2 and layer weight then activates the result using by sigmoidal function (Simon Haykin, 2014):

$$n = \sum_{i=1}^{9} w_i . x_i + b1 \quad (1)$$

$$a1 = \frac{2}{(1 + e^{-2n})} - 1 \quad (2)$$

$$y = a1 . w_l + b2 \quad (3)$$

The ANN model consists of nine nodes for variables input data and one node for output FP as shown in Figure 3. There is one hidden layer in which the number of neurons increased to find the best fit by trial-and-error (Boussabaine, 1996; Adya and Collopy, 1998; Kulkarni, Londhe and Deo, 2017) or handcrafting (Hegazy, Fazio and Moselhi, 1994). Bearing in mind, the number of hidden nodes is less than a maximum limit $NHN \leq N_{INP} + 1$ where N_{INP} is the number of input nodes (Basheer and Hajmeer, 2000). The value of mean squared error (Leave, Freeman and Skapura, 2006) or sum square error (Basheer and Hajmeer, 2000) of validation data are commonly used to stop the training. That is when the error starts to rise, training stops to avoid over-fitting or overtraining as shown in Figure 4 and Table 1.

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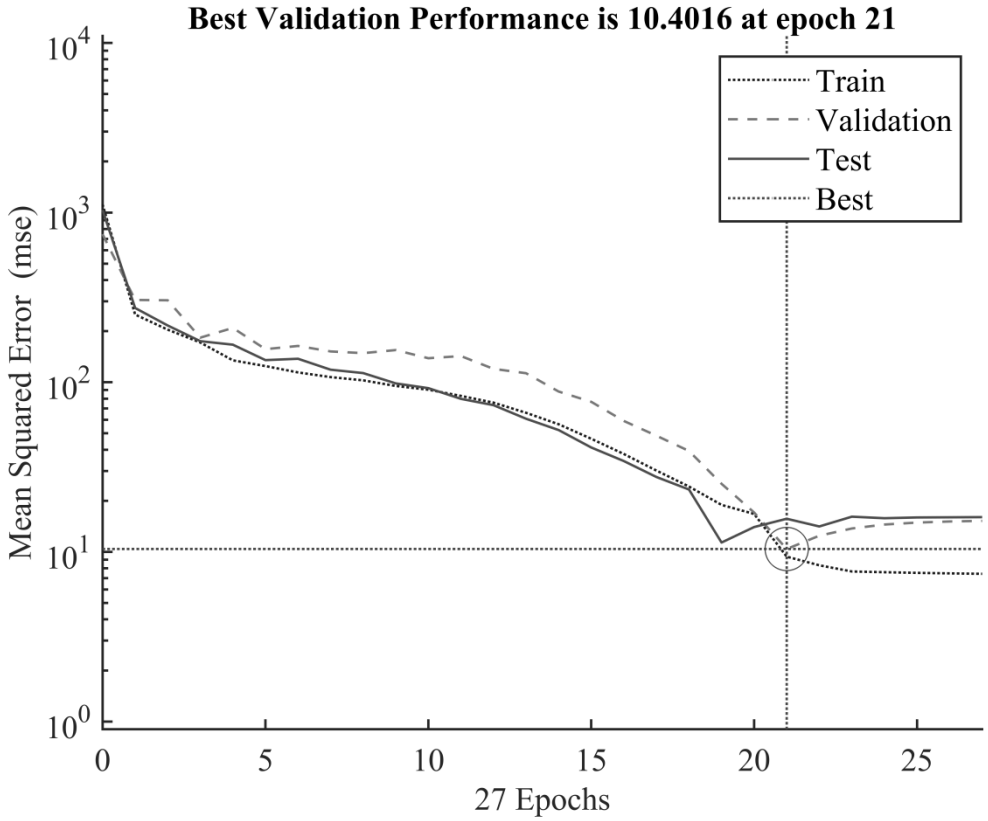

Figure4 neural network peroformance

C. Sensitivity analysis of financial performance

The percentage of difference in performance is measured for each project separately, and then averaged within each grade to differentiate between contractor capability requirements and sizes. Therefore, the sensitivity is measured and graphed in Figure 5 to overview the effect of variables. The predicted values are used to measure the difference percentage:

A variable percentage of difference:

$$d_x = \frac{x_{new} - x_{old}}{x_{old}} \quad (4)$$

The output percentage of difference

$$d_y = \frac{y_{new} - y_{old}}{y_{old}} \quad (5)$$

Sensitivity

$$S = \frac{d_{y1} - d_{y2}}{d_{x1} - d_{x2}} \quad (6)$$

Despite the contractor grade, an increase in the value of the cumulative contract amount was advantageous to FP. On the other hand, lower grades contractors performed better when they had previous successful projects of higher values, expressly the largest successful project in the past, the aggregate amount of completed projects in the past. Also, findings where revealed that the higher the value of on-going projects adversely impacted the performance of contractors grade A while positively impacted grades C and D.

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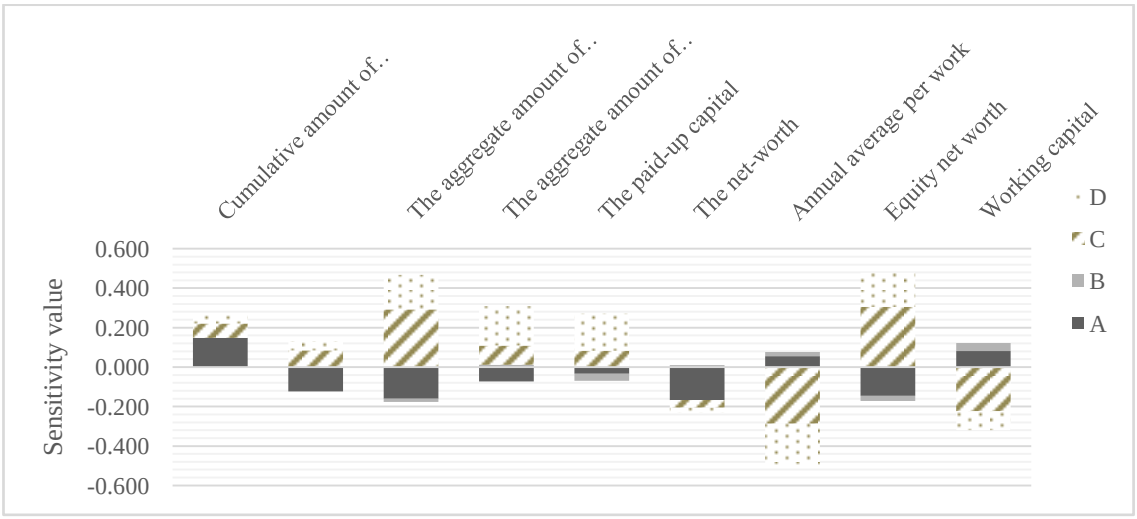

Figure 5: the sensitivity value for FP with each variable affecting it

The increase in value of paid-up capital and equity net-worth was associated with prevent financial failures suffered by contractors A and B. What's more, the increase in the amount of contractor net-worth was not associated with a better FP by contractors A, C, and D. Besides, the annual average, and the working capital had a good impact on the performance of contractors A and B but adversely on contractors of grades C and D.

V. CONCLUSION AND RECOMENDATIONS

Although it appears rational to anticipate that more competing contractors who meet the prequalification financial criteria perform better than less competitive ones, the outcome of this study demonstrates that this is not certainly right. This is because the study reveals that the current system used in the prequalification phase in Bahraini road works is not sufficient in screening contractors in complicated situations such as when contracting in several projects. To enumerate, increasing some characteristics values that suggest scoring contractors higher in the traditional prequalification system though they associate with a drop in the actual FP value.

Although each project has its uniqueness in characteristics interactions but taking the mean sensitivity of FP into consideration, can help understand the general prequalification situation better. Overall, the project amount has a positive impact on the performance of contractors while net-worth does not assure better FP. Noticeably, increasing in the values of the largest and cumulative completed projects, and paid-up capital reflects on a higher FP only for smaller contractors only. While the number of on-going projects can unfavourably influence the large contractor performance while a higher annual average amount per work and working capital indicate a higher FP.

The study is limited to the contracts used in training and testing networks and no global generalities are potential, as the contractors' financial capabilities criteria are varying with countries' laws and conditions. Nevertheless, the study demonstrates the existence of such a strategy to allow public clients to predict FP at the prequalification phase:

- Understanding of contractor financial capabilities and predicts the contractor performance based on them in the early stages.
- Anticipating risks of low performance related to financial capabilities is important for planning and performing risk assessments.
- Early Knowledge of the predicted value of FP help decision-makers put contractual restrictions on criteria such as the number of projects the contractors are allowed to be

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involved in while executing the construction project.

Equally, the use of this model is not only for clients' benefits, it is also for the local and international contractors' survival in the Bahraini industry by detecting their potential financial failure at early stages by avoiding or reducing it. To emphasise, avoiding prequalifying contractors whose strategy is to win numerous contracts at a time by offering bids with low mark-up values while risking their FP and likely to have the winner curse.

For the most of this research, training of ANN network on the 72 contracts satisfactorily (1) correlated the contractors' historical data to predict the FP, (2) provided a method to answer the "what if?" question ni siar tahtthe prequalification phase, (3) explained the current contractor's behaviours. Although the limitation of these findings are for current Bahraini road works systems thus, any revolving in this system the model grows smarter then department shall originate continuous improvement scheme to reduce uncertainty.

The recommendation of future studies is for instance FP observation using detailed of data such as (a) resources allocation the manpower and equipment throughout the on-going projects at assessment time (b) shorter period financial statement and records instead of using the annual statement in representing contractor capabilities (c) cash flow data instead of the accumulative amount of projects.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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TABLES

Table 1 the ANN network information

Hidden laye	Regression				Training			RMS			
Neurons	Training Re	Validation	Testing	All	Gradient	At Epochs	Mu	Training %	Testing %	Validation %	At epochs
7	0.981	0.98	0.978	0.979	3.803	27	0.01	3.06	3.96	3.23	21