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Predicting the Final Cost of Iraqi Construction Project Using Artificial Neural Network (ANN)

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Abstract

Objectives: It is very hard estimated the budget of construction projects at the first step of the building because of the limited data about the project at this step. Developing a mathematical equation to estimate the budget of the Iraqi construction project at initial step is the aim of this study. **Method:** It involves using of Artificial Neural Network (ANN) to develop the mathematical equation. The researchers collected the information about cost for 501 sets project for the duration (2005–2015). The total costs of 25 activity of construction work such as (excavation the foundation works, Landfill works, filling with sub-base works, Construction works under moisture proof layer, Construction works above moisture proof layer, Construction works of sections, ordinary concrete for walkways, reinforced concrete foundation, reinforced concrete column, reinforced concrete lintel, reinforced concrete slabs, reinforced concrete beams, reinforced concrete stair, reinforced concrete for the sun bumper, plaster finishing works, cement finishing works, Plastic Paints, Pentellite paints, pigment color, Stone packaging, Works of placing marble, Ceramic works for floor, Ceramic works for walls, Flattening (two opposite layers of lime), Flattening (Tiling)) are utilized for cost prediction. **Findings:** The results of the correlation factor equal to (100%), the percentage of error equal (5.81%) and amount of precision was (94.19%) which indicated that the artificial neural network gives very good performance in prediction construction cost. **Applications:** ANN is proved useful in estimating the costs of construction well in advance especially when the data are incomplete or limited.

Keywords: Artificial Neural Network, Construction Project, Cost Estimate, Cost Estimation Model

1. Introduction

The essential thing for construction managers is the budget of the construction; if the project completed with the same determined budget, time and quality required, the project considered successful[1]. Planning the project in an inappropriate manner or put insufficient budget and time, construction project subject to failure[2]. Therefore, a correct estimation of the budget of construction is a key element for profit[3]. Cost estimation assists the owners and planners in assessing the purpose of building project and controls costs successfully[4]. Project managers were interested in estimating the cost of construction because of the importance of the subject, especially in the first stages of the work when the data is incomplete[2]. So, cost prediction is considered a key element in decision-making. Due to important and difficulty of cost estimation, many researchers look for either traditional or artificial intelligence methods and examined for their validity in predicting the budget of construction work at the first step. A new method has recently emerged based on computer systems and simulating the human brain namely Artificial Neural Networks (ANN)[5]. This technique is characterized by the other techniques, such as regression analysis technology, the ability to deal with the most complex cases[6]. In addition, it can approximate functions well without explanation them that means the outputs are produced based on several input signals and through training those networks, accurate estimates can be made[7].

First research wrote by[8] studied the ANN uses in the civil engineering department. This research encouraged many researchers into the use in the construction sector.

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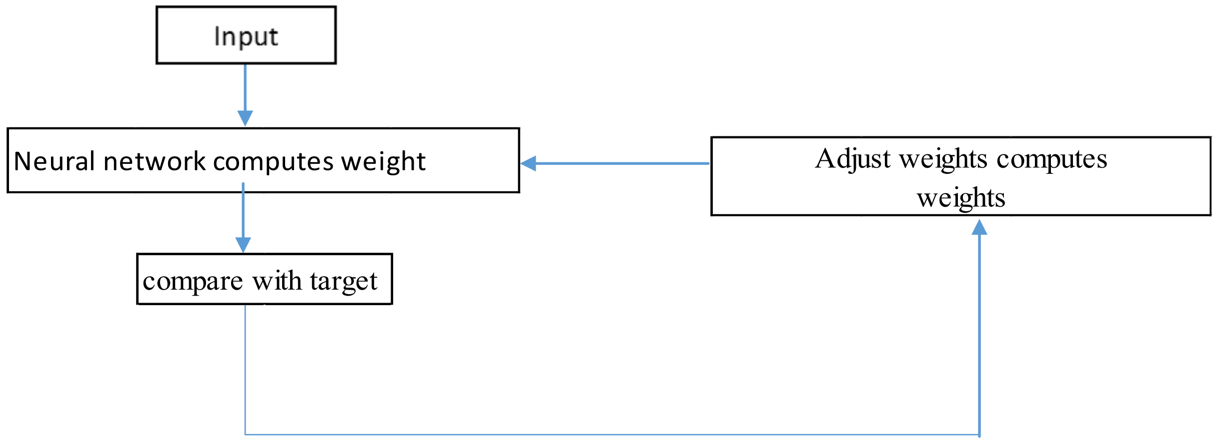

Figure 1. Correction of error by using target data[18].

In[9] used two types of neural network such machine learning the general regression neural network GRNN and multiple layer feed-forward networks MLFN to predict road tunnel construction cost. The researcher made a comparison between these models with real quantities and costs to check the accuracy. They found the GRNN model more accurate than MLFN model. The main weakness of this research not taking into account the factors that affect construction projects such as duration and tendering method.

In[10] used ANNs with back propagation algorithm to estimate the cost of structure works for the highway project. In this research, the researcher checked the ability of this technique in prediction costs. The researcher determined many variables that effect on the highway project as inputs to develop the prediction model. The researcher found the ANNs model gave very good performance in predicting the budget of highway projects.

In[11] use ANN to develop a model used to predict the budget expressway. To build the model, the researcher used 169 building projects were gathered from the construction industry in the Gaza Strip. At the last, the researcher concluded that ANN proved it's the ability in calculating the budget of highway construction projects with high performance.

In[12] used ANN to create mathematical equation used to determine the budget of the expressway projects. The researcher collected his data Stat Commission for Roads and Bridges in Iraq. At last, this technique gives very good result in predicting the budget of expressway project according to correlation factor and the precision of model.

2. Overview on Artificial Neural Network

Artificial neural networks consist of several components such as connection neurons or nodes, the output layer function, transfer function, the activation rule, the propagation rule, the connectivity pattern, the learning rule and the environment in which the system work[13]. The interconnected neurons that are trained using a set of data to select the base pattern. Neural networks contain a numbers of layers contained a number of neurons such as the inputs layer, hidden layer, and the outputs layer. The network receives the data through the first layer which is the input layer, and then the data is transferred to the second layer, which is hidden layer by the weights that connect the nodes. The information is then transferred to the last layer which is the output layer, where offers the result in this layer. Input data are weighted to indicate how much it impacts on the output data. Inputs that have a larger weight have a higher impact, transfer function is then applied to the weighted inputs, to produce the output signals by altering the inputs. The first layer includes one or more nodes describe various parameters where every input nodes represent as an inputs to the second layer. The second layer contains a number of nodes which determine the weighted summation of the input data.

Figure 1 demonstrates the work of neural networks in the modernization of weights and biases by comparing the real output with the desired. After gaining experience with a number of iteration Network, weights are adjusting[13]. Neural networks are used for many purposes such as solve the classification problem, function approximation, predicting, clustering/categorizing, function approximation, optimization, control, and content-addressable memory[14].

3. Development of ANN model

This study attempts to overcome some of the difficulties found in neural network technology for the purpose of using it effortlessly in the field in the field of construction and to build an accurate cost prediction model. The organization of the network comprises of three layer, ANNs should be built in an orderly manner to make the network work in height efficiently by addressing key network factors such as the selection of model inputs and outputs, Splitting and Scaling the data, determination the structure of the network, training the network, and validity the model[15].

4. ANN Model Inputs and output

The model input variables for cost estimation model were consisting of twenty-five parameters symbol by x is the cost of excavation the foundation works, Landfill works, filling with sub-base works, Construction works under moisture proof layer, Construction works above moisture-proof layer, Construction works of sections, ordinary concrete for walkways, reinforcement foundation, reinforcement concrete column, reinforcement lintel, reinforcement slabs, reinforcement beams, reinforcement stair, reinforcement concrete for the sun bumper, plaster finishing works, cement finishing works, Plastic Paints, Pentellite paints, pigment color, Stone packaging, Works of placing marble, Ceramic works for floor, Ceramic works for walls, Flattening (two opposite layers of lime), Flattening (Tiling). The construction cost is determined as the output variable (dependent variable) and the observations consist of the individual projects. An effort is performed to formulate an equation including input variables predicting the costs of every project.

5. Data Division for ANN Model

Training, testing and validation set is the three splittings of data. Data is splitting by trials and errors to get the lowest errors and top coefficient of correlation. The division performed in the Matlab software. The selection of the neural network depends on the good results that the network gave with respect to training and testing error and coefficient of correlation.

The researcher found the best divisions are 70% of data for the training and 20% for the testing and 10% for validation. In this research, the method of learning that use for the network is the supervised learning because the input data with outputs are available so by training the network can learn to know the relation between inputs and outputs. The essential process in building the ANN model is determining the number of hidden layers and its nodes[16]. By made many trials, the researchers' utilized single hidden layer with two hidden nodes to develop the estimation model.

6. Scaling of Data

The main objective of scaling data is to confirm that data take the same attention during the training process and to eliminate their dimension. Data is limited between 0.0 to 1.0 if the sigmoid activation function used in the hidden and output layer and limited between –1.0 to 1.0 if the Tanh activation function is used[17]. The scaled equation S can be express by the following:

$$S = (x - x\mathrm{min})/(x\mathrm{max} - x\mathrm{min}) \tag{1}$$

Where x is original value of variable

7. Model Architecture, Optimization and Stopping Criteria

The difficult and essential process in the building of neural model is the definition of the aarchitecture of the neural network. The technique must be training several times to get the lowest error rate and the highest correlation of validation or testing data set, by choosing the appropriate features of model , such as the number of hidden layer and its nodes, momentum terms, learning rates, and activation function.

The researcher believed the optimal network of cost estimation model that give minimal testing and training errors and highest coefficient of correlation consists of two hidden nodes and when sigmoid activation function was used for hidden and outputs layer.

8. ANN Model Final Equations

The connection weights between layers and threshold levels (bias) are summarized in Table 1

$$Y = 1/(1 + e\text{^}(-(3.1061 - 3.2144 \tanh(y1) + 3.2079 \tanh(y2)))) \tag{2}$$

$$Y1 = \{\theta 26 + (w26 - 1 * x1) + (w26 - 2 * x2) + (w26 - 3 * x3) + (w26 - 4 * x4) + (w26 - 5 * x5) + (w26 - 6 * x6) + (w26 - 7 * x7) + (w26 - 8 * x8) + (w26 - 9 * x9) + (w26 - 10 * x10) + (w26 - 11 * x11) + (w26 - 12 * x12) + (w26 - 13 * x13) + (w26 - 14 * x14) + (w26-15 * x15) + (w26 - 16 * x16) + (w26-17 * x17) + (w26 - 18 * x18) + (w26 - 19 * x19) + (w26 - 20 * x20) + (w26 - 21 * x21) + (w26 - 22 * x22) + (w26 - 23 * x23) + (w26 - 24 * x24) + (w26 - 25 * x25)\} \tag{3}$$

$$Y2 = \{\theta 27 + (w27 - 1 * x1) + (w27 - 2 * x2) + (w27 - 3 * x3) + (w27 - 4 * x4) + (w29 - 5 * x5) + (w27 - 6 * x6) + (w27 - 7 * x7) + (w27 - 8 * x8) + (w27 - 9 * x9) + (w27 - 10 * x10) + (w27 - 11 * x11) + (w27 - 12 * x12) + (w27 - 13 * x13) + (w27 - 14 * x14) + (w27 - 15 * x15) + (w27 - 16 * x16) + (w27 - 17 * x17) + (w27 - 18 * x18) + (w27 - 19 * x19) + (w27 - 20 * x20) + (w27 - 21 * x21) + (w27 - 22 * x22) + (w27 - 23 * x23) + (w27 - 24 * x24) +) + (w27 - 25 * x25)\} \tag{4}$$

It is necessary to limit all inputs data between (0 and 1) before use Equation (3) and (4), by utilizing Equation (1) and use the range of training data in Table 2. The value extracted from the Equation (2) is the estimated value of the cost is also must be limited between (0 and 1) by Equation (1) and the range of inputs and outputs in the Table 2 to get the actual value. By scaling and entering the information of the network in the Table (2), Equations (2) and (3) and (4) can be modified as showed below:

$$Y = 4.1376/(1 + e\text{^}(-(3.1061-3.2079 \tanh(y1) + 3.2079 \tanh(y2)))) + 7.7724 \tag{5}$$

$$Y1 = \{0.0679 + (4.15042E - 10 * x1) + (2.1796E - 08 * x2) + (1.50925E - 08 * x3) + (-9.07722E - 09 * x4) + (1.10181E - 09 * x5) + (-9.04671E - 08 * x6) + (-7.95008E - 09 * x7) + (7.889636711 * x8) + (4.73359E - 09 * x9) + (-1.0063E - 08 * x10) + (1.64803E - 09 * x11) + (-3.88695E - 08 * x12) + (-8.85867E - 08 * x13) + (8.15341E - 09 * x14) + (3.35171E - 12 * x15) + (3.22401E - 08 * x16) + (-2.6512E - 09 * x17) + (-1.68278E - 07 * x18) + (-5.85897E - 08 * x19) + (4.6794E - 08 * x20) + (4.83987E - 09 * x21) + (-7.73854E - 08 * x22) + (-1.04134E - 10 * x23) + (7.92797E - 08 * x24) + (2.30057E - 09 * x25)\} \tag{6}$$

$$Y2 = \{-4.9575 + (7.31034E - 08 * x1) + (-5.80315E - 09 * x2) + (-1.34782E - 07 * x3) + (-1.90056E\ 09 * x4) + (4.31584E - 09 * x5) + (-1.91576E - 08 * x6) + (1.08618E - 08 * x7) + (-2.47533E\ 09 * x8) + (7.87023E - 08 * x9) + (3.82913E - 10 * x10) + (-3.11741E - 09 * x11) + (-7.66564E - 09 * x12) + (1.82317E - 07 * x13) + (2.91136E - 09 * x14) + (7.9924E - 11 * x15) + (1.3336E - 09 * x16) + (4.71763E - 08 * x17) + (-1.21211E - 08 * x18) + (2.92125E - 07 * x19) + (1.14073E - 09 * x20) + (-8.03621E - 09 * x21) + (3.45464E - 10 * x22) + (3.88375E - 10 * x23) + (1.21089E - 09 * x24) + (-5.55862E - 09 * x25)\} \tag{7}$$

9. Validity of the Cost Estimation Model

1. Determination Factor R.
2. Correlation Factor R.
3. Mean Absolute Percentage Error (MAPE),

$$\text{MAPE} = \left(\left(\sum_{i=1}^{no} \left| R - P \right| / R \right) / n \right) * 100\% \tag{8}$$

Where:
R = Real value.
P = Prediction value.
no = numbers of validation data.

4. Percent of accuracy average

$$(AA\ \%)\ AA\% = 100\% - MAPE \tag{9}$$

The Table 3 shows the results of the artificial neural network model where value % AA was (94.19%) and MAPE was (5.81%). So the researcher found that ANN estimation model gives a very good performance.

The logarithm of prediction cost values was drawn with the logarithm of actual values for data of validation to validate the prediction model as shown in Figure 2. It is clear from this figure the generalization capability of ANNs techniques using the data of validation. Determination factor (R^2) is (98.7%), so the researcher concluded that ANNs model (estimation model) give excellent agreement with the actual measurements.

Figure 3 show the final real costs according to estimation cost for testing data. There is a small variance between the two costs.

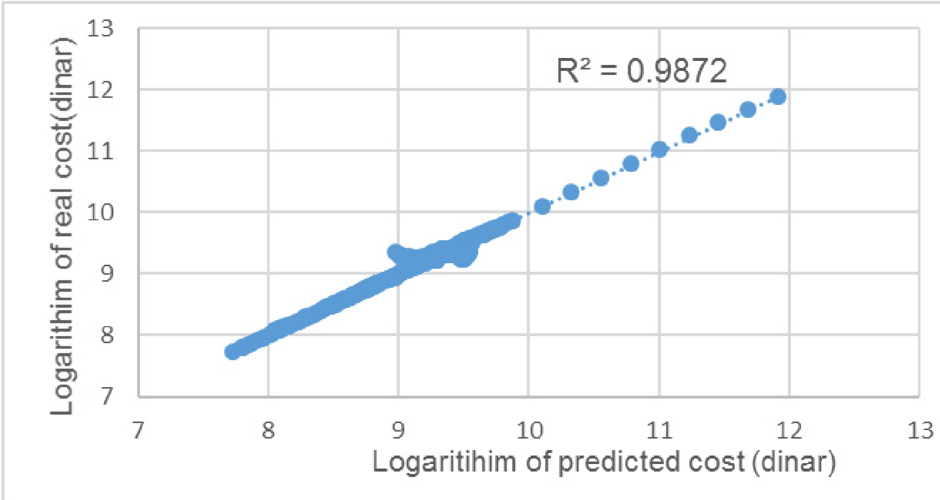

Figure 2. Prediction and real final cost for testing data.

Table 1. Weights and threshold levels for the ANN optimal model

Hidden layer nodes	Wij (weight connection in node i in input layer to node j in hidden layer)				Hidden layer bias θj
	i1 = 0.0141	i2 = 1.117	i3 = 0.4436	i4 = −1.6339	
j = 26	i5 = 0.7305	i6 = −5.3267	i7 = −0.6116	i8 = −0.5772	0.0679
	i9 = 0.6201	i10 = −3.5925	i11 = 1.297	i12 = −0.7971	
	i13 = −2.4007	i14 = 1.435	i15 = 0.1763	i16 = 2.8962	
	i17 = −0.2421	i18 = −8.57	i19 = −0.619	i20 = 11.6049	
	i21 = 1.4568	i22 = −5.1521	i23 = −0.5769	i24 = 3.8105	
	i25 = 0.4003				
j = 27	i1 = 2.4835	i2 = 2.4835	i3 = −3.9615	i4 = −0.3421	−4.9575
	i5 = 2.8614	i6 = −1.128	i7 = 0.8356	i8 = −1.2946	
	i9 = 10.31	i10 = 0.1367	i11 = −2.4534	i12 = −0.1572	
	i13 = 4.9408	i14 = 0.5124	i15 = 4.204	i16 = 0.1198	
	i17 = 4.308	i18 = −0.6173	i19 = 3.0863	i20 = 0.2829	
	i21 = −2.4189	i22 = 0.023	i23 = 2.1516	i24 = 0.0582	
	i25 = −0.9672				
Output layer nodes	**Wij (weight connection in node i in hidden layer to node j in output layer)**				**output layer bias θj**
	i = 26	i = 27			
j = 28	−3.2144	3.2079			3.1061

Table 2. Input and output statistics for the ANNs model

Variable	Max.	Min.	Range
x1	34568800	596370	33972430
x2	1552000	1552000	51248000
x3	30890900	1498900	29392000

Variable	Max.	Min.	Range
x4	184523200	27926000	179821600
x5	691400000	27926000	663474000
x6	60000000	1120000	58880000
x7	78550000	1620000	58880000
x8	78550000	1620000	76930000
x9	533730000	10403000	523327000
x10	360000000	2568500	357431500
x11	791500000	4398000	787102000
x12	23720000	3212900	20507100
x13	29600000	2500000	27100000
x14	181106000	5500000	52568500000
x15	95381000	5548700	89832300
x16	97320000	6003000	91317000
x17	52784000	1856400	50927600
x18	10965000	400000	10565000
x19	248650000	943160	247706840
x20	312840000	11617000	301223000
x21	312840000	11617000	66577200
x22	5542000000	3736600	5538263400
x23	48063980	2023900	48063980
x24	180980000	6522200	48063980
x25	180980000	6522200	174457800
Log output	11.91	7.7724	4.1376

Table 3. Results of the ANN estimation model

Description	MAPE	AA	R	R^2
ANN Model	5.81%	94.19%	100%	98.7%

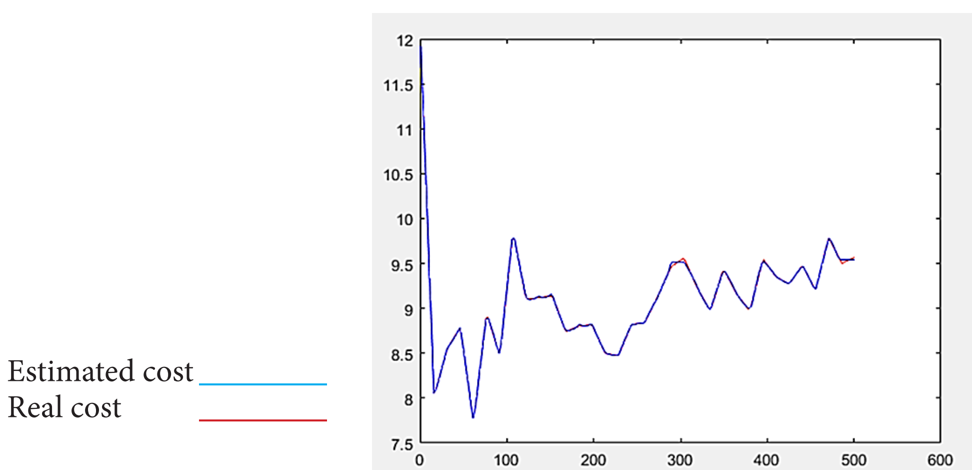

Figure 3. Designates the real cost with estimation costs for testing data sets. There is a small variance between the two costs.

10. Conclusions

- Neural network technology has the ability to develop an efficient mathematical equation used to calculate the cost of the construction project in the initial stages of the life of the project, particularly when data is incomplete.
- The researchers built the neural network of three layers that include inputs layer, hidden layer and output layer. The first layer consist of twenty-five nodes represent the items of construction project, the second layer contains two hidden nodes and the last layer contain single node represent cost of construction cost.

The results included the following:

- Mean Absolute Percentage Error (MAPE) equal to 5.81%.
- Average Accuracy Percentage (AA %) equal to 94.19%.
- Determination factor (R^2) equal to 98.7%.
- Correlation factor (R) equal to 100%.

11. References

1. Rezaian A. Time-cost-quality-risk of construction and development projects or investment. Middle-East Journal of Scientific Research. 2011; 10(2):218-23.
2. Cheng MY, Tsai HC, Sudjono E. Conceptual cost estimates using evolutionary fuzzy hybrid neural network for projects in construction industry. Expert Systems with Applications. 2010; 37(6):4224-31. https://doi.org/10.1016/j.eswa.2009.11.080
3. A cost estimate system for Gaza Strip construction contractors. Available from: https://iugspace.iugaza.edu.ps/bitstream/handle/20.500.12358/18997/file_1.pdf?sequence=1&isAllowed=y
4. Feng GL, Li L. Application of genetic algorithm and neural network in construction cost estimate. Proceedings of the 2012 2nd International Conference on Computer and Information Application; 2012. p. 1036-9. https://doi.org/10.2991/iccia.2012.254
5. Cavalieri S, Maccarrone P, Pinto R. Parametric vs neural network models for the estimation of production costs: A case study in the automotive industry. International Journal of Production Economics. 2004; 91(2):165-77. https://doi.org/10.1016/j.ijpe.2003.08.005
6. Weckman GR, Paschold HW, Dowler JD, Whiting HS, Young WA. Using neural networks with limited data to estimate manufacturing cost. International Journal of Industrial and Systems Engineering. 2010; 3(4):257-74.
7. Verlinden B, Duflou J, Collin P, Cattrysse D. Cost estimation for sheet metal parts using multiple regression and artificial neural networks: A case study. International Journal of Production Economics. 2008; 111(2):484-92. https://doi.org/10.1016/j.ijpe.2007.02.004
8. Flood I, Kartam NJ. Neural networks in civil engineering. I: Principles and understanding. Journal of Computing in Civil Engineering. 1994; 8(2):131-48. https://doi.org/10.1061/(ASCE)0887-3801(1994)8:2(131)
9. Petroutsatou K, Georgopoulos E, Lambropoulos S, Pantouvakis JP. Early cost estimating of road tunnel construction using neural networks. Journal of Construction Engineering and Management. 2011; 138(6):679-87. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000479
10. AL-Zwainy FM, Aidan IAA. Forecasting the cost of structure of infrastructure projects utilizing artificial neural network model (highway projects as case study). Indian Journal of Science and Technology. 2017; 10(20):1-12. https://doi.org/10.17485/ijst/2017/v10i19/108567
11. Cost estimation for building construction projects in Gaza Strip using Artificial Neural Network (ANN). Available from: https://www.semanticscholar.org/paper/Cost-Estimation-for-Building-Construction-Projects-Shehatto/b74344c2ec57e61edcad581e1bbf5eb5cb4c92b8
12. Khaleel TAM. Development of the artificial neural network model for prediction of Iraqi express ways construction cost. International Journal of Civil Engineering and Technology (IJCIET). 2015; 6(10):62-76.
13. Parallel distributed processing. Available from: https://dl.acm.org/citation.cfm?id=104279
14. Artificial Neural Networks: A tutorial. Available from: http://csc.lsu.edu/~jianhua/nn.pdf
15. Shahin MA, Jaksa MB, Maier HR. Artificial neural network based settlement prediction formula for shallow foundations on granular soils. Australian Geomechanics Journal. 2002; 37(4):45-52.
16. Kamruzzaman J, Sarker RA. Artificial Neural Networks: Applications in finance and manufacturing; 2006. p. 1-31. https://doi.org/10.4018/978-1-59140-670-9.ch001
17. Predicting the settlement of shallow foundations on cohesion less soils using back-propagation neural networks. Available from: https://pdfs.semanticscholar.org/8fa0/b9fc8c0948329d1092c8ad55ed1534182c98.pdf
18. Neural Network Toolbox. Available from: http://cda.psych.uiuc.edu/matlab_pdf/nnet.pdf