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PREDICTING INDEX TO COMPLETE SCHEDULE PERFORMANCE INDICATOR IN HIGHWAY PROJECTS USING ARTIFICIAL NEURAL NETWORK MODEL

NIDAL A. JASIM[1], SHELAN M. MARUF[2], HADI S.M. ALJUMAILY[3],FAIQ M. S. AL-ZWAINY[4]

Abstract: Inaccurate estimation in highway projects represents a major problem facing planners and estimators, especially when data and information about the projects are not available, and therefore the need to use modern technologies that addresses the problem of inaccuracy of estimation arises. The current methods and techniques used to estimate earned value indexes in Iraq are weak and inefficient. In addition, there is a need to adopt new and advanced technologies to estimate earned value indexes that are fast, accurate and flexible to use. The main objective of this research is to use an advanced method known as artificial neural networks to estimate the TSPI of highway buildings. The application of artificial neural networks as a new digital technology in the construction industrial in Republic of Iraq is absolutely necessary to ensure successful project management. One model built to predict the TCSPI of highway projects. In this current study, artificial neural network model were used to model the process of estimating earned value indexes, and several cases related to the construction of artificial neural networks have been studied, including network architecture and internal factors and the extent of their impact on the performance of artificial neural network models. Easy equation was developed to calculate that TSPI. It was found that these networks have the ability to predict the TSPI of highway projects with a very outstanding saucepan of reliability (97.00%), and the accounting coefficients (R) (95.43%).

Keywords: Highway Project, Artificial Neural Network, To Complete Schedule Performance Indicator (TCSPI), GMDH Shell Software, Budget at Completion (BAC). Earned Value (EV), Planning Value (PV).

[1] Assist. Prof., PhD., Eng., University of Diyala, College of Engineering, Department of Civil Engineering, Iraq, e-mail: nidaladnan@gmail.com

[2] Lecturer., Eng., Erbil Polytechnic University, Erbil Technology Institute, Department of Road Construction, Erbil-Iraq, e-mail: shelan.maruf@epu.edu.iq

[3] Assist. Prof., Eng., University of Mustansiriyah, College of Engineering, Department of Environmental Engineering, Iraq, e-mail: hadi.aljumaily@uomustansiriyah.edu.iq

[4] Prof., PhD., Eng., Al-Nahrain University, College of Engineering, Department of Civil Engineering, Iraq, e-mail: faiq.al-zwainy@eng.nahrainuniv.edu.iq (Corresponding author)

1. INTRODUCTION

Highway projects in the Republic of Iraq are considered important infrastructure projects, which serve a broad segment of society. One of the most important obstacles facing highway projects when implementing is the difficulty of controlling time and the planned cost together. It is known to stakeholders in construction projects that managing the value gained is the only tool that provides the ability to plan and control the duration of construction projects and their costs [1].

Schedule Indicators is very important in earned value management, this index content on three elements [2]: Schedule Variance (SV) and Schedule Performance Indicator (SPI) and To Complete Schedule Performance Indicator (TCSPI), in this study will be consetreted on TSPI deu to the important it in follow up the implementation the highway project. To Complete Schedule Performance Indicator (TCSPI) is an index showing the efficiency at which the remaining time on the construction project should be utilized. It can be determined using equation no. (1.1):

$$TCSPI = (\text{Total Budget} - EV) / (\text{Total Budget} - PV) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1.1)$$

This equation gives the efficiency at which project team should utilize the remaining time allocated for the construction projects.

1) A TCSPI value below 1 indicates the project team can be lenient in utilizing the remaining time allocated to the project.
2) A TCSPI value above 1 indicates the project team needs to work harder in utilizing the remaining time allocated to the project.

Good planning for the implementation of highway projects requires the presence of modern techniques and methods that are of high accuracy, in order for the outputs of the planning process to be of high efficiency and sufficient flexibility, and the most important of these techniques are artificial neural networks [3].

In recent years, artificial neural networks have been pushed as an alternative to traditional forecasting models in construction project. Artificial neural systems have become noteworthy data explanatory apparatuses that permit information to be broke down so as to locate the utilitarian connections among the factors under any contemplations. These factors are generally trial information and characterized into reliant and autonomous factors, Artificial neural system permits the use of more than one dependent varaible to be utilized in a useful, practical relationship [4].

A run of the neural system comprises of various layers; each layer blended of various number of neurons (processing components) as portrayed in Figure (1-a). The input layer speaks to affecting components of a particular problem. The output layer in which the arrangement of the difficult problem takes place, for example forecast, classification, and so on. The shrouded layer (hidden layer) through which the data is handled. The quantities of concealed layers and shrouded neurons are normally dictated by experimentation as indicated by the multifaceted nature of the problem, [5]. Figure (1-b) is a schematic drawing of a typical Neurons variously known as processing elements (PEs), or nodes , The input from each (PE) in the previous layer (xi) is multiplied by an adjustable connection weight (wij) at each PE, the weighted input signals are summed, with a threshold value (θj) may be added. This combined input (Ij) is then passed through a transfer (activation) function (f (.)) to produce the output of the PE (yj). The output of one PE provides the input to the PEs in the next layer [5].

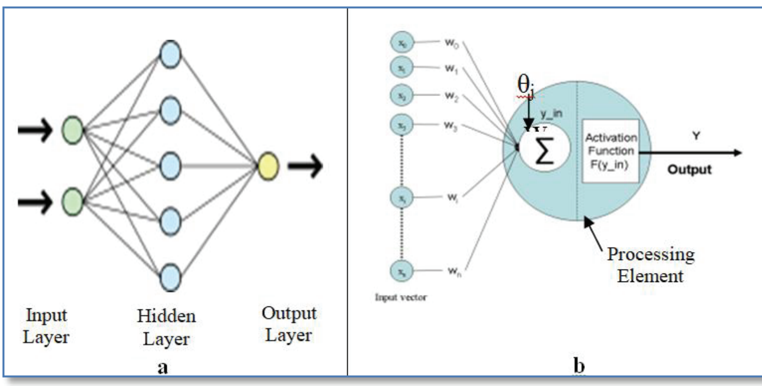

Figure 1: Typical Structure and Typical Neurons [5]

Different studies have used ANNs model in construction management. Mainly for the classification, making the decision, planning, optimization, and the predicting. William in 2004 promoted networks of back-propagation to estimate varies in the cost index of the construction [6]. Murtaza and Deborah in 1994 applied a neural network individually together with Khonen Algorithm for creating the decision on the modularization of the construction [7]. Mr. Hegazy and Mr. Moselhi in 1994 applied artificial neural network of back-propagation to obtain a best markup model of estimation, so that resulting in having solutions to new tender situations [8]. Lippmann in 1988 applied an ANN for modeling the rough cost calculations of construction [9]. Chua et al. in 1997 applied ANNs to point out main management factors which have an effect on budget activity in and project [10]. Al- Tabtabai et al. in 1997 applied a network of BP to obtain the decision-making process for the project professionals drawn in schedule monitoring and prediction for incomplete projects of multistory buildings [11]. Adeli and Wu in 1998 presented a regularization neural network to predict the reinforced concrete pavement cost [12]. Hegazy and Ayed in 1998 applied the neural network process to create a model of a parametric cost-estimating for projects of highway [13]. Zamim et al in 2020 used neural networks for prediction of dust storms in construction projects using intelligent artificial neural network technology [14].

Consequently, for the studies of the project management, ANNs are now widely used in construction project. A significant gap has been noticed which that none of the above-mentioned studies was interested in earned value management predicting. In Iraq, some scholars have used ANNs in project management. Ibraheem et al in 2020 used neural networks for predicting the earned value indexs in residential Complexes' Projects [15]. Firas et al in 2020 used forecasting techniques such as ANN to calculate the earned value indicators and performance of tall building. [16]

The main objective of this study is to develop a mathematical model for artificial neural networks in order to predict the most important indicator of the earned value indexes in highway project, which is the To Complete Schedule Performance Indicator (TCSPI), while identifying the factors affecting it, as well as finding a mathematical equation to calculate the time index easily and simply.

This study highlights on the infrastructur projects and its relationship with engineering project management. for the reason that, it have effective on the Iraqi economy, where the growth of construction sector steadily at the present time in terms of use of technological techniques in different areas of life. Earned value indexes are significant to owners and contractors due to they should be sufficiently exact to grant the certainty required to submit extra assets to the infrastructure project such as highway project. Consequently, construction engineers should have the data and technologes to precisely anticipate the earned value indexes of any size and kind of expressway undertaking and monitor the expense and durations. Be that as it may, this earned value indexes prediction practice in the infrastructur project is inadequate and insufficient. This will be a result of deficient and fluffy nature of sources of inputs and outputs for the implemention highway project. In light of the significance of variables that couldn't be evaluated, the advanced choice neural networks have minimal possibility of accomplishment. However, an excellent prediction technique should include both construction experience and historical information, data and knowledge. The prediction strategies planned during these analysis use neural network method to provide an estimate that includes both objective and subjective information. These computing based mostly techniques either emulates the human ability to be told from past and historical expertise and to use fast solutions to novel things or use analogy-based selections to introduce a new solutions. The planned techniques use the judgment method of intimate planners to improvement forecasting models. Finally, the results expected from this research is provides a great tool for the estimaters and planners who are responsible for predicting earned value indexes in their early construction process, to forecasting project earned value indexes. Thus, the outputs will probably offer early warning of over under-budge or over under-duration.

2. CHOOSE THE APPROPRIATE NEURAL NETWORKS SOFTWARE

GMDH Shell software, is a professional neural network software, solutions for construction activities forecasting such as cost, productivity, cash-flow etc. by building and development artificial neural networks and applying them for the input and output data. Designed to help even non-experienced planners and estimators accomplish their construction forecasting. GMDH Shell is consist of several plug are linked in a chain that can be seen in Figure (2), while, Figure (3) shows the schematic of the GMDH Shell.

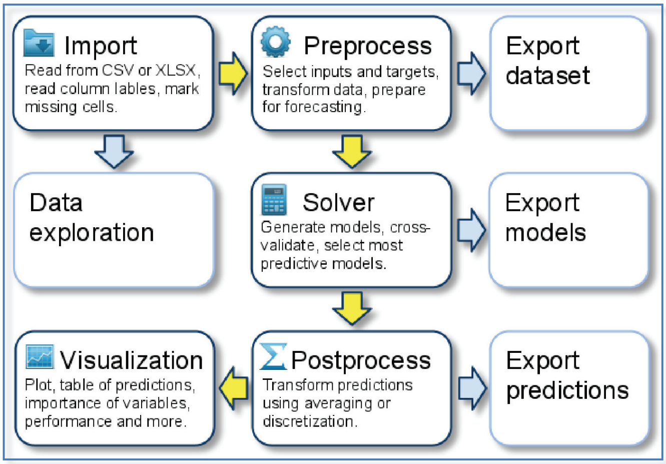

Figure 2: Component of GMDH Shell

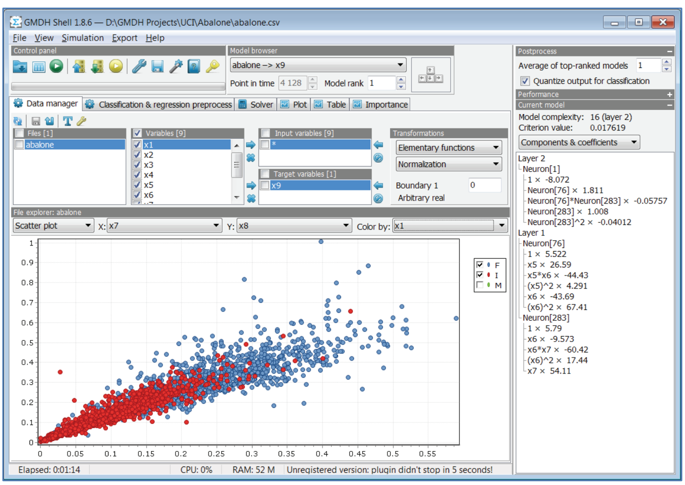

Figure 3: Graphing of GMDH Shell

3. IDENTIFICATION OF ANNS MODELS VARIABLES

There are two types of variables that affected on the earned value indexs in highway project in Republic of Iraq that is dependent variables (To Complete Schedule Performance Indicator (TCSPI)) and Independent such as:

1) F1: BAC, Budget at Completion.
2) F4: EV, Earned Value.
3) F6: PV, Planning Value,

ANN technique necessitates lots of information and data. Consequently, many historic highway projects were collected which had done between 2017 and 2019 from Ministry of Construction and Housing (MCH) in Iraq. Moreover, the detail of these data, dependent variables and independent variables that effect on the earned value indexes as shown in the Table (1).

Table1. Variables of TCSPI-ANN Models

Parameters	Input			Output
	BAC	EV	PV	TCSPI
MAX.	988475000	577555000	620005000	1.64
MIN.	988475000	317778000	388495000	0.88
AV.	988475000	463332000	447890000	0.78
RANGE	0.00	259777000	231510000	1.02
ST.D	0.00	60467000	45626000	0.67

4. DEVELOPMENT OF TCSPI-ANN MODEL

Artificial Intelligent Neural Network (AINN) has five main steps: Model inputs and outputs; Data division; Model architecture; ANNs Model Equation and ANNs Model Validity

4.1 DEVELOPMENT OF TCSPI-ANN MODEL INPUTS AND OUTPUTS

The researcher used approach (Method of prior knowledge) as a method to determining the variables for only three inputs (BAC, EV, PV) and only one output (TCSPI) in ANN model.

4.2 DATA DIVISION TCSPI-ANN MODEL

In this step of the ANN models development, the collected data has divided into three sets: training sets, testing sets, and validation sets.Detail outputs are briefed in Table (2). It could be noticed that the optimum result is 75% for training group, 15% testing group, and 10% for validation group, in relation to taken testing error (4.45%), also, coefficient of correlation (94.55%) and using striped distribution.

Table 2. Effect of Behaviour on Data Division of TCSPI-ANN Model

Data partition %			Error of Training %	Error of Testing %	Coefficient Correlation(r) %
Training group	Testing group	Querying group			
80	10	10	8.09	6.51	90.34
75	5	20	8.09	6.66	90.56
75	10	15	7.99	6.74	92.78
70	5	25	7.88	6.82	93.24
70	20	10	6.93	5.85	93.56
75	15	10	5.62	4.45	94.55
80	10	10	5.62	5.54	94.00
85	5	10	5.210	5.410	90.70

4.3 ARCHITECTURE OF TCSPI-ANN MODEL

One of the most important characteristics of neural networks is network architecture. In this study, the researcher used the default parameters of the neural network model, namely (learning rate is 0.3 and momentum term is 0.9 and the transfer functions in hidden are tanh function and output layer node is sigmoid function). Figure 1 shows the number of the researcher's attempts to find the ideal architecture for the artificial neural network by increasing the number of nodes in the single hidden layer starting from one node to fifteen nodes, and found that the best results for the artificial neural network are at one node, because it gives the lowest error rate for the training group with Highest correlation coefficient.

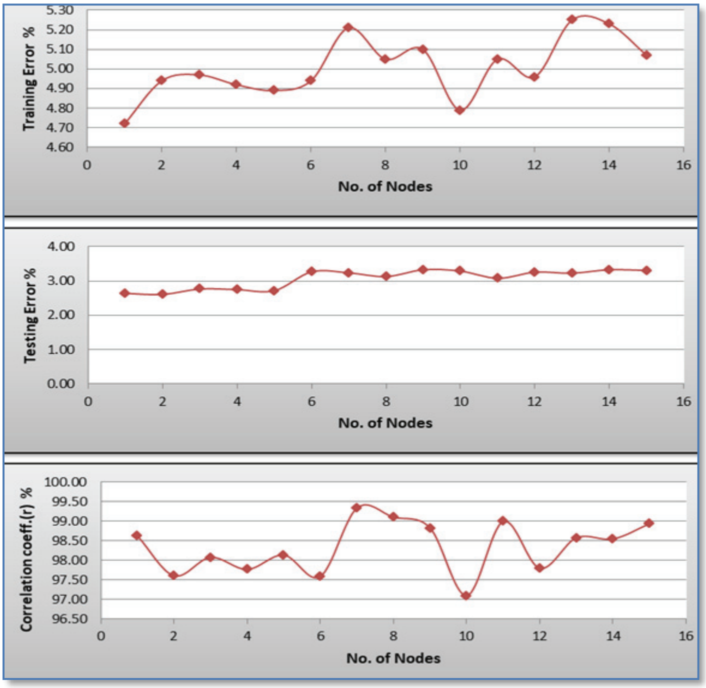

Figure 4: Influences the Number of Neuron on the TCSPI-ANN Model Performance.

4.4 TSPI–ANN MODEL EQUATION

Number of connection weights obtained by GMDH Shell equal to four connection weights and the optimal TCSPI-ANNs model enables the artificial network to be translated into relatively simple formula. To demonstrate this, the structure of the ANNs model is shown in Figure (5) Which shows the architectural form of the artificial neural network, which consists of three layers, which is the input layer that contains three variables, one hidden layer with only one nerve nodes, and finally the output layer with one nervous node.; while as connection weights and threshold levels are summarized in Table (3).

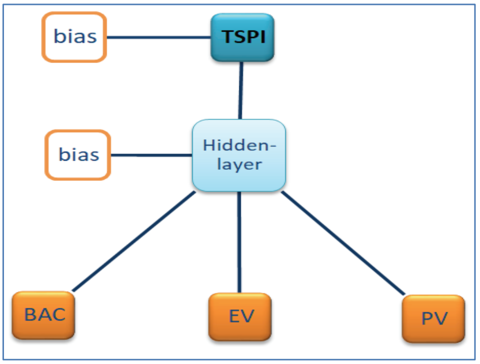

Figure 5. Architecture of TCSPI-ANN Model

Table 3. Weights and Threshold Levels for the TSPI Model

Predictor		Predicted	
		Hidden Layer 1	**Output Layer**
		H(1:1)	**TCSPI**
Input Layer	**(Bias)**	-0.181	
	BAC	0.215	
	EV	1.346	
	PV	0.666	
Hidden Layer 1	**(Bias)**		0.994
	H(1:1)		- 4.555

Based on connection weight besides the threshold levels presented in Table (3), the prediction of the TSPI-ANN model is written as:

$$\mathbf{TCSPI = \{1 / [1+e^{(-0.994+4.555 tanhx1)}] +0.905\}} \text{ ……………..… } \mathbf{(4.1)}$$

Where:

$$\mathbf{X = [-0.181 + (0.215*BAC) + (1.346*EV)+(0.666*PV)]} \text{ ……..}\mathbf{(4.2)}$$

5. VERIFICATION AND VALIDATION OF THE TCSPI-ANN MODEL

The most common statistical approaches have been utilized to determine the models accuracy is; Mean Percentage Error (MPE); Root Mean Squared Error (RMSE), Mean Absolute Percentage Error (MAPE), Average Accuracy Percentage (AA%), Coefficient of Determination (R^2), Coefficient of Correlation (R). Results outputs of the comparative study have been clear in Table (4). The Mean Percentage Error (MPR) is 0.19%, Root Mean Squared Error (RMSE) is 0.051, Mean Absolute Percentage Error (MAPE), is 7%, Average Accuracy Percentage (AA%) is 93%, Coefficient of Determination (R2) is 95.43% and Coefficient of Correlation (R) is 91.1%. Consequently, TCSPI-ANN model had a very outstanding saucepan of reliability with actual data.

Table 4: Output of the Validation Study for TCSPI-ANN Model

Parameters	Equations	TSPI-ANN for model
MPE	$\mathrm{MPE} = \left(\frac{\sum \frac{X-Y}{X}}{n}\right) * 10 \ldots\ldots (5.1)$	0.19%
RMSE	$RMSE = \sqrt{\frac{\sum (Y-X)2}{n}} \ldots\ldots\ldots (5.2)$	0.051
MAPE	$\mathrm{MAPE} = \frac{\sum \frac{\lvert X-Y \rvert}{X} * 100\%}{n} \ldots\ldots (5.3)$	7.00%
AA%	$(AA\%) = 100\% - MAPE \ldots\ldots (5.4)$	93.00%
R	$\mathrm{r} = \frac{\sum (x-\bar{x})(y-\bar{y})}{\sqrt{\sum (x-\bar{x})2 \sum (y-\bar{y})2}} \ldots\ldots\ldots (5.5)$	95.43%
R^2		91.1%
Notes	x= actual value y= estimated value or predicted value n= total number of observations	

The summary of computing To Complete Cost Performance Indicator (TCSPI) by ANN for verification of estimating models has explained by Table (5). Where column two has actual Index that gotten from highway project under construction in Iraq, and other column represents estimate Index after applying ANN equation on them.

Table 5. TCSPI Calculated through ANN for Verification of Estimating Model

Projects	TCSPI	
	Actual	Estimate by ANN
A1	1.00	0.99
A2	1.55	1.30
A3	1.78	1.56
A4	1.99	1.97
Correlation Coefficient	**95.43%**	

Correlation coefficient between (Actual-TCSPI Index) and Estimate (Predicting-TCSPI Index) by ANN equal to 95.43%, therefore it can be concluded that this model has an excellent covenant with the raw measured data, as presented in Figure (6).

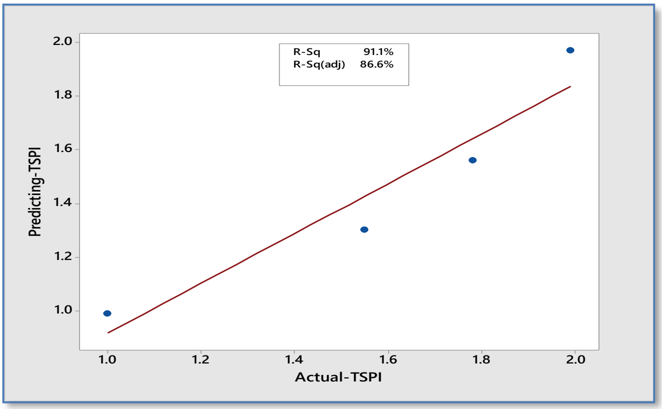

Figure 6. Study the relationship between Observed and Predicted TCPI for Validation Data

6. CONCLUSIONS

Highway project are among the most important projects today in Iraq, and for this the idea of this study came to predict the earned value index (To Complete Schedule Performance Indicator (TCSPI)) of implementing highway projects using artificial neural networks, only one model was adopted in this study using three variables as inputs which is the BAC, PV, and EV, and an equation was found, and an equation was found Mathematical accuracy of 93.00% to predict the TCSPI of highway projects in Iraq.

It is worth noting that the results of this study are an important indicator and an additional predictive guide for predicting the performance of highway projects, although the earned value-added indicators are mainly considered indicators to predict future events for the project itself, now that this developed model lies in its importance for future forecasts for other projects that have not started implementing.

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LIST OF FIGURES AND TABLES:

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