DOI:10.22337/2587-9618-2022-18-1-51-60

FORECASTING AND DETERMINING OF COST PERFORMANCE INDEX OF TUNNELS PROJECTS USING ARTIFICIAL NEURAL NETWORKS

Oday Hammoody [1], Jumaa A. Al-Somaydaii [2], Faiq M.S. Al-Zwainy [3], Gasim Hayder [4]

[1]Civil Engineering Department, University of Technology, Baghdad, IRAQ
[2] College of Engineering, Al-Anbar University, Anbar, IRAQ
[3] Forensic DNA for Research and Training Center, Al-Nahrain University, Baghdad, IRAQ
[4] Institute of Energy Infrastructure (IEI), Universiti Tenaga Nasional (UNITEN), Selangor, MALAYSIA

Abstract. Construction projects, especially tunnel projects in the Arab world, suffer from poor documentation of data and information, and therefore there is a difficulty in estimating the budget or total costs or indicators of earned value, and with the advancement of artificial neural networks, the urgent need arises to estimate the earned value indicators for tunnels projects in the absence or lack of data required for the purpose of estimating costs and durations together. Objective: The primary aim of the current study is to introduce Artificial Intelligence (AI) in conducting statistical approach for earned value management of the tunnels projects. Methodology: The study was based on the assurance of different variables that effect on the Earned Value Management (EVM) of the tunnels projects that involves historical data in Iraq and Jordan. Five independent variables were randomly selected (Actual Cost AC, Planning Value PV, Earned Value EV, Actual Duration AD and Planning Duration PD), which were all around characterized for each tunnel project, and one dependent variable Cost Performance Index (CPI) was selected. NEUFRAME V.5 Program was selected, which is the premier neural network simulation environment. The methodology of ANN embraced for finding best network architecture and inside parameters that control and monitoring the preparation procedure which did by utilizing the default parameters of the NEUFRAME programming package. Results: The experimentation results reveal that, Mean Absolut Percentage Error (MAPE) and Average Accuracy percentage (AA) generated by ANN model (CPI) were found to be 9.6% and 90.368%, respectively. Therefore, the ANN model (CPI.model.1) shows a magnificent concurrence with the real estimations.

Keywords: Forecasting, artificial neural networks, tunnel project, cost performance index.

ПРОГНОЗИРОВАНИЕ И ОПРЕДЕЛЕНИЕ ИНДЕКСА ЭФФЕКТИВНОСТИ ЗАТРАТ ДЛЯ ПРОЕКТОВ ТУННЕЛЕЙ С ИСПОЛЬЗОВАНИЕМ ИСКУССТВЕННЫХ НЕЙРОННЫХ СЕТЕЙ

Одай Хаммуди [1], Джумаа А. Аль-Сомайдаии [2], Фаик М.С. Аль-Звайни [3], Гасим Хайдер [4]

[1] Факультет гражданского строительства, Технологический университет, Багдад, ИРАК
[2] Инженерный колледж, Университет Аль-Анбар, Анбар, ИРАК
[3] Научно-исследовательский и учебный центр судебно-медицинской экспертизы ДНК, Университет Аль-Нахрейн, Багдад, ИРАК
[4] Институт энергетической инфраструктуры (IEI), Национальный университет Тенага (UNITEN), Селангор, МАЛАЙЗИЯ

Аннотация. Строительные проекты, особенно проекты туннелей в арабском мире, страдают от плохого документирования данных и информации, и поэтому возникают трудности с оценкой бюджета, или общих затрат, или показателей заработанной стоимости. С развитием искусственных нейронных сетей становится актуальной оценка показателей заработанной стоимости для проектов тоннелей в связи с отсутствием или недостатком данных, необходимых для комплексной оценки затрат и сроков выполнения работ. Цель исследования: Основная цель настоящего исследования является внедрение искусственного интеллекта (ИИ) для применения статистического подхода к управлению заработанной стоимостью проектов строительства туннелей. Методология: В исследовании выполнено обоснование различных переменных, влияющих на управление заработанной стоимостью (EVM) проектов туннелей, которые включают исторические данные в Ираке и Иордании. Были случайным образом выбраны пять независимых переменных (фактическая стоимость AC, плановая стоимость PV, заработанная стоимость EV, фактическая продолжительность AD и планируемая продолжительность PD), которые были всесторонне охарактеризованы для каждого проекта туннеля, а также была выбрана одна зависимая переменная - индекс эффективности затрат (CPI). Была выбрана программа NEUFRAME V.5, которая является ведущей средой моделирования искусственных нейронных сетей (ANN). Методология ANN использовалась для поиска лучшей сетевой архитектуры и внутренних параметров, которые контролируют и управляют процедурой подготовки, используя параметры по умолчанию пакета программирования NEUFRAME. Результаты. Результаты экспериментов показывают, что средняя абсолютная ошибка в процентах (MAPE) и средний процент точности (AA), полученные с помощью модели ANN (CPI), составляют 9,6% и 90,368% соответственно. Таким образом, модель ANN (CPI.model.1) показывает хорошее совпадение с реальными оценками.

Ключевые слова: прогнозирование, искусственная нейронная сеть, проекты туннелей, индекс эффективности затрат.

1. INTRODUCTION

From numerous decades, earned value management has happened to an extraordinary significance in the space of engineering industry. Managing the earned worth administration subject beginnings from the commencement of thought in the brain of the proprietor or the engineer and proceeds for the duration of the life of the task. Earned Value is a notable task the executive's apparatus that utilizes data on cost, duration and work execution to build up the present status of the undertaking. By methods for a couple of straightforward rates, it permits the supervisor to extrapolate current patterns to foresee their presumable last impact. The technique depends on a rearranged model of a task however end up being valuable by and by of cost control. It is being created to account better for schedule and time stages [1].

There are a lot of definitions for Earned Value Management (EVM), (Zhuo, 2005) defined EVM as an effective method of combination control to the scope, schedule and cost of the project [2]. EVM is a method of project management, which facilitates project control and provides support in forecasting final cost [3]. VM is an administration system for project execution monitoring. EVM coordinates cost, and timetable control under a similar structure, and it gives execution changes, and records which permit chiefs to distinguish over-expenses and deferrals [4]. EVM can offer many benefits to construction companies. They include [5, 6]:

1) Accurate estimate of task culmination and total cost.
2) Objective measurement of accomplishments against cost and schedule,
3) Early alerts to deferrals and overruns.
4) Information about schedule and cost variances during the course of the project.
5) Minimizing little changes in plan that can turn out to be huge after some time (scope creep) and that can lessen gainfulness.
6) Improvement in the control of contract performance.
7) Demonstrating a competitive advantage and improving customer goodwill.

2. RESEARCH OBJECTIVES

The primary goal of this study was, to present a factual methodology for earned value management of the construction tunnels projects. This target can be done during following advances:

1) An overview of EVM in engineering project management.
2) Identify the variables' that have an effect on the earned value management of tunnels projects.
3) Developing a mathematically model for earned value management using the Artificial Neural Network technique (ANN), to predict the Cost Performance Index (CPI) in tunnels projects
4) Verification and approval of the scientific model created.
5) Illation of a simply mathematical formula in order to estimating the CPI of tunnels projects.
6) Finding the value of accuracy of the mathematical formula, and the explained of the value of the correlation between predicting CPI (calculated), and CPI as actual value.

3. RESEARCH METHODOLOGY

Current methodology utilizes to accomplish the current study objectives can be abridged as follow advances:

1) Theoretical Survey: Theoretical survey was made to review the development of ANN on the EVM in project management field. The concept of the neural networks, and concept of earned value management, which include the review of literatures involving references, distractions, articles, handbooks and web-site relating to the task of research especially that are related to the construction projects sector.
2) Field Work Included Four Stages:

a) Preliminary stage, involves data description and identification, which describes the factors affecting the application of predicting the earned value for tunnels project, It is worth noting that the method of collecting historical data is a direct method through continuous field visits to spending projects under implementation, and it is the same method used in reference [7]

b) Secondary stage includes building of the ANN model to estimating Cost Performance Index (CPI).

c) Thirdly stage presents the verification and validation of the ANN model;

d) In the final stage, conclusions are drawn for this study and the results are discussed.

4. APPLICATION OF ARTIFICIAL NEURAL NETWORK IN EARNED VALUE MANAGEMENT

One of the most powerful and popular multilayer feed forward network is trained with back-propagation. The training of the developed network is conducted by back-propagation algorithm which was developed and involves only four stages; the feed forward stage of the input training patterns, the calculation and back-propagation stage of the associated error, and the adjustment stage of the weights [8].

Main aim of this study is to develop artificial neural networks model to predict and estimate the earned value indicators of tunnel projects in Iraq and Jordan. To attain this, there was a requirement to determine the factors that react the efficiency for tunnel projects. Therefore, the researchers in this study are attempting building and evaluation EVM model through the following stages:

1) Chose Software of ANN
2) Diagnostics of ANN model factors.
3) Building and evaluation of the developed ANN models
4) Validation of the developed ANN model

4.1. Neuframe Software Applications

The reproduction of neural system on a NEUFRAME program exhibits its hidden numerical equations in a basic with completely control-able structure. A few applications that help the foundation of neural systems like

SPSS, MATLAB and NeuroSolutions; however, this examination was chosen NEUFRAME Program, where NEUFRAME is the head neural system reproduction condition. The NEUFRAME run gives a simple to-utilize, visual, object-situated way to deal with critical thinking utilizing savvy advances. It gives highlights to empower organizations to research and apply clever innovations from introductory experimentation through structure installed applications utilizing programming segments. NEUFRAME is an incorporated gathering of knowledge Technology instruments that incorporate ANN rationale that permit putting the intensity of artificial neural lattice to turn on beginning of black box. Fig. 1 shows the schematic of the NEUFRAME V.5 program which is worked to decide the connection between the autonomous factors (information) and ward factors (yield) [9].

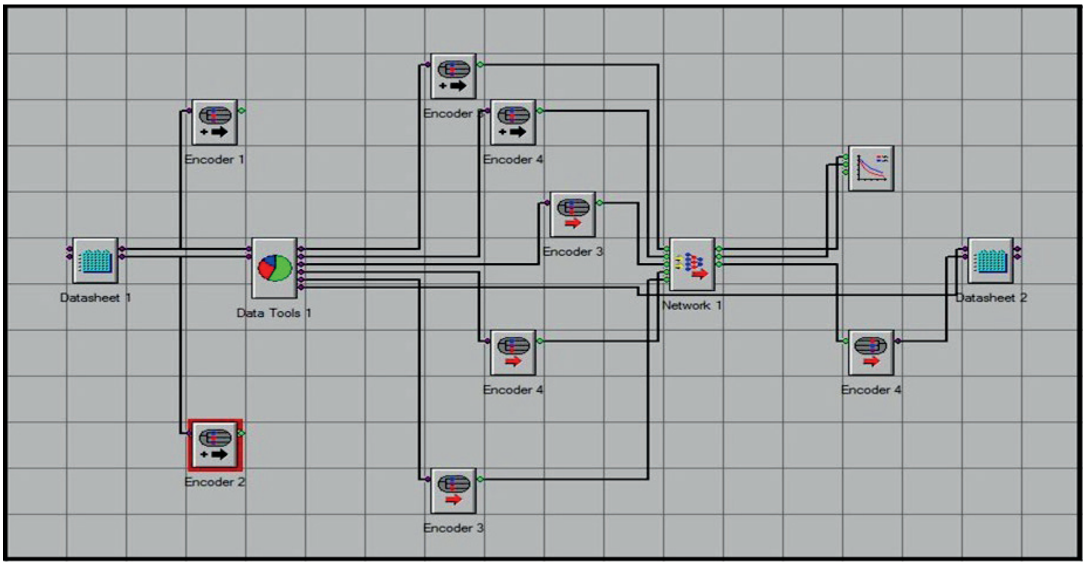

Figure 1. NEUFRAME V.5 interface (Researcher)

4.2. Diagnostics of ANN Model Factors

This study embraces historical information investigation as the establishment to this technique. In addition, the utilization of verifiable information helps with giving a connection between the principle factors influencing the earned value parameters of the tunnels projects to make estimates for new projects. Therefore, historical data of tunnels projects were collected, which were done between 2005 and 2017 in Ministry of Housing and construction in Kurdistan of Iraq, with Amman Municipality in Jordan, as shown in Fig. 2.

Figure 2. Tunnel Project in Amman (Researcher)

Six factors were painstakingly chosen and were all around characterized for each tunnel project. These illustrative factors can be ordered into two sorts: dependent and independent factors.

1) Dependent variables (factors): Cost Performance Index (CPI) is defined as the dependent factor and each individual tunnel project is used as the basic unit of the surveillance.

2) Independent variables (factors): After building up the reliant factors which are to be anticipated by neural system model, it was important to create autonomous factors to clarify any variety in project cost. Only five variables were adopted in this study as independent variables as follows:

a) F1: AC, Actual Cost.
b) F2: EV, Earned Value.
c) F3: PV, Planning Value,
d) F4: AD, Actual Duration.
e) F5: PD, Planning Duration,

4.3. Development of CPI-ANN Model

Neural Network (NN) models should be in an efficient way to improve its presentation. Such strategy needs address main considerations, for example, advancement of model inputs, information and data division and pre-handling, improvement of model design (architecture), model enhancement (training and preparing), halting standards, and model approval (validation). An organized procedure for building up the model has been utilized to tackle the current issue. This methodology fuses four principle stages:

a) Inputs and output Model
b) data division and pre-handling
c) Architecture of ANN Model
d) Equation of ANNs Model

4.3.1. Development of Model Inputs and Outputs

The determination of model info factors that have the most noteworthy effect on the model execution is a significant advance in creating ANN models. Introducing as enormous number of info factors as conceivable to ANN models for the most part builds the system size, bringing about a decline in preparing speed, and a decrease in the effectiveness of the system. Various strategies have been proposed to help the determination of info factors, for example, Method of prior knowledge: in view of earlier information, the suitable information factors can be chosen. This Methodology is basically used for the field of undertaking the board, and is received in this examination. As a primer stage to neural system displaying, the current issue needs to distinguish and label the information as info or as yield. NEUFRAME v.4 gives Microsoft Excel sheet, which is utilized through this progression. The independent factors influencing the issue are recognized and considered as (N) input parameters, which are spoken to by hubs at the info cushion of a neural system. The output of the model is Cost Performance Index (CPI).

4.3.2. Data and Information Division

Information and data pre-preparing is significant for utilizing ANN efficacious. It figures out what data is introduced to make the model during the preparation phase [10, 11]. In this way, the following stage in the advancement of ANN models is separating the accessible raw-data into three subsets, training, testing and validation sets. Learning was performed on the preparation set, which utilized for evaluating the loads while the cross-approval set was utilized for speculation that is to create best model for concealed models. In any case, the test set is utilized for estimating the speculation capacity of the system and assessed arranges execution. The complete accessible information is 45 tunnel projects that are isolated arbitrarily into three sets with the accompanying proportion:

a) Training set: includes (30) projects equal to (67%).
b) Testing set: includes (10) projects equal to (22%).
c) Validation set: includes (5) projects equal to (11%).

4.3.3. Model Architecture

One of the most significant and hard errands in the improvement of ANN models into decide the model engineering. For the most part, there is no immediate and exact method for deciding the most suitable number of neurons to remember for each concealed layer, and this issue turns out to be increasingly confounded as the quantity of shrouded layers in the system increments. Since ANN has one hidden layer can rough any persistent capacity, giving that adequate connection weights are utilize. Only one hidden layer was used to build CPI model. The methodology embraced for finding the ideal ANN design and interior parameters that mentoring the preparation procedure that were completed by utilizing the default parameters of the NEUFRAME package with one hidden layer and one hidden node. Also, a learning rate is (0.30), also, momentum term is (0.90), and hidden layer had sigmoid transfer functions and output layer had sigmoid transfer functions. Results were summarized in Table 1 for the CPI model.

Table 1: Effect of Parameters on ANN Performance

ANN Model for CPI			
Nodes		Learning Rate	Momentum term
1		0.3	0.9
Transfer functions			
Hidden layers		Output layers	
Sigmoid		Sigmoid	
Error %	Error of Training	Error of Testing	Correlation Coefficient
	4.50	5.40	0.88

4.3.4. Equation of CPI Model

The modest number of comradeship (connection) weights got by NEUFRAME for the ideal ANNs model (CPI model) empowers the system to be converted into relative straightforward equation. To exhibit this, the structure of ANNs model as appeared in Fig. 3, while connection weights and limit plane (bais) are condensed in Table 2.

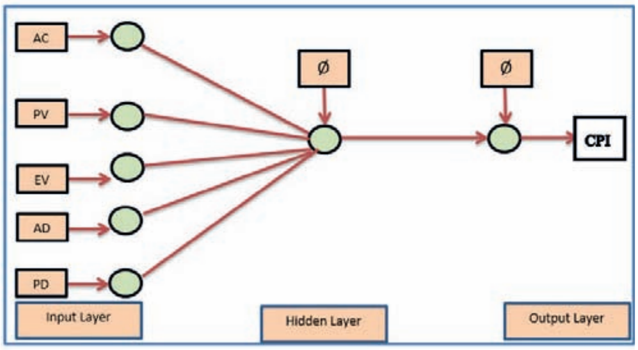

Figure 3. Architecture of the CPI Model (Researcher)

Table 2. Weight and Bais in ANN Optimal

weight from nodes input layer to nodes in hidden layer					
W_1=1	W_2=2	W_3=3	W_4= 4	W_5= 5	W_6=6
2.88	2. 55	0.77	1.88	0.66	2.44
Hidden layer threshold Θ_j			Output layer threshold Θ_j		
1.44			2.33		

Utilization the association weight with Baises as in Table (2), calculate CPI can be expressed as follow equation:

$$CPI = \{1/[1+e(2.33+2.44 \tanh (x))]+0.81\} \quad (1)$$

Where:

$$X = [1300 + (2.88*AC) + (2.55*PV) + (0.77*EV) + (1.88*AD) + (0.66*PD)] \quad (2)$$

A numerical model is given to more readily clarify the execution of the recipe. The condition was tried against the information utilized in the CPI model preparing, data and information as in below:

AC= 25,898,722 $
EV= 25,555,077 $
PV= 22,365,353 $
AD= 275 day
PD= 310 day

The estimated value using equation (1) was (0.854), compares well with actual value (measured value), (CPI=0.961). The difference is very little; this shows the strength of the predicted neural network developed in this research, as will be seen in the next section.

4.3.5. Validation of the Developed CPI-ANN Model

The synopsis of registering Cost Performance Index (CPI) by ANN for confirmation of assessing models is appeared in the following Table 3. Where section (2) presents actual Cost Performance Index that has been gotten from tunnels projects under development in Iraq, and section (3) speaks to assess Cost Performance Index subsequent to applying ANN condition on them, where ANN condition is acquired by NEUFRAME V.4, and the correlation between the actual and estimated Cost Performance Index is appeared.
Correlation coefficient through columns (Actual CPI and measure CPI by ANN is 75.0%), in this way it very well may be presumed that this model shows a decent concurrence with the genuine estimations, as shown in Fig. 4. Where, Y-axes represent Actual CPI, X-axes represent Estimated CPI.

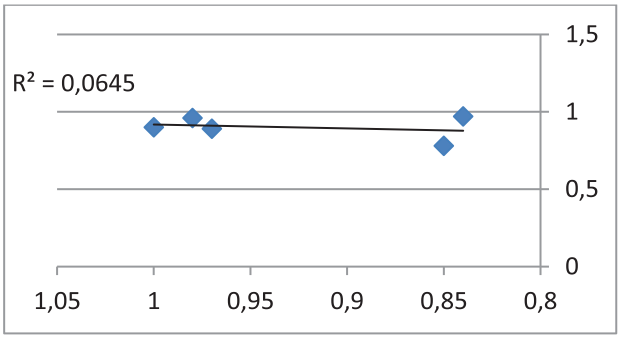

Figure 4. Comparison of Predicted and Observed CPI for Validation Data

The description of five (5) observations of tunnels projects (variables) was shown in Table 4.

Table 3. Validation of the developed ANN model

Projects	Actual CPI	Estimate CPI by ANN
1	0.96	0.98
2	0.78	0.85
3	0.90	1.0
4	0.97	0.84
5	0.89	0.97

Table 4. Verification for CPI Model.

Project.	AC	PV	EV	AD	PD	CPI
1	21,889,822	20,567,354	21,556,078	395	355	0.98
2	98,511,540	105,978,004	87,977,501	360	495	0.85
3	18,889,197	15,281,994	17,280,998	405	405	1.0
4	23,299,665	25,112,254	25,781,671	370	495	0.84
5	28,622,733	29,660,594	27,779,457	355	315	0.97

In this way it very well may be presumed that this model shows a decent concurrence with the genuine estimations.

a) Mean Absolute Percentage Error (MAPE):
According to (Aidan et al, 2020) and (Jasim et al, 2020) error of mean absolute percentage is designate by the next equation [12, 13]:

$$MAPE = \{ \sum_{i=1}^{n} \frac{|A-E|}{A} * 100\ \% \backslash n \} \quad (3)$$

Table 5. Mean Absolute Percentage Error (MAPE)

Projects	Actual CPI	Estimate CPI by ANN	MAPE%
1	0.96	0.98	18.68
2	0.78	0.85	5.46
3	0.90	1.0	6.60
4	0.97	0.84	6.54
5	0.89	0.97	10.88
MAPE%			48.16/5=9.6

b) Average Accuracy (AA %):
According to (Zamim et al, 2019) and (Jaber et al, 2020) Average Accuracy performance is defined as (100−MAPE) %. Average Accuracy (AA) can be designate by the next equation [14, 15, 16]:

AA %= 100-MAPE% = 100-9.6 = 90.368% (4)

Discussion the results in current study are specified in Table (6). MAPE % and average AA % created by ANN model (CPI) were originated to be 9.6% and 90.368% respectively. Therefore, it can be summarized that CPI-ANN model shows an excellent agree within the raw data.

Table 6. Conclusion of the Comparative Study

Details	CPI- ANN model
MAPE	9.6%
AA	90.368%
R	0.75
R^2	0.5625

5. CONCLUSIONS

Earned Value is exceptionally amazing asset to assessment execution for tunnels projects.. There is shortcoming in chronicling information and records in development and construction sector for Iraqi and Jordan. Methodology is primarily relied upon the assurance of different components that influence the EVM of the tunnels projects extends that includes historical information. In addition, five independent factors were arbitrarily chosen which were very much characterized for individual construction tunnel project and one only depended variable (CPI) was chosen. Information gathered was examined and the exploration issue recognized. In this manner, supervised learning algorithm was utilized for preparing the ANN. This relies upon the back-propagation algorithm, which is a kind of supervised learning algorithms that generally utilized in project management. The data was divided randomly into three sets: training set, testing set and cross validation set according to these percentage 67 %, 22 % and 11 % respectively for model (CPI). ANN technique was used to find the optimum model, which included one only hidden layer together, one only neuron with sigmoid transfer function, also, the output neuron had a sigmoid transfer function. Accuracy performances of the optimum model are 90.368% and Mean Absolute Percentage Error (MAPE) 9.6%. This study recommends the necessity of adopting artificial neural networks in estimating earned value in construction projects in general and tunnel projects in particular, as they are considered an important, simple and accurate method in planning and cost control work.

The Availability of Data
The datasets generated during and/or analysed during the current study are available from the corresponding authors on reasonable request.

Conflicts of Interest
All authors have no conflicts of interest or intersection of interest.

ACKNOWLEDGMENT

All the authors extend their sincere thanks and appreciation and great gratitude to all officials at

Al-Nahrain University, University of Technology, Anbar University, AlMaarif University College in Iraq, as well as Universiti Tenaga Nasional (UNITEN) in Malaysia for their support for this manuscript financially and morally. Thanks are extended to all the engineers who provided advice and guidance throughout the completion of the manuscript.

Author Contributions

Oday Hammoody contributed to the planning, enforcement, and writing of the manuscript, Faiq M. S. Al-Zwainy presented the original idea and contributed to model design and prescribe the manuscript. Jumaa A. building the ANN model and performed the computations. Gasim Hayder helped supervise the manuscript. All authors discussed the results and contributed to the final manuscript.

REFERENCES

1. **Jumaa A. AL-Somaydaii and HADI S. M. Aljumaily FAIQ M. S. AL-Zwainy,** "tilization Multifactor Linear Regression Technique for Prediction the Earned Value in Bridges Projects", *Journal of Engineering and Applied Sciences*, Vol. 13, No. 7, pp:1676-1682, 2018.
2. **Zhang Z.** "Project management". Beijing: Science-Publishing Inc; 2005, p. 168–173.
3. **Lipke W., Zwikael O., Henderson K., Anbari F.,** 2009. "Prediction of project outcome the application of statistical methods to earned value management and earned schedule performance indexes", International Journal of Project Management. Vol. 1, No. 27, pp: 400-407, 2018.
4. **Pajares J., López-Paredes A**., 2011. "An extension of the EVM analysis for project monitoring: The Cost Control Index and the Schedule Control Index". International Journal of Project Management. Vol. 1, No. 29, pp: 615-621, 2011.
5. **Koster K., Wallace D., Kinder J., Bell C.,** "Earned Value Management for Dummies", Deltek Special Edition, Wiley Publishing, Inc. 2011.
6. **Faiq. M. S. Al-Zwainy, Rafaa H. Al-Suhaily, Zuher S.,** "Project Management and Artificial Neural Networks: Fundamental and Application", LAP LAMBERT Academic Publishing, 2015.
7. **Faiq Ms Al-Zwainy, Shakir A Salih, Mohammed R Aldikheeli**, "Prediction of residual strength of sustainable self-consolidating concrete exposed to elevated temperature using artificial intelligent technique", International Journal of Applied Science and Engineering, Vol. 18, No. 2, pp. 42-60, 2012.
8. **Faiq M. S. Al-Zwainy,** "The Use of Artificial Neural Networks for Productivity Estimation of finish Works for Building Projects", Journal of Engineering and Development, Vol. 16, No. 2, pp. 1-15, 2021.
9. **Faiq M. S. Al-Zwainy**, "The Use of Artificial Neural Network for Estimating Total Cost of Highway Construction Projects", a thesis submitted to the Civil Engineering Department, College of Engineering, Baghdad University, Ph.D., 2009.
10. **Faiq M. S. Al-Zwainy And Ibrahim A. Aidan,** "Forecasting the cost of structure of infrastructure projects utilizing artificial neural network model (highway projects as case study)", Indian Journal of Science and Technology, Vol. 10, No. 20, pp. 1-12, 2017.
11. **Jumaa A. Al-Somaydaii,** "Development Mathematical Model for Brick Works Productivity by Using Support Vector Machine", International Journal of Applied Engineering Research, Vol. 11, No. 23, pp:11126-11131, 2016.
12. **Ibrahim A. Aidan, Duaa Al-Jeznawi, Faiq M. S. Al-Zwainy,** "Predicting Earned Value Indexes in Residential Complexes' Construction Projects Using Artificial

Neural Network Model", International Journal of Intelligent Engineering and Systems, Vol. 13, No. 4, pp. 248-259, 2020.
13. **Nidal A. Jasim, Shelan M. Maruf, Hadi S. M. Aljumaily, Faiq M. S. Al-Zwainy,** "Predicting Index to Complete Schedule Performance Indicator in Highway Projects Using Artificial Neural Network Model", Archives of Civil Engineering, Vol. 66, No. 3, pp. 541-554, 2020.
14. **Salah Kh. Zamim, Nora S. Faraj, Ibrahim A. Aidan, Faiq M. S. Al-Zwainy, Mohammed A. Abdulqader, and Ibraheem A. Mohammed**, "Prediction of dust storms in construction projects using intelligent artificial neural network technology", Periodicals of Engineering and Natural Sciences, Vol. 7, No. 4, pp. 1659-1666, 2019.
15. **Firas Kh. Jaber, Nidal A. Jasim, Faiq M. S. Al-Zwainy,** "Forecasting techniques in Construction industry: Earned value indicators and performance models", Scientific Review Engineering and Environmental Sciences, Przegląd Naukowy Inżynieria i Kształtowanie Środowiska, Vol. 29, No. 2, pp. 234-554, 2020.
16. **Doseva, Nadezhda and Chakyrova, Daniela.** "Life Cycle Cost Optimization of Residential Buildings in Bulgaria: a Case Study of the Building Envelope" Civil and Environmental Engineering, vol.17, no.1, 2021, pp.107-116. https://doi.org/10.2478/cee-2021-0012

Oday Hammoody. Civil Engineering Department, University of Technology, Sinaa Str., 10066, Baghdad, Iraq.

Jumaa A. Al-Somaydaii. College of Engineering, Al-Anbar University, Ramadi City, 31001, Anbar, Iraq.

Faiq M. S. Al-Zwainy. Forensic DNA for Research and Training Center, Al-Nahrain University, Al-Jadraia, 10072, Baghdad, Iraq. Corresponding author: faiq.al-zwainy@eng.nahrainuniv.edu.iq, faiqalzwainy@gmail.com

Gasim Hayder. Institute of Energy Infrastructure (IEI), Universiti Tenaga Nasional (UNITEN), Jalan Ikram-Uniten, 43000, Kajang, Selangor, Malaysia.

Одай Хаммуди. Факультет гражданского строительства, Технологический университет, ул. Синаа, 10066, Багдад, Ирак.

Джумаа А. Аль-Сомайдаии. Инженерный колледж, Университет Аль-Анбар, город Рамади, 31001, Анбар, Ирак.

Фаик М.С. Аль-Звайни. Научно-исследовательский и учебный центр судебно-медицинской экспертизы ДНК, Университет Аль-Нахрейн, Аль-Джадрайя, 10072, Багдад, Ирак. Автор, ответственный за переписку: faiq.al-zwainy@eng.nahrainuniv.edu.iq, faiqalzwainy@gmail.com

Гасим Хайдер. Институт энергетической инфраструктуры (IEI), Национальный университет Тенага (UNITEN), Джалан Икрам-Унитен, 43000, Каджанг, Селангор, Малайзия.