Development of an Analytical Software for Cost Estimation for Highway Project

[1]Ibrahim A. Mohammed, [1]Faiq M. S. AL-Zwainy, [2]Huda F. Ibraheem, [1]Moatasem Ibrahim Abed

[1]Faculty of Engineering, Isra University, Jordon.

[2]Head of Quality Section, College of Management and Economics, Al-Iraqia University. Iraq.

Abstract

Background and Objective: This study deals with the problem of estimating accurate costs at early stage of a highway project, where project budgets are to be decided, detailed information is not available and parametric cost estimating techniques are most applicable. The main objective of this study was to introduce a new and alternative approach of using an analytical software for cost estimation of the highway project at the early stage. **Methodology**: In this study, a complete cost estimating software was presented and coded in user-friendly software using Visual Basic language. The software uses neural networks for cost estimation that derive solutions for new highway project. The proposed computer software was developed and evaluated using some projects of highway construction market in Iraq (through questionnaire, personal interviews with experts in the field highway construction contracts). **Results:** The software was successfully run-tested (applicable) on some highway projects. A trial use of the software was conducted with a user guide to simplify the use of software and a complete detailed explanation of each step of cost estimation was presented with a list for each symbol mentioned in the proposed software. **Conclusions:** Evaluation of the proposed cost estimation software indicates that it is effective in cost estimating for highway project.

Keyword: Cost Estimation, Computer Software, Highway Project, Evaluation

INTRODUCTION

The main advantage of cost management process was to provide direction for the project costs management during the project life [1]. Cost estimates evolve through preliminary or conceptual phases into detailed, final, or definitive estimates, depending on the amount of information known when the estimate is prepared. During the preliminary or conceptual phase, minimal information is available about the project, which makes these estimates less accurate. However, preliminary estimates are important to owners, who need to examine these approximate numbers before deciding to continue with a project [2].

Good estimate depends on various factors including estimator's experience, time given to the estimator, and the wide range of assumptions that regarding the project [3]. Construction cost estimating includes collecting, analyzing, and summarizing for all available data of a project [4,5,6].

Cost prediction remains a difficult and complex problem, in spite that, the researchers were still studying and trying different approaches and methodologies to solve it. Preparation of a construction cost estimate for any project is a very complex process. Process of construction cost estimation contains many variable factors [6]. Every variable has to be correctly estimated based on proper study, past experience and research to calculate total project cost of construction [7].

Objective (mathematical and quantitative analysis) and subjective (judgment) techniques are available to modify the reference project and to obtain current costs. A major advantage of the objective method is the ability to identify elements such as seasonal changes and trends in an objective and explicit manner. However, cost estimates are generally prepared by estimators directly involved with the project, so subjective estimates have the advantage of incorporating up-to-date knowledge and feelings about the project. Mathematical techniques cannot represent these things. Estimators tend to develop their own procedures to compile construction costs, based mainly on their experience and intuition [8]. A good estimating technique should include both historical trend-based data and construction experience and knowledge [9,10,11].

It is well known that cost estimation is a process that should be carried out throughout the life cycle of a project from the inception of an idea in the client's mind to the final completion of the project and the final payment to the contractor [12,13]. Traditionally, cost control in the construction industry has not received the attention that it has in other industries, while it is necessary to use cost control to keep the total cost of the job within the building of the client's budget [14,15]. This study represented the development and evaluation of an analytical software which could be used to predict future highway construction costs, throughout the following steps:

1) Development the computer software.

2) Evaluating the computer software.

It can be summarized the importance of this study, as follows:

1) This study provides a simple and effective way to the cost estimation for highway projects. Since this type of the projects have a great importance among other types of the construction projects.

2) Encourage researchers, lecturers and academics to conduct further researchers and integrate with the results of the current study. The motivation of this

study is the limited number of research in the area of cost estimation with regard to highway projects, and the need for a better cost management in highway project.

DEVELOPING OF THE COMPUTER SOFTWARE

The main objective of this computer software was to provide a cost estimation, which also supports bid estimation. This may be justified according to the following points;

1) The importance of such a software is due to its high accuracy in comparison with other cost estimating methods since the recent error that has occurred by the use of such a software is so small that it can be neglected.

2) The lack of effective documentation software in Iraq which can be used to recover the typical costs of highway project, using them to predict construction highway costs for future projects

3) There is no similar software currently in use by highway contracting companies, highway constructing contractors, or any other organization related to highway construction in Iraq. All these authorities and organizations have agreed on the importance of the software as indicated by the questionnaire and personal interviews.

4) In spite of the complicated large highway construction projects Iraq is undertaking, it still suffers from the lack of scientific software and expert for calculating accurate highway estimated construction cost, the total construction cost estimation is important in the bidding stage; therefore, the most popular reason for the failure to awarding construction contracts is the weakness in cost estimation process and the misleading inspections of the construction market.

5) A single completed cost estimate is very seldom considered to be as the last estimate made for the project. As the project progresses, the estimates will need modification for any changes in scope; or any extra costs that may be approved for the project which, as a result, is due to the unforeseen problems or complexity during construction.

In parametric cost estimating models, it is always difficult to decide which parameters to be measured and how to evaluate their significance to the model. This is due to the lack of information at the early stage of project life cycle at which the parametric cost estimating is usually performed. Thus, it is desirable to find the key parameters which give the relevant information and measure the level of importance and uncertainty for each parameter. Such uncertainty can be accounted for by conducting a sensitivity analysis, additional modules also need to be integrated with the software to facilitate the storage of the data and adapt the developed model to new environments.

Once the optimum neural network model was selected, as discussed in chapter six, other modules have been integrated with the optimum Neural Network to develop a comprehensive parametric estimating computer software Figure (1). The computer software consists of:

1) A user interface;

2) Sensitivity analysis module to determine the sensitivity of the predicted cost to changes in cost-related parameters;

3) Database module to store new highway projects into the historical cases; and

4) Adaptation module to re-optimize the Neural Network model on new historical cases and accordingly adapt the model's performance to new environments.

The development of these modules and the operation of the whole software are described in the following sub-sections.
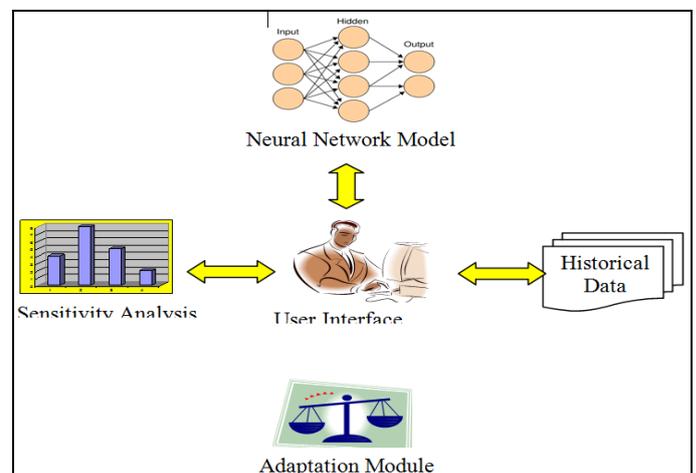

Figure 1. Components of a Parametric Cost Estimating Software.

USER INTERFACE

A user-friendly interface to the estimating software was developed by using Visual Basic programming language. The user interface was developed to facilitate the operation of all modules. This comprehensive parametric estimating software has been designed to be used easily and efficiently by engineers who have little computing experience. So the user will find it easy to make, simple and easy to understand.

The comprehensive parametric estimating software now provides a less inexpensive way to transfer information between different software and users, the technology focus on links, share, change of format, and exchange transformed information and data of the existing software's (Newframe, Microsoft Excel, Microsoft Access and Microsoft Project) by a control software written in Visual Basic (VB).

Visual Basic (VB) was successfully used in developing a wide spectrum of software applications, ranging from simple games

to large business applications used throughout the world. VB is often referred to as a Rapid Application Development (RAD) tool, due to the relative ease with which applications can be developed.

One of the advantage of software developed using VB lies in their Graphical User Interface (GUI), which has the familiar windows look that users are accustomed. The same features and controls, like list boxes, dialog boxes, option buttons, and command buttons, can be incorporated into the applications screen displays. VB is a graphically oriented language, so mush of our software can be accomplished with the click of a mouse.

The operation of the developed computer software is represented by the overall flow chart, which shows the logic used and the components of the developed software-user interface and as shown in Figure (2).
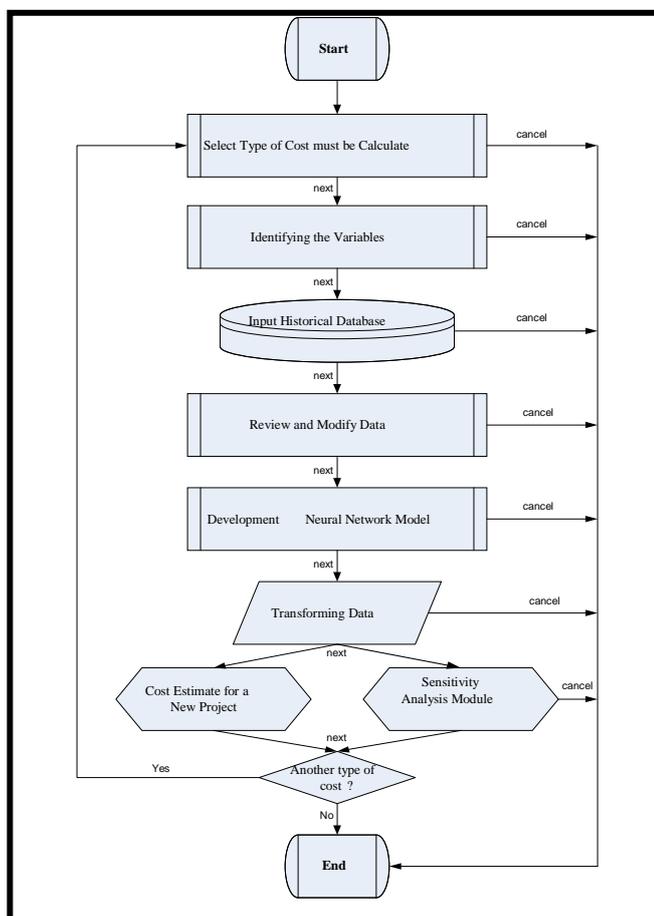

Figure 2. Main Computer Software Steps

HISTORICAL DATABASE AND SOFTWARE-ADAPTATION MODULES

One important aspect of a practical model is to adapt it to new project situations. This enables it to adjust its contractor-independent nature to become more suitable to the user's own work environment. It also enables the build-up experience and incorporates new experiences into the model. In the present study, therefore, an adaptation module has been added to the model. This module uses the user's own historical project

cases as a representative of his work environment. It then re-optimizes the Neural Networks of the model on cases. Initially, the user's historical projects need to be entered into the model by selecting "Add a New Project" button. The user will be prompted for project data and accordingly the cell ranges. Once all data is entered, the "Review and Modify Data" button can be used to browse and modify the projects' data in a manner similar. To re-optimize the neural networks, the user has the flexibility to re-optimize on the total number of projects in the historical database by clicking the "Development Neural Network Model" button.

SENSITIVITY ANALYSIS MODULE

Once the optimum Neural Network model has been selected as described early in Chapter six, it can be put to actual use in predicting the budget cost for a new highway project. In this case, the Neural Network is presented with the user's best judgment concerning the twenty characteristic factors that describe the project.

However, at this early project stage in which the model is applicable, project characteristics might not be decided for certain. A practical model, therefore, has to assess the sensitivity of the model's predictions to the variation in the project characteristics Therefore; a sensitivity analysis module has been incorporated into the present model. This module was coded in Microsoft Excel and was linked to the Neural Networks model. Sensitivity analysis had some steps for performing the analysis. First, the user inputs the weights of variables (from input layer to hidden layer). Second, the user inputs the number of hidden node, and then inputs the weights (from hidden layer to output layer). Third, the user inputs the number of output nodes. Finally, the calculations underlying the sensitivity analysis was done in spreadsheets similar to the computational process according to Al-Zwainy [2]. This approach can be used to determine the relative significance of each input parameter in the model.

COMPUTER SOFTWARE DIALOG

The developed computer software consists of many designed interactive windows as explained in detail below;

1- Start Windows: The first window shows the computer software name, version and copyright, and has three options:

   a) Start

   b) About

   c) Close

Start; to continue work with the software, About; to display general information about the software and Close; to end the computer software as shown in Figure (3) and Figure (4).
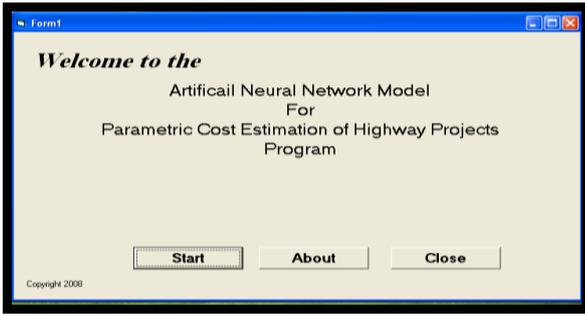
Figure 3. Start Window of the Developed Cost Estimation Software
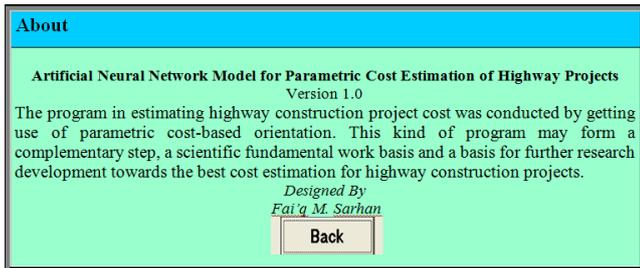

Figure 4. Use of "About" Option

2- Select Cost Estimation of highway project menu.

The second window (Select type of cost highway project window) has four options to select type of cost for highway projects and two command buttons. This window gives the user four options to select the type of cost

      a) Total Cost of Highway Project (TCHP),

      b) Structural Works Cost of Highway Project (SWCHP),

      c) Paving Works Cost of Highway Project (PWCHP),

      d) Earth Works Cost of Highway Project (EWCHP)

The user has to select just one cost type from these four choices. After selecting the required cost, the user should click on one of the two commands, next command, go to the next window, while quit command, go to end or quit from the software. At the starting of the software the default cost type is Total Cost of Highway Project (TCHP), as shown in Figure (5). It is worth to mention that this window can be easily modified to include more selection options (add other cost type).
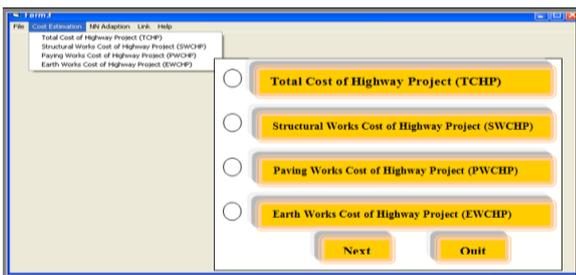

Figure 5. Presentation of Software Calculations.

3- Historical database window.

The third window (historical database), shown in Figure (6), has three options to input the data and information of highway project and two command button. This window has the control of VB on Microsoft Access objects. If the users click on the (**Add New Project**) option, the software automatically open the access software and fill the cells with the required information like (Length of the Pavement in (Km) and number of standard Width lanes, etc). These processes during the dialog box are shown in Figure (7). Once all data is entered, the "**Review and Modify Data**" option can be used to browse and modify the projects' data as shown in Figure (8). If the user clicks on the (Quit) button the software will hide this window and returns to the previous window. But, if the user clicks on the (Next) button the software will appear the next window (**NN Adaptation Options**), Figure (9).
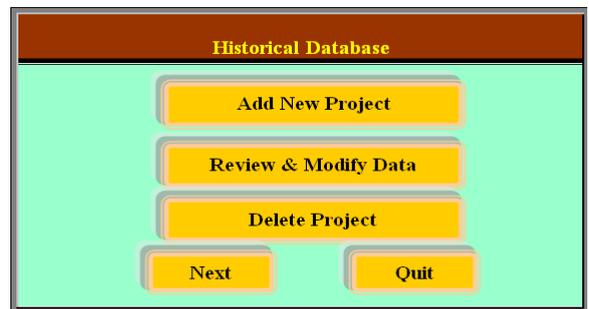

Figure 6. Presentation Historical Database

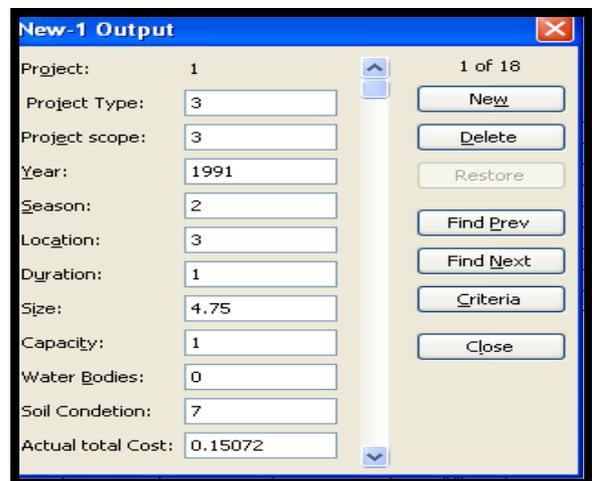**Figure 7.** Input Data for New Project

Figure 8. Review and Modify Data

Figure 9. Use of "NN Adaptation" Options

4- NN Adaptation Options window.

The forth window (NN Adaptation Options), as shown in Figure (9), has the control of VB on *Neuframe* software and *Microsoft Excel* objects. Three options appear in this window as the following;

    a) Development of Neural Network Model

    b) Sensitivity of Analysis Module

    c) Cost Estimate for a New Project

If the user clicks on the (Development Neural Network Model) option, the software automatically opens the *Neuframe* software. This software is used to obtain the optimal network architecture determined by trial-and-error. The small number of connection weights obtained by *Neuframe* for the optimal ANNs model enables the network to be translated into a relatively simple formula. When the user selects the (Sensitivity Analysis Module) option, the weights can be used to identify which of the input variables have the most significant impact on the output predictions; this can be done by using *Microsoft Excel* software

Once the model is re-optimized or developed, it can be used to estimate the cost of new projects by selecting the "calculate the highway construction cost estimation" option. It should be noted that model adaptation permits the user to add new historical data to the model, without introducing changes to the structure of the model itself such as the number of inputs and hidden nodes, which had been fixed at an early stage.

To calculate the highway construction cost estimation, the user clicks on the (**calculate the highway construction cost estimation**) option, and the user should be entering the value of all variables as shown in Figure (10). Then the software will summarize and present the cost estimation results on the basis of either, total cost, structural cost, paving cost or earth cost.
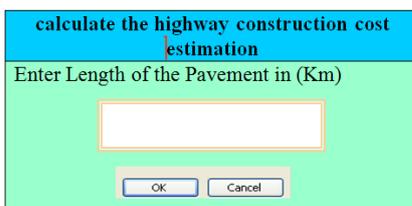

Figure 10. Calculation of the Highway Construction Cost Estimation

The software will have the ability of print and save the cost estimation results as shown in Figure (11) and Figure (12) Respectively.
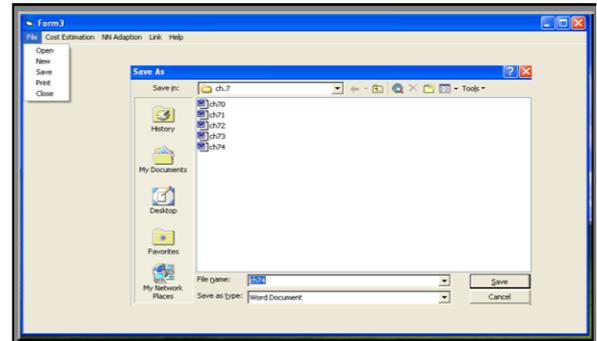

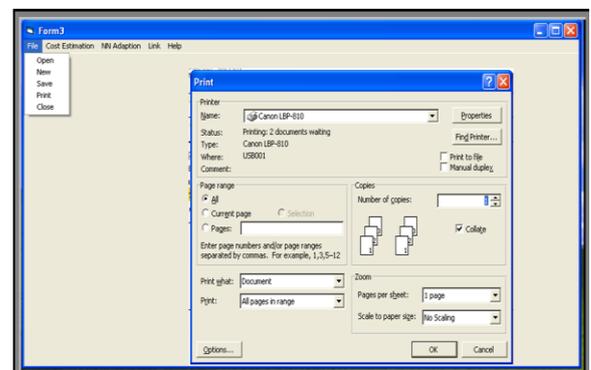**Figure 11.** Use of "Save" Option

Figure 12. Use of "Print" Option

Finally, the software will have the ability to work, in link with other useful related software (Microsoft Project, Microsoft Visio, Microsoft Excel and SPSS), to get the support of statistical, mathematical, analytical and data preserving abilities of such software. Figure (13) shows this facility.
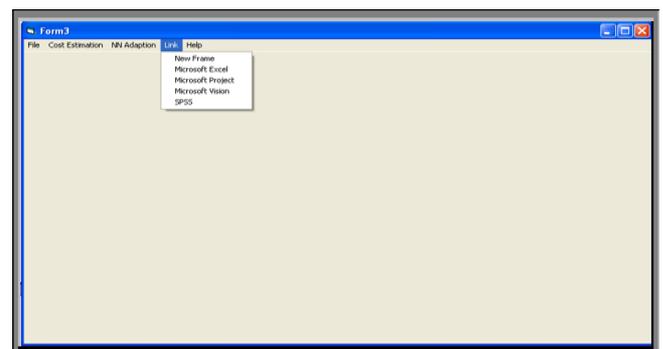

Figure 13. Use of "Link" Option

The computer software includes a help list facility which consists of two items. The first one is the "about" item, which deals with the software itself (version, year of publication and introduction of software, etc.) the second item is the "topics" which deals with the manual usage of the software. The help facility print screen is shown in Figure (14).
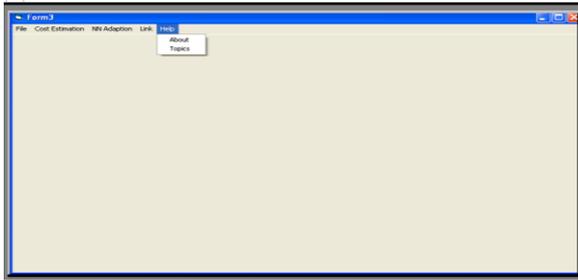
Figure 14. Use of "Help" Option

EVALUATION OF THE PROPOSED SOFTWARE

The proposed software evaluation process should take into account operating the software before an open discussion connected with some of specialized experts concerning with this type of work. This process was performed through two evolutionary steps which are:

1. Application of the Proposed Software

2. Evaluation interviews.

Application of the Proposed Software

The purpose of the application of the software is to examine the efficiency and verify the performance, also to detect any error, defects, difficulties that may face the users through their application of the proposed software.

The computer software was successfully run-test on some highway projects, not included in the model calibration procedures, and was used as independent verification checks. The results of the analysis are presented in Table (1). The data collected from the three companies derived for projects performed after the war out break in (March 2003), to ensure that all the projects constructed in the same period.

Table (1) Highway Cost as Computed Using the Proposed Software, Compared to the Actual Submitted Bid Cost.

Project No.	Length (Km)	Actual Cost (Submitted Bid Cost) (A)	Estimated Cost (Using Proposed Software) (E)	|A-E|/A
Prj.1	40	60000000	58550000	0.024
Prj.2	15	22500000	22430000	0.0031
Prj.3	30	48000000	47115000	0.018
Prj.4	50	70000000	69050000	0.0136
Prj.5	23	33350000	30250000	0.093

The analyzed result indicates that the project construction costs predicted by the proposed software are closer to the actual construction cost. Finally, due to non-availability of the breakdown details in bids, it is impossible to indicate how the details of the bids deviate if they are prepared without using the software.

Evaluation Interviews

The evaluation process consists of fifteen experts, from the three companies, having experience in planning and cost processes. The evaluation form was distributed to the individuals to get their opinions, comments and recommendations about the operation and the feasibility of the proposed software. The characteristics of these personnel summarized in Table (2).

Table (2) Characteristic of the Interviewees.

No.	Work Sector	Position	Eng. Field	Academic Degree	Experience Years
1	State S.C.R.B.	Highway Designer	Civil	B.Sc.	16
2	State S.C.R.B.	Highway Designer	Civil	B.Sc.	20
3	State S.C.R.B.	Highway Designer	Civil	B.Sc.	24
4	State S.C.R.B.	Highway Projects Resident Eng.	Civil	M.Sc.	15
5	State S.C.R.B.	Highway Projects Resident Eng.	Civil	B.Sc.	13
6	State A.C.C.	Project Manager	Civil	B.Sc.	20
7	State A.C.C.	Project Manager	Civil	M.Sc.	20
8	State A.C.C.	Project Manager	Civil	B.Sc.	18
9	State A.C.C.	Highway Projects Resident Eng.	Civil	M.Sc.	10
10	State A.C.C.	Highway Projects Resident Eng.	Civil	B.Sc.	16
11	State H.C.C.	Project Manager	Civil	M.Sc.	22
12	State H.C.C.	Chief Engineer	Civil	M.Sc.	20
13	State H.C.C.	Chief Engineer	Civil	B.Sc.	22
14	State H.C.C.	Chief Engineer	Civil	B.Sc.	22
15	State H.C.C.	Highway Projects Resident Eng.	Civil	M.Sc.	18

The following sequences of steps were undertaken to complete the computer software evaluation interviews:

1) The evaluation documents were prepared to include a summary of the prepared software such as software dialog.

2) The prepared evaluation documents were handed over to the selected concerned people with a general overall preliminary presentation of its contents.

3) Sufficient time period was allowed to study these documents.

4) A prepared sort of questionnaire form Table (2) was filled for each evaluation characteristics or questions.

5) Five answers as choices (excellent, very good, good, poor, none) were given.

6) Selection of the appropriate answer choice was left up to the satisfaction of the concerned person for estimation.

7) Upon completion of the interview, evaluation replies were personally collected.

The characteristics or questions related to evaluate the proposed software and the respondent's answer are summarized in Table (3) below, which also contain the evaluation degree for each question.

Table (3) Evaluation the Questions and Answers.

The Questions and Program Characteristics	Observed Frequency						Mean Score	Results
	<50	50-60	60-70	70-80	80-90	90-100		
	Poor	Acceptable	Moderate	Good	Very Good	Excellent		
The important of the proposed program to your company.				2	10	3	86	Very Good
The assistants that the program provides to the planners and estimators (Effectiveness)				1	4	10	91	Excellent
Accuracy of estimations				1	13	1	85	Very Good
The flexibility of collect and entering the data in the program (user interface). (Usability)				1	1	13	93	Excellent
The need of support from decision making authorities				4	8	3	84	Very Good
The need for qualified users			1	3	8	3	84	Very Good

The results indicate that the proposed development of the computer software is acceptable and can achieve the required estimation and control of highway construction cost. This indicates that the proposed software is efficient and complete and it can be used with more effectiveness if the decision making authorities support it.

Although the proposed software is efficient, it required personnel which are rare to find in the field of managerial cost estimation conditions. Therefore, the proposed software can be applied gradually while subsequently qualified computer staffs are being trained on the software.

CONCLUSION

This study gives a description of the developed computer software, which is an efficient tool for cost estimation. It also includes the evaluation of the computer software by the experienced engineers in the field of construction management. The use of the proposed software was proved to be practical, reliable, fast and efficient in cost estimation techniques from both principle and applicable point of view. Furthermore, every highway company can suit its needs with the software. The evaluation result of the proposed software shows the importance of implementing such a software in the construction companies. Certain comments and notes have been raised concerning the proposed managerial tool applicability, which can be handled through an effective support at the decision making levels and improving computer skill of the users.

Conflicts of Interest

Authors declare that there are no conflicts of interest regarding the publication of this research.

REFERENCES

[1] Faiq, M. S., Reem, A., and Tareq, Kh., 2016, "Reviewing of the Simulation Models in Cost Management of the Construction Projects", Civil Engineering Journal,2:607-622, http://civilejournal.org/index.php/cej/article/view/186, [Accessed 15 Aug. 2017].

[2] Al-Zwainy F. M., 2009. "The Use of Artificial Neural Net Work for Estimate Total Cost of Highway Construction Projects", Ph.D. thesis, Civil Engineering Department, Baghdad University, Iraq.

[3] Jrade A. and Alkass S., 2007, "Computer-Integrated System for Estimating the Costs of Building Projects", Journal of Architectural Engineering, 13, **https://doi.org/10.1061/(ASCE)1076-0431(2007)13:4(205)**, [Accessed 10 Aug. 2017].

[4] Holm L., Schaufelberger J. E., Griffin D., and Cole T., 2005, "Construction Cost Estimating Process and Practices", Pearson Education, Upper Saddle River, NJ, USA.

[5] Al-Zwainy, F. M. S. and Hadhal, N. T., 2016. "Application Artificial Forecasting Techniques in Cost Management (review)", Journal of Engineering, 8:1-15, https://www.iasj.net/iasj?func=article&aId=112083, [Accessed 28 Aug. 2017].

[6] Al-Zwainy, F. M. S. and Hadhal, N. T., 2016, "Building a Mathematical Model for Predicting the Cost of the Communication Towers Projects Using Multifactor Linear Regression Technique", International Journal of Construction Engineering and Management, 5: 25-29, DOI: 10.5923/j.ijcem.20160501.03

[7] Al-Zwainy, F. M. S. and Hadhal, N. T., 2015. "Investigation and Evaluation of the Cost Estimation Methods of Iraqi Communication Projects", International Journal of Engineering and Management Research, IJEMR, 5:41-48, http://www.ijemr.net/DOC/InvestigationAndEvaluation OfTheCostEstimationMethodsOfIraqiCommunicationP rojects(41-48).pdf, [Accessed 2 Sep. 2017].

[8] Purifoy, R. L.and Oberlender G. D., 2002, "Estimating Construction Costs", 5th ed., McGraw-Hill.

[9] Al-Zwainy, F. M. S., Al-Suhaily, R. H. and Saco, Z. M., 2015. "Project Management and Artificial Neural Networks: Fundamental and Application", 1st ed., LAP LAMBERT Academic Publishing, Germany.

[10] Ibrahim Abed Mohammed, Faiq Mohammed Sarhan, and Duha Sameer, 2014. "Evaluation The Performance of the Infrastructure Project Using Earned Value

Management". International Journal of Civil Engineering and Technology (Ijciet), 5:145-155.

[11] Ibrahim A. Mohammed, Duha S. Mohsen, Faiq M. Sarhan Alzwainy. 2015. "Earned Value Management in Construction Project". 1st ed., LAP LAMBERT Academic Publishing, Germany.

[12] Al-Suhaily, R. H., Saco, Z. M., Al-Zwainy, F. M. S., 2010. "Using the Artificial Neural Networks for Predicting the Total Cost of Highway Projects in Iraq", The 2nd Regional Conference for Engineering Sciences, College. of Engineering, Al-Nahrain University, Iraq, pp 846-867.

[13] Faiq M. Al-Zwainy, Reem Amer, 2016. "Investigation Cost Deviation of Highway Project". Research Journal of Applied Sciences, Engineering and Technology, 13:843-855.

[14] Al-Zwainy, F.M.S. and Mezher, R.A. 2017. "Diagnose the Causes of Cost Deviation in Highway Construction Projects by Using Root Cause Analysis Techniques". Arab Journal Science and Engineering 1-12, https://doi.org/10.1007/s13369-017-2850-2.

[15] AL-Zwainy, F.M.S. and Aidan, I.A., 2017. "Forecasting the cost of structure of infrastructure projects utilizing artificial neural network model (highway projects as case study)". Indian J. Sci. Technol. 10(20), 1–12. doi:10.17485/ijst/2017/v10i20/108567