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# Application of Artificial Neural Network to Forecast Actual Cost of a Project to Improve Earned Value Management System

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***Abstract*—**This paper presents an application of Artificial Neural Network (ANN) to forecast actual cost of a project based on the earned value management system (EVMS). For this purpose, some projects randomly selected based on the standard data set , and it is produced necessary progress data such as actual cost ,actual percent complete , baseline cost and percent complete for five periods of project. Then an ANN with five inputs and five outputs and one hidden layer is trained to produce forecasted actual costs. The comparison between real and forecasted data show better performance based on the Mean Absolute Percentage Error (MAPE) criterion. This approach could be applicable to better forecasting the project cost and result in decreasing the risk of project cost overrun, and therefore it is beneficial for planning preventive actions.

***Keywords*—**Earned Value Management System (EVMS), Artificial Neural Network (ANN), Estimate At Completion, Forecasting Methods, Project Performance Measurement.

## I. Introduction

### A. Earned Value Management System (EVMS)

AT recent years, one of the important problems for project management team is accurate estimation time and cost of work completion in a project. EVMS is known method with wide application which is used for project cost (time) forecasting in management of a project. EVMS was initially conceived by industrial engineers in the USA, such as Fredrick W. Taylor, Henry L. Gantt, and others in late 19th century (Fleming & Koppelman, 2005, p. 26) [1]. Earned Value Management System (EVMS) is a systematic approach for EAC estimation and EVMS concept is used to measure project progress and calculate Earned Value (EV) of project and forecast EAC in every period of controlling the project progress, on that basis, EVM is seen as a useful control and communication technique that, should assist management in achieving the successful completion of the project. The earned value cost management report is a valuable management tool for project managers. The problem of estimating its completed cost was a critical contributing factor. One of the core pieces of information necessary for fasten contract is an accurate forecast of ACWP and EAC.

The Project Management Institute defines earned value management (EVM) as "a management methodology for integrating scope, schedule, and resources, and for objectively measuring project performance and progress. Performance is measured by determining the budgeted cost of the work performed (i.e. earned value or BCWP) and comparing it to the actual cost of the work performed (i.e. ACWP), that in this paper to estimate actual cost using ANN method.

This paper is structured as follows: Section II includes a brief explanation about artificial neural network. Section III exhibits a method for forecasting actual cost, Section IV presents the case studies based on the real projects and its accuracy for two selected random project is studied and finally, section V presents conclusion of this work.

### B. EAC Formulas

All EAC formulas are based on the combination of several data elements presented on the cost management report: Budgeted Cost of Work Scheduled (BCWS), Budgeted Cost of Work Performed (BCWP) and Actual Cost of Work Performed (ACWP). The basic data elements are shown in Fig. 1 as time-cost curve with S shape in EVMS literature [2].

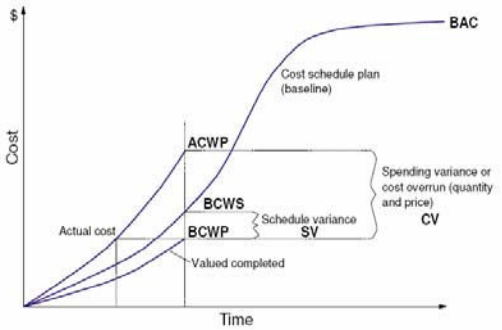


Fig. 1 Basic time and cost S-curve in EVMS

According to work Christensen and et al. at reference [3] EAC formulas are classified into three categories:

1. Index
2. Regression (linear regression analysis, non linear regression analysis, …)
3. New method (Time series, ANN, …)

Generally index based formula is as follows:

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$$EAC = ACWP_c + (BAC - BCWP_c)/Index \quad (1)$$

The subscript "c" indicates cumulative data. Budget at Completion (BAC) is the total budget for the identified work. The performance indices are classified into four groups.

Cost Performance Index:

$$(CPI) = BCWP/ACWP \quad (2)$$

Schedule Performance Index:

$$(SPI) = BCWP/BCWS \quad (3)$$

Schedule Cost Index:

$$(SCI) = SPI \times CPI \quad (4)$$

Composite Index:

$$(CI) = w_1.SPI + w_2.CPI \quad (5)$$

The weights ($w_1$ and $w_2$) shown in Equation (5) can take on any value from 0 to 1, and normally add to unity. The indices can be based on monthly, cumulative, or averaged data. The formulas for Regression models are presented in some papers mention at references [7], [8], [9], [10].

### C. Literature Review of EAC

The cancellation of the Navy's A-12 program has increased interest in forecasting the completed cost of a defense contract, termed "Estimate at Completion" (EAC) [4]. The work done in this topic generally estimate (EAC) on based one of the explained three class at up. Also, there have been many studies that either compare existing EAC formulas and models, or propose new ones, few have been published in journals or magazines and there is little guidance regarding which formula or model is most accurate.

The main core of the EV is forecasting and it needs to improve the technique in this area of study. That through them, we could point to some study as follows:

Parker's [5] (Defense Logistics Agency, 1980) method consists of simply computing a range of composite indices, with the weights varying from 0 to 1 in increments of 0.1. The analyst would then subjectively decide which composite index to be most appropriate given the conditions of the contract. Haydon and Riether [6] (ManTech Corporation for Navy Weapons Engineering Support Activity (NAVWESA, 1982) proposed a technique to develop a point estimate from a range of EACs computed using various formulas.

Sincavage [7] (Army Aviation Systems Command, 1974) proposed using time series analysis to forecast the EAC.

Watkins [8] (Navy Postgraduate School, 1982) proposed using linear regression analysis and an adaptive form of the Rayleigh-Norden model. In this study, the model is used in a linear regression analysis of ACWP against time.

Altogether these studies propose forecasting methods which are based on other techniques such as regression analysis, time series or performance indices. In literature, some study has compared the two or more EAC formulas such as: Karsch [9] (Aeronautical Systems Division, 1974) compared one index based formula (CPIc) and two nonlinear models using data from a development contract managed by the Air Force. Price [10] (Air Force Institute of Technology, 1985) evaluated five index-based formulas and one linear Regression model using data from 57 development contracts managed by the Air Force.

Literature review shows that presented methods at estimate of EAC research are very limited. But recently, there are a few works using new method, alike conference paper Iranmanesh and et al. [11] that presented new method for EAC, and a new formalism and a corresponding new notation for earned value analysis were presented in Reference [12] as well. Also, Vandevoorde, et al. compared different project duration forecasting methods using earned value metrics [13]. Gray et al. [14] includes good materials for new methods and the reader could refer to it. In this paper it is focused on the development of a new method to forecast ACWP and EAC based on the artificial intelligence methods.

## II. Forecasting with Neural Networks

Forecasting with artificial neural networks before the early 1920s, forecasts were calculated by simply extrapolating time series. What might be dubbed as ''modern forecasting'' began in 1927, when Yule presented auto-regressive techniques to forecast the annual number of sun spots (Yule, 1927). Gradually, two crucial developments took place that changed time series research. On the one hand, ever increasing capacity and enhanced features of personal computers meant that much longer time series could be handled and more sophisticated algorithms could be used. This went hand in hand with a second aspect the development of machine learning techniques, such as ANNs [15].

ANNs are mathematical models based upon the functioning of the human brain, and are composed of three different layers input, hidden and output layers each of which are composed of a certain number of neurons. Also ANN is ability to approximate practically any function (even non-linear ones) and the opportunity for ''piece-wise'' approximations of the functions. This means that ANNs have the capacity to build non-linear piece-wise models. ANN network composed of three are named, input layer, output layer and hidden layer that usually selected of number of layer ANN is important problem for designer ANN. ANNs with one or more hidden layers can separate the space in different areas and build different functions for each of them. Forecasting with neural networks involves two steps: training and learning. Training of feedforward networks is normally performed in a supervised manner. One assumes that a training set is available, given by the historical data, containing both inputs and the corresponding desired outputs, which is presented to the network. The adequate selection of inputs for neural network training is highly influential to the success of training. In the learning process a neural network constructs an input–output mapping, adjusting the weights and biases at each iteration based on the minimization of some error measure between the output produced and the desired output. Thus, learning entails an optimization process.

The error minimization process is repeated until an acceptable criterion for convergence is reached. For evaluate the accuracy of the neural network approach in forecasting

cost, we compute the mean absolute percentage error MAPE criterion, that MAPE criterion is given by:

$$MAPE = \frac{1}{N}\sum_{t=1}^{N}\frac{|y_t-\hat{y}_t|}{(y_t+\hat{y}_t)/2}\times 100 \quad (6)$$

Where $y_t$ and $\hat{y}_t$ are the actual and forecast values, and N is the number of forecasts.

In this paper we apply ANN for assessment EAC such that explained properties ANN at up. For these work, we use MLP (multiple layer perceptron) architecture with traditional learning algorithm for the MLP is called backpropagation (PB). Fig. 2 shows a MLP with $l$ layer.

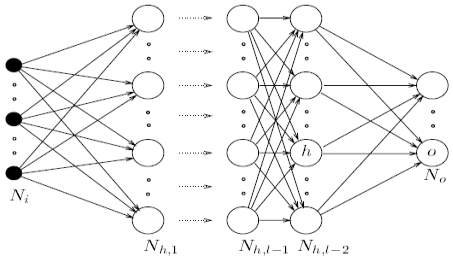


Fig. 2 A multi layer perceptron network with $l$ layer

## III. Methodology

One of the core pieces of necessary information for a project management team is an accurate estimation of Actual Cost of Work Performed (ACWP) and EAC. Usually project manager need to estimate this values at short time and calculate EAC at the start of their contracts. For this reason selection of ANN approach can be recommended. Other reasons are:

1. S- shape is a common trend for all of projects in a period of time and this behavior can be modeled by NN properly.
2. NN is a fast and accurate method for estimating rather than traditional methods.
3. In this study, as the basic data can be generated via a project simulator, so we do not have any limitation in data for training NN. Therefore, ANN can be a good option for forecasting.

This paper has utilized of 100 sample projects which were simulated randomly. These simulated projects have 92 tasks with various precedence networks which were selected from a ProGen software. ProGen was a known project generator software and generates typical projects for Resource Project Scheduling Problem (RCPS). The reader, for more information about the recent researches on RCPS could refer to [16]. As it was needed project progress data at five periods for input of NN, so we generated these data by using a progress simulator which was presented in reference [11]. The selected periods in this study are 20%, 40%, 60%, 80% and 100% of project duration.

A three-layered feedforward neural network with one hidden layer and five input neurons, which are the value of BCWS in 20% to 100% duration periods, was designed for forecasting. This NN has a layer in output which is ACWP in similar five input periods (20% to 100%). The NN was trained through 100 projects with above specification in similar short periods which was about 3 months for all of the projects. The neural network toolbox of MATLAB was selected due to its flexibility and simplicity [17].

## IV. Case Study

Five different type of neural networks, respectively with 2, 3, 5, 7 and 10 neurons in hidden layer were designed for selecting NN with better architecture. Then, it was calculated error MAPE criterion for test data. Table I shows these MAPE values.

TABLE I
MAPE FOR DIFFERENT TYPE OF NN STRUCTURE

| Number of neurons in hidden layer | 2 | 3 | 5 | 7 | 10 |
|---|---|---|---|---|---|
| MAPE | 5.2485 | 4.5378 | 3.8632 | 4.0724 | 5.3650 |

By comparing computed errors, we selected NN with 5 neurons in hidden layer which has minimum MAPE, as shown in Table I.

After training this NN, to test network performance, it was selected two random projects, and then forecast linear piece-wise curve of ACWP and EAC for them. For each project, the network was run and the result could be seen in Figs. 3 and 4.

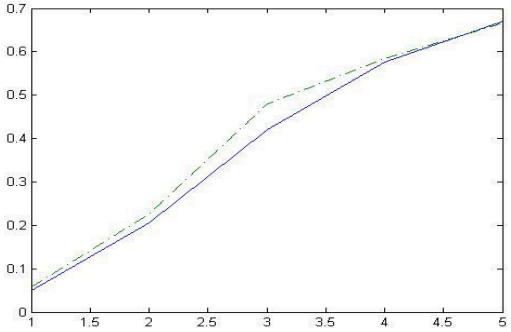


Fig. 3 Forecasted results and actual results for project 1

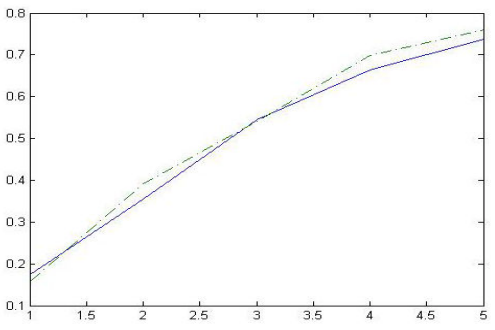


Fig. 4 Forecasted results and actual results for project 2

In Figs. 3 and 4, continuous line is real value of ACWP for five periods of time for the first and second projects, and dash line is forecasted values. These figures show that error of forecasting is low. Table II shows average absolute percentage error in each period of time for two projects.

TABLE II
AVERAGE ABSOLUTE ERROR FOR TWO PROJECTS

| Name | average absolute percentage error In each period of time |
|---|---|
| Project 1 | 6.1055 |
| Project 2 | 5.7267 |

The results show a strong relation between forecasted costs and actual costs, also those possibly confirm the ability of ANN approach in forecasting for other projects.

This experiment and study shows using ANN approach can be successful for estimating ACWP and it is a good news for further researches and they maybe they can change the NN structure to get better results forecasting.

## V. Conclusion

In this paper a neural network approach to forecast actual cost was studied based on two typical projects to achieve some evidences for successfully of ANN approach in project cost forecasting. It was generated some progress data for five periods of time (20%, 40%, 60%, 80%, 100%) for two above random projects and trained a NN. The result show average errors in two typical samples are acceptable and it can be hopeful for researcher to applying this method with new hypothesis on network structure. It is notable that this study is an introductory study and can be extend in various areas such as changing the NN structure, time periods and so on. But, it is notable that our purpose of this study is only discovering of the role of ANN approach in project forecasting. As there are a few studies on application of ANN in project estimation, therefore it is a good opportunity to accurately forecast time and cost of a project through applying ANN approach.

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