HBRC Journal (2014) **10**, 35–42

Housing and Building National Research Center

HBRC Journal

http://ees.elsevier.com/hbrcj

FULL LENGTH ARTICLE

Forecasting project schedule performance using probabilistic and deterministic models

Abdel Azeem S.A. *, Hossam E. Hosny, Ahmed H. Ibrahim

Department of Construction Engineering, Faculty of Engineering, Zagazig University, Egypt

Received 20 January 2013; revised 14 August 2013; accepted 2 September 2013

KEYWORDS

Cost control;
Construction;
Earned value;
Forecasting;
Kalman;
Probabilistic

Abstract Earned value management (EVM) was originally developed for cost management and has not widely been used for forecasting project duration. In addition, EVM based formulas for cost or schedule forecasting are still deterministic and do not provide any information about the range of possible outcomes and the probability of meeting the project objectives. The objective of this paper is to develop three models to forecast the estimated duration at completion. Two of these models are deterministic; earned value (EV) and earned schedule (ES) models. The third model is a probabilistic model and developed based on Kalman filter algorithm and earned schedule management. Hence, the accuracies of the EV, ES and Kalman Filter Forecasting Model (KFFM) through the different project periods will be assessed and compared with the other forecasting methods such as the Critical Path Method (CPM), which makes the time forecast at activity level by revising the actual reporting data for each activity at a certain data date. A case study project is used to validate the results of the three models. Hence, the best model is selected based on the lowest average percentage of error. The results showed that the KFFM developed in this study provides probabilistic prediction bounds of project duration at completion and can be applied through the different project periods with smaller errors than those observed in EV and ES forecasting models.

Introduction

A typical project control process consists of monitoring actual performance, comparing it with planned performance, analyzing the difference, and forecasting the final outcomes at completion resulting from management actions [1]. EVM was originally developed for cost management and has not widely been used for forecasting project duration [2]. Three fundamental limitations arise in EVM-based cost or schedule forecasting. First, EVM based formulas for cost or schedule forecasting are deterministic and do not provide any information about the range of possible outcomes and the probability

* Corresponding author. Tel.: +20 1002835881.
E-mail addresses: eng_abdel82@yahoo.com (S.A. Abdel Azeem), hosny_hosm@yahoo.com (H.E. Hosny), mekky69@yahoo.com (A.H. Ibrahim).
Peer review under responsibility of Housing and Building National Research Center.

Production and hosting by Elsevier

1687-4048 © 2013 Production and hosting by Elsevier B.V. on behalf of Housing and Building National Research Center.
http://dx.doi.org/10.1016/j.hbrcj.2013.09.002

Notation

CPM	Critical Path Method
EDAC	Estimated Duration At Completion
ES	earned schedule
EV	earned value
KFFM	Kalman filter forecasting model
PD	planned duration
PV	planned value
SPI(t)	schedule performance index calculated by earned schedule
SPI	schedule performance index calculated by earned value
SV	schedule variance
TV(t)	time variation calculated by earned schedule

of meeting the project objectives. Second, EVM have some measurement errors because of the difficulty of measuring the progress on projects exactly. Such these measurement errors make the forecast unreliable for the project managers [1]. Third, the schedule variance calculated by the EVM does not measure time but is expressed in a monetary unit [2]. Recently, Naeini, and Heravi developed a probabilistic project control concept based on stochastic S curves to assure an acceptable forecast of project cost performance [3]. Vandevoorde and Vanhoucke [2] compared three different EV-based approaches for schedule forecasting and demonstrated that the Earned Schedule Management (ESM) is the only method among those tested methods that provides reliable forecasting results. Kim and Reinschmidt [1] compared the results of Kalman filter forecasting model (KFFM) against the results of the ES model and such the comparison showed that the ES model produced more erratic responses to reported performance than the KFFM, resulting in large changes to the forecasted Estimated Duration At Completion (EDAC). The EV, ES and KFFM models make the time forecast at the project level by comparing the EV cost versus the planned value cost (PV) at a certain data date. Therefore, the accuracies of the three developed models from the start of a project to the completion will be assessed and compared with the other time forecasting methods such as the Critical Path Method (CPM) that makes the time forecast at activity level through updating the planned original network by actual report data for each activity at a specified data date. In this paper, a new forecasting method will be developed based on Kalman filter and the earned schedule method. The ESM serves as a basic performance measurement system and the KFFM proposed in this paper is based on time variation in the time dimension and provides confidence bounds on the time predictions, which can be used as an effective tool to predict the time forecast at the project level. The outline of this paper is as follows. In the next section, research objectives, EV and ES forecasting methods are reviewed, with a discussion of their limitations for practical implementation. Then, the ESM and the Kalman filter are briefly described in order to facilitate the understanding of the formulation of the KFFM. Based on the reviews of ESM, and Kalman filter, the KFFM is formulated. Numerical example is presented to validate the three models against the most accurate method (CPM).

Research objectives

This study presents a probabilistic project time forecast concept to assure an acceptable forecast of project time performance. Three models will be developed to forecast the estimated duration at completion. Two deterministic models were developed, based on the EV, ES principles. The results of those models were compared with the similar results of a suggested probabilistic model that was developed based on Kalman filter algorithm and earned schedule management. Hence, the accuracies of the EV, ES, and KFFM models through the different project periods will be assessed and compared with the other forecasting methods such as the traditional Critical Path Method (CPM), which makes the time forecast at the activity level. Subsequently, the best time forecasting model will be selected based on the lowest mean absolute invalidity percent. In the next section of this paper, the principles of the earned value, earned schedule, and Kalman filter will be discussed. Hence, a case study project will be used to validate the results of the three models. Finally, based on the results of such case study, some conclusions regarding the best model for project duration forecasting will be provided.

Methodology

Earned value management

The Project Management Institute (PMI, 2008) [4] defined EVM as a management methodology for integrating the project's scope, schedule, and resources, and for objectively measuring project performance and progress from project initiation through closeout. EVM relies on three basic performance variables earned value (EV), actual cost (AC), and planned value (PV), to evaluate where a project is and where it was supposed to be. The schedule variance (SV), schedule performance index (SPI), Estimated Duration At Completion is calculated by EV model ($EDAC_{(EV)}$) as

$$SV = EV - PV \tag{1}$$

$$SPI = EV/PV \tag{2}$$

$$EDAC_{(EV)} = PD/SPI \tag{3}$$

where PD is planned duration. At the end of a project, the EV = PV = BAC (budget at completion), and hence, the SV and SPI always equals 0 and 1, respectively. If SV = 0 and SPI = 1, the earned work is exactly as planned, regardless of the real project status (behind, on schedule or ahead) [1,5]. Fig. 1 shows a graphical representation of the two variables (EV and PV) regarding to the time forecast.