Available online at www.sciencedirect.com
ScienceDirect

International Journal of Project Management 35 (2017) 28 – 43

International Journal of Project Management
www.elsevier.com/locate/ijproman

Improving project forecast accuracy by integrating earned value management with exponential smoothing and reference class forecasting

Jordy Batselier [a], Mario Vanhoucke [a,b,c,*]

[a] Faculty of Economics and Business Administration, Ghent University Tweekerkenstraat 2, 9000 Ghent, Belgium
[b] Technology and Operations Management Area, Vlerick Business School Reep 1, 9000 Ghent, Belgium
[c] UCL School of Management, University College London, 1 Canada Square, London E14 5AA, United Kingdom

Received 4 May 2016; received in revised form 22 September 2016; accepted 3 October 2016
Available online xxxx

Abstract

In this paper, the earned value management (EVM) project control methodology is integrated with the exponential smoothing forecasting approach. This results in an extension of the known EVM and earned schedule (ES) cost and time forecasting formulas. A clear correspondence between the established approaches and the newly introduced method – called the XSM – is identified, which could facilitate future implementation. More specifically, only one smoothing parameter is needed to calculate the enhanced EVM performance factor. Moreover, this parameter can be dynamically adjusted during project progress based on information of past performance and/or anticipated management actions. Additionally, the reference class forecasting (RCF) technique can be incorporated into the XSM. Results from 23 real-life projects show that, for both time and cost forecasting, the XSM exhibits a considerable overall performance improvement with respect to the most accurate project forecasting methods identified by previous research, especially when incorporating the RCF concept.

Keywords: Project management; Time series forecasting; Duration forecasting; Cost forecasting; Project control; Empirical database

1. Introduction

Forecasting an ongoing project's actual duration and cost is an essential aspect of project management. One of the most widely used and best performing approaches for obtaining such forecasts is that based on the earned value management (EVM) methodology. To ensure the standalone comprehensibility of this paper, a concise summary of EVM's key definitions and formulas is included in Table 1.

The metrics below the middle line in Table 1 can be used to indicate a project's schedule and cost performance at a certain point during project execution (i.e. at a certain tracking period). More specifically, a schedule variance SV or $SV(t) < 0$ (>0) and a schedule performance index SPI or $SPI(t)$ <1 (>1) express that the project is behind (ahead of) schedule. Similarly, regarding project cost, a cost variance CV <0 (>0) and a cost performance index CPI <1 (>1) reflect a project that is over (under) budget. When the schedule or cost variances are equal to zero, the project is right on schedule or on budget, respectively. This corresponds with schedule or cost performance indices that are equal to unity.

The utility and reliability of EVM as a method for evaluating a project's current cost performance and forecasting its actual cost has been endorsed ever since the introduction of the technique in the 1960s. The performance of EVM for the time dimension, however, only got the necessary boost from the introduction of the extending concept of earned schedule (ES)

---

[*] Corresponding author at: Technology and Operations Management Area, Vlerick Business School Reep 1, 9000 Ghent, Belgium.
E-mail addresses: jordy.batselier@ugent.be (J. Batselier), mario.vanhoucke@ugent.be (M. Vanhoucke).

http://dx.doi.org/10.1016/j.ijproman.2016.10.003
0263-7863/00

Table 1
EVM key metrics and formulas.

Metric	Definition/formula
PD	Planned duration, the planned total duration of the project
BAC	Budget at completion, the budgeted total cost of the project
AT	Actual time
PV	Planned value, the value[a] that was planned to be earned at AT
EV	Earned value, the value that has actually been earned at AT
AC	Actual cost, the costs that have actually been incurred at AT
ES	Earned schedule, the time at which the EV should have been earned according to plan, $ES = t + \frac{EV-PV_t}{PV_{t+1}-PV_t}$ with t the (integer) point in time (i.e. tracking period) for which $EV \geq PV_t$ and $EV < PV_{t+1}$
$EAC(t)$	Estimated duration at completion, the prediction of RD made at AT
$EAC(\$)$	Estimated cost at completion[b], the prediction of RC made at AT
RD	Real duration, the actual total duration of the project
RC	Real cost, the actual total cost of the project
SV	Schedule variance, $SV=EV-PV$
SPI	Schedule performance index, $SPI = \frac{EV}{PV}$
$SV(t)$	Schedule variance (time), $SV(t)=ES-AT$
$SPI(t)$	Schedule performance index (time), $SPI(t) = \frac{ES}{AT}$
CV	Cost variance, $CV=EV-AC$
CPI	Cost performance index, $CPI = \frac{EV}{AC}$
SCI	Schedule cost index, $SCI=SPI*CPI$
$SCI(t)$	Schedule cost index (time), $SCI(t)=SPI(t)*CPI$

[a] In these definitions, *value* always alludes to the cumulative value over all activities up to a certain point in time.

[b] In some papers, the estimated cost at completion is simply abbreviated by *EAC*, without the addition of the dollar sign. However, in other papers just as in this one, it is preferred to add the dollar sign anyhow in order to make a clearer distinction between the cost context and the time context (the latter is always indicated by a suffix *t*).

by Lipke (2003). A recent study (Batselier and Vanhoucke, 2015b) explicitly showed that, when implementing ES, EVM time forecasting is at virtually the same accuracy level as EVM cost forecasting. Therefore, the EVM technique can indeed be deemed a viable and valuable basis for the forecasting of both project duration and cost.

Furthermore, multiple extensions of the traditional EVM forecasting approaches have been proposed in literature the past several years (Kim and Reinschmidt, 2010; Lipke, 2011; Elshaer, 2013; Khamooshi and Golafshani, 2014; Mortaji et al., 2014; Baqerin et al., 2015; Chen et al., 2016). This list is obviously not exhaustive, as to provide a complete overview and description of the existing EVM extensions is beyond the scope of this study, and so is the quantitative comparison of all those techniques (including the one developed in this paper). The latter defines an evident subject for future research, similar to the study performed by Batselier and Vanhoucke (2015c), in which three EVM forecasting extensions (Lipke, 2011; Elshaer, 2013; Khamooshi and Golafshani, 2014) are compared and combined.

Another widely used and well-performing technique for making forecasts based on time series data is exponential smoothing. This technique arose in the late 1950s and early 1960s (Brown, 1956, 1959, 1963; Holt, 1957; Holt et al., 1960; Muth, 1960; Winters, 1960)[1] and has formed the basis for some of the most successful forecasting methods ever since. The main feature of an exponential smoothing method is that the produced forecasts are based on weighted averages of past observations, moreover, with the weights decaying exponentially as the observations age. Furthermore, the technique enables forecasting for time series data that display a trend and/or seasonality. For more background information regarding the origins, formulations, variations, applications, and state-of-the-art of exponential smoothing, the reader is referred to Gardner (2006). Nevertheless, the formulations relevant to the study in this paper will also be presented in later sections.

Although the technique of exponential smoothing is mainly used in financial and economic settings, it can in fact be applied to any discrete set of repeated measurements (i.e. to any time series). Since the tracking data gathered during project progress constitute a time series, exponential smoothing can also be applied to forecast project duration and project cost. Intuitively, this shows potential. Indeed, traditional EVM forecasting assigns equal importance (or weight) to all past observations, whereas the exponential smoothing approach makes it possible to gradually decrease the weights of older observations. The latter could be a very useful feature in a project management context, as it allows to account for the effect of both natural performance improvement and corrective management actions that might occur during the course of a project (see Section 2.1 for a more elaborate discussion).

Therefore, a novel forecasting approach for both project duration and project cost based on the integration of well-known EVM metrics in the exponential smoothing forecasting technique is developed in this paper. From now on, this novel approach will be referred to as the XSM, which is an acronym for eXponential Smoothing-based Method. Moreover, note that the general notation of XSM refers to both the time and cost forecasting dimension of the novel technique. As an overview, all notations for the different components of the XSM that will be introduced and discussed later in this paper are presented in Appendix A.

The outline of this paper can be summarized along the following lines. The derivation of the XSM formulations and explanation of their application (static/dynamic) will be the subject of Section 2, preceded by a qualitative discussion on the motivation for adapting the current EVM forecasting methods and why the exponential smoothing technique is appropriate for this. Furthermore, in the same section, we will make the link between the XSM and the established EVM forecasting methods. Section 3 then proposes an evaluation approach for the XSM, based on accuracy comparison with the known EVM top forecasting techniques. Furthermore, the proposition to incorporate the reference class forecasting (RCF) technique – in which a relevant reference class of similar historical projects is used as a basis for making forecasts for the considered project – into the XSM methodology is made in Section 3.2. In Section 4, the results of the evaluation are presented and discussed, for time forecasting as well as for cost forecasting. Moreover, both a static and a dynamic approach to the XSM will be assessed. Finally, Section 5 draws more general conclusions and suggests several future research actions.

---

[1] The 1957 report by Holt (1957) has been republished as Holt (2004) in order to provide greater accessibility to the paper.