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Evaluation of deterministic state-of-the-art forecasting approaches for project duration based on earned value management

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Abstract

In recent years, a variety of novel approaches for fulfilling the important management task of accurately forecasting project duration have been proposed, with many of them based on the earned value management (EVM) methodology. However, these state-of-the-art approaches have often not been adequately tested on a large database, nor has their validity been empirically proven. Therefore, we evaluate the accuracy and timeliness of three promising deterministic techniques and their mutual combinations on a real-life project database. More specifically, two techniques respectively integrate rework and activity sensitivity in EVM time forecasting as extensions, while a third innovatively calculates schedule performance from time-based metrics and is appropriately called earned duration management or EDM(t). The results indicate that all three of the considered techniques are relevant. More concretely, the two EVM extensions exhibit accuracy-enhancing power for different applications, while EDM(t) performs very similar to the best EVM methods and shows potential to improve them.

Keywords: Project management; Time forecasting; Earned value management; Earned duration management; Rework; Sensitivity measures; Empirical database; Project control

1. Introduction

Being able to accurately predict the final duration of a project is essential to good project management. The widely-used project control technique of earned value management (EVM) provides a basis for obtaining such project duration forecasts. A presentation of the basic and more thoroughgoing aspects of the EVM methodology can be found in several works (Anbari, 2003; Fleming and Koppelman, 2010; PMI, 2008; Vanhoucke, 2010a, 2014). The traditional EVM time[1] forecasting approaches — the planned value method (PVM) by Anbari (2003), the earned duration method (EDM) by Jacob and Kane (2004) and the earned schedule method (ESM) by Lipke (2003) — have recently been evaluated by Batselier and Vanhoucke (2015b) based on the real-life project database constructed by Batselier and Vanhoucke (2015a). The said empirical research supported the findings of the simulation study of Vanhoucke and Vandevoorde (2007) by also indicating ESM as the most accurate method.

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[1] Following earlier works related to this paper (Batselier and Vanhoucke, 2015b; Elshaer, 2013; Khamooshi and Golafshani, 2014; Vanhoucke and Vandevoorde, 2007, etc.), the terms “time” and “duration” are interchangeable when used in the context of EVM forecasting (apart from linguistic preferences).

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However, a variety of novel EVM-based time forecasting approaches has been developed in the last five years. These state-of-the-art techniques can be subdivided into two major categories, namely deterministic and probabilistic approaches (Barraza et al., 2004). Deterministic approaches — like the three traditional EVM time forecasting methods — yield a point estimate of the eventual project duration, whereas probabilistic techniques provide confidence intervals and/or distributions of possible durations. The latter techniques can, for example, make use of stochastic S-curves, which produce upper and lower bounds for the range of acceptable outcomes based on the uncertainty about the predictions (Barraza et al., 2004). Moreover, an extending probabilistic approach is provided by the fuzzy methodology, which can overcome vagueness of data by introducing linguistic terms that can be translated into fuzzy numbers through a membership function (Naeni et al., 2011). An extensive overview of the existing literature on both deterministic and probabilistic[2] approaches is given by Willems and Vanhoucke (under submission). The said paper also provides a summary of other recently developed project forecasting methods, like those based on neural networks (e.g. Pewdum et al., 2009; Rujirayanyong, 2009) and support vector machines (e.g. Cheng et al., 2010; Wauters and Vanhoucke, 2014). Although these methods have been proven useful for making project forecasts, an extensive survey is beyond the scope of this paper, as the current focus is on deterministic EVM-based forecasting approaches for project duration. More specifically, three recent and promising techniques are considered. The logical basic principles on which they build are as follows:

- Lipke (2011) integrates the effect of rework in ESM time forecasting.
- Elshaer (2013) integrates activity sensitivity information in ESM time forecasting.
- Khamooshi and Golafshani (2014) introduce earned duration management or EDM(t)[3], where schedule performance is calculated from metrics expressed in time units (and not in cost units).

These logical basic principles in fact demonstrate the relevance of introducing the three selected methods. A more concrete presentation of the three techniques is provided in Section 2. Moreover, the last two papers in the list above are also included in the overview of Willems and Vanhoucke (2015), of course under the category of deterministic approaches.

In the respective papers, all three of the methods are said to have the potential to improve the accuracy of the traditional EVM time forecasting methods. Nevertheless, these assertions have not yet been adequately tested on a large database, nor has the validity of the considered techniques been empirically proven. More concretely, Lipke (2011) and Khamooshi and Golafshani (2014) apply their technique on just one real-life project, whereas Elshaer (2013) only considers projects generated by the RanGen project network generator (Demeulemeester et al., 2003; Vanhoucke et al., 2008) that were already used in many earlier project management studies (Vandevoorde and Vanhoucke, 2006; Vanhoucke, 2010a,2010b, 2011, 2012; Vanhoucke and Vandevoorde, 2007).

Moreover, it is not known which one of the three considered methods — or which combination of the methods — would yield the best results, overall and in different stages of the project. Therefore, the goal of this paper is to compare the forecasting accuracy and timeliness of the three novel time forecasting techniques and all of their mutual combinations based on the real-life project data of Batselier and Vanhoucke (2015a). As such, recommendations can be made concerning which method — or combination of methods — best to use in a certain situation and which future research actions to take to further improve the methods' utility. Furthermore, the proposed combination of the three novel techniques for time forecasting is innovative in itself and can therefore also be seen as a contribution of this paper.

The remainder of the paper is organized as follows. In Section 2, the three considered state-of-the-art time forecasting methods are presented. Section 3 then proposes the methodology for evaluating the accuracy and timeliness of these methods on real-life project data. Subsequently, the results of this evaluation are presented and discussed in Section 4. And finally, in Section 5, conclusions are drawn and suggestions for future research actions are made.

2. Presentation of the three state-of-the-art time forecasting methods

In this section, the three considered state-of-the-art time forecasting methods (Elshaer, 2013; Khamooshi and Golafshani, 2014; Lipke, 2011) are presented in chronological order. The concerning subsections are assigned a name which reflects the basic principle of the respective method. We restrict ourselves to a brief explanation of the three methods. Although the provided explanation should suffice for understanding the techniques, if desired, the reader can find more elaborate discussions on the different methodologies in the originating papers. However, before we can present the three novel time forecasting methods — which are all based on EVM — a more general discussion needs to be conducted.

Since earlier studies on EVM forecasting accuracy (Batselier and Vanhoucke, 2015b; Vanhoucke and Vandevoorde, 2007) have proven the dominance of ESM over PVM and EDM, the former method is used as a basis (and benchmark) for all three novel deterministic approaches. The generic ESM formula for obtaining the project duration forecast or estimated time at completion $EAC(t)$ is given by:

$$EAC(t) = AT + \frac{PD - ES}{PF}. \quad (1)$$

[2] In Willems and Vanhoucke (2015), the probabilistic approaches are further subdivided into stochastic and fuzzy techniques.

[3] Khamooshi and Golafshani (2014) in fact use the abbreviation EDM for earned duration management. However, this abbreviation was already introduced for the earned duration method of Jacob and Kane (2004). In order to avoid confusion, we therefore refer to earned duration management by EDM(t). Furthermore, the suffix (t) also clearly indicates that the technique is based on time metrics instead of cost metrics.