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Erratum

A fuzzy approach for the earned value management

Leila Moslemi Naeni [a], Shahram Shadrokh [a], Amir Salehipour [b,*]

[a] Department of Industrial Engineering, Sharif Univ. of Tech., Tehran, Iran
[b] School of Industrial Engineering, Islamic Azad University, Tehran South Branch, Tehran, Iran

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Abstract

The Earned Value technique is a crucial technique in analyzing and controlling the performance of a project which allows a more accurate measurement of both the performance and the progress of a project. This paper presents a new fuzzy-based earned value model with the advantage of developing and analyzing the earned value indices, and the time and the cost estimates at completion under uncertainty. As the uncertainty is inherent in real-life activities, the developed model is very useful in evaluating the progress of a project where uncertainty arises. A small example illustrates how the new model can be implemented in reality.

Keywords: Fuzzy earned value; Earned Value Technique; Uncertainty; Project progress

1. Introduction

Earned value management (EVM) is a project management technique used to measure project progress in an objective manner. According to Project Management Institute (PMI),[1] when properly applied, EVM provides an early warning of performance problems. Referring EVM to EV (Earned Value) most often, the EV measures the project performance and the project progress by integrating efficiently the management of the three most important elements in a project, i.e. cost, schedule and scope. In fact, it calculates the cost and time performance indices of a project, estimates the completion cost and the completion time of a project, and measures the performance and the progress of a project by comparing the planned value and the actual costs of activities to their corresponding earned values.

Although being introduced in 2000 in PMBOK® guide (PMI, 2000), the first complete guide on the EV has been published in 2005 (PMI, 2005). Nowadays, it is widely believed that implementing EV techniques has many advantages and would enhance the cost and the schedule performances of a project, but on the contrary the research on the EV is very limited. Lipke (1999) developed cost ratio and schedule ratio to manage the cost and the schedule reserves in projects. Later he introduced the Earned Schedule (ES) concept to resolve the limitations and peculiarities inherent in the use of the historical EV Schedule Variance (SV) and Schedule Performance Index (SPI) (Lipke, 2003). Henderson (2003, 2004) studied the applicability and reliability of the ES. Also Vandevoorde and Vanhoucke (2005) concluded that the best and the most reliable method to estimate time at completion is the ES method. Anbari (2003) enhanced the effectiveness of EV implementation. Kim et al. (2003) studied the implementation of the EV in different types of organizations and projects. Lipke (2004) developed project cost and time performance probabilities. A new notation for the EV analysis is presented in Cioffi (2006) to make EV mathematics more transparent and flexible. Lipke et al. (2009) provided a reliable forecasting method of the final cost and duration to improve the capability of project managers for making informed decisions.

The motivation behind this paper is derived from the fact that despite the uncertain nature of the activities' progress involved in a project, they are considered deterministic in all available EV techniques. In reality the data regarding the activities come from people's judgments; hence they carry some degree of uncertainty.

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* Corresponding author.
E-mail addresses: leila.moslemi@gmail.com (L. Moslemi Naeni), shadrokh@sharif.edu (S. Shadrokh), a.salehipour@modares.ac.ir, amir.salehipour@gmail.com (A. Salehipour).
[1] In a more accurate definition by PMI (2005), the EVM combines measurements of technical performance (i.e., accomplishment of planned work), schedule performance (i.e., behind/ahead of schedule), and cost performance (i.e., under/over budget) within a single integrated methodology.

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Considering this uncertainty into interpretations and calculations, helps not only in measuring better the performance and the progress of a project, but also in extending the applicability of the EV techniques under the real-life and uncertain conditions. The major contribution of this paper is to develop a new fuzzy-based EV technique to measure and evaluate the performance and the progress of a project and its activities under uncertainty. The developed model benefits from the linguistic terms and the fuzzy theory. Through the paper, our terminology is based on the PMBOK guideline (PMI, 2004). For the simplicity, by "activity", we mean both activities and the work packages. The remaining of this paper is organized as follows. Section 2 brings an introduction into the EV and its techniques. Section 3 explains briefly the fuzzy theory and its application to the EV. Developing the new fuzzy-based EV technique and its interpretations are covered in Section 4. For clarification purposes, a simple example is studied in details in Section 5. The paper ends with the conclusion.

2. The Earned Value Measurement techniques

The EV consists of techniques to assist project managers in measuring and evaluating the progress and the performance of a project by estimating the completion cost and completion time of a project based on its actual cost and actual time up to any given point in the project. The EV of an activity is a measure of the completed work and represents the budgeted cost of work performed, and indicates how efficiently the project team utilizes the project resources.

Table 1 presents a list of available techniques in calculating the EV of either an activity or a project. More details can be found in "Practice Standard for Earned Value Management" (PMI, 2005).

To keep the paper short, we avoid explaining these techniques here, except the Percent Complete technique which is the basis of the calculation in the proposed model.

In the Percent Complete, one of the simplest techniques for measuring the EV, in each measurement period the person-in-charge makes an estimate of the percentage of the activity complete, e.g. 26%. This technique can be the most subjective of the EV measurement techniques if there are no objective indicators based on which the estimates should be made. This greatly incorporates into errors and uncertainty which cause biased judgments. An idea to overcome this problem is to use the linguistic terms in estimating the completion percent of each activity, as the imprecise and uncertain data of activity performance and activity progress are common to arise. This forms the basis of our novel idea.

Table 1
The EV measurement techniques.

Activity product	Activity duration	
	1 or 2 measurement periods	More than 2 measurement periods
Tangible	Fixed formula	Weighted milestone Percent complete
Intangible	Level of effort Apportioned effort	

3. Using fuzzy theory to measure the Earned Value

First introduced by Lotfi Zadeh (1965) fuzzy theory explains uncertainty in events and systems where uncertainty arises due to vagueness or fuzziness rather than due to randomness alone. It is reasonable to model and treat the uncertainty using the linguistic terms with the fuzzy theory. For instance, if an activity progress cannot be stated in certainty, using linguistic terms it may be stated as "very low", etc.[2] Clearly, this linguistic term cannot be applied on the EV technique before transforming it to a number. Thus, first we apply the fuzzy principles on the linguistic terms to convert them into fuzzy numbers. Then we modify the EV mathematics to reflect the new values (fuzzy numbers). Typically the project experts perform this transformation in accordance with their knowledge and their experience about the project, and with activity attributes.

The application of the proposed method arises in situations where the total amount of the work required to perform the activities are unknown or uncertain, and is out of control. Examples are, in construction project of a dam the ground should be excavated until hard layer of rock is reached. Before reaching this layer, the exact amount of the operations and the required work are unknown, and also this is out of our control, so the percent complete of excavation activity cannot exactly be measured. In medical research projects and drug development projects, a majority of resources are devoted to the clinical experiments' aims at testing the new drug for its benefits and potential side effects. The exact amount of work required to derive scientific conclusions is unknown in advance. In these cases and many other similar cases to include this uncertainty in our results, it would be better and easier to evaluate the percentage of the activity completed by linguistic terms rather to evaluate it exactly and deterministically.

In fact, a linguistic term helps to estimate the activity progress easier by answering the question "What fraction/percent of the activity is complete?" We strongly believe the new developed technique reflects better the uncertain nature of the project. The example below clarifies the core idea of this paper.

Assume the completion percent of an activity includes uncertainty and is expressed as "half". As mentioned earlier the project expert should transform this into a fuzzy number by assigning a membership function[3] to this linguistic term, to express the relationship between the linguistic term and the fuzzy number (like the one showed in the Fig. 1. In this figure the horizontal axis refers to the progress and is on a scale of 1.). The summary of the transformation associated with Fig. 1 is shown in Table 2. Obviously, the output of this transformation is a fuzzy number. Note that Fig. 1 and Table 2 are only an example.[4]

[2] Other linguistic terms include but not limited to less than half, half, more than half, high, very high, etc.

[3] The membership degree $\mu_{\tilde{A}}(x)$ quantifies the grade of membership of the element x to the fuzzy set $\tilde{A}$.

[4] Completion percent of an activity can be expressed using terms "approximately x" or "between x and y". This way is more suitable when dealing with long duration activities.