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# A new approach for project control under uncertainty. Going back to the basics

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**Abstract**

In this paper we propose a new methodology for project control under uncertainty. In particular, we integrate Earned Value Methodology (EVM) with project risk analysis. The methodology helps project managers to know whether the project deviations from planned values are within the “expected” deviations derived from activity planned variability. Although the methodology is new and innovative, we only go back to the fundamentals of project simulation to generate the “universe” of possible projects, according to the assumed variability of project activities. Then we organize and gather the information in order to make the data coherent with EVM. We explain the steps to implement the methodology and we show three case studies. The methodology makes explicit that the schedule and budget resulting from traditional methods like PERT are statistically very optimistic.
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## 1. Introduction

Project control consists in the comparison of a plan or baseline with the actual results of the project to identify deviations and activate early corrective actions if needed. Earned Value Management (EVM) is a widely used project management methodology for project control, as it integrates scope, time and cost control under the same framework (Abba and Niel, 2010; Anbari, 2003; Blanco, 2013; Burke, 2003; Cioffi, 2006; Fleming and Koppelman, 2005; Henderson, 2003; Henderson, 2004; Jacob, 2003; Jacob and Kane, 2004; Kim et al., 2003; Lipke, 1999; Lipke, 2003; Lipke, 2004b; McKim et al., 2000).

Anbari (2003), Fleming and Koppelman (2005) and PMI (2005) explain the main features of the methodology and how to implement it. Several authors have improved the traditional EV by enhancing its capability in evaluating and monitoring project progress (Naeni et al., 2011; Navon, 2005; Vanhoucke and Vandevoorde, 2007; Warburton, 2011). It is not surprising that EV has been applied to many different disciplines and projects (Al-Jibouri, 2003; Chen and Zhang, 2012; Gowan et al., 2006; Hanna, 2012; Kwak and Anbari, 2012; Naderpour and Mofid, 2011).

Succinctly, EVM is based on the representation of three measures: First, the budgeted cost for work scheduled (BCWS) also called planned value (PV); second, the actual cost for work performed (ACWP) also called actual cost (AC); and finally, the budgeted cost for work performed (BCWP) or earned value (EV).

The Earned Value Management indicators are derived from the three previous values: Cost variance (CV = EV − AC) and schedule variance (SV = EV − PV). A positive variance indicates in the case of CV that the project is under budget and in the case of SV, ahead of schedule. On the other hand, a negative variance might be a warning of a problematic situation, showing

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that project is behind schedule or exceeding the planned budget. In order to compare projects with different sizes, the Performance Indexes are defined: Cost Performance Index (CPI = EV / AC) and Schedule Performance Index (SPI = EV / PV). Performance Indexes are below 1 whenever the variances are below 0. Variables and variances can be represented graphically (see Fig. 1), helping project managers to monitor project evolution. The graphical representation of PV is the project cost baseline.

Lipke (2003, 2004a) introduced a new measure, the Earned Schedule (ES), defined as the date when the current earned value should have been achieved. ES is calculated by projecting the EV on the PV curve. Once ES is determined, time-based indicators can be easily derived from SV(t) = ES − AT and the corresponding ratio measure SPI(t) = ES / AT, where AT is the actual time defined as the elapsed time since the beginning of the project.

Given the non-repetitive nature of projects, uncertainty and risk are at the very core of Project Management, and project managers are used to face project delays (and over-costs) beyond the planned values; consequently project managers need methodologies to take decisions under project uncertainty. The typical way to incorporate this uncertainty in project modeling is by means of stochastic networks where activity costs and durations are not deterministic but follow certain probability distributions.

But traditional EVM assumes certainty about the durations and costs of project activities. For this reason, EVM reports the project manager whether the project has overruns (costs, delays) or it is running better than planned, but the methodology does not specify whether the deviation from planned values is within (or not) the possible deviations derived from the expected variability of the project. In other words, perhaps the project is delayed from planned values (computed, for instance, by means of CPM (Kelley, 1961; Kelley and Walker, 1989) or PERT (Fazar, 1959; Malcolm et al., 1959) methodologies), but the delay could remain within the possible (and most probable) range of delays, taking into account the intrinsic variability of activities. Alternatively, the project delay (or over-cost) could be higher than the possible values of delay, so that some changes have taken place in the project and some conditions have changed from the planned conditions of activities variability.

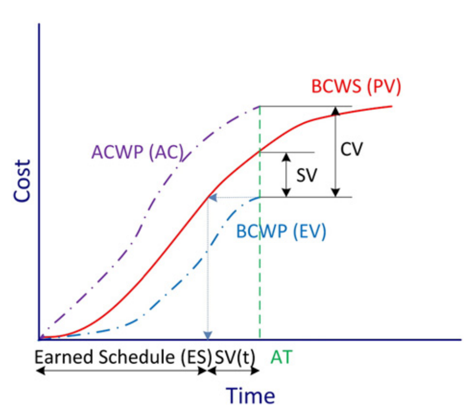


Fig. 1. EVM main variables and variance.

The inclusion of project variability in control methodologies in general, and EVM in particular is becoming an interesting research topic within academics.

Barraza et al. (2004) applied stochastic S-curves to determine forecasted project estimates. Later, Barraza and Bueno (2007) introduced a probabilistic project control concept by extending the performance control limit curves to derive an acceptable forecast of final project performance.

The implications of this stochastic approach in EVM have been recently incorporated by means of fuzzy approaches (Naeni et al., 2011). They developed fuzzy control charts to monitor several EV indexes, and provided a transformation method based on fuzzified indexes. Leu and Lin (2008) improved the performance of traditional EV by implementing the statistical quality control charts. They implemented individual control charts to monitor project performance data, and provided a log transformation method. Finally, Aliverdi et al (2013) apply statistical quality control charts to monitor earned value indexes.

Vanhoucke (2011) suggested monitoring projects with two approaches: top-down, based on earned value metrics; and bottom-up, based on the schedule risk analysis method. Vanhoucke (2012) studied the reasons why EVM and schedule risk analysis give better results in some projects than in others. Hazir and Shtub (2011) explored the relation between information presentation and project control and they developed simulation software to face with uncertain environments.

By means of Monte Carlo simulation, we can compute the statistical distribution functions of project cost and duration when the project is finished. Therefore, at the end of the project, we can know, within a particular confidence level, whether the project finished or not within the “expected variability” (project under control), and, as a consequence, we can compute buffers for the project to be under control at the end of the project. However, project managers do not want to wait until the end of the project to know whether the project is under control: They need to know it during project runtime, in order to take decisions and corrective actions whenever delays (or over-costs) are out of the expected values.

In order to answer the former question, Pajares and López-Paredes (2011) suggested to split the final project buffer into small buffers for every time interval, being the interval buffers proportional to the risk reduced at the particular time interval. To this aim, they defined the concept of risk baseline as the “the evolution of ‘project risk value’ through project execution lifecycle. The risk of the project at any given time is calculated as the risk of the project pending tasks (those not yet completed), assuming that the project has performed as planned until that given time” (statistical variance can be used as a measure of risk, both for duration and cost). The risk reduced at any particular interval can be computed as the difference between the values of the risk baseline within the interval.

Pajares and López-Paredes (2011) linked the interval buffers to EVM methodology by comparing cumulative buffers with cost and time variances at any time. They define two new control indexes that showed whether the project was under control (cost, time) or not. Finally, using these indicators,

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