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Estimating a project's earned and final duration

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Abstract

Using standard Earned Value Management (EVM) protocols, the current approach to Earned Schedule (ES) is extended and formalized to establish its rigorous, theoretical foundation. A precise definition is provided for what we term the project's earned duration, whose creation completes the triad of planned, actual, and earned durations. The published ES formula emerges as a linear approximation, but is found to work with some nonlinear cost profiles, and the conditions under which it gives both correct and incorrect duration estimates are noted. In the several planned and earned value functional profiles examined, no approximations are required to derive an exact analytical expression for the final duration; most duration formulas are straightforward and useful. The reliability and accuracy of the duration formulas are demonstrated with several examples of real, nonlinear project data that represent large classes of projects. We conclude with practical guidance for project managers.
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1. Introduction

When a project goes into execution, many stakeholders wish to know when the project will finish. Currently, while there exists a formula to estimate a project's final duration, there is no theory to support its use. Therefore, a project manager cannot know, for example, the accuracy of an estimate or, even, if the formula is relevant to that particular project. This represents a major shortcoming in project management and our goal is to address this deficiency by providing a sound, formally justifiable approach to duration estimation.

The current approach to duration estimation is based on Earned Schedule (ES) and several research studies claim that ES works well in some instances (Vanhoucke & Vandevoorde, 2006, 2007; Lipke et al., 2009). However, the concept of ES is not without its problems (Book, 2006; Kim, 2000).

Currently, ES begins with a geometrical construction that defines the delay as the horizontal projection from the earned value curve to the planned value curve, see Fig. 1 (Lipke, 2003, 2010). However, Evensmo & Karlsen (2006) pointed out that the resulting duration formula is based on linear cumulative planned and earned value cost curves. Why should such a linear theory work when real-world project cost curves are usually presented as S-shaped? Further, Batseliera & Vanhoucke (2015) suggest that duration forecasting methods have not been empirically proven.

This is an example of the criticism by Koskela & Howell (2002, p.293) that project management is a "narrow and implicit theory." The theory is narrow because ES is a linear theory and it is implicit because the assumptions, such as linearity, are rarely acknowledged.

Koskela & Howell (2002) also point out that project management is often dominated the dispatching, or thermostat, model and such criticisms are well known (Johnston & Brennan, 1996). In the primitive, thermostat model, project managers attempt to correct deviations from set parameters. Hofstede (1978) explains that this requires several assumptions: that there is a performance standard that can be defined and measured; that there is a causal relation between management actions and project outcomes; and that management actions can return the project to the desired state.

However, without a formal underlying theory that defines the relevant project observables, and the relations between

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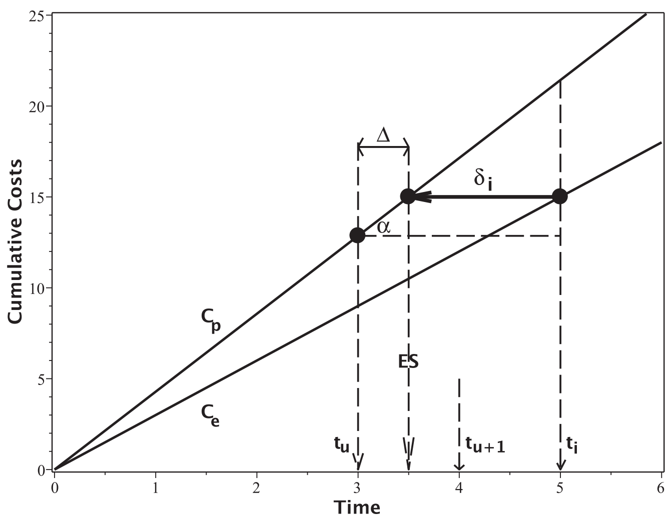

Fig. 1. For the linear case, the definitions of the delay, δ_i, at the time, t_i, and the earned schedule, *ES*.

them, there is no guarantee that any specific action by a project manager will fix or, even, affect a particular observable. Thus, a major shortcoming of the thermostat model is that, without an underlying theory, the relevant project observables remain unknown. In the context of duration estimation, therefore, one does not know which parameters to measure or which to attempt to manage to effect change. By proposing a formal theoretical foundation for duration estimation, we demonstrate to project managers which quantities are important and should be measured, and which to prioritize to help them manage effectively.

As an example of common practice, we note that in many types of large projects the cumulative cost profile follows an S-shaped curve (Christian & Kallouris, 1991) and using such curves for cash flow projections can achieve accuracies of over 90% (Singh & Lakanathan, 1992). It is implicitly assumed, therefore, that such cost curves have universal applicability and the success of such estimation tools suggests that there might be some fundamental, structural underpinning that is common to projects. If duration estimation is similarly to apply universally to projects, that also requires the existence of some underlying theoretical structure to give it legitimacy.

Another basic tenet of project management is that, during execution, one can predict the project's future duration from some initial data. There are a number of hidden assumptions implied in this approach: that there exist project parameters that can be measured; that these parameters remain constant (or at least predictable) over the life of the project; and that the estimation process is robust against uncertainties in the data. Interestingly, industrial data strongly suggest that some project parameters do indeed remain constant over time, e.g., error rates, see McGarry et al. (1994).

The goal of this work is to eliminate this critical deficiency in project management by establishing a formal theoretical foundation for duration estimation. A further goal is to verify that the theory is practically useful by demonstrating that it provides estimates of the final duration early enough to be practically useful on real-world projects. We also wish to establish a theory that can be applied to all projects, including those with nonlinear, S-shaped cost profiles. Finally, our goal is to define the validity, range of applicability, and accuracy to be expected from the use of a specific duration formula. With such a theory, we should be able to advise project managers on how to improve the accuracy of their duration predictions.

Our research contribution is that we do, in fact, establish such a theory and it is based on the standard underlying assumptions for Earned Value Management (EVM), which means it should be familiar to project managers and require little additional effort in its use. Our research is also validated because the current approach to ES is entirely contained in our model as the special case of linear cumulative planned and earned value cost curves.

However, our new definition allows us to extend EVM into new areas and to derive duration estimates for any type of realistic, nonlinear cost curve. No approximations are required, which allows us to formally establish the validity and accuracy of all duration estimation formulas. We explain that duration estimation depends on structural assumptions about cost profiles and, so, understanding their shapes and parameters will lead project managers to a better appreciation of the issues in duration estimation.

Finally, we estimate the duration for several well-known, nonlinear cost curves, which demonstrates the method's successful application to more realistic projects than the current linear version. Even for nonlinear profiles, in most cases, a simple duration formula emerges, validating the practicality of the theory. The agreement between theory and practice shows that it is possible to create a theory of duration estimation that has immediate practical benefits. The theory is, for the most part, no more complex than the current version of ES, which is used for estimation and tracking.

The paper proceeds with a review of the applicable literature, after which we undertake a critical evaluation of the existing ES concept (Section 2). In Section 3 we propose a new, formal definition for the project delay, which allows us to derive exact, analytical expressions for the project duration. In Section 4, we analyze several well-established, practical, nonlinear representations of the cost profile and derive exact expressions for the final duration. In Section 5, we present practical project data for each of the cost profiles and show that the relevant formula accurately predicts the final duration. We also explain for which profiles the linear formula gives incorrect duration estimates, as well as the degradation in duration accuracy from its use. Section 6 concludes with a review of the project management implications.

1.1. Previous efforts examining duration prediction

Standard EVM techniques yield reliable predictions only when applied to cost estimation (Vanhoucke & Vandevoorde, 2006; Christensen, 1993) and the problems of applying EVM to schedule prediction are well known (Marshall, 2006; Book, 2003, 2006). Lipke (2003, 2010) was one of the first to address this issue by defining a geometrical construction procedure for ES and Stratton (2007) later provided one of its first formal definitions.

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