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International Journal of Project Management 24 (2006) 136–144
INTERNATIONAL JOURNAL OF PROJECT MANAGEMENT
www.elsevier.com/locate/ijproman

Designing project management: A scientific notation and an improved formalism for earned value calculations

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Received 5 August 2004; received in revised form 15 October 2004; accepted 15 July 2005

Abstract

A new formalism and a corresponding new notation for earned value analysis are presented. With compact, consistent, mnemonic notation, earned value calculations become more transparent and flexible, leading to insights about standard quantities and advances through new measures. As an example of the notation's utility, it is used to generate a modified earned value approach that weights quantities according to their position in a project's timeline.

Keywords: Earned value; Managing projects; Progress; Cost; Cash flow management

1. Introduction: design and revolution

Thomas Kuhn introduced the now oft-misused term "paradigm shift" in his seminal book, *The Structure of Scientific Revolutions* [1]. Scientists build models or "paradigms" to explain the composition and behaviour (physical and biological) of the universe. Most models work well when first proffered. With time, however, improved technology and more sophisticated experimental techniques lead to more and better data. Deeper thinking with these new data eventually shows shortcomings, inconsistencies, or downright errors in the accepted paradigm of the day. At first, the community responds with minor reconstructions of the paradigm so that it agrees with the new data and understanding. Eventually, however, the new perspective of the world differs so greatly from that provided through the old paradigm that a shift occurs. The old paradigm is replaced by a new one, e.g., special relativity replaces Newtonian dynamics at speeds near that of light. Such new models give new perspectives that provide better explanations of the world in which we live.

In a manner analogous to shifts in scientific theories, earned value analysis began, we hope, a paradigm shift in project management. The actual progress of any given project has not changed, but our measurement techniques have changed because of a new perspective. Separate views of budget or schedule should not be accepted. Instead, good management demands the integrated view provided by earned value analysis. However, whatever their ultimate worth, paradigm shifts do not occur overnight, either in the physical sciences or in the *Sciences of the Artificial* [2], which include project management.

In these sciences, according to Simon, "Everyone designs who devises courses of actions aimed at changing existing situations into preferred ones..." Just as earned value itself is a design aimed at changing the estimation of project progress into a "preferred situation", this contribution of a new notation for earned value is a design that aims to further the ongoing paradigm shift.

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0263-7863/$30.00
doi:10.1016/j.ijproman.2005.07.003

2. Earned value

"If you can't measure it, you can't manage it". Whether one trusts the validity of this common phrase most of the time or all of the time, measuring the true progress of a project presents a formidable task.

Given a baseline plan, projects typically report a measure of the completed work and compare it to that scheduled. Similarly, most projects can and do measure the current cost and compare it to the planned spending. But for a more comprehensive view, how does one measure the progress of a project against the triple constraint of cost, schedule, and scope? The two simple measures above separate schedule and cost and include scope only indirectly, as a function of schedule.

Post-World War II military projects advanced the field of project management. In 1967 the US Department of Defense released its first official list of "Cost/Schedule Control Systems Criteria" (C/SCSC) [3], signaling the formal initiation of earned value analysis, which still represents management's best chance at measuring a project's progress in an integrated manner.

Many (probably most) projects do not use earned value, however, and the historically arcane terminology and calculational notation have stood as roadblocks to its embrace by the management community. In an attempt to evolve the system to a more scientific format, this paper further formalizes a notation developed originally in *Managing Project Integration* [4].

2.1. Efforts and S-curves

Earned value analysis combines the three elements of budget, schedule, and scope by using cost as the common exchange medium. Thus, the unit of a project's primary financial currency (e.g., dollars, pounds, the Euro) becomes the unit for all earned value measures. One can therefore compare different measurements because they have a common basis. How is this process possible?

At least one published version of the standard project management S-curve plots "labor hours" to illustrate the rise and fall of effort through the life of a project. Adding labor hours generated by different resources, however, is the project management equivalent of adding those proverbial apples and oranges, e.g., adding the labor hours of the attorney and the bulldozer (or the bulldozer operator) makes no sense: the number of personnel can be added, but disparate efforts cannot be combined.

Earned value avoids this problem by reducing efforts to a common basis—costs—and measuring those costs in a common unit of currency. To formalize the implicit assumptions underlying earned value, we can define the effort, E_R, that results from a resource used at some intensity, R_I, through a given duration, Δt. When considering the optimum duration of a task [4], the duration and therefore the effort become functions of the resource intensity itself, but here we will use the common linear approximation

$$E_R \equiv R_I \Delta t. \tag{1}$$

To quantify the example offered above, consider the resources attorneys and bulldozers in intensities of 1 and 10, respectively, for durations of 6 min and 2 days. The resulting efforts are six attorney minutes and 20 bulldozer days. One compares these efforts by converting them to costs through a cost rate, $\dot{C}_R$, that might be obtained from a resource breakdown structure [5]. The units of these particular cost rates are currency units per unit of effort (e.g., dollars per attorney minute), and the subscript R reminds us that the cost rate varies with each individual resource. To summarize

$$C = E_R \dot{C}_R, \tag{2}$$

which properly introduces the generic cost, C, that becomes specific in earned value calculations.

2.2. Earned value defined

The earned value system incorporates scope and integrates it with cost and schedule. First, the manager determines the value of a project's fully completed or partially completed efforts (consistent with the effort definition above) in the context of the cost that was budgeted and (presumably) agreed upon in the project plans. Only when a specified amount of task work is accomplished does a project earn value, and the amount of that value is determined by the cost that was budgeted. I have seen no better definition and no better or more concise way to express this special type of value than "the budgeted cost of work performed", which in a shorthand we refer to as "earned value".

In this framework, the mere contemplation of the budgeted cost of work performed cries out for an immediate comparison to the actual cost. Earned value analysis next brings the schedule into this common comparison basis by asking how much spending should have occurred, i.e., according to a project's schedule, at the specific time of any comparison.

2.3. Standard notation

Prior to the latest edition of the Project Management Institute's *A Guide to the Project Management Body of Knowledge* (PMBOK®) [6], the abbreviations used for these three essential earned value quantities were taken directly from the initials of the defining nomenclature:

- BCWP: the budgeted cost of work performed
- ACWP: the actual cost of work performed
- BCWS: the budgeted cost of work scheduled