IS THE EARNED-VALUE METHOD AN ENEMY OF WORK FLOW?

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ABSTRACT

Project control tools are commonly used in the construction industry. Unfortunately, many projects run over budget and behind schedule, which suggests that there is something wrong in our project control system. The earned-value method (EVM) is a project control technique that provides a quantitative measure of work performance. It is considered the most advanced technique for integration of schedule and cost.

Work flow can be defined as the movement of information and materials through a network of production units. Current construction control systems focus on local speed and cost rather than reliable release of work downstream; i.e., reliable work flow. This paper presents potential problems of the earned-value method with a brief review of the cost management concept. Traditional cost systems are reviewed in this paper from the viewpoint of work flow. Critique of the earned-value method includes: 1) While each cost account or activity is assumed to be independent in the earned-value method, they should be considered dependent. 2) Managers can manipulate work sequences when releasing work to the field and it is possible to release work assignments that are not shielded from uncertainty. 3) In order to make cost variance (CV) positive, managers try to decrease the actual cost of work performed (ACWP) as much as possible. Overload resulting from reduced capacity can make work flow less reliable, which in turn can impact the performance of downstream production units (PUs).

KEY WORDS

Earned value, dependence, work flow, quality assignment

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INTRODUCTION

Modern or advanced project control uses an integrated cost/schedule concept called the earned value method (EVM). Project progress is measured against an earnings plan; e.g., after a slower ramp-up over a 12 week period to 15% complete, the project may be scheduled to 'earn' 3% progress for each of the next twenty five weeks, bringing it to 90% complete at Week 37, with 6 weeks remaining for punch list work, testing, and commissioning of the facility, which will earn the remaining 10%. Progress is earned based on the budgeted dollars or labor hours for completing various types of work. If steel erection has a budget of 10 labor hours per ton, then every ton of steel erected earns 10 labor hours. The entire project is divided into the various types of work required, each with their own budget unit rates, with 100% corresponding to their aggregated budgets.

Separate control of cost and schedule is vulnerable to distortions. For example, it is possible to be within a cost budget, but not producing at a rate sufficient to meet project schedule. On the other hand, it is possible to be meeting schedule, but also be over budget on cost. With EVM, such distortion is less likely because progress is itself expressed in terms of budgeted rates. 'How much work have we done and how much do we have left to do?' 'We've spent 70% of our budgeted labor hours for doing steel erection, but have earned only 60% of our earnable hours, so our productivity is poor relative to what we expected. We had better get some more workers in here so we can catch up.'

Where cost risk has been contractually shifted to others, EVM is less popular. However, where cost and schedule risk are partially or wholly vested in a single entity, EVM is currently the best available tool for controlling projects. However, it is still vulnerable to distortions. That vulnerability is rooted in its conceptual framework; i.e., its assumption that one earned hour is as good as another, and the correlative assumption that the productivity of each type of work activity is independent of the performance of other work activities, even when they are in a predecessors-successor network.

Even though some negative aspects were pointed out by Fleming and Koppelman (1994), but these are implementation issues rather than system perspectives.

The purpose of this paper is to expose these weaknesses of EVM and to suggest a direction for improvement; namely, lean construction theory and techniques

BRIEF REVIEW OF THE EARNED VALUE METHOD (EVM)

EVM is a project control technique, which provides a quantitative measure of work performance. It involves a crediting of budget dollars or labor hours as scheduled work is performed. The earned value technique is superior to independent schedule and cost control for evaluating work progress in order to identify potential schedule slippage and areas of budget overruns.

Cost Account & Work Package Concept

The work packaging concept is well described by Elmore and Sullivan (1986) as “small, discrete elements of work are budgeted with realistic and challenging targets and are assigned to supervisors to be completed in a relatively short period of time. (Over time)… actual costs and progress are collected and compared to budget and schedule for each cost account.”

A Work Breakdown Structure (WBS) divides a project into the elements of work to be accomplished. Integrated with **Organization Breakdown Structure (OBS)** that provides the "Responsibility" field, WBS provides cost accounts, which function as management control points. Management control points represent the most detailed breakdown for project control where resources are allocated, costs are collected and performance is formally assessed (McConnell 1984). McConnell's (1984) graphical representation of a WBS/OBS matrix is shown in Figure 1.

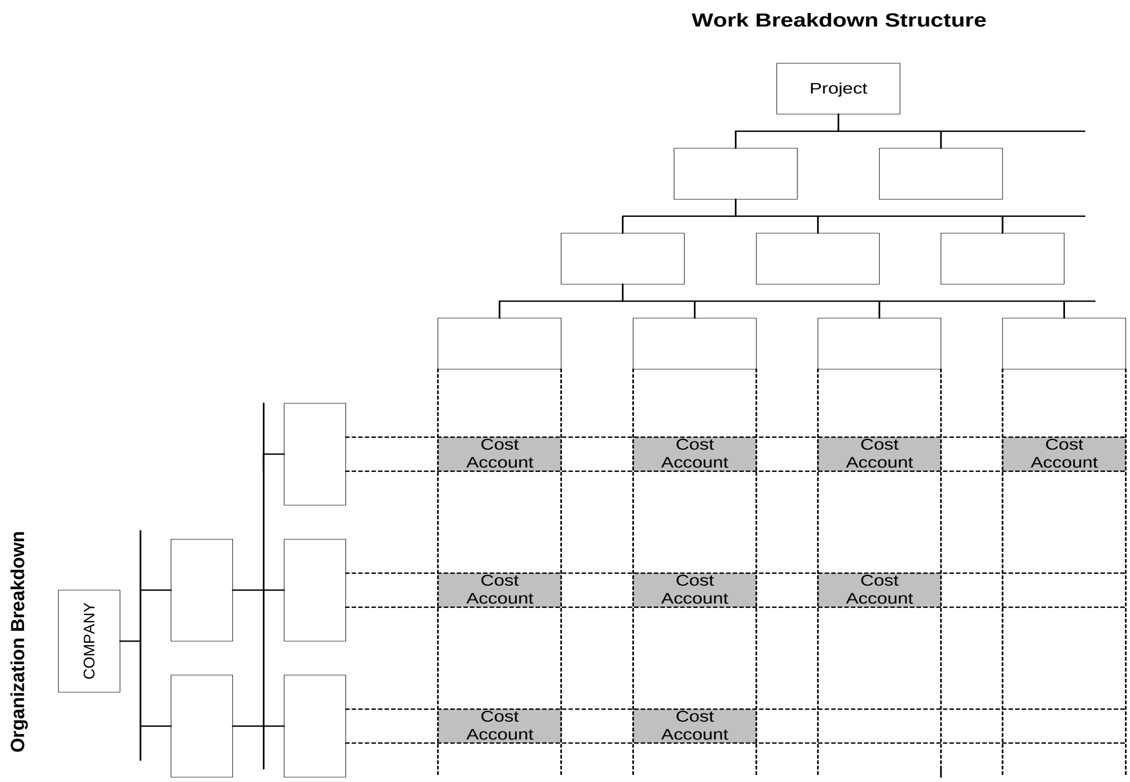

Figure 1: WBS/OBS

Each cost account, which has schedule and budget information, is a control point in cost control. It is the lowest level at which individual variance analysis can be made. Variance analysis can be made at any point in a WBS hierarchy. C/SCS (Cost/Schedule Control System Criteria) issued by US DOD (Department of Defense) defines a cost account as "A management control point at which actual cost can be accumulated and compared to budgeted cost for work performed. A cost account is a natural control point for cost/schedule planning and control since it represents the work assigned to one responsible organizational element on one contract work breakdown structure element." Since integrated control of cost and schedule is the core of EVM, it is desirable that cost accounts be identical to elements activities in the network schedule. However, each cost account usually has several work packages since cost accounts are too coarse to be assigned in the schedule. Each work package has its own schedule duration and assigned budget. The sum of the budgets of each work package that makes up one cost account must be the same as the budget of the cost account. If necessary, an organization can divide a work package into several work elements as a unit of schedule. The extent of breakdown of the various project elements is a function of work complexity and contractor preference (Abu-Hijleh 1991).

Cost Variances / Indices

Variance analysis quantifies the deviations from the budget based on the data collected. Variance used in EVM can be usually divided into two terms; Cost Variance (CV) and Schedule Variance (SV). On the other hand, data collected for analysis can be divided into three terms; Actual Cost of Work Performed (ACWP), Budgeted Cost of Work Performed (BCWP), and Budgeted Cost of Work Scheduled (BCWS).

1. **Actual Cost of Work Performed (ACWP)** is the actual incurred cost, usually in terms of dollars or man-hours, of work performed in a specified period of time (Actual).
2. **Budgeted Cost of Work Performed (BCWP),** or **Earned Value,** is the budgeted value, usually in terms of dollars or man-hours, of work actually performed in a specified period of time.
3. **Budgeted Cost of Work Scheduled (BCWS)** is the budgeted value, usually in terms of dollars or man-hours, of work scheduled to be performed in a specified period of time (Plan).

Since the objective of EVM is to achieve an integrated cost/schedule progress monitoring and control system, it requires the monitoring of two kinds of variances as mentioned.

1. **Cost Variance (CV)** is the difference between the budgeted and actual costs of the work performed:
   CV = BCWP – ACWP
   Or CV (%) = (BCWP – ACWP) / BCWP
2. **Schedule Variance (SV)** is the difference between the budgeted cost of work actually performed and the budgeted cost of the work schedules to be performed:
   SV = BCWP – BCWS
   Or SV (%) = (BCWP – BCWS) / BCWS

Figure 2 shows the relationships between BCWS, BCWP, ACWP, CV, and SV. AV (Accounting or Spending Variance) which appears in Figure 2, is not discussed here because it simply indicates variance between how much we are supposed to spend regardless of progress and how much we actually spent. Early cost control systems focused on AV to monitor cost variance, but EVM does not use it anymore since it lacks the concept of performance.

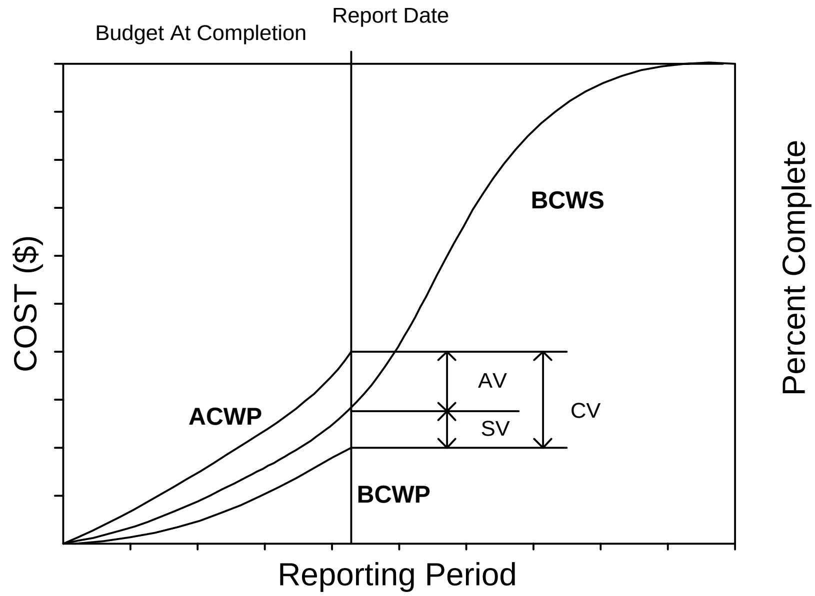

Figure 2: Variance Analysis

The performance interpretations that may be drawn from cost and schedule variance values are summarized in Table 1.

Table 1

Variance	-	0	+
Cost Variance (CV)	Cost Overrun	On Budget	Cost Underrun
Schedule Variance (SV)	Behind Schedule	On Schedule	Ahead of Sched.

IMPACT OF ACTIVITY DEPENDENCY

The effect of dependence and variation in construction is demonstrated by Tommelein et al. (1998) in “Parade Game”. Alarcon and Ashley (1999) showed the impact of uncertainty on schedule and cost in “Playing Games”. Dependence and variation impact is extended to cost control in this paper.

Even though the EVM considers the variances of each cost account to be independent, the effect of dependence and variation should be considered. The problem of dependence and variation in cost control can be illustrated by a simple example. Performance in EVM is represented in the form of CV (cost variance) and SV (schedule variance) based on three parameters; planned (BCWS), progress (BCWP), and actual cost (ACWP).

Figure 3 shows a situation where multiple trades follow each other in a linear sequence. Under this situation work output of Trade A becomes an input of Trade B, and so on. So performance of Trade B depends heavily on the performance of Trade A, a precedent of Trade B. Schedule (starting/finishing date and duration) as well as budget should be assigned to each activity of each Trade. Suppose Trade A is to produce 100 units of output in one month, with a budget of $100.

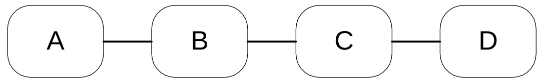

Figure 3: Parade of Trade

If Trade A produces 25/25/25/25 good units each of the four weeks, 100 monthly within budget, workflow is very stable. In this situation, performance of B in terms of schedule as well as cost is not constrained or limited by A. In other words, B is responsible[1] if the result of performance of its work turns out to be behind schedule or over budget.

On the other hand, if A was supposed to produce 25 units each week, but actually produces 10/30/15/35 units each of the four weeks, 100 monthly within budget, work flow becomes unreliable. In this situation, performance of B might be worse (behind schedule and/or overrun) due to unreliable work flow. Table 2 shows two different situations and performance factors in terms of the earned-value method.

Table 2: EVM Contradictions

Case 1 As of 31 July

Trade	Schedule		Performance						
	Starting	Finishing	Output (usually not in the report)	BCWS	BCWP	ACWP	SV(%)	CV(%)	EVM says
A	1-Jul	31-Jul	25/25/25/25	$100	$100	$95	0%	5%	Green Light
B	7-Jul	7-Aug							

Case 2

Trade	Schedule		Performance						
	Starting	Finishing	Output (usually not in the report)	BCWS	BCWP	ACWP	SV(%)	CV(%)	EVM says
A	1-Jul	31-Jul	10/30/15/45	$100	$100	$99	0%	1%	Green Light
B	7-Jul	7-Aug							

Current control systems red flag B, which prompts the manager to penalize and rectify B. However, bad performance of B results not from B but from A. Earned value control systems do not reveal that A is causing the problem of unreliable workflow.

Another issue is matching downstream[2]. The example in Table 2 needs to be modified since it assumes all output of trade A is equivalent to trade B. In other words, trade B can use any output of trade A. However, the situation can be different when outputs of trade A are not equivalent. Suppose, in this case, Trade A produces 25 for area A, 25 for area B, 25 for area C, and 25 for area D. Even though sequence is determined by contract or master schedule, priority of output of Trade A can be different during implementation depending on downstream demand. The best sequencing for Trade A does not always

[1] Of course, there may be other external constraints impacting B's performance; e.g., failure to coordinate space or shared resources, late or inaccurate deliveries, safety hazards caused by others, etc.

[2] See an example in Tommelein (1998).

match downstream demand. Producing what the downstream trade does not need only increases the amount of buffer between trades. However, current control systems give equivalent BCWP to Trade A without regard to the mismatch with downstream demands.

Table 3 shows a simple example. In case 1, Trade A produces as sequenced in the contract or original schedule without regard to downstream demand. It can be said that trade A's sequence in case 1 is best only for its own productivity. In case 2, on the other hand, Trade A's work sequence reflects downstream demand. As seen in Table 3, matching its sequence with downstream demands can bring about longer duration of its production in some cases comparing to sequencing without considering downstream demands. However, it makes downstream work flow more reliable than case 1. Value is generated if Trade A produces what downstream workstations need when they need it. EVM does not differentiate between value-generating operations and non-value generation because calculation of BCWP disregards downstream demand.

Table 3: Local Optimization

Case 1 As of July 14

	Schedule		Performance						
	Starting	Finishing	Output (usually not in the report)	BCWS	BCWP	ACWP	SV (%)	CV (%)	EVM says
A	1-Jul	31-Jul	25(A)/25(B)	$50	$50	$45	0%	10%	Green Lightl
B	7-Jul	7-Aug		$50	0	0			Red Light

Case 2

	Schedule		Performance						
	Starting	Finishing	Output (usually not in the report)	BCWS	BCWP	ACWP	SV (%)	CV (%)	EVM says
A	1-Jul	31-Jul	25(D)/20(B) by B's demand	$50	$40	$40	-20%	0%	Red Light
B	7-Jul	7-Aug		$50	$50	$45	0%	10%	

The examples above occur when control accounts or activities are linked dependently. However, not all control accounts are tightly linked. The examples shown above are made to illustrate the impact of dependence. Some accounts are inherently independent, and sometimes managers isolate (decouple) accounts or activities from immediate interaction with other accounts to cope with the uncertainty (Howell et al. 1992). Two primary kinds of couplings exists between accounts or activities: 1) intermediate product and 2) shared resources. Coupling and decoupling relations between accounts affect many management decisions, one of which is forecasting results. EVM uses two forecasting methods. One is to forecast based on a planned rate, and the other is to forecast based on an observed rate. (Detailed description of methods of forecasting is not within the scope of this paper.) It is clear that current control systems do not recognize these relations between activities. Forecasting without considering these relations yields unreliable results. This could be a reason why managers often resort to an 'educated guess' in lieu of a quantitative forecast of time and cost based on EVM. Control accounts tightly linked, or coupled, should be forecasted taking into account the reliability of workflow.

With this simple example, it is found that current EVM ignores the concepts of work flow and value-generation based on customer needs. Work activities are not discrete, independent elements.

Overloading From Reducing PU[3] Capacity

A manager with responsibility for operations might want to reduce capacity (e.g. reduce workforce) if that would make his performance appear better in cost reports. Reducing capacity and pushing “SHOULD” assignments results in overloading of production units (PUs). Ballard (1999) showed underloading increases the capacity of following PUs through its impact on work flow reliability. In other words, overloading upstream, assigning more jobs than a PU’s capacity, decreases the productivity of the downstream production units.

Lack of Flow and Value Generation Views

According to Koskela (1999), production systems have three goals: 1) To do what is necessary, 2) To do as little of what is unnecessary as possible, and 3) To generate value for customers and stakeholders. Production systems can be conceived in three different ways, corresponding to those three goals; i.e., as a transformation of inputs into outputs, as a flow of materials or information among specialists, and as a value generating process.

The traditional cost control system, including EVM, breaks a project into pieces (cost accounts or work packages) and monitors what should be done and what has been done in terms of progress and cost. It is based on a transformation view in that the needed tasks are identified and progress is monitored to get them done within budgetary constraints.[4] This is not totally wrong, but it is partial and limited because it lacks the concept of flow and flow control, not to mention value generation. Controlling work flow is vital to project control and requires equal attention.

Enemy of Work Flow

First of all, it is necessary to discuss what work flow is. The Lean Construction Institute (1999) defined work flow as the movement of information and materials through a network of production units, each of which processes them before releasing to those downstream. Ballard and Howell (1997) showed work flow could be improved by making only quality assignments, which shields production from work flow uncertainty.

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[3] A group of direct production workers that do or share responsibility for similar work, drawing on the same skills and techniques. (See Glossary at <www.leanconstruction.org>.)

[4] The limitations of this way of thinking has been characterized by Ballard et al. (1996) as the "contract mind", which degenerates into trying to manage production exclusively through contracts.

They proposed five criteria for quality assignments; Definition, soundness, sequence, size, and learning.

As discussed earlier, schedule variance (SV) is the difference between BCWP (Budgeted Cost of Work Performed) and BCWS (Budgeted Cost of Work Scheduled) [SV = BCWP – BCWS]. If schedule variance is shown as a negative value on a specific cost account as of a reporting date, the manager of the organization in charge of the "red-flagged" cost account will be in trouble. It is the way project control goes. Therefore the only way to prevent his own cost account from being behind schedule is to increase BCWP as much as possible as of the reporting date.

On the other hand, cost accounts or work packages are different from work tasks assigned to the field. Since detailed work procedure or sequence is usually at the manager's discretion, managers can manipulate work sequences or release work assignments in order to make their performance appear better, without regard to work flow uncertainty and its negative impact on performance downstream.

If budget/cost on each cost account is the main decision criterion for releasing work assignments rather than the five quality criteria, work flow can be unreliable, which results in longer durations and higher costs than necessary, and possibly schedule and cost overruns relative to budget.

An illustrative case is earthwork on the Tabuk Cement Plant Project (Saudi Arabia, 1994 - 1997)[5] that was implemented in 1995. 1,500,000 m3 of materials was to be removed by excavator and explosion, slope trimming, and leveling. The earthwork contractor tried to tackle the easiest most lucrative part of the job, which was excavation by excavator/explosion all across the site. However, they procrastinated on slope trimming and leveling, which were slow to progress and unbeneficial in terms of earned value and consequently cash flow. Earthwork's internal customer, its successor, was complaining since they could not start work due to unreleased area. When the project manager directed Earthwork to produce according to schedule, he said "Okay, I will do that tomorrow," but he made a different excuse every day for not doing so.

CONCLUSION

The earned-value method has been developed for integrating schedule and cost. However, prevailing project control, including EVM, is an effective tool only under the limiting assumption that every activity or cost account is independent. Making BCWP (earned-value) a priority in releasing assignments to the field prevents quality assignments, which results in unreliability of work flow.

Research is needed to develop alternative project accounting systems that are not subject to these same limitations and distortions. The authors are working on this problem and will report progress in future papers. The alternative system being explored would result from adding work flow reliability measures to traditional cost and schedule measures. Such a system is hypothesized to provide managers better insight into actual project conditions and to help them make better control decisions. Other researchers

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[5] The first author worked as planning engineer in charge of schedule/cost reporting on the Tabuk project.

working in this area are encouraged to contact the authors to share ideas and coordinate future research.

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