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CURRENT STATE OF THE APPLICATION OF EVM IN THE CONSTRUCTION INDUSTRY

Theresia Avila Bria
PhD Candidate, Graduate School of Engineering Science and Technology, National Yunlin University of Science and Technology, Douliu City, Taiwan
Department of Civil Engineering, Politeknik Negeri Kupang, Kupang City, Indonesia
thessabria12@gmail.com

Muhammad Mubasher
Graduate Student, Department of Civil & Construction Engineering; National Yunlin University of Science and Technology, Douliu City, Taiwan
mubasher_civil@outlook.com

Wei Tong Chen*
Distinguished Professor, Graduate School of Engineering Science and Technology/ Department of Civil & Construction Engineering; National Yunlin University of Science and Technology, Douliu City, Taiwan
*(corresponding author) chenwt@yuntech.edu.tw

Abstract

Budget overruns and work delays are recurring issues in the construction business. Construction projects are seen as interconnected nodes in larger organizational networks, driving a surge in research interest in construction project management (CPM). Earned value management (EVM) is a widely used project management (PM) approach that provides early warning of potential problems and helps control costs and schedules. This study aims to analyze EVM articles to determine the field's current state and identify promising avenues for further investigation.

Key words: Earned value management, construction project, cost and time, performance

Introduction

Effectively controlling project schedules and costs is a frequent challenge for construction professionals. A survey of 290 projects around the world found average cost overruns of 73% [30]. Over half of 137 projects (55%) in

Nigeria suffered budget overruns ranging from 5% to 808% [31]. Construction costs and duration differences are an issue in both first world and third-world nations. In response, over the past two decades, earned value management (EVM) has been increasingly applied the field of construction project management (CPM). Motivated by the emerging view of projects as temporary network-based organizations, these studies seek to provide a deeper understanding of the management characteristics of construction projects. Compared to permanent organizations such as corporations or public institutions, construction project structures are transitory and short-lived, but are purposefully created to accomplish the long-term aims and aspirations of the permanent organization or of a subset of project owners.

EVM is a project management approach that considers not just project budgets but also timelines and work quality. First proposed in 1996, the concept of EVM Systems (EVMS) has transformed EVM from a requirement for government contracts to a practical best practice tool for project managers in the commercial sector, as "an integrated collection of rules, procedures, and practices to support programmed PM as a decision enhancing tool and a crucial component of risk management". Currently, EVM is one of the most widely utilized approaches for evaluating project success.

Although terms like Earned Value Management (EVM) are mostly interchangeable with other project evaluation methods, which provides the project manager with a mechanism for conducting regular, timely checks on the project's overall health. EVM has been use for a variety of purposes, including, but not limited to, (1) cost and time estimation; (2) determining the cost and schedule impacts of problems; (3) providing an accurate portrayal of the project's cost status; (4) identifying the root causes of problems; (5) showing project's schedule status; (6) providing timely project information, and (7) locating previously unrecognized trouble spots .

EVM is now commonly used in commercial and governmental projects of all sizes, mostly using EVM software applications that integrate with other popular PM tools like MS Project and Project Server, win sight, Cobra, and Open Plan to simplify the analytic procedures [6**Error! Reference source not found.**]. These software packages help operators manage staff expansion, tool installation and training. However, research interest in EVM has grown over the years, a systematic evaluation of the current research is lacking, and the present study seeks to address this gap.

Background of EVM

Terminology of EVM

Parts of the EVM have been extensively argued and derived [10]. In standard practice, key features of EVM, such as planned value (PV), earned value (EV), actual cost (AC), and EVM measurements, are separated into these two groups: variances, indices, and forecasts [6]. Additionally, the development of EVM ideas has increased discrepancies (variations between primary metrics within EVM) like earned schedule (ES) and earned duration (ED).

EVM is heavily dependent on performance metrics. The EV method uses the schedule performance index (SPI) and the cost performance index (CPI). Cost and schedule management are linked, as shown by the critical ratio (CR) which is a composite statistic calculated by multiplying the CPI and SPI. The weighted performance index is the sum of the SPI and the CPI, recognizing that the weights assigned to these two metrics may reflect the fact that cost performance and schedule performance are affected by distinct factors .

EVM has been criticized for its reliance on antiquated and cumbersome jargon. The 2004 PMBOK® Guide tried to streamline the language requirements to only two words per critical factor. For instance, the term "earned value" (EV) might be used to refer to the amount of money spent on a project rather than the "budgeted cost of work produced" (BCWP). Furthermore, a general formula for estimating total project completion time relies on three different techniques. Tables 1 & 2 define the terms of EVM.

To calculate ACWP and BCWP, EVM must be applied to construction projects using consistent cost and time log data (typically weekly). In addition, the BCWS must be met before any construction work can begin; this number forms the foundation of both the work schedule and the associated cost plan.

Table 1. Terms Related to EVM

EVM Metrics	Description of EVM Metrics
BCWS	The dollarized value of all work scheduled to be accomplished in each period. This key variable symbolizes the planning function required by EVM. BCWS = % Complete (Planned) × Project Budget
BCWP	The dollarized (budgeted) value of all work accomplished in each period. The variable is also called EV and symbolizes the completion of work. BCWP is not 'earned' until the work is completed. The formula reads as follows: BCWP = % Work Performed (Actual) × Project Budget.
ACWP	The cost actually incurred and recorded to accomplish the work performed within a given accounting period, with reporting accumulated over time. ACWP is reported by the contractor's accounting system in accordance with generally accepted accounting procedures. The formula reads as follows: BCWP = % Work Performed (Actual) × Project Budget.
BAC	A measure that is often used in EVM to track the actual cost of a project against its forecasted budget. It is calculated at the start of a project based on the project work and its individual components.
T	The planned period of the project.

Notes:
BCWS (Budgeted Cost of Work Scheduled) can be regarded as PV (Planned Value); BCWP (Budgeted Cost of Work Performed) can be regarded as EV (Earned Value); ACWP (Actual Cost of Work Performed) can be regarded as AC (Actual Cost).

Table 2. Additional EVM-Related Key Terms

Performance Metrics	Overview of Performance Metrics
SPI	A measure of the conformance of actual progress (EV) to the planned progress: SPI = EV / PV.A value of 1.0 indicates that the project performance is on target. To find the schedule performance index, we must first find the planned value and the earned value. SPI is then calculated by dividing this earned value integer by the planned value integer. Therefore, the schedule performance index is a ratio of earned value to planned value.
CPI	A measure of the conformance of the actual work completed (measured by its earned value) to the actual cost incurred: CPI = EV / AC. SPI is a measure of the conformance of actual progress (EV) to the planned progress: SPI = EV / PV. CPI is a metric used to determine if tasks within a project use up more or less of the budget assigned to that project. If CPI is over 1.00 it means it's under-budgeted, and otherwise over-budgeted.
SV	Indicates the degree to which a project is ahead of or behind schedule by calculating actual progress against expected progress. SV is a part of EVM and is used by the Program Manager and program personnel to determine project scheduling performance and how best to utilize their remaining resources. To calculate SV, subtract project's PV from its EV: SV = EV – PV.
CV	The difference between project costs estimated during the planning phase (i.e., budgeted costs) and actual costs. Project managers calculate cost variance to determine if a project is under or over budget. The cost variance formula is defined as the 'difference between EV and AC. (CV = EV – AC) Sometimes this formula is expressed as the difference between budgeted cost of work performed and actual cost work performed.

Notes:
SV (Schedule Variance): VP = EV – PV; CV (Cost Variance): VC = EV – AC

Several performance indicators may be used to obtain the cost EAC (= AC+BAC-EV) and anticipated cost for remaining work, where BAC is the total budget and the index is composed mostly of a performance index and a regression index. The three most frequently ways to estimate project duration are PV, ED, and ES. The method of estimating the time needed to complete a project in general is represented by the formula EAC = AD + PDWR.

Advantages and Disadvantages of EVM

EVM can be used to streamline project reporting requirements. Valle and Soares outlined the primary benefits of EVM as follows: (1) a unified approach to effectively manage budgets, schedules, and progress; (2) enhanced insight into project scope and procurement; (3) prompt notification of problems/issues; (4) the ability to anticipate trends in project deviations; (5) reducing the time needed to understand problems and find solutions; (6) inspires team members to actively participate in the control process; and (7) improved project outcomes .

However, previous studies have found various barriers to effective EVM implementation, including: (1) high cost and complex documentation requirements, (2) poor understanding of EVM, (3) distrust and conflict between project managers, project consultants, and regulators ,(4) pressures to report only good news and (5) contracts with fixed pricing may make project managers cautious about implementing EVM. EVM analysis results are not directly tied to potential management action, performance indicators may suffer from poor accuracy.

Empirical Studies of Construction EVM

This work surveys various journals, conference papers and books related to EVM dividing the EVM literature into two categories: empirical and non-empirical. Key challenges for empirical investigations include efficient EVM implementation, CPI behaviors, cost control method accuracy, and time control technique accuracy. The topics of the theoretical investigations include SPI at various WBS levels, time control method precision, and the combination of EVM with other PM approaches.

Effective EVM implementation

Successful EVM implementation requires several key practices in process planning, execution, and control, in addition to adopting the PM principles defined in PMBOOK Guide in normal project management procedures. Moreover, there are three key crucial success factors (usage, acceptance, and performance) are defined to improve the probability of successful EVM adoption. Each component is then broken down into several smaller success sub-factors.

Cultural issues, such as a lack of openness to sharing negative information or an overly optimistic outlook on recovering from cost overruns, were also found to impede efficient PM. In particular, contractors or government project managers may not be primarily concerned with identifying the most accurate estimate, but rather with safeguarding the project and the career prospects of its managers by hiding "bad news”. One study [32] argued that fixing "lingering cultural issues" is more important than improving EAC prediction accuracy.

Accuracy of Cost and Time Control Techniques

Several studies sought to better understand CPI behavior throughout the project duration. After a project reaches 20% completion, the cumulative CPI value stabilizes at about 0.1 and often declines from there. For extended projects lasting more than 6.7 years, it was found that the conclusion drawn by Christensen and Heise [9] remains valid.

Multiple studies on the reliability of the various methods for independent estimates for project completion were prompted by the rapid conclusion to the US Navy's A-12 Avenger Acquisition Program. Such studies typically compare actual contract costs to EAC calculated using a variety of index-based methods. EAC estimates based on CPI averaged over shorter periods were found to be somewhat higher, and a survey of over 25 EAC studies found no clear evidence that either regression-based models or index-based models are either inherently more accurate. The precision of results is determined by the systems used and the contracts' current development state. Past research shows that the cumulative cost estimate at completion based on the CPI refers to the lower bound. This estimate was the closest to the estimation supported by contractor and government program managers, based on data taken from completed contracts extracted from the US Defense Acquisition Executive Summary database. However, in most cases, the average EAC calculated from the cumulative CR provided the most reliable results. Data from real-world projects used to assess the validity of three schedule forecasting approaches found that the ES method is more accurate at predicting total project duration [33].

Empirical Studies of EVM in Construction

SPI at Different WBS Levels

Lipke (2005) [25] noted traditional SPI metrics might give incorrect time projections in a project's latter stages, and thus proposed ES, which adds a temporal dimension to the financial metrics, along with a modified schedule performance indicator [SPI(t)] for tracking progress over the course of a project's lifetime. If these methods are used at the activity level rather than the control account level or higher WBS levels, SPI and SPI(t) are accurate measures of PM. The impact of false SPI values on the accuracy of three forecasting approaches was also probed. Minor delays in key operations, paired with significantly quicker progress in non-critical activities, may result in a false SPI number.

Practitioners may only use the measurements at higher levels. A full schedule analysis might place an undue amount of stress and disruption on the project team. Furthermore, accurate measurement of PM on high WBS levels is possible when the project network has a relatively serial structure that merges many important activities. The new approach to a float-based weighted SPI and a float-based critical parameter is used to quantify the importance of each activity.

Accuracy of Time Control Techniques

In this context, it is necessary to compare the efficacy of PV, ED, and ES. The three approaches in project monitoring with ES provide the most valid and accurate findings through the project's life. But when the SPI(t) value is false, the ES approach underperformed the other two methods. The use of simulation mode to examine critical and non-critical activities in a network affected the precision of the three duration forecasting techniques.

Results from simulations suggest that a greater criticality of project activities, as opposed to more parallel networks, may lead to improved prediction accuracy. When plotted as a function of time, the intended value often follows an S-curve along which the project expenses will rise and fall throughout the project's lifecycle as the number of concurrent operations will fluctuate. However, EVM procedures often assume a linear relationship between the intended value and the actual value, potentially resulting in errors. Thus, Cioffi created an analytic description for the shape in different contexts. EVM is potentially controversial for projects is subject to extensive rework, as it may lead to incorrect management decisions and thus a decline in the cumulative value of CPI from the moment of stability until project completion. The "effective EV" combines the concept of EV with an assessment of schedule adherence. The logistic-curve based technique that interpolates the nonlinear S-curve allows for the assessment of EAC(t) by considering the unique beginning behavior of a project's schedule as an alternative to using index-based calculations.

The Integration of EVM with Other Project Management Techniques

Intuitive principles were integrated in the 'percent complete' technique which offers EV indexes and estimations based on fuzzy logic. This EVM method blends technical performance, SP, and CP into the standard EVM framework, thus satisfying product quality standards.
To account for the unpredictability of project parameters, a new set of EVM indicators were developed to serve as an early warning system for systemic and structural changes that might have a negative impact on project risk, cost, or schedule. Combining the Kalman filter forecasting approach with ES may offer probabilistic estimates of the project completion time.

Estimates for future projects and the effectiveness of suggested fixes were calculated using the stochastic S-curves (SS curves). Utilizing statistical methods such as Weibull analysis enables forecasting of ultimate project cost and duration [29], offering a solution to the challenge of limited availability of broad-based data [25].

Conclusions

To sum up, EVM is crucial to the overall management of project scope, timeline, and budget. In addition, there are now guidelines for using this technique to manage future construction projects. In this study, we survey the state of the art regarding current and prominent EVM research paths. The study starts with a summary of EVM's history, defining its key concepts and describing its terminology, performance analysis, forecasting metrics, along with its benefits and drawbacks. We suggest the retrieval studies are organized via a categorization system that was devised. A vast amount of project data was evaluated to illustrate the behaviors of CPI and explore the accuracy of various cost forecasting approaches, such as trend analysis, regression models, and expert judgment. Additionally, case studies were used to highlight the factors that facilitate and impede efficient EVM implementation. Our findings show that the use of models and simulations has significantly improved EVM effectiveness. The successful application of EVM requires establishing an appropriate data representation model that can effectively gather and process integrated data for both costs and scheduling, along with structural modification of local PM practices.

Determining the optimal level of detail for projects of different sizes and types is crucial for effective control during information integration. A mathematical explanation and solution would be useful for addressing the issue of inaccuracies in implementing SPI(t) at higher WBS levels. Additionally, considering a qualitative approach alongside mathematical methods could provide valuable insights and complement the quantitative analysis. For comprehensive schedule analysis while minimizing negative outcomes, the project team must use the appropriate model. The assumption of linear intended value may lead to errors in EVM outputs. Further investigation is needed to obtain a better understanding of the impact of the linear intended value assumption on EVM outputs and to predict type-specific analytical expressions. Future studies should seek to identify the most accurate performance index for a given project. While prior research has relied heavily on information collected from military contracts, the formula's predicted accuracy depends on characteristics unique to individual projects.

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