

# Earned value analysis in project management: Survey and research potential

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**Abstract:** Earned Value Analysis is a recommended technique for monitoring and controlling project execution. Yet, despite four decades of institutional backing and sustained advocacy, its adoption still remains limited. It draws loyal adherents as well as opponents, and an ongoing debate about its practical utility. Empirical studies of its effectiveness or adaptation for different situations are sparse; and the claims, objections do not appear to be reconciled. In this paper, we survey academic and practitioner literature on Earned Value Management and its extensions, and attempt to reconcile the debate by juxtaposing the claims and counterclaims against parallel research streams in project management. We suggest an integrative schema to ground the technique amidst the various bodies of research opinions in order to elicit future directions.

**Keywords:** Earned Value Management, Project management, Literature survey

## Introduction

Despite many decades of practice and academic attention, project performance remains problematic. Empirical evidence suggests that projects do not generally achieve the required scope, are often late, and perform badly on quality of deliverables as well as on cost budgets. According to a recent Standish Group survey report, 61% of the projects either failed or were challenged to meet success criteria; and 74% faced schedule overruns (Standish 2013).

Earned Value Analysis (EVA) is a classical technique to monitor and control project performance. It owes its genesis to US Department of Defense (DOD), which formalized Cost/Schedule Control Systems Criteria (C/SCSC) in 1967, and mandated that defense contractors must use it and report progress in specified formats. C/SCSC was updated to Earned Value Management System (EVMS) in 1997 by Electronic Industry Association through ANSI/EIA-748 standard. At this time, the acronyms used by C/SCSC such as BCWS, ACWP, and BCWP, were simplified to PV (Planned Value), AC (Actual Cost), and EV (Earned Value) respectively. As EVMS was more flexible, DOD and US Federal agencies adopted it replacing C/SCSC (Fleming and Koppelman 2005). Subsequently, Project Management Institute adopted it as a standard: i) Calling it Earned Value Management (EVM), the technique was included in its *Guide to the Project Management Body of Knowledge (PMBOK®)* 2000 edition as one of the standard methods of controlling performance, and ii) Included EVM in PMP – its flagship certification program as part of the Project Integration Management knowledge area, and under Monitoring and Controlling Process Group. These initiatives have led to high level of awareness

about EVM among the practicing project managers as confirmed by several studies (Kim et al. 2003; Besner and Hobbs 2006). Yet, despite these attempts, EVM remains underutilized by the private industry (Kim et al. 2003; Besner and Hobbs 2006; Marshall et al. 2008; Kwak and Anbari 2012; De Marco and Narbaev 2013; Singh et al. 2014).

EVM integrates three key project performance criteria: *scope, time and cost* (Anbari 2003). EVM is fundamentally deterministic (Kim and Reinschmidt 2009), i.e. it is grounded in the assumption that the project scope, master schedules and cost budgets are completely determined and fixed from start. Throughout its history, EVM has enjoyed strong advocacy from its proponents – many of whom were involved with DOD programs. On the other hand, several scholars and practitioners contest its practicality from an implementation point of view, and question its structural rigidity. In response, proponents have attempted to address the objections by suggesting extensions. In parallel, a separate line of empirical research has focused on key success factors to explain project outcomes. Some of these factors are also the pre-requisites for successful EVM adoption, and thus lend support to the objections. Finally, yet another stream of research recognizes the innate indeterminacy of the project phenomena and studies them through uncertainty or complexity lenses. The research under these lenses rejects determinism, negating the basic plank of EVM. Thus, multiple research streams bear on the EVM debate.

Given these developments, it would be pertinent to ask what sort of future awaits EVM outside the US DOD and Federal government-mandated projects. We note that most objections to EVM question its applicability and cost/benefits, but not its usefulness. It would be instructive to examine the evolution and the current state of this debate; and what implications it might have on EVM as well as future research potential in this area. We review available literature on EVM and offer a perspective on the different strands of debate along with contextual findings from parallel research streams. We propose a schematic to integrate the views from different scholars and attempt to derive future directions for research.

This paper is organized as follows. We provide a brief description of EVM concepts and technique, followed by a summary of the cross-currents in the debate to propose an integrative schema for situating the various viewpoints. Next, we discuss the implications and future possibilities for EVM research before concluding with the limitations of our study.

## **Earned Value Management**

EVM integrates project scope, time and cost through periodic measurements of actual cost and work completion. It views project progress in terms of cost as a function of time against a firm baseline set up at the start of the project. When the project is originally planned, it is divided into Work Breakdown Structure (WBS) and further sub-divided into work packages. These work packages are assessed for cost estimates and scheduled in a time sequence. Taken together, WBS, master schedule and cost budgets form the baseline, represented as a graph of planned costs over time. This is the planned value (PV). It simply tells how the costs will flow over time *as planned*. During the project execution, actual costs (AC) and the quantum of work completed are periodically noted. The work completion is pro-rated to equivalent monetary value based on the budgetary costs for the work packages completed (work-in-progress packages are assessed on % completion). This is the earned value (EV). These three numbers, i.e. PV, AC and EV drive the operation of EVM. In essence,  $(EV - AC)$  measures cost performance and  $(EV - PV)$  measures

schedule performance. By measuring at periodic intervals, EVM focuses on the flow rates of actual cost and completion against the planned cost and completion. PV, EV and AC make it possible to compute cost and time variances, as well as extrapolate how much cost and time would be required for project completion (Figure 1). Simple calculations based on these three numbers yield several ratios for project control. Of these, three ratios can be regarded as important: Cost Performance Index (CPI), Schedule Performance Index (SPI), and Cost Estimate at Completion (CEAC). By giving historical and forward information about the project, EVM becomes a tool for monitoring and course corrections.

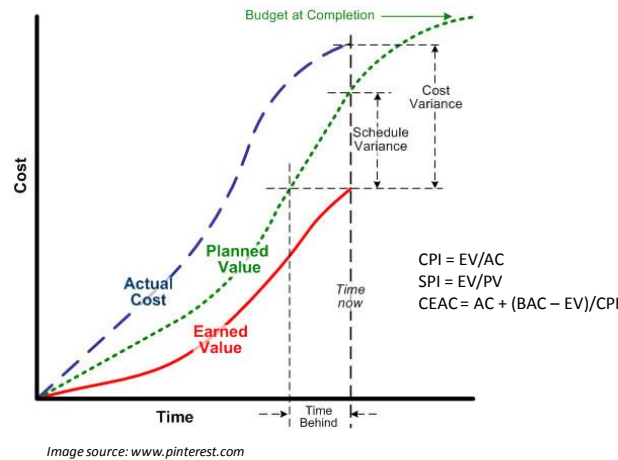


Figure 1: PV, AC and EV

Our purpose is not to give an exhaustive description of EVM, as several excellent papers exist (Fleming and Koppelman 2000; 2005; 2009; Anbari 2003), but to examine its utility as a control technique. Towards this, we now turn to review the debate that surrounds EVM.

## Cross-currents in EVM literature

DOD contractors were clearly the early adopters of the technique. 1967-97 can be seen as the era of C/SCSC, which listed 35 requirements – widely seen to be excessive and over-specified, requiring a lot of paperwork (Abba 1997). Hence, C/SCSC was not enthusiastically received by DOD contractors, and the private industry almost completely ignored it. EVM fared better as a control technique for a number of reasons. First, it dropped some of the cumbersome aspects of C/SCSC and made it more flexible. Second, several US Federal Government Agencies such as NASA and Department of Energy adopted EVM, and began to push for its adoption by the private industry. Third, Project Management Institute accepted it as a standard for project control and included it in PMBOK<sup>®</sup> and PMP certifications. Fourth, a small body of advocates emerged from the practitioners who had used it on DOD projects. From late 90's, private firms began to use EVM. However, it does not appear to enjoy widespread usage. A survey on project management tools revealed that EVM was underutilized (Besner and Hobbs 2006). Surveys from construction industry show poor adoption (Beatham et al. 2004; Chan and Chan 2004). When used, an evidence of positive relationship with project performance is seen (Marshall et al. 2008).

Based on a review of available EVM literature, we note two facts: i) adoption levels of EVM remain low (Kim et al. 2003; Besner and Hobbs 2006; Rozenes et al. 2006; Marshall et al.

2008; De Marco and Narbaev 2013; Singh et al. 2014), and ii) the literature is ‘largely anecdotal’ in nature, with very few empirical studies on post-adoption experience (Kim et al. 2003; Marshall et al. 2008). Therefore, much of the available literature can be regarded as representing views, claims and counterclaims of scholars and practitioners based on their studies and/or experience. Thus, it is possible to group the various articles in two categories: Protagonist literature and Objectionist literature. By ‘objectionist’ we mean challenging the orthodoxy with objective arguments, anecdotal evidence or data. We observe that the objectionist literature challenges the assumptions of determinism and measurability of EVM variables; however, we do not find studies that evaluate or question EVM’s theoretical base. There is a third stream that seeks to extend EVM to overcome the objections. Separately, project management literature has a long-standing empirical stream informing on success/failure factors linked to project outcomes. Some of these variables e.g. scope instability, control systems maturity, etc. overlap with the objectionist claims. Thus the empirical research stream has a bearing on the debate between protagonist and objectionist literatures. Finally, a recent trend is to view the project phenomena through non-deterministic lenses of uncertainty and complexity (Svejvig and Andersen 2015). Since EVM is anchored in a deterministic paradigm, this line of research would appear to question the fundamental basis of EVM. Table 1 lists these five streams of research.

*Table 1 – Research streams related to EVM*

<b>Category</b>	<b>Description of research stream</b>	<b>Research orientation</b>
Protagonist	Support and advocacy of EVM	Deterministic and method-centric
Objectionist	Challenges EVM on the basis of utility, practicality, reliability	Empirical or logical negation of assumptions
Extensionist	Extensions to EVM to overcome objections	Bridge between the two schools
Empiricist	Searches explanatory factors for outcomes	Empirical
Non-determinist	Holds that phenomena are inherently non-deterministic	Models phenomena to gain further insights and to obtain tractability

We proceed with a review of research in the first four categories. As the non-determinist research does not relate to our enquiry, we do not include it in our review and analysis. For our survey, we focus on journal articles on the grounds that non-journal writings are normally not peer-reviewed, often lack the requisite academic rigor, and are generally anchored to a methods-orientation that is non-contestable. We note that though several conference papers on EVM exist, these are generally not subjected to rigorous peer-level scrutiny. Hence we exclude conference papers unless they happen to be well-cited and presented in top conferences such as POMS or DSI.

### **Review of protagonist literature on EVM**

Clearly, US Government Agencies and Project Management Institute are the main protagonists. By publishing the standards and mandating or recommending their adoption makes EVM the de jure method of project control. EVM has spawned a number of loyal adherents that include practitioners, consultants and academia. Protagonist writings on EVM tend to be articles in journals, business media, monographs and topic-focused books. There are two broad themes in protagonist journal writings: i) articles in the nature of explanation of EVM and elaboration of key parameters, and ii) articles on EVM as a tool to control future adverse events.

Under the first theme, Abba (1997; 2000) provides background on the historical events leading to the EVM standard, and discusses A-12 program cancellation to underline its capability to issue early alerts for a potential failure. Christensen (1998) reviews literature to report costs and benefits of EVM. Anbari (2003) gives a comprehensive description of EVM illustrating the use of its various parameters. He also provides extensions to EVM by describing more ratios and their potential utility, while remaining firmly anchored in the deterministic paradigm. Raby (2000) provides easy description of EVM for lay users. In an HBR article, Fleming and Koppelman (2003) describe EVM and argue Cost Performance Index (CPI) as a key parameter that predicts the final cost at completion with reliable accuracy much earlier in the project. Cioffi (2006) contests the usefulness of acronyms used in EVM and claims that simplified, intuitive acronyms can improve the adoption behavior among practitioners. Kuehn (2007) uses the metaphor of flight path to give a detailed description of EVM and illustrates it with an example. Fleming and Koppelman (2009) illustrate the importance of CPI and its ability to forecast via another parameter called TCPI. A study by Marshall et al (2008) finds moderate evidence of EVM as a predictor of project outcomes.

The second theme examines the forecasting ability of the technique, posting that early stability of the indices imparts early alert capability. Christensen and Heise (1993) study 155 completed DOD projects to find stable CPI beyond 20 percent complete point. Lipke (2002) shows that the reciprocals of CPI and SPI are log-normally distributed; and hence amenable to statistical reliability techniques. Christensen and Templin (2002) analyze 240 DOD contracts to show that stability of CPI from 20 percent complete point is a good predictor of cost estimate at completion. Working on his master's degree thesis, Mitchell (2007) studies 181 completed DOD projects to show that cumulative CPI stabilized at or before 50 percent complete point. Vandevor and Vanhoucke (2006) describe EVM to forecast project schedule performance.

## **Review of objectionist literature on EVM**

The objectionist literature is small and mostly comes from defense projects or the construction industry. Cooper (2003) points to the fact that complex projects often involve unanticipated rework, making them unsuitable for EVM. Rozenes et al., (2006) question the hierarchical nature of work breakdown structure (WBS), on which EVM is based, and claim that most common success factors include clear goals and effective control mechanisms, which are generally weak in practice. These deficiencies could explain the low adoption of EVM by the private industry. Putz et al., (2006) describe a NASA case study pointing out problems in setting up baselines, lack of baseline validation, and weaknesses in cost estimates. Lukas (2007) lists ten pitfalls for EVM usage including incomplete requirements or their documentation, WBS-Schedule-Budget integration issues, inapplicability/resistance to WBS, ineffective change processes, inadequate costing systems etc. De Marco and Narbaev (2013) describe the stumbling blocks for EVM such as level of detail in plans/schedules and measurement reliability – especially assessment of work package completion. They observe that SPI tends to 1 as the project nears completion, and hence it is not useful predictor beyond a 60 percent complete point. It appears that the authors are unaware of the concept of Earned Schedule introduced by Lipke (2003). Singh et al. (2014) criticize EVM as a reactive and lagging technique in context of renovation construction industry. They claim that it does not reveal the causes of delays or budget overruns and hence does not advise the future plan of action. EVM is also not suitable when changes to budgets, scope or schedules occur. As such changes are endemic, agile methods have been developed to address

them through iterative processes and non-linear feedback loops. Adapting EVM for Agile methods has been discussed in few conference proceedings (Cabri and Griffiths 2006; Sulaiman et al. 2006). However, EVM's applicability for Agile methods is yet to be rigorously established. Contrasting the above against protagonist research, we observe that neither of the protagonist themes attempts to engage the objections raised by researchers.

## Review of extensionist literature on EVM

Literature to bridge the above cross-currents is very sparse, and offers concrete opportunity for future work in this stream. Bauch and Chung (2001) suggest a modified technique using Shewhart statistical control charts to dynamically monitor time-cost-scope parameters. Pajares and Lopez-Paredes (2011) offer a revised method to integrate risk management with EVM. Kim et al (2003) propose an implementation methodology for EVM based on a four-factor model of EVM acceptance. Lipke et al. (2009) suggest statistical inference techniques to fix confidence intervals for parameters. To overcome the anomalous behavior of SPI (tending to 1 towards completion) cited in the objectionist literature, Lipke (2003; 2004; 2006) proposes the concept of Earned Schedule (ES), involving mapping EV back to time by referencing the baseline. Using simulation, ES is shown to be a better indicator of schedule at completion than traditional EVM methods (Vanhoucke and Vandevorde, 2007; Lipke, 2009). Kim and Reinschmidt (2009) use Bayesian inference on beta-S curve and show that the method delivers narrower intervals compared to earned schedule or the traditional method. It can be seen that the extensionist approach is centered on using statistical techniques to study instability of the EVM indicators. It does not address the underlying causes for instability.

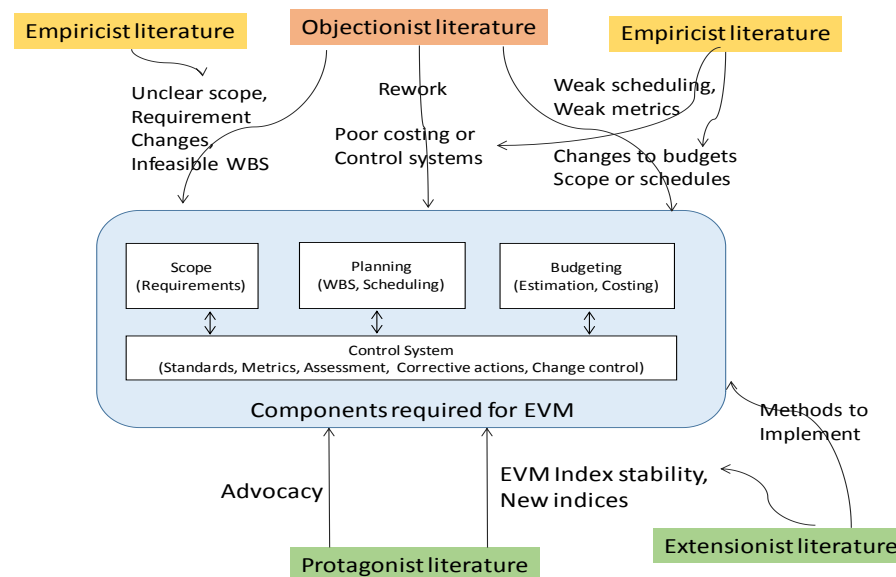


Figure 2: Integrated view of multiple lines of research enquiry

## Review of empiricist project management literature

Project management literature offers considerable quantum of empirical research on success or failure factors to explain the project outcomes. Recall that creating a firm baseline is a fundamental requirement for EVM. It stands to reason that any project variable that interacts

with the baseline components would influence EVM. The empirical research on project management identifies several factors related to project failures such as fixed schedules with no iterative processes, ineffective change management, weak requirements, high complexity, erroneous estimation or metrics, insufficient planning, unclear or shifting goals, etc., showing that actual project environment is anything but deterministic (Whittaker 1999; Cooke-Davis 2002; Kappelman et al. 2006; Nelson 2007; Chua 2009). These factors induce instability in scope, requirements, and estimates and adversely affect the necessary conditions for EVM.

Taking an integral view of these four streams of research, we note that the protagonist writings have continued to advocate the technique, taking little cognizance of the objections raised from various quarters (Figure 2), despite such objections being grounded in empirical reality. The extensionist research has remained peripheral to main concerns about lack of robustness of scope, requirements, and estimates.

## Discussion

A timeline view of the four research streams (Figure 3) indicates that they run contemporaneously. Interestingly, the objections to EVM do not seem to be engaged by EVM researchers, hence the debate on its applicability remains open and relevant.

EVM is powerful because it is a simple, yet an elegant technique, deriving from basic costing principles. By requiring a baseline, it forces an integrated view of work completion and cost flow over time. Without such a technique, the three parameters of scope, schedule and cost are often monitored independently (Rozenes et al., 2006). We observe that it is well subscribed on government projects, since compliance is a necessary pre-requisite of doing business with the government. However, its adoption in that sector does not testify to execution efficiency. Recall that many objections to EVM relate to excessive paperwork and difficulty of hard measurements.

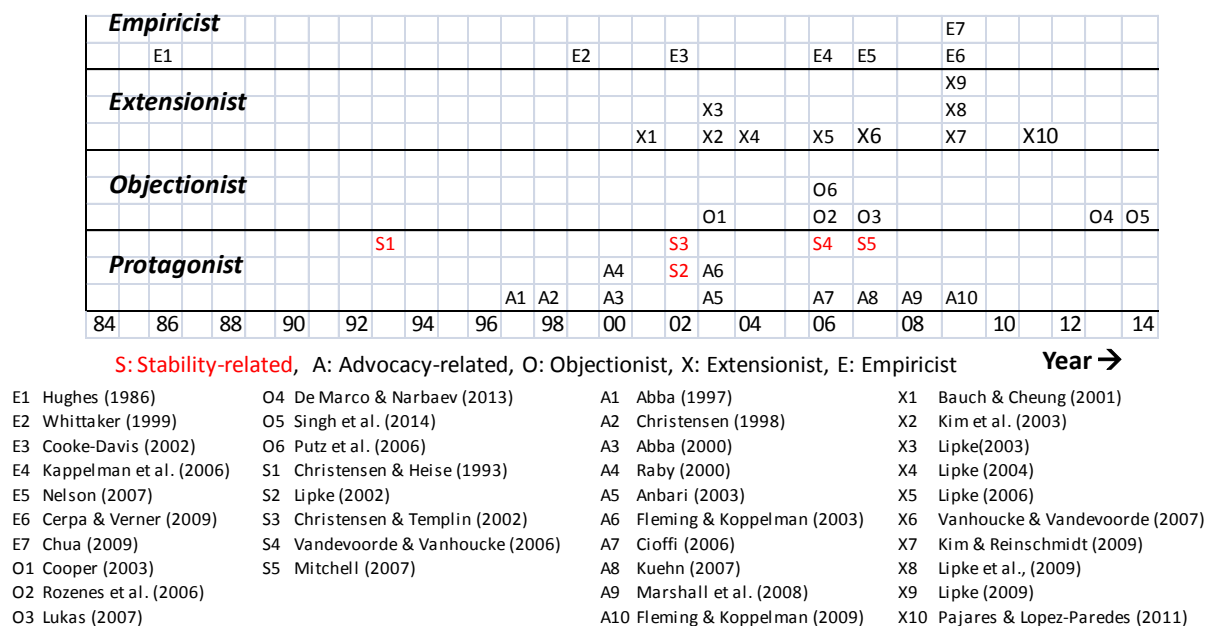


Figure 3: Timeline view of the different research streams

Whether the extra cost of compliance is recovered from incremental efficiencies, pre-emption of budgetary overruns or from the government clients is not clear. But, despite persistent advocacy, there is no evidence of its widespread adoption within the private industry. Empirical studies on EVM usage are very sparse, with one study (Marshall et al. 2008) showing only a moderate relationship ( $R^2 = 0.2247$ ) between EVM adoption and project performance.

We believe that the simplicity of the technique is exactly what reduces its applicability. Because it is grounded in costing principles, it can operate only if the baseline costs and the project plan are fully detailed at project initiation. This implies that project goals, requirements, scope, work breakdown structures, work package definitions, estimates, master schedules, and cost budgets must be firm at the project set-up. There is considerable empirical evidence that information about these elements either does not exist, or is incomplete at the project set-up. Thus, the project baseline is approximate and includes unknown error. EVM literature provides little guidance on project set-up strategies when one or more of these elements are insufficiently informed. Even assuming that the baseline is accurate and detailed, changes in scope, schedule or cost budgets can occur due to endogenous or exogenous events. Empiricist surveys report that such changes are common and consistently rank high in the list of factors critical to project performance. EVM literature does not inform on how the technique should be adapted when changes happen. A typology of changes and how they can be flexibly accommodated within EVM would be useful for the practitioners. Another commonly reported problem relates to inadequacy of the measurement systems. Even with perfect project set-up, measurement errors cannot be avoided. Established costing systems can measure AC with fair accuracy, but EV measures remain fuzzy. To compute EV, one must measure completion of work packages. This requires subjective judgment for in-progress work packages. To overcome the problem of errors of judgment, 50/50 rule has been suggested. This however leads to EV being overstated or understated by an average 25% of each work package baseline. When EV is aggregated over work package differing in size, it is not possible to specify the error in total EV. Objectionist literature points this out, and the extensionist stream appears to have engaged this issue by looking at statistical inference methods (Lipke et al. 2009). But such research investigates confidence intervals on CPI and not EV. This problem possibly merits attention from other research streams such as work measurement.

EVM serves two main purposes. First, it tells the project manager where the project is, by connecting work completion, costs incurred and time taken. Second, it supplies the arithmetic to predict the cost and time parameters at completion. Arguably, anything that offers an ability to predict future outcomes should be much valued, and it is no surprise that it is the dominant theme in all protagonist writings. Moreover, the objectionist papers do not explicitly challenge EVM's prediction ability while questioning its practicability. It is puzzling that a technique offers a very useful feature which is not contested, and yet gets ignored in practice. Since empirical evidence about EVM remains very sparse, we offer a couple of conjectures to explain its low adoption. First, we note that the arithmetic to calculate the predicted values of parameters follows the method of linear extrapolation using CPI, which is simply the rate at which actual cost inflow converts to productive cost outflow. For true predictive ability, CPI must achieve a constant value, which explains the search for 'stable CPI' in protagonist literature. There is no reason to believe that actual cost will convert to productive work at a constant rate. Indeed the graphs illustrating EVM generally show different S-curves for AC and EV. If the two cost flows are differently non-linear, EVM loses its ability to predict because CPI becomes a function of time.



Second, deriving the shapes of cost functions is not possible because it requires a precise understanding of causal model of work and costs. Costing logic is rarely possessed of such an understanding (Lebas 1995). By forcing linearity on patently non-linear phenomena, EVM does much disservice to its claim of prediction accuracy.

Even so, EVM remains one of the few techniques that generate progress data from which it is possible to learn the function shapes. Such data, coupled with prior knowledge could be used to make statistically robust inferences about the cost functions. We note a few initial attempts towards this end in the extensionist literature (Lipke et al. 2009; Pajares and Lopez-Paredes 2011), which use confidence interval-based methods. However, the computed confidence intervals are likely to be too broad in the early stages to be of much practical use. Also, these methods assume that underlying variables follow normal distributions; but there is no reason to assume such normality (Lipke 2002). Other methods such as Bayesian inference or stochastic models could deliver narrower, robust intervals, and have been attempted with encouraging results (Kim and Reinschmidt 2009). With better grasp of function shapes, Monte Carlo methods and/or systems dynamics could deliver further insights into the behavior of costs. Such methods have already been used to deliver useful insights (Lipke 2009; Vanhoucke and Vandevoorde 2007), and could advance the extensionist enquiry to act as an effective bridge between the protagonist and the objectionist schools and may aid the adoption of EVM.

To conclude, our paper surveys the cross-currents in EVM literature and finds the debate to be disengaged, with no early signs of greater adoption by practitioners. We also find the research on EVM to be sparse, both in terms of empirical findings and conceptual models. Our paper contributes to the literature by integrating the dispersed research streams into a framework, and by positing multiple lines of future research. We acknowledge the limitations of our work. First, due to dispersed nature of research, our findings are limited by the papers we could find for our review. Second, due to acute paucity of empirical studies, we are forced to offer conjectural explanations. Such explanations may stand altered if more empirical data were available. Despite these limitations, we hope that our contribution offers utility for future researchers.

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