International Journal of Engineering Research and Reviews ISSN 2348-697X (Online)
Vol. 6, Issue 3, pp: (4-10), Month: July - September 2018, Available at: www.researchpublish.com

REVIEW OF EARNED VALUE MANAGEMENT (EVM) TOOL FOR PROJECT MANAGEMENT

Andy-Al-Affendi[1], Mohd Khairol Anuar Mohd Ariffin[2]

Department of Mechanical and Manufacturing Engineering, Faculty of Engineering, University Putra Malaysia, 43400, UPM Serdang, Selangor, Malaysia.

Author Email: andyalaffendi@gmail.com[1], khairol@upm.edu.my[2]

Abstract: **This paper presents a review of an Earned Value Management System (EVM) for assessing project performance compared to others methodology. This study attempts to solve problem to the project manager and project stake holder in handling complicated, dynamic and massive project information especially when changes to the project baseline which is unavoidable. Through feasibility review study, it has been shown that the EVM provide an objective measures of the work that project manager can access project achievement by converting the project data into manageable information clusters and in parallel promoting the earned value management method as an effective tool to monitor and control project constraints which are cost, timeline and scope.**

Keywords: **Earned Value Management.**

1. INTRODUCTION

The performance of a project manager is usually appraised based on project key performance indicator (KPI) which mostly derived from the project triple constraint [1]. In product development projects, the main KPI are normally the product profitability which are measured by the product return of sales (ROS) and the internal return rate (IRR) for the capital deployed to fund the development.

In assisting the project manager to manage the project, there are many method available and can be used depending on the type and complexity of the project. Among popular methods are Critical Path Method (CPM) [2][3][4], Program Evaluation Review Technique (PERT) [5][6][7], Monte Carlo Simulation [8][9][10], S-Curve [11][12][13] and least explore method, Earned Value Analysis Method (EVM) [11][12][13].

All methods available serve the same purpose which is to gauge the progress and report the project execution status against the project initial plan. Even they are quite similar and project manager can actually use either of them to access the project progress on a specific task. Some method and technique are focusing on project schedule thru project work breakdown structure, the financial impact on the project budget are noticeably neglected. Small and quick changes deviated from the project baseline were implemented with the assumption that it would not impact the project total budget. However, this, accumulated changes in the end can significantly damage the project profitability and easily caused project budget overrun.

Nonetheless, EVM method provide complete evaluation of the project status which covers financially, overview of the project progress and also reliable forecast of the project schedule and budget at very early of the project execution phase [14].

2. EARNED VALUE DEFINITION

"Earned Value" is basically the value (usually expressed in ringgit) of the work accomplished up to a point in time based upon the planned (or budgeted) value for that work [15]. The government's term for earned value is "Budgeted Cost of Work Performed" (BCWP) [16].

Typically when a schedule is being formulated, the work to be done is broken down into tasks or "work packets" which are organized into a logical pattern usually called a "Work Breakdown Structure" (WBS) [16]. The WBS is usually formulated in a hierarchical manner.

Each work packages is assigned to an organization for work management/responsibility. The organizational structure may also be represented in a hierarchical manner typically called "Work Breakdown Structure" (WBS). The amount and type of cost to complete each work packet is then estimated. Resources to perform the work are identified for each packet and may be coded by using a "Resource Breakdown Structure" (RBS). Each packet typically has one type of cost (labor, travel, materials, etc.), coded by an "Element of Cost Breakdown" (EOC) or simple general ledger account number.

3. COMPARISON WITH OTHER METHODOLOGY

Network based technique such as CPM and PERT which widely used in late 1950s and still today, recognized as important project management tools and technique [17]. Other methods of project performance evaluation such as Monte Carlo simulation and S-curve had been widely used as effective tool in providing trend of the project execution to assist project manager steer the project.

Critical Path Method (CPM)

Critical Path Method can help project manager to determine how long a project will take to complete, by identifying "critical" activities in the project's work breakdown structure [18]. If the information about cost of each activities, and how much it cost to expedite the activities, CPM can provide forecast such as whether the project should try to speed up and if so, what is the least costly way to expedite the project. CPM is also used to provide estimation on time to complete by measuring the longest overall duration through the sequence network diagram [19]. Any delay of an activity in the critical path directly impacts the planned project completion date.

Project Evaluation and Review Technique (PERT)

PERT is designed to analyse and represent the tasks involved in completing a given project. It was originated by the U.S. Navy in 1958 as a tool for scheduling the development of a complete weapons system [5][20]. The critical path includes a sequence of activities that cannot be delayed without jeopardy to the entire project. PERT can be used to estimate the probability of completing either a project or individual activities by any specified time. It is also possible to determine the time duration corresponding to a given probability [21]. Subsequently, PERT was developed to simplify the planning and scheduling of large and complex projects. PERT is concerned with the time needed to complete each task, and the minimum time needed to complete the total project and it incorporates uncertainty to 21 schedule a project while not knowing precisely the details and durations of all the activities [19].

Various criticisms and proposed modifications to PERT have appeared in the literature since the early 1960s. There are five recognized problems with PERT. First, it is difficult for project engineers and planners to accurately estimate the optimistic, most likely, and pessimistic durations of an activity [5]. Grubbs (1962) [22] note that subjective estimates of a, m, and b are based on judgment and may not be closely related to statistical sampling of the actual times. The latter authors note that the subjectivity is compounded by the fact that the activity duration distribution is purely hypothetical, as well, as discussed later.

MacCrimmon and Ryavec (1964) [21] calculate the sensitivity of (1) and (2) to incorrect estimates of a, m, and b. Swanson and Pazer (1971) [23] indicate that ''optimistic'' and ''pessimistic'' are ambiguous and are subject to interpretation. For example, b has been described as having a ''small chance'' or a ''one in 100'' chance of being exceeded [23]. Littlefield Jr and Randolph (1987) [24] state that, based on past research, ''people are not very good estimators of the extreme values.'' Moder and Rodgers (1968) [19] relax this requirement. The simplification of PERT proposed in the present paper reduces the dependence on subjective estimation of activity durations by decreasing the number of time estimates from three to two.

Monte Carlo simulation

Other technique commonly used in managing project with huge time uncertainties is Monte Carlo or also known as Monte Carlo simulation or method. The benefits of Monte Carlo simulation are using quantified data, allowing project managers to better justify and communicate their arguments when senior management is pushing for unrealistic project expectations [25].

This method furnishes the decision maker with a range of possible outcomes and the probabilities they will occur with any choice of options. The technique was used by scientist working on the atomic bomb during the last World War II [26]. This technique is stochastic, which based on the use of random numbers and probability statistic to investigate problems. Monte Carlo simulation can quantify the effect of risk and uncertainties in the project schedule and budget, giving the project manager a statistical indicator of project performance such as target project completion date and budget.

In the field of computer engineering and design, Bhanot et al. (2005) [27] described the use of simulation when optimizing the problem layout of IBM's Blue Gene?/L supercomputer. In geophysical engineering, Monte Carlo analysis has been used to predict slope stability given a variety of factors [28]. In marine engineering, Santos and Soares, (2005) [29] described a probabilistic methodology they have developed to assess damaged ship survivability based on Monte Carlo simulation. Kwak and Ingall, (2007) [25] explained their use of Monte Carlo simulation in aerospace engineering to geometrically model an entire spacecraft and its payload, using The Integral Mass Model.

S-Curve

The S-Curve is used in project management as mean of representing the various expenditures of resources over the project life time of the project or in other word as means of charting the real time expenditure of resources. An S-Curve is a sigmoid curve. The S-Curve used in project management to monitor the project as its progresses and compared it to the projected S-Curve to determine whether the project is being completed within the time and budget limitation. An S-Curve is a tool of quantitative risk analysis which project management would use to determine the possible danger of any given course of action [30]. Comparisons of each methodology discussed above are simplified in Table-1. Note that this comparison only provides a general overview of each technique and does not include deep dive investigation.

4. CURRENT EVM AND ASSOCIATED PROBLEMS

EVM is a methodology used to measure and communicate the real physical progress of a project and to integrate the three critical elements of project management which are scope, time and cost management[14]. Although EVM has been setup to follow-up both time and cost, the majority of the research has been focused on the cost aspect.

EVM is now accepted by many project managers. Survey conducted by other researchers indicated that project manager who have used and are using EVM accepted this methodology. The survey done also concluded that this acceptance has become increasingly common in both the public and private sectors, implying that EVM can be applied successfully in both sectors [31]. The survey however was conducted in the United State and unfortunately, there are less empirical studies on EVM implementation were found in Malaysia private and government sectors.

The EVM policy that evolved in the 1970's, was in the traditional "oversight" mode than used in the US DoD. S/S CSC developed to manage complex and demanding military projects was not achieving its intended objectives [32]. Studies in multibillion dollar projects revealed that the problem were apparent, if not avoidable long before the project manager acknowledge the problems. This showed that the information was not being used effectively throughout the project management processes. Instead, the information was assigned to project finance or controller and view as financial reporting requirement. Intensive work had been done to improve EVM application and towards end of 1990's, EVM was largely accepted by project management community as standard for project management purpose.

Previous work done claimed that EVM is a powerful methodology to that can be implemented by any kind of projects with a different sizes and types. There appears to be several assumptions for this reason. Firstly, commercial awareness of EVM is very minimal among project managers. Most project managers are technical focused and having less understanding on financial aspect of the project. Corporate rarely discuss earned value and there is relatively little in commercial print on the subject.

Secondly, data acquisition required is too costly and time consuming. Earned value reporting has not been handled in an easily manner and there are significant resistance problems when trying to put earned value in to practice.

Related researches which had been carried out in earned value mostly focused on application of earned value method in different projects as well as organizations. The other category also provided an insight to earned value development which earned value parameters was taken into considerations. As a closely related research, Anbari (2003) [33] provided an excellent insight to earned value management method and also proposed a simple control limit for earned value metric. He considered simple numerical control limits as caution and poor area for evaluating SPI/CPI indexes respectively.

However, he did not provide more detail for intermediate SPI/CPI amounts. Vandevoorde and Vanhoucke, (2006) [14] had studied the strange behavior in schedule performance indicator of conventional earned value management. It was known that schedule indicators are flawed as it reached the final stage of the project duration. Earned Schedule method was then developed to overcome this problem in traditional EVM. Based on Earned Schedule method, SPI was calculated based on time rather than using cost as calculated in E VM.

As a recent work, Vandevoorde and Vanhoucke (2006) [14] not only focused on traditional earned value metrics, but also they deployed earned schedule performance indicator namely SV(t) and SPI(t). Their proposed approach also was able to yield forecast total project duration. Moreover, their developed formula compared with three available methods in the literature based on testing three real life projects in several situations. Finally, they concluded the superiority of the proposed approach. However, they recommended that maybe based on situation e.g. project manager knowledge and project management team other methods also would be useful.

Vitner et al, (2006) [34] applied a Data Envelopment Analysis (DEA) in order to performance evaluation in a multi project environment where each project has been defined uniquely. They integrated both Earned Value Management System (EVMS) and Multi Denominational Control System (MDCS). They also provided a new approach in order to reduce number of inputs and outputs in their developed approach to get better results in multi project environment. However, they pointed out, it was for the first time that DEA had been applied in project environment where it has been previously used in organizations e.g. hospital, banking etc.

Cioffi (2006) [35] presented a new formalism notations used in earned value analysis and reproduced standard earned value parameters. He also presented additional quantities defined there. He pointed out that his proposed approach can accomplish because of several objectives e.g. earned value analysis can be used faster, easier, more frequently and more useful especially for nonlinear prediction. Prior to this work, Cioffi (2005) [36] presented an analytical parameterization for S-curve where the curves were normalized two basic parameters. However, it can be further used for earned value analysis when the curve appropriately fitted.

Kim et al (2003) [31] developed a model based on research conducted on a two year period in different types of projects and organizations e.g. public and private organizations as well as large and small projects. Firstly, they discussed the problems arising during earned value implementation e.g. too much cost and paper work. Secondly as another finding, based on their conceptual model, it is necessary to consider four group namely earned value users, EV methodology, implementation process and project environment together. As a major conclusion, they expressed that in Noori et al, (2008) [37] in order to implement earned value method; it is not simple to introduce a methodology in an organization. Instead it should be embedded with overall organizational approaches such as “colleague-based organizational culture, continuing top-level management attention” and facilitating supporting systems e.g. project management office.

Moselhi et al, (2004) [38] presented an integrated web based time and cost control system for construction projects which mapped Work Breakdown Structure (WBS) in to an object oriented model to enable generate earned value reports at control objects, resource levels. Moreover, in order to analyze project variance, a set of resource performance indicators used. This system also assists to share data in within a world wide web.

Al-Jibouri (2003) [39] evaluated effectiveness of three monitoring systems namely leading parameters technique, variance method and activity based ratio technique in construction projects from both theoretical and experimental point of view. Their investigations indicated that activity based ration and variance method have a better performance than leading parameter technique. Also, they introduced activity based ratio a faster and simpler method in comparison with other two approaches. However, they pointed out that it is difficult to generalize the results found on their investigation and further it can be customized based on the nature of project and amount of information required for further actions.

Lipke et al (2009) [40] discussed applying earned schedule analysis in order to estimate completion date. Firstly, he presented commonly earned value technique including Schedule Performance Index (SPI) and then SPI (t) that can be estimated based on dividing earned schedule on actual time where earned schedule can be calculated based on mapping earned value amount on time (horizontal) axis. As it is well indicated, although there are some researches about both earned value analysis and (fuzzy) control chart, no related research found in which applied both control chart and earned value analysis simultaneously even deterministically. However, in this paper, a fuzzy control chart is developed to manage earned value metrics e.g. SPI and CPI which integrated with the existing project management status system. The manager here is able to use intermediate decision levels as well as traditional control levels.

Table-1: Comparison of the techniques.

Technique	Advantage	Disadvantage
Earned Value Analysis Method, EVM	1.Provide integrated and comprehensive view of project status 2. Provide an early warning to proactively plan the contingency.	1. Ignore critical and non-critical activities. 2. Requires understanding of project financial aspect.
Critical Path Method, CPM	1.Provide relationship between activities in WBS 2. Help to spot which activities have some slack and therefore could transfer some resources for better resources allocation	1. Used when activities time are certain. Risk analysis could not be performed. 2. Reliability largely based on accurate estimates and assumption made. 3. Too many activities may the turn the network diagram becoming too complicated. The activities themselves might have to be broken down into mini projects.
Program Evaluation Review Technique, PERT	1.Integrate risk management in evaluation (duration variable) 2. Focus on critical activities 3.Enable resources management and allocation	1. Requires longer time for evaluation 2. Time estimates are often biased. 3. Can be complex to evaluate.
Monte Carlo Simulation	1. Powerful methodology to deal with project uncertainties. 2. Involve risk management	1. Do not provide exact answers but only estimates.
S-Curve	1. Simple projection technique and easy understand and maintained.	1. Some data set may be too immature for valid application.

5. CONCLUSION

This paper reviews the comparison of EVM and other methodology which are CPM, PERT, Monte Carlo Simulation and S-Curve. CPM technique manage to relationship between activities in WBS, however risk analysis could not be performed. Although, PERT technique capable to integrate risk management in evaluation but it enquires longer time for evaluation and time estimates are often biased. For Monte Carlo Simulation, it is a powerful methodology to deal with project uncertainties, however it do not provide exact answers but only estimation. S-Curve offers a simple projection technique and easy understands and maintained but so some data set may be too immature for valid application. By considering of providing integrated and comprehensive view of project status and ability to provide an early warning to proactively plan the contingency EVM technique was selected for this research. The survey shows that most of project manager are using EVM and it acceptance is become increasingly common in both the public and private sectors. However, visualized EVM is less studied and the implementation of EVM in Malaysia are also lacking in both public and private sectors which appears to be a strong limitation that need to be developed.

REFERENCES

[1] F. A. Mir and A. H. Pinnington, "Exploring the value of project management: linking project management performance and project success," *Int. J. Proj. Manag.*, vol. 32, no. 2, pp. 202–217, 2014.

[2] J. E. Kelley Jr and M. R. Walker, "Critical-path planning and scheduling," in *Papers presented at the December 1-3, 1959, eastern joint IRE-AIEE-ACM computer conference*, 1959, pp. 160–173.

[3] R. J. Luttman, G. L. Laffel, and S. D. Pearson, "Using PERT/CPM (Program Evaluation and Review Technique/Critical Path Method) to design and improve clinical processes.," *Qual. Manag. Health Care*, vol. 3, no. 2, pp. 1–13, 1995.

[4] S. D. Pearson, D. Goulart-Fisher, and T. H. Lee, "Critical pathways as a strategy for improving care: problems and potential," *Ann. Intern. Med.*, vol. 123, no. 12, pp. 941–948, 1995.

[5] W. D. Cottrell, "Simplified program evaluation and review technique (PERT)," *J. Constr. Eng. Manag.*, vol. 125,

no. 1, pp. 16–22, 1999.

[6] D. D. Roman, "The PERT system: An appraisal of program evaluation review technique," *Acad. Manag. J.*, vol. 5, no. 1, pp. 57–65, 1962.

[7] C. R. Woolf, W. Cass, and J. McElroy, "The use of 'Program Evaluation and Review Technique'(PERT) in the design and control of a medical research project," *Comput. Biomed. Res.*, vol. 2, no. 2, pp. 176–186, 1968.

[8] W. W. Chin, B. L. Marcolin, and P. R. Newsted, "A partial least squares latent variable modeling approach for measuring interaction effects: Results from a Monte Carlo simulation study and an electronic-mail emotion/adoption study," *Inf. Syst. Res.*, vol. 14, no. 2, pp. 189–217, 2003.

[9] K. Kurihara and N. Nishiuchi, "Efficient Monte Carlo simulation method of GERT-type network for project management," *Comput. Ind. Eng.*, vol. 42, no. 2–4, pp. 521–531, 2002.

[10] R. Y. Rubinstein and D. P. Kroese, *Simulation and the Monte Carlo method*, vol. 10. John Wiley & Sons, 2016.

[11] R. H. Becker and L. M. Speltz, "Putting the S-curve concept to work," *Res. Manage.*, vol. 26, no. 5, pp. 31–33, 1983.

[12] C. M. Christensen, "Exploring the limits of the technology S-curve. Part I: component technologies," *Prod. Oper. Manag.*, vol. 1, no. 4, pp. 334–357, 1992.

[13] W. Skinner, "Manufacturing strategy on the 'S' curve," *Prod. Oper. Manag.*, vol. 5, no. 1, pp. 3–14, 1996.

[14] S. Vandevoorde and M. Vanhoucke, "A comparison of different project duration forecasting methods using earned value metrics," *Int. J. Proj. Manag.*, vol. 24, no. 4, pp. 289–302, 2006.

[15] M. F. Khamidi, A. K. Waris, and A. Idrus, "The cost monitoring of construction projects through earned value analysis," 2011.

[16] D. M. Brandon and M. Daniel, "Implementing earned value easily and effectively," *Proj. Manag. J.*, vol. 29, pp. 11–18, 1998.

[17] P. W. G. Morris, *The management of projects*. Thomas Telford, 1997.

[18] H. Kerzner and H. R. Kerzner, *Project management: a systems approach to planning, scheduling, and controlling*. John Wiley & Sons, 2017.

[19] J. J. Moder and E. G. Rodgers, "Judgment estimates of the moments of PERT type distributions," *Manage. Sci.*, vol. 15, no. 2, p. B-76, 1968.

[20] D. G. Malcolm, J. H. Roseboom, C. E. Clark, and W. Fazar, "Application of a technique for research and development program evaluation," *Oper. Res.*, vol. 7, no. 5, pp. 646–669, 1959.

[21] K. R. MacCrimmon and C. A. Ryavec, "An analytical study of the PERT assumptions," *Oper. Res.*, vol. 12, no. 1, pp. 16–37, 1964.

[22] F. E. Grubbs, "Letter to the Editor—Attempts to Validate Certain PERT Statistics or 'Picking on PERT,'" *Oper. Res.*, vol. 10, no. 6, pp. 912–915, 1962.

[23] L. A. Swanson and H. L. Pazer, "Implications of the underlying assumptions of PERT," *Decis. Sci.*, vol. 2, no. 4, pp. 461–480, 1971.

[24] T. K. Littlefield Jr and P. H. Randolph, "Reply—An Answer to Sasieni's Question on PERT Times," *Manage. Sci.*, vol. 33, no. 10, pp. 1357–1359, 1987.

[25] Y. H. Kwak and L. Ingall, "Exploring Monte Carlo simulation applications for project management," *Risk Manag.*, vol. 9, no. 1, pp. 44–57, 2007.

[26] B. Eckhardt, "Fractal properties of scattering singularities," *J. Phys. A. Math. Gen.*, vol. 20, no. 17, p. 5971, 1987.

[27] G. Bhanot, A. Gara, P. Heidelberger, E. Lawless, J. C. Sexton, and R. Walkup, "Optimizing task layout on the Blue Gene/L supercomputer," *IBM J. Res. Dev.*, vol. 49, no. 2.3, pp. 489–500, 2005.

[28] H. El-Ramly, N. R. Morgenstern, and D. M. Cruden, "Probabilistic slope stability analysis for practice," *Can.*

Geotech. J., vol. 39, no. 3, pp. 665–683, 2002.

[29] T. A. Santos and C. G. Soares, "Monte Carlo simulation of damaged ship survivability," *Proc. Inst. Mech. Eng. Part M J. Eng. Marit. Environ.*, vol. 219, no. 1, pp. 25–35, 2005.

[30] J. R. Meredith and S. J. Mantel Jr, *Project management: a managerial approach*. John Wiley & Sons, 2011.

[31] E. Kim, W. G. Wells, and M. R. Duffey, "A model for effective implementation of Earned Value Management methodology," *Int. J. Proj. Manag.*, vol. 21, no. 5, pp. 375–382, 2003.

[32] R. M. S. Wilson and C. Gilligan, *Strategic marketing management*. Routledge, 2012.

[33] F. T. Anbari, "Earned value project management method and extensions," *Proj. Manag. J.*, vol. 34, no. 4, pp. 12–23, 2003.

[34] G. Vitner, S. Rozenes, and S. Spraggett, "Using data envelope analysis to compare project efficiency in a multi-project environment," *Int. J. Proj. Manag.*, vol. 24, no. 4, pp. 323–329, 2006.

[35] D. F. Cioffi, "Designing project management: A scientific notation and an improved formalism for earned value calculations," *Int. J. Proj. Manag.*, vol. 24, no. 2, pp. 136–144, 2006.

[36] D. F. Cioffi, "A tool for managing projects: an analytic parameterization of the S-curve," *Int. J. Proj. Manag.*, vol. 23, no. 3, pp. 215–222, 2005.

[37] S. Noori, M. Bagherpour, and A. Zareei, "Applying fuzzy control chart in earned value analysis: a new application," *World Appl. Sci. J.*, vol. 3, no. 4, pp. 684–690, 2008.

[38] O. Moselhi, J. Li, and S. Alkass, "Web-based integrated project control system," *Constr. Manag. Econ.*, vol. 22, no. 1, pp. 35–46, 2004.

[39] S. H. Al-Jibouri, "Monitoring systems and their effectiveness for project cost control in construction," *Int. J. Proj. Manag.*, vol. 21, no. 2, pp. 145–154, 2003.

[40] W. Lipke, O. Zwikael, K. Henderson, and F. Anbari, "Prediction of project outcome: The application of statistical methods to earned value management and earned schedule performance indexes," *Int. J. Proj. Manag.*, vol. 27, no. 4, pp. 400–407, 2009.