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PROJECT PERFORMANCE MONITORING METHODS USED IN MALAYSIA AND PERSPECTIVES OF INTRODUCING EVA AS A STANDARD APPROACH

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Abstract. Earned value analysis (EVA) is a well-known project management tool for monitoring and forecasting the project performance such as time and cost. Despite the benefits found in the manufacturing industry, EVA has not been widely implemented in the Malaysian construction industry. This study is aimed to determine the advantages of EVA over other project control methods, to determine the suitability of implementing EVA in construction projects, and to develop a working flowchart as a guide in implementing EVA. Accordingly, qualitative approaches including the structured interview survey and the flowchart development were employed in this study. Findings reveal that comparing to stochastic methods, Fuzzy logic model, and miscellaneous methods, the EVA has remarkable advantages in accuracy, flexibility, and adaptability for complexity. Malaysian government has decided to implement EVA to enhance the level of project management for the whole country. Hence, an EVA working flowchart was developed by the authors, through which more detailed project status could be monitored and more accurate future performance of the project could be forecasted.

Keywords: project monitoring, performance forecasting, earned value analysis (EVA), construction industry, project management, civil engineering.

1. Introduction

Project management is a process which consists of planning, organizing, scheduling and controlling all aspects of a project and the motivation of all those in involved in it to achieve a specific projects goals and objective on time and to the specified cost, quality and performance (Carayannis *et al.* 2005). Amongst major problems in construction projects are cost overrun and delay for instance, cost overrunsof 25–33% are common in the construction industry (Marshall 2007). The construction industry has seen substantial growth in projects ending in either dispute or litigation (Levin 1998). Cost overruns are common in infrastructure, building, and technology projects (Flyvbjerg *et al.* 2002). Without good management, clients suffer the compensation liabilities. In order to mitigate the overrun cost and delay in construction project, project managers need to use effective and powerful tools and techniques to forecast the status of project during construction stage (Fleming and Koppelman 2006). One such method believed to be effective is the earned value analysis (EVA) (Carayannis *et al.* 2005). According to Fleming and Koppelman (2002), EVA is the best indicator of future performance and therefore by using trend data it is possible to forecast cost or schedule overruns at quite an early stage in a construction project. EVA addresses many project management areas including project organizing, planning, scheduling and budgeting, accounting, analyzing, reporting and change controlling (Fleming and Koppelman 1998).

Stochastic methods, EVA (as a deterministic method), Fuzzy logic model, and miscellaneous methods are the four major project performance monitoring methods used in the Malaysian construction industry. This study aims to determine the advantages of EVA over other project control methods, to determine the suitability of implementing EVA in construction projects, and to develop a working flowchart as a guide in implementing EVA. Through qualitative approaches including the structured interview survey and the flowchart development, findings reveal that the private sector in Malaysian construction industry has well implemented the stochastic methods and miscellaneous methods. However, comparing to stochastic methods and Fuzzy logic model, EVA has remarkable advantages in accuracy and flexibility.

2. Earned value analysis (EVA) and its elements

According to Cooper *et al.* (2002), learning how to learn lessons from past performance will systematically and continuously improve the management of projects. Project learning provides a mechanism for documenting lesson learned from any source, tracking the closure or implementation of improvement actions. Figure 1 illustrates that actual learning takes place in four areas, unfortunately this kind of learning is hardly ever reached (Kerzner 2003). Project performance monitoring and forecasting are supported by project learning activities and the level of lesson learned is related to inter-project learning (Kerzner 2003). Abba (1996) stated earned value

analysis (EVA) is a management technique that relates the learning to technical performance. However, Czarnigowska (2008) defined earned value (EV) as a well-known project management tool that uses information on cost, schedule and work performance to establish the current status of the project. One reason for EVA method not being widely accepted in construction is because project managers lack in understanding the concept of EVA (Kim *et al.* 2003). Anbari (2003) mentioned that there might be important lessons to learn from each step or formulas in terms of estimating, budgeting, performance management, and cost control in EVA. Reallocation of organizational resources might be another outcome from EVA (Lewis 2001).
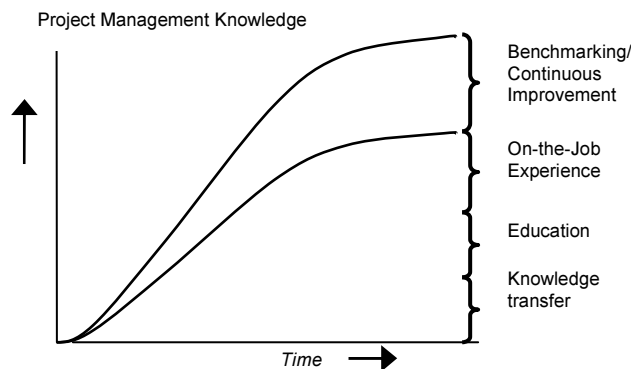
Project Management Knowledge

Fig. 1. Project management learning curve (Kerzner 2003)

The basic concept of EVA has not changed for three decades since its inception (Brandon 1998; McConnell 1985; Fleming and Koppelman 1994; Howes 2000). EVA is used for forecasting of project cost and schedule at completion and highlights the possible need for corrective action (Kim *et al.* 2003). According to Anbari (2003), the inputs of EVA are periodic monitored actual expenditures and physical scope accomplishments such as the planned value, earned value, and actual cost. On the other hand, the outputs of EVA are cost and schedule predictions along with performance indices such as the schedule performance index and cost performance index. EVA is also defined as a management technique that relates resource planning and usage to schedules and to technical performance requirement and to bring cost and schedule variance analysis together to provide managers with a more accurate status of a project (Kim *et al.* 2003). EVA is the methods used to measure and communicate the real physical progress of a project taking into account the work complete, the time taken, and the costs incurred to complete that work (Fleming and Koppelman 2006; Iranmanesh and Hojati 2008).

According to McConnell (1985), EVA is an established method for the evaluation and financial analysis of project performances throughout project life cycle. According to PMI (2004b), EVA can play a crucial role in answering following management questions that are critical to the success of every project:

  a) Is the project ahead of or behind schedule?
  b) How efficiently is the project using the time?

  c) When is the project likely to be completed?
  d) Is the project currently under or over budget?
  e) How efficiently is the project using its resources?
  f) What is the remaining work likely to cost?
  g) What is the entire project likely to cost?
  h) How much the project will be under or over budget at the end?

However, the EVA's answer to question c) of the PMI's (2004b) list has been recently criticized by Lipke *et al.* (2009) and Vandevoorde and Vanhoucke (2006) that EVA methods are probably applicable only to extremely large projects of very long duration and the general findings from their analysis were higher variation than expected and consistently better performance for schedule than cost.

2.1. Planned value, earned value and actual cost

According to Anbari (2003) and Budd C. I. and Budd C. S. (2005), EVA uses four parameters to evaluate project performance, namely: planned value (PV), budget at completion (BAC), actual cost (AC), and earned value (EV). PMI (2004a,b) mentioned that PV, EV and AC values are used in combination to provide performance measures of whether or not work is being accomplished as planned at any given point in time. Oberlender (2000) and Marshall (2007) point out that the three elements PV, EV and AC are the key components in EVA methods. EV is also known as budgeted cost of work performed (BCWP); PV is known as budgeted cost of work schedule (BCWS); and AC is known as the actual cost of work performed (ACWP) (Leu *et al.* 2006). PV describes how far along project work is supposed to be at any given point in the project schedule (PMI 2004b). PV (or BCWS) is the planned value, so the approved budget for accomplishing an activity (Oberlender 2000; PMI 2004b; Leu *et al.* 2006). Meanwhile, the definition of EV represents the amount budgeted for performing the work that was accomplished by the given point in time (Anbari 2003). AC is the indication of the level of resources that have been expended to achieve the actual work performed to date (PMI 2004b).

2.2. Variances in EVA

Variances can be divided into two categories including the cost variance (CV) and the schedule variance (SV) (Oberlender 2000). According to PMI (2004b), the cost variance at the end of the project is the difference between the budget at completion (BAC) and the actual amount spent. Meanwhile, schedule variance will ultimately equal zero when the project is completed because all of the planned values will have been earned. However Anbari (2003) and Fleming and Koppelman (2002) stated that CV is a measure of the budgetary conformance of actual cost of work performed and SV is a measure of the conformance of actual progress to the schedule. Fig. 2 shows one screen in EVA where PV, EV, and AC are presented in one diagram.
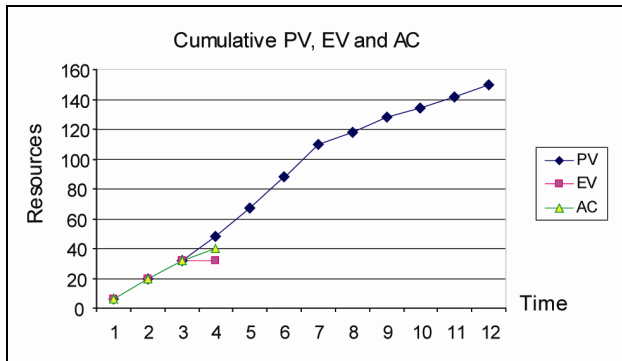
Fig. 2. Planned Values (PV), Earned Value (EV) and Actual Cost (AV) (PMI 2004b)

Anbari's (2003) formulas of cost variance and schedule variance are illustrated in Eq. (1) and Eq. (2), respectively:

$$Cost\ Variance\ (CV) = Earned\ Value\ (EV) - Actual\ Cost\ (AC). \qquad (1)$$

$$Schedule\ Variance\ (SV) = Earned\ Value\ (EV) - Planned\ Value\ (PV). \qquad (2)$$

2.3. Performance indices

According to Leu *et al.* (2006), the two important performance indices are the cost performance index (CPI) and the schedule performance index (SPI). CPI and SPI provide a quantity measurement of the progress of a project (Oberlender 2000). During project execution, CPI and SPI also provide information on performance efficiency. Anbari's (2003) formulas of cost performance index and schedule performance index are illustrated in Eq. (3) and Eq. (4), respectively:

$$Cost\ Performance\ Index\ (CPI) = Earned\ Value\ (EV)/Actual\ Cost\ (AC). \qquad (3)$$

$$Schedule\ Performance\ Index\ SPI = Earned\ Value\ (EV)/Planned\ Value\ (PV). \qquad (4)$$

2.4. Approaches to predictions made by means of EVA

Performance forecasting includes making estimates or predictions of conditions in the project's future based on information and knowledge available at the time of forecast (PMI 2004a). According to Anbari (2003), the estimated cost to complete the remainder of the project is usually called the estimate to complete (ETC). There are two ways to develop ETC, the first way shows what the remaining work will cost and the second is developed by workers and/or managers based on an analysis of the remaining work. The management ETC can be added to the AC to derive the management ETC of the total cost of the project at completion (PMI 2004b). EAC may differ based on the assumptions made about future performance and the PMBOK Guide, provides three such estimates, based on three different assumptions. The PMBOK Guide is a guide to the project management body of knowledge

and an internationally recognized standard that provides the fundamentals of project management as they apply to a wide range of projects, including construction, software, engineering, automotive, etc. The purpose of the PMBOK is to provide and promote a common vocabulary within the project management profession for discussing, writing, and applying project management concepts (PMI 2004b). Czarnigowska (2008) defined the estimate at completion (EAC) is calculated at the date of reporting progress to serve as an estimate of the effect of deviations cumulated from the project's start on the total project cost, so it informs how much the project is going to be in the end. In current practice, project baselines or planned S-curves is used to determine variances in cost or schedule and to measure the EV. Anbari's (2003) formulas of the estimate to complete (ETC) and the estimate at complete (EAC) are illustrated in Eq. (5) and Eq. (6), respectively:

$$Estimate\ to\ Complete\ (ETC) = [Budget\ at\ Completion\ (BAC) - Earned\ Value\ (EV)] / Cost\ Performance\ Index\ (CPI). \qquad (5)$$

$$Estimate\ at\ Complete\ (EAC) = Actual\ Cost\ (AC) + Estimate\ to\ Complete\ (ETC). \qquad (6)$$

Seiler (1985) recommended forecast techniques for predicting cost and schedule performance. The estimate at completion is assumed to be the same level of cost efficiency experienced to-date continues in the future. The study argues that at later stages of progress the future cost and schedule performance efficiency need to be modified based upon known conditions being experimented by the project. He suggested modifying the CPI and/or the SPI by estimating a line of best fit through the monthly data points on the trend line. Eldin and Hughes (1992) presented a detailed discussion of the use of unit costs to forecast the final cost. The study stated that an accurate forecast of final cost is based on applying unit costs to quantities using two approaches. The first approach is using the cumulative to-date unit cost to estimate future unit costs. The second approach is assuming that the current-period unit cost is the best available estimate for future unit costs. Christensen (1993) and Christensen *et al.* (1995) provided a comprehensive review of 25 studies that dealt with estimate at completion (EAC) formulas and models. The EAC formulas were classified into three categories: index, regression, and other (for example: formulas based on heuristics). The study briefly reviewed comparative and non-comparative EAC research conducted over a period of sixteen years and made the following conclusions: (1) the study showed that no one formula or model is always best. Attempting to generalize from a large and diverse set of EAC formulas is dangerous, (2) the study did not establish the accuracy of regression-based models over index-based formulas. Additional research with regression models is needed, (3) the study concluded that the accuracy of index-based formulas is a function of the system, and the stage and phase of the project. In addition, averaging over short periods is more accurate than averaging over longer periods, for example, 6–12 months, especially during the mid

stage of the project when costs are often accelerating. Brown (1996) slightly modified the EAC proposed in Christensen (1993) to correct for variance in future cost performance rates by introducing Forecasted Cost Performance Index for the remainder of the budgeted work to be performed. Fleming and Koppelman (1994) proposed a constant budget model. The model assumes that all cost overruns can be absorbed through corrective action by the project end date and that the final cost will be equal to the original budget. The major drawback is that the assumption implied by the model could apply to a very small number of projects and in most cases the actual cost at completion will differ from the budgeted cost. Shtub *et al.* (1994) developed the constant performance efficiency model, which assumed that the cumulative cost and schedule performance indices (CPI and SPI) remain unchanged or constant throughout the remaining project duration. Fleming and Koppelman (2002) and Zwikael *et al.* (2000) suggested that this model is better that the other earned-value based models. Fleming and Koppelman (1999) proposed the schedule performance efficiency model that assumed that the forecasted final cost (EAC) is a function of both the Cost Performance Index (CPI), and the Schedule Performance Index (SPI). However, research carried out by Zwikael *et al.* (2000) showed that this model is inferior to the model where EAC is function of the CPI only. Section 2.2, 2.3, and 2.4 present the elements in EVA.

2.5. Advantages of EVA in construction projects

EVA is particularly useful in forecasting the cost and time of the project at completion, based on actual performance up to any given point in the project. EVA provides project managers and the organization with triggers or early warning signal that allow to take timely actions in response to indicators of poor performance and enhance the opportunities for project success (Iranmanesh and Johati 2008). The importance of EVA is to measure project progress, to calculate EV, and to forecast EAC, since correct and on time EAC is very important to plan preventive actions during the project life cycle. Anbari (2003) identifies that the graphs of performance indices provide valuable indicators of trends in project performance and the impact of any corrective actions. These graphs can be very effective in indicating the status of a project. According to Fleming and Koppelman (2002), better planning and resource allocation associated with the early periods of a project might be the cause of this reliability. The advantages of EVA can also be used for progress payments to contractor based on the EV of contracted.

For long-term project, it may be appropriate to consider incorporating the time value of money and time-discounted cash flows into EVA (Budd, C. I. and Budd, C. S. 2005). Inflation can be explicitly considered in EVA, and the inflation variance can be calculated (Farid and Karshenas 1988). Budd, C. I. and Budd, C. S. (2005) stated EVA supported both the project manager and the performing contractor because it could:

a) Provide early identification of adverse trends and potential problems.
b) Provide an accurate picture of contract status with regard to cost, schedule and technical performance.
c) Establish the baseline for corrective actions, as needed.
d) Support the cost and schedule goals of the customer, project manager, and performing contractor.

Christensen (1993) listed the benefits for using EVA as follows:

a) It is a single management control system that provides reliable data
b) It integrates work, schedule, and cost into a work breakdown structure
c) The associated database of completed projects is useful for comparative analysis
d) The cumulative CPI provides an early warning signal
e) The schedule performance index provides an early warning signal
f) The CPI is a predictor of the final cost of the project
g) EVA uses an index-based method to forecast the final cost of the project
h) The "to-complete" performance index allows evaluation of the forecasted final cost
i) The periodic (e.g., weekly or monthly) CPI is a benchmark
j) The management by exception principle can reduce information overload

According to Anbari (2003), an organization may elect to apply EVA uniformly in all of its projects or only in projects exceeding its own thresholds for cost and schedule reporting and control. EVA can be applied to projects in various types and sizes in the public and private sectors. It can be applied at various levels of a project's work breakdown structure and to various cost components, such as labor, material and subcontractors (Anbari 2003).

3. Project forecasting methods used in Malaysia

A few project forecasting methods have been mentioned in literatures, namely: 1) Deterministic methods; 2) Stochastic methods; 3) Fuzzy logic model; 4) Miscellaneous methods. The four types of methods are classified by the authors in terms of their analytic concepts. In brief, the deterministic methods normally use deterministic S-curve (DS-curves) technique while stochastic methods normally use stochastic S-curve (SS-curves). DS-curves provide one possible deterministic outcome while SS-curves provide probability distributions for expected cost and duration for a given percentage of work completed. In SS-curve, monitoring project performance is performed by comparing the most likely budget and duration values, obtained from respective probability distributions for actual progress, with the project's actual data and cumulative cost (Barraza *et al.* 2000). Different from the deterministic methods and the stochastic methods, the

Fuzzy logic model does not use S-curves but use fuzzy binary relation or fuzzy inference process to predict project performance (Knight and Fayek 2002; Tah and Carr 2000; Li 2004). Miscellaneous methods include all the other methods that are not yet commonly used, which could not also be classified into deterministic methods, stochastic methods, or fuzzy logic model.

3.1. Deterministic methods

EVA is a deterministic method. The deterministic approach estimates cost and schedule using the most likely values. More specifically, it is more commonly used by construction organizations because they are based on simpler models (Crandall and Woolery 1982). Many of the deterministic forecasting methods use performance trend analysis. Wheelwright and Makridakis (1985) evaluated various subjective and deterministic mathematical methods and concluded that there is no single deterministic forecasting method that is accurate and superior for all projects and under all circumstances. However, some simple techniques, such as the moving average, might produce better forecasts than complicated techniques. The forecasting module predicts the cost indices for six quarters ahead and uses various forecasting techniques like: simple moving average, single exponential smoothing, exponential smoothing and decomposition method. It is capable to handle judgmental feedback to tune the final forecasting figures. Forecasting in this method is limited to predicting future expenditures at early stages of project design and before construction starts.

3.2. Stochastic methods

Barraza *et al.* (2004) studied a methodology using the concept of stochastic S-curve. This method enables Project Manager to forecast the at-completion project cost and schedule performance as well as at each 10% increment of project progress. The principle objective of this method is using simulation approach to generate the stochastic S-curve based on the variability in cost and duration of activities. The method enable one possible S-curve be generated for each simulation iteration. Distributions of possible values of at completion budgeted cost and at-completion schedule duration can be analyzed at 100% progress. Using the simulation method, stochastic S-curves providing cost and time distributions can be obtained at any percent of work performed. The key objective of this method is to estimate at-completion performance variations in order to obtain the need for corrective action. Over the years, various mathematical formulas have been proposed for generalizing the S-curve by making cumulative project progress a function of time, e.g. the polynomial and exponential functions in Gates and Scarpa (1979), Peer (1982), Tucker (1988), Miskawi (1989), Khosrowshahi (1991) and the Logit transformation formula in Kenley and Wilson (1986). These formulas contain two or more parameters, which are solved mathematically for a project by fitting to its progress data. Comparisons made by Skitmore and Ng (2003) and Navon (1996) show that the best closeness of fit is

achieved by the Logit transformation formula, which has been widely referred to by other researches. Since the Logit transformation formula fails to meet the boundary conditions of 0% progress at 0% time and 100% progress at 100% time, the starting and final parts of project progress data must be truncated before it can be solved using the regression method, which causes inconvenience in application. To address existing formulas' problem of complicated calculations as well as to improve fitting accuracy, Chao and Chien (2010) proposed a more succinct cubic polynomial for fitting S-curves, which is shown in Eq. (7):

$$y = ax3+bx2+(1-a-b)x, \qquad (7)$$

where y and x denotes standardized progress and standardized project time, i.e. percent progress and percent project time, respectively; a, b are the parameters to be determined. Eq. (7) can meet the required boundary conditions. For a project of a duration of d time units (usually in months) through d progress measurements, its all d progress measurements can be standardized in a set of d pairs of percent time and percent progress xt, yt for time point $t = 1, 2, … d$, and the values of a and b in Eq. (7) can be solved by using the least squared error method. See Chao and Chien (2010) for details of the solution procedure and equations. Then, a fitted S-curve can be constructed; for example, the S-curve fitted to the actual progress data of a project ($d = 42$) of Taiwan's second freeway is $y = -1.629x3 + 2.414x2 + 0.215x$ and shown in Fig. 3.
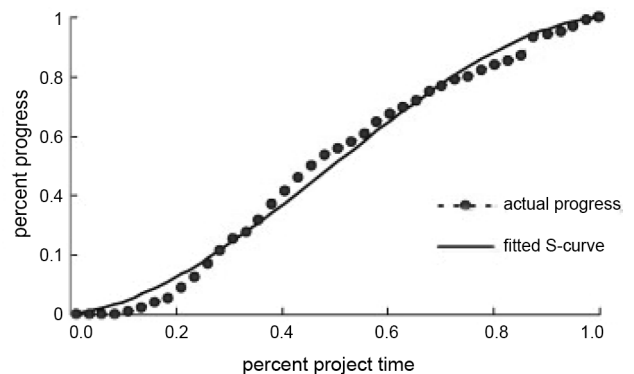
Fig. 3. Example project's actual progress versus fitted S-curve (Chao and Chien 2010)

The root of mean squared error (RMSE) is used to measure the accuracy of an S-curve formula in fitting to actual progress data as well as to evaluate the estimation performance of an S-curve model. RMSE is a straight measure of the average error of the estimated progress from the actual progress for the duration of a project and is a stricter error measure than mean absolute error (MAE) as it enlarges the effects of larger individual errors, where the result $\hat{yt}$ is calculated percent progress at time point t (percent time xt) from an S-curve formula, the input yt is actual percent progress at time point t, and the input d is number of time units for a project. As an illustration, for the fitted curve in Fig. 3, the RMSE ob-

tained is 0.0322 or 3.22%. Chao and Chien (2010) fitted Eq. (7) to the 27 projects in Skitmore and Ng (2003) and 101 projects of Taiwan's second freeway completed in 1991–2001 and made a comparison with the Logit transformation formula, which is also a two-parameter formula. The result shows that Eq. (7) is at least on a par with it, considering both fitting accuracy and calculation simplicity.

3.3. Fuzzy logic model

Knight and Fayek (2002) proposed a fuzzy logic model to predict cost overruns/under runs in engineering design projects and consequently forecast profit. Fuzzy binary relation was used to model the relation between thirteen project characteristics and eight risk events on one hand, and the cost overruns resulting from any combination of project characteristics and risk events on the other hand. Li (2004) developed an indicator-based fuzzy forecasting method to forecast the project cost and duration at completion as well as at interim future points. The method utilized the fuzzy inference process and the principle of GMP (Generalized Modus Ponens) type reasoning. The model used thirteen terminal indicators as input variables to predict future cost values. Two performance indicators were utilized to predict the project duration of a control object. The developed system could generate reports at three levels: project, control-object, and individual resource.

3.4. Miscellaneous methods

Miscellaneous methods include all the other methods that are not yet commonly used, which could not also be classified into deterministic methods, stochastic methods, or fuzzy logic model. For example, Khosrowshahi (1988) developed a mathematical model for use by the client and the contractor to forecast the project costs and revenues. The model is capable of generating a satisfactory forecast quickly and easily at any time of the project. While the model demands little input from the user, it does allow the user to develop a solution. The model parameters can be adapted, without modifying the structure of the mathematical expression, to meet the requirements of specific users with specific project characteristics. Mazzini (1991) applied the Momentum Theory, an alternative approach to cost analysis founded on the dynamics of spending, for cost analysis, forecasting, and control. This new technique involves a multi-step process to transform historical data into the characteristic momentum patterns. The resulting patterns, and the future course of spending they produce, allow the cost analyst to accurately forecast the future. Both Khosrowshahi's method and Mazzini's method are not any of the deterministic method, stochastic method, or fuzzy logic model, so that they are called miscellaneous methods.

4. Research procedures and scope

The method of structured interview was employed in this study as a quantitative approach to determine the advantages of EVA over other project control methods, to determine the suitability of implementing EVA in con-

struction projects, and to develop a working flowchart as a guide in implementing EVA. Interviews were conducted to obtain the interviewees' understanding of EVA method in construction projects. This kind of one-to-one personal qualitative approach helps to cultivate a better understanding of the experiences that have taken place. Thus, the interviewees knew clearly in advance what the researcher is looking for. The interview survey was conducted in year 2009 to 2010, and each interview session was scheduled to a period of 45 minutes to 2 hours. The interviews including 7 from the private sector and 5 from the public sector were limited in Kuala Lumpur and Selangor in Malaysia. Each of the twelve interviewees involved in this study comes from a different contractor, which were numbered as Contractor A to Contractor L. Each of these 12 interviewees was involved in one ongoing project under their organization while they were interviewed. In Malaysia, construction contractors are categorized from grade G1 to G7 by many KPIs including but not limited to the number of employees and a yearly turnover under construction industry development board (CIDB) registration, where G7 is the top grade. The information about contractors from A to L is summarized in Table 1.

5. Results and discussion on research findings

5.1. Tools and techniques for monitoring performance

There are 7 interviewees from the private sector, 5 of which (Interviewees A, B, C, D, H) are using stochastic methods to monitor the projects performance in their companies, within which Interviewee A and B are also using EVA beside stochastic methods because their main contractors (both from public sector) required them to do. Among the rest 2 interviewees from the private sector, one is using the Fuzzy logic model (Interviewee K), and another one is using EVA (Interviewee J). Interviewee K felt that the Fuzzy logic model performed well in the adaptability for complexity. On the contrary, for the public sector, companies are likely using EVA more than that in the private sector. Four (Interviewees E, G, I, L) out of five public companies are using EVA in their on-going projects. The rest 1 public company (F) is using miscellaneous methods, respectively. Interviewee B mentioned that in his organization, progress reports for all work/activities were programmed and the two S-curves including the physical graph and the financial graph were then developed. The physical graph shows the work performance in percentage and the financial graph shows the payment progress that the client should pay to the contractor. From the two graphs, the project duration and the budget expenditure could be identified and evaluated. The third S-curve was developed later to forecast the cost of project and to determine the value of future payment. If the third S-curve significantly matched the financial S-curve and the physical S-curve, the payment progress and the schedule of project were considered as perfect. On the other hand, if the third S-curve did not significantly match the financial graph and the physical graph, there

Table 1. Profiles of interviewees

No	Location	Post	Experience	Sector	CIDB Grade	Average Number of Projects	Type of Project	ISO 9000 certified	Project Value (RM)	Project Progress	Methods Used
A	Selangor	QS	5 years	Private	G5	8	Computer lab for a technical school	Yes	500,000	35%	Stochastic methods & EVA
B	Selangor	Scheduler	13 years	Private	G5	5	30-units apartment	No	3,500,000	25%	Stochastic methods
C	Selangor	QS	8 years	Private	G7	11	23-units shop-offices	Yes	6,000,000	55%	Stochastic methods
D	Kuala Lumpur	QS	8 years	Private	G7	17	11-storey commercial complex with 2-level basement	Yes	20,000,000	90%	Stochastic methods & EVA
E	Kuala Lumpur	QS	15 years	Public	G7	37	Infrastructure, road, bridge	Yes	87,000,000	30%	EVA
F	Kuala Lumpur	QS	25 years	Public	G7	22	mosque	Yes	5,200,000	15%	Miscellaneous methods
G	Selangor	PM	19 years	Public	G7	13	Commercial and residential complex comprising a 10-storey low cost flat, three blocks of 3-storey shop-office building	Yes	13,000,000	5%	EVA
H	Kuala Lumpur	GM	17 years	Private	G5	7	infrastructure	No	710,000	60%	Stochastic methods
I	Kuala Lumpur	PM	22 years	Public	G7	58	Oil and gas associated	Yes	116,300,000	85%	EVA
J	Selangor	QS	27 years	Private	G5	19	Hostel in a public university	Yes	28,700,000	99%	EVA
K	Selangor	PM	18 years	Private	G7	24	High-rise condominium	Yes	19,200,000	40%	Fuzzy Logic Model
L	Kuala Lumpur	GM	23 years	Public	G7	43	Staff quarters in a public university	Yes	26,100,000	70%	EVA

must be problems occurred. Interviewees C and H commented that stochastic methods were widely used in the private sector because it was simple and easy to implement in a construction project. Interviewees D and H agreed that by using stochastic methods, the performance of a project could be monitored and controlled. According to Interviewee A and Interviewee D, besides the stochastic methods, their companies needed to prepare EVA for project scheduling. Both interviewees agreed that by applying EVA, contractors were able to determine the duration of a project so that a practicable Gantt chart could be prepared.

Interviewee F stated that the public sector normally conducted project planning through history data from past projects using the miscellaneous methods because it was easy in implementation though not good in accuracy; however, stochastic methods and EVA were normally prepared by sub-contractors. According to Interviewees F, G, I, L, the Malaysian government has decided to use EVA to measure and to forecast the project performance to avoid cost overrun and delay in construction projects. However, it was still in the planning stage and the Malaysian government was still studying the feasibility of adopting EVA in government projects.

5.2. Differences among four tools

According to Interviewees A, B, C, H, I, stochastic methods had two curves in one graph while EVA had three curves, and the third curve in EVA indicated the earned value (EV). On the other hand, Interviewee D looked from another aspect. He commented that the stochastic method was simpler and easier to use compared to the EVA method. EVA method was more complicated and it had many formulas for users to understand. Based on the experience of Interviewee D, EVA method was quite difficult for a new user to implement especially when there was no initiative to start. However, if the user could catch the concept and could understand each formula in EVA, it was more powerful than the Stochastic S-curve method. Interviewees A, D, E, and K also stated that she did not use EVA but heard about this method when attending a conference. They knew that EVA could forecast the performance of a project and it could be an indicator to prevent the overrun and delay. All the 12 interviewees agreed that it was unique for EVA to forecast future trend because stochastic methods could only monitor the performance of a project but could not forecast it. Interviewees A, D, H, I, L stated that the miscellaneous methods performed poor in its accuracy and was also cost consuming.
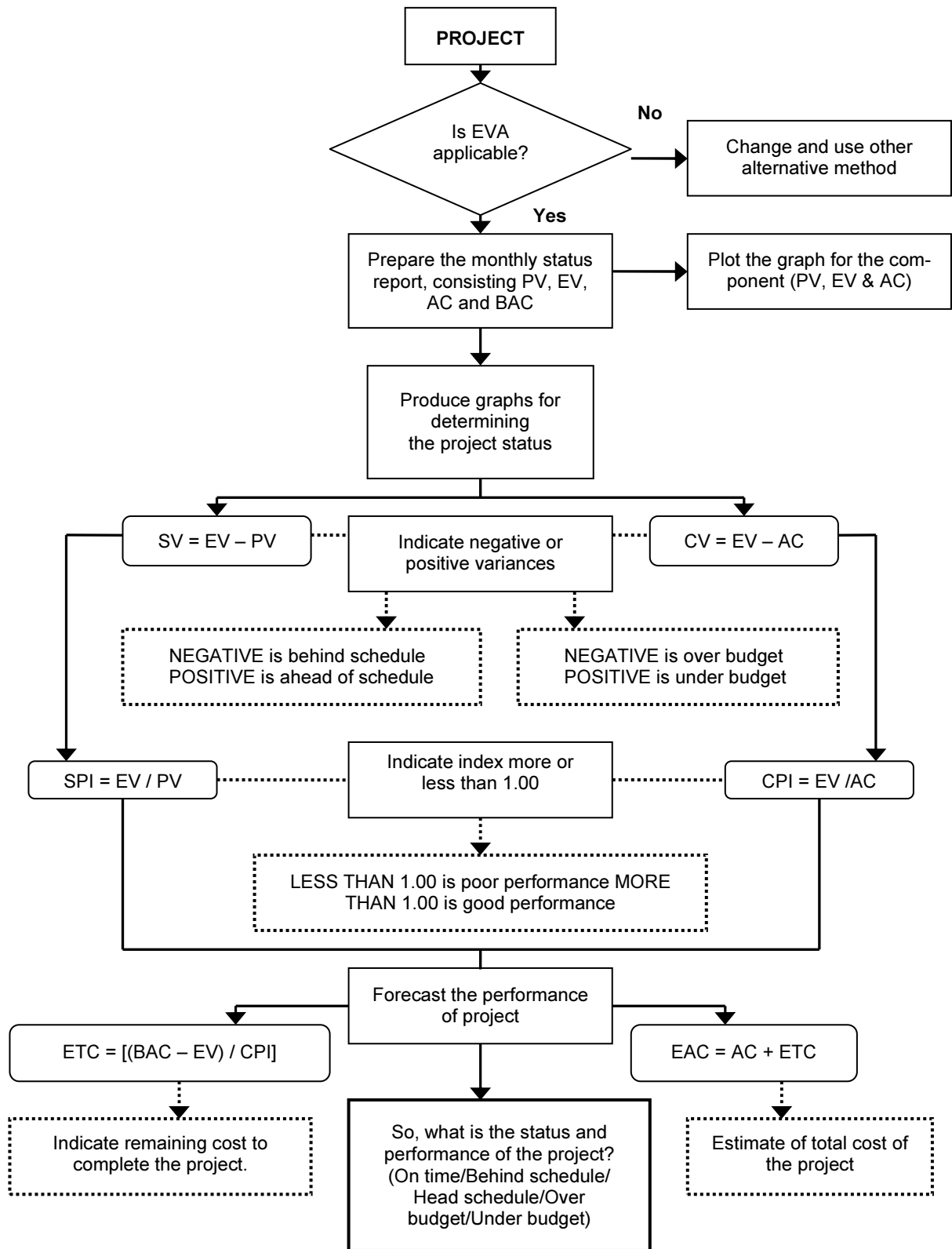
Fig. 4. Developed EVA working flowchart

Interviewees A, D, F, J, L commented that the reason for them not use the Fuzzy logic model is because this model is not easy to implement since extra computer knowledge had to be educated to staff. Further, comparing to the stochastic methods and EVA, Fuzzy logic model does not perform well in accuracy even though it is more suitable for complex analysis. Interviewees D, F, G, H, J and L stated that EVA was suitable to be applied in large scale and mega projects because it was more systematic than stochastic methods and miscellaneous methods. Even though stochastic methods and miscellaneous methods were easier than EVA to implement in the public sector, EVA was more flexible to be adopted in a complex project as Fuzzy logic model did because its formulas were much more powerful in measuring the details of a project. Interviewees A, D, F, G, I, J, L stated that EVA was the best method to track project performance. Interviewee A commented that the advantage of EVA was not only to forecast the status of project schedule and budget but also to determine the final total cost by using EAC and ETC formulas and the reason why they did not use this method was just because their main contractor required them to use stochastic methods. Interviewees B, C. J, K stated that there were a lot of advantages of EVA that could not be realized on the current stage because the Malaysian construction industry had not really adopted this method well.

Though all the interviewees agreed the advantages of EVA, Interviewees A, B and E mentioned some limitations of this method. According to Interviewee B, EVA needed more time for preparing the paper work and calculation than stochastic methods so that it was not suitable for small projects. Interviewee A discussed that the complicated formulas in EVA might cause miscalculation by unskilled staff. Interviewee E agreed with Interviewee B that EVA was time consuming in measuring PV, EV and AC during construction progress. The differences among the four tools namely: stochastic methods, EVA, Fuzzy logic model, and miscellaneous methods are summarized in Table 2. Each of the factors in Table 2 were given a same weight as recommended by 12 interviewees so that a sore for each factor were provided in the last line of Table 2, from which the advantages of EVA (score 6) over other methods such as stochastic methods (score 4), miscellaneous methods (score 3) and Fuzzy logic model (score 2) were revealed.

Table 2. Summary of differences among stochastic methods, EVA, Fuzzy Logic Model and miscellaneous methods

Factor of the differences in Forecasting method	Stochastic methods	EVA	Fuzzy Logic Model	Miscellaneous Methods
Applicability	√	√		√
Accuracy		√		
Ease of implementation	√			√
Flexibility		√		√
Reliability of warning	√	√	√	
Cost consuming		√		
Adaptability for complexity	√	√	√	
Score	**4**	**6**	**2**	**3**

5.3. Implementing EVA in Malaysian construction industry, a working flowchart

According to Interviewees F, G, I, L, the Malaysian government has taken initiatives to start implementing EVA in public companies since it is able to improve the total project performance and able to mitigate the cost overrun and delay in Malaysian. For the private sector, all the Interviewees (A, B, C, D, H, J, K) mentioned that EVA was not the common tool used in Malaysia except for mega private projects managed by foreign contractors. The reason was that it might be time-consuming and cost-inefficient to educate and to train the local staff. Interviewee D suggested the characteristics of a project that could influence the usage of EVA were the complexity of the project. On the other hand, Interviewees E, F, I, J and L who were from the public sector stated that the cost and time would not be barriers for government projects to implement EVA since the Malaysian government would rather spend more money and time to enhance the level of project management for the whole country.

Interviewees B, H and I commented that EVA is suitable for civil construction projects such as bridge, airport, and highway because those projects normally had a very high requirement in time and cost control. Interviewees A, C, E, H, J and K agreed that EVA was potentially suitable for both the private sectors and the public sector. Interviewee D added that EVA is quite suitable for design-and-build procurement because the overlapping measurement between consultants and contractors could be avoided. All the 12 interviewees agreed that the government is one major source for contractors to get the tenders especially for local contractors so that if EVA could be adopted by all public projects, the private sector would follow automatically and EVA could be widely used in Malaysia. All the 12 interviewees commented that a practicable working flowchart for EVA should be proposed for the Malaysian construction industry.

To practice the working flowchart, firstly a project team has to decide whether or not EVA is applicable for the project. If not, then other alternative methods could be employed. Otherwise, the project team should prepare monthly status report consisting PV, EV, AC and BAC. Then graphs for project status determination should be produced. Using Eq. (1) and Eq. (2), SV and CV could then be figured out. The value of SV will indicate whether the actual schedule is ahead or behind the plan. The value of CV will indicate whether the actual cost is under budget or over budget.

After the actual schedule and actual cost are determined, SPI and CPI could be calculated using Eq. (3) and Eq. (4). For both SPI and CPI, any value less than 1.00 is considered that the project is performing poorly. On the other hand, any value of more than 1.00 is considered good. From then on, ETC and EAC could be figured out through Eq. (5) and Eq. (6). ETC indicates the remaining cost to complete the project and EAC indicates the current total cost of project. Consequently, the future performance of the project could be forecasted.

6. Conclusions and recommendations for future study

Based on the interviewees' opinion, stochastic methods, EVA, Fuzzy logic model, and miscellaneous method are the four major project performance monitoring methods used in the Malaysian construction industry. The private sector in Malaysian construction industry has well implemented the stochastic methods since these methods are much easier than EVA as the latter's input might be difficult and laborious to collect on regular basis. However, comparing to stochastic methods and Fuzzy logic model, EVA has remarkable advantages in accuracy and flexibility. Accordingly, an EVA working flowchart was developed by the authors, through which more detailed project performance could be monitored and more accurate future performance of the project could be forecasted, so that the project management quality and efficiency in the Malaysian construction industry could be brought to a higher level. For future research, case studies are recommended to be conducted for the application of this proposed EVA working flowchart.

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MALAIZIJOJE NAUDOJAMI PROJEKTŲ EFEKTYVUMO STEBĖJIMO METODAI IR GALIMYBĖS EVA NAUDOTI KAIP STANDARTINĘ METODIKĄ

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S a n t r a u k a

Uždirbtos vertės analizė (UVA, angl. *Earned Value Analysis*, EVA) – paplitęs projektų valdymo įrankis, skirtas projekto efektyvumui, pavyzdžiui, laikui ir sąnaudoms, stebėti ir prognozuoti. Nors UVA nauda gamybos sektoriuje akivaizdi, Malaizijos statybų sektoriuje ji nėra plačiai taikoma. Šiuo tyrimu siekiama nustatyti UVA pranašumus prieš kitus projektų kontrolės metodus, nustatyti UVA tinkamumą statybų projektams ir sukurti darbinę srautų diagramą, kuri padėtų diegiant UVA. Taigi tyrime taikyti kokybiniai metodai, įskaitant apklausą, naudojant nustatytos struktūros pokalbius, ir srautų diagramos kūrimą. Išvados rodo, kad tikslumu, lankstumu ir pritaikymu sudėtingiems atvejams UVA yra gerokai pranašesnė už stochastinius metodus, neraiškiosios logikos modelį ir įvairius kitus metodus. Malaizijos Vyriausybė nutarė įdiegti UVA, taip pagerindama projektų valdymą visoje šalyje. Dėl to autoriai sukūrė darbinę UVA srautų diagramą, kuri leidžia stebėti smulkesnius projekto būsenos aspektus ir tiksliau prognozuoti projekto efektyvumą ateityje.

Reikšminiai žodžiai: projekto stebėsena, efektyvumo prognozės, uždirbtos vertės analizė (UVA), statybų sektorius, projektų vadyba, statyba.

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