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Application of Earned Value Management System on an Infrastructure Project: A Malaysian Case Study

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Abstract. Earned Value Management (EVM) System describes the core processes that are required for the effective use of Earned Value Analysis (EVA). It is a project performance measurement technique which is widely adopted by the construction industries of USA, UK, Australia and South Korea. However, its application as project control technique is not very common in Malaysia. In this paper, EVM System was applied on a construction of railway track project in peninsula Malaysia. This is a government funded project of worth RM 12.485 billion and awarded in December 2007 on design and build basis. This project will be completed in 2013. The case study includes contractor scope of work; schedule charts; physical progress reports; budgeted and actual cost reports. The aim of this case study is to practically demonstrate that how Earned Value Management (EVM) System can be applied on Malaysian construction projects. This will facilitate the project practitioners to the further use of EVA for the schedule and cost control of their construction projects.

Keywords: Earned Value Management (EVM), Performance Measurement, Construction Management.

1. Introduction

The performance of a construction project can be judged by using different traditional approach like day to day monitoring, monthly or weekly management reports, performance reviews, key performance indicators, project audit reports etc. In these traditional approaches, usually there are two data sources, the budget (or planned) expenditures and the actual expenditures. The comparison of budget versus actual expenditures merely indicates what was planned to be spent versus what was actually spent at any given time. And also, how much has been produced. With this approach there is no way to determine the physical amount of work performed. It does not indicate anything about what has actually been produced for the amount of money spent nor whether it is being produced at the rate, or according to the schedule, originally planned. In other words, it does not relate the true cost performance of the project [1]. Based on these limitations of traditional performance measurement tools, this paper discusses Earned Value Analysis (EVA) technique as an effective tool for monitoring and control of construction projects. It is a project control method which integrates the cost, schedule and technical performance.

EVA takes these three data sources and is able to compare the budgeted value of work scheduled (PV) with the Earned Value (EV) of physical work completed and the Actual Cost (AC) of work completed [1]. Hence, performance data achieved by using EVA is an objective measure of actual work performed and can be used for the future performance analysis and forecasting. It supports efficient risk management by providing early identification of possible trouble area. This technique has also attracted many government procurement departments including industrial sectors like engineering, construction, oil and gas, infrastructure, Information technology etc. [2].

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EVA is relatively a less common project performance measurement technique for the Malaysian construction industries. Currently, it has a limited usage as a project monitoring tool. Therefore, this case study demonstrates that how an EVM System can be implemented in order to get an effective EVA on construction projects in Malaysia.

2. Background

This case study describes the Earned Value Management (EVM) method for the Larut tunnel section of Electrified Double Track Project (EDTP) in the Western part of peninsular Malaysia. The EDTP is a Government funded project of worth RM 12.485 billion and awarded in December 2007 on design and build basis. An equal joint venture was established between two Malaysian construction groups to undertake the project. The overall scope of work includes design and construction of an electrified double tracking railway line between Ipoh (capital of Perak) and Padang Besar (a town near Thailand border in Perlis) measuring 329 Kilometer (Km). This project is expected to complete in 2013 [3].

The case study embarks the construction of Larut tunnel at Air Kuning, Taiping, Perak. The site work started in the first quarter of 2008. It is 342m in length; the single Larut tunnel has a “horse shoe” diameter shape which is 13m in width and 10m in height. For drilling this tunnel a combined method was adopted for drilling simultaneous holes at a time (drilling jumbo; high speed drill) and control blasting was used depending upon the requirements [4].

3. Application of EVM System

The implementation of EVM System on construction of Larut tunnel is performed in the following steps:

3.1. Development of Work Breakdown Structure

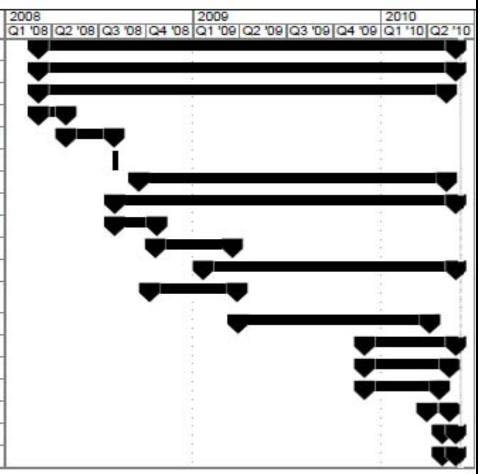
The development of Work Breakdown Structure (WBS) is the core process of an EVM System. It is the hierarchical decomposition of project activities into manageable work packages. It is of particular importance because as it provides a basis for calculating the EVM matrices. This study considers the “Larut Tunnel” as a whole project with WBS level 0. It is then decompose into two major heads as mentioned below and having WBS Level 1.

- Civil & Structural Works
- Mechanical & Electrical Works

A Work Breakdown Structure (WBS) provides firm basis for establishing a project schedule. It comprises of a detailed list of work package activities with intended start and finish dates. In construction industry, usually the project scheduler is responsible for making the schedules. Table 1 shows a summary schedule of drill and blast construction programme for Larut tunnel section.

TABLE 1. SUMMARY OF WORK SCHEDULE

S.No.		Task Name	Duration	Start	Finish
1		Larut Tunnel	639 days	Fri 3/7/08	Wed 5/26/10
2		Civil & Structural works	639 days	Fri 3/7/08	Wed 5/26/10
3		South Portal	626 days	Fri 3/7/08	Sat 5/8/10
4		Preparation & Mobilization	53 days	Fri 3/7/08	Mon 4/28/08
9		Excavation Works	94 days	Tue 4/29/08	Thu 7/31/08
53		Drainage works	7 days	Thu 7/31/08	Wed 8/6/08
54		Portal Works	435 days	Thu 9/18/08	Sat 5/8/10
59		Noth Portal	491 days	Sat 8/2/08	Wed 5/26/10
60		Preparation & Mobilization	69 days	Sat 8/2/08	Wed 10/22/08
65		Excavation Works	111 days	Mon 10/20/08	Wed 3/18/09
81		Portal Works	356 days	Wed 1/21/09	Wed 5/26/10
87		Mined Tunnel Construction (L = 338.4 m)	126 days	Thu 10/9/08	Fri 3/27/09
93		Final Lining	267 days	Mon 3/30/09	Mon 4/5/10
99		Mechanical & Electrical Works	131 days	Tue 12/1/09	Wed 5/26/10
100		Service Installtion	123 days	Tue 12/1/09	Fri 5/14/10
101		Utilities	106 days	Tue 12/1/09	Sat 4/24/10
105		System Installation	36 days	Thu 4/1/10	Fri 5/14/10
110		Track Works	20 days	Sat 5/1/10	Wed 5/26/10
111		Track Formation	20 days	Sat 5/1/10	Wed 5/26/10



3.2. Organizational Breakdown Structure

Organizational Breakdown Structure (OBS) generally illustrates the position description of project team members. It is also used to define the project team relationships and to assign the roles and responsibilities. The OBS provides a hierarchical type organizational chart rather than a task-based outlook of the overall project. The hierarchical structure of the OBS allows the aggregation of project information to higher levels. When project roles and responsibilities are defined, the OBS and WBS are merged together to develop a Human Resource Plan. In using WBS and OBS, it is assured that all elements (scope) of a project will be assigned to each project team members on the basis of Responsibility Assignment Matrix (RAM).

3.3. Budget Allocation

The "Electrified Double Track Railway Project" was awarded at a fixed price contract for which the baseline cost is RM 12.485 billion. The project cash flow report for the Larut tunnel section was obtained for the period of March 2008 to May 2010 in order to establish a time-phased budget. In construction industry, the cumulative illustration of budgeted cost is very common in the form of a non-linear graphical image. This is known as S-curve and shown in Fig. 1. It shows a trend of budgeted expenditures over a period of time. It is also known as the Performance Measurement Baseline (PMB) which is the summation of budgets of work scheduled with in a stated period (Planned Value).

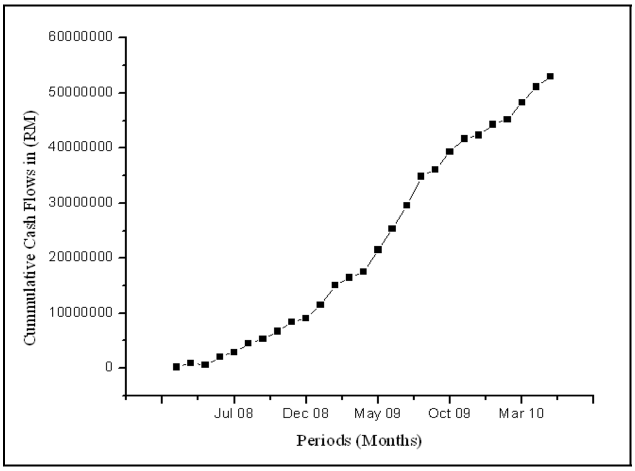


Fig. 1: S-Curve for Cumulative Cash Flows.

3.4. Earned Value Analysis

The performance management of an ongoing project can be observed by calculating the EV metrics i.e. Planned Value (PV), Earned Value (EV) and Actual Cost (AC). Fig. 2 shows a graph of Earned Value Analysis on quarterly basis for a period of 24 months (March 2008 – 2010). A scheduling software package was used to carry out this analysis. It is apparent from the data that during the entire project duration the AC remained less than PV and the EV also remained less than the PV and AC. Hence, the performance is unsatisfactory.

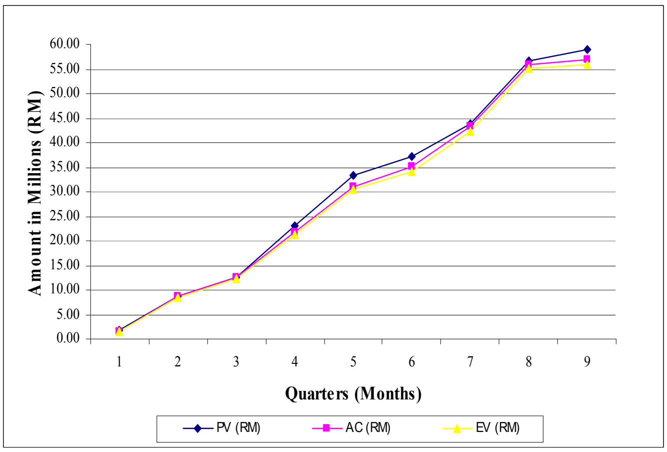


Fig. 2: PV/AC/EV Graphical Analysis.

4. Results and Discussion

By knowing the basic EVM parameters i.e. PV, AC and EV in the previous section, the Earned Value (EV) schedule and cost analysis can be summarized as follows;

4.1. Schedule Analysis

This case study depicts a scenario in which the EV schedule analysis was carried out quarterly. Table 2 shows Schedule Variance (SV), SV%, SPI and actual physical progress.

TABLE 2. EV SCHEDULE ANALYSIS (AMOUNT IN RM)

S.No.	Description	EV Schedule Analysis			% of Completed Work
		SV	***SV%***	***SPI***	
1	1st Quarter, 2008	-418,861	-22.581	0.77	2.17
2	2nd Quarter, 2008	-260,655	-3.029	0.97	12.58
3	3rd Quarter, 2008	-260,655	-2.068	0.98	18.60
4	4th Quarter, 2008	-1,761,588	-7.634	0.92	32.13
5	5th Quarter, 2009	-2,976,538	-8.918	0.91	45.83
6	6th Quarter, 2009	-3,243,478	-8.711	0.91	51.24
7	7th Quarter, 2009	-1,702,432	-3.875	0.96	63.66
8	8th Quarter, 2009	-1,683,160	-2.969	0.97	82.92
9	9th Quarter, 2010	-2,969,571	-5.044	0.95	84.28

The results of the EV schedule analysis indicate that the project progress is unfavorable and it can be discussed as follows:

i. The Schedule Variance (SV) values are consistently negative within the first 09 quarters which determines that the project is fall behind the original schedule.

ii. The SV% varies between -22.581% to -2.068% indicating that the percentage of works which have not been accomplished against the planned schedule.

iii. The efficiency of project team is demonstrated by Schedule Performance Index (SPI) which is less than 1.0. It shows that the team has performed work less efficiently and the schedule objectives are achieved within the range of 77% (Min.) to 98% (Max.) efficiency at every quarter.

iv. Table 2 shows a very useful assessment of SV% and actual percentage of completed work. This type of comparison cannot be possible without EVA. The percentage of completed work shows that project is succeeding well. However, corresponding SV% indicates that work has not been accomplished as per original planned. For example, at the end of quarter 4, the project is 32.13% completed. But its corresponding SV% point out that 7.634% of planned work is still remaining (due to negative value). Hence, the project progress is unfavorable and it requires appropriate remedial measures to fill up this gap.

4.2. Schedule Forecasting

The original schedule completion time for this project was 27 months. However, due to the less efficient performance of the project team, it is predicted that project will fall behind the schedule. Therefore, Time Estimate at Completion (EACt) at the end of March 2010 will make possible to forecast any additional time required for project completion.

$EACt = (BAC \div SPI) \div (BAC \div Months)$

$EACt = (RM\ 58x10^6 \div 0.95) \div (RM\ 58x10^6 \div 27)$

$EACt = 28.5$ Months

The EACt shows that if the current progress trend continues, the project will likely to finish in 28.5 months (approx.) as compared to initial scheduled completion time which is 27 months.

4.3. Cost Analysis

The EV cost analysis make possible to measure and forecast the project progress cost-wise. Table 3 shows the value of CV, CV% and CPI.

TABLE 3. EV COST ANALYSIS (AMOUNT IN RM)

S.No.	Description	EV Cost Analysis		
		CV	***CV%***	***CPI***
1	1st Quarter, 2008	-168,861	-11.76	0.89
2	2nd Quarter, 2008	-249,377	-2.99	0.97
3	3rd Quarter, 2008	-110,655	-0.90	0.99
4	4th Quarter, 2008	-437,554	-2.05	0.98
5	5th Quarter, 2009	-580,538	-1.91	0.98
6	6th Quarter, 2009	-1,248,783	-3.67	0.96
7	7th Quarter, 2009	-1,176,722	-2.79	0.97
8	8th Quarter, 2009	-1,014,130	-1.84	0.98
9	9th Quarter, 2010	-953,287	-1.71	0.98

Additional analysis can be done as follows;

i. The Cost Variance (CV) is calculated by subtracting the EV from the AC. For this project, it has a consistently negative value which depicts an unfavorable scenario. It can also be expressed as a percentage by dividing the CV by the EV as shown in Table 3. The CV% values lie in the range of -0.90% (Min.) to -11.76% (Max.) during the entire period. It indicates that the project progress was fairly good at the end of 3rd quarter of 2008 when it was 0.90% over budget compared to 11.76% over budget at the end of 1st quarter of 2008.

ii. Refer to Table 3, it shows Cost Index Values (CPI) values at different project durations. CPI indicates the efficiency of project resource utilization. For a best-case scenario, it must be equal to 1.00 or higher than 1.00. However, for the current case study the CPI values are in-between 0.89 and 0.99. This shows that the project has a low cost efficiency as compared to its spending.

5. Conclusions

The EVM System for the performance measurement of construction project was successfully tested on the above case study. The EVA provides a clear insight in to the project progress. It facilitates the project team to carry-out more in-depth assessment of project status and predicts future performance trends as well. The calculation of performance indices and variances from the case study make it possible to examine the current, and forecast the future schedule and cost performances in a variety of ways.

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