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Earned Value Analysis-based Performance Monitoring of Infrastructure Project

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***Abstract*—Project monitoring plays a vital role in improving the prospects of successful implementation of infrastructure projects. Project monitoring enables review of the progress of the project against the plan and identification of variables to be improved. The project management technique i.e., the Earned Value Analysis (EVA) has been performed on an infrastructure project during its construction phase to examine its utility as a classical monitoring and control methodology. EVA evaluates project performance to understand not only the ongoing progress but also the future implications on the project, mainly concerning cost aspects. This project performance analysis potentially provides early warning signs of cost and time overruns during the construction phase of the project to take appropriate action. The paper recommends effective project monitoring using the EVA techniques of performance evaluation with periodic measurements for project cost and time control. In addition, the study also recommends the consideration of other performance parameters as well as techniques for the successful completion of the infrastructure projects than only the actual cost and work completion against the plan.**

Keywords*— Earned Value Analysis (EVA); Infrastructure Projects; Project Monitoring and Control; Project Performance Analysis; Project Cost and Time Control

I. INTRODUCTION

The challenges of the projects increase in infrastructure projects because of their complexities and multi-stakeholders involvement. For example, globally 90 percent of infrastructure projects suffer cost overrun [1] and are more frequently impeded by delays [2] during the construction phase. Moreover, the overruns and or underperformances of infrastructure projects also adversely impact their economic viability and hence require to be managed efficiently [3]. Thus, efficient monitoring is essential to improve the performance of infrastructure projects, especially in respect of time and cost performance parameters.

Project control techniques like network scheduling and Gantt charts though commonly used in practice but there are some other important project control techniques such as program evaluation and review technique (PERT), critical path method (CPM), and earned value analysis (EVA) which have been used by the project team [4] for many decades. The application of some of these techniques gets supported by a variety of software tools like Microsoft Project (MSP) and Primavera etc.

EVA is an integrated “managerial methodology to monitor and control projects and it uses monetary units as a common basis to measure and communicate the progress of a project” [5]. It is based on the actual cost (incurred), budgeted values of the work performed, and planned (budgeted) value.

Thus, the objective of the project case study primarily involves monitoring an infrastructure project based on its performance evaluation using EVA for cost as well as time control (mainly in respect/terms of cost) to understand the project’s achieved performance or overruns for initiating the corrective action or control as required.

II. EARNED VALUE ANALYSIS

A. Introduction to Earned Value Analysis

EVA is a classical technique, originally developed by the US Department of Defense (DOD), to formalize Cost/Schedule Control Systems Criteria (C/SCSC) in 1967 for monitoring and controlling project performance [6]. Subsequently, it has been adopted by Project Management Institute (PMI) as a standard, named Earned Value Management (EVM), including in its “Guide to the Project Management Body of Knowledge (PMBOK®)”. EVM integrates three key project performance criteria: scope, time, and cost [7]. Focusing on time and cost control, EVA evaluates the actual performance of the project, variance analysis, and forecasting [8]. Traditionally, EVA is one of the methods to measure project performance and compares expected progress with the actual progress to date. It indicates how much of the budget should have been spent for the amount of work done so far and the baseline cost for tasks, assignments, or resources. Earned value is also referred to as budgeted cost of work performed (BCWP) and earned value analysis as budgeted cost analysis. It also indicates cost trends or forecasts [9].

B. Purpose of EVA [9]

Earned value analysis serves two purposes:

- To evaluate the possible cost over-run or performance for taking corrective actions, for example, modification of cash flow, updating budget plan or forecasts, and expected profits/profitability from the project.

- To update key personnel as well as concerned on expected cost variations to create cost awareness for finding the ways to minimize wastage and reduce cost.
- It also indicates project progress in terms of cost and schedule (in terms of cost)

C. *Shortcomings of EVA and Other Streams of Research*

Despite the benefits of EVA for project control (mainly for time and cost), there are some limitations of EVA in practice: such as no differentiation between critical and noncritical activities, assumption of activities as independent, no consideration for technical, operational, quality performance measures and behavioral aspects of management along with high requirement of information for analysis [10].

Reference [11] integrates project scope, cost and schedule control under the same framework. There is another stream of studies on experimentation with EVA/EVM for further improvement or modifications such as earned duration management for better measurement of schedule performance by [12]; incorporating the fuzzy principles into EVA for more robust and reliable project status forecasting by [13]; incorporating the statistical quality control charts in EVA for reporting deviation effectively, hence contributing to a more reliable project control process by [14]; integrating the earned value methodology with project risk analysis for better understanding the root cause of project deviations to take early corrective actions by [15].

D. *How to Perform EVA [9]*

Earned value analysis involves the following steps:

- Evaluation of cost variances by comparing actual costs with budgeted costs, to determine cost overrun/under-run.
- Computing schedule variances by comparing budgeted costs of work schedule and work performed, to determine deviations from the schedule. The time over-run/under-run reveals the cost and time the project is behind or ahead of schedule.
- Estimate project cost at completion.

The budget relates the costs with time progress. Commonly used monitoring parameters are:

- Budget cost of Work scheduled (BCWS) or Planned Value (PV) represents time-phased cost projections made in the budget and shows what is planned for execution.
- Budgeted cost for Work performed (BCWP) or Earned Value (EV) shows the cost budgeted i.e., earned value for the work performed to date.
- Actual cost for the work performed (ACWP) or Actual Cost (AC) is the sum of actual cost incurred to date in progressing i.e., completing work packages.

1) Variance analysis: The variances and performance indexes relating to earned value are calculated below.

a) Cost variance (CV): Cost variance is computed by comparing actual performance/cost (ACWP/AC) with the budgeted cost of work performed (BCWP/EV).

$$CV = BCWP - ACWP \quad (1)$$

If the cost variance is positive, then the project has a cost under-run, i.e., the cost incurred is less than the planned or budgeted cost. If the cost variance is negative, then there is a cost overrun, i.e., the cost incurred is more than the planned or budgeted cost. If the cost variance is zero, then the project is proceeding according to the budgeted cost. Cost overrun or under-run are usually expressed in percentage [9].

$$CV(\%) = (CV \times 100) / BCWP \quad (2)$$

b) Schedule variance (SV) [9]: SV is computed by comparing the budgeted cost of work performed (BCWP/EV) with the budgeted cost of work scheduled (BCWS/PV).

$$SV = BCWP - BCWS \quad (3)$$

If the schedule variance is positive, then the project is ahead of planned cost, i.e., earned value of work performed is higher than the planned or scheduled earned value. If the schedule variance is negative, then the project is behind its planned cost, i.e., earned value of work performed is less than the planned or scheduled earned value. If the scheduled variance is zero, then the project is proceeding according to the planned schedule.

$$SV(\%) = (SV \times 100) / BCWP \quad (4)$$

2) Performance indices and forecasts/trends: Variance analysis reveals the extent and causes of variances. While the performance analysis determines how efficiently the task was done and what its implications will be on future trends [9].

$$\text{Cost performance index (CPI)} = BCWP / ACWP \quad (5)$$

$$\text{Schedule performance index (SPI)} = BCWP / BCWS \quad (6)$$

An index of 1.0 or greater indicates a favorable performance and less than 1.0 implies an unfavorable trend. CPI indicates “how efficiently a project team is using its resources whereas SPI indicates how efficiently the team is using its time” [6]. Performance indices vary during the execution of a project. Minor variances are normal, but significant changes in indices call for forecasting of probable performance on completion.

Assuming the future trend at the originally planned rate, the cost forecast at completion i.e., estimate at completion (EAC) calculated as

$$EAC = (ACWP - BCWP) + (\text{planned BCWS on completion})$$

Or

$$EAC = ACWP + BAC - BCWP \quad (7)$$

BAC = Budgeted cost at completion i.e., planned BCWS on completion

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Assuming that the future rate of progress will continue at the present trend, the cost forecast at completion i.e., EAC calculated as

Cost forecast at completion = (Planned BCWS on completion) / (cost performance index or trend)

Or

EAC = BAC / CPI (8)

BCWS or PV, when plotted graphically against the time scale, resembles the S curve patterns. Graphical representation of the BCWS/PV along with BCWP/EV and actual performance i.e., ACWP/AC for two typical projects, one with favorable and the other with unfavorable variances are shown below in Fig. 1 and 2 respectively.

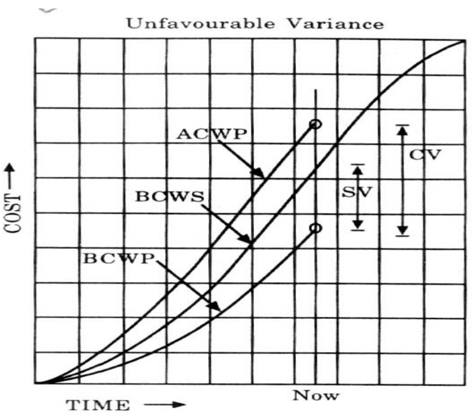

Fig. 1. Unfavorable variance

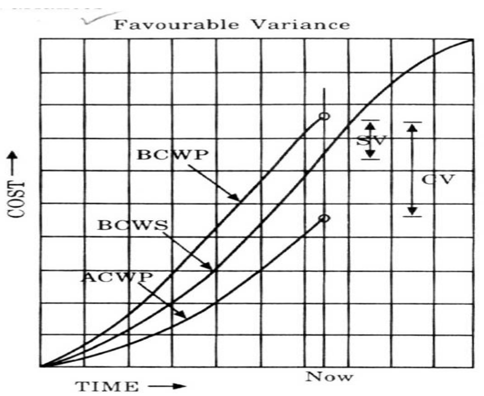

Fig. 2. Favorable variance

III. Research Methodology

In this paper, project performance has been evaluated through a systematic approach and methodology mainly in respect of cost as well as time performance using EVA based on a case study approach. For the case study, a prestigious infrastructure project of constructing an elevated highway by a leading infrastructure developer (company) in India has been selected as a representative case.

Data collection was done from secondary sources of the internal records and reports from the company on project monitoring, specifically regarding the cost details (monthly budget plan for the project and cost incurred against monthly budget), project status/progress (value/cost of work done as per budget). In addition, some informal interviews and discussions have been conducted with the company executives, managers, engineers and site supervisors engaged in the project as primary data collection methods to understand the reasons behind the overruns or underperformances (if any) during the execution phase of the project.

Analysis has been performed based on EVA to evaluate project performance in respect of (mainly) cost as well as time by identifying the variances against the plan, performance indices and their implications on the project.

IV. Case Study, Results and Discussion

The selected case for the study was an infrastructure project for the construction of an elevated highway, by a leading infrastructure developer in India, as already mentioned in the research methodology section (III) above, considering the significance of monitoring and control of the project. The main scope of the project was the construction of i) an elevated highway of 3 km including all ground-level existing road improvement works. ii) 4 pedestrian underpasses and 2 flyovers iii) work related to toll plazas and 800 m^2 of administration building. The duration of the project was 24 months and the cost of 227.24 cr. (project budget or BUD/BAC). The case study primarily involves project progress, performance evaluation and trend forecasting using the EVA technique to understand the project's achieved performance or overruns for suggesting the corrective action as required.

A. Earn Value Analysis for Elevated Highway Project

The earned value analysis or budgeted cost analysis was being done for the project. EVA was conducted to evaluate integrated project performance in terms of cost and time and to focus on estimate at completion (EAC) at present cost trend as well as planned as on the last day (at the end) of the 10^{th} month i.e., March' 17 after starting of the project.

- Measures project performance and compares expected progress with the actual progress to date.
- Indicates how much of the budget should have been spent for work done (budgeted cost of work performed/BCWP) so far and the baseline cost for that work.
- Indicates cost trends or forecasts.

1) Project cost and time performance: Based on the procedure explained before (section II sub-section D.), project performance analysis using EVA can be done as follows on 31st March 17.

a) Variance analysis:

- Cost variance = -5.65 crore (using equation 1). Cost-variance is negative, so there is a cost overrun i.e., the cost incurred is more than the

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planned or budgeted cost of work performed i.e., earned value.

- Cost variance (%) = -27.33% (using equation 2). Thus, the project cost overrun is 27.33%.
- Schedule variance (SV) = -58.97 Cr. (using equation 3, in terms of cost). Schedule variance is negative, so the project is behind its planned cost, i.e., earned value of work performed is less than the planned or scheduled value.
- Schedule Variance% (SV %) = -74% (using equation 4). That is project is behind schedule (in terms of cost) by 74%.

b) Performance Indices and Cost Forecasting:

- Project Cost Performance Index (CPI) = 0.79 (using equation 5).
- Project Schedule Performance Index (SPI) = 0.26 (using equation 6).
- Both indices are less than 1.0 and imply an unfavorable trend that is project is performing inefficiently in respect of both time and cost. Especially, the project schedule performance index is showing very poor performance as SPI is much less than 1 at 0.26.
- Assuming the future trend at the originally planned rate.
  - Cost forecast at completion = 232.89 Cr. (using equation 7).
  - Cost variance at completion = - 5.65 Cr
- Assuming the future rate of progress will continue at the present trend
  - Cost forecast at completion = 289.35 Cr. (using equation 8)
  - Cost variance at completion = - 62.11 Cr.

Table I shows the EVA results for the project performance variances and indices at the end of March 17.

TABLE I. EARNED VALUE ANALYSIS RESULTS FOR PROJECT PERFORMANCE INDICES AND VARIANCES

Month	Month-wise budget (BCWS/PV) (Cr.)	Monthly Cumulative budget (BCWS/PV/BUD) (Cr.)	Cumulative achieved (BCWP /EV/BTD) (cr.)	Actual Cost of Work Performed (ACWP/AC) (Cr.)	SV (cr.)	SV%	SPI	CV (Cr.)	CV%	CPI
Jun-16	4.53	4.53	2.00	5.34	-2.53	-55.85	0.44	-3.34	-167.00	0.37
Jul-16	4.22	8.75	3.25	6.00	-5.50	-62.86	0.37	-2.75	-84.62	0.54
Aug-16	4.45	13.20	4.00	7.75	-9.20	-69.70	0.30	-3.75	-93.75	0.52
Sep-16	4.01	17.21	6.00	9.11	-11.21	-65.14	0.35	-3.11	-51.83	0.66
Oct-16	8.19	25.40	7.00	10.00	-18.40	-72.44	0.28	-3.00	-42.86	0.70
Nov-16	11.08	36.48	8.26	13.45	-28.22	-77.36	0.23	-5.19	-62.83	0.61
Dec-16	11.14	47.62	10.41	17.21	-37.21	-78.14	0.22	-6.80	-65.32	0.60
Jan-17	11.29	58.91	12.04	19.55	-46.87	-79.56	0.20	-7.51	-62.38	0.62
Feb-17	10.96	69.87	17.46	21.32	-52.41	-75.01	0.25	-3.86	-22.11	0.82
Mar-17[a]	9.77	79.64	20.67	26.32	-58.97	-74.05	0.26	-5.65	-27.33	0.79

a. As on 31-07-17

Graphical representation of earn value analysis i.e., earn value chart indicating the integrated time-cost performance of the elevated highway project at the end of March 17 i.e., as on 31.07.17 is shown below in Fig. 3. SV in time units can be found from the graph as 5 months.

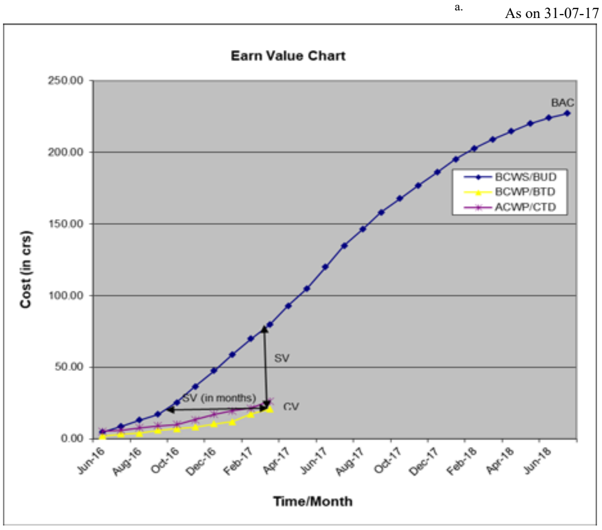

Fig. 3. Earn value chart for elevated highway project as on 31-03-17

EVA of the project was done based on available data, budget and cost reports from the project. The analysis indicates that the project is behind schedule by 74% i.e., financial progress is at 26%, project cost overrun by 62.11 cr. and the cost estimate at completion (present cost trend) is 289.39 Cr. Cumulative cost figures are used for forecasting the cost trend. The estimate would be more accurate if activity-based costing was used for forecasting. Earn value chart for the project in Fig. 3 also shows cost and schedule variances graphically along with the schedule variance in months of five i.e., project schedule overrun by 5 months. Table II shows the EVA results for the project cost forecasting along with variances at the end of March' 17.

TABLE II. EVA RESULTS FOR PROJECT VARIANCES AND FORECASTING AS ON 31-03-17

Project variances, performances and forecasting	*Values*
Cost forecast at completion at present cost trend	289.35 Cr.
Cost variance at completion (at present cost trend)	62.11 Cr.
Cost forecast at completion at planned cost	232.89 Cr.
Cost variance at completion (at planned cost)	5.65 Cr.
Project cost overrun percentage by	27%
Project behind schedule (time overrun in terms of cost) percentage by	74%
Project schedule overrun (from EV chart)	5 months

B. *Reasons for Project Overruns and Recommendations*

Informal interviews, discussion with project team members and internal records analysis revealed some of the following reasons for project overruns or underperformance.

Cost overrun due to design change and project delays in various accounts as mentioned below. For ex., "In most of the cases, land acquisition and approvals from various departments further increases the complexity, delays and hence cost overrun" shared by the team members. Delays happened due to design changes, land acquisition, procurement and utility shifting. "Delays in land acquisition, procurement and utility shifting, re-designing of the project for value addition resulted in time and cost overrun of elevated highway project" as mentioned by the project team leader.

These project delays could not be recoverable using the time crash technique or rescheduling to recover slippage time and ultimately resulting in an overall delay in the project. "Delays in regulatory clearances or land acquisition can severely impact the progress and delay the project … in most of the cases, this delay cannot be avoided resulting in time overruns and thus cost overruns" as claimed by the project manager.

It is recommended that the project baseline plan of the project should include provisions for such delays. This would help in developing a realistic project schedule and also in forecasting the time and cost overrun in the financial model at the beginning of the project. This will also help in effective resource mobilization.

The two commonly used techniques for reducing time overruns are i) compressing the critical path and ii) trading time with cost. Some common methods of time reduction in this regard are to increase the resources allotted and/or work overtime and change the mode of execution/performance of an activity.

The following options are to be evaluated in the project to reduce time overrun and hence to control.

- Increase resources for long-duration critical activity such as the number of casting molds for superstructure (of elevated highway) at the earliest to avoid further time overrun.
- Mastic asphalt wearing coats and road furniture on elevated highway can be re-planned as parallel activities which can reduce the project completion time.
- Proper attention to be given to reduce wastage and resource utilization during the construction of the project to avoid and or reduce the cost overrun further by updating the key personnel as well as concerned on cost changes and creating cost consciousness.

Besides, some other identified problems with the management and control practices adopted in the project are, for ex., more focus was being given by the project team on routine records and reports regarding project progress (that also in an unorganized and informal way) but less emphasis on regular monitoring and control through analysis or analytical review (using a technique like EVA or MSP, etc.). As the project was already suffering overruns, it was suggested that the project plan and budget should be updated every week to facilitate periodic monitoring and analysis using EVA which can ensure timely identification of slippages to work out action plans and reduce further time/cost overrun.

In addition, the use of MSP/Primavera software may save considerable time of resources and management in data collation, analysis and project reviews which would be an added benefit as it not only supports the EVA technique/feature but also efficient scheduling/planning and tracking/monitoring of any size of the projects. Commonly in practice by the industry, EVA is being used for cost monitoring and control [16] whereas PMS tools like MSP or Primavera are for schedule control [17]. EVA is possibly the most prominent method for project cost/performance analysis and forecasting to take corrective action for project control [18].

Despite the benefits of EVA for project cost and time (but in terms of cost) control, it lacks differentiation between critical and noncritical activities and no consideration of task dependencies. In addition, EVA doesn't give any consideration to technical, operational aspects, quality performance measures and behavioral aspects of management. Thus, it is recommended that for projects like infrastructure, additional attention be given to other performance parameters

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such as quality, safety, environment and stakeholders' satisfaction, etc. other than the cost and time performance alone.

V. CONCLUSION

Time and cost overruns are very common in the implementation of infrastructure projects which impact the economic viability of the projects. The complex nature, long development duration, huge funding requirements and multiple shareholders' involvement in long gestational periods make infrastructure project management and monitoring more challenging than a simple construction project. Project control and monitoring play a critical role in the completion of infrastructure projects on time and within budget.

The current study demonstrates the applicability and viability of the EVA as a classic performance evaluation technique through a case-study application for effective monitoring and control of an infrastructure project. Thus, the study recommends that earned value analysis or budgeted cost analysis needs to be performed periodically for evaluating project performance and trend forecasting to avoid or minimize cost overruns and also to understand schedule variance (in terms of cost). This ultimately facilitates in timely identification of project cost/overruns and the taking of necessary action for cost and time control.

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