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Assessment of Project Progress By EVM And ESM Technique

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Abstract : *Cost is one of the main parameters for the success of a project. Earned Value Analysis is a method to check the actual project progress and compare the actual cost incurred to the value of the work performed. This technique is very useful in comparing the budgeted cost of work to the actual cost. Earned Value analysis is very valuable in determining profits and losses and the total cost overhead during the project. Using Earned Value analysis provides us the means to determine the activity which is contributing to the project delay and increase in cost. It is a powerful tool to control project progress and cost. The objective of the research is to provide advantages and also to discuss the main aspects of Earned Value management. This paper will also compare traditional means of cost assessment in construction and Earned Value analysis and how it can change the way we look at the construction project. This type of value analysis is particularly useful while working on a mega construction project. In spite of all the advantages, there is still a restricted use of this method in some countries. This paper will also deal with the conservative use of this method and how that can be changed in order to ensure a cost effective project with no delay.*

Keywords - *Cost overrun, Delay, Earned Value Management, Earned Schedule Management, Project performance*

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I. Introduction

Managing a project consists of numerous phases, starting from planning to the execution and finally to the closure of the project. Project Management is a very broad and the most important aspect for a project to be successful. Because of numerous activities and enormous amount of capital invested in a Construction project, project management has become very vital for construction industry. Success of a construction project is always calculated in terms of time and cost. Time and cost are the two most pivotal parameters for a successful project. An investor would want to finish the project within the scheduled time with no delay, as more capital would be required to mitigate the impact of that very delay. So, it is important to schedule the project efficiently such that additional buffer is already allotted for each activity well before the construction starts. Managing that buffer to ensure minimal delays with no addition to the cost comes under monitoring and control of the project. One such process for monitoring the project efficiently is Earned Value Analysis. This analysis provides a construction manager with information regarding the value of work performed in terms of money during a particular stage and the cost required to reach that stage. It also tells us if the project is running behind schedule with cost overrun or the project is on schedule with or without incurring additional cost. It provides the manager with an incentive to think about immediate measures to ensure that there is minimal impact of the delay and the reason behind increase in cost incurred and providing ways to reduce the same.

II. Concept

If you try to walk with your eyes closed, chances of a mishap or an accident are significantly increased. But, if you walk with your eyes opened, chances of the same are significantly reduced. Similarly, Earned Value Analysis provides us with the vision and sight required to move ahead with a construction project. It helps the construction manager to choose the required path from a particular stage of the project depending on the result of this analysis. The path once chosen after the analysis does not necessarily mean that the project will be completed successfully, but it increases the chances of finishing the project successfully. Earned Value Analysis basically is a comparison between the value of work performed in terms of money, amount of work scheduled and the actual cost needed to reach that stage. A schedule for construction project is prepared. Based on the schedule we can find the amount of work that should have been completed at a particular stage. It is necessary to have a common unit for recording progress of all the construction activities. Here, we have taken money as that common unit. Hence, we find the amount of work scheduled at a particular stage in terms of money and compare it with the amount or value of work actually performed. If the former is more than the

latter, the project is behind schedule and there is a delay. Similarly, if the actual cost is more than the work performed, the project is facing cost overrun. We can also find activities contributing to this additional increase in cost. Value of work performed can be calculated using percentage completion of the activities involved. Calculation of percentage complete can be computed by many methods. By this analysis, we calculate cost and schedule variances, along with performance indices for project performance management. Examining the results, we can forecast the total cost required at completion and new schedule for the project because of the delay. It is an effective and useful project tool that helps the client and as well as contractor to assess the project performance. This method gives construction manager a chance to make his project successful. It is a powerful tool to control the project by monitoring the progress and cash inflow.

III. Need of Earned Value Analysis

The Earned Value Analysis is needed to check whether the project is running ahead or behind the planned schedule. By applying this analysis at any intermediate interval, we can find when the project is likely to be completed. The earned value analysis checks whether the construction of a project is currently under or over budget prepared by estimating the quantities of work involved. By forecasting the data, we can know the cost needed to complete the remaining or the entire project. By analyzing the data collected at regular intervals and studying the schedule and cost parameters, we are now able to check how efficiently we are working with the project.

IV. Elements of Earned Value Management

EVM uses the following project parameters to evaluate project performance.

BCWS or PV: This is called budgeted cost of work scheduled. It is the money required to finish the scheduled work at a particular stage or time of the project. It is also called as planned value. In other words, it is the planned cost of work completed till date.

BCWP or EV: It is the total value of work actually performed. It is termed as budgeted cost of work performed. It is basically the money required to complete the actual work completed till date. It is also called as Earned Value.

ACWP or AC: It is defined as the actual cost incurred while completing the project at a given stage or time. It is termed as the actual cost of work performed. In other words, it is the actual money required for the work performed by the company. It is also called as the Actual Cost.

BAC: Budget at completion is total cost required for completing the project on scheduled time. It is prepared during the planning stage of the project.

V. Variance Analysis

This is the measurement of the two main elements of the project: cost and time.

Cost Variance (CV): It is defined as the difference between the Earned Value and Actual Value of the project. It gives us the information whether the project is under budget, on budget or over budget. It also gives us the net amount by which the company is over budget or under till date.

CV = EV – AC
If CV < 0, project is over budget.
If CV = 0, project is on budget.
If CV > 0, project is under budget.

Schedule Variance (SV): It is the difference between Earned Value and Planned Value of the project. It gives us the information whether the project is ahead of schedule, on schedule or behind the schedule.

SV = EV-PV
If SV < 0, project is behind schedule.
If SV = 0, project is on schedule.
If SV > 0, project is ahead of schedule.

The ideal project will be the one which is under budget and ahead of schedule. In other words, it is the project where CV will be greater than zero and SV will also be greater than zero.

Performance indexes:

Another way to monitor the performance is by using performance indexes.

Cost Performance Index (CPI): It is defined as the ratio of Earned Value to the Actual Cost.

CPI = EV/AC
If CPI < 1, then the project is over budget.
If CPI = 0, the project is on budget.
If CPI > 0, the project is under budget.

Schedule Performance Index (SPI): It is defined as the ratio of the Earned Value to the Planned Value.

SPI = EV/PV
If SPI < 1, project is behind schedule.
If SPI = 1, project is on schedule.
If SPI > 1, project is ahead of schedule.

Performance Indexes are very important because their only function is not only to determine the state of the project. It also tells about the Estimate cost needed to complete the project.

Estimated Cost at Completion (EAC): It is obtained by dividing BAC by CPI. It helps us to forecast the amount required for completion after reaching a particular stage of the project.

$$EAC = BAC/CPI$$

It is important to note that the EAC keeps on changing depending on the measures taken by the construction manager.

Variation at Completion (VAC): It is the difference between BAC and EAC. If the value of VAC is negative, it tells us the additional amount required by the company to complete the project. If the value is positive, it tells us the amount saved by the company when the project is complete.

$$VAC = BAC – EAC$$

Estimate to Complete (ETC): It is the difference between EAC and AC. It is the net additional amount required for the project to complete.

$$ETC = EAC – AC$$

Critical Ratio (CR): This is one tool which combines both schedule as well as the cost parameters of the project.

$$CR = CPI \times SPI$$

It determines the overall performance of the project. If the value is > 1, the project is successful till date.

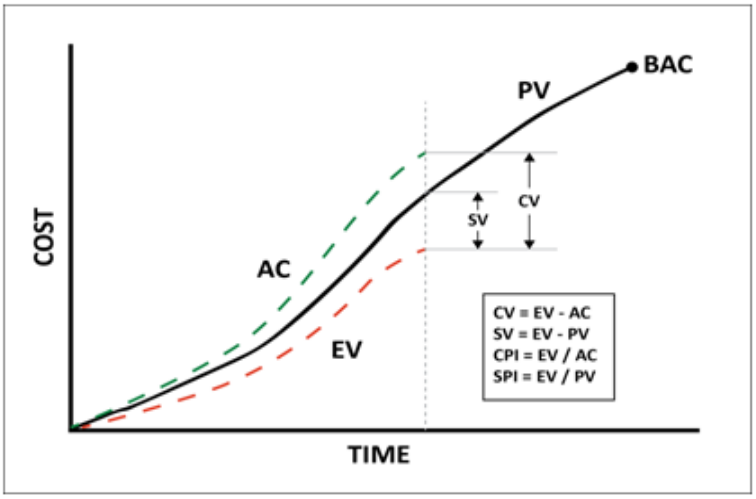

Figure 1. Earned Value Graph.

I. ELEMENTS OF EARNED SCHEDULE MANAGEMENT

Actual Time (AT): It is the duration right from the beginning of the project till the date on which the status of project is needed to be checked.
Schedule at Completion (SAC): It is the initial planned duration for completion of the project.
Earned Schedule (ES): The time span from the beginning of the project to the date when the planned value of the project is equal to the earned value of that date.

$$ES = Month\ (X) + [(\Sigma\ BCWPt – \Sigma\ BCWSx) \div (\Sigma\ BCWSy – \Sigma\ BCWSx)]$$

Where,
x = whole month earned;
y = month following x;
t = Actual Time (Time Now)

Time Variance (TV): when the schedule performance is measured in terms of time units instead of cost units, it is called as time variance

$$TV = ES - AT$$

If TV<0, project is behind schedule
If TV=0, project is on schedule
If TV>0, project is ahead schedule

Time Performance Index (TPI): This is Schedule Performance Index with time factors.

$$TPI = ES / AT$$

If TPI > 1, Project is ahead of schedule
If TPI < 1project is behind the schedule

Time Estimate at Completion (TEAC): The forecasting of time for project completion when the work is being done at the same rate is called TEAC.

$$TEAC = SAC / TPI$$

Time Variance at Completion (TVAC): It points out the estimated amount of time by which the project will be completed ahead or behind the planned schedule.

$$TVAC = SAC - TEAC$$

If TVAC > 0, project will complete ahead of schedule
If TVAC < 0, project will complete behind schedule

II. Advantages of using Earned Value Analysis

1) Enables one to find out about the status of the project based on the result.
2) It tells us about the activity contributing most to the cost overruns.
3) Forewarns the manager and compels him to think about the measures to mitigate the impact of the delay.
4) Gives the owner or the stake-holders information about the additional cash inflow.
5) Forecasts about the money required till the time of completion and the schedule.
6) Identifying risks and risk mitigation measures.

III. Case Study

To understand the earned value concept discussed in this paper more clearly, we have considered to apply this analysis on a construction project. The project has a baseline budget at completion of Rs. 3,52,00,000/- and baseline schedule of 10 months. The analysis is done at the end of 3rd month, 6th month and at the end of scheduled completion of the project.

Activity	Quantity	Rate per unit	Total cost (in lakhs)
Earthwork	5000 cum.	100	5
Concreting	1500 cum.	7000	105
Formwork	12000 sqm.	400	48
Reinforcement Fabrication	200 tonnes	72000	144
Brickwork	700 cum.	5000	35
Plastering	10000 sqm.	150	15

Table 1. Cost Distribution for Activities.

Therefore, total cost of the project = Rs. 3,52,00,000/-

Activity/Month	1	2	3	4	5	6	7	8	9	10
Earthwork	250	750	1000	1250	1250	500				
Concreting		150	300	300	375	225	150			
Formwork		1200	2400	2400	3000	1800	1200			
Reinforcement		20	40	40	50	30	20			
Brickwork			70	105	140	140	140	70	35	
Plastering				1000	1500	2000	2000	2000	1000	500

Table 2. Schedule of Project (Quantity Distribution).

By using EVM method:

Activity	% Scheduled	% performed	PV	EV	AC
Earthwork	0.4	0.5	2	2.5	3
Concreting	0.3	0.2	31.5	21	22
Formwork	0.3	0.3	14.4	14.4	15
Reinforcement	0.3	0.3	43.2	43.2	45
Brickwork	0.15	0.1	3.5	5.3	5
Plastering	0	0	0	0	0
Total	-	-	94.6	86.4	90

Table 3. At the end of 3rd month (all values are in lakhs)

Calculations at the end of 3rd months:

Earned Value analysis.

SV = EV – PV = 86.4 – 94.6 = – 8.2 lakh Rupees
CV = EV – AC = 86.4 – 90 = – 3.6 lakh Rupees
SPI = EV/PV = 86.4/94.6 = 0.91
CPI =EV/AC = 86.4/90 = 0.96
CR = CPI x SPI = 0.96 x 0.91 = 0.87
EAC = BAC/CPI = 352/0.96 = 366.67 lakh Rupees
VAC = EAC – BAC = 366.67 – 352 = 14.67 lakh Rupees

Earned Schedule Analysis.

AT = 3 months
SAC = 10 months
ES = 2 + (86.4 – 20.7) / (94.6 – 20.7) = 2.9 months
TV = ES – AT = 2.9 – 3 = – 0.1 months
TPI = ES / AT = 2.9/3 = 0.97
TEAC = SAC / TPI = 10/0.97 = 10.31 months
TVAC = SAC – TEAC = 10 – 10.31 = – 0.31 months

Activity	% Scheduled	% performed	PV	EV	AC
Earthwork	1	1	5	5	6
Concreting	0.9	0.84	94.5	88	93
Formwork	0.9	0.82	43.2	39.6	41
Reinforcement	0.9	0.86	129.6	123.5	120.5
Brickwork	0.65	0.56	22.8	19.5	22.5
Plastering	0.45	0.33	6.8	5	4
Total	-	-	301.9	280.6	287

Table 4. At the end of 6th month (all values are in lakhs)

Calculations at the end of 6th months:

Earned Value analysis.

SV = EV – PV = 280.6 – 301.9 = – 21.3 lakh Rupees
CV = EV – AC = 280.6 – 287 = – 6.4 lakh Rupees
SPI = EV/PV = 280.6/301.9 = 0.93
CPI =EV/AC = 280.6/287 = 0.98
CR = CPI x SPI = 0.98 x 0.93 = 0.91
EAC = BAC/CPI = 352/0.98 = 359.2 lakh Rupees
VAC = EAC – BAC = 359.2 – 352 = 7.2 lakh Rupees

Earned Schedule Analysis.

AT = 6 months
SAC = 10 months
ES = 5 + (280.6 – 246.75) / (301.9 – 246.75) = 5.6 months
TV = ES – AT = 5.6 – 6 = – 0.4 months
TPI = ES / AT = 5.6/6 = 0.93
TEAC = SAC / TPI = 10/0.93 = 10.75 months
TVAC = SAC – TEAC = 10 – 10.75 = – 0.75 months

Activity	% Scheduled	% performed	PV	EV	AC
Earthwork	1	1	5	5	6
Concreting	1	1	105	105	114
Formwork	1	1	48	48	50
Reinforcement	1	1	144	144	140
Brickwork	1	0.9	35	31.5	32
Plastering	1	0.7	15	10.5	7
Total	-	-	352	344	349

Table 5. At the end of Scheduled Completion- 10th month (all values are in lakhs)

Calculations at the end of 10th months:

Earned Value analysis.

SV = EV – PV = 344 – 352 = – 8 lakh Rupees
CV = EV – AC = 344 – 349 = –5 lakh Rupees
SPI = EV/PV = 344/352 = 0.98
CPI =EV/AC = 344/349 = 0.99
CR = CPI x SPI = 0.98 x 0.99 = 0.97
EAC = BAC/CPI = 352/0.99 = 355.56 lakh Rupees
VAC = EAC – BAC = 355 – 352 = 3 lakh Rupees

Earned Schedule Analysis.

AT = 10 months
SAC = 10 months
ES = 9 + (344 – 347.24) / (352 – 347.24) = 8.31 months
TV = ES – AT = 8.31 – 10 = – 1.69 months
TPI = ES / AT = 8.31/10 = 0.83
TEAC = SAC / TPI = 10/0.83 = 12.04 months
TVAC = SAC – TEAC = 10 – 12.04 = – 2.04 months

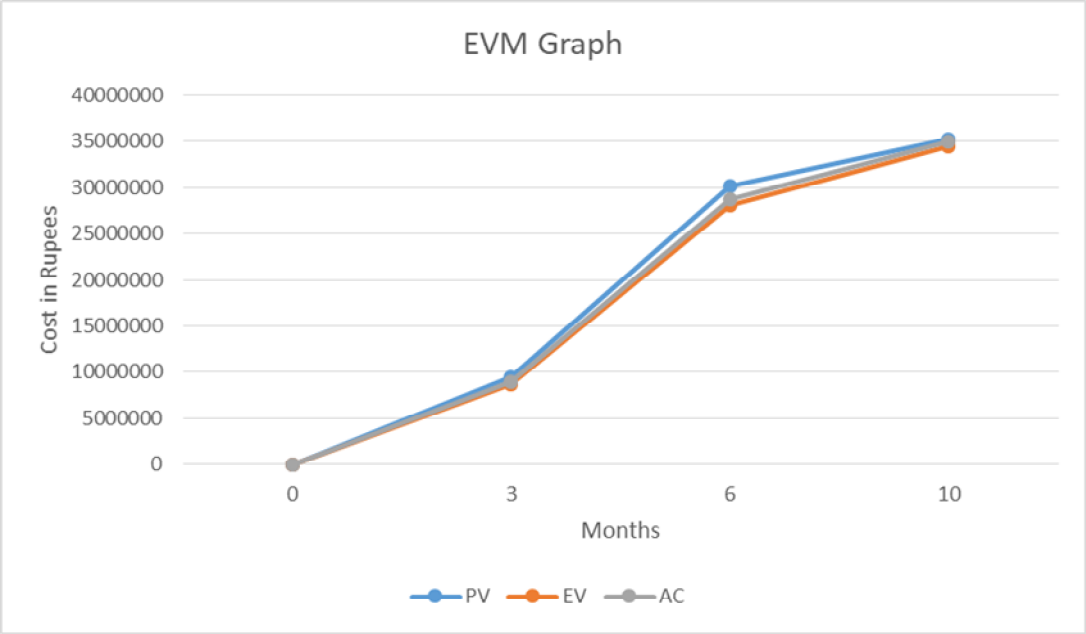

Figure 2. Earned Value Graph

The above graph (Fig. 2.) is cost vs. time, which depicts behaviour of Earned Value, Planned Value and Actual Cost of construction work throughout the project duration.

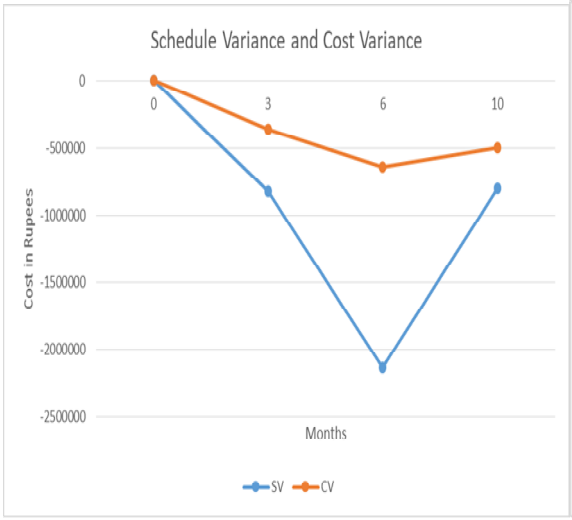

Figure 3. Schedule Variance and Cost Variance

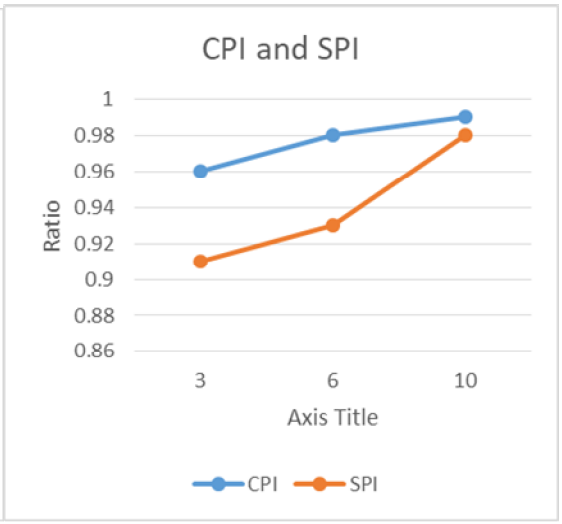

Figure 4. CPI and SPI

The above graph (Fig. 3.) is cost vs. time, which depicts behaviour of Cost Variance and Schedule Variance of construction project throughout its duration. Negative values suggests that more money and more time is required to complete the project. The above graph (Fig. 4.) is ratio vs. time, which depicts behaviour of Cost Performance Index and Schedule Performance Index of construction project throughout its duration. All the values are less than 1 which represents cost overrun and project delay.

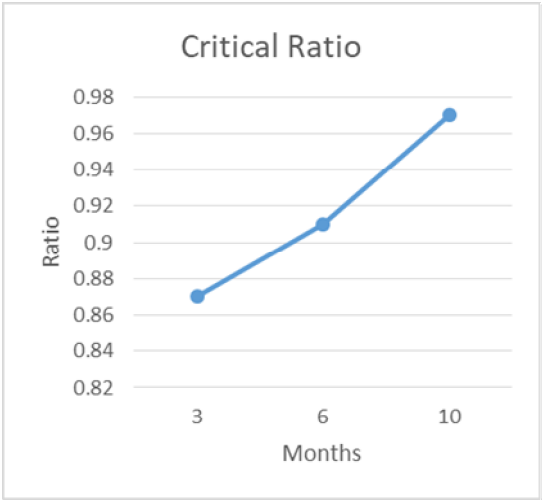

Figure 5. Critical Ratio

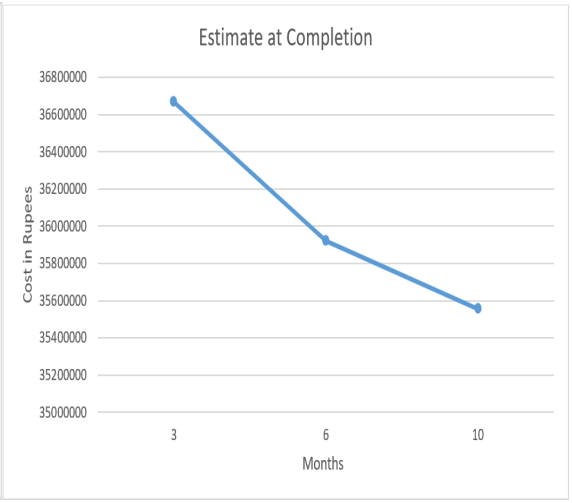

Figure 6. Estimate at Completion

The above graph (Fig. 5.) is ratio vs. time, which depicts behaviour of Critical Ratio of construction project throughout its duration. It combines both schedule as well as the cost parameters. Values below 1 represents cost overrun and project delay. The above graph (Fig. 6.) is a cost vs. time graph for Estimate at Completion. It shows the changing values of cost estimation done at 3rd, 6th and 10th month.

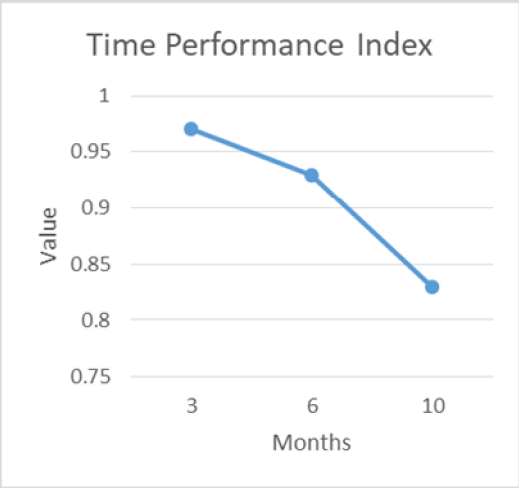

Figure 7. Time Performance Index

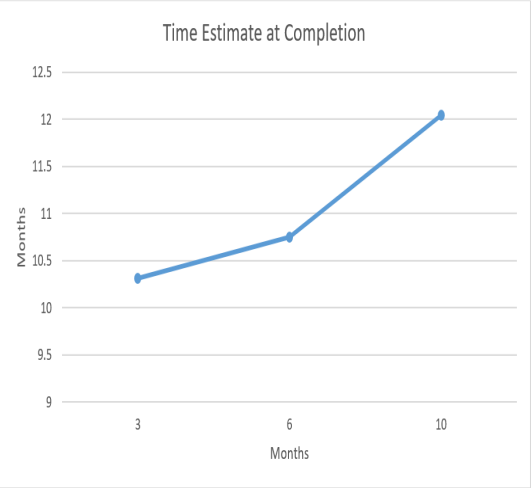

Figure 8. Time Estimate at Completion

The graph (Fig. 7.) is a value vs. time graph for Time Performance Index of construction project throughout its duration. The above graph (Fig. 8.) is a time vs. time graph for Time Estimate at Completion. It shows the changing values of time estimation done at 3rd, 6th and 10th month.

IV. Data Analysis

Cost variance calculated by EVM at the end of 3 months, 6 months and 10 months is -3.6 lakh, -6.4 lakh and -5 lakh Rupees respectively. Negative sign indicates that the project is overrun by cost. Similarly, Schedule Variance calculated at the end of 3 months, 6 months and 10 months respectively is -8.2 lakh, -21.3 lakh and -8 lakh Rupees respectively. Negative sign indicates that the project is behind schedule. Since, the Schedule Variance values are all in terms of money, SV by cost is not the desired indicator for determining the actual delay of project in terms of months. CPI values at the given intervals respectively are 0.96, 0.98 and 0.99. We can see that the values are increasing with the passage of time. Even though the project is over budget at the end of 10th month, but the project manager has taken considerable steps to ensure that the project is not overrun by a huge amount. Critical ratio is one tool which combines both schedule as well as cost indexes. Values of Critical Ratio at the given intervals are 0.87, 0.91 and 0.97 respectively. This indicates that even though there is a delay and cost overrun, the overall performance of the project is increasing mainly because of the steps taken by the construction manager after EVM analysis to ensure that there is no further addition to cost and delay. At the end of the 3rd month, activity contributing most to the increase in cost is concreting which is 4.7% over budget while reinforcement is 4.1% over budget. At the end of 10th month we can clearly see that concreting is still the main reason for increase in cost and is 8.57% over budget. Therefore, we can identify the activity contributing most to the cost overrun and we can take steps to keep the cost of that activity under control. EAC or estimate at completion at the given intervals are 366.7 lakhs, 359.2 lakhs and 355 lakhs respectively. Therefore, at the end of the 10th month project is just 3 lakh rupees over budget and steps would have been taken by the manager to ensure the same. Since, actual delay can't be determined in terms of cost, Earned Schedule Management is an important tool for determining the same. Values of Time Performance Index at the given intervals are 0.97, 0.93 and 0.83 respectively. This indicates that there is a continuous increase in delay throughout the project. At the end of 3rd and 6th month, Time Estimated at Completion is 10.31 and 10.75. But at the end of 10th month, Estimated Time at Completion is 12.04 months which indicates that there will be a delay of 2.04 months. Project is delayed and over budget but the cost overrun is continuously decreasing and delay is continuously increasing according to the analysis by EVM and ESM.

V. Conservative Usage Of These Techniques

1) Implementing EVM and ESM at a particular interval requires collection of all the data from all the activities which is quite laborious. This can be avoided if the progress and cost of each activity is updated daily or even weekly. This can also be done by using a suitable software nowadays which can easily record daily updates regarding all the ongoing activities.

2) When the project is completed, Earned Value is equal to the Planned Value. This indicates that SV is equal to zero and SPI is equal to one. SPI and SV do not give any indication about the project delay whatsoever. Thus, EVM technique is useful mainly during the project. It is a forewarning tool and cannot be used for analysis once the project is completed.

3) Delay of any critical activity leads to delay in the project. While calculating the delay, importance is not given to critical activities and non critical activities are also taken under consideration for recording the progress of the project which can lead to deceptive values of SPI and TPI. One solution to this problem is to avoid non critical activities while calculating delay. Non critical activities can only be considered once they have used up the respective float and have become critical. Cost indicators have no such problem as all the activities are responsible if there is a change in the value of estimated cost at completion (EAC).

4) While EVM is extensively used in developed countries like USA, UK, China, Japan, same cannot be said about all the developing countries. For example, many small construction firms in India are completely unaware of EVM and ESM technique. This is mainly because of a huge gap created by people which does not let them to be updated with major technological developments happening around the world. This can be changed by making EVM mandatory by the government and introducing the detailed study of the same in the curriculum of Civil Engineering Colleges across India. EVM should definitely be used in major government projects as it is more transparent and regular EVM report can be shared with the people to let them know about the progress of major projects happening in their respective cities.

VI. Conclusion

EVM and ESM are important tools which cannot be avoided now when the times have changed and the importance of finishing the project on time and under the given budget is all the more important for all the stake-holders involved. Despite all the above restrictions, EVM is considered one of the most important technique for monitoring the project as it leads to smart management of the construction project. With all the technological developments happening in the construction industry around the world, proper management of the project has become crucial because of the use of time and money to implement these new advancements. Thus, proper implementation of these tools is paramount to ensure maximum profits with minimum delay in a construction project. It is high time that people around the world are made aware of these techniques as correct monitoring of a construction project directly affects its outcome

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