Schedule Forecasting Of Project Using EVM and PERT

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Abstract – *A project is said to be successfully completed if it is completed on or within planned duration and is under budget. The Earned Value Method (EVM) is recognized as a well established method for evaluating and forecasting project cost performance and schedule performance. However, its application to schedule performance forecasting has been limited due to poor accuracy in predicting project durations. Recently, several EVM-based schedule forecasting methods are being introduced but they are still in developing phase and have large prediction errors early in the project. This paper analyzes a mathematical model which can serve as a prediction tool for forecasting the project duration at completion in terms of probability and can act as a monitoring tool for a project manager in addition to Earned Value method.*

***Key Words*: Crashing, Earned value management, PERT, Probability, Standard deviation, Variance.**

1. INTRODUCTION

The project manager has to control the project by continuously monitoring the actual performance, compare its results with the planned performance, analyse the reasons for difference in the performances and then forecast the final outcomes at the completion in terms of cost and time. The purpose of project control is to identify potential future problems in order to take necessary actions in a timely manner. Forecasting of project completion time and cost at completion are the critical elements of the project control process. Earned value management (EVM) is a project control methodology which is widely used method for evaluating, analyzing and forecasting project cost performance and schedule performance. However, the application of schedule forecasting is limited largely due to the approach of EVM towards evaluating schedule performance in terms of unit of value i.e. cost rather than unit of time(lipke 2006)[1]. There are mainly two limitations in EVM based schedule forecasting. 1) The EVM does not provide any information regarding the probability in meeting the project objectives. 2) The forecasting made in EVM are misleading early in the project due to small sample size (Christensen and Heise 1993)[2]. Another limitation of schedule forecasting in EVM is that the schedule variance approaches to zero and the schedule performance index attains unity when the project approaches its completion, whatever may me the status of the project. This paper analyzes the mathematical model which can predict the probability of meeting the project objectives and serve as a monitoring tool with addition to the EVM.

1.1 PERT FOR FINDING PROJECT COMPLETION IN PROBABILITY

The project evaluation and review technique (PERT) is a tool, used in project management, which was designed to analyze and represent the tasks involved in completing a given project. PERT was developed primarily to simplify the planning and scheduling of large and complex projects. It was developed for the U.S. Navy Special Projects Office in 1957 to support the U.S. Navy's Polaris nuclear submarine project. The probability of a project to be completed as per scheduled time can be formulated as follow:

$$Z = \frac{\text{Planned date of completion} - \text{Expected date of completion}}{\text{Project Standard deviation}}$$

$$Z = \frac{T_d - T_e}{\sigma}$$

Here, Z is the number by which the target data lies from the mean or expected duration of project. T_e is expected date of project completion which can be calculated by adding the duration of all activities on the critical path. It can formulate as follow:

$$T_e = \sum_{i=1}^{k} t_i \ , i = 1,2, \ldots\ldots\ldots, k.$$

T_d is planned date of completion of the project and σ is the total project standard deviation which can be found out using the formula as below:

$$\sigma = \sqrt{\text{Project Variance}}$$

$$= \sqrt{\sum \text{Variance of activities on critical path}}$$

$$= \sqrt{\sum_{i=1}^{k} v_i}$$

t_i and v_i can be found out by using the three point estimate approach. In this approach the three time estimate are required for each activity. These are calculated by using the following formulae:

$$t_i = \frac{a+4m+b}{6} \text{ and } v_i = \left[\frac{b-a}{6}\right]^2$$

The time estimates a, m and b are defined as follow:

Optimistic time (a): the minimum possible time required to accomplish a task, assuming everything proceeds better than is normally expected.
Most likely time (m): the best estimate of the time required to accomplish a task, assuming everything proceeds as normal.
Pessimistic time (b): the maximum possible time required to accomplish a task, assuming everything goes wrong.

1.2 PROJECT CRASHING

The project manager has to reduce the scheduled project time in order to compensate the delay occurred in the project and meet the deadline. Project duration can be reduced by assigning more labor to the activities or by adding or replacing the resources. This reduction in the duration of activities is called as crashing. Project crashing is a method for shortening the project duration by reducing the time of one (or more) of the critical project activities to less than its normal activity time. Chao and Yum (1997) investigated the concept of crashing PERT network [3]. There also an example given by Nicholas and Steyn (2008) that the probability that project will finished before the expected duration are 1% to 50% and the probability that the project will be finished after the expected duration are 51% to 99% [4].(M Nazrul, Eugen D and M. Sharif) have analyzed the mathematical model for estimating the project completion duration by crashing the PERT/CPM network [5]. A new method has been also developed for probabilistic forecasting of project duration using kalman filter and earn schedule method (Kim Byung C and Reinschmiet Kenneth F 2010) [6]. In this paper the concept of crashing is applied to the PERT network in order to compensate the delay that have occurred in the project, and thereby also increasing the probability of completing the project on or before planned time by adding the additional funds for the activities on critical path.

2. OBJECTIVE OF THIS STUDY

The objective of this study is to find the probability of completion of project as per planned duration using PERT network and try to improve the probability by reducing the time of critical activities with the help of crashing the activities. It also aims at comparing the two methods of schedule forecasting the EVM and PERT.

3. METHODOLOGY ADOPTED

Scheduling, tracking and probability steps

1] Plan the entire project using PRIMAVERA software.
2] Determine the activities on the critical path.
3] Record the planned duration, total cost and set the baseline for the project.
4] Estimate optimistic time (a), optimistic time (o) and pessimistic time (b) for each activity.
5] Calculate the total expected time of each activity using the following formula

$$t = \frac{a + 4m + b}{6}$$

6] Calculate the variance of all the critical activities by using the following formula

$$v = \left[\frac{b-a}{6}\right]^2$$

7] To calculate the project variance, sum the variance of all activities.
8] To calculate the project standard deviation use the following formula

$$\sigma = \sqrt{\text{Project Variance}}$$

9] The total project completion time (T_d) is equal to the planned duration of the project.
10] The expected project completion time is calculated by adding the expected time of each critical activity in a project.
11] Use the normal distribution formula to find out the probability of completion of project within the planned duration (T_d).
12] Track the project at the periodic interval of 2 weeks as per the daily progress report of the construction site.

13] After 2 weeks, record the status of the project, if delay has occurred crash the critical activities and if delay has not occurred continue further to track the project.

Project Crashing Steps

1] Calculate the crash duration, crash cost, and cost slope for each critical activity at the start of the project.
2] Reduce the activity times of the critical activities in ascending order of the cost slope as per the delay occurred.
3] After crashing the activity continue the scheduling and tracking steps.

4. CASE STUDY

The case study selected for this research is a commercial plus residential project. The project is planned and tracked with the help of primavera software. The project has been tracked as per the daily progress report of the site. The probability for project completion as per planned duration has been calculated for an interval of 2 weeks. The indirect cost is assumed to be 5% of the total project cost which comes around Rs 3000 per day. The indirect cost includes the general overhead cost and project overhead cost. The critical activities running parallel are considered to be acting as a single activity so as to ease in calculating total duration of project. Here two cases are considered as follow:

1] Case I: - Project tracked as per actual duration.

2] Case II: - Project tracked as per actual duration (with crashing of activities)

Comparison is then done between case I and case II with respect to the probability, Total cost, EVM metrics, total duration etc. Then from these results we can conclude which method provides the better results and accuracy in schedule forecasting of project.

In Table 1 we can see that the planned duration of the project was 164 days but actually the project was completed in 189 days, a total delay of 25 days. In comparison to the case I the case II has performed well which can be seen in Table 2. Till week no 20 the project has progressed as per planned duration, but in the remaining weeks the project was delayed by 4 days mainly due to non availability of activity to be crashed. The total planned cost of the project was Rs. 9395689.3. But from Table 1 and Table 2, it can be seen that the project had cost overruns in both the cases. But, compared to case I the total cost of project for case II is less though crashing have been applied for case II. Though cost overruns have occurred in both the cases, the case II would have saved Rs 91800 in the project.

Table -1: Summary of case I

Week No.	Total Planned Duration of project	Total Estimated Project Duration at completion	Total Expected Project Duration at Completion	Total standard deviation of project	Z Factor	Probability of completion at due date	Direct Cost	Indirect Cost	Total Project Cost	Cost Performance Index	Schedule Performance Index
	(T)		(Te)	σ	(z)	(%)	(RS)	(RS)	(RS)	(CPI)	(SPI)
0	164	164	168.33	3.91	-1.11	13.35	8903689.3	492000	9395689.3	1.00	1.00
2	164	166	169.67	3.91	-1.45	7.35	8903689.3	498000	9401689.3	1.00	1.00
4	164	167	170.33	3.91	-1.61	5.26	8905489.3	501000	9406489.3	0.94	0.92
6	164	169	171.61	3.91	-1.96	2.5	8906689.3	507000	9413689.3	0.98	0.27
8	164	171	173	3.91	-2.3	1.07	8918489.3	513000	9431489.3	0.99	0.82
10	164	173	175.67	3.91	-2.98	0.14	8947789.3	519000	9466789.3	0.99	0.80
12	164	176	175.67	3.91	-2.98	0.14	8954989.3	528000	9482989.3	0.98	0.70
14	164	177	176.33	3.91	-3.15	0.01	8962189.3	531000	9493189.3	0.99	0.81
16	164	177	176.33	3.91	-3.15	0.01	8962189.3	531000	9493189.3	0.99	0.86
18	164	177	177.67	3.91	-3.5	0.01	8962189.3	531000	9493189.3	0.99	0.86
20	164	179	179	3.91	-3.84	0.01	8982589.3	537000	9519589.3	0.99	0.86
22	164	181	179	3.91	-3.84	0.01	9010189.3	543000	9553189.3	0.99	0.86
24	164	181	180.33	3.91	-4.18	0.01	9010189.3	543000	9553189.3	0.99	0.89
26	164	181	183	3.91	-4.86	0.01	9010189.3	543000	9553189.3	0.99	0.93
28	164	189	189	3.91	-5.37	0.01	9044589.3	567000	9611589.3	0.98	1.00

Table -2: Summary of case II

Week No.	Total Planned Duration of project	Total Estimated Project Duration at completion	Total Expected Project Duration at Completion	Total standard deviation of project	Z Factor	Probability of completion at due date	Activity Crashed	Direct Cost	Indirect Cost	Total Project Cost	Cost Performance Index	Schedule Performance Index
	(T)		(Te)	σ	(z)	(%)	(Days)	(RS)	(RS)	(RS)	(CPI)	(SPI)
0	164	164	168.33	3.91	-1.11	13.35	-	8903689.30	492000	9395689.3	1.00	1.00
2	164	164	168	3.87	-1.07	14.92	A2190 and A2200 by 2 Days	8905589.30	492000	9397589.3	1.00	1.00
4	164	164	167.8	3.85	-0.99	16.11	A2220 and A2250 by 1 Day	8908489.30	492000	9400489.3	0.94	0.92
6	164	164	167.5	3.8	-0.92	17.88	A2140 and A2170 by 2 Days	8911289.30	492000	9403289.3	0.98	0.37
8	164	164	167.33	3.78	-0.88	18.94	A1540 and A1570 by 1 Day	8921389.30	492000	9413389.3	0.99	0.82
10	164	164	167	3.47	-0.80	21.19	A1540 and A1570 by 1 Day and A2470 and A2500 by 1 day	8947289.30	492000	9439289.3	0.98	0.80
12	164	164	166.5	3.67	-0.68	24.83	A2350 and A2380 by 2 Days and A2470 and A2500 by 1 day	8951789.30	492000	9443789.3	0.99	0.70
14	164	164	166.5	3.67	-0.68	24.83	No Delay	8954389.30	492000	9446389.3	0.99	0.84
16	164	164	166.33	3.65	-0.64	26.11	A1780 and A1810 by 1 Day	8971689.30	492000	9463689.3	0.99	0.87
18	164	164	166.17	3.62	-0.60	27.43	A1780 and A1810 by 1 Day	8979989.30	492000	9471989.3	0.99	0.87
20	164	164	166.17	3.62	-0.60	27.43	No Delay	8980789.30	492000	9472789.3	0.99	0.92
22	164	165	166.67	3.62	-0.74	22.96	A2070 and A2080 by 1 Day	8983489.30	495000	9478489.3	0.99	0.90
24	164	165	166.67	3.62	-0.74	22.96	No Crashing Available	9008989.30	495000	9503989.3	0.99	0.93
26	164	165	166.67	3.62	-0.74	22.96	No Crashing Available	9011089.30	495000	9506089.3	0.99	0.96
28	164	168	168.67	3.6	-1.30	9.46	No Crashing Available	9015789.30	504000	9519789.3	0.99	1.00

From chart 1, we can see that in both the cases the probability of project completion as per planned duration was 13.35%. In case I due to delay caused in the project the probability started to decreased from the week 2 itself and dropped below 1% at week 14. It shows that the project manager had no control on the project from the starting itself. In such case where the project is behind the schedule, the probability helps the project manager to make an evaluation regarding the significance of the gap between the planned schedule and the actual performance. These results can be seen in case II. For case II, the critical activities were crashed as per the delay occurred in the project. The probability showed a steady rise as the project progressed. The probability increased from 13.35% to 27.43% from start of project to week 20. As discussed earlier that no activity was available for crashing the project got delayed by 4 days in case II and its effect was seen on probability. After week 20 the probability reduced to 22.96% and remained steady for 6 weeks and eventually ended at 9.68 % at the end of project.

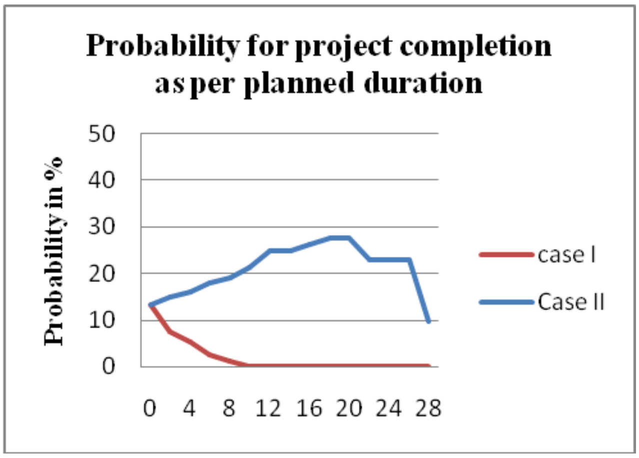

Chart -1: Probability graph for case I and case II

From table 1 and table 2, it can be seen that the SPI and CPI indices have performed slightly better in case II than in case I. But the reliability of these indices is the bigger problem for the project manager. In case I the SPI index dropped from 0.94 to 0.27 and again rose to 0.82 in the interval of 4 weeks. Same situation has been observed in case II though in case II the probability of project completion as per planned duration have increased in that period. Earlier, we discussed about the limitation of SPI index at the project completion stage which can be seen here. In both the cases, at the project completion the SPI attained unity though in case I the project was delayed by 25 days and in case II by 4 days. So, in such cases the probability of project completion at planned duration can really help the project managers to take correct decisions regarding the project performance and control.

5. CASE STUDY

This paper analyzes a mathematical forecasting tool for project managers to enhance their capabilities of project schedule risk so that proper decisions are taken well in advance. The main feature of probabilistic forecasting using PERT with respect to EVM based forecasting method is that it provides probabilistic prediction of project duration at completion which can be used from the beginning with better accuracy than the EVM method. The forecasting tool was applied to residential cum commercial project. From the two cases we can conclude that PERT probabilistic forecasting provided better results than the EVM forecast methods. In case II the crashing of critical activities as per delay occurred showed a much better probability of completing the project on time rather than in case I. It means, in case of delay by adding extra cost to the project, we can reduced the expected time of completion and increase the probability of completion of project on time. By using this tool, the project manager will able to answer basic question regarding forecasting of project to the top management, project stakeholders and customers such as (1) What is the probability of completing the project as per planned schedule? (2) What is expected project completion duration at different stages of project? (3) What is the overall performance of the project? There are also several issues which need to be investigated further. The main limitation of this tool is that it is applicable only to forecasting of project duration at completion and not to forecasting of project total cost at completion.

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