THE USE OF EARNED VALUE IN FORCASTING PROJECT DURATIONS

Osama Moselhi*

Department of Building, Civil and Environmental Engineering, Concordia University, Montreal, Canada
** Corresponding author (moselhi@encs.concordia.ca)*

ABSTRACT: This paper highlights the limitations of the current applications of EVM method in forecasting project durations and introduces a novel concept, embedded in an integrated method, in lieu of those currently in use. The proposed method is designed to improve the accuracy of forecasting, and can be used as an add-on utility to existing software systems that perform forecasting using the earned value method. The proposed method is based on a new formulation for the schedule performance index, which takes into consideration the concurrent nature of project activities in schedules and the manner used to generate cumulative progress. The main concepts behind the developed method are the use of "critical project baseline" and the use the status of critical activities only. A numerical example is presented to highlight the limitations of current forecasting methods and demonstrate the use of the proposed method and to illustrate its improvement of forecasting accuracy over current methods.

***Keywords**: Earned Value, Forecasting, Project Duration, Critical Project Baseline*

1. INTRODUCTION

Since the introduction of earned value management (EVM) back in 1976 by the United States Department of Defense [3], the use and applications of this method in management of engineering, procurement and construction projects has been the subject of numerous publications, most notably those produced by the U.S.A. Department of Energy [4], and National Aeronautics and Space Agency [10]. Despite this sizable body of literature [1 to12], including that dedicated to forecasting [2, 6, 7, 11 and 12], the current use of EVM in forecasting project duration is inadequate and calls for further improvements. While using the current practice and methods in forecasting project cost at completion, as early as 15% completion of project scope of work, was reported to be reasonably accurate of EVM, this is not the case in forecasting project durations. This paper highlights the limitations of the current application of EVM method in forecasting project durations and introduces a novel concepts and an integrated method in lieu of those currently used. The proposed method is designed to improve the accuracy of forecasting, and can be used as an add-on utility to existing software systems that perform forecasting using the earned value method. The proposed procedure is based on a new formulation for the schedule performance index, which takes into consideration the concurrent nature of project activities in schedules and the manner used to generate cumulative progress. A numerical example is presented to demonstrate the use of the proposed method and to illustrate its improved forecasting accuracy over current methods.

.

2. LIMITATIONS OF EVM IN FORCASTING

EVM is designed to provide integrated time and cost reporting on the status of projects at the end each reporting period and in forecasting the project status at completion using a set of cost and schedule variances (CV and SV) and indices (CPI and SPI). This is carried out making use of 1) the project baseline (see Figure 1) or budgeted cost of work scheduled (BCWS), actual cost of work performed (ACWP) and budgeted cost of work performed (BCWP) and 2) the following equations:

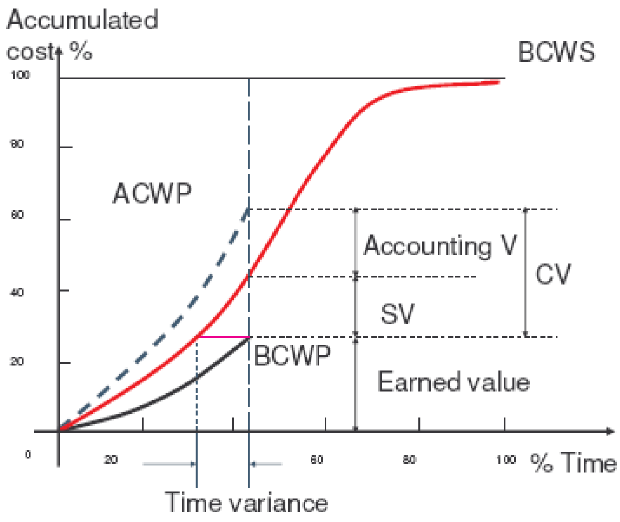

Figure 1: EVM Parameters

CV = ACWP – BCWP ……………………………... (1)

SV = BCWP - BCWS……………………….……... (2)

CPI = BCWP/ACWP………………..………………... (3)

SPI = BCWP/BCWS…………………..…..………... (4)

While CV and CPI (Equations 1 and 3) represent reasonably the cost status of a project, SV and SPI do not equally represent its schedule status. Consider, for example, a scenario where at the end of a reporting period it was found that a number of critical activates are experiencing considerable delays while non critical activities are way ahead of planned progress such that the resulting SPI is equal to1.0. Clearly such SPI erroneously indicates that the project is on target schedule without any delay while in actuality the project is behind schedule. In other words, Equation 4 can mask the actual schedule performance as the inclusion of noncritical activities could distort and misrepresent the status of the project schedule.

In addition, while the above variances and indices provide time and cost status reporting at the end of each reporting period, forecasting the project status at completion in current methods are based either on:

a) assuming the performance attained so far will continue in the future all the way to project completion, or
b) assuming that the project performance will be as planned in the future all the way to project completion

Accordingly, the forecasted project duration (Df) is calculated respectively, based on its planned original duration (Do) by:

Df = Do/SPI ....(5)

or

Df = Do + SVt ………………….…………………….(6)

Others may ignore the application of EVM in such forecasting and resort to updating/revising the project schedule, focusing primarily on the remaining work to completion. This, however, is costly and time consuming in comparison to the direct application of EVM.

.

3. PROPSED METHOD

The proposed method considers:

(1) Critical activities to generate C-BCWS (critical project baseline) and C-BCWP (earned value of critical activities) to generate more realistic schedule variance (R-SV) and schedule performance index (R-SPI) as follows:

R-SV = C-BCWP – C-WCWS ……….……………….. (7)

R-SPI = C-BCWP/ C-BCWS ……..……………………(8)

The time variance in units of time (SVt) is calculated as depicted diagrammatically in Figure 1.

(2) The impact of performance unrepresentative periods, which experienced unexpected weather conditions or accidents, by either revising the performance or by dropping such periods when generating the cumulative performance.

(3) Incremental adaptive learning by forecasting C-BCWP at the end of each remaining periods and comparing it with actual when reaching that time. As such, adjustment factors (AFs) at the end of each reporting period are generated:

AF = R-SPI actual/ R-SPI forecasted ……………..… (9)

The AF is then used to calculate adjusted R-SPI (A-R-SPI) as:

A-R-SPI = AF * R-SPI .... (10)

The forecasted project duration (Df) is then calculated as:

Df = Do / (A-R-SPI) .... (11)

or

Df = Do + SVt ……………..…………………… .. (12)

or

Df = De + SVt + (Do- De) / (A-R-SPI)......................... (13)

In which De is the elapsed duration

4. NUMERICAL EXAMPLE

The PDM network of this project example is shown in Figure 1. The project has duration of 8 month and the latest progress period is at half way of its planned original duration. This example is used here to highlight the limitations of current methods, to demonstrate the use of the proposed method and to illustrate its improvement in the accuracy of forecasting project duration at completion. The data used in the analysis is included in Table 1.

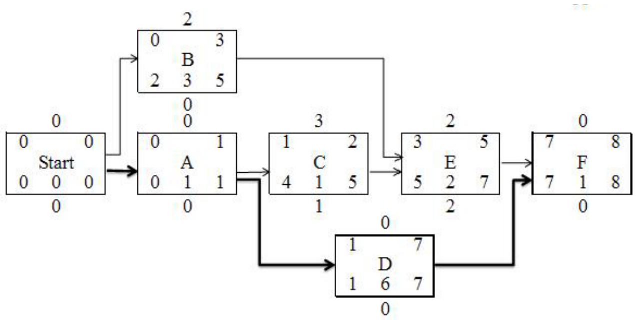

Fig.1 PDM Diagram

Table 1 Activities durations and direct cost

Activity	Duration	ES	EF	LS	LF	TF	Total Direct Cost	Direct Cost / Month
A	1	0	1	0	1	0	$1,000	$1,000
B	3	0	3	2	5	2	$12,000	$4,000
C	1	1	2	4	5	3	$4,000	$4,000
D	6	1	7	1	7	0	$6,000	$1,000
E	2	3	5	5	7	2	$16,000	$8,000
F	1	7	8	7	8	0	$1,000	$1,000

The project baseline under three different scenarios was generated as shown in Table 2 and in Figure 2. The cumulative progress at the end of month 4 was calculated as shown in Table 3.

Table 2: Project baseline (BCWS)

	Early start		Late start		Critical Activities	
Time (month)	Period	BCWS (ES)*	Period	BCWS (LS)*	Period	BCWS (Cri.)*
1	5	5	1	1	1	1
2	11	16	3	4	3	4
3	7	23	7	11	3	7
4	11	34	7	18	3	1
5	11	45	11	29	3	13
6	3	48	11	4	3	16
7	3	51	11	51	3	19
8	1	52	1	52	1	20

*Cost is in thousands of dollars

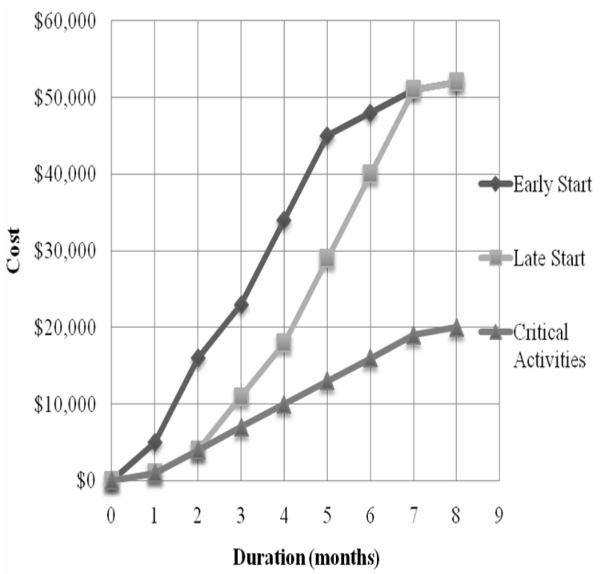

Fig. 2 Project baseline (BCWS)

The earned value analyses were performed using current methods, i.e. Equations 1 to 6, and the proposed method as described in Section 3 above. Three scenarios were considered; 1) current EVM methods based on early start schedule, 2) as in 1) but based on late start schedule and 3) using only critical activities. The analysis was carried to determine project schedule status at the end of month 4 and to forecast the project duration at completion as follows:

Scenario-1: Based on early start

Schedule Variance (SV) = BCWP − BCWS= -$6,000.0

Schedule Performance Index (SPI) = BCWP / BCWS = 0.82352

Original Duration Do = 8 month

Forecasted Project Duration-I = Do/SPI = 9.7142 month

Schedule Variance (SVt) = 0.55 month

Forecasted Project Duration-II = Do + SVt = 8.55 month

Senario-2: Based on late start

Schedule Variance (SV) = BCWP − BCWS= $10,000.0

Schedule Performance Index (SPI) = BCWP / BCWS = 1.5556

Original Duration Do = 8 month

Forecasted Project Duration-I = Do / SPI = 5.1428month

Schedule Variance (SVt) = -0.9 month

Forecasted Project Duration-II = Do + SVt = 7.1 month

Table 3 Earned value analysis

Activity	% Complete	BCWS(ES)*	BCWS(LS)*	BCWS (Cri.)*	BCWP*	BCWP (cri.)*	ACWP*
A**	100%	1	1	1	1	1	1.1
B	100%	1.2	8		12		11
C	100%	4	0		4		3.5
D**	30%	9	9	9	5.4	5.4	6.5
E	35%	8	0		5.6		8
F**	0%	0	0	0	0	0	0
Total		34	18	10	28	6.4	30.1

*Cost in thousands of dollars, **Critical activities

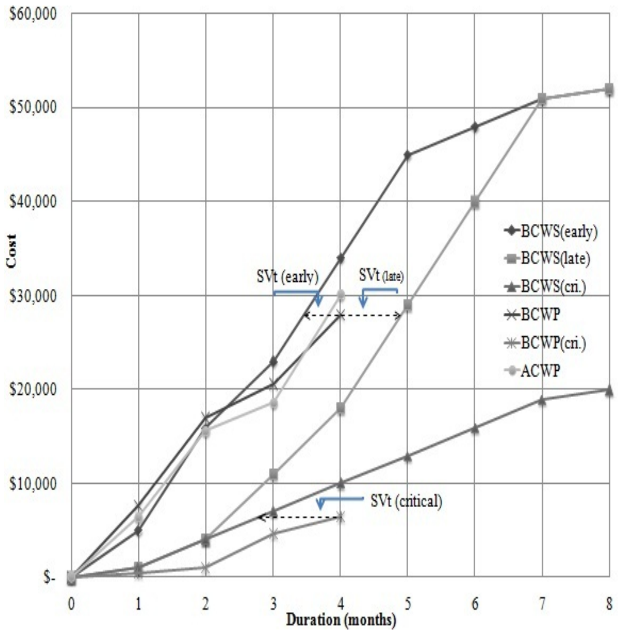

Fig.3 Earned value analysis at the end of month 4

Scenario-3: Based on critical activities only

The proposed method is applied in this scenario (i.e. Equations 7 to 13). For simplicity it is assumed that no unusual incidents have impacted the performance in the 4 periods and therefore AF is set equals to 1.0.

R-SV = C-BCWP − C-BCWS= -$3,600.0

R-SPI = C-BCWP / C-BCWS = 0.64

A-R-SPI = 0.64 x 1.0 = 0.64

Original Duration Do = 8 month

Forecasted Project Duration-I = Do / (A-R-SPI) = 12.5 month

Schedule Variance (SVt) = 1.25 month

Forecasted Project Duration-II = Do + SVt = 9.25 month

Elapsed Duration De = 4 month

Forecasted Project Duration-III = De + SVt + (Do- De)/ (A-R-SPI) = 11.50 month

5. DISCUSSION OF RESULTS

The results obtained in the numerical example exhibit considerable differences (see Table 4) and clearly demonstrate the limitations of current methods used in the application of EVM for reporting the status of project schedules and for forecasting their duration at completion.

Table 4 Forecasted project durations (month)

Duration	Scenario 1	Scenario 2	Average 1&2	Scenario 3
I	9.71	5.14	7.42	12.50
II	8.55	7.10	7.82	9.25
III	---	---		11.50

Clearly the differences between scenarios 1 and 2 may not be encountered in practice as the schedule will be that approved by the owner and/or its agent and it commonly leans toward early start schedule. It is included in this example to demonstrate its impact on earned value analysis. It is important here to compare scenario 1, or the average of scenarios 1 and 2, to scenario 3. We see in this example how current methods (used in scenarios 1 and 2) underestimate the forecasted project duration at completion.

6. SUMMARY AND CONCLUDING REMARKS

The use the two the widely used two methods, described above in Section 2, for forecasting may produce to inaccurate results, which leads to unrealistic forecasting of the project status at completion. This is of considerable importance, particularly in forecasting project durations. In this case it is recommended to use only critical activities in generating project baseline and subsequently in generating schedule variances and indices as outlined in the proposed method. The results obtained from the numerical example demonstrate how erroneous forecasting project duration can be when applying the current EVM methods.

ACKNOWLEDGMENTS

The author would like to thanks Mr. Ali Montaser for his assistance in generating the results of the numerical example and the preparation of its related tables and figures.

REFERENCES

[1] Alshibani, A., *"A computerized cost and schedule control system for construction projects"*, Master's thesis, Civil, Building, and Environmental Engineering, Concordia University, Montreal, Canada, 1999.

[2] Christensen, D.S, Antolini, R.C. and Mckinney, J.W., "A review of EAC Research", *Journal of Cost Analysis and Management*, Spring Issue, pp. 41-62, 1995.

[3] Department of Defense, 1967. Performance Measurement for Selected Acquisitions, DODI 7000.2.

[4] Department of Energy, 1980. Cost/Schedule Control Systems Criteria for Contract Performance Measurement: Implementation Guide, DOE/CR-0015, Office of the Controller.

[5] Fleming, Q. W. and Koppelman, J.M., *Earned Value Project Management*, *3rd Ed.*, Newton Square, Pa., USA: Project Management Institute, 2005.

[6] Hassanein A., and Moselhi O., "Tracking and Control of Linear Infrastructure Projects", *5th Construction Specialty Conference of the Canadian Society for Civil Engineering*, Moncton, Nouveau-Brunswick, Canada, 2003.

[7] Ji, Li. *"Web-based integrated project control"*, PhD's thesis, Civil, Building, and Environmental Engineering, Concordia University, Montreal, Canada, 2004.

[8] Moselhi, O.,. Applied Earned Value for Project Control, proc. of the CIB W-65 7th International Symposium on Organization and Management of Construction, Port of Spain, Trinidad. 1993

[9] Moselhi, O., Ji,li, and Alkass, Sabah,"Web-based integrated project control System." *Construction Management and Economics*. Vol. 1, pp. 35-46, 2004.

[10] NASA, "Integrated Baseline Review (IBR) Handbook, SP-2010-3406.

[11] Paul Teicholz, "Forecasting final cost and budget of construction projects", *Journal of Computing in Civil Engineering*, Vol. 7, No. 4, October, 1993.

[12] Xiao hui, Xiao, *"Trending and forecasting in construction operations"*, Master's thesis, Civil, Building, and Environmental Engineering, Concordia University, Montreal, Canada. 2009.