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Project Duration Forecasting Using Earned Value Method and Time Series

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Abstract*— Earned Value Method is recognized as one of the reliable method in project monitoring and controlling. EVM has been used over the period of four decades all over the globe. Many researchers have proved that application of EVM gives good results to project cost forecasting. However its application to duration forecasting has been limited due to lack of accuracy. This paper illustrates how project managers could use time series as an effective tool for project duration forecasting. Time series is a forecasting method used in statistics, signal processing, econometrics and mathematical finance. Time series forecasting is the use of a model to forecast future events based on known past events to predict data points before they are measured. Use of time series as a forecasting tool in construction industry is limited. Methodologies are demonstrated in this paper using an example case. All possible cases with respect to project duration have been considered for comparison between EVM and time series.

Index Terms— **Duration forecasting, EVM, Project management, Time Series.**

I. INTRODUCTION

Construction sector is the second largest employment driver in India next to agriculture. Its contribution is more than 5% of nation's GDP. Total capital expenditure was 802087 crore in 2011-12 which is nearly 8 times than that in 1999-2000 [3]. A typical project control process consists of monitoring actual performance, comparing it with planned performance, analyzing the difference, and forecasting the final outcome of the project at completion. The purpose of project control is to identify potential future problems in order to take necessary actions in a timely manner. If the project or task is deemed not in control, the project manager needs to identify the causes of variance and take necessary actions to get the project back under control and within acceptable performance limits. [6] Earned Value method (EVM) and Time Series method are used for forecasting the project duration. Results obtained can be compared with actual project data to find out suitability of the above two methods.

II. EARNED VALUE MANAGEMENT

EVM began in 1960s, in US department of Defense sponsored format known as C/SCSC (Cost Schedule Control System Criteria) for forecasting large scale projects.EVM is a management technique that relates resource planning and usage to schedules and to technical performance requirement. More specifically, EVM can be said to bring cost and schedule variance analysis together to provide managers with more accurate status of project. [1], [2], [6].

Abbreviations and Formulae Used In EVM

1. BCWS - Budgeted Cost of Work Scheduled
2. BCWP - Budgeted Cost of Work Performed
3. ACWP- Actual Cost of Work Performed
4. BAC – Budget At Completion
5. CV- Cost Variance
6. CV = CPI – Cost Performance Index

$$CPI = \frac{BCWP}{ACWP}$$

ACWP –BCWP

$$CV\ \% = \frac{CV}{BCWP} \times 100\ \%$$

7. SV- Schedule Variance

SV = BCWP - BCWS

$$SV\ \% = \frac{SV}{BCWS} \times 100\ \%$$

8. SPI – Schedule Performance Index
9. EAC – Estimate At Completion

$$EAC = \frac{BAC}{CPI}$$

10. ETC - Estimate to Complete

ETC =BAC -EV

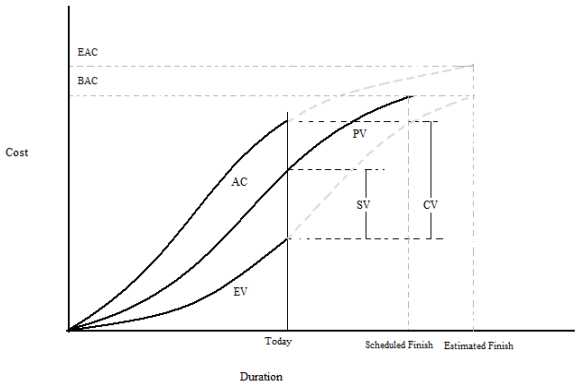

Fig.1. Graph of Earned Value Management

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III. TIME SERIES AND FORECASTING

A time series is a sequence of data points, measured typically at successive times, spaced at uniform time intervals. Time series forecasting is the use of a model to forecast future events based on known past events to predict data points. Time series data have a natural temporal ordering. This makes time series analysis distinct from other common data analysis problems, in which there is no natural ordering of the observations [5].

A. Variation in Time Series

1. *Secular Trend*

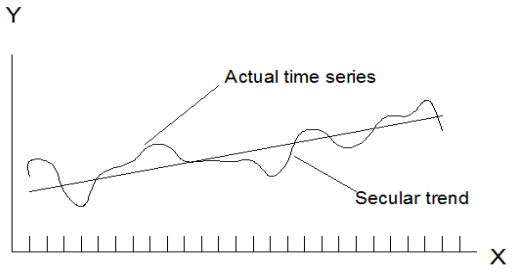

Fig. 2. Secular Trend

2. *Cyclical Fluctuation*

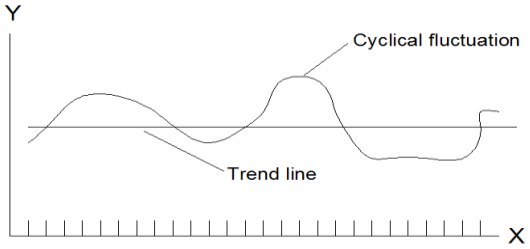

Fig. 3. Cyclical Fluctuation

3. *Seasonal Fluctuation*

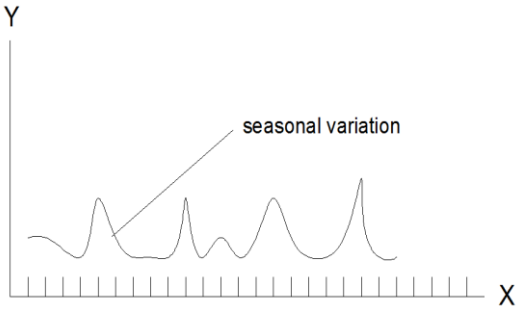

Fig. 4. Seasonal Fluctuation

4. *Irregular Variation*

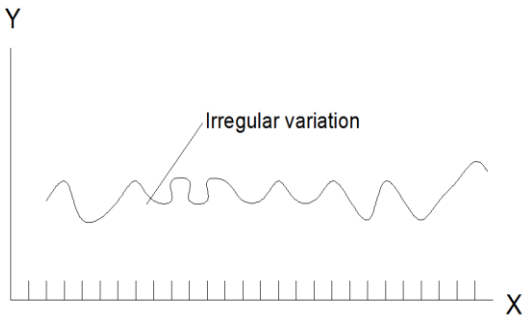

Fig. 5. Irregular Variation

IV. CASE STUDY

Example case is considered for the implementation of EVM and Time Series for the prediction of duration. Three possible cases are considered for forecasting,

i) Schedule behind the planned value,
ii) Schedule as per planned value and
iii) Schedule ahead of planned value.

Forecasting is done after first milestone in each Case. Table 1 & 2 are shown in Appendix.

Case I) When Tasks Are Running Behind the Planned Values

1. Forecasting Using Earned Value Method

CV = BCWP – ACWP = 10000
CPI = 1.041 >1
Task is running slightly Under Budget SV = EV – PV = -69602
SPI = 0.7822 <1
Task is running behind the Schedule. Prediction:
Estimate to Complete (ETC)
ETC = BAC – EV
= Rs. 69602 for first milestone
= Rs. 1421835 for complete project.
Time at Completion (TAC):
= 7 /0.7822 milestones
= 135days

2. Forecasting Using Time Series:

Considering duration vs. cost graph, from duration 0 to 45 days resulting curve is second degree parabola, from 45 days to 60 days curve is of straight line and 60 days Formulation of equations for different curve Patterns onwards pattern is different. During forecasting using Time Series we assume that, future work follow the planned pattern.

Table 3. From 0 to 45 days

Y	X	$x-\bar{x}=$ X	2x X	X^2	X^4	Xy	X^2y
0	0	-7.5	-15	225	50625	0	0
135000	7.5	0	0	0	0	0	0
250000	15	7.5	15	225	50625	3750000	56250000
∑y=385000				$\sum X^2$= 450	$\sum X^4$= 101250	∑Xy =3750000	$\sum X^2y$ =562500000

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$\sum y = an + c\sum X^2$
$\sum X^2 y = a\sum X^2 + c \sum X^4$
a = 135000
c = - 44.44
$b = \frac{\sum Xy}{\sum x^2}$
b = 8333.33
$y = a + bX + cX^2$
Put X = 75 for finding expenditure at 45 days,
Cost at 45 day = Rs. 510025

2. From 45 to 60 days, we assume expenditure varies linearly, with same slope as planned
y = mx + c
m = 38489, slope of planned cash flow.
c = 510025, cost at 45 days
Putting x = 15, to find expenditure at 60 days y = 1087360

Table 4. From day 60 onward, curve follows different Pattern

Y	x	$X = x - \bar{x}$	X^2	X^4	Xy	X^2y
1100000	65	-5	25	625	-5500000	27500000
1115000	70	0	0	0	0	0
1133000	75	5	25	625	5665000	28325000
$\sum y$ =3348000			$\sum X^2$ = 50	$\sum X^4$=1250	$\sum$ Xy=16500	$\sum X^2y$=5825000

$y = 1115000 + 3300 X + 60 X^2$
Expenditure of the project on 105 day
Put X = 35, we get y = 1304000

To find out duration for the completion of the project,
Put y = 1671835, we get X, convert X to x, original duration.
X = 72.68
$x = X + \bar{x}$ = 72.68 + 70 = 143 days

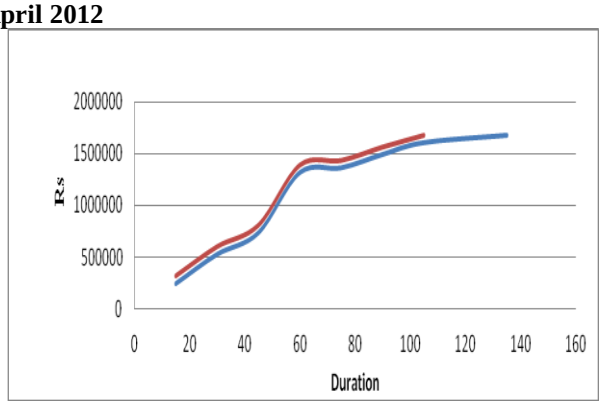

Fig.6. Graph Showing Behavior of Expenditure Curve

Upper curve indicates planned value of the project duration, and lower curve indicates forecasted project duration using Time Series.

Table 5. Comparison between forecasted duration using EVM, Time Series

Method of Forecasting	Forecasted Duration
EVM	135 days
Time Series	143 days

Case II) Tasks Are Running As Per Planned Value: **Table 6 is shown in Appendix.**

1. Forecasting Using Earned Value Method
CV = 4602, CPI = 1.0>1 task is running slightly under budget.
SV = 0
SPI = 1
Task is running as per the schedule.
Prediction: ETC = Rs. 1352233 for whole project
Time at Completion (TAC) = 105 Days

2. Forecasting Using Time Series
A. From 0 to 45 days (Table 7 is shown in Appendix)
B. From 45 to 60 days
y = 38489 x + 807975
y = 1385310 (Expenditure at 60 day)

C. From day 60 onwards(Table 8 is shown in Appendix)
$y = 1412500 + 3088.5 X + 97.7 X^2$ Put y = 1671835, X=38.08
$x = X + \bar{x}$ = 38.08 + 70 x= 108.08 days

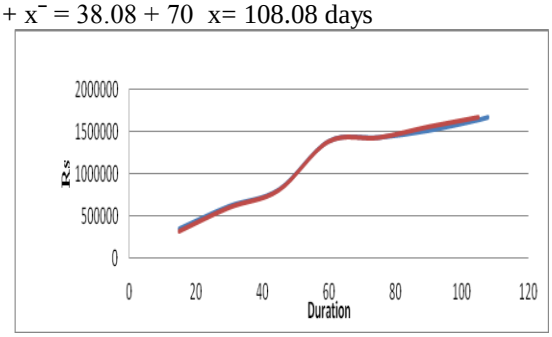

Fig. 7 Graph showing behavior of expenditure curve

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Table 9.Comparison between forecasted duration using EVM, Time Series

Method of Forecasting	Forecasted Duration
EVM	105 days
Time Series	108 days

***Case III) Task Is Running Ahead of Planned Value (*Table 10 is shown in Appendix)**

1. Forecasting Using Earned Value Method

CV = 5000, CPI = 1.01>1 Task is running slightly under budget. SV = 20398

SPI = 1.06 >1 Task is running ahead of schedule.

Prediction: Estimate To Complete, ETC = Rs. 1331835 for whole project.

Time at Completion (TAC): = 7/1.06 = 6.603milestones = 100 days

2. Forecasting Using Time Series

A. From 0 to 45 days (Table 11 is shown in Appendix)

$y = 177500 + 11333.33\ x - 33.33\ x^2$

Cost at 45 day = Rs.840019

B. From 45 to 60 days

y = 38489 x + 840019 Putting x = 15,

y = 38489 (15) +840019 = 1417354(expenditure at 60 days)

C. *From day 60 onwards*(Table 12 is shown in Appendix)

$y = 1444995 + 3500.5\ X + 100.1\ X^2$

For finding project duration, put y = 1671835

We get, X = 33.22, x = X + 70 = 103 days

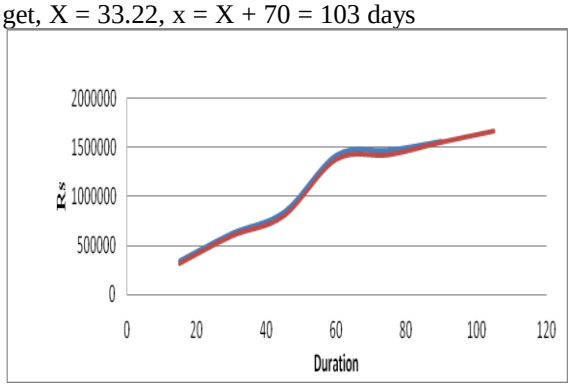

Fig. 8 Graph showing behavior of expenditure curve.

Table 13. Comparison between forecasted duration using EVM, Time Series

Method of Forecasting	Forecasted Duration
EVM	100 days
Time Series	103 days

V. CONCLUSION

Project duration forecasting is prime factor in project monitoring and controlling. Failure of proper project duration forecasting may lead to delay in project completion which may ultimately lead to cost overrun. This paper compares Time Series with Earned Value Method. By analysis it is found that statistical approach also has potential to forecast project duration. Time Series gives results similar to that of EVM.

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APPENDIX

Table 1 Budgeted cost in each milestone.

Task	Budgeted Cost (Rs)	Expenditure in each milestone (Rs)						
		1	2	3	4	5	6	7
Site Development	100000	40000	40000				12000	8000
Masonry Work	535000	90000	178500	133750	44583			90000
Concrete work	632000	189602	63200		316000		63200	
Steel / framing work	168000			56000	112000			
Wood/ Roof	85000			17000	29750		38250	
Interior / plumbing/ electrical work	150000				75000	45000	15000	15000

Table 2.BCWS, BCWP and ACWP in each milestone

Task		Expenditure in each milestone (Rs)						
		1	2	3	4	5	6	7
A	BCWS	40000	40000				12000	8000
	BCWP	40000						
	ACWP	40000						
B	BCWS	90000	208500	133750	44583			90000
	BCWP	60000						
	ACWP	80000						
C	BCWS	189602	102802		316000		63200	
	BCWP	150000						
	ACWP	120000						
D	BCWS			56000	112000			
	BCWP							
	ACWP							
E	BCWS			17000	29750		38250	
	BCWP							
	ACWP							
F	BCWS				75000	45000	15000	15000
	BCWP							
	ACWP							

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Table 6 BCWS, BCWP and ACWP

Task		Expenditure in each milestone (Rs)						
		1	2	3	4	5	6	7
A	BCWS	40000	40000				12000	8000
	BCWP	40000						
	ACWP	40000						
B	BCWS	90000	178500	133750	44583			90000
	BCWP	90000						
	ACWP	80000						
C	BCWS	189602	63200		316000		63200	
	BCWP	189602						
	ACWP	195000						
D	BCWS			56000	112000			
	BCWP							
	ACWP							
E	BCWS			17000	29750		38250	
	BCWP							
	ACWP							
F	BCWS				75000	45000	15000	15000
	BCWP							
	ACWP							

Table 7

Y	X	$x-\bar{x} = X$	X x 2	X^2	X^4	Xy	X^2y
0	0	-7.5	-15	225	50625	0	0
180000	7.5	0	0	0	0	0	0
341865	15	7.5	15	225	50625	5127900	76918500
$\sum y$ =521865				$\sum X^2$= 450	$\sum X^4$= 101250	$\sum$ Xy =5127900	$\sum X^2y$=76918500

Table 8

Y	x	$X = x-\bar{x}$	X^2	X^4	Xy	X^2y
1399500	65	-5	25	625	-6997500	34987500
1412500	70	0	0	0	0	0
1430385	75	5	25	625	7151925	35759625
$\sum y$ =4242385			$\sum X^2$= 50	$\sum X^4$=1250	$\sum$ Xy=154425	$\sum X^2y$=70747125

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Task		Expenditure in each milestone (Rs)						
		1	2	3	4	5	6	7
A	BCWS	40 000	30000				12000	8000
	BCWP	50 000						
	ACWP	40000						
B	BCWS	90000	178500	133750	44583			90000
	BCWP	90000						
	ACWP	80000						
C	BCWS	189602	52802		316000		63200	
	BCWP	200000						
	ACWP	215000						
D	BCWS			56000	112000			
	BCWP							
	ACWP							
E	BCWS			17000	29750		38250	
	BCWP							
	ACWP							
F	BCWS				75000	45000	15000	15000
	BCWP							
	ACWP							

Table 10 BCWS, BCWP and ACWP

Table 11

Y	X	$x-\bar{x} = X$	2x X	X^2	X^4	Xy	X^2y
0	0	-7.5	-15	225	50625	0	0
177500	7.5	0	0	0	0	0	0
340000	15	7.5	15	225	50625	5100000	76500000
$\sum y = 517500$				$\sum X^2 = 450$	$\sum X^4 = 101250$	$\sum Xy = 5100000$	$\sum X^2y = 76500000$

Table 12

Y	x	$X = x-\bar{x}$	X^2	X^4	Xy	X^2y
1429995	65	-5	25	625	-7149975	35749875
1444995	70	0	0	0	0	0
1465000	75	5	25	625	7325000	36625000
$\sum y = 4339990$			$\sum X^2 = 50$	$\sum X^4 = 1250$	$\sum Xy = 175025$	$\sum X^2y = 72374875$