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Forecasting Accurate Cost 'Estimate at Completion' Using Earned Value Management Along with 6 Sigma Method for Running Projects

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Abstract

The research concept and aim were to help the running projects sponsors & managers to predict the future expenses and the total cost at completion of the project during early stage of project execution. The research was applied in Construction Management System 'CMS' software application which belongs to Intellectual Property Rights no. 711/2017 form United Arab of Emirates. The research based on creation of new equations & relations between Earned Value Management, 6 Sigma & projects contractual penalties. And the results were calculated based on a case study for a construction project.

Keywords: *Forecast, Estimate Cost, Earned Value, Project management & Expenses at Completion.*

Introduction

For any type of projects –especially the construction Projects-, it is mandatory to predict the expected cost estimation at completion for the project during early stages of execution; this is to allow taking the necessary precautions & mitigation actions. According to project management theories; Earned Value Management 'EVM' is the most popular & common method to Estimate & forecast project cost at completion.

The available Equations -as per Earned Value Management 'EVM' giving in PMBOK- are giving big range of Estimate At Completion 'EAC' values which is depending on the deferent cases & statuses of the Cost Performance Index 'CPI' & Schedule Performance Index 'SPI' & didn't consider the preliminaries cost & Delay Penalties impact in the forecasted cost at completion.

To obtain a correct figure for the expected Estimate At Completion; it is required to find a method of choosing the correct case to determine the Cost Performance Index 'CPI' status & to consider the preliminaries cost & Delay Penalties impact to minimize the range of the forecasted Estimate At Completion 'EAC' & to stand on the most correct figures during project stages.

The research created an approach to minimize the range of final cost prediction & to facilitate choosing & forecasting a proper accurate value of Project Estimation At Completion 'EAC' during early stages of project execution. This theory depends on incorporating Earned value management 'EVM' equations with

6 sigma '6σ' equations to elect the suitable status of the Cost Performance Index 'CPI' further to considering the preliminaries cost & Delay Penalties impact which is the key of calculating the project Estimate At Completion 'EAC'.

Literature Review

Materials of research

The new method of calculation to forecast EAC is explained in the following part of the research:

The Existing Project Management theories which was discussed in the research:

- Earned Value Management EVM, PMBOK 5th edition
- 6 sigma '6σ' equations
- Equations for determining Projects Estimation At Completion, PMBOK 5th edition
- PMBOK Equations for determining CPI & SPI for 3 cases:

Case 1: If values of (CPI) are always Unstable:

Estimate At Completion (EAC) = AC+ BAC- EV

Case 2: If values of (CPI) are always stable:

Estimate At Completion (EAC) = BAC/CPI

Case 3: If values of (SPI) strictly impact the project:

Estimate At Completion (EAC) = AC+ ((BAC- EV)/ (CPI*SPI))

Method of research

The main benefits of the new method in the field of Project Management:

The research incorporates 6 sigma '6σ' formulas with Earned value Management (EVM) to choose the accurate status of CPI –either stable or not-. Furthermore, the research approach considered the preliminaries cost & Delay Penalties to give the correct figure of project estimated budget at completion 'EAC'

Methodologies used to find the results: -Table # 01 is a case study for illustration-

a- Method to determine/choose the accurate Cost Performance Index 'CPI' status:

Cost Performance Index CPI = EV/AC

According to Earned Value Management, CPI has two cases during project execution:

Case 1: If values of (CPI) are always Unstable;

In Case 1, Estimate At completion 'EAC' is calculated according to the following equation:

Estimate At Completion (EAC) = AC+ BAC- EV

Case 2: If values of (CPI) are always stable

In Case 2, Estimate At completion 'EAC' is calculated according to the following equation:

Estimate At Completion (EAC) = BAC/CPI

The new method helps to determine/choose the suitable EAC either from case1 or case2 at cutoff date of evaluation by using Sigma equation to determine if the CPI stable or not.

Approach Steps:

Step 1: Determining Standard of Deviation 'Sigma σ ' of CPI:

1- Find the Minimum value of CPI from beginning of the project till the evaluation date (h)
2- Find the Maximum value of CPI from beginning of the project till the evaluation date (i)
3- Standard of Deviation 'Sigma σ' (j) = (i-h)/6

Step 2: Determining if CPI Stable or Not stable:

1- Find the average value of CPI from beginning of the project till evaluation date (g).
2- Add & deduct 'Sigma σ ' to CPI average = g ± j = acceptable range for CPI
3- Account the numbers of CPI falls within acceptable range.
4- Find the ratio between this number & total number of CPI.
5- As per 2Sigma '2σ' rule,

- If percentage of 68.27% -or above- of CPIs are within acceptable range; then CPI is always stable. Accordingly, Estimate At Completion (EAC) = BAC/CPI
- If percentage less than 68.27% of CPIs is within acceptable range; then CPI is always Unstable. Accordingly, Estimate At Completion (EAC)= AC+ BAC- EV

b- Method to Determine EAC; if the Schedule impacts the project Budget (Case 3) -which is common Case-:

Case 3: If the value of Schedule Performance Index 'SPI' strictly impact the project Estimate At Completion (EAC) = AC+ ((BAC- EV)/ (CPI*SPI))

Schedule Performance Index SPI = EV/PV

Earned Value Management EVM method is calculating EAC according to SPI without limitation. But practically; EAC & SPI have limits related to Delay Cost –not considering LD Liquidity Damages or disputes-:

- Daily Delay Penalty
- Maximum deduction due to delay according to contract
- Daily administration & preliminaries Cost

By default, the research calculated the daily delay Penalty = MDP * final price / (project period/5). But it is able to be modified according to the project contract.

Results

According to the case study on Table #01:

Project Budget 'BAC' = 111,699,203 AED
Contractual Project price = 123,652,254 AED
Project Period = 670 days
Therefore, Daily Delay Penalties 'DDP' = 10% * 123,652,254 / (670 / 5) = 92,278 AED
Daily Administration & preliminaries Cost 'DAPC' = 7,689.8 AED
Max. Daily Delay Penalties as per contract 'MDP' =10% of project Price = 12,365,225 AED

At month 04 as per table #01:
Current Delay (DY) = -25 days
Delay Cost (DC) = 92,278 * 25 days = 2,306,950 AED

Therefore, Total Delay Administration & preliminaries Cost (TAPC) = 7,689.8* 25 days = 192,245 AED
So, The Maximum Delay & Administration Penalties (S) = The Lesser value of the delay cost (DC) Or the Maximum delay Penalty as per contract (MDP), Further to Administration cost for the same numbers of delay (TAPC).
= (Min of (DC or MDP)) + TAPC =2,306,950 + 192,245 = 2,499,195 AED

Therefore, the Maximum Delay Impact (MDI) = Amount of Delay/ BAC =
= 2,499,195 / 111,699,203 = 2.23% = 0.0223
So the minimum limit of SPI is (1-MDI) = 1- 0.0223 = 0.977

Then the Chosen SPI will be the maximum of (EV/PV) and (1-MDI). Consequently, the chosen SPI will be used in forecasting the Actual Estimation At Completion:

- If 'CPI' is stable, Estimate At Completion (EAC) = AC+ ((BAC- EV)/ (CPI*SPI))
- If CPI is Unstable, EAC= The Chosen 'EAC' according to sigma (O) + Max. Delay & admin. Penalties (S)

Attachment: Table #01 Showing the monthly Data & results reflecting above formulas for 22 months.

Analysis & Discussion

As mentioned in the above example, Table #01 & the related results;

- Planed Budget At Completion 'BAC' = 111,699,203 AED
- But Final Actual Cost which is the Actual executed Budget at completion = 117,903,031 AED
- Project Planed Period = 670 days (22.33 months)
- Project Actual Period = 700 days (23.33 months), (30 days delay)

Zone of discussion is the tenses of 4th & 5th months which are early stages of project life, & 9th & 10th which are medium stage of project life. Meanwhile, each month of 4,5,9 & 10 had extreme variances of Estimate At Completion EAC

Month 4:

CPI = 0.813
Case 1 (CPI unstable), (EAC) = AC+ BAC- EV = 113,563,203
Case 2 (CPI stable), (EAC) = BAC/CPI = 137,403,810

By using 6 Sigma equations, the research finds that CPI is Unstable. Therefore 'Case 1' was elected & the chosen EAC was 113,563,203 which is closer than 'Case 2' from the final Actual cost.

But, because of the project is affected by time constrain & delay penalties –as the common projects-; 'Case 3' should be considered as following:

According to the example results:
SPI = 0.885
As per Earned Value Management -previous theory-:
Case 3 (EAC) = AC+ ((BAC- EV)/ (CPI*SPI)) = 154,043,296 AED (which is varied away from the actual cost).

Meanwhile, using the research approach & theory considering the correct CPI & the actual effect of delay cost; the estimated cost at completion changed to 115,839,389 AED which is more accurate & closes for the actual final Cost at completion (117,903,031 AED)

The same is applicable for months 5, 9 & 10

Month 5:

CPI = 0.87 & SPI = 0.878
As per Earned Value Management -previous theory-:

Case 3 (EAC) = AC+ ((BAC- EV)/ (CPI*SPI)) = 144,648,079 AED (which is varied away from the actual cost).

But as per the research theory EAC = 115,519,889 which is more accurate & closes for the actual final Cost at completion.

Month 9:

CPI = 0.836 & SPI = 0.786
As per Earned Value Management -previous theory-:

Case 3 (EAC) = AC+ ((BAC- EV)/ (CPI*SPI)) = 160,734,234 AED (which is varied away from the actual cost).

But as per the research theory EAC = 119,188,244 which is more accurate & closes for the actual final Cost at completion.

Month 10:

CPI = 0.841 & SPI = 0.839
As per Earned Value Management -previous theory-:

Case 3 (EAC) = AC+ ((BAC- EV)/ (CPI*SPI)) = 149,742,146 AED (which is varied away from the actual cost).

But as per the research theory EAC = 120,610,421 which is more accurate & closes for the actual final Cost at completion.

Conclusion

The research provided an approach & method to forecast accurate Estimation At Completion 'EAC' for ongoing project during early stage of execution.

References

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PMI, Project Management Institute, (2013). *Project management body of knowledge (PMBOK® guide). -- Fifth edition*.

Abbreviations

CMS : Construction Management System
PMBOK: Project Management Body Of Knowledge (PMI)
FIDIC : International Federation of Consulting Engineers
Federation Internationale des Ingenieurs Conseils
σ : Sigma, (Standard of Deviation)
EVM : Earned Value Management
BAC : Budget At Completion, Planned Budget for the project
EAC : Estimate At Completion, Estimated Budget during Execution
CPI : Cost Performance Index.
SPI : Schedule Performance Index.
CV : Cost Variance
SV : Schedule Variance
EV : Earned Value
PV : Planned Value
AC : Actual Cost
LD : Liquidity Damages
DDP : Daily Delay Penalties
DAPC : Daily Administration & preliminaries Cost
MDP : Max. Daily Delay Penalties as per contract
Dy : Current Delay
DC : Delay Cost
TAPC : Total Delay Administration & preliminaries Cost
MDI : Maximum delay impact

Appendix (Table #01)

Appendix D

Forecasting accurate Cost 'Estimate At Completion' using Earned Value Management along with 6 sigma method for running projects

Budget At Completion (BAC)= 111,699,203 | Planned Period = 670 days

month	*Earned Value (EV)*[c]	*Actual Cost (AC)*[c]	*CPI= EV/AC*	number of CPI	Average of CPI	CIP variance	Min CIP	Max CIP	Standard of Division, Sigma	No. of CPI within limit of +/- 1 sigma (2sigma)	No. of considered CPI variance	For 6sigma; Stability of CIP Below 68.27% is unstable		Determine EAC according to CPI: Case 1 (CPI unstable) (EAC)= AC+ BAC- EV	Determine EAC according to CPI: Case 2 (CPI stable) (EAC)= BAC/CPI	Determine EAC according to CPI: Chosen EAS according Sigma
a	b	c	d	e	f	g	h	i	j	k		L		M	N	O
			b/c		d sum / e	d-f			(i-h)/6							
1	600,000	650,000	0.923	1								No sigma		111,749,203	121,007,470	121,007,470
2	3,600,000	3,434,000	1.048	2	0.986	0.063	0.923	1.048	0.021	0	1	0%	Unstable	111,533,203	106,548,629	111,533,203
3	5,600,000	5,944,000	0.942	3	0.971	0.029	0.923	1.048	0.021	0	2	0%	Unstable	112,043,203	118,560,725	112,043,203
4	8,100,000	9,964,000	0.813	4	0.932	0.119	0.813	1.048	0.039	1	3	33%	Unstable	113,563,203	137,403,810	113,563,203
5	10,300,000	11,844,500	0.870	5	0.919	0.050	0.813	1.048	0.039	1	4	25%	Unstable	113,243,703	128,448,661	113,243,703
6	13,932,000	13,769,500	1.012	6	0.935	0.077	0.813	1.048	0.039	1	5	20%	Unstable	111,536,703	110,396,366	111,536,703
7	16,768,951	17,416,788	0.963	7	0.939	0.024	0.813	1.048	0.039	2	6	33%	Unstable	112,347,040	116,014,492	112,347,040
8	22,814,426	24,031,280	0.949	8	0.940	0.009	0.813	1.048	0.039	3	7	43%	Unstable	112,916,057	117,656,908	112,916,057
9	28,819,732	34,487,824	0.836	9	0.928	0.093	0.813	1.048	0.039	3	8	38%	Unstable	117,367,295	133,667,532	117,367,295
10	37,509,565	44,599,834	0.841	10	0.920	0.079	0.813	1.048	0.039	3	9	33%	Unstable	118,789,472	132,813,215	118,789,472
11	45,379,066	50,342,334	0.901	11	0.918	0.017	0.813	1.048	0.039	4	10	40%	Unstable	116,662,471	123,916,137	116,662,471
12	53,541,906	55,292,154	0.968	12	0.922	0.046	0.813	1.048	0.039	4	11	36%	Unstable	113,449,451	115,350,573	113,449,451
13	59,915,711	59,326,124	1.010	13	0.929	0.081	0.813	1.048	0.039	4	12	33%	Unstable	111,109,616	110,600,052	111,109,616
14	64,575,304	65,239,461	0.990	14	0.933	0.057	0.813	1.048	0.039	4	13	31%	Unstable	112,363,360	112,848,029	112,363,360
15	69,431,551	70,252,270	0.988	15	0.937	0.051	0.813	1.048	0.039	4	14	29%	Unstable	112,519,922	113,019,549	112,519,922
16	73,932,037	76,933,514	0.961	16	0.938	0.023	0.813	1.048	0.039	5	15	33%	Unstable	114,700,680	116,233,943	114,700,680
17	78,794,562	84,907,159	0.928	17	0.938	0.010	0.813	1.048	0.039	6	16	38%	Unstable	117,811,800	120,364,423	117,811,800
18	84,491,292	95,818,425	0.882	18	0.935	0.053	0.813	1.048	0.039	6	17	35%	Unstable	123,026,336	126,673,903	123,026,336
19	91,989,873	102,906,625	0.894	19	0.933	0.039	0.813	1.048	0.039	7	18	39%	Unstable	122,615,955	124,954,928	122,615,955
20	98,965,510	108,434,481	0.913	20	0.932	0.019	0.813	1.048	0.039	8	19	42%	Unstable	121,168,174	122,386,527	121,168,174
21	103,718,428	112,659,181	0.921	21	0.931	0.010	0.813	1.048	0.039	9	20	45%	Unstable	120,639,956	121,327,916	120,639,956
22	106,652,713	115,051,031	0.927	22	0.931	0.004	0.813	1.048	0.039	10	21	48%	Unstable	120,097,521	120,494,904	120,097,521
23	108,258,792	116,711,031	0.928	23	0.931	0.003	0.813	1.048	0.039	11	22	50%	Unstable	120,151,442	120,420,050	120,151,442
24	111,699,203	117,903,031	0.947	24	0.931	0.016	0.813	1.048	0.039	12	23	52%	Unstable	117,903,031	117,903,031	117,903,031

Determine EAC according to CPI & SPI

month	Planed Value (PV)	Schedule Performance Index (SPI)	Case 3 (EAC)= AC+((BAC-EV)/(CPI*SPI))	Current delay per days Delay in Minus	Maximum Delay & Administration Penalties	Maximum delay impact	SPI will not be considered if <	The Considered SPI	Case 3 (If CPI is Stable) (EAC)= AC+((BAC-EV)/(CPI*SPI))	(EAC) (If CPI is UnStable)= The Choosen 'EAC' according to sigma (O) + Max. delay & admin. Penalties (S)
a	p	Q	W	R	S	T	U	V	Y	X
						S/BAC	1-T	Max(Q,U)		
1	661,656	0.907	133,375,394		0.0	0.000	1.000	1.00	121,007,470	121,007,470
2	3,676,257	0.979	108,732,861		0.0	0.000	1.000	1.00	106,548,629	111,533,203
3	6,416,927	0.873	134,989,226	-15	1,365,711.5	0.012	0.988	0.99	119,954,699	113,408,914
4	9,157,596	0.885	154,043,296	-25	2,276,185.8	0.020	0.980	0.98	140,054,775	115,839,389
5	11,730,944	0.878	144,648,079	-25	2,276,185.8	0.020	0.980	0.98	130,874,227	115,519,889
6	13,577,643	1.026	107,938,683	-20	1,820,948.6	0.016	0.984	1.00	110,396,366	113,357,652
7	18,207,905	0.921	124,475,221	-20	1,820,948.6	0.016	0.984	0.98	117,648,495	114,167,989
8	26,597,836	0.858	133,183,229	-20	1,820,948.6	0.016	0.984	0.98	119,208,511	114,737,006
9	36,684,799	0.786	160,734,234	-20	1,820,948.6	0.016	0.984	0.98	135,311,180	119,188,244
10	44,707,984	0.839	149,742,146	-20	1,820,948.6	0.016	0.984	0.98	134,275,124	120,610,421
11	49,928,896	0.909	131,292,849	-20	1,820,948.6	0.016	0.984	0.98	125,135,433	118,483,420
12	55,149,808	0.971	117,154,170	-25	2,276,185.8	0.020	0.980	0.98	116,599,891	115,725,637
13	60,370,720	0.992	110,989,434	-25	2,276,185.8	0.020	0.980	0.99	110,989,434	113,385,802
14	65,591,632	0.985	113,597,324	-27	2,458,280.6	0.022	0.978	0.98	113,597,324	114,821,641
15	74,907,206	0.927	116,392,351	-28	2,549,328.1	0.023	0.977	0.98	114,018,431	115,069,250
16	83,320,925	0.887	121,224,842	-30	2,731,422.9	0.024	0.976	0.98	117,219,061	117,432,103
17	92,700,648	0.850	126,622,111	-30	2,731,422.9	0.024	0.976	0.98	121,253,207	120,543,223
18	98,712,627	0.856	131,867,409	-30	2,731,422.9	0.024	0.976	0.98	127,447,336	125,757,759
19	103,769,670	0.886	127,778,332	-30	2,731,422.9	0.024	0.976	0.98	125,507,599	125,347,378
20	108,178,999	0.915	123,685,435	-30	2,731,422.9	0.024	0.976	0.98	122,736,254	123,899,597
21	110,780,096	0.936	121,918,127	-30	2,731,422.9	0.024	0.976	0.98	121,545,209	123,371,379
22	111,699,203	0.955	120,752,492	-30	2,731,422.9	0.024	0.976	0.98	120,631,362	122,828,944
23	111,699,203	0.969	120,537,921	-30	2,731,422.9	0.024	0.976	0.98	120,513,021	122,882,865
24	111,699,203	1.000	117,903,031	-29	2,640,375.5	0.024	0.976	1.00	117,903,031	120,543,406