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Forecasting Final Schedule and Cost of Projects by Using Statistical and Mathematical Method

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Abstract Earned value management (EVM) has prepared some methods to forecast final costs of projects. These methods were not developed since the start of formation and were gradually completed, of course with one exception that is its authenticity, they are still remained unchanged. At the present time EVM guide does not apply from schedule indices to forecast schedule for completion of project and lacks such ability. The goal of the present study is to improve abilities of project managers for making logical and intelligent decisions through trustable forecasting methods and final cost of project. Regardless the type of work, time, and range, this method is recommended for project managers. This method is based on technique of EVM which is able to forecast schedule for completion of project by using statistical methods. Results of studies indicate that it is possible to provide statistical methods to forecast final costs of project.

Keywords Earned Value Management (EVM), Planned Value (PV), Earned Schedule (ES), Independent Estimate at Completion (IEAC), Actual Cost (AC), Earned Value (EV).

1 Introduction

EVM is one of the methods for project management which facilitates the process of controlling a project by forecasting the final cost of project. One of the fundamental factors that shall be studied and controlled at the stage of executing a project is the way of spending the allocated budget for the project. Under different time periods, this question was always raised for persons in charge that, whether the spent amount in comparison to volume of fulfilled work was higher than amount which was forecasted in budget or there is balance. It is obvious that it is not possible to hope that there may be always exact and non-contradictory balance in this field. Factors such as excess inflation in price of building materials or human work force and also unexpected events that may occur during project may result in possible increase or decrease in cost of projects [1]. EVM is a managerial technique to control the efficiency of project. In EVM structure the indices of efficiency and deviation indicates that whether the project is at status over than budget or planning of organization or not [2].

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Measuring control indices may be on daily, weekly or monthly basis. This technique applies from 2 information sources as final forecasted cost and actual completion cost for comparison and offering report [3]. By virtue of studies at U.S. Department of Defense the EVM forecasts is very trustable for great projects. Having trustable forecast tools and independent calculation tool is very important for project managers to forecast final cost of projects. The provided methods may offer better information for future activities of project managers.

2 Literature review

2.1 Basics of value

2.1.1 Planned value (PV) or budgeted cost of work scheduled (BCWS)

PV is defined as budgeted cost of work scheduled which is part of estimated cost that is spent during specified time period. In fact PV is budget that is allocated to each time period of activities which is estimated as start of project. In other words PV is scheduled physical work with approved budget to fulfill work in which final point of this value is budget at completion (the planned cost of project) (BAC) which obtains from sum of all budgets of project [4].

2.1.2 Earned value (EV) or budgeted cost for work performed (BCWP)

It is the budget of fulfilled work or earned value during activities of project or work package. If the original budget is not exactly estimated in analyzing the earned value of project, all of the advancement measurements during the execution of project may face wrong budget and its results may be unrealistic.

2.1.3 Actual cost (AC) or actual cost of work performed (ACWP)

Actual cost is all of the costs that are spent during the time of executing project. Actual cost shall be calculated in accordance with PV and EV i.e. if at estimation of PV the only direct costs(direct hours or costs) for fulfilling work is observed, while calculating actual costs only actual direct costs are observed and vice versa. If costs include direct and indirect costs of estimating PV in order to calculate AC, all direct and indirect costs shall be calculated. Amount of AC of a project or work package is specified by financial department (accounting) which may be higher, lower or equal to PV and EV at any time point of project. Accounting system of project or organization in order to support project manager and EVM system shall be able to register all direct and indirect information costs and communication among spent cots and fulfilled costs of project [5]. These costs include human work force costs, building materials, subsidiary contracts and all direct and indirect costs of projects. Positive comparisons indicate good performance of project such as cost and schedule. Lack of having contradiction indicates that the project is advancing according to the planning and negative contradiction indicates that performance of the project is poor. This situation is shown in fig 1.

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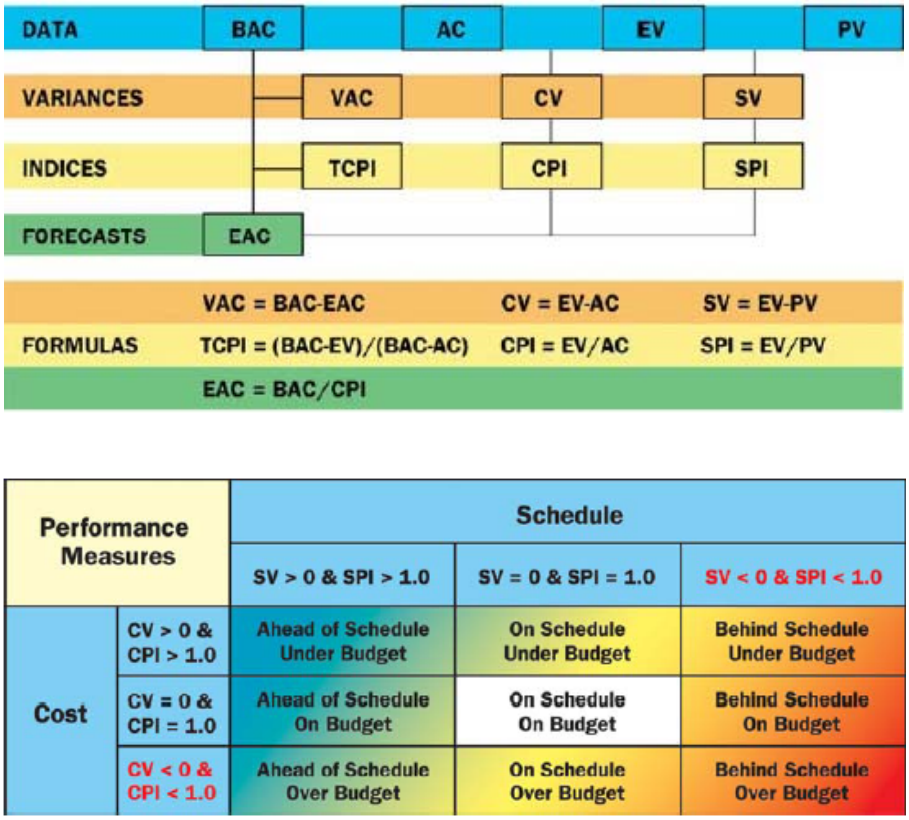


Fig. 1 Analysis of various indices and variances

2.1.4 Results of researches by US department of defense

Many studies are conducted in relation to CPI (cost performance index) [CPI= EV/AC] and IEAC (independent estimate at completion) [the forecasted final cost] and less studies are conducted in relation to SPI (schedule performance index) [CPI= EV/AC]. Summary of these findings are as follows:

1. Result of IEAC = BAC/CPI formula for calculating the final cost of project does not have high stability
2. The cumulative value of CPI after project reached to 20% completion has balance and stable mode
3. The range of final cost which is mentioned at article 2 is able to be obtained through following formula: IEAC= BAC/ (CPI20%+-0.1)
4. CPI value from stability point to completion point of project attitudes toward being worse

The above mentioned findings are obtained from US Department of Defense. These findings are obtained from different projects such as construction, developing new defense system, developing software and also several billion dollar projects during time period more than one decade and also short term IT projects are observed. Managers of small project report that rarely they observe stability of CPI. Managers without CPI behavior (in great and

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small projects) have less ability in providing trustable forecasts for final costs of project. Recent studies indicate that findings of article 2, 3 that need stability of CPI index at 20% completion of project, may be applicable for very great and long term projects. Therefore this question is raised whether managers of small projects may expect that this information has trustable results or not.

2.1.5 Review of ES (earned schedule)

ES (earned schedule) is a method for obtaining schedule information from EVM [11]. Many studies are conducted in relation to CPI and EAC behavior but SPI is a different issue. SPI and SV (schedule variance) [SV=EV-PV] are not exactly studied. Recent development of EVM offers useful and trustable information in relation to time indices and schedule indices or ES. In short it can be said that on the contrary of cost based indices that are offered by EVM for schedule efficiency, ES provides schedule based indices [6]. This is shown in fig 2.

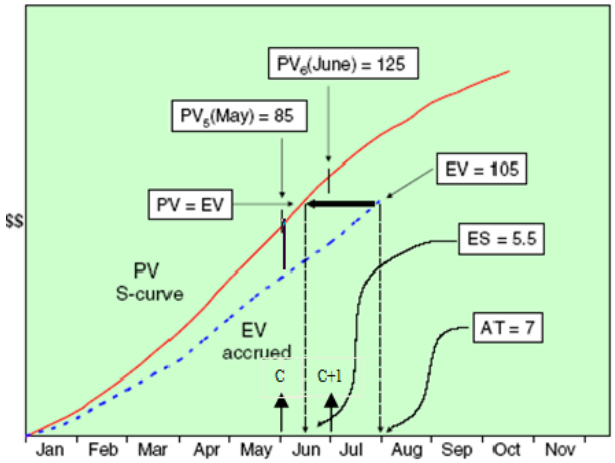


Fig. 2 Es concept

ES indicates EV with the amount of fulfilled activity. As it is indicated in above diagram it is the point on PMB (performance measurement baseline) curve in which PV is equal to EV. The vertical line of this point until schedule x axis indicates obtained level of schedule. Time of starting project until intersection point of this line with schedule axis indicates earned schedule. When ES is possible to show as figure it is possible to be obtained as formula. In order to perform ES calculations on mathematical basis, 2 parameters are required. The first principal counter is schedule unit based on hour, day or month that is determined at x axis and is specified by C. So C in this relation indicates that it is the closest period in which the present EV is higher than PV of the same period [7] i.e.

$$PV_c<EV<PV_{c+1}$$

The second section is I that is calculated through linear finding. As it is indicated the line orthogonal on x axis is not exactly located on schedule counter and is located among 2

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counters. The level of linear finding by using formula $I = \frac{(EV - PV_C)}{(PV_{C+1} - PV_C)}$ is calculated. Therefore the level of I at earned schedule in growth curve PMB from PV at C point to PV is at C+1 point. Therefore ES= C+1

By increasing the C level, the level of finding may also be less and therefore the error of ES due to approximating line I is small. For example, maximum ES error by 3 months EVM information may be 3% and after 10 months this number reaches to 1%. Upon calculating ES the index for schedule of axis is calculated. PMB (performance measurement baseline) is not mathematical defined function rather this curve is obtained from cumulative PV during periodical time distances. As it is indicated in fig 2 the actual schedule is shown by AT. Time indexes by using AT and ES is calculated as follows:

SV(t) = ES-AT	Time invert
SPI (t) = ES/AT	Time Performance Index
AT:	Real Time (Inspection Time)
EV:	Earned Value
ES:	Earned Time
$SV_{(t)}$ = ES-AT	Time invert
$SPI_{(t)}$ = ES/AT	Time invert Index

As it is indicated in the diagram total in fig 2, schedules for month May and only part of June in comparison to the baseline is obtained. Duration of completed section of planned schedule at x axis is 5 months i.e. c=5. Actual schedule of AT is end of July and as it was already mentioned the method of calculating obtained schedule at part of June plays important role at calculating ES and is performed through linear finding. PV at month May is 85 and at end of June is 125 and EV is 105.

EV-PV5 ($_{May}$) = 105-85=20
PV6 ($_{June}$)-PV5 ($_{may}$) = 125-85=40
I=20/40 = 0.5
ES=C+I=5+0.5=5.5 AT=7
SV (I) = 5.5-7=-1.5
SPI (t) = 5.5/7=0.79
IEAC=BAC/CPI (estimating final cost of project)
IEAC (t) =PD/SPI (t) (independent estimating final schedule of project)

In which PD15 is the planned schedule. Generally, it may be said that the previous indices provide better forecasts in relation to common schedule indices for EVM axis.

2.2 Management & cost estimation in projects

Project cost management is related with the cost of required resource to complete the activities of the project. Generally, the cost management shall observe the effect of taken decisions during project on consumed cost of product. Estimation process provides an approximation for cost finding related to required resources to complete activities of project.

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In estimating cost, the estimator (with the goal of project management) observes the reason of difference in estimating the final cost of project.

2.2.1 Tools & techniques of cost estimation

a) Analogous estimating

Analogous estimating means estimating from top to bottom, using actual costs of project like previous one as basics for estimating current costs of project. Analogous estimating is generally cheaper than other techniques but it has less exactness.

b) Parametric modeling

Parametric modeling is using the property of each project within the mathematical model with the goal of forecasting costs of projects. This model may be simple (for example cost of constructing one unit of apartment as per square meter of space which is fixed amount) or is complicated (for example model for estimating cost of project as software development). Cost of models and also their exactness is very diverse. Ability for trusting to these models is at its maximum level under the following conditions:

Firstly: Previous information and records that shall be exacted for creating and developing model

Secondly: Parameters that are used in model shall be easily measured

Thirdly: The constructed model shall have scale (i.e. it shall have as good performance as very small project and during great project it shall have same efficiency of small projects).

c) Bottom to top estimating

This technique deals with estimating costs of activities or separate working packages and then accumulating and summarizing independent estimations and finally obtaining the total costs of project. Amount of cost and exactness of estimation depends on size of activities or working packages and also their complexity. Smaller activities results in increasing cost and exactness for estimation process. The project management team shall have additional exactness against additional costs.

d) Computer tools

Computer tools such as project management software, spreadsheet, simulation tools and statistical tools are used in the way of assisting to cost estimation of project. Such products may facilitate using aforesaid tools and therefore they facilitate more prompt and exact access to many choices related to cost estimation [8].

3 Research methodology

The present research is historical research based on previous research background which has collected scientific information and basics by library method.

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4 Research model (forecasting schedule and final cost of projects by using statistical methods)

The science of statistics by having trustable branches for estimating schedule and CPI costs through EVM and SPI and ES provides useful information to project managers. Statistical mathematics provides some facilities for repeated improving forecasted branches of cost and final schedule such as forecasting the minimum and maximum output of projects. Project managers by having forecasts related to top bound and bottom bound and final cost of project may have more complete information for making effective decisions in the way of success of project. These bounds are level of certainty of projects.

The following formula is used to calculate top and bottom bound

$$CL=\mu \pm Z^* \frac{\sigma}{\sqrt{n}}$$

which Z is calculated amount from standard normal distribution based on level of certainty, σ is standard deviation and n is number of sample observations.

The level of certainty is calculated as 90% or 95%. In normal distribution z=+-1, 6449 for level of certainty as90% and z=+-1.9600 is for level of certainty as 95%. Upon increase in level of z the possible value may also increase. When the number of observations is less than 30 instead of Z distribution we use from T distribution. As it is obvious in the above mentioned formula in order to calculate CL we require calculating the level of certainty, average and standard deviation. Logarithm is cumulative and estimating index of certainty. Standard deviation is calculated by using logarithm indices such as SPI (t) p and CPI p. Standard deviation is calculated through the following formula:

$$\sigma = \sqrt{(\sum (\ln \text{ periodic index (i)} - \ln \text{ cumulative index})^2/(n-1))}$$

In the aforesaid formula the total periodic observations since the start of project until now are defined by i. The reason of using logarithm function is that periodic value of indices may be estimated as normal distribution. The assumption of statistical method is that statistical universe of the present research is unbounded, but projects are bounded since they have start and end points. For statistical calculations of bounded universes it is required to apply the adjustment factor (AF). These adjustments result in closing top and bottom bounds to same value when projects are going to be completed. The adjustment factor is calculated by $\sqrt{(N-n)(N-1)}$ in which N is the total number of observations and n is the sample observations. Through the following formula:

$$AFc = \sqrt{\frac{(BAC-EV)}{BAC-(EV/n)}}$$

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$$\text{AFs} = \sqrt{\frac{(PD - ES)}{PD - (ES/n)}}$$

Upon analyzing aforesaid discussions it is possible to provide a general equation for level of certainty in the present study.

$$\text{CL} = \ln \text{index(cum)} \pm Z * \frac{\sigma}{\sqrt{n}} * \text{AF}$$

The result of aforesaid formula is logarithm for cumulative indices. By increasing e number to CL power and inverting this number, the top and bottom bound of schedule and final cost of project is calculated; for example, in order to calculate the top bound of final cost it is used with following formula

$$\text{IEACH} = \frac{BAC}{EXP(CL_{C(-)})}$$

By using the same method the top and bottom bound for schedule and through level of certainty for cumulative periodic value, the SPI index is calculated. Through the following formula:

$$\text{IEAC}_{(t)} = \frac{PD}{EXP(CL_S)}$$

It is to be noted that index s at CLs indicates level of certainty originates from schedule performance.

5 Results of the model test

The goal of statistical studies of 2 famous researches (Stephen Wavnderverd and Mario Vanhaak) is that project managers shall have trustable controllable information to forecast schedule and final cost of projects. For each group it is used from project information in which all calculations are repeated for creating top and bottom bounds. Top and bottom bounds are tested by statistical assumption from first to end. Specially mark test at significance point (accepting or rejecting) 5% may be used to evaluate tendency of sample to be greater, equal or smaller than the next sample. In the present study the mark test is separately observed for greater and smaller conditions as follows:

1. H1 (cost-high bound): IEAC H (final cost less than this value)
2. H2 (cost low bound): IEAC L (final cost higher than this value)
3. H3 (schedule high bound): IEAC L (final schedule less than this value)
4. H4 (cost low bound): IEAC (t) L (final schedule higher than this value)

When the value of statistical test at critical point is 5% then H0 is zero assumption. For bounds of each project H0 shall be registered. These results are listed for top and bottom bounds of each project, and they are used to calculate the possibility of trustable results. The possibility of obtaining trustable results Ha is calculated by using Binem distribution. This

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formula has application for top and bottom bounds at different levels of certainty. The levels of certainty that are used at the present study are 90%, 95%, 98%. Also 3 groups of data are analyzed within time period 10%, 30% and 60% of completion of project. By mixing the level of certainty and class information, a general method is obtained to forecast schedule and cost of project. 12 projects with 497months EVM information are studied in the present research. The entire budget and cost information are obtained from managerial information. Projects have low risk and output of projects is HIGH TECHNOLOGY product. Cost information and planned scheduled and also schedule efficiency index and cost index are provided in table 1.

Table 1 Planned cost and time data and performance indicators of time and cost

Project	BAC (×$000)	PD (months)	CPI_c (final)	$SPI(t)_c$ (final)	CPI_c		$\sigma(\ln CPI_p)$		$SPI(t)_c$		$\sigma(\ln SPI(t)_p)$	
					High	Low	High	Low	High	Low	High	Low
1	898	21	0.741	0.875	0.875	0.608	1.093	0.448	1.950	0.875	0.539	0.204
2	605	32	0.695	0.842	0.887	0.566	0.713	0.028	1.139	0.710	0.653	0.035
3	322	36	0.481	0.837	0.841	0.472	0.704	0.055	0.899	0.326	1.421	0.124
4	613	43	0.793	0.915	0.986	0.775	0.683	0.205	1.000	0.583	1.009	0.287
5	291	24	1.051	1.000	1.354	1.041	0.525	0.132	1.082	0.875	0.347	0.201
6	1525	50	0.625	0.847	1.000	0.566	0.835	0.147	0.972	0.667	0.759	0.247
7	585	46	0.763	0.852	1.042	0.667	0.683	0.321	1.018	0.727	0.668	0.283
8	1026	29	0.877	0.967	0.914	0.714	0.253	0.087	1.054	0.761	0.622	0.000
9	2223	45	0.746	0.818	1.043	0.610	1.410	0.036	1.000	0.650	1.297	0.000
10	6077	44	0.870	0.880	1.053	0.870	0.452	0.009	1.657	0.592	1.033	0.385
11	353	17	0.546	0.739	0.672	0.443	0.654	0.100	1.005	0.619	0.777	0.042
12	1305	50	0.650	1.000	0.863	0.526	0.747	0.054	1.000	0.774	0.636	0.000

According to information of table 1, the planned cost of projects is among $291000 to $6077000. Range of schedule is among 17 to 55 months. CPI index is among 0.481 to 1.051 and SPI index is among 0.739 to 1. Except row 5, the value of SPI in projects is better than CPI. Numbers indicate that schedule index has higher priority toward cost index i.e. schedule goals are more important than cost goals. As it is indicated the only projects No.5 and 12 are reached to schedule. An elementary comparison of projects indicates high level of deviation at cumulative index and standard deviation both for schedule and cost. Index c indicates cumulative and index p indicates periodic index. These indices and standard deviation and by using all information are calculated for each project.

6 Analyzing results

One sample of top bound and bottom bound forecast by using statistical calculation method is shown in fig 3. Calculations are performed at 90% certainty level. The important point is the difference among top bound and bottom bound in which by increasing percentage for schedule of completing project, it may be either smaller or greater and finally ends it schedule for completion the project. This diagram indicates that CPI cumulative index during schedule range 50% to 100% of completing project and due to stability of IEAC is stable. Top bound of IEAC that starts from nearly 30% advancement schedule of project, indicates complete closeness to final time of completing project. Table 2 indicates results of hypothesis test by aforesaid conditions and rejection area of 5%.

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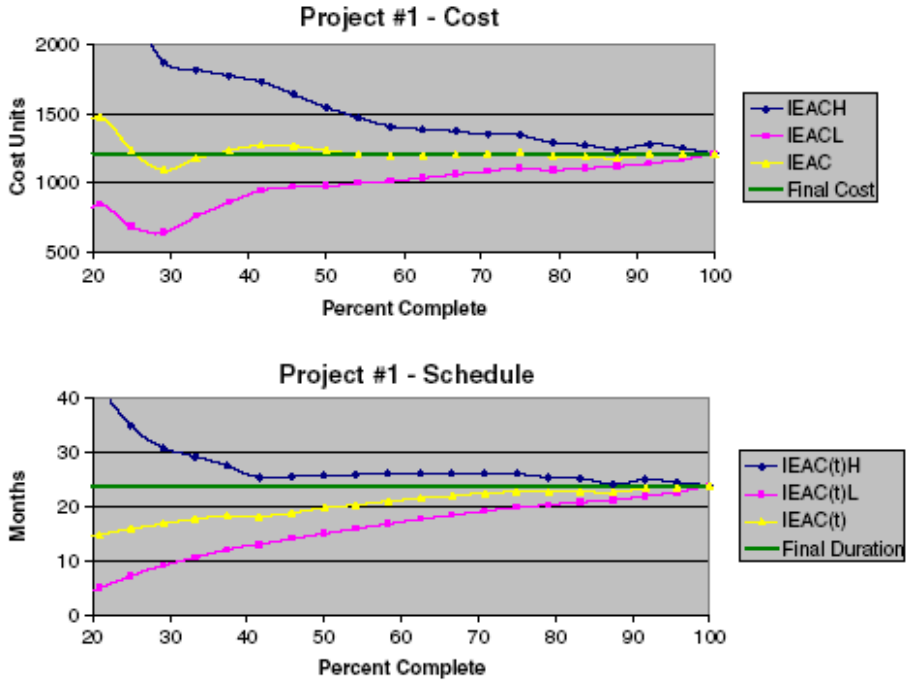


Fig. 3 Samples of upper bound and lower predict using statistical calculations

Table 2 Test results is the confidence level of 90% and failure level of 5%

Hypothesis test results @ 98% confidence ≥ 10% complete

Bounds	Project number												Probability
	1	2	3	4	5	6	7	8	9	10	11	12	
Cost high	Ha	Ha	Ho	Ha	Ho	Ha	Ho	Ha	Ha	Ho	Ha	Ha	0.927
	0.000	0.000	0.500	0.044	0.500	0.000	0.844	0.000	0.000	0.116	0.000	0.000	
Cost low	Ha	Ho	Ha	Ha	Ha	Ha	Ha	Ha	Ha	Ha	Ha	Ha	1.000
	0.000	0.804	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
Schedule high	Ha	Ha	Ha	Ha	Ha	Ha	Ha	Ha	Ha	Ha	Ho	Ha	1.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.132	0.000	
Schedule low	Ha	Ha	Ho	Ha	Ha	Ha	Ha	Ha	Ha	Ha	Ha	Ho	0.997
	0.000	0.000	0.791	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	
Composite probability													1.000

Upon increasing level of certainty the possibility of H0 hypothesis is increased. Results of able 3 indicate that the highest certainty and trustable estimation for top and bottom bounds is 98% confidence level. Having 90% and 95% confidence level has risk and may result in failure.

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Table 3 Hypothesis test results in different confidence levels

Bounds		Prediction probability: 90% Confidence ≥10% Complete	90% Confidence ≥30% Complete	90% Confidence ≥60% Complete	95% Confidence ≥10% Complete	98% Confidence ≥10% Complete
Cost	High	0.613	0.613	0.927	0.613	0.927
	Low	1.000	1.000	0.981	1.000	1.000
Schedule	High	1.000	1.000	1.000	1.000	1.000
	Low	0.997	0.981	0.997	0.997	0.997

7 Discussion & conclusion

Application of EVM in forecasting final costs with small changes has been used for 40 years and during recent 15 years some researches used it for validity of results to forecast costs of project. Result of these researches is applicable in large projects. Recent research in the field of ES shows that these indices are better than EVM schedule indices to forecast final schedule for completion of project. Also relationship for level of certainty by having possibility of trustable bounds is direct. By using 98% confidence level it is possible to provide good forecasts for top and bottom bounds at 10% schedule of completing project. At 90% confidence level it is possible to forecast top and bottom bounds at 60% schedule of completing project. In order to have equal data it is possible to say that 90% confidence level is suitable for most of the conditions. Results of studies provide the possibility of having statistical method to forecast final costs of projects.

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