The International Journal Of Engineering And Science (IJES)
|| Volume || 5 || Issue || 5 || Pages || PP -131-136 || 2016 ||
ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805

Study of Probability Distributions of Cpi and Spi in Earned Value Analysis

Priya Deshpande[1] , Harihar S. Lunge[2]
[1] *Institute of Industrial and Computer management and Research, Nigdi , Pune.(M.S.)*
[2]*Shri Shivaji Science college, Amaravati , (M.S.)*

----------ABSTRACT----------
Earned Value analysis (EVA) is the most efficient tool used for transitional review of project execution .It is helpful to project managers and management team to value the progress of project work throughout the project life cycle. The Earned Schedule (ES) is used to approximate the time or duration of project/ s for appropriate evaluation of project execution. ES also help to forecast the time required to complete the project. When combined with schedule analysis, ES can enhance the project. EVA provides the controlling tool for better decision making in project management. The paper discuss about the probability distribution of Cost performance Index (CPI) and Schedule performance Index (SPI). Best fitted distribution will help for forecasting project duration effectively. This helps the Project Manager to prevent the over budgeted cost in future. So an attempt is made to find the alternative distribution of CPI and SPI for better decision making. If the project schedule performance shows poor results then manager need to take the corrective action with the help of this tool. Weibull, Gamma and Exponentiated Exponential Distribution functions are used to study the effect of SPI on CPI. For making better decision in project scheduling, Project managers can review the parameters using EVM tool. The tool is useful in all types of civil engineering and software engineering projects.

Keywords: Earned Value Analysis(EVA), Earned Value Management(EVM), Cost Performance Index(CPI), Scheduled Performance Index(SPI) , Probability distribution.

Date of Submission: 06 May 2016 Date of Accepted: 25 May 2016

I. INTRODUCTION

In project management, it is very important to keep the completion deadlines and project cost in control .Each project should be completed in scheduled time and in budgeted cost and as per customer's dynamic expectation, is a big task. Guiding the project team in appropriate direction with proper risk assessment associated with project activities is not a very easy task. If the project manager is capable of executing the project plan as per schedule with minimum variation, then it will certainly shows better performance as the project progresses.

If some problem arises during project execution, then some reserved sources are used to compensate that impact on project. EVA minimizes the use of reserves by anticipating and estimating the performance of activities during the execution of project. The effective use of EVA and ES will create good opportunities to complete the project within time and cost.

In EVM, Earned value analysis (EVA) is used for measuring project progress in an effective way. EVA has the capability to measurements of scope, schedule, and cost collectively. Earned value is the cumulative value of work completed at that point of time. Planned value is the budgeted cost for accomplishing that activity. Actual cost is the cumulative money spent to accomplish that activity at given point of time. The Earned Value Management (EVM) indicators are Schedule Variance (SV) is used to compute the cost difference, i.e.SV= Earned Value –Planned Value, while the Cost Variance (CV) = Earned Value – Actual Cost. The Cost and Schedule Performance Indexes, CPI and SPI, respectively, are ratios. SPI is computed from the ratio, EV/PV, while CPI equals EV/AC.

The cost indicators behave differently from those for schedule. The cost indicators appear to establish a trend with some variation. Similarly, the schedule indicators initially appear to establish a trend, The study of Cost Performance Index (CPI), Schedule Performance Index (SPI), will be studied to develop the new regression model to forecast the project cost.

This paper discusses about effectiveness of Earned Value Management and Earned Schedule for better results and proper decision making in Project and risk management. By knowing the over exact function form of CPI and SPI, Project manager can work better on cost and time so as to reduce delay time. Project manager can prepare alternative contingency plan to reduce risk and avoid the delay in project completion in minimal over budget cast.

1.2.1 Problem statement: How to control the risk, delay in time and cost of the project using Earned Value Management and Earned Scheduled?

1.2.2 Research objective: The main objective of this paper is to study the best suited distribution for CPI and SPI to reduce risk, to study delay time in completion and to estimate the minimum budgeted cost.
H0: The assumed distribution of the data set is same as the observed one.
H1: The assumed distribution of the data set is not same as the observed one

II. LITERATURE REVIEW

(ES) is an extension to Earned Value Management (EVM) providing the capability of schedule analysis. ES was introduced in 2003 by Lipke in article "Schedule Is Different" [6]. "Connecting Earned Value to the Schedule," [6] "ES can be used for much more. It facilitates the ability to identify constraints, impediments, and the possibility of rework at the task level. This information is very useful for management purposes, but it does not provide performance indicators below the project level. ES can be applied to sub-levels of the project. Using this capability, the project manager can analyze schedule performance at virtually any level desired – control accounts, work packages, and critical path activities."[6]
Earned Value Management is a system which integrate the scope, cost and time management of project by using the resource –loaded project schedule and facilitate the systematic measurement of various factors involved in it.[11] EVM is endorsed by the Project management Institute [10] and is implemented by public and private organization for project progress evaluation .The main benefit of EVM is that it is applicable to all types and sizes of projects. Furthermore, the method is being used in research, instructed in several universities, and is included in recent project management texts and the newer EVM analysis tools. Presently an appendix describing ES is being prepared for inclusion in the *PMI Practice Standard for Earned Value Management* [9].

III. TERMINOLOGY AND METHODS

3.1 Project Management

There are many tools to measure the project progress and evaluate the performance of the project. But EVA and ES gives the efficient way of measuring the performance using cost performance index , schedule performance index, ,earned scheduled and the various indices associated with it. During project execution if CPI = 1, it indicates that the project is as per scheduled and completed at planned or budgeted cost. If SPI = 1 then it indicates that the project is on schedule and it will be completed in estimated time. Now the project manager is capable of estimating the delay time and over budgeted cost and can use the reserved resources to complete the project in forecasted time and with minimal use of reserved resources.

3.1.1 Elements of Earned Value Management

There are 3 major elements of project management: scope, cost and time management. In EVM the review is taken after specific interval of time and continuous monitoring is required to find the actual expenses and actual amount of work completed. The periodic comparison is done between actual expenses and planned or budgeted cost of that work done and ii) actual amount of work done and scheduled amount of work to be done in that period. In this regard, two performance indices SPI and CPI are measured in terms of four indicators using three functions.

3.1.2 Three functions of EVM:

1) Planned value,(PV) 2) Earned value (EV) and 3) Actual cost (AC)
Four factors and indicators used to in Earned value Analysis: -

1) Cost variance (CV) = EV – AC
2) Cost Performance Index (CPI) = EV /AC
3) Schedule Variance (SV) = EV – PV
4) Schedule Performance Index (SPI) = EV/ PV

Earned Value Management (EVM) has been applied to various projects from several years. It has proven to be a successful tool to project planning, tracking, and decision-making. And, the Reporting methods of EVM are proved a very good tool for communicating with management ,customers and stakeholders. From many years, in the Software Development Industry ,the EVM is applied to study the project performance . Statistical techniques are used to predict project outcomes, and past data is used for new project planning. To confidently apply EVM data for outcome prediction and project planning, data must be recorded in correct and accurate manner. It is identified that the schedule indicators of EVM fall short to provide correct and good information. To overcome this deficiency, the Software Development Industry has been applying the concept and methods of "Earned Schedule".

3.2 Earned Value Analysis

(EVA): Earned Value Analysis is computed by taking product os budgeted cost per activity and completion percentage and sum all activities in the project. Basic elements required for Earned Value Analysis are :Budget At Completion (BAC).

Total budgeted cost of project.

Planned value (PV): Earlier it is also called as Budgeted Cost of Work Scheduled (BCWS).

Budgeted cost of work performed (BCWP): Budgeted cost of work that is completed in given point of time in project.

Actual cost (AC) or Actual Cost of Work Performed (ACWP).

3.3 ES: Earned Schedule

ES method is largely measured to be a important advancement to the practice of EVM. Canada, India, Japan and other countries, as ES is being used majorly in all industries where EVM is applied for all sizes of projects.

The measure of ES has provided schedule analysis and forecasting capacity to those using EVM. ES facilitates a simple calculation for the forecasting of project duration and completion dates. In addition, it has been shown that the forecasting is improved through the application of statistical methods [16]. "Earned Schedule is a fairly new method for analyzing schedule performance; it is a derived application of Earned Value Management (EVM) data. Created three years ago, the method has propagated to several countries and been used for various types of work spanning a large and varied range of project sizes.

3.4 Forecasts

"A significant advantage from applying ES is that the method provides the capability to forecast the project duration and the expected completion date. Other methods exist; however, through studies it has been shown that ES is the most reliable forecasting method using EVM data." [15]

3.4.1 Elements of Earned Schedule Management

Various parameters used in Earned Value Management and Earned Schedule:

Actual Time (AT): This is the duration from the beginning of the project to status date.

Schedule at Completion (SAC): This is the original planned completion duration of the project.

Earned Schedule (ES): This is the duration from the beginning of the project to the date on which PV should have been equal to the current value of EV.

ES = % Complete x SAC

Time Variance (TV): The Time variance is a measure of schedule performance in time units rather than cost units.

TV = ES – AT

If TV value is negative the project is behind schedule, and if it is positive it is ahead of schedule.

Planned Value (PV) is the estimated value of the work planned to be done.

Earned Value (EV) is the estimated value of the work actually accomplished.

Actual Cost (AC) is the actual cost incurred for the work accomplished.

Cost Variance CV = EV - AC If it is negative then project is going to be over Budget.

Cost Performance Index (CPI) = EV / AC

Critical Ratio (CR) = CPI * SPI Overall Performance of the Project.

IV. PROBABILITY DISTRIBUTIONS

The basic need of knowing the exact form of distribution followed by CPI and SPI is to understand the nature of these parameters. With the help of accurate function form of CPI and SPI, forecasting models can be developed based on these distributions to reduce delay time and ultimately project cost.

Alternative distribution function forms will be available for predictive analysis which will enhance the application domain area of the predictive models based on these distribution in Project management.

Diversity in projects causes the limitation for application of specific distribution in forecasting or predictive models of project management.

To overcome this limitation, the paper discusses the set of various distributions which will be available to develop the models for different types of projects.

Following distributions are used in project forecasting models:

4.1 Gamma-Type Density Function:

The Gamma-Type Density Function is having both a shape and a scale parameter. In Gamma distribution the shape and scale parameters equal to 1, this results in the exponential density function.

The p.d.f. of Gamma distribution is:

$$f(x, \square, \square) = (\square / \square \square) x^{\square - 1} e^{- \square x} \quad ; \square , \square , x > 0$$

Applications: It is used for the variables which are one sided bounded at one side ; for example x greater than or equal to zero. The gamma density gives distribution of time required for exactly k independent events to occur, assuming events take place at a constant rate. It is used frequently in queuing theory, reliability, and other industrial applications. The parameters of Gamma distribution describes the scale and shape of the distribution. The distribution shows great flexibility for analysis for positive real data.

Comments: Erlangian, Exponential, and Chi-square distributions are special cases. The negative binomial is an similar to gamma distribution with discrete random variable.
Limitations of Gamma distribution: The distribution function or survival function cannot be expressed in a closed form if shape parameter is not integer[17].

4.2 Exponentiated Exponential distribution: The Probability density function of exponentiated exponential is defined by Gupta and Kunda (2001) with parameters α and λ as

$$f(x, \square, \square) = \square \square 1(\square e \square \square x)\square \square .e \square \square x \ 1 \text{ Where } \square, \square, x > 0$$

Here α is the shape parameter and λ is the scale parameter. When α=1 it represent the exponential family.
Application: It gives distribution of time between independent events occurring at a constant rate.
Example: Distribution of time between arrival of jobs at a machine. It is useful in framing the strategy and techniques in preventive maintenance.

4.3 Weibull distribution: Weibull distribution is more popular than Gamma distribution according to Gupta and Kundu for analysis of lifetime data. [17]
The p.d.f. of Weibull distribution is as follows:

$$f(x, \square, \square) = \square \square (x \square)\} e^{(-\square \square)}; \ \square, \ \square, x > 0$$

Application: Weibull distribution is generally useful for random variables which are left side bounded. To determine the hazard rate of a system Weibull distribution is widely used.
The Weibull distribution is often used to model "time until failure." In this manner, it is applied in actuarial science and in engineering work.
Example: Life distribution for some capacitors, ball bearings, relays, and similar variables..
Comments: Rayleigh and exponential distribution are special cases.
Advantage of Weibull distribution over Gamma distribution: Weibull distribution has an important property that distribution function of Weibull distribution can be expressed in closed form for fractional and integer value which does not hold true in Gamma distribution.
Due to this property, Weibull distribution is useful for any type of data.

Extreme value Distribution:
Application: Limiting model for the distribution of the maximum or minimum of N values selected from an "exponential-type" distribution, such as the normal, gamma, or exponential.
Example: Distribution of breaking strength of some materials, capacitor breakdown voltage, gust velocities encountered by airplanes, bacteria extinction times. These distributions are useful in Civil and Mechanical engineering project management.

V. DATA SOURCES

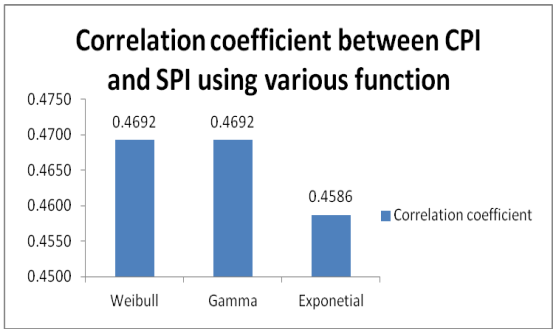
The Secondary data [14] of eight projects is used.CPI and SPI of projects are computed from the data available using SPSS version 20.The correlation between CPI and SPI is shown in the Table no.1

5.1 Data analysis for CPI and SPI in EVM and ES for performance measures
Data analysis is done using MS- Excel and SPSS Version 20 .Chi- square test is used to test the goodness of fit.
The chi-square test is used to test the validity of a distribution assumed for a random phenomenon. The test evaluates the null hypotheses
H_0: The data are governed by the assumed distribution against
H^1: The data are not drawn from the assumed distribution.

Comparison of Correlation and regression coefficient using Weibull , Gamma, and Exponential distribution.

Function	Weibull	Gamma	Exponetial
CPI and SPI			
Correlation coefficient	0.4692	0.4692	0.4586
Regression coefficient	0.4968	0.4968	0.4843

Table 1



Graph 1

The correlation is used to describe the existence of relationship between variables.
Pearson Correlation coefficients is used to evaluate the correlation between two variables is. It is denoted by 'r' and it lies between -1 and 1.
If r = 1, then there is prefect positive correlation between variables under consideration.
Gamma distribution:
The table shows 2 and 3 the results of test of Goodness of fit using SPSS version 20.

Outcome of Chi- square Test of Goodness of Fit

Table 2

Test Statistics			
	EE_SPI	weibull_SPI	Gamma_SPI
Chi-Square	.000[a]	.000[a]	.000[a]
Df	7	7	7
Asymp. Sig.	1.000	1.000	1.000
a. 8 cells (100.0%) have expected frequencies less than 5. The minimum expected cell frequency is 1.0.			

Table 3

Test Statistics			
	Weibull_CPI	Gamma_CPI	EE_CPI
Chi-Square	.000[a]	.000[a]	.000[a]
Df	7	7	7
Asymp. Sig.	1.000	1.000	1.000
a. 8 cells (100.0%) have expected frequencies less than 5. The minimum expected cell frequency is 1.0.			

From the Table No. 2 and 3, we have observed that Weibull , Gamma and EE distributions are equally suitable to know the nature of CPI and SPI. We accept the hypothesis that the distribution assumed for CPI and SPI is same as the observed one.
CPI and SPI follows the Weibull and Gamma distribution according to [11] but EE also became an alternative distribution to measure the CPI and SPI of the projects. This finding will help to measure the CPI and SPI in case of weak performance of Weibull and Gamma distribution in forecasting models of project management.

VI. CONCLUSION

Project management is concerned with planning, controlling, checking project progress, monitoring milestones, deliverables and managing risk in project execution. Earned Value Management provides the alarming signals to project manager for making strategic decisions to avoid future loss. Earned Value Management technique helps Project Manager to take corrective actions if project is not going as per schedule. It also helps to reduce the risk

involved in it by changing strategy and implementing corrective action to meet the dead lines and complete the project in budgeted cost.

From the discussion , it has be concluded that along with Weibull and Gamma distribution ,Exponentiated Exponential distribution is also most suitable distribution to study the cost and schedule performance indices .

In above discussion, Chi square test of hypothesis is applied to civil engineering project data. It has proved that Exponentiated Exponential distribution can be suitable alternative to Weibull and Gamma distribution to study the CPI and SPI in EVM.

The Chi square goodness of fit is applied to test the goodness of fit .The EE family of distribution has quite similar properties as that of 2 parameter Weibull and Gamma distributions. Weibull distribution function and Gamma distribution function showed the same result while EE family of distribution gave better results in some data sets. Also it has been observed that in few cases Weibull is better distribution in terms of fitting of the distribution to data set. Along with Weibull and Gamma distribution, EE also can be used very effectively to forecast the project cost on the basis of schedule performance index.From this discussion, we expect that EE can provide constructive result to know the exact nature of CPI and SPI in EVM.

This study confirms that EE family can be used as an alternative distribution to study CPI and SPI. Further research can be carried out to study the effect of ratio of CPI and SPI which is significantly contributing and other interdependency factors in variation in CPI and SPI. This work can be extended to compare the application of properties of Weibull, Gamma and EE family of distributions in project management tools like EVM and ES.The nature of CPI and SPI will help to develop the strategic action plan which reduces the risk of overrun and over budgeted cost of the project/s in Project Management.

VII. RECOMMENDATIONS

The present study analyses the major projects which generally operates with traditional projects management standards. It is a contribution which gives greater reliability application of EE in estimation of CPI and SPI of the projects, because of equivalence among the Weibull, Gamma and EE distribution.

We recommend that the training of implementation of EVA and ES should be given to project Managers and generate skills in the use of project management (EVA) and ES methodologies. The combination of these two methodologies caters the need of the project planning and controlling in the Project management field.

Also the projects leaders should encourage the combined application of EVA and ES methodologies which causes them to have greater certainty in the project delivery time and therefore the organization can maintain their competitive advantage in a sustainable manner.

REFERENCES

[1]. C. R. Kothari, Research Methodology, Methods and techniques, 2nd edition (2008), New age International publishers.
[2]. Hira and Gupta, Operation Research, 1st Edition (2003), S Chand Publications.
[3]. Walt Lipke. Earned Schedule, Schedule performance analysis from EVM measures, PM World Today – January 2011 (Vol XIII, Issue I), originally published in Projects and Profits magazine, India (January 2010, pp 53-61)
[4]. Kym Henderson, Education Director, Project Management Institute, Sydney Australia Chapter, Earned Schedule: A Breakthrough Extension to Earned Value Management, © Kym Henderson Page 1 of 10, Originally published as a part of 2007 PMI Asia Pacific Global Congress Proceedings – Hong Kong.
[5]. Walt Lipke, Earned Schedule Application to Small Projects, PM World Today – April 2011 (Vol. XIII, Issue IV)
[6]. Lipke, Walt. "Schedule is Different," The Measurable News, March 2003: 10-15.
[7]. Siamak Noori, Morteza Bagherpour and Abalfazl Zareei, Department of Industrial Engineering, Iran University of Science and Technology, Tehran, IranWorld, Applying Fuzzy Control Chart in Earned Value Analysis: A New Application Applied Sciences Journal 3 (4): 684-690, 2008ISSN 1818-4952© IDOSI Publications, 2008
[8]. Henderson, Kym. "Further Developments in Earned Schedule," The MeasurableNews, Spring 2004: 15-22.
[9]. PMI Practice Standard for Earned Value Management [PMI, 2005].
[10]. PMI. A Guide to The Project Management Body Of Knowledge. Upper Derby: PMI, 1996.
[11]. Byung cheol Kim,Texas A&M university, 2007," Forecasting project progress and early warning of project overruns with probabilistic methods ."
[12]. Rajesh Ganpat Virle1* and Sumedh Y Mhaske1, Int. J. Struct. & Civil Engg. Res. 2013, " MONITORING OF CONSTRUCTION PROJECTS USING EVM AND ESM TOOLS".
[13]. Ricardo M. Olano, Luis F. Alarcon and Carlos Razuri, Proceedings for the 17th Annual Conference of the International Group for Lean Construction, "UNDERSTANDING THE RELATIONSHIP BETWEEN PLANNING RELIABILITY AND SCHEDULE PERFORMANCE: A CASE STUDY".
[14]. Danial M Brandon, Jr. ,Published in Project Management Journal, June 1998, " Implementing Earned Value Easily and Effectively".
[15]. Lipke W, 2008a Project duration forecasting : A comparison of earned value management methods to earned schedule —, Cross talk 10-
[16]. Lipke,W.,O.Zwikael,F.Anbari,K.Henderson. —Prediction of project outcome, the application of statistical methods to Earned Schedule performance indexes, International Journal pf Project Management , 2009.
[17]. Rameshwar Gupta and Debasis Kundu ,"Exponentiated Exponential Family: An Alternative to Gamma and Weibull Distributions", Biometrical Journal 43(2001) 1 , 117-130.
[18]. Dr. Arsham's Statistics Site home.ubalt.edu/ntsbarsh/business-stat/opre504.htm visited on 2015-10-25.