International Journal of Economics, Finance and Management Sciences
2013; 1(1) : 54-60
Published online February 20, 2013 (http://www.sciencepublishinggroup.com/j/ijefm)
doi: 10.11648/j.ijefm.20130101.17

Cost control development under stochastic performance control

Milad Eghtedari Naeini[1,2,*]

[1]Civil Engineering Department, Pardis, Iran
[2]Pardis Islamic Azad University, Pardis, Iran

Email address:
men.cme@gmail.com (M. E. Naeini)

To cite this article:
Milad Eghtedari Naeini. Cost Control Development under Stochastic Performance Control, *International Journal of Nutrition and Food Sciences.* Vol. 1, No. 1, 2013, pp. 54-60. doi: 10.11648/j.ijefm.20130101.17

Abstract: In this research, a model to forecast project's cost will be presented with due attention to performance time and cost of the project, based on Earned Value Management (EVM) and with regarding real circumstances caused by uncertainties, risk factors and using simulation methods. All the uncertainties will be related to cost of work packages as well as its changes over time by probability distribution functions. Probabilistic distribution functions will be determined based on existing information obtained from previous projects and experts' opinion. In this model, project's activities will be classified to subgroups calling control accounts. Each of them has a controlling limit to control project's performance. Then, using simulation methods, stochastic s-curve for each control account will be determined to clarify project stochastic s-curve from total of these s-curves. When a percentage of the project has been performed, using modern methods of Earned Value Management, the performance of the project will be measured, therefore, it will be possible to adjust probability distribution functions and forecast the future performance of the project using simulation model of Monte Carlo.

Keywords: Monte Carlo Method, Probabilistic Model, Project Forecasting, Stochastic S-Curve, Project Monitoring

1. Introduction

At the beginning of a project, it is necessary to have reliable forecasts because of existence of naturally risk factors even when there is a detailed plot; these factors may affect actual performance of the project. Therefore, a project manager should constantly seek leading indices for potential problems to have an appropriate performance at suitable time. Current deviation of the plan functions as an early index of the potential deviation of duration and final cost of project of its purposes.

To control project's performance is necessary not only for supervision on time and cost variance of the actual project progress, but also it is important for suitable determination of the actual project status based on absolute forecast of final performance of the project. Such forecasts are vital for the project's manager to know if corrective actions are needed to minimize expected variances of scheduled performance.

Forecast of duration and final cost of the project will be done using two different approaches: deterministic and probabilistic. In the deterministic approach, estimation of time and final costs will be determined considering the most likely time and cost for each activity. However, in the probabilistic approach, time estimation and planned costs will be determined based on the variability of time and cost distribution for each activity [1].

The final purpose of project performance forecast is to have decision-makers in an appropriate situation achieved from giving them improved and objective pre-awareness; though the experiences of actual performance which might be the most objective and certain information resource for forecasted performances, is limited at the beginning of the project. Therefore, the biggest challenge in forecasting project's performance is to have a subjective judgment and use prior knowledge to overwhelm the lack of performance experiences achieved to be applied in first phases of the project [2].

The aim of this research is to present a probabilistic model to forecast and control the performance of the project. For this purpose, there are four steps as follows:

- Classifying activities based on their working field in subgroups called control accounts.
- Determining base cost distribution for each activity and escalation cost distribution function for each control account
- Forecasting baseline cost

• Controlling and update cost baseline using earned value management

Finally, the application of the model will be shown by giving an example.

2. Probabilistic Approach of the Cost Baseline

Simulation approach is used to produce the stochastic S-curves (SS-curves) which are based on defined variability in duration and cost of the individual activities in process. SS-curves provide probability distributions of required time and budget to complete the project in its middle points [3]. General process of the method to determine distribution of time and cost includes three steps: 1) to produce primary distribution of model's parameters; 2) to improve model's parameters based on reported data; 3) to use the improved model to forecast performance [4]. Kim and Reinschmidt (2011) suggested a probabilistic cost forecasting method using Bayesian inference and the Bayesian model averaging technique [5]. Lee et al (2012) proposed the system that assigns probability distribution functions of historical activity durations to activities, computes the deterministic and stochastic project cashflows, and estimates the best-fit probability distribution functions of overdraft and net profit of a project [6].

At first, to guess the cost of each activity a probability distribution function is supposed and the time for each activity is considered as a certain and the most likely value. Then, using simulation model of Monte Carlo, distribution of the total cost of the project is estimated. According to Central Limit Theorem, distribution of final cost is normal.

Though SS-curve does not resolve the basic problem of inability in estimation, it is preferred over deterministic S-curve for providing information according to the probable output of the project at different phases of project's progress [7].

3. Approaches to Measure Project Performance

Approaches to follow the performance are divided into two main groups: (1) Progress Based S-Curve; (2) Time Based S-Curve.

In Progress Based S-Curve, the progress is generally measured according to the amount of completed work not the time taken to finish it. The percentage of the planned work done (progress) is considered as an independent variable for being dependent only on the project scope (which is one for actual and planned performance), then time and cost are regarded as dependent variables of progress [8].

Time Based S-Curve is divided into two approaches of EVM and Work/Schedule/Cost/Integrated; in both of them time is independent variable and cost and progress are independent ones. In integrated approach, both cumulative cost and progress are shown in a diagram based on time; generally, progress (the amount of the work done) is determined based on budget which is measured on the basis of cost, time-worker or physical volume of the work. One of the advantages of this approach is showing progress and cost in one diagram [9].

Earned value management is a valuable methodology in analysis and control of project's performance. By integration of dimensions of time, cost and scope, the obtained value makes exact measurement of projects' progress possible and paves the way to on time decision to embark on improving measures. Of course, the focus is mainly on management of costs; even timing indices are calculated on the basis of the costs [10].

4. Developing Probabilistic Approach of Cost Baseline

In present model, cost distribution functions are divided into two distribution function. The first distribution is determined on the basis of the rate of contractor's productivity in each activity and is allocated to each activity which is started at the beginning of the work and called 'base cost distribution'. The second distribution is determined on the basis of price change in each activity over time because of environmental factors and is called 'escalation distribution'. Final price for each activity over time is gained by multiplying the values obtained from these functions.

In previous models, for each activity, a probability distribution function has been considered; therefore it was impossible to find that changes in costs were because of cost change over time or change of contractor's productivity in that activity. Further, to define a distribution for long term activities is accompanied with troubles in cost forecast. Considering that the cost of these activities will be with a lot of changes over time, the range of probability distribution function for these activities is more extent. It causes that the cost of a part of project which is done sooner to be under the influence of the cost of activity in future raising the price.

4.1. Base Cost Distribution Function of Activities

In this model, Beta function is applied as the base cost distribution. This distribution is based on the cost of each activity at beginning of the work and is determined by using collected data. A more dependent activity to contractor's productivity, more extent range it will have. More dependency on material leads to have a smaller range. Beta distribution has a significant application in engineering and project management [11]. Especially in modeling of random entrance process of construction duration, Beta distribution is recommended in stimulation studies [12]. Love et al (2013) used the Kolmogorov-Smirnov, Anderson-Darling, and chi-squared nonparametric tests to determine the goodness of fit of the selected probability distributions. Also the Frechet distribution is used to calculate the probability of a cost overrun [13].

The basic advantage of using beta distribution is its ability in extensive distribution of forms only with two shape parameters; also, the best distribution is for the time when there is small amount of data [14]. The Beta distribution is a continuous probability distribution on a finite interval A to B with two shape parameters α and β. The Beta probability density function and the Beta function are obtained through Equations 1 and 2 respectively:

$$f(x;\alpha,\beta)=\frac{1}{B(\alpha,\beta)}\frac{(x-A)^{\alpha-1}(B-x)^{\beta-1}}{(B-A)^{\alpha+\beta-1}} \qquad (1)$$
$$A \le x \le B$$

$$B(\alpha,\beta)=\int_0^1 t^{\alpha-1}(1-t)^{\beta-1}dt \qquad (2)$$

Shape parameters are determined by collecting data of previous projects and by virtue of Central Limitation theorem [11].

4.2. Escalation Distribution Function of Control Accounts

To model changes of activity costs over time (escalation), we suggest normal distribution. This distribution is determined on the basis of the rate of price change of an activity over time. To avoid long calculations, this function is allocated to control accounts instead of each activity. Control accounts are a type of activity grouping each of which belongs to one field. It will be explained in following sections.

Change in activity cost (escalation) may be created of different factors such as inflation, markets' conditions, articles of risk attribution in the contract, interest, and tax rates [15]. Touran et al (2006) applied normal distribution to forecast escalation rates, too [16]. In suggested model of Touran and Lopez (2006), for each stimulation repetition a random value for escalation is generated for the first period. In latter periods, obtained amounts of previous periods are regarded as mean; however, standard deviation is constant [16]. The proposed system of Hwang et al (2012) can help decision makers in the construction industry deal with changes in economic conditions and design by estimating cost escalations caused by volatile factors such as inflation [17].

In this model, to determine escalation rates of each period, first data will be collected from escalation rates of each control account in previous periods. Then, using predictor software, escalation rates in next periods will be forecasted. The obtained escalation rates are considered as the mean of normal distributions of each control account.

4.3. Determining Cost of Project

The main purpose of escalation cost modeling is to model probabilistic escalation for each control account and finally all the constructing project. This section consists of three steps: 1) to determine base coat distribution for each control account, 2) to determine distribution of escalation rate, 3) to stimulate cost distribution of escalated project.

At first step, distribution of base cost for each control account will be obtained. Base cost is estimated cost for each control account with the current price. Distribution of base account for each control account is obtained by adding base cost distributions of existing activities in each control account.

In the second step, distribution of escalation rate of control account for each period is determined. Using programs for forecasting, the process of escalation rates are determined and considered as mean of the normal distribution for each control account in every period.

In the last step, distribution of project's final cost in each period will be obtained by multiply escalation distribution of each control account by base cost distribution for existing activities in that control account; figure 1. Developed system utilizes stimulated software to implement stimulation. All the explained steps above are repeated in the two steps above for specific times. The repetition number in stimulation stage depends on confidence intervals accepted for the results.

In probabilistic methods, the word 'variance' has statistical meaning and the word 'variation' is applied to measure probabilistic performance of the project. In probabilistic approach, cost variation (CV) is the difference between the expected budgeted cost of work performed (μBCWP) and actual cost of wok performed (ACWP). At-completion cost variation (ACV) is evaluated as the difference between expected budget at completion (μBAC) and expected estimate at completion (μEAC), as shown in Figure 1.

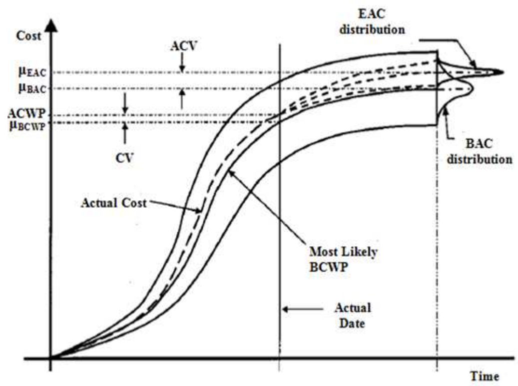

Figure 1. *Project Stochastic S-Curve.*

5. Probabilistic Model of Project Performance

5.1. Performance Monitor and Control Functions

In the method of earned value management, early indices of project performance to be bolded provide the need to improvement, including: Schedule Performance Index (SPI), this index shows that how actual progression of works is favorite or adverse, and Cost Performance Index (CPI) shows the actual process of cost consuming revealing how this cost was spent favorite or adversely determined by formulas 3 and 4 [10].

$$SPI = \frac{BCWP}{BCWS} \quad (3)$$

$$CPI = \frac{BCWP}{ACWP} \quad (4)$$

Where, BCWS: Budgeted Cost of Wok Scheduled; BCWP: Budgeted Cost of Wok Performed; ACWP: Actual Cost of Wok Performed.

For each control account, indices are allocated. Threshold and deviation scope should be determined at the stage of scheduling and used as a guide to test project performance. Managers and authorities of projects should decide where there is problem and what should be done or suggested for that. There are four general responses for deviation reports in projects: 1) ignoring that, 2) Functional improvements, 3) Replanning, 4) redesign of system [18].

After carrying out a percentage of project, future performance of project and estimates at completion (EAC) can be forecast using two approaches: 1) future performance does not depend upon past performances and will be done according to predicted schedule, so, to estimate final cost of project, relation 5 will be used. 2) Future performance will be similar to past performance, so, probabilistic estimation of project future performance will be same as past performance, so, to estimate at completion of the project, relations 6 and 7 are utilized [10].

EAC method in formula 5 accepts actual performance of project which is expressed in actual costs up to now and predicates that all the remained works will be done in budgeting rate. EAC method in formula 6 supposes that one can expect that the project will continue in future according to what it has experienced in the past. In formula 7, remained work will be done according to efficiency rate regarding two performance indices, schedule and cost. These two methods suppose negative cost index up to now and the need to provide a scheduled commitment. This method is most useful when the project schedule is a factor impacting the estimate to complete effort. Coefficients a1 and a2 are weighting coefficients of CPI and SPI (such as 50/50 and 20/80 or another relationship) depending on judgment of project management [10].

$$EAC = ACWP + (BAC - BCWP) \quad (5)$$

$$EAC = \frac{BAC}{CPI} \quad (6)$$

$$EAC = ACWP + \left[(BAC - BCWP) / (a_1 CPI + a_2 SPI) \right] \quad (7)$$

One of the useful indices is To-Complete Performance Index (TCPI) which is a calculated plan of cost performance. It should be obtained for rest of the work to provide a specific management purpose such as budget at completion (BAC) or estimate at completion (EAC). If it is observed that the budget at completion is not valuable, project manager increases predicted completion estimation for EAC. To complete performance index can be obtained by dividing the remained work into the remained invest [10].

$$TCPI = (BAC - BCWP)/(BAC - ACWP) \quad (8)$$

Finally, using these two approaches, allocated distributions to activities will be corrected and future performance of the project will be predicted using a new distribution.

5.2. Assigning Control Accounts and Control Limits

To draw an S-curve for the entire project and determine a general performance index for it brings about some problems. This approach causes that performance defects of some of the work packages or sub-projects generalize to the entire project. To resolve this problem, the project is divided into sub-groups called control accounts; then, performance of each account will be evaluate and control based on its assigned control limit [19].

Activities which are similar in working will be put in groups called control account. These groups or control accounts are determined by project manager and can be within the framework of Master Format [20]. Then, an S-curve will be drawn for each control account, so, the S-curve of the entire project will be obtained from the total of these S-curves. Further, control limits are specified for each control account. In conclusion, good or bad performance of each control account affects future performance of only the same control account not that of other control accounts. In this model, cost performance indices (CPI) and scheduling performance (SPI) are considered as control limits to evaluate performance of each control account.

5.3. Specification Limits

Specification limits are the area at both sides of expected baseline showing accepted limitations by the employer for a service or a product [21].

One of the main reasons of limiting uncertainty in some stages is to help imposing pressure on all the members and organization management to understand the importance to differentiate between ‘targets’, which can be desired, ‘expected values’, to predict output, and ‘commitments’ which provide some levels of contingency allowance amount. Targets, expected values and commitments are necessary to be specified regarding their cost, time and all the performing units.

Targets must be realistic to be believed. If optimistic targets are not believed, the expected costs will not be fulfilled. If expected costs and contingency funds are considered as targets, according to Parkinson’s Law, a part of confidence to fulfill expected values has been disregarded in advance. Further, if expected value is considered as the target, even the probability to achieve that will decrease significantly. Generally, values are specified for targets that their probability of fulfillment (or values less than those) is to 20% [22].

Commitments usually are determined as standards which in cases when they are not fulfilled, penalties will be enforced. The level of commitments is specified based on threatens evaluation and probable opportunities. The level of commitments is normal at maximally 80-90%, so, we considered 80% [22].

6. Numerical Example

In this section, the mentioned model is practiced on a project with 32 activities as a numeral example. This project is construction of a prestressed concrete girder bridge of three 30 meters spans, with a cast-in situ deck and two middle piers and two abutments [23]. Project duration is 289 days whose network scheduling is shown in figure 2. Two shape parameters α and β are determined by collecting data of previous projects and fitting distribution to data. By using fitting tool, data distribution will be coincided with appropriate beta probability distribution. Maximum and minimum cost for each activity, accounts and control limits are specified according to contract's conditions and project by project management shown in tables 1 and 2

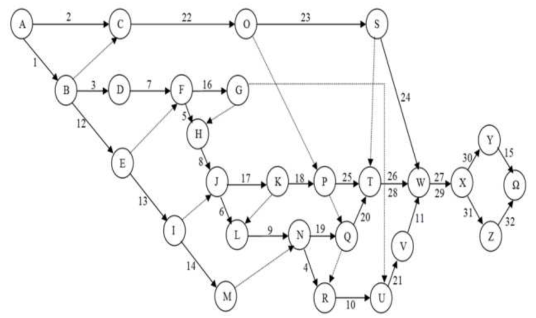

Figure 2. *Project network diagram.*

Table 1. *Project activities data.*

Activity	Predecessor	Description	Duration	Prime cost distribution ($) Maximum	Minimum	α	β
1	-	Mobilization	30	11250	6750	104	104
2	-	Girder casting yard	30	15750	9450	388	331
3	1	Drive piles in Abutment A	24	9750	5850	154	119
4	9,14	Drive piles in Abutment B	24	10125	6075	160	138
5	7,12	Drive piles in Pier no. 1	23	10125	6075	160	138
6	8,13	Drive piles in Pier no. 2	23	7500	4500	46	46
7	3	Cofferdam-install at Abutment A	15	20000	12000	338	209
8	5,16	Cofferdam remove-install Pier 1	20	26250	15750	36	34
9	6,17	Cofferdam remove-install Pier 2	20	26250	15750	36	34
10	4,18,19,22	Cofferdam remove-install Abut. B	20	26250	15750	36	34
11	21	Cofferdam remove from Abut. B	15	3750	2250	3	4
12	1	Erect falsework in Span 1	25	15000	9000	24	86
13	12	Erect falsework in Span 2	25	15000	9000	93	66
14	13	Erect falsework in Span 3	25	15000	9000	12	6
15	30	Remove falsework, all spans	20	7500	4500	8	7
16	7,12	Reinforced concrete, Abutment A	20	18750	11250	137	117
17	8,13	Reinforced concrete, Pier 1 (1/2)	20	20625	12375	39	38
18	17	Reinforced concrete, Pier 1 (1/2)	20	20625	12375	39	38
19	9,14	Reinforced concrete, Pier 2 (1/2)	20	20625	12375	39	38
20	18,19,22	Reinforced concrete, Pier 2 (1/2)	20	20625	12375	39	38
21	10,16	Reinforced concrete, Abutment B	20	18750	11250	38	37
22	1,2	Manufacture PC Girders, Span 1	70	120000	72000	200	245
23	22	Manufacture PC Girders, Span 2	65	120000	72000	200	245
24	23	Manufacture PC Girders, Span 3	65	120000	72000	200	245
25	18,22	Erection of PC Girders, Span 1	15	6750	4050	9	9
26	20,23,25	Erection of PC Girders, Span 2	15	7500	4500	6	6
27	11,24,26,28	Erection of PC Girders, Span 3	15	8250	4950	7	7
28	20,23,25	In-situ concrete deck, Span 1	15	11250	6750	14	13
29	11,24,26,28	In-situ concrete deck, Span 2	15	11250	6750	14	13
30	27,29	In-situ concrete deck, Span 3	15	11250	6750	14	13
31	27,29.	Approaches, handrails, etc	30	26250	15750	22	22
32	31	Clean up and move out	10	7500	4500	6	5

Table 2. *Performance control accounts and limits.*

Control accounts	Activity	Control limits CPI	SPI
Mobilization - Demobilization	1,32	0.95-1.05	0.92-1.08
Earth work	2	0.93-1.07	0.92-1.08
Driven piles	3,4,5,6	0.95-1.05	0.92-1.08
Caissons	7,8,9,10,11	0.95-1.05	0.92-1.08
Concrete forming	12,13,14,15	0.96-1.04	0.92-1.08
Cast in place concrete	16,17,18,19,20,21	0.96-1.04	0.92-1.08
Precast concrete	22,23,24,25,26,27	0.94-1.06	0.92-1.08
Cast decks	28,29,30	0.96-1.04	0.92-1.08
Paving	31	0.98-1.02	0.92-1.08

The mean of escalation distribution for each activity will be determined using predictor software with 5% standard deviation, as shown in table 3 [3,16].

Table 3. *Control accounts escalation.*

Control accounts	Activity	Escalation (day)			
		1-90	91-180	181-270	271-289
Mobilization - Demobilization	1,32	1.019	1.033	1.050	1.066
Earth work	2	1.019	1.042	1.065	1.087
Driven piles	3,4,5,6	1.013	1.030	1.046	1.063
Caissons	7,8,9,10,11	1.019	1.037	1.056	1.075
Concrete forming	12,13,14,15	1.018	1.035	1.053	1.071
Cast in place concrete	16,17,18,19,20,21	1.013	1.031	1.047	1.062
Precast concrete	22,23,24,25,26,27	1.019	1.037	1.056	1.075
Cast decks	28,29,30	1.018	1.031	1.047	1.062
Paving	31	1.015	1.016	1.026	1.036

Monte Carlo stimulation has been applied in this case. After 1000 trails, an estimation of expected cost to complete the project will be obtained. The forecast cost to complete the project is estimated 643987 $ with standard deviation of 627$.

The result of supervising project's performance at middle point, 100th day by applying the presented model is shown in tables 4 and 5.

Table 4. *Project performance monitoring data at day 100.*

Control accounts	Activity	Expected values	Actual values	Earned values
Mobilization - Demobilization	Mobilization	9170	8800	9200
	Sum	9170	8800	9200
Earth work	Girder casting yard	13110	12700	13200
	Sum	13110	12700	13200
Driven piles	Drive piles in abutment A	8120	8120	7800
	Drive piles in pier no. 1	6880	6500	6400
	Sum	15000	14620	14200
Caissons	Cofferdam-install at abutment A	17520	18150	16100
	Cofferdam remove-install pier 1	8960	8650	8100
	Sum	26480	26800	24200
Concrete forming	Erect falsework in span 1	10490	10416	10000
	Erect falsework in span 2	12720	12400	11960
	Erect falsework in span 3	10490	10500	10100
	Sum	33700	33316	32060
Cast in place concrete	Reinforced concrete, abutment A	15450	15200	14620
	Sum	15450	15200	14620
Precast concrete	Manufacture PC girders, span 1	95440	93600	89850
	Sum	95440	93600	89850

Table 5. *Project performance indices for control accounts at day 100.*

Control accounts		Mobilization - Demobilization	Earth work	Driven piles	Caisson	Concrete forming	Cast in place concrete	Precast concrete
Performance Index	CPI	1.04	1.03	0.97	0.9	0.96	0.96	0.96
	SPI	1	1	0.95	0.91	095	0.95	0.94

As it has been expressed in table 5, control account of 'Caisson' is passed the control limit of time and cost performance (CPI, SPI). Therefore, this control account has to be improved and rescheduled. If the purpose is to complete the project with initial budget at completion, efficiency (TCPI) should increase to 4% according to formula no. 8. By using formulas 5, 6, 7, the budget at completion can be estimated. Because this control account has crossed the scheduled performance index (SPI), using formula 7 with a coefficient of 20-80 would be an appropriate method to estimate the cost of this control account for lack of influence of time performance.

Once the project data have been updated with a corrective action, a new project performance forecast could be run in order to evaluate effects in the probabilistic schedule and the revised at-completion performance forecast. If revised at-completion cost and duration variances were improved with respect to the previous forecasted values, the proposed corrective action could be considered acceptable. The corrective performance productivity and the estimate cost forecasts for "Caissons" are shown in Table 6. Based on performance reports on a project, the project manager updates the base and escalation distributions and decides whether the project performance is under control and within acceptable control limits so that intervention is not necessary. If the project or task is deemed not in control, the project manager needs to identify the causes of the variance and take necessary actions to get the project back under control and within the acceptable performance limits.

Table 6. *Performance productivity correction and estimate cost forecasts for "Caissons" at day 100.*

TCPI	EAC (Eq. 5)	EAC (Eq. 6)	EAC (Eq. 7)	
1.04	89,583 $	96,328 $	80-20 96,161 $	50-50 95,911 $

The graphical representations of forecasting SS-curves are shown in figure 3.

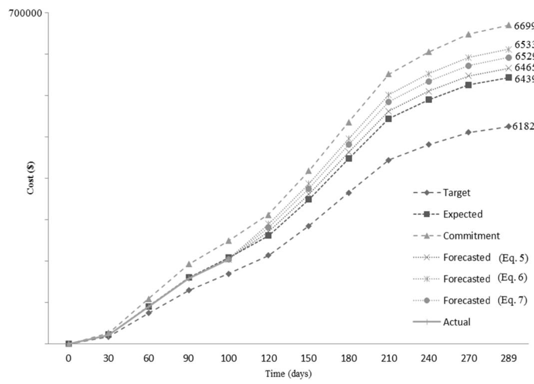

Figure 3. *The Project forecasting Stochastic S-Curves at day 100.*

5. Conclusions

In this paper cost distribution functions of activities are divided in to two distribution functions: (1) Base Cost Distribution; (2) Escalation Distribution. Ultimate cost of the activity is determined by multiplying base cost distribution by escalation distribution. This fact causes the reason of the change of activity's cost is discerned whether because of change of cost along the time or change of contractor's productivity.

The new probabilistic cost forecasting and monitoring method has been developed. It is also an adaptive method that starts with the original estimation of project cost distribution function and adjusts the influence of prior performance information on prediction as actual performance data accrues.

In this method project activities are classified into sub-groups entitled control accounts. Then, Stochastic S-Curve is obtained for each sub-group and project SS-Curve is obtained by summing sub-groups' SS-Curve. Thus, project is divided into sub-projects that cause easier and more accurate forecasting and monitoring. Moreover, control limit is determined for each control account to control project performance. If one sub-group needs modification, it just justifies and it does not affect other sub-groups.

References

[1] K.C. Crandall, and J.C. Woolery, "Schedule development under stochastic scheduling,"Journal of Construction Division, ASCE, vol.108, pp. 321–329, 1982.

[2] P. Gardoni, K.F. Reinschmidt, and R. Kumar, "A probabilistic framework for Bayesian adaptive forecasting of project progress," Computer Aided and Civil Infrastruct. Engineering, vol. 22, pp. 182–196, 2007.

[3] G.A. Barraza, E. Back, and F. Mata, "Probabilistic Forecasting of Project Performance Using Stochastic S Curves," Journal of Construction Engineering and Management, ASCE, vol. 130, pp. 25-32, 2004.

[4] B.C. kim, and K.F. Reinschmidt, "Probabilistic Forecasting of Project Duration Using Bayesian Inference and the Beta Distribution," Journal of Construction Engineering and Management, ASCE, vol. 135, pp. 178-186, 2009.

[5] B.C. Kim, and K.F. Reinschmidt, "Combination of Project Cost Forecasts in Earned Value Management," Journal of Construction Engineering and Management, ASCE, vol. 137, pp. 958–966, 2011.

[6] D. Lee, T. Lim, and D. Arditi, "Stochastic Project Financing Analysis System for Construction," Journal of Construction Engineering and Management, ASCE, vol. 138, pp. 376–389, 2012.

[7] G.A. Barraza, E. Back, and F. Mata, "Probabilistic Monitoring of Project Performance Using SS-Curves," Journal of Construction Engineering and Management, ASCE, vol. 126, pp. 142-148, 2000.

[8] M. Pultar, "Progress-based construction scheduling," Journal of Construction Engineering and Management, ASCE, vol. 116, pp. 670–688, 1990.

[9] S.A. Ward, and T. Lithfield, Cost control in design and construction.McGraw-Hill, New York, NY, USA, 1980.

[10] PMI.Practice Standard for Earned Value Management. Project Management Institute, Inc., Pennsylvania, Pa, USA, 2005.

[11] S.M. AbouRizk, D.W. Halpin, and J.R. Wilson, "Visual Interactive Fitting of Beta Distributions," Journal of Construction Engineering and Management, ASCE, vol. 117, pp. 589-605, 1991.

[12] S.M. AbouRizk, and D.W. Halpin, "Statistical Properties of Construction Duration Data," Journal of Construction Engineering and Management, ASCE, vol. 118, pp. 525-544, 1992.

[13] P. Love, X. Wang, C. Sing, and R. Tiong, "Determining the Probability of Project Cost Overruns," Journal of Construction Engineering and Management, ASCE, vol. 139, pp. 321–330, 2013.

[14] A. Touran, M. Atgun, and I. Bhurisith, "Analysis of the United States Dept. of Transportation prompt pay provisions," Journal of Construction Engineering and Management, ASCE, vol. 130, pp. 719–725, 2004.

[15] A.S. Hanna, and A.N. Blair, "Computerized approach for forecasting the rate of cost escalation," Proc., Comput. Civ. Build. Tech. Conf., pp. 401–408, 1993.

[16] A. Touran, and R. Lopez, "Modeling Cost Escalation in Large Infrastructure Projects," Journal of Construction Engineering and Management, ASCE, vol. 132, pp. 853–860, 2006.

[17] S. Hwang, M. Park, H. Lee, and H. Kim, 2012. "Automated Time-Series Cost Forecasting System for Construction Materials," Journal of Construction Engineering and Management, ASCE, vol. 138, pp. 1259–1269, 2012.

[18] H. Kerzner, Project Management: A Systems Approach to Planning, Scheduling, and Controlling. 10th ed., John Wiley & Sons, New york, NY, USA, 2009.

[19] M. Eghetdari Naeini, and G. Heravi, "Probabilistic Model Development for Project Performance Forecasting," World Academy of Science, Engineering and Technology, vol. 58, pp. 396-401, 2011.

[20] CSC., CSI, MASTERFORMAT. The Construction Specifications Institute and Construction Specifications Canada, Alexandria, VA, USA, 2004.

[21] PMI, A guide to the project management body of knowledge.4thed., Project Management Institute Inc., Pennsylvania, Pa, USA, 2008.

[22] C. Chapman, and W. Ward, Project Risk Management Processes, Techniques and Insights. 2nd ed. , John Wiley & Sons, New york, NY, USA, 2003.

[23] J.M. Antill,. and R.W. Woodhead, Critical path methods in construction practice. 4th ed. John Wiley & Sons, New york, NY, USA, 1990.