Performance risk evaluation of long term infrastructure projects (PPP-BOT projects) using probabilistic methods

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Abstract

Estimation and forecasting are critical functions of project control and management especially in long term infrastructure PPP-BOT projects. Reliable estimation and forecasting enables the PPP-BOT project manager to make better informed decisions for timely control actions. This prevents or mitigates adverse project outcomes, such as schedule delays and/or cost overruns which are critical success factors from concessionaire's perspective in these projects. Recently, a new probabilistic approach for project schedule forecasting was developed based on the Kalman filter method and the earned value method.

In this paper, these new estimation and forecasting methods for schedule and cost are extended to formulate a consistent and practical approach for long term infrastructure projects schedule, cost performance estimation and forecasting. Using a case study, a numerical example is presented to demonstrate how the new methods can be efficiently employed in real projects. Monte Carlo simulation is also conducted to evaluate the accuracy of the proposed method.

Keywords: Performance, Risk evaluation, Infrastructure projects, PPP, Probabilistic methods

Introduction

Estimation and forecasting are critical functions of project control especially in long term infrastructure PPP-BOT projects. Because it provides the project manager with early warning of potential problems, so that timely actions can be taken before it becomes too late. According to experiences in PPP-BOT projects project manager of Special Purpose Vehicle (Project Company) has essential role which is crucial for project success.

Common estimation and forecasting methods in the construction industry, for instance the critical path method (CPM) and the earned value method (EVM), are mostly deterministic and fail to provide the project manager with necessary information about the range of possible outcomes and the probability of completing the project on time and within budget. (Antill and Woodhead 1990)

Time and budget are the two most important and crucial items for long term infrastructure projects such as PPP-BOT projects, because time is restricted to concession period which is included construction period and operation period, furthermore budget is restricted to project income based on the agreeable price in concession agreement. In the most cases, EPC (Lump sum contract) is used as construction contract.

Moreover, common practices for schedule and cost forecasting in the project management community and the construction industry are dealing with schedule and cost

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separately. For instant, CPM is only for schedule performance monitoring and controlling, while EVM is recommended only for cost performance forecasting (Fleming and Koppelman 2006). CPM and EVM provide predictions based on different assumptions about the relationship between the past and future performance. In addition, the CPM requires detailed activity-level progress information while the EVM uses project-level summary performance metrics such as the Actual Cost of Work Performed (ACWP), the Budgeted Cost of Work Performed (BCWP), or "Earned Value" (EV) and the Budgeted Cost of Work Scheduled (BCWS).

This paper introduces a new probabilistic estimation and forecasting method, the schedule and cost kalman filter method (S-CKFM) for consistent prediction of project schedule cost performance based on the earned value metrics. With a long term infrastructure project (PPP-BOT project), the benefits of a probabilistic approach and the ease of implementing the S-CKFM in real projects are demonstrated.

Model formulation

The schedule-cost Kalman filter method is formulated by extending the Kalman filter method for project duration at completion (Kim and Reinschmidt 2010) to incorporate estimating and forecasting of project cost at completion. The schedule Kalman filter model (SKFM) aims at probabilistic forecasting of project duration at completion using the baseline progress curve and actual progress from periodic progress reports.

In the SKFM, the Kalman filter provides a probabilistic framework for integrating prior knowledge based on pre-construction planning and posterior observation from actual progress reports. Furthermore, inherent uncertainty in actual progress measurement is systematically taken into account within the Kalman filter method (Kim and Reinschmidt 2010).

Figure 2, shows the input requirements of the SKFM along with conceptual probability curves for the estimated duration at completion (EDAC). The SKFM starts with the planned project duration, the budget at completion (BAC), and baseline progress curve (PV curve) that depicts the cumulative project- level progress at a specific time until the project complete. Moreover, a probability distribution of the project duration is required as shown with prior *p*(EDAC).

The prior EDAC probability curve represents the degree of accuracy in the original estimate of the project duration. Once a project starts and earned value at each reporting period is being monitored and reported, the SKFM update the prior EDAC probability curve to a posterior EDAC curve. In the SKFM, the Kalman filter combines the prior information with the new information observed by a progress monitoring and reporting system with some errors in such a manner that the error is minimized statically (Maybeek 1979). This updating process is repeated after each reporting period throughout the project execution period.

Given the inputs displayed as can be calculated from figure 2, the procedures developed for the SKFM can also be used for the S-CKFM expect that the state of the system is now defined with four state variables (the time variation and the rate of time variation) in SKFM, two new system variables (the cost variation and the rate of cost variation) are added in the S-CKFM. These four variables are collectively used to monitor, track and estimate and forecast schedule and cost performance simultaneously.

Application and discussion:

In this part, practical application of the S-CKFM for probabilistic Estimation and forecasting of project duration and cost at completion is illustrated with a BOT power plant project from a less developed country. At first we focus on concessionaire selection process in a competitive tender of a BOT Project as shown in table1. Table 1 summarizes the precedence relationships among all activities along with single-point estimates of the duration and cost of each activity. Moreover, variability of activity durations and costs is considered by assuming normal distributions with means of single-point estimates shown in Table 1 and coefficient of variation of 0.2.

Act. ID	Description	Predecessor	Duration (weeks)	Cost($1000)
1	Government issues RFQ	None	1	5
2	Pre-qualification process	1	4	50
3	Government Prequalifies & issues RFQ	2	1	10
4	Tendering process	3	10	100
5	Government evaluates & shortlists	4	1	5
6	Detailed negotiations	5	6	100
7	Government selects winner-concessionaire	6	1	5

Table 1: BOT power plant Project data

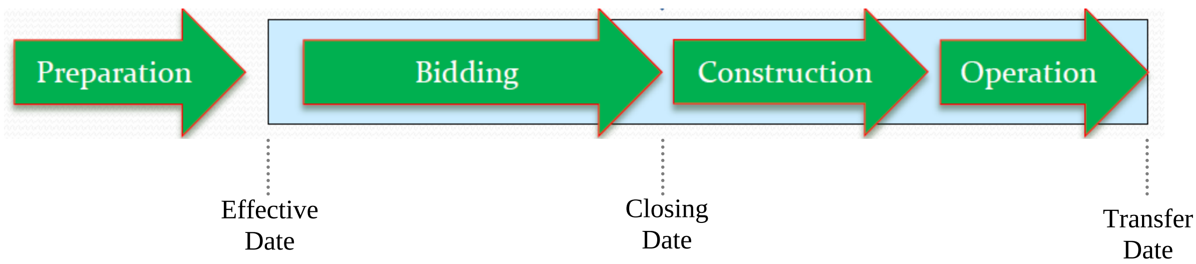

Figure1: Whole Process & phases in a BOT Project

In this case, a simulation approach is also applied and compared with the S-CKFM. Monte Carlo simulation is a technique for formal risk analysis in project scheduling and cost forecasting and estimating especially in long term infrastructure projects such as PPP-BOT projects. Based on the information in table1 and variability assumption of activity duration and costs, a simulation approach is applied to generate stochastic S-curve for earned value and for the actual cost of the PPP-BOT project. All the simulation outcomes were obtained from 200 S-curves. From this simulation results, probability distributions for the project and cost can be generated (Hulett 1996).

The main outcome of this research is to update the probabilistic estimates of project duration and cost at completion in a *progressive method*. So, the prior estimates of project duration and cost need to be updated as the project proceeds and more information accrues reveling actual performance of project periodically. Periodic progress reports, usually biweekly or monthly, which are reported to stakeholder, investors, banks, export credit agency and etc, are considered here a reliable source for forecasting and estimation future performance.

In order to demonstrate how the S-CKFM updates its predictions in real project, a pair of earned value and actual cost curve is chosen to simulate a likely actual progress of the project. Figure 3 shows earn value curve and actual cost curve used in the analysis following.

It should be noted that, in theory, each progress curve has the same probability of becoming the actual progress of the project. Therefore, the randomly generated S-curves in figure 3 must be considered one of the probable outcomes of the project due to network structure and the variability of activity durations and costs. Figure 3 also shows the baseline progress curve against which the earned value and actual cost are compared.

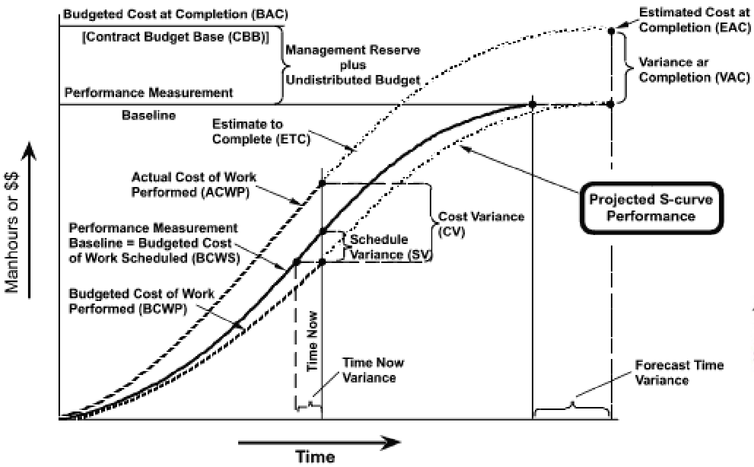

Fig 2: Schedule-Cost Kalman Filter estimation and forecasting

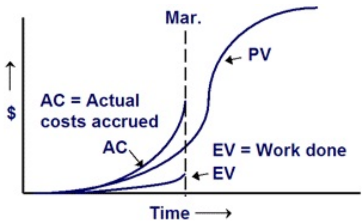

Fig 3: Progress curve

Network Simulation Results

First, the network schedule simulation is applied using the data available at week 10. At this point, actual finish dates of the finished activities are used to determine the status of the project in terms of EV and AC. then, with the remaining activities, including ongoing activities, the simulation approach is again applied to generate two groups of 1000 likely progress curves of EV and AC, respectively.

From the outcomes, the expected value and standard deviation of the estimated duration at completion (EDAC) and the estimate at completion (EAC) at week 10 can be calculated. Of course, this progressive simulation approach can be applied after each reporting period, with new EV, and AC values.

Kalman Filter Estimation and Forecasting Method

The same project network was analysis with the S-CKFM. In contrast to the simulation approach, S-CKFM does not require detailed activity-level data. Major input is the three basic performance indicators in the earned value method (PV, EV, and AC) and prior estimates of the project duration and cost at completion. The prior probabilistic estimates can be made in various ways (Kim and Reinschmidt 2009; 2010).

A practical way of estimating the initial uncertainty in project duration and budget is the three-point method (or PERT estimate), which uses the optimistic value, the most likely value, and the pessimistic value. In this paper, the three-point method is adopted and the value of each parameter is determined from preliminary simulation analysis.

Conclusion

In this paper, a new probabilistic method for forecasting of project duration and cost at completion during the execution period is introduced. The schedule and cost Kalman filter estimation and forecasting method (S-CKFM) is formulated by extending a previous research by the author about for probabilistic estimation and forecasting of project duration at completion. From a practical point of view, the S-CKFM is an intuitive method which can be efficiently incorporated to any EVM-based performance reporting systems without additional burden of data collection or data analysis.

With a BOT power plant project, the S-CKFM is successfully applied to provide reliable predictions about the project duration and cost at completion. A comparison with the simulation results revealed that the S-CKFM provides reliable forecast without any requirements for extensive data acquisition for activity-level progress as the simulation approach does.

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