Project Control Using a Bayesian Approach

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INTRODUCTION

Forecasting is a critical activity in project management: relying upon sound estimates to complete, the project manager can steer the ongoing project in order to meet specific time and cost objectives (Dvir and Lechler, 2004). Moreover, foresight is needed to avoid constantly being forced to manage emergencies, since emergency implies a reactive action. Without anticipation there can be no rationale in making a decision and what we can do is just to be adaptable to changing circumstances.

Planning and forecasting are strictly intertwined both in the early stage when the project baseline must be determined and throughout the entire project life cycle when the project baseline has to be followed (Hogarth and Makridakis, 1981). Forecasting feeds (re)planning (corrective measures are taken based on forecast) and (re) planning feeds forecasting (corrective measures will influence the future).

In the project control process the role of the Estimate to Complete (ETC) is critical, since the information drawn from the ETC, compared with the project baseline, should highlight the need for and the type of corrective action that may improve the project performance. In fact, ETC is the base for any effective corrective action. This approach to project control corresponds to a *feed-forward* type control loop (Anbari, 2003; Christensen, 1996), since the forecast informs present-day decisions.

From a recent survey (Merrow, 2011), analyzing the data of more than 300 global mega-projects, it appeared that in 2010 65% of the industrial projects with a minimum budget of 1 billion US dollars did not succeed in meeting the objectives of cost, duration and quality. However, it remains an open question whether these failures are due to a poor performance during the execution stage or to a lack of forecasting accuracy during the planning and control process. In the former case, both positive and negative deviations from the project baseline should be expected. On the contrary, a systematic overrun in terms of cost and/or time may be easier explained as a weakness in the forecasting process since the beginning of the project. As a consequence, the forecasting process plays a critical role.

To explain the accuracy of the forecasting process, some considerations must be developed about the knowledge sources feeding the process, the forecasting techniques to be applied and the mitigating measures taken in order to avoid possible biases affecting the forecasting process.

As shown in Figure 1, at a given time of the project duration, i.e. the time now (TN), a certain amount of the work will be already completed (Work Completed, WC), while the rest of the work will be ahead, corresponding to the Work Remaining (WR). The cost and time performance related to the Work Completed will be known, while a forecast will have to be developed for the WR.

It should be noted that both the *accuracy of the forecast about WR* and the *impact of the corrective actions* that may be implemented based on the forecast depend on the progress of the project at the Time Now. The effectiveness of the corrective actions is greater in the early stages of the project execution and progressively diminishes while progress increases: in fact, as progress increases, the degrees of freedom available to steer the project tend to reduce progressively. On the other hand, the capability to forecast the project final duration and the final cost follows an opposite trend. In fact, at an early time in the execution phase, the knowledge available to the decision maker is

DOI: 10.4018/978-1-5225-2255-3.ch493

Figure 1. Estimation at completion at time now (internal view)

scant and rapidly evolving; therefore, the capability to provide a *reliable forecast* is jeopardized, particularly if the forecast is based only upon the knowledge related to the ongoing project.

Drawing on a set of case studies (Caron et al., 2013a; Caron et al. 2013b, Caron et al., 2016), this paper proposes a Bayesian approach to determine the estimate to complete for a project. The paper has a twofold objective:

- To identify all the available knowledge in order to improve the forecasting process;
- To develop a Bayesian approach in order to integrate in a formal and rigorous way the diverse knowledge sources.

The second section analyzes the different knowledge sources available; the third section addresses the issue of possible bias during the forecasting process; the fourth section introduces the Earned Value Management approach frequently used to determine the estimate at completion for a project, both in terms of cost and time; the fifth section introduces the general structure of a Bayesian model and eventually some results are given stemming from the application of the model to some projects in the oil and gas industry.

BACKGROUND

As mentioned above, all the knowledge available should be used in order to address the planning and control process for a complex project (Caron, 2014; Reich et al., 2014; Schindler and Eppler, 2003).

In general, the knowledge available to the project team may be classified in two ways: explicit/ tacit and internal/external. Explicit external knowledge corresponds to data records about projects completed in the past, including measures of forecasting capability in terms of the difference between estimated and actual final cost and duration. Taking into consideration past experience should mitigate possible "optimistic" bias in estimating future project performance (Lovallo and Kahneman, 2003). Explicit internal knowledge corresponds to data records concerning the work completed WC, allowing for an evaluation of project performance at Time Now. Tacit external knowledge concerns the similarities between the current project and some past projects in order to transfer past data to the current project. Tacit internal project is about possible events/situations affecting the project's work remaining.

In fact, relying only on data records related to WC while developing a forecast could be misleading, since it would be similar to driving a car whilst looking just in the rear view mirror, so making it impossible to dodge the obstacles that may lie on the route ahead. It should be noted that the contribution deriving from the data records to the estimate at completion may be considered reliable just for the near future and losing progressively accurateness if a more extended horizon is considered. Since the reliability of the estimation based just on data records rapidly decreases, so the