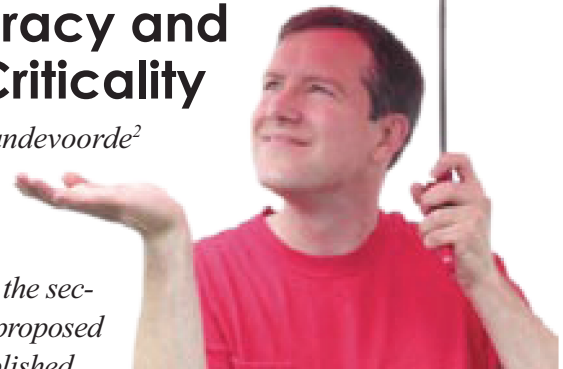


## Earned Value Forecast Accuracy and Activity Criticality

By Mario Vanhoucke<sup>1</sup> and Stephan Vandevoorde<sup>2</sup>

### Abstract

*This paper presents new simulation results on the forecast accuracy of earned value based metrics to predict a project's final duration. This is the second paper in a series of papers based on the simulation study initially proposed by Vanhoucke and Vandevoorde (2007a). In a previous manuscript published in the Measurable News (Vanhoucke and Vandevoorde, 2007b), it has been shown that the earned schedule method outperforms, on average, the more traditional earned value based methods to predict the final duration of a project, both for early and late projects. In the current manuscript, the simulation study is extended to new simulation scenarios that measure the influence of inaccuracies in the planned duration estimates for critical and non-critical activities on the accuracy of forecasting methods.*



Since the introduction of the earned schedule method, initially proposed by Lipke (2003), both researchers from the academic world as well as managers dealing with real-world practical projects have critically analyzed the forecasting power of the new method for predicting a project's final duration.

Most research analyzed data from real-life projects and concluded that the earned schedule method can better predict the total duration of a project [see e.g. Vandevoorde and Vanhoucke (2006); Henderson (2004, 2005)]. In a previous edition of the Measurable News [see reference Vanhoucke and Vandevoorde (2007b)] we have tested the forecast accuracy of three methods to predict the final project duration on a large and diverse set of fictive projects. We basically reviewed the results of the simulation study published in Vanhoucke and Vandevoorde (2007a) and concluded that the earned schedule method outperforms, on average, the two other methods [the planned value method (Anbari, 2003) and the earned duration method (Jacob, 2003)].

In this paper, new results from the same simulation study are presented. These results focus on the accuracy of the three methods for different scenarios measuring the activity criticality. The outline of the paper is as follows. Section 2 reviews the results of the previous simulation study and presents four new

simulation settings. Section 3 compares the new forecast accuracy results with the ones previously discussed in Vanhoucke and Vandevoorde (2007b).

### Simulation Scenarios

The simulation study uses fictive projects for which an initial baseline schedule is constructed based on the straightforward critical path based calculations. The set of projects is the same as used in the Vanhoucke and Vandevoorde (2007a) research and contains 4,100 project networks with 30 activities and a varying number of precedence relations. During the simulation runs, the actual activity durations may differ from their original planned values, leading to an overall project finishing early or late. During each simulation run, the final project duration is predicted along the review periods during the life of the project by means of the EAC(t) formulas of the three forecasting methods, i.e. the planned value method PV (Anbari, 2003), the earned duration method ED (Jacob, 2003) and the earned schedule method ES (Lipke, 2003). Each simulation run contains 100 repetitions to guarantee convergence. Table 1 shows the four simulation scenarios used in the current paper. The second and third columns describe the change in the original planned duration for critical and non-critical activities (increase, no change or decrease), while the last column shows the simulated effect of these changes on the real project duration.

<sup>1</sup>Ghent University, Tweekerkenstraat 2, 9000 Gent (Belgium) and the Vlerick Leuven Gent Management School, Reep 1, 9000 Gent (Belgium), mario.vanhoucke@ugent.be

<sup>2</sup>Fabricom GTI Suez, Rue Gatti de Gammond 254, 1180 Brussel (Belgium), stephan.vandevoorde@fabricom-gti.com

**TABLE 1:** FOUR SIMULATION SCENARIOS FOR CRITICAL AND NON-CRITICAL ACTIVITIES.

SIMULATION RUN	CRITICAL ACTIVITIES	NON-CRITICAL ACTIVITIES	AHEAD OR DELAY?
1	Decrease or no change	Decrease or no change	Project ahead of schedule
2	Increase or no change	Increase or no change	Project delay
3	Decrease	Increase	Project ahead of schedule
4	Increase	Decrease	Project delay

**SCENARIO 1:** When both the critical and non-critical activities are performed faster than expected or without any change compared to the planned duration, the SPI and SPI(t) indicators will report an excellent performance (i.e.  $SPI > 1$  and  $SPI(t) > 1$ ) and the project will end sooner than expected.

**SCENARIO 2:** Similar to scenario 1, a project with delays for all activities will end later than expected and the schedule performance indicators will report a project delay during project execution.

These two scenarios have been tested in the study of Vanhoucke and Vandevorde (2007b) and the results have shown that the earned schedule method outperforms both the planned value and earned duration method for early (scenario 1) and late (scenario 2) projects. Moreover, the study has shown that the best forecast accuracy can be reached when the EAC(t) is calculated under the assumption that future project performance follows the current SPI or SPI(t) trend. Last, the results have also shown that the earned schedule method is stable along the progress of the project, and certainly at the end of the project, where the other methods show an unreliable trend.

The two following scenarios have not been simulated yet and can be interpreted as follows:

**SCENARIO 3:** when critical activities are performed faster than expected and non-critical activities show delays, it might be possible that the schedule indicators report a low project performance ( $SPI < 1$  and  $SPI(t) < 1$ ) although the project finishes sooner than expected. In this case, many non-critical will be delayed within their activity slack (such that it does not lead to an overall project delay) while only a few critical activities are performed slightly faster than expected. Consequently, the schedule performance indicators will report a false warning signal predicting a project delay which turns out to be the opposite at the end of the project (project ahead of schedule).

**SCENARIO 4:** Similar to scenario 3, this scenario simulates project progress where the schedule performance indicators report a false warning signal. Tiny delays in only a few critical activities combined with faster performance in many non-critical activities obviously leads to a total project delay, while the schedule performance indicators might report the opposite.

These last two scenarios have been inspired by Jacob and Kane (2004) who argue that earned value management indicators have to be calculated at the activity level and not at higher WBS levels. They illustrate their statement with a simple example and conclude that small delays in critical activities combined with much faster progress in non-critical activities can result in a false SPI value (in this case,  $SPI > 1$ ), and hence, the SPI reports can possibly mask potential problems leading to wrong forecasts. Hence, the authors claim that the only way to obtain accurate schedule forecasting results is by applying the predictive methods on a single activity rather than on groups of activities. In the current study, we measure the earned value based metrics at the activity level, but the schedule performance indicators are calculated at the project level (e.g. the SPI is equal to the total earned value divided by the total planned value of all activities at the current review moment). Although we realize that this approach might potentially mask certain project problems or opportunities (cf. scenarios 3 and 4), it is our goal to test the influence of these false SPI values on the accuracy of the three forecasting methods. The results of the scenarios are discussed in the next section.

## Simulation Results

Figure 1 displays the forecast accuracy results of the simulation runs for all four scenarios. The accuracy has been measured as the percentage deviation between the actual project duration, measured at the end of each simulation run, and the average

of all duration forecasts  $EAC(t)$  measured during the progress of the project. Positive percentage deviations denote an average over-estimation of the real duration and negative percentages denote an average underestimation of the real project duration.<sup>3</sup>

The results in the figure confirm the previously reported results that the earned schedule method (ES) outperforms on average both the planned value (PV) and earned duration (ED) methods. Both scenario 1 and scenario 2 clearly show a better forecast accuracy close to 0%.

Scenarios 3 and 4, however, clearly show the power of the ES method, compared to the PV and ED methods. These scenarios have been simulated as special scenarios where the schedule performance indicators report a false warning signal. Figure 1 shows that this false warning signal has an immediate effect on the accuracy of the  $EAC(t)$  measures, with the ES method showing the lowest accuracy. Scenario 3 reports a project delay during its progress, although the project ultimately finishes early. Hence, the indicators clearly show an overestimation (due to the false SPI and  $SPI(t)$  warnings). In these cases, the forecasts are no longer reliable, which explains the low performance of the ES method. Scenario 4 is similar, but opposite, leading to an underestimation of all forecasting methods, where the ES method has the lowest performance illustrating the unreliable character of the method for this scenario. Consequently, since the  $SPI(t)$  indicator is a reliable measure for the project performance along all stages of the project life cycle, the forecast accuracy is eventually determined by the reported  $SPI(t)$  values along the life of the project. In case the  $SPI(t)$  reports false warning signals (cf. scenarios 3 and 4), the forecast accuracy suffers from this error, resulting in a poor predictive quality of the  $EAC(t)$  for the ES method. Since the SPI indicator is less reliable compared to the  $SPI(t)$  (certainly at the late stage of the project, where the SPI indicator tends to go to one, regardless of the real project performance),

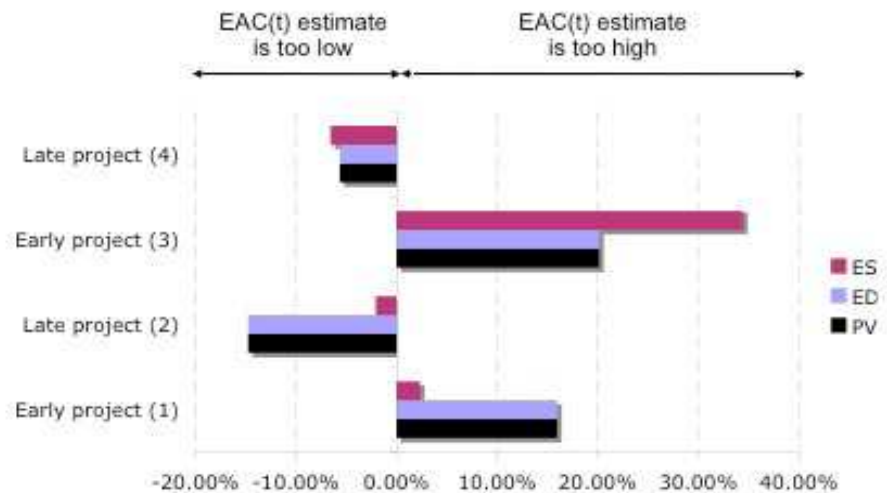


FIGURE 1: FORECAST ACCURACY ( $EAC(t)$ ) UNDER- OR OVERESTIMATIONS FOR THE FOUR SCENARIOS.

the forecast accuracy is more a random guess having an average forecast accuracy which does not vary as much between the four scenarios as for the ES method. Hence, the difference between correct SPI reports (scenarios 1 and 2) and false SPI reports (scenarios 3 and 4) is less than for the  $SPI(t)$  indicator in the ES method.

## Conclusions

In this paper, the forecast accuracy of three methods has been simulated under four different scenarios. The results show that under 'normal' circumstances the earned schedule method has the best performance, leading to small deviations between the duration forecast and the final project duration. Normal circumstances are defined as project progress where the schedule performance indicators report reliable results during the life of the project.

However, special scenarios have been simulated to force the schedule performance indicators to report unreliable results. Under these 'unreliable' circumstances, the earned schedule method performs worse than other methods. This illustrates the power of the earned schedule method, as the method's forecast is strongly based on the schedule performance indicator  $SPI(t)$ . Consequently, the ES can be considered as a good forecasting predictor, forecasting the final project project duration in an accurate way

<sup>3</sup>□

and hence, there was no difference between under- and overestimations.

when the schedule performance indicator SPI(t) reports a correct warning signal about the current project performance.

## Acknowledgements

We acknowledge the support by the research collaboration fund of PMI Belgium received in Brussels in 2007 at the Belgian Chapter meeting.

## References

- Anbari, F. (2003). Earned value project management method and extensions. *Project Management Journal*, 34:12–23
- Henderson, K. (2004). Further developments in earned schedule. *The Measurable News*, Spring:15–17, 20–22.
- Henderson, K. (2005). Earned schedule in action. *The Measurable News*, Spring:23–28, 30.
- Jacob, D. (2003). Forecasting project schedule completion with earned value metrics. *The Measurable News*, March:1, 7–9.
- Jacob, D. and Kane, M. (2004). Forecasting schedule completion using earned value metrics revisited. *The Measurable News*, Summer:1, 11–17.
- Lipke, W. (2003). Schedule is different. *The Measurable News*, Summer:31–34.
- Vandevoorde, S. and Vanhoucke, M. (2006). A comparison of different project duration forecasting methods using earned value metrics. *International Journal of Project Management*, 24:289–302.
- Vanhoucke, M. and Vandevoorde, S. (2007a). A simulation and evaluation of earned value metrics to forecast the project duration. *Journal of the Operational Research Society*, 58:1361–1374.
- Vanhoucke, M. and Vandevoorde, S. (2007b). Measuring the accuracy of earned value/earned schedule forecasting predictors. *The Measurable News*, Winter:26–30.

## Author Biographies



Dr. Mario Vanhoucke is an associate professor at the Ghent University and the Vlerick Leuven Gent Management School (Belgium). He teaches Project Management, Business Statistics, and Applied Operations Research. He is the program director of the Commercial Engineers and

the advanced Master in Operations and Technology Management. He is partner of the company OR-AS ([www.or-as.be](http://www.or-as.be)), where he is involved in the development of a project scheduling software package with earned schedule tracking capabilities. His main research interest lies in simulation and optimization models in project scheduling and scheduling in the health-care sector. He is advisor to various PhD projects, in collaboration with different university hospitals. He has articles published in international journals, such as *Annals of Operations Research*, *Management Science*, *Operations Research*, *The Accounting Review*, *International Journal of Production Research*, *Journal of the Operational Research Society*, *Journal of Scheduling*, *International Journal of Project Management*, *Project Management Journal*, *European Journal of Operational Research*, and *Lecture Notes on Computer Science*.



Stephan Vandevoorde is a division manager in Fabricom GTI Suez, for airport baggage handling systems. He has an industrial engineer diploma and is a member of PMI, Project Management Belgium, PMI College of Performance Management, and director of programs of the PMI Belgium Chapter. He has been working on a number of large-scale international projects (Europe, Asia) across many industries, including construction, retail, automotive, and airline. Stephan has extensive experience in using EVM techniques to assist in evaluating and predicting project performance, including the newly developed earned schedule concept. On several occasions, he has given presentations on different project management topics for V.I.K., Vlerick Management School, Ghent University, and Boston University, Brussels. In collaboration with the Institute for Business Development, Stephan is docent for the courses Earned Value Management and Project Management for the Construction industry.