Forecasting a Project's Duration under Various Topological Structures

Mario Vanhoucke[1] and Stephan Vandevoorde[2]

Abstract

In this third paper about the simulation study to measure the accuracy of three earned value based forecasting techniques to predict the final project duration, we elaborate on the influence of the degree of project criticality on the quality of project duration predictions. Based on simulation results of Vanhoucke and Vandevoorde (2007b) and the network paper of Vanhoucke et al. (2008), we present an indicator to measure the structure of a project network, defined by the distribution of activities and the amount of precedence relations and show that this measure clearly influences the accuracy of duration forecasting. Rather than drawing results on a small set of real-life projects, we present simulation results for a large and diverse set of different project networks to be able to draw general results that hold for a wide variety of projects in practice.

Introduction

In this third paper about a simulation study to measure the forecast accuracy of earned value based metrics to predict a project's final duration, we elaborate on our search to factors that might influence the accuracy of the forecast.

Indeed, the forecast accuracy depends on numerous often unknown factors. In this article, we conjecture that the structure of the project network is an important influencing parameter, which will be discussed and tested by means of project simulations initiated by Vanhoucke and Vandevoorde (2007b). Other results of the simulation study have been discussed in previous editions of *The Measurable News*: a first study focused on the general forecast accuracy of projects finishing early and late (Vanhoucke and Vandevoorde, 2007a) while a second study presented forecasting results for projects under different degrees of criticality (Vanhoucke and Vandevoorde, 2008).

In this article, we extend the simulation study by measuring the influence of the topological structure of the project network on the average duration forecast accuracy of earned value based predictive methods. The outline of this manuscript is as follows. In "Characterization of Project Networks", the settings of the simulation study are briefly outlined. The "Simulation Results" section discusses the results for early and late projects, and the "Conclusion" section gives overall conclusions and future research avenues.

Characterization of Project Networks

The simulation study uses fictitious projects for which an initial baseline schedule is constructed based on the straightforward critical-path-based calculations. The set of projects contains 4,100 project networks with 30 activities and a varying number of precedence relations. The projects have been generated by the RanGen network generator (Demeulemeester et al., 2003; Vanhoucke et al., 2008) to vary the topological structure of the project network, resulting in a large and diverse set of projects.

The topological structure of a network is defined by the distribution of the activities in the network and the precedence relations between these activities. Projects with various network structures have been generated that differ substantially from each other to draw general conclusions that hold for a wide variety of projects.

[1]*Ghent University, Tweekerkenstraat 2, 9000 Gent (Belgium) and the Vlerick Leuven Gent Management School, Reep 1, 9000 Gent (Belgium), mario.vanhoucke@ugent.be.*

[2]*Fabricom GTI Suez, Rue Gatti de Gammond 254, 1180 Brussel (Belgium), stephan.vandevoorde@fabricom-gti.com*

We used four network structure indicators to assure diversity in their project set, originally investigated in the PhD of Vanhoucke (Vanhoucke, 2001) and further developed in a research project in collaboration with the Technical University of Lisbon (Portugal). These four indicators are as follows:

Serial/parallel indicator SP: measures how closely the project network lies to a 100% serial or 100% parallel network. This indicator can be considered as a measure for the amount of critical and non-critical activities in a network.

Activity distribution indicator AD: measures the distribution of the activities along the network, from a uniformly distribution across the project network to a highly skewed distribution (e.g., a lot of activities in the beginning, followed by only a few activities near the end). Consequently, the AD indicator serves as a measure for the workload variability.

Length of arcs indicator LA: measures the tightness of each precedence relation between two activities as the distance between two activities in the project network.

Topological float indicator TF: measures the degrees of freedom for each activity as the amount of slack or float an activity has.

In this article, results for only one indicator, the serial/parallel SP indicator, are presented in detail[3]. The motivation for this choice lies in the remark given by Jacob and Kane (2004) in an article in *The Measurable News* who correctly claimed that the best forecasting accuracy can be reached by calculating the earned value metrics on the activity level (and not on higher WBS levels). They show on a simple project example that small delays in critical activities and huge accelerations in non-critical activities might mask potential problems since the schedule performance indicator SPI might report good project performance while the opposite is true. Hence, they implicitly conjecture that this potential error is influenced by the degree of criticality in the project network, which can be measured by the SP

indicator as previously explained. Indeed, a more serial network results in a lot of critical activities (in the extreme, a 100% serial network contains only one path that is undoubtedly the critical path consisting of only critical activities), while a more parallel network might result in a lot of non-critical activities. In the next section, we present the details and results of the simulation study on a large set of projects by varying the degree of criticality of a project measured by the SP indicator.

Simulation Results

This section displays results of the simulation runs on a set of projects where each project has a different degree of criticality. More precisely, the networks have been generated for different values of the SP indicator, going from a complete serial project network to a complete parallel network, including all possible SP values in between. In doing so, we have the guarantee that our project dataset contains a very diverse set of projects, each having a different degree of criticality.

Each project activity has a randomly generated activity duration and cost. During the simulation runs, the activity durations may differ from their original planned values, leading to an overall project finishing early or late. During the simulations, 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. The simulation settings are similar to the study presented in the Summer 2008 edition of *The Measurable News* (Vanhoucke and Vandevoorde, 2008).

Figure 1 displays the results of the simulation runs for early (left) and late (right) projects for the three forecasting methods PV, ED, and ES. The horizontal axis measures the SP indicator, and hence, displays results for parallel to serial networks. The vertical

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[3]*Mathematical calculations of the indicators are beyond the scope of this manuscript. For details, we refer to Vanhoucke et al. (2008).*
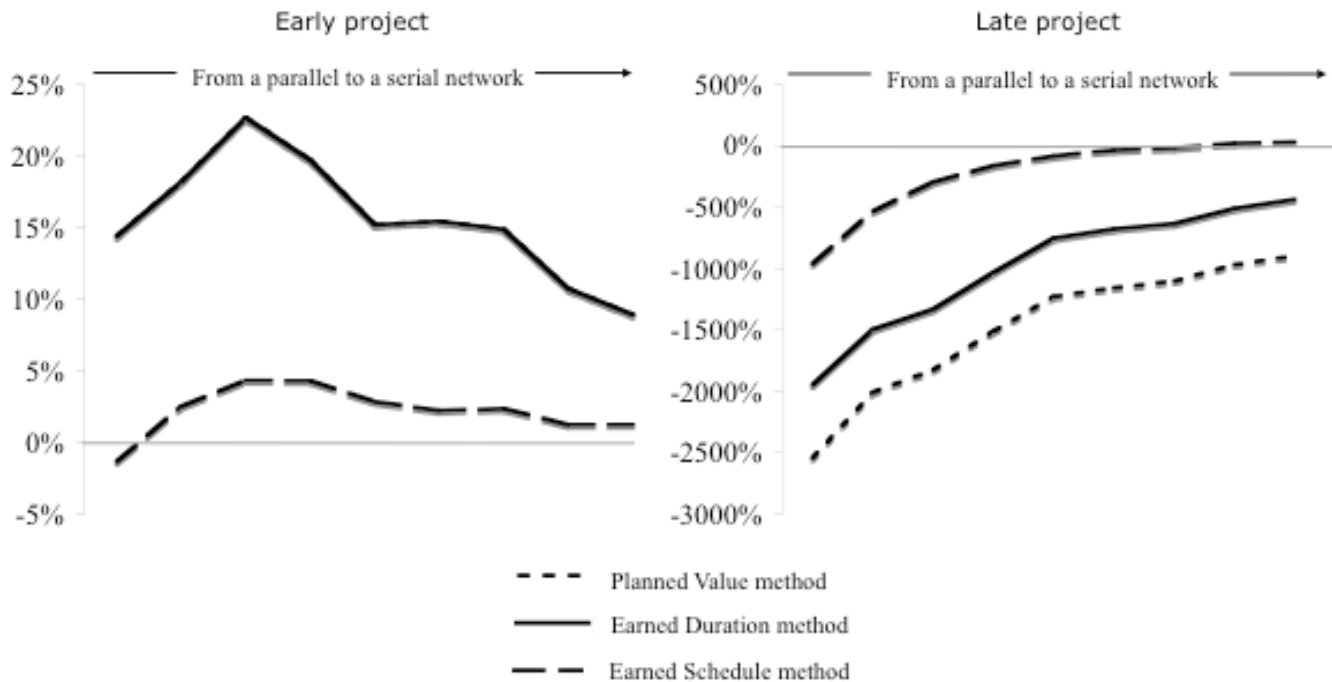
Figure 1. Duration forecast accuracy for early and late projects for three methods.

axis measures the forecast accuracy as the percentage deviation between the average predicted project duration along the project life cycle (i.e., the EAC(t) formulas) and the final (simulated) project duration. Negative values indicate that the predictions are, on average, underestimations for the real project duration, while positive values indicate average overestimations of the final project duration. Obviously, the closer the values lie to zero, the better the forecast accuracy is.

The results of the table can be summarized as follows:

- The ES method clearly outperforms the two other duration forecasting methods (PV and ED), both for projects finishing early and late, which confirms the previously found results in Vanhoucke and Vandevoorde (2007 a, b).
- The ED method is similar to the PV method for early projects and differs for late projects. Intuitively, the PV forecasting metric is measured as PD / SPI during the whole life of the project; however, the ED metric equals PD / SPI until the project exceeds the original baseline schedule (i.e., the planned duration PD) and becomes

equal to AD / SPI (with AD > PD the actual duration of the project) from the moment the project is late.

- The more serial the project network, the better the average forecast accuracy of all duration forecasting methods. This conclusion is intuitively clear because more serial networks involve more critical activities, and hence, the probability that the schedule performance indicators masks potential errors and/or opportunities due to changes in non-critical activities decreases.

As a summary, this third simulation study confirms previous results that the earned schedule method outperforms the planned value and the earned duration methods when forecasting the final duration of the project. Moreover, these new results show that the forecast quality depends on the structure of the project network. The higher the degree of criticality of the various project activities (expressed in more serial networks), the more reliable the project duration forecasts made during the project progress will be.

Conclusions

In this article, we have shown that the topological structure of a project network, measured as the closeness of a project network to a serial or parallel network, clearly determines the forecast accuracy of earned value based metrics to predict a project's final duration. A more serial network contains, on average, more critical activities, which results in a better forecast accuracy compared to more parallel networks.

In the near future, our research will focus on other possible determinants that affect the forecast accuracy of earned value forecasting metrics. More details about the simulation methodology, the calculations of the network indicators, and many more results have been summarized in the book *Measuring Time* and implemented in the software tool ProTrack. More information can be found at www.protrack.be.

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References

Anbari, F. (2003). Earned value project management method and extensions. *Project Management Journal*, 34:12–23.

Demeulemeester, E., Vanhoucke, M., and Herroelen, W. (2003). A random network generator for activity-on-the-node networks. *Journal of Scheduling*, 6:13–34.

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.

Vanhoucke, M. (2001). Exact algorithms for various types of project scheduling problems: nonregular objectives and time/cost trade-offs. PhD thesis, Katholieke Universiteit Leuven.

Vanhoucke, M., Coelho, J., Debels, D., Maenhout, B., and Tavares, L. (2008). An evaluation of the adequacy of project network generators with systematically sampled networks. *European Journal of Operational Research*, 187:511–524.

Vanhoucke, M. and Vandevoorde, S. (2007a). Measuring the accuracy of earned value/earned schedule forecasting predictors. *The Measurable News*, Winter:26–30.

Vanhoucke, M. and Vandevoorde, S. (2007b). 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. (2008). Earned value forecast accuracy and activity criticality. *The Measurable News*, Summer, 3:13–16.

About the Authors

Prof. 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 programme 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) and is co-developer of ProTrack (www.protrack.be), a new, project-scheduling software tool 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 of various PhD projects in collaboration with different university hospitals. He has articles published in international journals such as *Annals of Opera-*

tions 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 division manager by Fabricom GTI Suez, for the department 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 PMI Belgium Chapter. He has been working on a number of large-scale international projects (Europe, Asia) across many industries including construction, retail, automotive industry, airport technics. Stephan has extensive experience in the use of 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, 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.