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Measuring time – A project performance simulation study

Introduction

Earned Value Management systems have been set up to deal with the complex task of controlling and adjusting the baseline project schedule during execution, taking into account project scope, timed delivery and total project budget. It is a well-known and generally accepted management system that integrates cost, schedule and technical performance. It is mainly used to calculate cost and schedule variances, performance indices and forecasts of a project's final cost and duration. The earned value method provides early indications of project performance to highlight the need for eventual corrective actions.

The research project deals with the project performance and control phase of the project life cycle, and the corresponding feedback loop from control to planning and scheduling to take corrective actions when necessary. More precisely, the focus is on a *reactive scheduling early warning system* by means of Earned Value Management (EVM) and Schedule Risk Analysis (SRA). Although EVM has been set up to follow up both time and cost, the majority of the research has been focused on the cost aspect. Recently, different sources in literature show that the 'classic' earned value metrics fail in predicting the total project duration in an accurate way (Lipke, 2003).

Research scope

The research aims at a detailed investigation of project (time and cost) performance measurement methods and risk analysis techniques in order to validate current and newly developed methods to improve the corrective actions decision making process during project tracking.

More precisely, the target of the research is to measure the *project performance sensitivity* and the *forecast accuracy* (both in terms of time and cost, but with a focus on the time dimension) of the existing and newly developed metrics based on the principles of EVM and SRA. The research question boils down to the determination of when and in which cases SRA and EVM could lead to improved project tracking and corrective actions decision making.

Although the classic earned value metrics are designed to forecast both time and cost, the majority of these metrics is purely cost-based. Recently, a number of new research ideas have been developed (e.g. Lipke (2003) and Vandevoorde and Vanhoucke (2006)) to increase the accuracy of total project duration forecasting. This technique, referred to as the *Earned Schedule method*, has shown promising results on a (small) number of real life projects, and can be considered as a new alternative for the more classic earned value metrics (referred to as the *Planned Value method* (Anbari, 2003) and the *Earned Duration method* (Jacob and Kane, 2004)). However, to the best of my knowledge, no research has been done prior to this research project to validate these forecasting methods on a wide set of fictive projects with known characteristics, a known contract structure, a predefined risk profile, etc… (see later: research methodology).

The specific targets and research hypotheses formulated in the research project can be summarized as follows:

- What are the static (before project execution) and dynamic (during project execution) drivers of forecast accuracy? Knowledge about project performance drivers and accurate forecast accuracy measures should allow the project manager to critically analyze EVM performance measures and to accurately predict the final cost and duration of a project. Static and dynamic drivers that have been investigated into detail are:
    - Static drivers:
        - Project network structure: Characteristics of the project can be easily calculated during the construction of the baseline schedule, and affect the accuracy of the performance measurement during project tracking.
        - Activity criticality: The degree of activity criticality affects the project tracking process and the performance accuracy.
    - Dynamic drivers:
        - Time span of control: The time span and the number of review periods during project performance measurement clearly affect the accuracy.
        - Schedule adherence: The project schedule and the adherence to that schedule (in terms of precedence logic, EVM measurement system, etc.) should have an effect on the accuracy of project performance measurement.
- How does the project time sensitivity affect the accuracy of performance measurement?
    - Information obtained during the scheduling step (baseline plan) as well as sensitivity information and risk analysis obtained through SRA should allow the project manager to improve the project tracking process and the corrective actions decision making process.
- How does the knowledge on forecast accuracy (two previous research questions) lead to improved corrective actions decision making during project tracking?
    - Since EVM is a methodology to provide an often quick sanity check of the project health on the cost control account level or even higher Work Breakdown Structure (WBS) levels, it cannot be considered as an alternative of the often time-consuming activity-based Critical Path Method (CPM) scheduling approach. The research aims at detecting when and how the EVM tracking approach offers a full alternative to the detailed CPM project tracking, and in which cases a need to drill down to lower WBS levels is necessary to take corrective actions.

Theoretical foundation and methodology

The theoretical foundation and methodology has been laid in research projects prior to the current research in the period between 1995 and 2005 at the Ghent University and Vlerick Leuven Gent Management School. In close collaboration with the industry, the Technical University of Lisbon and with the help of PhD assistants, project scheduling algorithms and project network generators have been developed and compared with the current state-of-the-art research at various project management and scheduling workshops. The theoretical foundation and research process can be briefly described along the following three steps (a summary is given in the figure below):

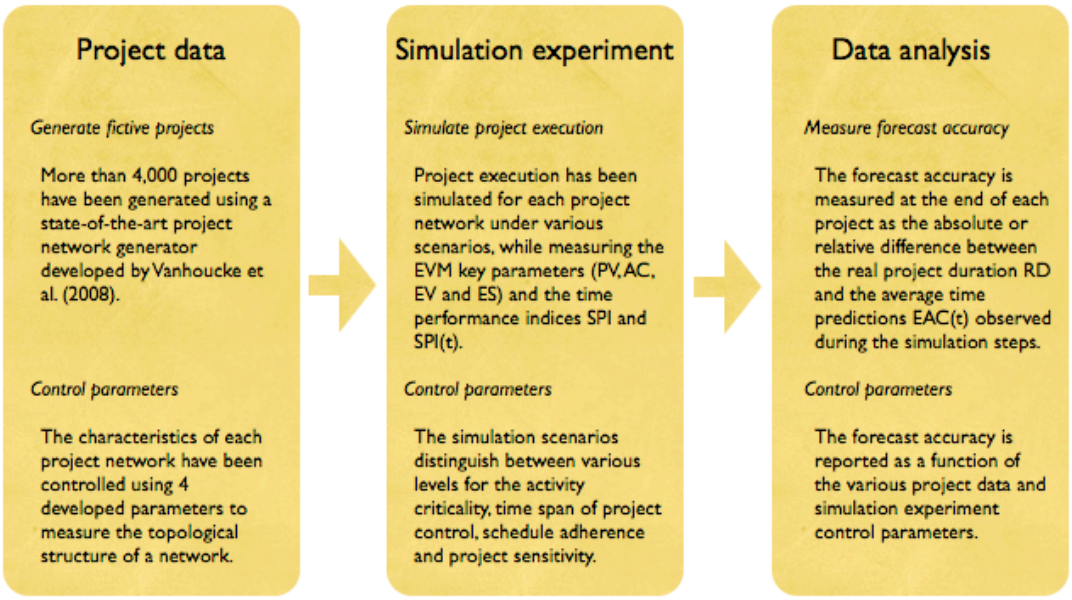
Data collection: The data collection consists of a well-balanced choice between fictive and real life data.

The fictive project data consist of more than 4,000 projects obtained through a well-known project generator from literature. To that purpose, the research relies on projects with a pre-defined network structure and generated by an existing state-of-the-art network generator (Vanhoucke et al. (2008)), rather than relying on only a smal set of real life projects with an unknown network structure or risk profile. Moreover, a well-defined classification of projects has been defined with respect to structure and risk which offers a project classification framework for the project manager.

The real life data only serve as a validation of the fictive results, and has been obtained by friends and colleagues from the field.

Methodology: The methodology used is Monte-Carlo simulation in order to set up a full-factorial simulation experiment. The simulation settings to execute all fictive projects are classified into 9 well-defined and clearly non-overlapping scenarios, and use the activity criticality as well as the average project performance as control parameters. As mentioned before, the simulation runs are also extended to a corrective actions decision making process under a controlled design.

Statistical analysis: Based on both simple rules-of-thumbs and advanced statistical techniques, the best performing forecasting technique has been selected, given the characteristics of the project. Both the topological structure, the risk profile and the generated schedule play a crucial role in the selection of the forecasting technique for an individual project. In doing so, the research provides the project manager with useful information about the technique applicable to his/her project. The statistical information is summarized and linked with the corrective actions decision making process, in order to provide guidelines and rules-of-thumbs to the project manager in which cases which tracking and risk analysis technique should be used for an individual project.



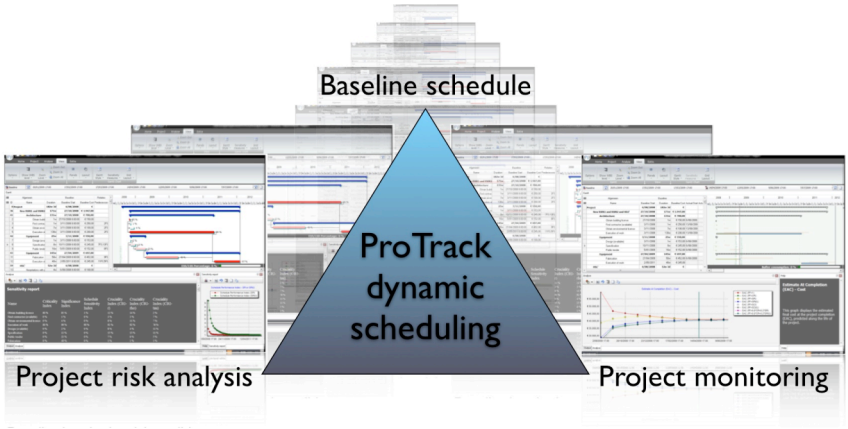
Research results

The main (static and dynamic) drivers that affect the forecast accuracy during project tracking have been reveiled, which results in interesting results for project managers using in one way or another a tracking system similar to EVM. The main results can be briefly summarized as follows:

- The earned schedule method can be considered as a full alternative to the planned value and earned duration methods, but not in all cases. Under normal project behavior, which is defined as project execution where the EVM based performance measures report reliable results, the earned schedule method outperforms the two other methods on the time dimension of performance measurement. However, when the EVM based performance measures provide less reliable results (e.g. when a delay in a non-critical activity reports an overall project delay, although the project is still on track), the planned value and earned duration methods are more reliable.
- EVM project tracking provides reliable results in case the project network contains many critical activities. Consequently, in these cases, there is no need for detailed activity based CPM project tracking, but instead, rough project based EVM performance measures can serve as reliable triggers to drill down to lower WBS levels (down to the activity level) to look for possible problems to take corrective actions.
- CPM project tracking combined with SRA provides reliable results in case the project has many parallel jobs. Moreover, the sensitivity information obtained through risk analysis enables the project manager to reduce the effort of CPM project tracking to those activities with a high expected effect on the project performance. Hence, a clear focus on only sensitivity activities in order to reduce the tracking effort still results in reliable results.
- The project topological structure and the project criticality are the main static drivers of project performance accuracy.
- The lead-time between review periods as well as the schedule adherence are the main dynamic drivers of project performance accuracy.

The research results have been translated into publications (some of them have been published (see e.g. Vanhoucke and Vandevoorde (2007)) while others are still under review) and case studies. Moreover, the results have been commercialized into a novel software tool ProTrack

(www.protrack.be) as a consequence of the consultancy projects and results achieved by the research, developed by OR-AS bvba (see figure below). The research results have also been summarized in a book titled “Measuring Time – An Earned Value Simulation Analysis“. The book is currently under evaluation, and news about the progress can be found on www.protrack.be/protrack_measuringtime.php.



Practical relevance

This research is highly relevant to both academics and practitioners and comes towards the need of a more profound study of newly developed EVM concepts for which only preliminary results and conclusions are often based on arbitrary cases or loose statements with detailed underlying theoretical knowledge and/or empirical observations based on test runs on large sets of data.

From an academic point of view, it is interesting to measure the influence of the project network characteristics on the behavior of both scheduling and monitoring tools. In literature, the influence of the structure of a project network on the risk of project delay (Tavares et al., 1999), the quality of the constructed schedule (Patterson, 1976), the criticality of a network (Tavares et al., 2004) or the computational effort an algorithm needs to schedule a project (e.g. Elmaghraby and Herroelen, 1980, amongst many others) have already been investigated in detail. However, to the best of my knowledge, no research attention has been spent on the influence of network characteristics on the accuracy of project monitoring tools and techniques.

This study can be used by practitioners who use earned value metrics and EVM principles on a daily basis, but who are unaware of the merits and the pitfalls of each individual EVM method. Moreover, this research also provides a framework for future research and consultancy purposes and hence, can be used as a guide for various consultancy projects on EVM. The contribution of the research results to project managers and practitioners can be summarized along the following lines:

- The research offers a summary and overview of the overwhelming amount of metrics, definitions and tools for project tracking.
- The research offers static project based drivers that affect project performance measurement accuracy. Consequently, it offers the practitioner a framework to decide which technique should be best used for his/her specific case and hence, the research provides mainly general results that can be translated into case-specific settings based on these drivers.
- The research offers the project manager a clear understanding in project performance behavior and its dynamic drivers that affect cost and time forecasts based on the current performance.
- The research offers clear guidelines on project tracking and distinguishes between top-down project tracking (EVM performance measurement as triggers at high WBS levels to drill down into lower WBS levels) and bottom-up project tracking (traditional activity based CPM project tracking, extended with project sensitivity information).
- The research also provides a detailed study of novel EVM concepts (e.g. the p-factor (Lipke, 2004)) that have neither been implemented in software yet nor widely used in practice, but that offer promising tools that can be used in the future.

Conclusion

As a brief summary, the main contributions of the research results are:

- The research offers a comparative study to both academics and practitioners, and provides an overview of and general results on EVM and SRA used during project performance measurement and project tracking.
- The research offers various project tracking and corrective actions decisions guidelines based on extensive tests on a wide and diverse set of fictive projects as well as on a relatively small sample of real life projects. A detailed bottom-up approach based on CPM principles and SRA and an EVM based top-down approach used as a trigger system to warn for the need for corrective actions need to be mixed carefully and highly depends on characteristics of the project.
- The research lies its main focus on the translation of general results to case-specific guidelines and rules-of-thumbs, directly applicable to individual projects. Consequently, this makes the research a valuable tool for the project management discipline with a great potential and a high practical value!

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Biography

Prof. Dr. Mario Vanhoucke is a full professor at Ghent University and Vlerick Leuven Gent Management School (Belgium). He teaches Project Management, Business Statistics and Applied Operations Research. He is programme director of the Commercial Engineers and the Advanced Master in Operations and Technology Management at the Ghent University and head of the Operations Management and Information Systems department. He is programme director of the Project Management Programme at Vlerick Leuven Gent Management School. He is also partner of a consultancy company OR-AS (www.or-as.be) where he is currently 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 of 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.