ABOUT ACADEMIC RESEARCH ON EARNED VALUE MANAGEMENT INSPIRED BY THE COLLEGE OF PERFORMANCE MANAGEMENT

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ABSTRACT

In this paper, I give a summary of the research done at the Operations Research and Scheduling (OR&S) group on project management and control. Much of the research is based on and inspired by professional project managers active and experienced in the field. Their valuable input has been crucial for defining my research agenda.

The research outcomes our OR&S research group has obtained in the form of academic publications are thanks to their critical comments and never-ending source of inspiration from their practical point-of-view. As a researcher in project scheduling, the step towards risk analysis and project control, and hence to the Earned Value Management (EVM) methodology, seemed to be an obvious step. However, this step was not as easy as I initially thought, not because of the huge complexity of the EVM methodology, but rather because this field has its origin and roots in the practical (i.e. real) world, and little to nothing was done to extend this wonderful and elegant method into a more theoretical setting. In the academic workshops I mainly attended at the beginning of my academic career, no attention was paid to EVM research, and the focus was mainly on presenting algorithms to schedule projects within limited resources. My initial meetings with professionals, through my own consultancy, but also by attending workshops such as the ones organized by the College of Performance Management, made me realize that there is a strong need for good and accurate project control methodologies, such as EVM, rather than only algorithms for scheduling projects. From that day, I decided to study this topic from an academic point of view. A challenge it was, and grateful I am to everyone who contributed to this inspiring search. Keywords: Earned Value Management; Earned Schedule; Academic Research

1. INTRODUCTION

In this paper, I will give a brief overview of the past decade of research done in the field of project management and control using Earned Value Management (EVM) and Earned Schedule (ES) (further abbreviated as EVM/ES). The purpose of the paper is not to give a full overview of the existing material in literature, but rather to give a summary of the last 10+ years of research done in this field at my OR&S research group in Ghent (Belgium). Since much of the work done at OR&S has been inspired and/or defined by various members of the College of Performance Management (CPM), I believe that, as a token of my gratitude, giving an overview is here at the right place. On the website of the College of Performance Management, the Measurable News is presented as a way to provide an opportunity to share success-story, innovative practices, or opinions on EVM with the community. Since I have been in contact with various members of CPM for years now, I therefore believe that an overview of my research outcomes might be interesting and valuable. It is thanks to the numerous contacts with professionals from the field that I was able to define my research agenda, and I hope that the results did not only contribute to the academic literature, but also acted as a source of inspiration for the professionals who helped me so much. However, I immediately have to admit that the overview in this manuscript will only contain references to academic journals, and not to the more professional oriented journals. Although I truly believe in the relevance of these professional journals, I think they differ in one important aspect that is crucial to an academic (like me): academic journals only accept papers after a peer-reviewed process.

The literature on project control and EVM is rich and diverse, and is spread over various journals, some of them with a peer-reviewed process and focusing on academic contributions, others with a more business-related orientation and focusing on practical relevance. Most of the academic journals are ranked in the Journal Citation Reports of the Web of Science and are able to report an impact factor. This index reflects the relative importance of a journal, measured by the number of citations to recent articles in the journal. On the other hand, numerous articles on EVM are published in journals that provide a reliable

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source of information for a wide audience and report relevant results or ideas that are interesting and of public concern. Quite often, however, these articles lack a methodological ground and test of logic and can therefore not always be readily used for research purposes. Hence, I believe that the choice of submitting an article to a peer-reviewed academic journal or to a more professional oriented journal (such as the Measurable News) is not a matter of quality, but rather a choice inspired by and based on the aim of the contribution. As an academic, the most important ambition is to add a contribution to the methodology, aiming at presenting new results, or performing new experiments, in order to improve the current state-of-the-art knowledge. Practical relevance, although crucial for each research study, often is of secondary importance, and comes after the theory. This manuscript focuses on the theoretical and academic research, and not on the practical relevance of my research studies. For this reason, I will only report my academic contributions in this manuscript, and skip any other references to professional journals or other outlets.

During numerous conversations I had in the last decade with professional project managers, I had the impression that the existence of such a peer-review process is not well-known. In academic publishing, the goal of peer review is to assess the quality of articles submitted for publication in a scholarly journal. Before an article is deemed appropriate to be published in an internationally recognized journal, it must undergo a process to check and recheck its quality, to make sure that its contribution is based on a sound and accepted methodology. In my book "The Art of Project Management: A Story about Work and Passion" (Vanhoucke, 2017), I wrote the following about the peer-review process:

> *"This process is often unknown or not well-understood by practitioners and non-academics who write articles in the more business-oriented journals. Despite the high relevance of these business journals, it is interesting to know that every academic paper is the result of years of hard work, literally months of testing on fast computers using a sound and proven methodology, additional months to years of working on the revisions and of course also a little bit of luck. Every little detail matters and the smallest ambiguity can lead to a rejection. There's no need to mention that we (academics) are proud on the outcome of our research."*

Performing academic research is like living a life on its own, sometimes far from reality, other times close to business, but always inspired by professional needs. Let me give you an overview of the research results at the OR&S group in the next paragraphs.

2. THREE PHASES

Looking back at the research studies done with my team during the last decade, I believe that the work has progressed in three major phases. In each phase, I was supported by many people from the field, some of them were colleagues and academics from different universities and business schools, but often times the people who helped me the most were professional project managers I have met at various workshops and company trainings. Figure 1 shows a summary of the three research phases, and a short overview of these phases is given along the following sections.

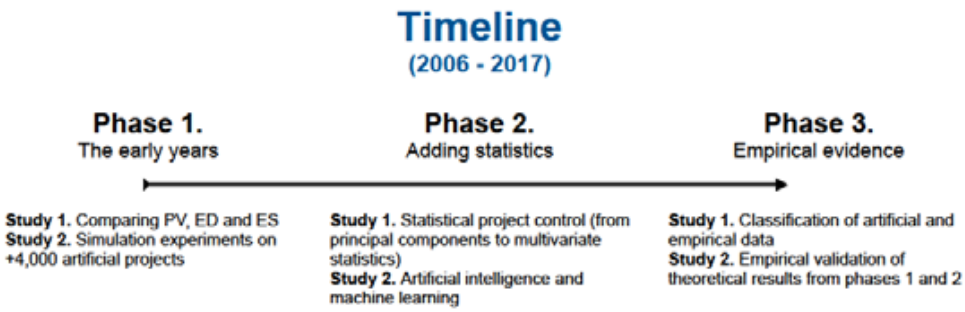

Figure 1: The three phases of my EVM research study

2.1 Phase 1. The early years

A comparative study. My initial steps into the world of Earned Value Management started in the early years of 2000, when I was working together with Stephan Vandevoorde on the integration of scheduling and risk analysis for some projects at the airport. At the time, we were running simple Monte Carlo simulations to get an idea about the expected duration and cost of real projects, and were looking for an easy-to-use methodology to

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implement a project control system. We quickly ended up with Earned Value Management as an easy-to-implement technique, and started to implement the basics of this technique into our spreadsheets. In an attempt to rely on the best performing methods to forecast the total project duration, we quickly noticed that the popular literature was not always unambiguously clear, and the results were not well-structured, or spread among different publications, mostly in the popular literature, almost never in the academic literature. That brought us to our idea to write an easy article that aimed at comparing three forecasting methods, two of them were well-known and published in the literature (the Planned Value Method and the Earned Duration Method) and a third one (at time of doing our simulations somewhat unknown) was presented as the novel Earned Schedule Method. This comparative study has been published in the International Journal of Project Management (Vandevoorde and Vanhoucke, 2006) and has, in retrospect, undoubtedly been the start of much more work in this field. But at that time, we did not realize that this could become much bigger than it initially intended to be. On the contrary, as a pure academic, I have to confess that this publication was one of the first papers in which I (with co-author Stephan) did not present very novel methodologies or techniques, no computational experiments or complex algorithms, just an easy but fair comparison between three existing techniques and that's it. None of us could have ever predicted that it would become one of our most read papers ever (as measured on ResearchGate).

A simulation study. Happily surprised by the positive reactions of readers, and inspired by the findings and fruitful collaboration with Stephan, we quickly decided to repeat the comparative study, but this time not by illustrating our findings using simple and trivial examples, but rather by an extensive detailed computer experiment. The use of Monte Carlo simulation to imitate real world progress in projects is of course a well-known technique in academia, but I believe that the specific design of the simulation study (the well-known 9 simulation scenarios that made a distinction between critical and non-critical activities) was the major contribution of the study. It allowed us to test in which scenarios EVM/ES methodologies work and in which scenarios they fail, and it also enabled us to detect the main drivers of the accuracy of the methods. One of the most well-known results was that the serial/parallel indicator (that expresses the closeness of a project to a complete serial or parallel network) could best predict the degree of accuracy of the forecasting techniques. The study has been published in the well-recognized Journal of the Operational Research Society (Vanhoucke and Vandevoorde, 2007), which made me realize that even the academic world could be interested in Earned Value Management. And being an academic in every bone of my body, I quickly decided to turn this wonderful domain deeper and closer towards academia!

Towards academia. Until that point in time, most of the work I had published in peer-reviewed academic journals was related to (resource-constrained) project scheduling, presenting algorithms and methodologies to improve the quality of project schedules. At that time, I was heavily involved in teaching "Project Management" course modules in business schools, and I quickly realized that project scheduling is important, as long as you could convince the students that this schedule can be useful for something. That something quickly became risk analysis and project control. Indeed, while it was often hard to convince my MBA students that they should spend some time at building a project baseline schedule, it was easy to convince them about the relevance of risk analysis and project performance measurement and control. This has directed my research agenda to the integration of scheduling, risk analysis and project control which I labelled later as "dynamic scheduling" (Vanhoucke, 2012). The problem however was that I had done lots of research on scheduling, but little to nothing on the two other facets of dynamic scheduling (risk analysis and project control). So I started a new research project, this time with only one goal in mind: extending my current research line from scheduling to risk and control and presenting sound and novel results that can be published in flagship journals! In my first paper in Omega - The International Journal of Management Science (Vanhoucke, 2010b), I relied on the well-known schedule risk analysis technique and tested the potential of several well-known schedule risk metrics (such as the criticality index, the schedule sensitivity index and the significance index) for their power to predict schedule risk. In a second publication in the same journal (Vanhoucke, 2011), I extended this study and compared the so-called bottom-up control approach with the top-down project control approach and measured the control efficiency of both methods. The study experimentally revealed that the structure of the project network was the main driver to choose between a top-down or bottom-up project control approach. I can fairly say that these two publications (who costed me months of hard work behind a computer screen running all kinds of different experiments) have literally changed my professional life. From that moment on, I knew that the bridge between academic experiments (working on the frontier of knowledge) and practical relevance (providing insights to business) is a matter of giving and taking, listening to the professionals at some

times, but also forgetting the practical issues at other times, and returning to the ivory tower for setting up computational experiments when necessary. My MBA students were my main inspiration for keeping the topics close to practical needs, while my academic background and urge to explore new research paths kept me going without bothering too much about practical issues of implementation. My first book "Measuring Time" (Vanhoucke, 2010a) was published by the well-recognized publisher Springer and awarded by the Belgian chapter of the Project Management Institute in 2007 and the International Project Management Association in 2008. At that time, I was fully aware of the research potential of this research topic, and I just knew it could be the beginning of much more. And it was.

2.2 Phase 2. Adding statistics

In 2011, I submitted a research proposal entitled "Searching for static and dynamic project drivers to predict and control the impact of management/contingency reserves on a project's success" at Ghent University and received one of the most prestigious grants at our university to carry out academic research. The research proposal was intended to be carried out at Ghent University (Belgium), in close collaboration with the two business schools (Vlerick Business School (Belgium) and UCL School of Management (UK)) where I work, but was also strongly supported by people of the George Washington University (USA) and CERN (Switzerland). Research is seldom done in isolation, and I am indebted to thank many people who helped me defining the research proposal, and the research outcomes resulting from it which I will describe here below.

Statistical project control. The extension of project control to statistical project control looked like an obvious next step to take, but nothing could be further from the truth. It is indeed easy to apply some basic statistical techniques on the EVM metrics to analyse the performance of projects in progress, and some attempts had already been done in the popular literature. The challenge, however, was not to come up with easy ways to integrate statistics in project control but rather in the correct use of these statistical techniques in a sound and theoretically correct way. Statistical process control is well-known in the process industry, and collects data on a repetitive basis to construct control limits for a manufacturing process. Projects, however, are unique endeavours, and therefore, no data is available to construct these control limits. Hence, the use of Monte Carlo simulation to generate artificial data for the project under study is necessary, and requires a good definition of in-control and out-of-control project behaviour (the so-called desired state of project progress), as well as the use of statistical distributions to model project uncertainty that imitates reality in the best possible way. The first paper we have published about the use of statistical project control was the most difficult one (Colin and Vanhoucke, 2014). We had the strong feeling that we had to "convince" the referees that the new statistical project control approach has its merits, and that the experiments had been carried out in an academic and sound way, following all the specific requirements that statistical techniques typically have (such as relying on the correct assumptions, carrying out the experiments under a full factorial design and other things that typify academic research). In my book "The Art of Project Management: A Story about Work and Passion" (Vanhoucke, 2017), I have written a chapter entitled "Academic publishing: Quality control using a peer review mechanism" in which I wrote the following about our first submission on the use of statistical project control:

> *"One of the first papers we have written about Statistical Process Control is an excellent illustration of how hard a peer review process can be, but also how it finally results in a much more improved version of the initial manuscript. Our paper has been initially submitted in January 2012, and three additional revisions were necessary, leading to literally almost 100 extra pages of material and terabytes of additional data to run new tests, before it could be accepted. Finally, the paper has been accepted in the third revision round in June 2014 under the title "Setting tolerance limits for statistical project control using earned value management"."*

Typically in academia, once you have published your first paper on a novel topic, you can rely on this foundation to extend the work to more advanced topics. A first paper often gives the authors some credibility and allows them to publish much more advanced stuff. In the years that followed our first paper, we wrote papers about the comparison of our statistical project control methodology with some other similar quantitative approaches in the literature (Colin and Vanhoucke, 2015b). We observed that no formal definition existed in the literature for defining a desired state of project control, and the unavailability of a benchmark dataset as well as the absence of measures to quantify the performance of these methods made the comparison of statistical project control methods difficult or even impossible. Therefore, we presented a unified framework for testing alternative statistical project control methods and set up an exhaustive experiment to compare and to discuss their value for the project management practice.

In a follow-up paper (Colin et al., 2015), we even extended the statistic project control methodology to a more advanced multivariate approach using a principal component analysis to reduce the number of control metrics. Two new multivariate schedule control metrics have been proposed (called T2 and SPE) that can be used to dynamically monitor project control charts. A further extension of this multivariate regression approach has been discussed in Vanhoucke and Colin (2016), but now using a kernel principal component regression method with a radial base function kernel. Heavy stuff at some times, but it always resulted in new insights and possible paths for future research. In the paper written by Colin and Vanhoucke (2015a), we integrated these EVM/ES methods within a multiple control points concept inspired by critical chain/buffer management (CC/BM), and we showed that the EVM/ES control approach can be complementary to the concept of using a buffering control approach. It is shown that the combined use of different EVM/ES top-down control methods can overcome some of the drawbacks of traditional EVM/ES mentioned in the literature, while minimally increasing the effort spent by the project manager.

All previous papers made use of Monte Carlo simulations to generate artificial project progress data in order to be able to construct control charts with easy or advanced statistics. The use of distributions for running the Monte Carlo simulations is key to the accuracy of the control charts, and should reflect the real-life behaviour of the project. To that purpose, we have written a final paper about the use of a procedure to transform empirical data into statistical distributions (Colin and Vanhoucke, 2015c). The paper illustrates how data from the construction industry can be used to derive realistic input distributions, and makes use of the so-called parkinson simulation model with a lognormal core initially proposed by Trietsch et al. (2012). Three possible uses are presented for the calibration procedure and the classification in project management simulation studies, and these were validated using a case study of a construction company.

Artificial intelligence. The previous studies clearly demonstrated that the use of easy or advanced statistical methods can lead to improvements in the quality of accuracy of control methods, and inspired us to extend these methodologies to even more advanced methodologies borrowed from the field of artificial intelligence and machine learning. Although we recognize that the practical implementation of these methods is not for tomorrow, they nevertheless showed us that improvements can be found when a data-driven approach is taken for monitoring projects in progress. In Wauters and Vanhoucke (2014), we tested the use of so-called support vector machines for controlling the timing of projects, and saw that this advanced machine learning method can lead to improvements in the accuracy of project forecasts. Inspired by these promising results, we later extended this method to the use of many other advanced methods such as decision trees, bagging, boosting and random forests (Wauters and Vanhoucke, 2016) as well as to a much more intuitive (and therefore easier to implement) method known as the nearest neighbour method (Wauters and Vanhoucke, 2017). Finally, in a last study (Wauters and Vanhoucke, 2015), the possible trade-off between accuracy and stability when predicting time and cost of a project in progress is studied. By means of a large computational experiment on a topologically diverse data set, we have analysed how and when accuracy and stability of predictions for a project in progress can be obtained.

An overview. Needless to say that the previous search of extending EVM to statistical project control and artificial intelligence was an exciting period for our research group, and has given us much more new insights that we initially thought. But academic research goes slow, and it took us years and years to get all the papers published. It also took me almost 10 years after my first publication on Earned Value Management before I believed that I started to understand the dynamics of project control, and I decided to wait until 2015 to write an overview and summary paper about the exciting research done in the literature. The summary paper of Willems and Vanhoucke (2015) therefore gives a good overview of the current state-of-the-art research in project control and EVM, and highlights some important directions for future research.

2.3 Phase 3. Empirical evidence

So far, much of the research done at my research group was highly theoretical, aiming at contributing to the academic literature, without focusing much on the practical implementation and validity for business. From an outsider (i.e. a non-academic), this might look rather strange, working on methods in an artificial setting, ignoring real-world applications and testing methodologies on artificial projects, but I believe it is the only approach that leads to academic improvements. In one of my books, I used the subtitle “first the theory, then the practice” (Vanhoucke, 2014), which is exactly the approach I proposed to follow all my research proposals. It makes academic research really academic research. But that doesn’t mean I ignored reality!

About data. Most of the work done so far was tested on artificial project data, either taken from literature, or generated by one of our random generators. It is a common misunderstanding that generating artificial data is easy as pie, and nothing could be further from the truth. During my research stay in Lisbon in 2015 and 2016, me and my friend and colleague José Coelho decided to collect everything that we currently knew about the use and generation of artificial project data and summarized it in a paper (Vanhoucke et al., 2016). But apart from our strong focus on artificial data, I believe that the time was ready for aiming at some empirical evidence. After years of collecting data, we finally decided to propose a framework to collect and evaluate real empirical data such that they can be used in studies similar to the ones discussed in the previous paragraph (Batselier and Vanhoucke, 2015a). From that moment on, we (and others) could test new (theoretical) methods using both artificial and real-life data. And so we did.

Empirical validation. We basically re-started much of the work done in the previous statistical project control study, but now we aimed at validating our theoretical results on the empirical data. Our ambition was to confirm or reject the theoretical findings, and to create some insights on how and why some methods worked, and why others failed so miserably. This is exactly the same ambition as the previous theoretical research, but now done on empirical data! In a first paper (Batselier and Vanhoucke, 2015b), the traditional EVM/ES techniques to predict the final project duration and costs were used on a set of 51 real-life projects, while Batselier and Vanhoucke (2015c) extended this research to the so-called novel earned duration management approach. The results showed us that most of the theoretical outcomes still hold when using real data, but some minor deviations could also be observed, and taught us a lot about the advantages and disadvantages of using artificial data. Overall, the conclusion is that both types of data have merits, but the dialogue between theoretical research and empirical validation is the method that leads to the biggest understanding. Given these positive results and the often positive reactions coming from both the academic and business world, we decided to extend this empirical research in three ways, as shortly described below.

In a first study (Batselier and Vanhoucke, 2016) the well-known reference class forecasting (RCF) technique is compared with the most common traditional project forecasting methods. Reference class forecasting bypasses human judgment by basing forecasts on the actual outcomes of past projects similar to the project being forecasted. The results have shown that RCF outperforms the traditional predictive techniques for both cost and time forecasting, and therefore supports the practical relevance of the technique. In another study (Batselier and Vanhoucke, 2017a), we aimed at improving the project forecast accuracy by integrating earned value management with exponential smoothing techniques, which are well-known and widely used for predicting the demand of products but which, to the best of my knowledge, have never been tested in a project control setting. Finally, in a paper by Batselier and Vanhoucke (2017b), we have analysed the impact of a new project characteristic, which we called the project regularity as a measure to predict how accurate the time and cost predictions will be.

Extensions. Academic research has no end. It doesn't have to have one. There are always new topics that need further investigation, and I therefore hope that the research outcome will continue to grow. Two recent extensions on the topic of data-driven project control are worth mentioning, although I hope that by the time you read this paper, they are already outdated. In a first extension, we have extended another line of research (not mentioned in this manuscript) on project contracting with incentives and proposed a project control system called earned incentive management to control not only the project time and cost, but also its incentives (Kerkhove and Vanhoucke, 2017). Secondly, at the time of writing this manuscript for the Measurable News, I received the positive news that the latest research topic entitled "A buffer control method for top-down project control" was accepted for publication after 3 revisions (and more than a year under submission) in the European Journal of Operational Research (Martens and Vanhoucke, 2017). This research aims at proposing a project control method that holds the middle ground between the easy EVM/ES methods used today and the (too) advanced methods proposed in our statistical project control research line. Finally, a few days before finalising the draft of this manuscript, we received the wonderful news that the presentation "In pursuit of more accurate project forecasts: Integration of earned value management with exponential smoothing and reference class forecasting" based on the research of Batselier and Vanhoucke (2016, 2017a) has received the Elsie Cropper Award for Best Paper presented at YOR20 in London (UK). Wonderful stuff. To be continued.

3. CONCLUSION

In this manuscript, I gave a complete overview on the last decade of research at my research group related to project management and control using earned value management. In the manuscript, I only referred to my own research outcomes, and largely ignored important contributions made by others. It is of course needless to say that all of this research work is based on the excellent work of other researchers. I have chosen not to mention the enormous list of references to papers and books that I have used as a background or source of inspiration for my own research for two reasons. The first and most obvious reason is that the list of references would simply become too long, and the risk that I should forget an important reference is not worth to be taken. A second and to what I believe a very pragmatic reason is that most, if not all, of the references can be found in my own work (books, papers, websites) that I have mentioned. However, by not mentioning other sources from literature, I do by no means wish to give the impression that these external references and their authors are less important. On the contrary! I realize that research is a dialogue between people, and all these other authors that I haven't mentioned have been crucial in formulating my own research ideas and hypotheses. They undoubtedly have played an essential role in defining my own research agenda. They have been my main inspiration and driver for gradually defining my own research track, and without them, there was no me.

Therefore, a special thank you goes to all the people I have met throughout the years and who were, and still are a source of inspiration. First and foremost, I am grateful to my co-authors with whom I have made this search to improvements possible. Without them, OR&S would simply not exist. Moreover, the close collaborations with many people from PMI Belgium and EVM Europe as well as the interesting talks with researchers at project management conferences have greatly contributed to the direction of my work at Ghent University, Vlerick Business School, University College London and OR-AS. The meetings with project managers in Belgium and the UK and the consultancy done at various companies have forced me to put the theoretical concepts into the right perspective. The discussions with some members of the American College of Performance Management have shown me that research can act as a bridge between Europe and the US, and brings researchers closer to the business. Last but not least, the intense work with my team at the OR&S research group of Ghent University has brought me where I am right now, and will probably bring us to new directions in the coming years. I won't mention names. Just a thank you to all of you. I also acknowledge the support provided by the "Bijzonder Onderzoeksfonds" (BOF) for the project with contract number BOF12GOA021, by the "Fonds Wetenschappelijk Onderzoek" (FWO) for the project with contract number G015711N and by the National Bank of Belgium (NBB).

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