MEASURING SCHEDULE ADHERENCE

By Mario Vanhoucke[1]

ABSTRACT

Ten years after the introduction of the Earned Schedule concept proposed by Lipke (2003), researchers and practitioners have investigated, validated, criticized and modified this novel concept and successfully used it in research simulation studies, software development and practical project control settings. Only one year later, Lipke (2004) proposed an extension on his Earned Schedule concept to measure the influence of rework due to the lack of scheduling adherence on the earned value. His new concept, known as the p-factor approach, measures the portion of the Earned Value (EV) accrued in congruence with the baseline schedule, which will be used to adapt the current EV to a so-called effective EV (EV(e)) taking the risk of rework into account. Unlike the ES concept, the p-factor approach has up to now stayed in the background, and little adoption by both researchers and practitioners has been detected. The aim of this article is to review this interesting p-factor concept with an artificial project example and to partially illustrate its strengths and weaknesses based on a research study using fictitious and empirical project data.

1.0 INTRODUCTION

Since the introduction of the Earned Schedule (ES) concept (Lipke, 2003) as a time related extension of the well-known Earned Value metrics, studies on the time dimension of EVM have been published throughout the popular and academic literature. I believe that an overview of many of the recent academic oriented research publications has been summarized in my research study published in Vanhoucke (2010a). Ever since, I have used the ES concept in university classes and company trainings, accompanied by a second book (Vanhoucke, 2012) and accepted articles in well-known flagship journals, such as Omega (Vanhoucke, 2010b, 2011). Thanks to the funding recently obtained at Ghent University (Belgium) for another six years of intensive research on project control, more results and publications are definitely on its way. Preliminary results will be updated yearly in the online overview written by Vanhoucke (2013a).

Despite the ever growing positive attention on EVM and the commonly accepted agreement on the importance of EVM in a project monitoring environment, both EVM in general and ES more specifically have not been free of criticism. As an example, authors such as Book (2006) and Abba (2008) have questioned the novelty and/or correctness of the ES formula. Probably the most fundamental criticism on an EVM/ES system is its assumption of a project setting where activities and precedence relations are known in advance and where estimates (activity durations, resource requirements, unexpected events, etc.) can be given within a certain range. However, Loch et al. (2006) mentioned that projects often do not fulfill these assumptions but, on the contrary, are commonly plagued by fundamentally unforeseeable events and/or unknown interactions among various actions and project parts. Consequently, due to the cycles of rework, the accuracy of the EVM metrics can be biased, leading to incorrect management decisions (Cooper, 2003).

While much of the criticism on the EVM/ES systems is probably correct and cannot be simply solved by presenting straightforward extensions on the current EVM/ES metrics, I believe that the p-factor makes a small yet possibly important step towards the right direction. The p-factor concept looks like a simple and straightforward extension on the ES method, and will therefore undoubtedly be part of criticism. As mentioned before, this new concept initially introduced in 2004 has not passed the test of logic yet due to the lack of fundamental research and practical validation, and therefore I believe that it deserves much

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more research attention to test its strengths and weaknesses, and its merits in a dynamic project control environment. The purpose of this article is only to give researchers an incentive to start and set up such a deeper analysis. The outline of this paper is as follows. Section 2 reviews the logic of the schedule adherence concept and illustrates its formula on a small fictitious project example. Section 3 briefly describes the main results of a research study on a wide set of fictitious projects and a limited set of real life projects. Section 4 makes conclusions and highlights paths for further research.

2.0 SCHEDULE ADHERENCE

2.1 Definition

The rationale behind the p-factor approach lies in the observation that performing work not according to the baseline schedule often indicates activity impediments or is likely a cause of rework. Consequently, the premise is that, whenever impediments occur (activities that are performed relatively less efficiently compared to the project progress), resources are shifted from these constrained activities to other activities where they could gain earned value. However, this results in a project execution which deviates from the original baseline schedule and might, consequently, involve a certain degree of risk. Indeed, the latter activities are performed without the necessary inputs, and might result in a certain portion of rework. Based on these observations, the p-factor has been introduced by Lipke (2004) as a measure to provide the connection of project output to EVM. It measures the portion of earned value accrued in congruence with the baseline schedule, i.e. the tasks which ought to be either completed or in progress, as follows:

$$p = \frac{\sum_{i \in N} min(\mathrm{PV}_{i,\mathrm{ES}}, \mathrm{EV}_{i,\mathrm{AT}})}{\sum_{i \in N} \mathrm{PV}_{i,\mathrm{ES}}}$$

with

p	Schedule adherence = 1: perfect schedule adherence < 1: lack of perfect schedule adherence
N	Set of activities in the project
$PV_{i,ES}$	Planned value of activity i at time instance ES
$EV_{i,AT}$	Earned value of activity i at the actual time AT

2.2 Example

Despite the simplicity of the p-factor formula presented earlier, it is often subject to confusion. Figure 1 shows a fictitious four-activity project with a pre-defined duration (above the node) and cost (below the node) for each activity. In order to illustrate the calculations of the p-factor, a baseline schedule and three possible project executions will be simulated and discussed.

The simulated project progress under the three scenarios is illustrated in figure 2. Each fictitious project execution represents a different situation which can be summarized as follows:

- Activity Overlapping: The p-factor concept does not take precedence relations into account, but instead takes a general project view on the schedule adherence. Nevertheless, it should be able to detect the presence of overlaps, which is probably the main reason for lack of information and risk of rework. Figure 2a gives an illustration of an overlap between two activities in series, and shows that the p-factor is able to detect this situation.
- PV/EV Accrue Deviations: Activities that are completed within their estimated time and budget are not necessarily performed in congruence with their predefined planned value. Since the p-factor is a concept to measure the degree of adherence to the baseline schedule, expressed as a relation between the project progress (Earned Value) and the baseline schedule (Planned Value), it should be able to give an indication of the deviation between PV and EV. In figure 2b, the EV accrued during the real life project progress is not in line with the PV curve of the baseline schedule, although the project finishes exactly on time. The p-factor measures this lack of schedule adherence.
- Ahead of Schedule and/or Delayed Project Execution: Obviously, deviations from the original baseline schedule during project progress leads to a final project status ending ahead or late. This lack of schedule adherence should be measured and reported by the p-factor concept in order to serve as a dynamic tool to forecast the final project status. Figure 2c shows a situation of a delayed project with activities finishing ahead of and behind schedule, resulting in p-factor values lower than 1.

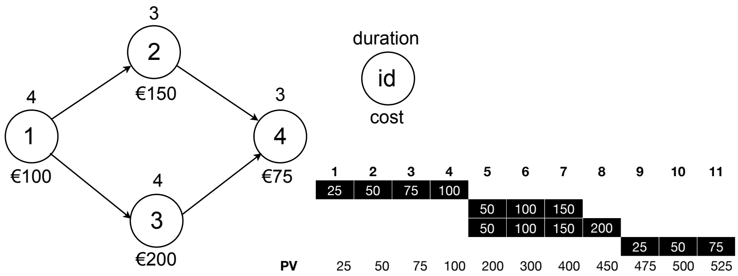

Figure 1: A fictitious four-activity project network

a. Activity Overlapping

Time	1	2	3	4	5	6	7	8	9	10	11	12
	25	50	75	100								
			50	100	150							
						50	100	150	200			
									25	50	75	
EV	25	50	125	200	250	300	350	400	475	500	525	
ES	1	2	4,25	5	5,5	6	6,5	7	9	10	11	
p	1	1	0,7	0,75	0,7	0,83	0,93	1	1	1	1	

b. PV/EV Accrue Deviation

Time	1	2	3	4	5	6	7	8	9	10	11	12
	15	35	65	100								
					25	75	150					
					100	175	200	200				
									50	60	75	
EV	15	35	65	100	225	350	450	450	500	510	525	
ES	0.6	1.4	2.6	4	5.25	6.5	8	8	10	10.4	11	
p	1	1	1	1	0.83	0.86	1	1	1	1	1	

c. Ahead/Behind Schedule

Time	1	2	3	4	5	6	7	8	9	10	11	12
	25	50	75	100								
					30	60	90	120	150			
					100	200						
										25	50	75
EV	25	50	75	100	230	360	390	420	450	475	500	525
ES	1	2	3	4	5,3	6,6	6,9	7,4	8	9	10	11
p	1	1	1	1	0,85	0,81	0,86	0,93	1	1	1	1

Figure 2: A fictitious four-activity project under 3 progress scenarios

2.3 Effective Earned Value

The p-factor assumes that lack of schedule adherence is caused by a combination of the presence of impediments or constraints and work performed under risk. Figure 3 shows an intermediate project progress state at the Actual Time AT = 6 for the project progress of figure 2b. The EV accrued at the current time AT = 6 is given in black and the ES = 6.5 (vertical line). The figure visualizes the p-factor as follows:

- The portion of the work to the left of the ES line is assumed to be performed without risk and indicates the presence of an impediment or project constraint.
- The portion of work to the right of the ES line indicates work which is ahead of the normal project performance and is assumed to have a certain degree of risk.
- The p-factor is equal to the EV (black bars) to the left of ES divided by the total EV.

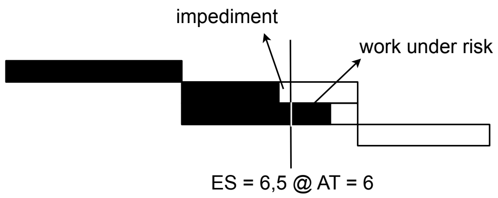

Figure 3: Activity impediments and work under risk to measure the p-factor

It is assumed that this degree of risk is the result of an inefficient use of resources which were shifted from the constrained activities to less constrained activities where the resources could gain earned value. However, these shifted resources work without the necessary inputs possible resulting in a certain portion of rework (i.e. risk). The p-factor is a measure to express the portion of the EV without risk (referred to as EV(p), while the remaining portion is denoted as EV(r)).

A project manager should realize that the remaining EV(r) portion might be subject to risk and possibly results in rework. The effective earned value EV(e) is defined as the risk-adapted portion of earned value that is performed within the expected baseline schedule performance, taking into account that only R% of the EV(r) will be accounted as risk-free. A value for R% is given by the project manager, based on his/her best guess and experience. Mathematically, these p-factor assumptions can be summarized as follows:

$$EV = p * EV + (1 - p) * EV = EV(p) + EV(r) * EV(e) = EV(p) + R\% * EV(r)$$

with

EV	Earned value
EV(p)	Risk-free earned value
EV(r)	Remaining earned value portion performed under risk
EV(e)	Effective earned value
R%	Estimated portion of EV(r) that is usable and requires no rework

3.0 SUMMARY OF RESEARCH RESULTS

3.1 Research results

In order to critically validate the p-factor concept, it has been tested on a large set of fictitious projects in a study by Vanhoucke (2010a, 2013b). During all experiments, various values for the R% estimate have been used. Details of the methodological approach can be found in the referenced study, but the main conclusions can be summarized as follows:

- Schedule Adherence: The p-factor measures the schedule adherence on the project level and not on the individual activity level, similar to the SPI and CPI measures. Despite this aggregated view on the project, it is able to detect lack of schedule adherence causes, such as activity overlapping, schedule delays, deviations between PV and EV accrue, etc, as discussed in section 2.2.
- Topological Structure: The structure of the project network, defined by the set of activities and precedence relations between these project activities, has an effect on the p-factor value. This observation is similar to the forecast accuracy of EVM time prediction methods as investigated in Vanhoucke and Vandevoorde (2007b) and as discussed in previous articles in the Measurable News (Vanhoucke and Vandevoorde, 2007a, 2008, 2009).
- Forecasting Accuracy: The use of the p-factor to improve the forecast accuracy of time prediction methods is limited and should therefore not be used. However, despite its failure to improve the accuracy of time forecasts, some results have shown that the p-factor is a good indicator for predicting how accurate forecasts will be (Vanhoucke, 2009).

3.2 Empirical evidence

Due to the novelty of the p-factor concept, limited empirical data or practical experience is available. In the current section, I briefly review the results of a consultancy project to highlight the merits of the p-factor, but results have to be taken with care and no generalizations can be made. This part can be considered as an open invitation to project management practitioners to share their findings and ideas on the p-factor concept with the EVM community.

The empirical data is based on a small set of projects that were all analyzed by the ProTrack (www.protrack.be) software tool. Many of the projects showed a random p-factor evolution over time and hence were not retained in the study. One set of projects, however, showed a systematic drop in the p-factor below 1 during the night activities, giving an indication of the less attractive working conditions. A deeper analysis into the project activities revealed that night operations were considered as less attractive and therefore often postponed to the early and day team members, while part of the day operations were often done at night. Consequently, many unattractive night operations were often shifted (i.e. seen as impediments) and more attractive day operations were done earlier than planned (i.e. against the logic of the network structure), resulting in resources (i.e. the night team) shifting towards others, more attractive day activities to gain earned value. More details of the empirical project data can be found in Vanhoucke (2013b).

It should be noted that this observation is based on only a small set of very similar projects, and hence, as a researcher, I should add the comment that these observations cannot be considered as generally true. More research is definitely needed, based on larger sets of simulated and empirical project data. However, the results were inspiring and might indicate that the p-factor is more than just another extension on the EVM/ES formulas without much added value. I believe that the preliminary observations show that it might be able to detect other planned deviations different than the traditional time and cost performance measures currently known in EVM/ES.

CONCLUSIONS

This paper briefly reviews the schedule adherence concept of Lipke (2003) based on a simulation study published in Vanhoucke (2013b). The two main conclusions of this study can be summarized along the following lines.

First, the computational results of the simulation study show that the p-factor is a promising concept. Although results are only preliminary and failed in improving current EVM techniques, such as forecasting time and cost, it is believed that the relevance of the p-factor concept mostly lies in the easy and simple detection of portions of work that show either constraints and impediments or performance under risk, relative to the baseline schedule. The results have shown that the simple dynamic calculation of the p-factor (based on the traditional EV metrics) might help to predict the accuracy of the forecasts along the life of the project. However, the use of this factor to improve forecast accuracy is limited to incorporating corrections for optimistic duration forecasts by adjusting the earned value to an effective earned value taking the possibility of rework into account. In doing so, the forecast accuracy of optimistic scenarios will be corrected to more realistic estimates while pessimistic forecasts will suffer under this correction mechanism.

Secondly, the study showed that the research on schedule adherence might be highly relevant to both academics and practitioners. Promising results on a small set of empirical projects trigger the need for more research. A more profound study of newly developed concepts such as the p-factor concept is what should drive researchers, who should not be satisfied with only preliminary results and conclusions based on arbitrary cases or loose statements. Instead, a profound and detailed theoretical knowledge supported by empirical observations and runs on extensive sets of data is what they need to move on. Although some interesting insights could be shown on a very limited set of real life projects, more research is definitely needed to further validate this concept on both fictitious as well as empirical data. The current work done at Ghent University is focusing on the relation between EVM accuracy and stability using schedule adherence concepts, and it is therefore hoped that new results will be published soon in the academic literature. It is believed that the current research efforts constitute the first step in this interesting future research direction.

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Prof Dr Mario Vanhoucke is a Full Professor of Business Management and Operations Research at Ghent University (Belgium), Vlerick Business School (Belgium, Russia, China) and University College London (UK). He has a Master's degree in Commercial Engineering and a PhD in Operations Management from the University of Leuven (Belgium). At Ghent University, he is the program director of the Commercial Engineering program where he teaches Project Management and Applied Operations Research. At Vlerick Business school, he teaches Decision Making for Business and Business Statistics to Master and MBA students.

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Mario Vanhoucke is also a founding member and director of the EVM Europe Association (www.evm-europe.eu). He is also a partner in the company OR-AS (www.or-as.be) which released a third version of its project management software tool ProTrack 3.0 (www.protrack.be). ProTrack is an advanced scheduling product which focuses on the integration of scheduling, risk, control management and online learning through a PM Knowledge Center (www.pmknowledgecenter.com). He leads a research group which has obtained Concerted Research Actions (CRA) funding of more than € 1 million for an integrated PM research study at Ghent University (Belgium). To that purpose, a derivative of the software tool ProTrack, known as the PM programming tool P2 Engine (www.p2engine.com), has recently been developed that will be used for testing novel ideas by the CRA research team members. The project management research undertaken by Mario Vanhoucke has received multiple awards including the 2008 International Project Management Association (IPMA) Research Award for his research project "Measuring Time: A Project Performance Simulation Study" which was received at the IPMA world congress held in Rome, Italy. He also received the "Notable Contributions to Management Accounting Literature Award" awarded by the American Accounting Association at their 2010 conference in Denver, Colorado.