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Setting tolerance limits for statistical project control using earned value management ☆

Jeroen Colin [a], Mario Vanhoucke [a,b,c,*]

[a] Faculty of Economics and Business Administration, Ghent University, Tweekerkenstraat 2, 9000 Gent, Belgium
[b] Technology and Operations Management, Vlerick Business School, Reep 1, 9000 Gent, Belgium
[c] Department of Management Science and Innovation, University College London, Gower Street, London WC1E 6BT, United Kingdom

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ABSTRACT

Project control has been a research topic since decades that attracts both academics and practitioners. Project control systems indicate the direction of change in preliminary planning variables compared with actual performance. In case their current project performance deviates from the planned performance, a warning is indicated by the system in order to take corrective actions.

Earned value management/earned schedule (EVM/ES) systems have played a central role in project control, and provide straightforward key performance metrics that measure the deviations between planned and actual performance in terms of time and cost. In this paper, a new statistical project control procedure sets tolerance limits to improve the discriminative power between progress situations that are either statistically likely or less likely to occur under the project baseline schedule. In this research, the tolerance limits are derived from subjective estimates for the activity durations of the project. Using the existing and commonly known EVM/ES metrics, the resulting project control charts will have an improved ability to trigger actions when variation in a project's progress exceeds certain predefined thresholds

A computational experiment has been set up to test the ability of these statistical project control charts to discriminate between variations that are either *acceptable* or *unacceptable* in the duration of the individual activities. The computational experiments compare the use of statistical tolerance limits with traditional earned value management thresholds and validate their power to report warning signals when projects tend to deviate significantly from the baseline schedule.

1. Introduction

Project management and control have been research topics since the development of project planning approaches such as the critical path method (CPM, [1,2]) and the Program Evaluation and Review Technique (PERT, [3]). The majority of the research endeavors published in the academic literature focus on the construction of a project baseline schedule within the presence of limited resource constraints (see e.g. a recent survey written by Hartmann and Briskorn [4]). Ever since, the use of a project baseline schedule has been put into the right perspective, as it only acts as a roadmap for the future project performance. If the project runs into trouble, the baseline schedule can be used to detect such problems and to trigger corrective actions. The construction of a project baseline schedule should go hand in hand with the development of a risk analysis [5] to detect the weak parts in the schedule. These two sources of information should therefore be used concurrently, both before and during the execution of the project. The need for the integration of the project baseline scheduling construction, the risk analysis and management and the project control step has been recently referred to as *dynamic scheduling* [6,7].

In this paper, the construction of a baseline schedule is assumed to be given, and the focus lies on the presentation of a new project control system [8]. Rozenes et al. [9] have characterized a project control system by stating that it should indicate the direction of change in preliminary planning variables when compared with actual performance. If there is an *unacceptable* gap between planning and performance, a warning should be generated by the system in order to take corrective action. In the remainder of this text, we will further elaborate on this *unacceptable* gap and quantify how it can be specified.

This study mainly focuses on the generation and the interpretation of warning signals during project control and hence it does not include results in the quality and input of corrective

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* Corresponding author at: Faculty of Economics and Business Administration, Ghent University, Tweekerkenstraat 2, 9000 Gent, Belgium.
E-mail addresses: jeroen.colin@ugent.be (J. Colin), mario.vanhoucke@ugent.be (M. Vanhoucke).

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actions, or on the use of these new methods for contingency planning.

A well-known and widely used project control system is Earned Value Management (EVM) originally developed in the '60s at the U.S. Department of Defense as a standard method to measure a project's performance. This system relies on a set of straightforward metrics to measure and evaluate the general health of a project. These metrics serve as early warning signals to timely detect project problems or to exploit project opportunities. EVM has been investigated and used widely in project management practice and has been brought into the attention of researchers by Fleming and Koppelman [10]. Recently, the research on EVM has produced the earned schedule method (ES, [11]) and a large study on the integration of risk management and EVM/ES was conducted [12].

EVM/ES calculations are based on the costs and durations for the activities in a project. Both in the planning phase and during the execution of the project, some detail of the individual activities is lost as the individual performance is summed up into the performance metrics observed and controlled at the project level. Earned value management is known to have some shortcomings when it comes to protecting the critical path in the schedule [10]. The summation of activity earned value into the aggregate level for the project does not incorporate schedule risk analysis (SRA, [13]) data, such as criticality. In spite of the complexity of this problem, EVM/ES use in practice is characterized by decision making from practical experience, rules-of-thumb and anecdotal evidence. In the academic literature, it is reasoned that the application of a statistical process control approach could benefit the EVM/ES project control process. These previous attempts depend on the availability of historical records that may or may not exist and may or may not be valid. We therefore also allow the use of subjective estimates.

In this paper, a new *statistical project control* approach is presented. It is inspired by the practical format of *statistical process control charts* and based on *tolerance intervals* produced by a simulated sample. A controlled simulation experiment will be used to specifically produce two types of project progress situations. First, project progress situations where the variation from plan is limited to some *acceptable* margin are used to produce project control charts. Second, we test the discriminative power of these control charts when the variation from plan exceeds the predefined *acceptable* margin.

The outline of this paper is as follows. In Section 2, we present a literature review on the use of statistical control principles in project management and control. We will present two project control charts, the X chart and the R chart. Section 3 illustrates these control charts on a fictitious project example. In Section 4, the design of the computational test experiments is outlined based on various sources from the literature. In Section 5, test results obtained by computational experiments using Monte Carlo simulation to imitate a fictitious project progress environment are discussed. Section 6 draws general conclusions and highlights future research avenues.

2. Statistical project control

2.1. Literature overview

This literature review introduces the main concepts of *statistical process control* (SPC) as they are applied to monitor and control processes in services and manufacturing. The application of SPC techniques to earned value management is not new in the literature. We introduce a *statistical project control* procedure that aims to overcome some of the issues with the previously published approaches, but which is not an implementation of SPC in the strict sense, although it reproduces some of its concepts and nomenclature. The last paragraph of this literature review is dedicated to a summation of the differences between our statistical project control procedure and the implications of applying SPC to project control in a strict sense.

In standard SPC applications a state of control is identified with a process generating samples for which the subgroup averages are approximately normal under the central limit theory. Control charts such as the Shewhart, cumulative sum (CUSUM) and exponentially weighted moving average (EWMA) charts serve as online procedures to monitor process stability, to detect assignable variation or to forecast process movements in industrial processes [14]. A process is said to be in-control when only common cause variation is present. This type of variation is characterized as coming from phenomena constantly active in a process, which can be predicted probabilistically. In his original work on process control, Shewhart [15] introduced the term chance cause. A process is said to be out-of-control if a second type of variation is present known as assignable cause variation. Assignable cause variation arises when a new previously unanticipated phenomenon is present in the system and should cause a signal.

Fig. 1 illustrates how a control chart applied to project control might be interpreted. Periodic observations of a performance measure for a fictitious project execution are outlined, along with an illustrative upper control limit (UCL) and lower control limit (LCL). For illustrative purposes, we will assume that the performance measure is of the type where a high value is good and a low value acts as a trigger for actions due to potential problems. The frequently encountered schedule performance index (SPI, Section 2.3.1) and schedule performance index using earned schedule (SPI(t), Section 2.3.1) measures in EVM/ES are of this type, although control charts of the opposite type have also been proposed where the natural logarithm of the reciprocal of SPI or SPI(t) is taken [16]. In case the observations fall outside the project control limits, the charts report a signal which could trigger actions to bring the

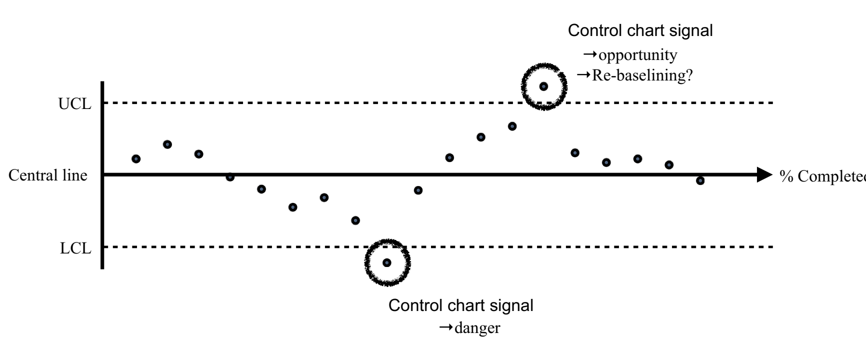

Fig. 1. Illustrative control chart and out-of-control indications.