Schedule Performance Impact from Rework[1]

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Abstract

The concept of schedule adherence (SA) was introduced several years ago, as a consequence of Earned Schedule. Applying SA in the analysis of project performance yielded task level information; tasks are identified that may have performance restricted by impediments or process constraints, and other tasks that may experience rework in the future. Presently, those applying SA in their management process have focused on the cost impact of rework. This paper takes the next step, providing methods for understanding the impact rework has on schedule performance.

Introduction

About fifteen years ago, a year after the introduction of Earned Schedule (ES) [Lipke, 2003], the concept of schedule adherence was published [Lipke, 2004]. Schedule adherence extended ES to project management methods for identifying tasks likely to be performance impeded or constrained and those having a potential of rework. As well, it provided methods for computing the portion of earned value (EV) that moves the project toward completion, termed "effective earned value." Effective EV allowed for computing an effective ES. These effective values could then be employed in the calculation of the variances, indexes, and forecasts attributed to the methods from Earned Value Management (EVM) and ES[2]; thereby providing a pessimistic, but truer view of project performance.

In 2011, the approach for forecasting the total cost of rework caused by SA was developed [Lipke, 2011]. Having the ability to compute the cost impact of rework, in turn, gave project managers reason to increase attention to managing schedule performance and improving planning.

Although facility has been available for calculating the schedule performance impacts of rework, it hasn't been fully recognized, and certainly not utilized. The application of SA from its introduction several years ago, primarily, has focused on the impact to project cost. This article provides a brief review of ES and SA, and then presents methods for computing the impact of rework on schedule performance.

[1] How to cite this paper: Lipke, W. (2020). Schedule Performance Impact from Rework; *PM World Journal*, Vol. IX, Issue I, January.
[2] Reference [PMI, 2011] for EVM and ES terminology definitions and formulas for variances, indexes, and forecasts.

Review

Earned Schedule

Earned Schedule is dependent upon EVM; the ES measure is derived from the accrued earned value (EV) and the performance measurement baseline (PMB) [Lipke, 2003]. As shown in figure 1, "…the idea is to determine the time at which the EV accrued should have occurred." The time duration from project start to the point on the PMB where the planned value (PV) equals the EV accrued is the earned portion of the planned duration (PD), i.e. ES. The calculation method for determining the value of ES is explained, in detail, in the *Earned Schedule* book [Lipke, 2009].

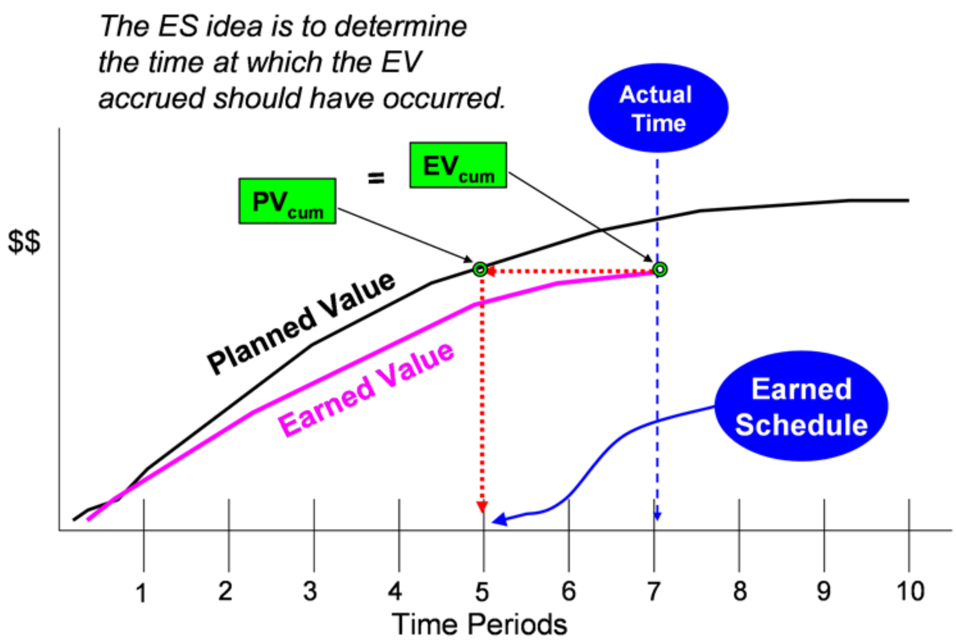

Figure 1. Earned Schedule Concept

Having the capability to determine ES and the actual time (AT) at which the EV is reported, the time-based indicators for schedule performance index, SPI(t), schedule variance, SV(t), and to complete schedule performance index (TSPI) are created:

SPI(t) = ES / AT
SV(t) = ES – AT
TSPI = (PD – ES) / (TD – AT)

where the target duration (TD) is the value of interest to the project manager or project customer.

Beyond assessing current status, the forecasting of project duration and completion date is made possible using the formula below:

$$IEAC(t) = PD / SPI(t)$$

IEAC(t) is the independent estimate at completion (time), i.e. the forecast duration, the expected time for project completion.

Schedule Adherence

Figure 2 provides a visual for discussing the concept of schedule adherence. The tasks to the left of the ES line, not completely darkened, are those possibly experiencing impediments and constraints (I/C), or poor process discipline. The darkened tasks to the right of the vertical ES line indicate performance resulting from voids identified by the I/C tasks. Frequently, those darkened tasks to the right are executed without complete information. The performers of these tasks must necessarily anticipate the inputs expected from the incomplete preceding tasks; this consumes time and effort and has no associated earned value. Because the anticipated inputs are very likely misrepresentations of the future reality, the work accomplished (EV accrued) for these tasks usually contains significant amounts of rework. Complicating the problem, the rework created for a specific task will not be recognized for a period of time. The eventual rework will not be apparent until all of the inputs to the task are known or its output is recognized to be incompatible with the requirements of a subsequent task.

This conceptual analysis leads to the measurement of schedule adherence. By determining the EV for the actual tasks performed congruent with the project schedule, a measure can be created. The adherence to schedule characteristic, P, is described mathematically as a ratio:

$$P = \Sigma\, EV_k / \Sigma\, PV_k$$

PV_k represents the planned value for a task associated with ES. The subscript "k" denotes the identity of the tasks from the schedule which comprise the planned accomplishment, either completed or in-work. The sum of all PV_k is equal to the EV accrued at AT. EV_k is the earned value for the "k" tasks, limited by the value attributed to the planned tasks, PV_k. Consequently, the value of P, or P-Factor, represents the proportion of the EV accrued which exactly matches the planned schedule.

When the value for P is much less than 1.0, indicating poor schedule adherence, the project manager has a strong indication the project will have rework at some point in the future. Conversely, when the value of P is very close to 1.0, the project manager (PM) can feel confident the schedule is being followed and that milestones and interim products are being accomplished in the proper sequence.

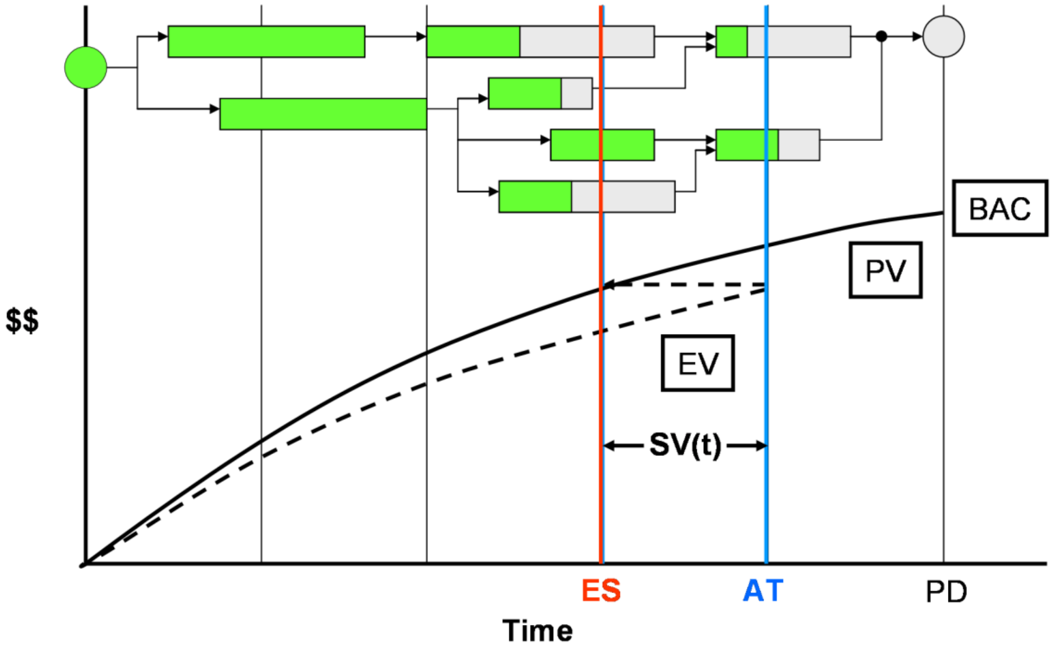

Figure 2. Actual versus Planned Performance

Rework Calculation

The diagram shown in figure 3 is provided to aid the understanding for computing rework. EV(p) represents the portion of the EV accrued that is in agreement with the schedule; whereas, EV(r) is the portion for which rework is probable. The fraction of EV(r) requiring rework is EV(-r). For notation simplicity in the subsequent discussion, R is substituted for EV(-r).

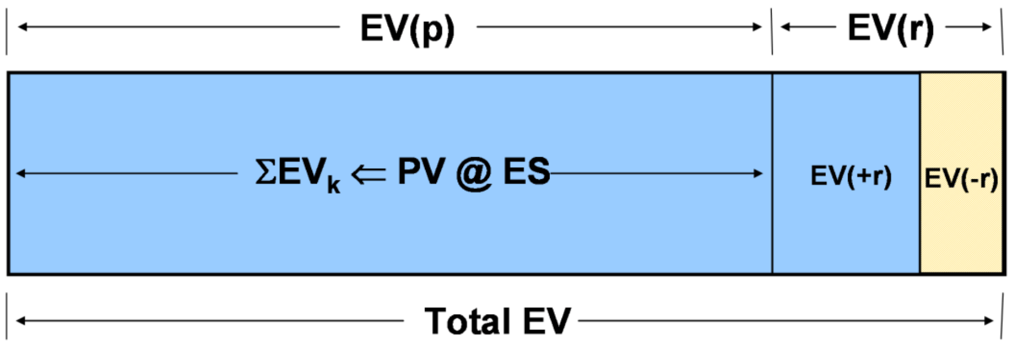

Figure 3. Rework Diagram

At each status point, the amount of rework from performing work out of sequence is given by the following equation:

$$R = EV(-r) = f(r) \times EV(r) = f(r) \times (1 - P) \times EV$$

where f(r) is a function for determining the portion of out of sequence work requiring rework. Other representations are possible[3], however the one presently in use is:

$$f(r) = 1 - C \times e^{(-0.5 \times (1 - C))}$$

where C is the fraction complete of the project; C equals EV divided by the planned project budget, i.e., Budget At Completion (BAC).

Schedule Impact

The impact to schedule performance from not adhering to the schedule can be observed by the change in the schedule indicators (SV(t), SPI(t), TSPI), and the duration forecast (IEAC(t)). When the change values are large, management investigation and intervention is needed. Conversely, when the change is small, the impact of SA can be ignored. Should the change be significant, management attention is appropriately focused on those tasks identified as having impediments or constraints. Additional rework is likely by not resolving problems impeding or constraining task progress.

Let's begin by examining the cost effect of rework. By subtracting R from the EV accrued, the accomplishment effectively moving the project to completion is determined:

$$EV_e = EV - R$$

The EV_e value is then used with the PMB to compute the effective Earned Schedule, ES_e. Just as EV_e is less than EV, ES_e will always be less than ES.

It follows that the schedule indicators and forecast must worsen when accounting for rework. Including effective ES, more pessimistic values are derived from the formulas:

$$SV(t)_e = ES_e - AT$$
$$SPI(t)_e = ES_e / AT$$
$$TSPI_e = (PD - ES_e) / (TD - AT)$$
$$IEAC(t)_e = PD / SPI(t)_e$$

So as to distinguish from the formulas not accounting for rework, those above have an "e" subscript.

To more directly assess the impact of rework, the indicator and forecast change values can be computed using the following equations:

[3] The general equation is given by f(r) = 1 – C^n × e^(-m × (1 – C)); where C is fraction complete of the project (EV/BAC), e is natural number (base "e"), ^ signifies an exponent follows, and n and m are curve shaping variables. The conditions for f(r) follow: when C = 0, f(r) = 1; when C= 1, f(r) = 0.

$$\Delta SV(t) = SV(t)_e - SV(t) = ES_e - ES = \Delta ES$$
$$\Delta SPI(t) = SPI(t)_e - SPI(t) = \Delta ES / AT$$
$$\Delta TSPI = TSPI_e - TSPI = -\Delta ES / (TD - AT)$$
$$\Delta IEAC(t) = IEAC(t)e - IEAC(t) = -\Delta ES \times (PD \times AT / ES_e \times ES)$$

The noticeable term appearing in all of the equations is ΔES, i.e., the impact to schedule progress. Its value will always be negative, unless the P-Factor equals 1.0. Understanding the change is negative, the values for ΔSV(t) and ΔSPI(t) will likewise be negative, logically indicating that poor SA causes SV(t) and SPI(t) to worsen.

The mathematical expressions for ΔTSPI and ΔIEAC(t) contain the term, -ΔES. The minus sign causes the change values to be positive. For both, TSPI and IEAC(t), positive values indicate worsening performance. When the increase causes $TSPI_e$ to be greater than 1.00, performance for the remainder of the project must be better than planned to achieve the desired delivery time. Or, if $TSPI_e$ becomes greater than 1.10, the project is not considered recoverable [Lipke, 2016]. Likewise, the positive value for ΔIEAC(t) tells the project manager the forecast duration is lengthened due to rework.

Although the application of SA provides a more accurate assessment of current status, it does involve considerably more analysis effort. Determining the value of the P-Factor is critical and difficult when the EVM/ES analysis tool in use does not have the capability. Therefore it is useful to examine SA behavior, seeking simplification and reduction of effort.

In general, there is variation in the indicator and forecast values from one status period to the next. As the project progresses the variation tends to decrease [Lipke, 2014]. Just as the indicator and forecast variation converge to the actual final values with progress, the change values will decrease, as the P-Factor converges to its final value, 1.0.

Because of the behavior of the P-Factor, the application of SA to amend indicators and forecasts has more impact early in the project execution. Thus, when managing without the benefit of SA analysis, it is recommended for project managers to consider performance status early in the execution as being overly optimistic. As a “rule of thumb,” after the project has accomplished 50 percent of its planned budget, the rework impact to cost and schedule indicators and forecasts is very likely not significant, and can be ignored.

Example Application

To demonstrate the impact of rework on schedule performance two scenarios are used. One depicts a late performing project and the other gives the illusion of completing early. For the late performing project, reference table 1. The top two rows provide the project data. Rows 3 and 4 are computed status values, while rows 5 and 6 indicate the change to the status values from impact of rework.

The project has little hope of achieving the target duration (22). Without accounting for rework, the forecast indicates the expected completion will be 25 periods, 3 periods overdue. The impact of rework indicates the situation is even worse; ∆IEAC(t) equals 3.6 periods, thus the amended expectation is more than 6 periods past due. This difference in forecasts is significant. Should the PM focus attention on TSPI only, he/she might assume the project is on course to complete at the target duration. However, with ∆TSPI = 0.08, $TSPI_e$ is nearing the threshold value of 1.10. Having this information the PM would have a very different view, most likely considering intervention for project recovery. From the table, -∆ES/ES is 12.5 percent, a fairly large value. This value, alone, makes it clear the "e" indicators and forecast are needed to appropriately manage the project.

PD	**AT**	**TD**	**ES**	
20	10	22	8	
SV(t)	**SPI(t)**	**TSPI**	**IEAC(t)**	**ES_e**
-2.0	0.80	1.00	25	7
∆SV(t)	**∆SPI(t)**	**∆TSPI**	**∆IEAC(t)**	**-∆ES/ES**
-1.0	-0.10	0.08	3.6	12.5%

Table 1. Late Finish Project

Next, let's examine the early finish project data presented in table 2. The PD and TD values are the same as those shown in table 1. The AT and ES values, 6 and 7, respectively, yield a very positive performance set of indicators and forecast. It appears the project is on course to complete 2.9 periods early. However, the out of sequence performance has created the possibility of significant rework; ES_e is computed to be 4 periods less than ES.

If the PM had the change information shown in rows 5 and 6, he/she would be alarmed, rather than feeling comfortable that the project is in good shape. Instead of completing early, the change values show a project in serious trouble. The recognition of rework in the analysis provides a much different assessment. The project, early in its execution, is behind by 3 periods; the schedule performance efficiency is 0.50, not 1.17; $TSPI_e$

equal to 1.06 indicates the project is not likely to achieve TD, and is barely recoverable; the forecast is 40 periods, twice PD. As well, -ΔES/ES equaling 57 percent is incredibly large; out of sequence task performance is predominant

Should the PM not perform the SA analysis and not recognize the performance deficiencies, more rework would be generated. The problems causing the out of sequence task performance and rework would not have been investigated, identified, and possibly resolved. The project would soon reach a point where recovery is not possible.

PD	**AT**	**TD**	**ES**	
20	6	22	7	
SV(t)	**SPI(t)**	**TSPI**	**IEAC(t)**	**ES_e**
1.0	1.17	0.81	17.1	3.0
ΔSV(t)	**ΔSPI(t)**	**ΔTSPI**	**ΔIEAC(t)**	**-ΔES/ES**
-4.0	-0.67	0.25	22.9	57%

Table 2. Early Finish Project

It is common knowledge that immediate correction of performance problems decreases their impact. Not allowing problems to propagate and become larger greatly increases the probability of having a successful project. Thus, application of SA analysis is highly recommended, especially during the first one-half of the project execution.

Summary/Conclusion

The concept of Schedule Adherence, derived from ES analysis, provides methods for assessing the impact of performing project tasks out of their planned sequence. When out of sequence performance occurs, it is probable that rework will be required at some future time. Thus far, the attention to rework has primarily been concerned with analyzing the increase to project cost. There has been little effort to understand the rework impact to schedule performance.

Applying SA analysis facilitates accounting for rework; amended formulas for schedule performance indicators and forecast are introduced. As well, formulas are provided for computing the amount of change rework causes to schedule performance. The computed value for -ΔES/ES is introduced as a simple way for assessing the magnitude of the negative impact that rework may cause. It is noted that as the project progresses the potential for rework diminishes as the P-Factor converges to its final value, 1.00.

The early and late project finish examples numerically demonstrate the impact of rework. For the early project, it is shown that analysis without including rework can provide a false understanding of project status. The observation was made that addressing the out of sequence performance early enhances the probability of having a successful project.

References

Lipke, W. (2016). "Examination of the Threshold for the To Complete Indexes," *The Measurable News*, Issue 1: 9-14

Lipke, W. (2014). "Testing Earned Schedule Forecasting Reliability," *PM World Journal*, July Vol III, Issue 7

Lipke, W. (2011). "Schedule Adherence and Rework," *The Measurable News*, Issue 1: 9-14

Lipke, W. (2009). *Earned Schedule,* Raleigh, NC: Lulu Publishing

Lipke, W. (2004). "Connecting Earned Value to the Schedule," *The Measurable News*, Winter: 1-16

Lipke, W. (2003). "Schedule is Different," *The Measurable News*, Summer: 31-34

Project Management Institute, *Practice Standard for Earned Value Management,* 2nd ed., Newtown Square, PA: PMI, 2011.

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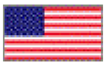

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- Master of Science Physics
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- PMI Metrics SIG Scholar Award (2007)
- PMI Eric Jenett Award (2007)
- Who's Who in the World (2010)
- EVM Europe Award (2013)
- CPM Driessnack Award (2014)
- Australian Project Governance and Control Symposium established the annual *Walt Lipke Project Governance and Control Excellence Award* (2017)
- Albert Nelson Marquis Lifetime Achievement Award (2018)

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