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Advances in Project Management [1]

Effective Measurement of Time Performance using Earned Value Management

A proposed modified version for SPI tested across various industries and project types

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Abstract

Earned Value Management (EVM) is a project performance measurement technique, sometimes referred to as being primarily oriented towards cost management but with limited applicability to managing time performance. There have been various arguments supporting this perspective, namely: it ignores the detailed aspects of the schedule like floats and the critical path, its indicators are based on currency value hence not intuitive for time management, and finally the time performance indicator SPI always gives the value of 1 (i.e. a project "on time") in late or early finishes. The last argument in particular is typically used to declare SPI as an invalid or unreliable time performance indicator. However, all of these arguments are only apparent. As we will demonstrate in this paper EVM can provide useful and valid time performance measures. The problem with the SPI indicator floating towards the value of 1 has been the subject of alternative approaches, for example its calculation based on the concept of *Earned Schedule*. While this alternative approach resolves the problem of SPI floating towards one in late or early finishes, the secondary effect is that it also gives this indicator a different meaning than the original concept. Based on academic research using computer simulation models, and on practical applications in real life projects, the author has developed an extended version of the original SPI (based on volume of work), which ensures the validity of this indicator throughout the whole

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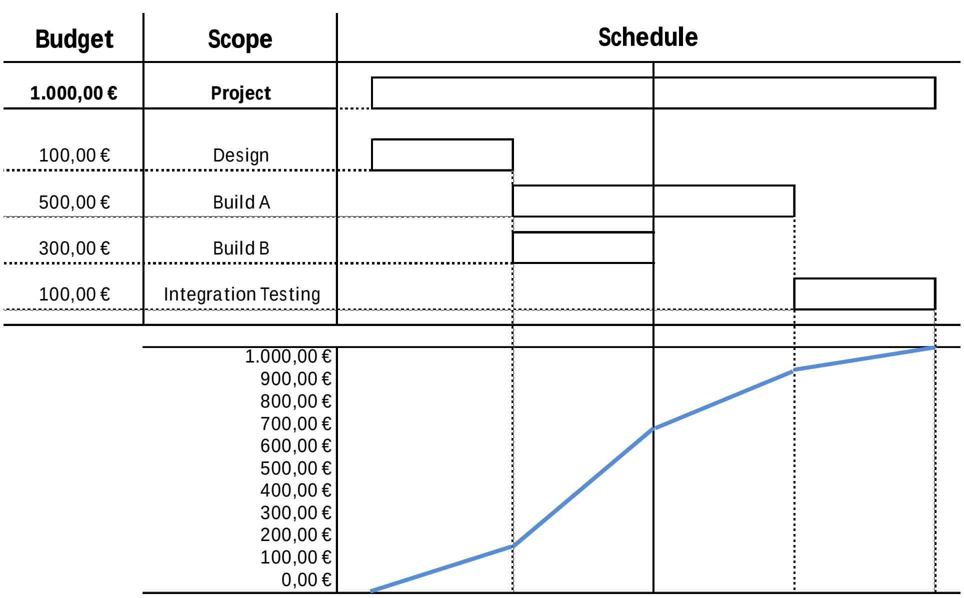
[1] *This series on Advances in Project Management was launched with a Guest Editorial by Professor Darren Dalcher and first article in the December 2009 edition of PM World Today. Please read that introductory editorial at http://www.pmworldtoday.net/editorials/2009/dec/GuestEditorial-DarrenDalcher.html where Professor Dalcher explains and sets the stage for articles in this exciting series by leading authors in the field of project management. Please read previous articles in the series by visiting http://www.pmworldtoday.net/archives/archives.htm, beginning with the December 2009 edition. Each month's article is introduced by Professor Darren Dalcher, special editor of the Series on Advances in Project Management. Darren is also the editor of the Advances in Project Management series of books for Gower Publishing in the UK – our series includes articles by authors in the Gower book series. To read Professor Dalcher's introduction to this month's article, click www.pmworldtoday.net.*

execution period for the project. The solution found to overcome the weakness of the original SPI indicator preserves the original meaning of the *time performance* concept, i.e. how fast against the plan is the volume of work being accomplished. This extended modified version of SPI has been used in several projects across various industries, in different countries, and it has successfully delivered useful and valid performance information. The extended model developed includes additional formulae for various "to complete on time" indicators (TSPI) and "at completion" forecasts. This paper briefly explains the modified version of SPI and it also discusses the overall validity of using EVM to support effectively project time management. Some practical examples are also presented to illustrate the concepts. The use of SPI-based time performance indicators for the purpose of Risk Management under conditions of uncertainty is also discussed.

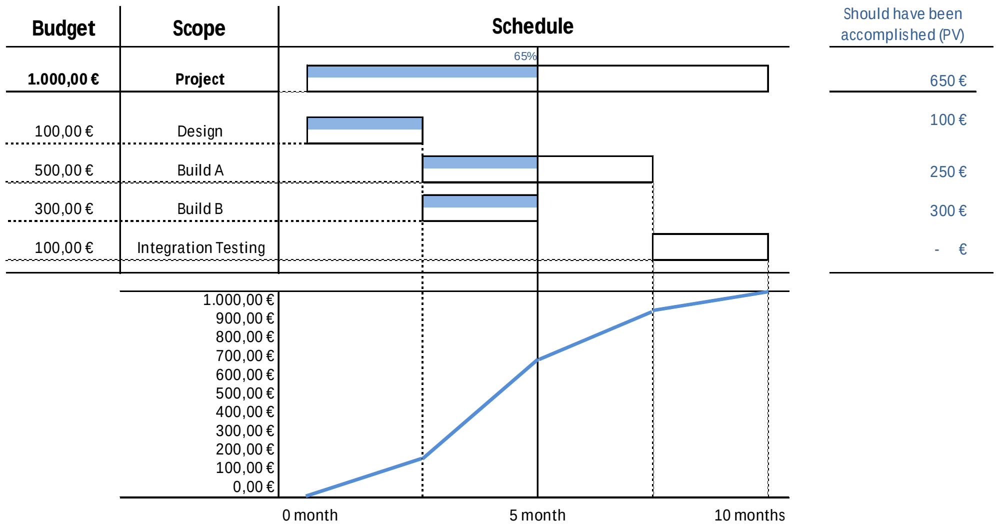
Introduction

The Earned Value Management method, often mistaken as an advanced technique only applicable to large complex multi-million projects, is grounded on the following key principles:

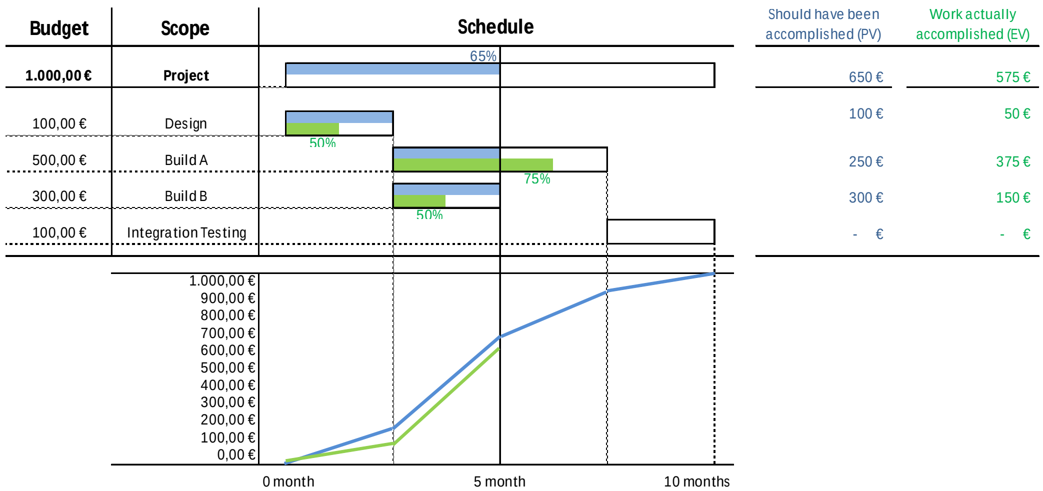
a) The project plan must integrate scope, cost and time elements. The work defined in the WBS, which is budgeted, it is also formally related to the project schedule. In simpler terms, the work budgeted is the same work that is scheduled. This formal relationship between the project scope cost and time elements allows for an accurate time distribution of the project budget, as illustrated in the figure below.



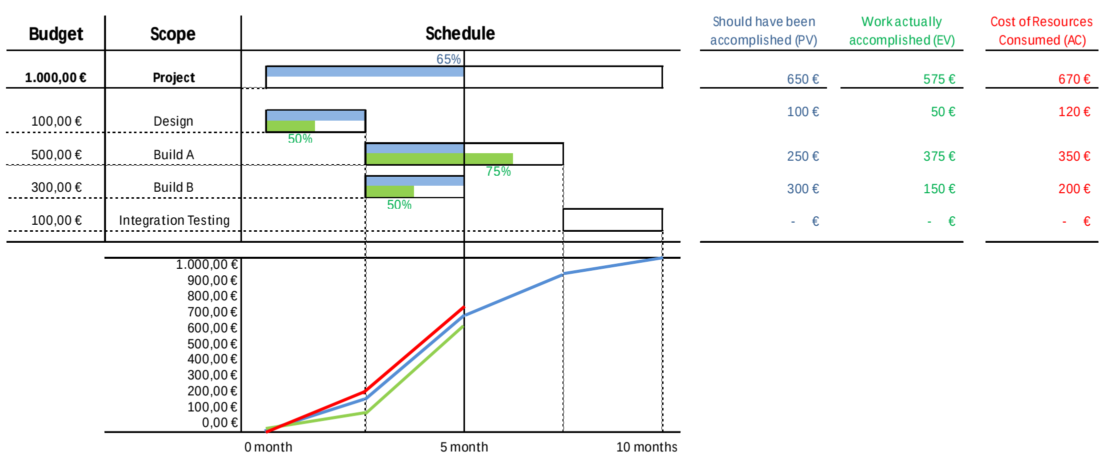
b) As time elapses, account can be made for the *volume* of work that should have been accomplished to date. This *volume of work* is to be measured as *monetary value*. In simpler terms, 1 $ = 1 unit of work. In our example, the amount of work that should have been accomplished by month 5 is 650 *units of work* (i.e. 650 $), which accounts for 65% of planned progress against the total scope of 1000 *units of work* (i.e. 1000 $). The measure of the volume of work that should have been accomplished to date is referred to in EVM as **Planned Value**. This is illustrated in figure below.



c) Work accomplishment must be measured in an objective and independent manner, leading to a % progress measure according to established criteria depending on the nature of the work – e.g. % work progress = no. tests passed / no. of total tests. Measuring % progress allows for the accounting for the *volume of the work* actually accomplished to date, which is again measured in *monetary value*. The measure of the volume of work that was actually accomplished to date is referred to in EVM as **Earned Value**. This is illustrated in figure below, where the total volume of the work actually accomplished to date equals 575 *units of work*, which accounts for 57,5% of the total scope.



d) As work is accomplished, various types of resources (internal or external to the organization) are consumed, accounting for the work and for the project actual cost incurred. Note that the cost incurred due to *resource consumption* is not necessarily the same as the official cost invoiced and/or paid in standard accounting terms. Sometimes resources are consumed for which payments or invoices have not yet been received; alternatively, invoices and payments might have been already issued for resources not yet consumed (e.g. pre-payments). This is illustrated in the figure below where a total cost of 670 $ was incurred to accomplish to date 575 $ of volume of work.



In summary, the Earned Value Management method is based on the principle that, as the project progresses, the following three questions can be answered in measurable terms and in the form of monetary value:

a) How much work should have been accomplished to date? (PV)

b) How much work was actually accomplished to date? (EV)

c) How much cost was incurred for the resources consumed to date? (AC)

The requirements to answer these questions in measurable terms as monetary value are:

a) The project plan formally integrates scope, cost and time elements;

b) Work accomplishment is measured independently in % progress;

c) The cost of the resources consumed is accounted for and allocated to the project work.

In the author's experience, answering the three questions above and meeting these three requirements is a matter of adopting essential planning and control best practices, and these are applicable to projects of all sizes and of any nature (e.g from construction to software development).

Measuring Time Performance with Earned Value

Based on the three main measures described (i.e. PV, EV and AC), it is possible to produce a variety of performance metrics in both cost and time dimensions.

Cost performance indicators have achieved wide acceptance, since the EVM method has always been primarily associated with cost control. In our example, it is apparent that:

a) There is currently a cost overrun, since 670 $ were spent (AC) to produce only 575 $ of work (EV). Since 1 $ = 1 unit of work, then if 575 units of work were produced only 575 $ should have been spent. The excess cost consumed to date (Cost Variance - CV) can be accounted as CV = EV-AC = -95 $.

b) The reason why excess cost was consumed relates to cost efficiency being lower than expected. In fact, for each 1 $ spent, 1 unit of work should have been produced. If that has been the case, then 670 units of work would have been produced. However, only 575 units of work were produced, implying that each 1 $ spent produced less than 1 unit of work. In fact, for each 1 $ spent only 575 / 670 = 0.86 units of work were produced. Or in other words, each 1 $ consumed produced only 0.86 $ of work value. This ratio of EV/AC (i.e. value of work produced / cost of resources consumed) is known as cost performance index (CPI) and it measures cost efficiency.

Besides CV and CPI, there other cost metrics and indicators are available in the EVM method, all of which generally achieve wide acceptance.

With regard to time performance, similar indicators have been produced, in particular:

a) Schedule Variance (SV) = EV – PV.

   If 575 units of work were produced while according to the project plan 650 units of work should have been produced, then less work was accomplished to date than planed and therefore overall there is work behind schedule that was not done and should have been done. In our example, this amounts to 75 units of work that should have been accomplished but which have not yet been produced. In monetary terms, the project is behind schedule by -75 $. That is, the budget of the *volume of work* behind schedule is 75 $.

b) Schedule Performance Index (SPI) = EV / PV.

   If 575 units of work were accomplished against 650 units of work that should have been accomplished according to the plan, then only a *fraction* of the planned work has been accomplished, and this is 575 / 650 = 0.88. In other words, only 88% of the volume of work planned to be accomplished to date was actually produced. Another immediate conclusion is that the work was executed at a slower rate (or speed) than assumed in the plan. The work rate was in fact 88% of the planned work rate. The SPI indicator is the counterpart of the cost efficiency indicator CPI for time performance and it is aimed at measuring time efficiency.

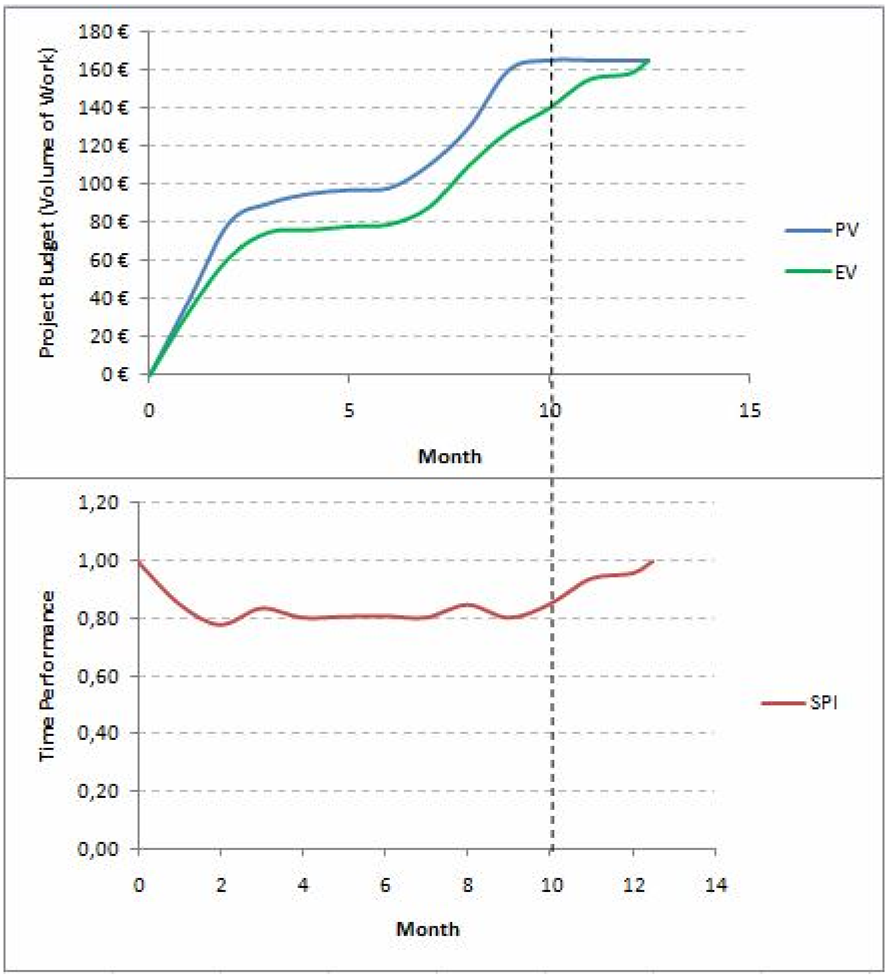
Perhaps all would be fine with EVM for time management purposes if there would be no problems with these performance indicators. But the reality has shown that there are issues in particular with the SPI indicator.

The Problem with the SPI indicator

The main problem with SPI is revealed when EVM is applied not just at the project level but also at the work package sub-level. At this level, work packages are often completed behind schedule or in advance of the scheduled completion date. On other occasions, the work is even started ahead of schedule. In these scenarios, the SPI indicator can produce values that seem to bear no relationship with reality. Some examples of these scenarios are given below.

The Late Finish Problem

When the baseline completion date is reached and the work is not totally completed, then execution extends beyond the baseline completion date and the SPI indicator continues to be calculated. However in this scenario, the SPI value will float towards 1 as the work reaches late completion, as illustrated in the figure below (see blue curve), where the project is schedule to be completed in 10 months but it takes 12.6 months to actually complete the entire project work.



The reason for this phenomenon is that as the work continues to be executed beyond the baseline completion date, the EV value (volume of work accomplished) continues to increase, whereas the PV value (planned volume of work) remains constant as it reached its maximum by the baseline completion date – i.e. the whole work was planned to be completed by the baseline completion date.

The problem with this phenomenon is also obvious: the SPI indicator will produce performance values that will suggest an increasingly better time performance, well above the real performance. Consider for example the following scenario:

- Project budget = 1000 $
- Baseline completion date = 5 months;
- Time now = 10 months;
- PV (planned work) = 1000 $ (i.e. 1000 units of work);
- EV (actual work accomplished)= 950 $ (950 units of work);
- SPI = 950 / 100 = 0,95 = 95%.

In this example, by reading the SPI indicator as previously described, one would conclude:

a) By month 10, 95% of the work that was planned to be accomplished (1000 units of work), was actually produced. While this is true, the 1000 units of work were already planned to be accomplished much earlier, by month 5;

b) The project work has been accomplished at a pace that is 95% of the planned work rate. This is, the actual work rate is 95% of the e work rate assumed in the project plan. <u>This is an incorrect conclusion</u>.

Overall, a performance of 95% seems to be very close to the planned performance, whereas one can easily verify that the project will take <u>more than twice</u> its originally planned duration and therefore time performance is actually less than half (i.e. <50%) of the planned performance. In the end of the project (or of the work package), the SPI will always be equal to 1, indicating a time performance of 100% even though the project was completed well beyond the baseline completion date.

This problem with SPI is aggravated when other time performance metrics are calculated based on SPI, such as the estimated final duration which is calculated as:

- Estimated Duration = Planned Duration / SPI (Time Efficiency)

  In our example:

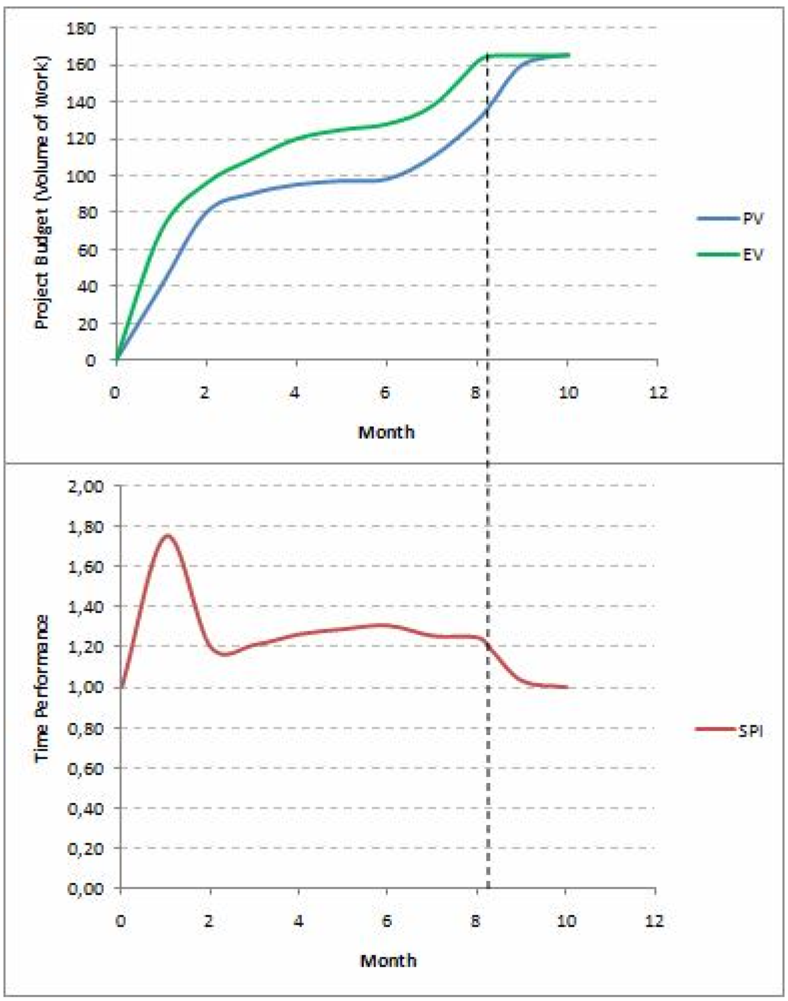
  Estimated Duration = 5 months / 0.95 = 5.26 months

Obviously, the project will never be completed in month 5.26, since we are already in month 10 and the whole work is not yet accomplished.

The Early Finish Problem

In a scenario of an early finish, time performance should be above 100%, or in other words the work was accomplished at a time rate (speed) higher than assume in the plan – the work was certainly done faster.

As illustrated in the following figure, in the scenario of an early finish, at the time the work is completed before the baseline completion date, the SPI indicator will give a value above 1, as expected. However, as time continues to elapse in the project, the value of PV (planned work) will continue to evolve until it reaches the total project scope by the baseline completion date.



At this new moment in time, the SPI indicator will produce a value of 1, since EV = PV = total work (or baseline budget). In summary, from the period ranging from the actual completion date to the baseline completion date, the SPI indicator will float again towards the value of 1. While this would not be a problem for the whole project (since performance is not longer measured after the project is completed), it is certainly a problem for individual work packages, or project phases. But the problem is still a bit worse, since for the final project performance the final figure of SPI is not totally correct.

Let us consider again the following scenario:

- Project budget = 1000 $
- Baseline completion date = 5 months;
- Time now = 4 months;
- PV (planned work) = 700 $ (i.e. 700 units of work);
- EV (actual work accomplished)= 1000 $ (100 units of work);
- SPI = 1000 / 700 = 1.43 = 143%.

In this situation a project that was planned to be completed in 5 months was actually accomplished in 4 months. By reading the SPI indicator, one would conclude:

a) By month 4, 143% of the work that was planned to be accomplished (700 units of work), was actually produced. This is a correct statement since 1000 = 143% x 700 units of work;

b) The project work has been accomplished at a pace that is 143% of the planned work rate. This is the actual work rate is 143% of the e work rate assumed in the plan. <u>This is an incorrect conclusion if applied to the final project performance</u>.

In fact, if the work had been accomplished at a 143% work rate, then each month on average would have produced 143% of the planned work and therefore the project would have been completed by month 3.5 (i.e. 5 months / 143% = 3.5 months), which is not the case. While it is true that by month 4, the work rate was 143% of the overall planned work rate for that moment in time, in terms of the total project, the whole scope was accomplished in 4 months instead of 5 months and this is not a 43% increase in time efficiency but rather it is a 25% increase, as it can be demonstrated:

- Planned work rate = 1000 units of work / 5 months= 200 units of work / month;

- Actual work rate = 1000 units of work / 4 months = 250 units of work / month;
- % Actual work rate / Planned work rate = 250 / 200 = 1.25 = 125%.

In conclusion, in an early finish scenario the final performance is incorrect and SPI will float towards 1 until the baseline completion date is reached.

Work Started Ahead of Schedule

When work is stated ahead of schedule, the EV will produce a value equal to the amount of work accomplished in a period of time where no work was supposed to have been done. Therefore, for that period, the PV will have a value of zero (no work supposed to be done). The results in terms of time performance will be:

- SV = EV – PV = EV.

  It will produce a positive value indicating the amount of work that has been accomplished ahead of schedule.

- SPI = EV / PV = EV / 0.

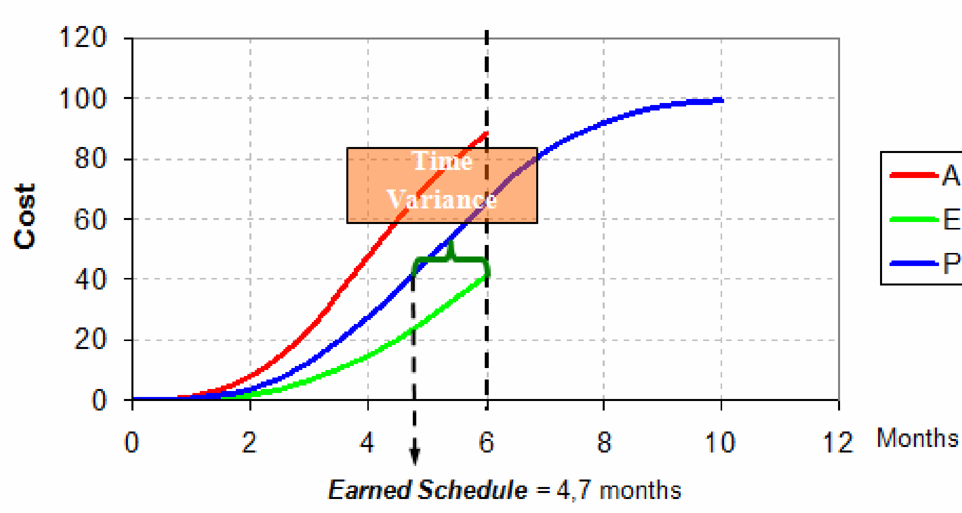
  This is indeterminate, since no value can be produced. In a period of time where there is not work planned to be executed (therefore no planed performance), the actual performance cannot be compared against a reference.

An Alternative Approach: Earned Schedule

An alternative approach to measure time performance under EVM has been proposed based on the concept of *Earned Schedule*. Basically, this approach converts the metrics PV and EV in to the time axis in the following way:

- PV is converted into Actual Time (AT) – this is the time planned to have elapsed in the project to date, or alternatively the *time consumed* in the project.
- EV is converted into Earned Schedule (ES) – this is the time that should have elapsed considering the actual work accomplished.

By comparing the difference between ES (time allocated in the plan for the work accomplished) and AT (time actually consumed, allocated for the work planned to date), a variance can be calculated called Time Variance (TV) = ES – AT, as illustrated in the figure below.



In this simple example, 6 months elapsed to date (AT) and about 65 units of work should have been accomplished (PV). However, only 40 units of work were actually accomplished (EV). According to the plan, this amount of work accomplishment was due by month 4.7 (this is the Earned Schedule value). Or in other words, it took 6 months to execute work that was planned to be executed in 4.7 months and therefore the project is behind schedule by 1.3 months – this is the Time Variance.

A first appearance of the concept of Time Variance calculated in this way dates back to 1990, in a book by John Nicholas ("Managing Business and Engineering Projects", Prentice-Hall), and where the concept of Earned Schedule is also present (although not under this name).

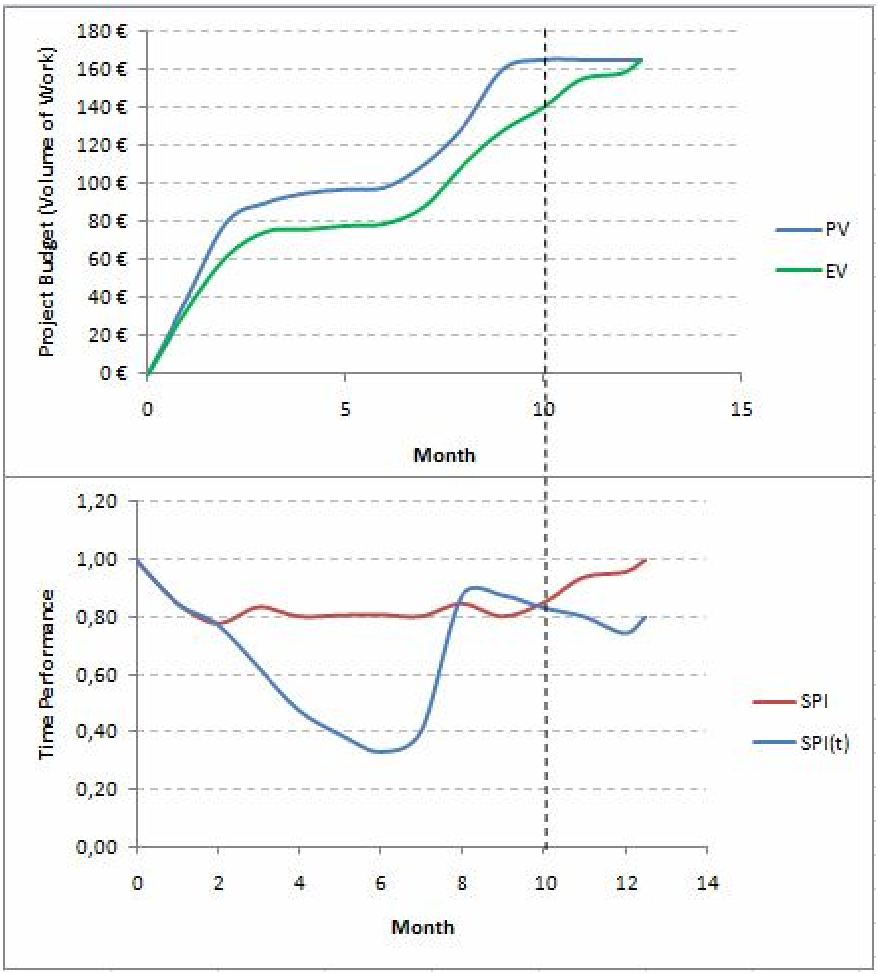
More recently, the use of EVM metrics based on this approach has deserved greater attention – the reader may wish to refer to the following website for more information and references: http://www.earnedschedule.com/. This approach suggests the following alternative metrics calculated in the time axis as opposed to the work volume (budget) axis:

- SV(t) = ES – AT. This is the concept of Time Variance in Nicholas book (1990);
- SPI(t) = ES / AT.

The first merit of this approach is that the problem of SPI floating towards the value of 1 in scenarios of early or late completion is resolved. Some of the main proponents of this approach also suggest that the ES based indicators also provide better predictions about the future project completion date.

Considering our previous example, the figure below shows the behavior of the SPI (t) indicator, showing that after the completion date performance continues to be measured in a more consistent manner. The final value is consistent with the final result: the project was initially planned to be executed in 10 months but it took 12.5 months to complete the work. Therefore, each month on average only produced 80% of the planned work (i.e. 10/12.5 = 0.8) and therefore more time was needed to complete the project. This is the final value for SPI(t) as follows:

- SPI(t) = ES / AT = 10 months / 12.5 months = 0.8



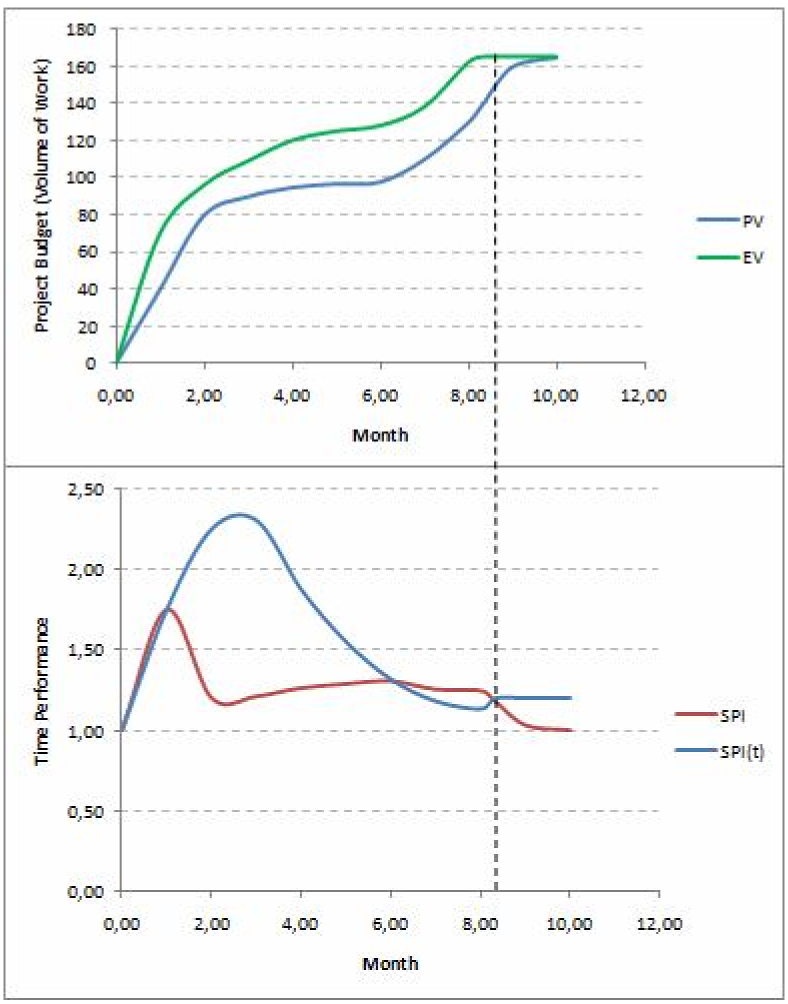
While the pattern of variation of the new indicator seems to be sensitive to periods of time where the intensity of the work rate is planned to be low (i.e. between months 2 a 8), its behavior is certainly more consistent in the late completion period than the conventional SPI indicator.

In scenarios of early finishes, this new version of SPI also seems to maintain a consistent behavior as shown in the following figure. It also corrects the final value of

SPI, since although it may appear to have the same value, by month 8.33 when the work is completed the scenario is as follows:

- PV = 140;
- EV = 165;
- SPI = 140/165 = 1.18;
- SPI(t) = 10/8.33 = 1,2.

As it can be seen the final value of the conventional SPI is not the same as SPI(t). As already mentioned before, in an early finish the final value of conventional SPI might not be correct, which is the case in this example. The final time performance is in fact 20% above the planned performance (i.e. 10 months of work were done in 8.33 months).



While the earned schedule approach seems to resolve the problem of conventional SPI, it also presents at least two issues:

a) It seems to be very sensitive to periods of time where the planned work rate is slow. For example:

    a. Project planned duration = 10 months
    b. Planned work (PV) by month 3 = 100 $
    c. Planned work (PV) by month 5 = 105 $
    d. Actual time (AT) = 5 months
    e. Earned Value (EV) = 100 $
    f. Earned Schedule (ES) = 3 months (time where PV = current EV)
    g. SV(t) = -2 months
    h. SV = -5 $
    i. SPI(t) = ES/AT = 3/5 = 0.6 = 60%
    j. SPI = EV / PV = 100/105 = 0.95 = 95%

   So, the SPI(t) indicates a very low level of performance of 60%, whereas in reality only about 5% less work was actually accomplished than planned for the current date. (i.e. 100 units of actual work, against 105 units of planned work).

b) The fundamental meaning of time performance is changed, shifting the focus from "how much work is behind / ahead of schedule" into "how much time is the project behind / ahead of schedule". In the simple example presented above one can confirm that the project is behind schedule by 2 months – but what is the real meaning of that measure? It means that the progress we currently achieved in the project (100 units of work) should have been achieved according to the plan 2 months ago. So one could say that this is "equivalent" to a scenario where the work planned for the last two months was not accomplished (the project would have been paused for the last two months). While this is correct, the amount of work planned for those two months is as little as 5$, representing less than 5% of the planned work (i.e. 5/105). Therefore, *these two months of delay represent a small volume of work and most likely are very easy to recover*. Therefore, *time variation during the project might not be as meaningful as volume variation in* *regards to appreciating the real size of a schedule performance problem*. *A recognized merit of EVM in measuring schedule performance is the focus on the volume of work behind schedule*, which in practice is the real size of the problem in a late project: how much extra work do we need to fit into the remaining future time in order to complete the project on schedule? The answer is: the amount of work currently behind schedule (i.e. SV). By focusing on the volume of work, the conventional SPI does have a merit over the Earned Schedule alternative, by focusing closer to the cause of the delay as opposed to the delay itself. Time variation, that is TV or SV(t), is an intuitive and useful information for the stakeholders, but a complete and more exhaustive appreciation of schedule performance must look into the volume of work behind schedule – the real problem that, if overcome by executing that work in the available time, will consequently eliminate the time delay (effect). Conventional SPI and SV relate and measure the size of that problem – how serious is the time delay? How much volume of work is within the current time delay? What does the current time delay represent in terms of work that needs to be recovered?

The author has developed another alternative to the calculation of SPI which on the one hand resolves the problems with the early and late finishes, while preserving the original focus of time performance on the volume of work ahead or behind schedule.

An Alternative Approach: Modified SPI

The alternative approach here presented was the result of various years of experience in implementing Earned Value Management in the field in a wide range of different projects and environments. It was also the result of academic research conducted by the author over the period of several years in the field of Project Management, using computer simulation models (System Dynamics modeling – see Rodrigues 2001).

The approach proposed for a modified version of the SPI indicator is inspired by the laws of physics, where time performance can be related to the concept of velocity as follows:

- Velocity (physics) = distance (km) / time (hours)
- Velocity (project) = work units accomplished / time elapsed
- SPI (time performance) = Actual Velocity / Planned Velocity (modified version of SPI)

Where:

- Actual velocity = actual work accomplished (EV) / time elapsed
- Planned velocity = work planned to be accomplished (PV) / time elapsed

And hence:

- SPI(modified) = (EV / time elapsed) / (PV / time elapsed)

And therefore SPI(m) = EV/PV = SPI (conventional)

This reasoning inspired by physics (where distance = work accomplished) leads us to the conventional SPI formula, so what is new? In the first place, this indicates that the volume-based SPI is consistent with the principles of time performance in physics.
It is irrefutable that the velocity of work accomplishment should equal the work accomplished to date divided by the time elapsed. Likewise, it is also irrefutable that the time performance measured in relative terms should be the ratio between the actual velocity and the planned velocity. So, let us consider our example again:

- Project budget = 1000 $
- Baseline completion date = 5 months;
- Time now = 4 months;
- PV (planned work) = 700 $ (i.e. 700 units of work);
- EV (actual work accomplished)= 500 $ (500 units of work);
- Planned velocity = PV / 4 months = 700 $ / 4 months = 175 units of work / month
- Actual velocity = EV / 4 months = 500 $ / 4 months = 125 units of work / month
- SPI(m) = Actual Velocity / Planned Velocity = 125 / 175 = 0.71 = 71%
- SPI = EV / PV = 500 / 700 = 0.71 = 71%

In summary, this project is being executed at a work rate (velocity) that is 71% of the originally planned work rate.

While this formula seems to produce the same result as the conventional SPI, in the cases of late finish and early finish the behavior is different.

The case of a Late Finish

Let us consider our previous example:

- Project budget = 1000 $
- Baseline completion date = 5 months
- Time now = 10 months
- PV (planned work) = 1000 $ (i.e. 1000 units of work)
- EV (actual work accomplished)= 950 $ (950 units of work)
- Planned Velocity = 1000 $ / 5 months = 200 $ / month
- Actual Velocity = 950$ / 10 months = 95 $ / month
- SPI (modified) = (95 $ / month) / (200 $ / month) = 0.475 = 47.5%
- SPI (conventional) = EV / PV = 950 / 100 = 0.95 = 95%.

The modified SPI(m) indicates a time performance of 47.5% well below the 95% given by the conventional SPI. This scenario also reveals the cause of the inconsistency with the conventional SPI in a late finish: when time moves beyond the baseline completion date the denominator for Actual Velocity and Planned Velocity is no longer the same and therefore the ratio of the work rates (planned and actual) can no longer be calculated as the ratio of EV / PV.

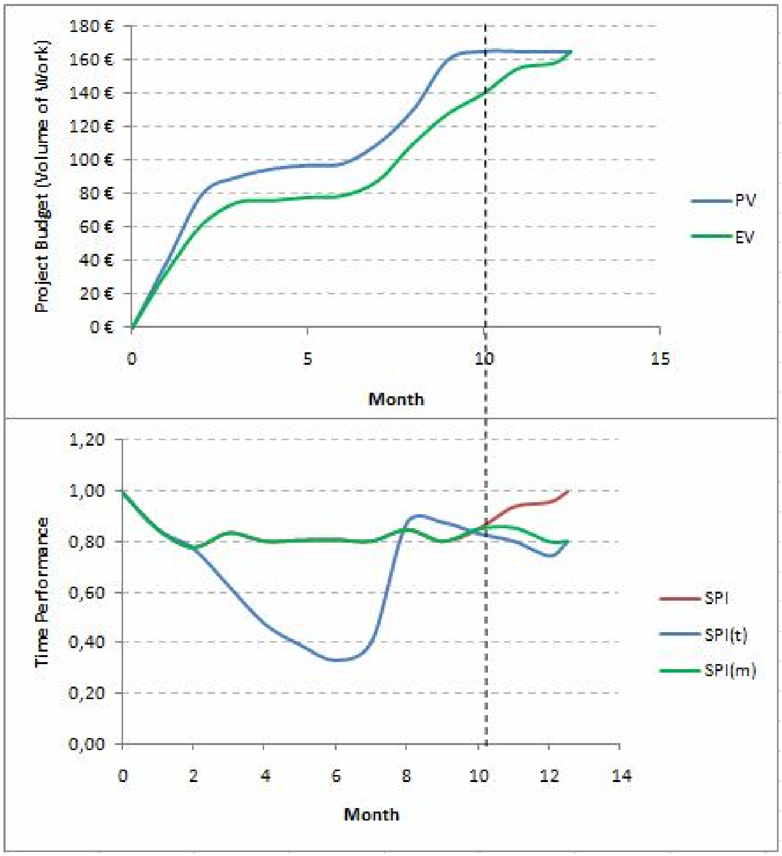
This leads us to a formula relating the modified SPI and the conventional SPI in a situation of a late finish:

- SPI(m) = SPI x (Time Elapsed / Planned Duration)

  Where:

  - Correction factor = Time Elapsed / Planned Duration
  - When EV = PV (all work done and completion date elapsed)
    - SPI(m) = Time Elapsed / Planned Duration

The behavior of SPI(m) in a situation of a late finish is illustrated in the figure below.



As it can be observed, SPI(m) behaves like SPI(conventional) until the baseline completion date. After that point onwards, it does not float towards the value of 1 and it exhibits a consistent behavior.

It can also be observed that during the planned period SPI(m) seems to be robust against scenarios of low work intensity, unlike the SP(t) indicator based on Earned Schedule.

In the period of delay, SPI(m) also shows a different performance than the SPI(t) indicator, although at the end of the project both will show exactly the same value (as can be demonstrated mathematically).

By looking at the whole period of project execution, the SPI(m) indicator seems to exhibit a more stable and consistent behavior, closer to the real final value than the SPI(t) indicator, which seems to be more sensitive and unstable. This may have a significant impact on the quality of these indicators as predictors of the final completion date during project execution.

The SPI(m) indicator also retains the perspective on the volume of work accomplished which, as argued earlier, is more relevant than the time perspective. By comparing again with the laws of physics, we can consider the examples of a Formula 1 race versus a cycling race. Is the meaning of a 5 seconds delay the same in both cases? Clearly not: 5 seconds in Formula 1 racing represents a significant distance (meters = volume of work) which generally is not easy to recover, whereas 5 seconds of delay in cycling racing can be meaningless because it represents a short distance between the two competitors. Likewise, in a project, a one month delay can sometimes represent less than a one week delay in terms of amount of work that needs to be recovered in the remaining future.

For information, the actual values that generated the figures for the late finish scenario are shown in the table below.

Time	PV	EV	SPI(m)	ES	SPI(t)	SPI
0	0	0	1,00	0,0	1	1,00
1	40	34	0,85	0,9	0,85	0,85
2	80	62	0,78	1,6	0,78	0,78
3	90	75	0,83	1,9	0,63	0,83
4	95	76	0,80	1,9	0,48	0,80
5	97	78	0,80	2,0	0,39	0,80
6	98	79	0,81	2,0	0,33	0,81
7	110	88	0,80	2,8	0,40	0,80
8	130	110	0,85	7,0	0,88	0,85
9	160	128	0,80	7,9	0,88	0,80
10	165	140	0,85	8,3	0,83	0,85
11	165	155	0,85	8,8	0,80	0,94
12	165	158	0,80	8,9	0,74	0,96
12,5	165	165	0,80	10,0	0,80	1,00

The case of an Early Finish

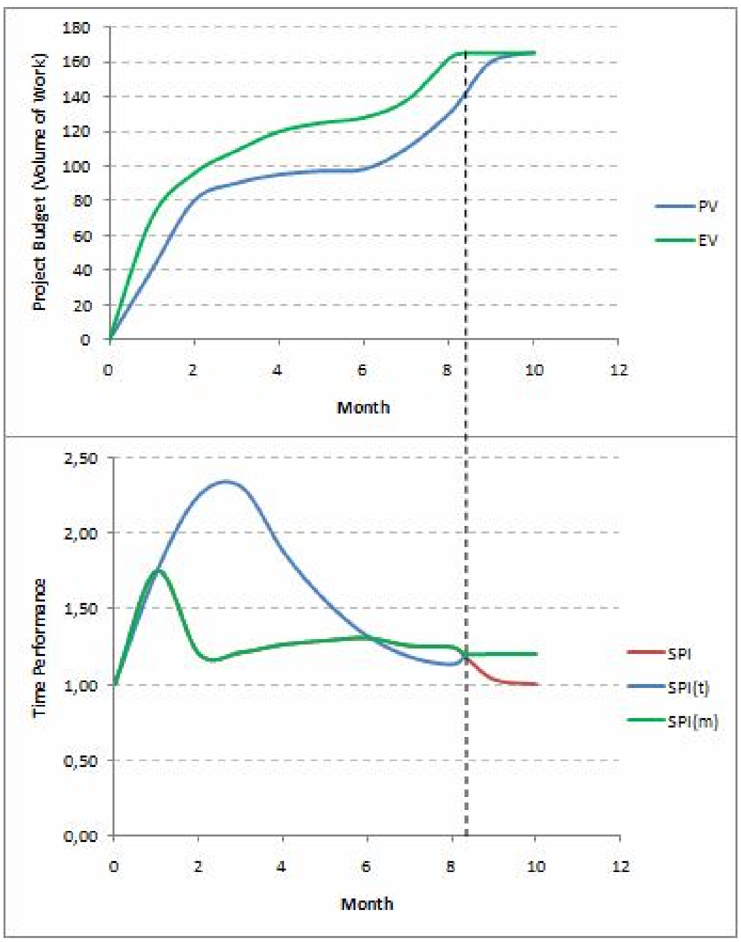
Let us again consider our previous example:

- Project budget = 1000 $
- Baseline completion date = 5 months
- Time now = 4 months
- PV (planned work) = 700 $ (i.e. 700 units of work)
- EV (actual work accomplished)= 1000 $ (100 units of work)
- Planned Velocity = 1000 $ / 5 months = 200 $ / month

- Actual Velocity = 1000 $ / 4 months = 250 $ / month
- SPI (modified) = (250 $ / month) / (200 $ / month) = 1.25 = 125%
- SPI (conventional) = EV / PV = 1000 / 700 = 1,43 = 143%

Again, the SPI(m) provides a different time performance value than the conventional SPI. It should be noted that when the work is completed earlier, the planned velocity should not be calculated as PV / Time Elapsed, but instead it should be calculated as the Budget at Completion (BAC) / Planned Duration (i.e. the whole work divided by the planned duration). Therefore, when we compare the actual velocity against the planned velocity we are comparing against 1000 units of work in 5 months (200 $/ month) and not against 700 units of work in 4 months – in fact, if we were to freeze the value of conventional SPI once the whole project work is completed, we would incorrectly conclude for a final time performance of 143%. This would also be the result of SPI(m) if we were not to look at the whole project once the work is completed.

The behavior of SPI(m) in a situation of an early finish is illustrated in the following figure.



The conclusions are similar to the scenario of a late finish, where it can be seen that SPI(m) will not float towards one, nor it will give an incorrect final value as the conventional SPI would do if we were to freeze its value at the moment where the project was completed.

For information, the actual values that generated the figures for the early finish scenario are shown in the table below.

Time	PV	EV	SPI(m)	ES	SPI(t)	SPI
0,00	0	0	1,00	0,0	1	1,00
1,00	40	70	1,75	1,8	1,75	1,75
2,00	80	96	1,20	4,5	2,25	1,20
3,00	90	109	1,21	6,9	2,31	1,21
4,00	95	120	1,26	7,5	1,88	1,26
5,00	97	125	1,29	7,8	1,55	1,29
6,00	98	128	1,31	7,9	1,32	1,31
7,00	110	138	1,25	8,3	1,18	1,25
8,00	130	162	1,25	9,1	1,13	1,25
8,33	140	165	1,20	10,0	1,20	1,18
9,00	160	165	1,20		1,20	1,03
10,00	165	165	1,20		1,20	1,00

An Extended EVM Model for Time Management Using the Modified SPI

The modified version of SPI proposed in his paper creates the opportunity to develop an enhanced model of EVM for the purpose of time management. In particular, it is possible to answer the following questions:

a) Given the current time performance level, what is the likely completion date if this level is maintained?

b) Given an expected future time performance, what is the likely completion date for the project?

c) What is the future time performance required to complete the project on a specific date?

    a. If future performance needs to be increased, what is the required overall increase of in resource capacity?

    b. If future performance can be decreased, what is the overall possible decrease in resource capacity?

d) If overall resource capacity is to be increased or decreased for the remainder of the project, what will be the impact on the likely project completion date?

e) If the current time performance is below the planned level, resource capacity is maintained, and the original completion date is imposed, what is the likely scope reduction?

f) If a given completion date is imposed, and an expected future time performance is assumed, what will be the likely impact on scope?

In order to answer all these important management questions, a mathematical model equipped with a set of formulae was developed by the author as an extension to the standard EVM model – the EVM Strategic Model (EVM-SM™) which is described in a forthcoming book. This model was developed in the field through practical applications in various types of projects and in different industries.

A very important aspect of this EVM based time management model is that it provides essential support to project risk management. In particular, the calculation of the required increase in the future time performance in order to complete the project on the original completion date is an effective indicator of the *schedule feasibility risk*. For example, if the future performance needs to be twice the planned level (i.e. 100% increase, e.g. executing two months of work in each remaining month) and such increase is known to be very unlikely (either based on expert judgment or even better on historical information), then the remaining schedule is most likely not feasible to attain and consequently time risk is very high. If on the other hand, the performance increase is feasible (e.g. a +10% increase) but the required resource capacity is not available, time risk will also be very high. By confronting the project manager with the assumptions behind a *desired* schedule recovery, time risks can be identified earlier in the project, both for the project completion date and also for intermediate project milestones. The impact on scope of time risk can also be calculated as an overall scope reduction in %.

But will all this be just mathematics? No. All of these concepts translate into real world practice if properly applied. Let us briefly consider a real life example that I have been through recently.

A real life example: using SPI(m) for risk management

A medium-size infra-structure construction project was scheduled for 12 months with a 25 million euro budget. What happened? Well the project started at a good pace in the first three months but after that SPI started to drop towards 0.5 and it stabilized at that level for the next other 3 months, an overall history of 6 months corresponding to an SPI of 0.5 (50% of time performance). Particular and specific engineering based explanations were given by the contractor as to why the problem had occurred (all of which were external, out of management reach, and with a hint of "acts of God"). Technical solutions were always presented alongside the problems for recovery in the following month. But month after month, SPI never increased… it maintained its value with a slight deterioration. By the eight month, the Client management finally confronted the contractor with the persistent trend, with a SPI of 0.47 – less than half of the planned work had been accomplished. What happened? Finally, a 3 months delay was admitted by the contractor, for a partial relief of the Client as after all the impact did not seem too bad given the circumstances. But was this partial recovery likely?

As external consultants we made use of the EVM-SM™ model by focusing on simple mathematics inspired (as previously described) in the laws of physics. First, by month 8 the contractor claimed the initial schedule proposed by the Client in the contract was infeasible. By looking at the original schedule, the current remaining scope had been planned to be executed in a period of time that implied a 2.5 million euro / month work rate – this was claimed by the contractor to be unrealistic given the characteristics of the scope and the project environment. As we looked into the recovery plan proposed by the contractor implying a 3 months delay, and by looking at the current status of the project, the work rate implied was of 3 million euro / month, greater than the initially proposed schedule for the exact same scope. An unrealistic compressed schedule explained the poor past performance (i.e. an "invalid" baseline), but the recovery plan looked even more unrealistic. The Client's management controller informed us that there was no historical evidence from past projects of work being executed at such an accelerated rate of 3 million euro / month. So, how was the contractor going to increase its overall resource capacity by over 50% (SPI_m based calculations)? Well, the contractor informed us that, (to the dismay of the Client), of course while the infra-structure would be fully operational in its "essential features" a "certain portion" of the scope would have to be postponed for a second phase. But what, and how much scope would have to be cut?

It can be seen that with simple calculations based on SPI_m it was possible to uncover the scope impact from the time risk of the recovery plan and thereby the otherwise implicit assumptions were discussed before a feasible solution was agreed. On the other hand, had the early warnings of SPI been heard by month 4 then most likely the project would have followed a different and better course towards completion.

The use of aggregate EVM time performance indicators (namely SPI) has often been the subject of criticisms due to disregarding the details of the schedule and its critical paths and task floats. The fundamental mistake in this type of comparative analysis is that two different perspectives (bottom-up versus top-down) developed for different purposes (and which should be complimentary), are being compared as if they were supposed to work at the same level of detail and perspective. The critical path analysis is grounded on a detailed perspective and provides a bottom-up estimation approach, certainly with the well known merits of this type of approach. On the other hand, Earned

Value Management works at the aggregate level and delivers a top-down estimation approach, a paradigm also with its own merits (e.g. parametric cost models). So oranges are being compared against apples. In regards to time estimation, top-down techniques are known to be more reliable for the short-term future and less reliable for the longer-term (due to the intrinsic exponential growth of uncertainty in the detail level as we look into the far future). Top-down techniques provide the complementary view. Based on aggregation of results and high-level patterns, they deliver a more stable and consistent estimate for the long-term future and less granularity for the short-term. Using both, top-down and bottom-up techniques to complement one another, seems to be the intelligent way that capitalizes on the best of both worlds.

Conclusions

This paper discussed the problem of the shortcomings of the conventional SPI indicator in the Earned Value Management Method as a reliable time performance indicator. The alternative method of evaluating time performance based on the concept of Earned Schedule was also discussed and it was confirmed that it resolves the limitations of the conventional SPI indicator but it also changes the perspective and meaning of the time performance concept, shifting the perspective away from the cause of the delays (volume of work behind schedule) to the delay itself (amount of time behind schedule). An alternative method for calculating SPI – herein referred to as "modified SPI", or simply SPI(m) – which preserves the original and valuable perspective of "work volume", was proposed by the author and it has been demonstrated that it retains the merits of the work volume approach while resolving the limitations of the conventional SPI. This finding was based on over 10 years of experience of using EVM in various different projects and organizational environments, plus several years of academic research based on computer simulation. The use of the proposed improved version of SPI, the SPI(m), has been successfully delivered over the last eight years in various real life projects. This finding is also important as it has a major impact on the potential of SPI to be used as a reliable predictor of the trend for the project completion date throughout execution and early in the project, as well as its potential to support effectively risk management. The overall validity of using EVM to support project time management and the use of SPI-based indicators for the purpose of Risk Management under conditions of uncertainty will be discussed in a separate paper in this series.

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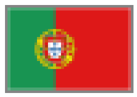

Highlights:

- Named PM Ambassador™ in Portugal by PMForum International (EUA)
- 5 year Degree in Engineering and a Ph.D. in Management Sciences
- 15+ years of international professional experience in Project Management
- Founding President of the PMI Portugal Chapter
- Mentor of PMI Chapters in Europe (2003-2007)
- Member of the PMBOK ® (3rd edition) and OPM3 ® (1st edition) development teams
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- Senior Consultant at Cutter Consortium (EUA)
- PM Forum (EUA) Correspondent for Portugal
- Visiting lecturer in several universities and Institutes
- Supervisor and Member of Jury for several M.Sc. and Doctorate research in Project Management

Holding a 5 year degree in Systems Engineering and Computer Science from the University of Minho, he obtained his PhD in Project Management from the University of Strathclyde (UK). Having developed much of his professional career in the UK and USA, he worked as a management consultant at PA Consulting Group (USA), having specialized in the use of dynamic simulation for computer support for Project Management. At this stage of his career, he was involved in major international projects, particularly of the defense area where he also developed applied research, particularly in British Aerospace (UK) where he received as a result of his work the "Mike Simpson Award 1996" handed by the prestigious British "Operational Research Society. In the initial phase of his career, he worked several years as a software engineer. Currently a *member of the Cutter Consortium, a Consortium for North American Information Technologies, where he participates as an expert in the practice of Agile Software Development, Risk Management and Business-IT Alignment. He regularly publishes articles in trade and scientific magazines, and is guest speaker at various national and international conferences. In 1996 he was co-organizer of a NATO Advanced Research Workshop on the theme "Managing and Modelling Complex Projects", which took place in Kiev (Ukraine) and brought together a range of international experts in this area. He was also guest editor of the April 2001 Journal of Cutter IT (Chair Ed.Yourdon) under the theme "Multicultural Project Management". In 2003 he was invited to publish an article in APM 2003 Year Book, published annually by the Association for Project Management (APM) of UK, under the theme "Earned Value Management in the International Scene." Since 2002, at the service of PMO Projects, a company which he is a co-founder, he designs and has taught several project management training courses in the scope of the PMP ® certification program from Project Management Institute (PMI), both in Portugal and abroad, in which the design and development of postgraduate studies in Project Management, the " PMP ® Best Practitioner Program" has been asserting itself in Portugal as the " standard fact " for the training in Project Management. In the quality of a Consultant, he directs and works to implement solutions aligned with PMI's project management standards and best practices, in particular the PMBOK ® and OPM3 ®, leading also implementation processes of Project Management Office (PMO) type structures. Besides his business activities, he developed over a decade of teaching experience in universities, having taught and conducted courses in the area of Project Management and Master's Degree in both Portuguese and British Universities. Throughout his academic career, has been supervisor of several works of Masters and PhD degrees, as also participating in the evaluation panels for these degrees. While serving PM as a volunteer, he was a project team member for the development of the PMBOK® (3rd edition) and of the OPM3® (Organizational Project Management Maturity Model). He is a member of the Project Management Institute, and was founding president of its representation in Portugal, the PMI-Portugal Chapter. From 2003-2007 he was mentor of PMI Chapters for the region of Europe. He was selected by the PM FORUM international as a correspondent for Portugal. He holds the Certificate of Pedagogic Aptitude (CAP) issued by the Employment and Vocational Training (IEFP) in Portugal. Alexandre Rodrigues recently received the prestigious nomination of Project Management Ambassador™ in Portugal by PM Forum International, and was in the beginning of 2010 invited by the Project Management Institute to join the international team of eight specialists who will be responsible for developing the second edition of the international standard for the Earned Value Management (EVM) method. Alexandre Rodrigues was invited in 2009 by the British publisher Gower Publishers to write a book dedicated to the method of EVM as part of a series dedicated to Project Management which is being published worldwide in English.*