FORECASTING PROJECT COMPLETION DATE USING EARNED SCHEDULE AND PRIMAVERA P6™

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ABSTRACT

Forecasting a project completion date based on project performance is an essential and ongoing task for the schedulers during the construction phase. Earned Schedule (ES) is an innovative forecasting technique that is derived from and is an extension to Earned Value Management (EVM). Research shows that ES is more accurate than EVM in terms of forecasting a project end date. Although several institutions have widely acclaimed and adopted ES, Oracle Primavera P6TM does not support the calculations of ES. This paper presents a method that implements ES concepts on the activity level using the advanced features of Primavera P6TM. The method suggested applies the concepts of ES to predict the remaining duration of activities in progress based on EVM information. It then uses these predictions to determine the project completion date. This method takes the Critical Path Method (CPM) into account in the forecasting process. In addition, this method helps primavera P6TM users benefit from ES indicators as a management tool.

INTRODUCTION

During the construction phase, there is a constant need to forecast project completion date based on the current rate of progress, in order to know whether or not the project will be finished on time. Delivering a project within a specified time frame is a requirement in most construction contracts. If the contractor or the owner cause a project to suffer delays, they will experience serious ramifications in the form of delay damages and/or financial loss.

One of the most effective tools for determining key information about a project's schedule and cost is earned value management (EVM). It has proven over decades to be a very beneficial project control technique.

In EVM, the scope, cost, and schedule baselines are incorporated in an effective way, first to measure the performance of the project in progress, and second to forecast future project outcomes. Applying the cumulative project cost for all planned work over the planned duration forms a performance measurement baseline (PMB), which is commonly shown as an S-curve. The point at the top of the curve is the budget at completion (BAC), which is associated with the planned finish date. At any point in time (data date) throughout the project duration, the project status can be represented as a budgeted value. This budgeted value is also known as the planned value (PV) and sometimes called the budgeted cost for work scheduled (BCWS). During the project progress, the actual cost (AC) of work performed is measured and plotted along with the planned value. This provides a method for determining whether costs are in alignment with the planned value, i.e., if expenditures exceed the planned budget or stay below the planned budget. However, with this model, it is difficult to know if actual costs are out of line unless they are compared with the concept of earned value (EV), which is sometimes called the budgeted cost for work performed (BCWP). Using these three data points (EV, AC, PV), variance and index values can be calculated to evaluate a project's status and to find out if the remaining time and budget are sufficient to achieve the project outcomes [1, p.217-224].

EVM has achieved significant success in describing and analyzing cost performance, but it has not succeeded as much in terms of analyzing and predicting schedule performance. The schedule indicators are measured in unit of cost, in lieu of unit of time. For example, if the schedule variance is −5,000 USD, it indicates that the project is behind schedule, but it provides no information about the length of the delay in terms of the number of days. There is a question of why a ratio of cost is used to calculate schedule indicators,

when really what is needed is a ratio of time. The big problem is that the indicators do not reflect the real situation of the project duration extending significantly beyond the planned completion date, but on the contrary, it provides satisfactory information about the project performance in terms of schedule. Common observations show that such schedule indicators become apparent when the project is nearly two-thirds complete. Thus, if the period starts from a certain point in time before the planned finish date, and it finishes at the actual completion date, these indicators may provide flawed performance measurements to the project managers. [2, p.26]

In 2003, in his paper "Schedule Is Different," engineer and author Walter Lipke introduced the earned schedule (ES) technique as a better version of EVM traditional schedule indication to overcome what he called the "the cost-schedule dilemma" [3]. The ES method derives the schedule information using same EVM data components. The ES method offers reliable figures that both describe the real performance and forecast the future outcome for projects, whether they are finished early or late. ES is considered a breakthrough technique in integrated performance management and EVM theory and practice. The method has spread rapidly, and it is known to be utilized as a management tool for construction, commercial, software, and defense projects in various countries, including Australia, Belgium, Sweden, the United States of America, and the United Kingdom. The ES principles have been incorporated in the Practice Standard for Earned Value Management and in the Project Management Institute (PMI) College of Performance Management [2, p.27].

Taking the advantages of the ES on the project level introduced so far, this paper aims to employ the concepts of ES on the activity level to obtain predictions of an activity's remaining duration and subsequently determine a project completion date using Oracle Primavera P6 software. Oracle Primavera P6 does not support ES computations; however, it is one of the most popular project management software programs in the construction industry due to its capabilities to perform complex analysis and data presentation. This paper describes the procedures of using Oracle Primavera P6 advanced features to accomplish ES computations and display ES metrics.

EARNED SCHEDULE APPLICATION ON THE ACTIVITY LEVEL

Lipke summarized the principles of ES on the project level as follows: "The ES idea is simple: identify the time at which the amount of earned value (EV) accrued should have been earned. By determining this time, time-based indicators can be formed to provide schedule variance and performance efficiency management information." [2, Page 28]. In other words, it is much more useful to calculate schedule variance by comparing the duration or date at the current time with the duration or date when the value of work (EV) was planned. Thereby, it is much easier for EV practitioners to look at ES in the S-curve chart and see that the project is ahead of or behind schedule in terms of time. Figure 1 describes the concepts of ES and its associated formulae to obtain ES time, schedule variance SV (t) and schedule performance index SPI (t) at the given actual time (AT). These indicators are used to evaluate the schedule performance and to determine the estimate at completion for time. Thus, the way to think about the estimate at completion for time is the point in time when earned value equals the budget at completion.
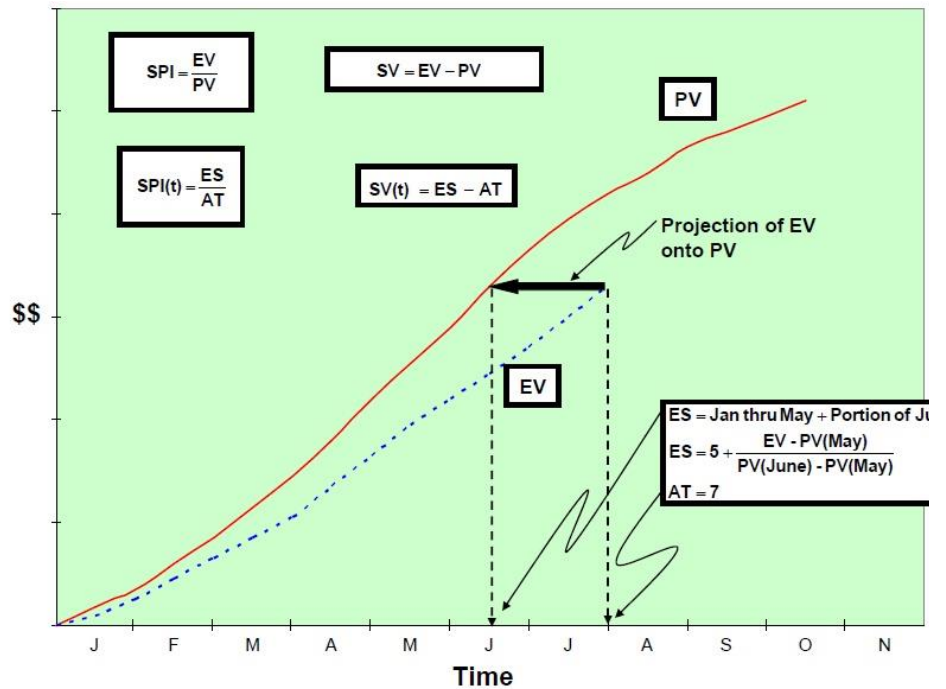
The chart contains the following labels and formulas:

$$SPI = \frac{EV}{PV}$$

$$SV = EV - PV$$

PV

$$SPI(t) = \frac{ES}{AT}$$

$$SV(t) = ES - AT$$

Projection of EV onto PV

EV

$$ES = Jan\,thru\,May + Portion\,of\,Ju$$

$$ES = 5 + \frac{EV - PV(May)}{PV(June) - PV(May)}$$

$$AT = 7$$

$$\$\$$$

J F M A M J J A S O N

Time

Figure 1 – Earned Schedule Concept [2]

The same method is followed to apply the ES concept on an individual activity in progress. The earned value accrued for an activity at the data date can be identified and then projected backward or forward in time to see when that value was planned to have been achieved, according to the budget. Then, ES and the actual time (AT) of EV accrued are derived to eventually calculate a schedule performance index and the schedule variance of the activity.

Figure 2 illustrates how the ES concept is applied to any activity in progress. The activity in progress in the update schedule is shown above the same activity in the baseline schedule, according to actual and planned dates, respectively. The activity in progress is shown as a green bar, and the shaded area represents the progress achieved during the performance period, from the actual start of the activity up to the data date when the EV accrued is measured. The blue bar represents the activity in the baseline schedule and the shaded area represents the point at which the PV is equal to the EV accrued. ES represents the time at which the PV in the baseline schedule is equal to the EV accrued of the same activity in the updated schedule at the data date. AT represents the performance period - working days only - between the activities' actual start and the data date when the EV accrued is measured. The difference between AT and ES is equal to schedule variance, SV(t), and the comparison between them is equal to the schedule performance index, SPI(t). Eventually, the remaining duration of the activity is forecasted based on its SPI(t).
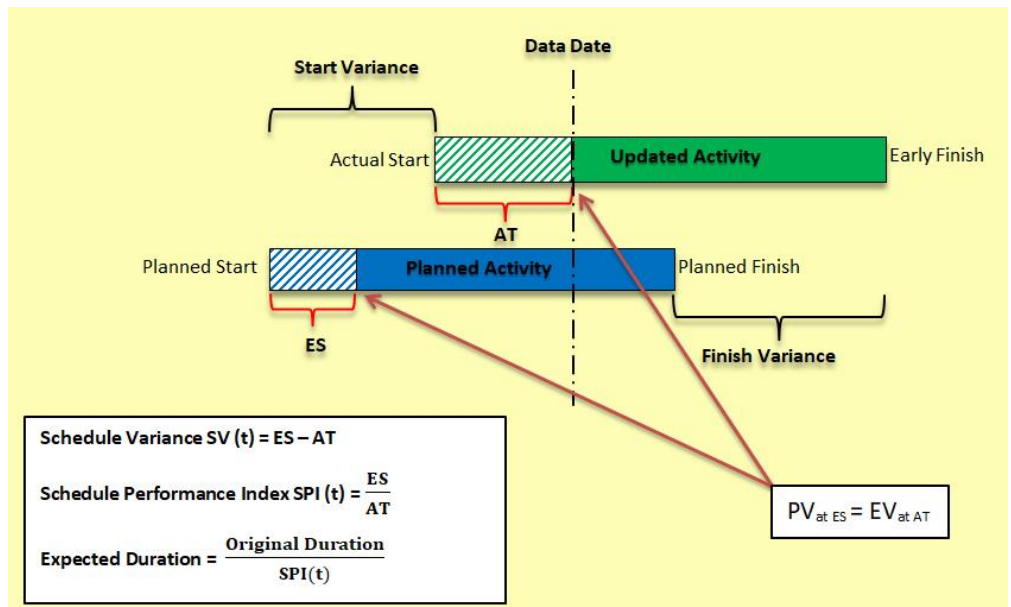
Figure 2- Earned Schedule Application on the Activity Level

Hypothetical Scenarios

Actual performance of a construction activity takes on many scenarios in a project site. For example, the start of a construction activity may be delayed, or various factors may have an impact on the production rate at which the activity can be completed. There are numerous reasons why an activity may be delayed. It could be because of climatic conditions, a lack or shortage of available resources, late deliveries, missing information, unforeseen circumstances, or unlimited other reasons. To illustrate ES computations, hypothetical examples of some scenarios are presented below. Assume the activity in figure 3 is planned to be accomplished in 6 days with the budgeted cost equal to 12,000 USD, and assume that the activity cost is distributed evenly on its original duration (OD).

Scenario #1: Ideal situation
- The activity started as scheduled.
- The activity progressed at the planned production rate for 3 days.
- The total EV is equal to 6,000 USD at the data date.
- AT = 3 days.
- ES = 3 days.
- SV(t) = ES − AT = 3 − 3 = 0.
- SPI(t) = ES / AT = 3 / 3 = 1.
- Expected duration (ED) = OD / SPI(t) = 6 / 1 = 6 days.
- Remaining duration (RD) = ED – AT= 6 – 3 = 3 days.
- The activity is not delayed as shown in figure 3 – Scenario 1.

Scenario #2: Same start and lack of performance

- The activity started as scheduled.
- For 3 days, the activity progressed more slowly than the planned production rate.
- The total EV is equal to 4,000 USD at the data date.
- AT = 3 days.
- ES = 2 days.
- SV(t) = ES - AT = 2 − 3 = −1.
- SPI(t) = ES / AT = 2 / 3 = 0.67.
- ED = OD / SPI(t) = 6 / 0.67 = 9 days.
- RD =ED − AT = 6 days.
- The activity is delayed 3 days due to a lack of performance as shown in figure 3 – Scenario 2.

Scenario #3: Same start and same performance but with suspension of works
- The activity started as scheduled.
- The activity progressed at the planned production rate for 2 days.
- The activity is suspended for 2 days, and then the work resumes for 1 day.
- The total EV is equal to 6,000 USD at the data date.

- AT = 3 days.
- ES = 3 days.
- Schedule variance SV(t) = ES-AT=3-3=0.
- Schedule performance index SPI(t) = 1.
- ED = OD / SPI(t) = 6 / 1 = 6 days.
- RD = ED-AT=6-3=3 days.
- The activity is delayed 2 days due to the suspension of work as shown in figure 3 – Scenario 3.

Scenario #4: Late start and same performance
- The activity started 2 days later than scheduled.
- For 3 days, the activity progressed more slowly than the planned production rate.
- The total EV is equal to 6,000 USD at the data date.
- AT = 3 days.
- ES = 3 days.
- SV(t) = ES - AT = 3 − 3 = 0.
- SPI(t) = ES / AT = 23 / 3 = 1.
- ED = OD / SPI(t) = 6 / 1 = 6 days.
- RD =ED − AT = 6-3=3 days.
- The activity is delayed 2 days due to slippage at the start as shown in figure 3 – Scenario 4.

Scenario #5: Early start and lack of performance
- The activity started 2 days earlier than scheduled.
- For 3 days, the activity progressed more slowly than the planned production rate.
- The total EV is equal to 4,000 USD at the data date.
- AT = 3 days.
- ES = 2 days.
- SV(t) = ES - AT= 2 − 3 = −1.
- SPI(t) = ES / AT = 2 / 3 = 0.67.
- ED = OD / SPI(t) = 6 / 0.67= 9 days.
- RD = ED − AT = 9-3=6 days.
- The activity is delayed 1 day due the lack of performance as shown in figure 3 – Scenario 5.

Looking carefully at the scenarios, ES measurements indicate the extent to which the progress of work is consistent with the plan, regardless of any delays that occurred due to an activity's start slippage or due to suspending and resuming the work. Namely, the schedule performance index and the schedule variance of an activity reflect the lack of performance only, and they do not necessarily provide enough information to draw a full conclusion of the activity's status. Therefore, these measurements should be combined with other schedule analysis information—such as critical path analysis, total float, start variance, and finish variance, for example—to give a comprehensive picture of the activity status and its effect on overall project schedule [3,p. 167-168].

The critical path method (CPM) plays a crucial role in finding the impact of activity delays on the project completion date. The power of the CPM lies in the relationship ties between activities, so if anything changes, its effects on the rest of the schedule can be seen immediately. The critical path is simply the possible chain of activities, from the beginning to the end of a project that has the least amount of float (the longest path), such that any delays in the critical path activities will negatively affect the finish date of the project. The usefulness of the CPM is that it allows one to run "what if" scenarios and spot potential problems areas early, while there is still time to proactively deal with them. It also provides an effective way of documenting the impact of delays on a project.

Thus, by using ES and schedule analysis together, one can draw a full conclusion of a project's status. The ES provides reliable figures of the activity's remaining duration, given the current rate of progress, while the CPM incorporates all delays and inefficiencies in the network schedule to measure the total impact on the future project outcomes.
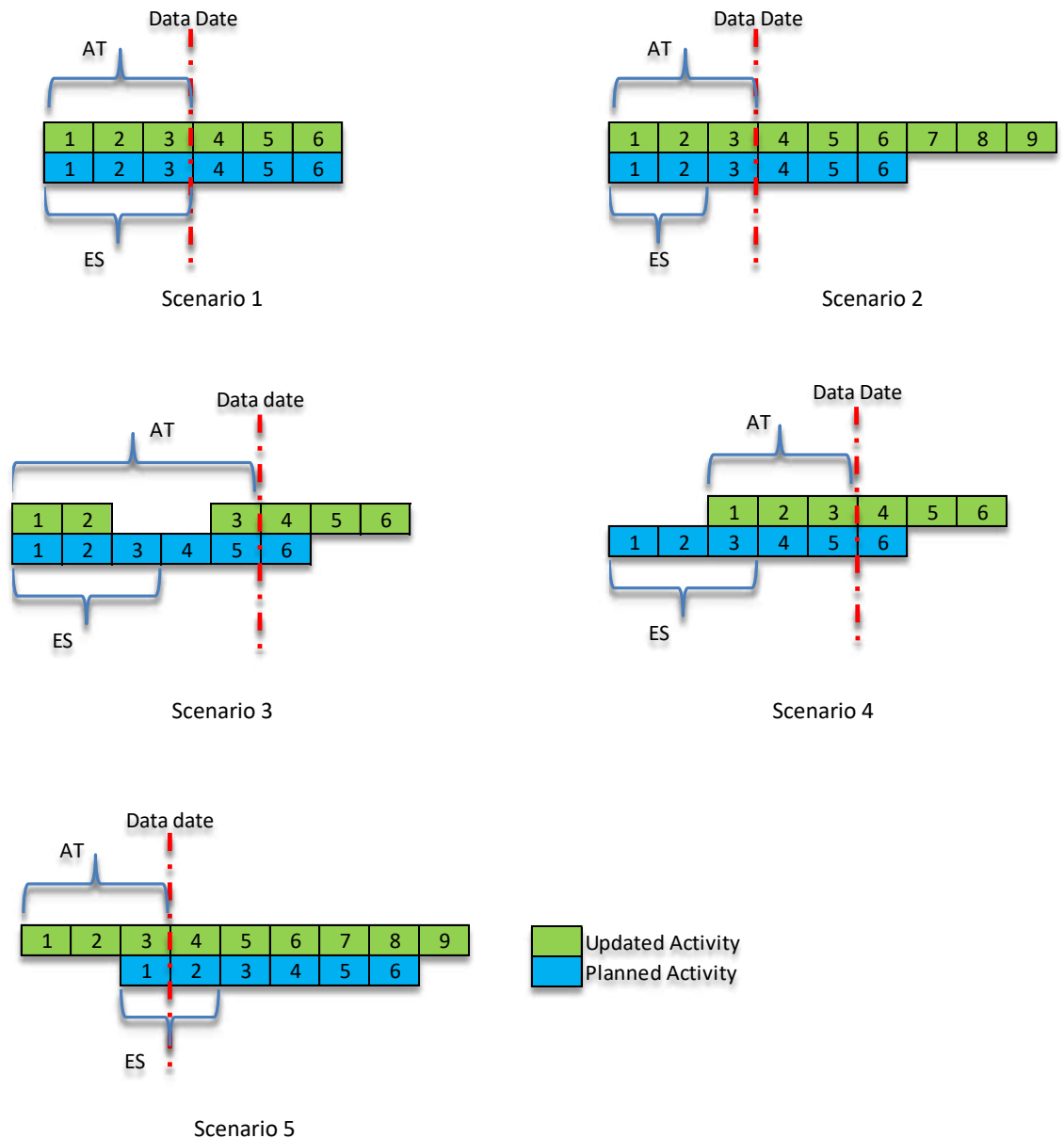
Figure 3- Five scenarios of ES application on the activity level

PRIMAVERA P6 SOLUTION FOR EARNED SCHEDULE

Oracle Primavera P6 is one of the most popular project management software programs that is used to plan, manage, and control all aspects of a construction project. It is a professional toolbox that provides a wide range of enterprise capabilities to the planners, project managers, schedulers, employers, and any other stakeholders who are involved in a given project.

Although Primavera P6 software does not support ES computations, it provides powerful capabilities that can be utilized to do so. User-defined fields and global changes, for instance, are two advanced features in Primavera P6 software, which also offers many mathematical and logical functions to perform complex analyses and processes.

Figure 4 illustrates the main steps to carry out ES demonstration using Primavera P6. The first two steps are required one time when working on a given schedule; the other steps are required every time to update the schedule and determine the project completion date.

Setup Stage	
Step 1	• Create User Defined Fields
Step 2	• Create A Global Change 1 & 2
Updating Stage	
Step 1	• Enter Update Information
Step 2	• Apply The Global Change 1 & 2
Step 3	• Schedule The Project
Step 4	• Display The Results
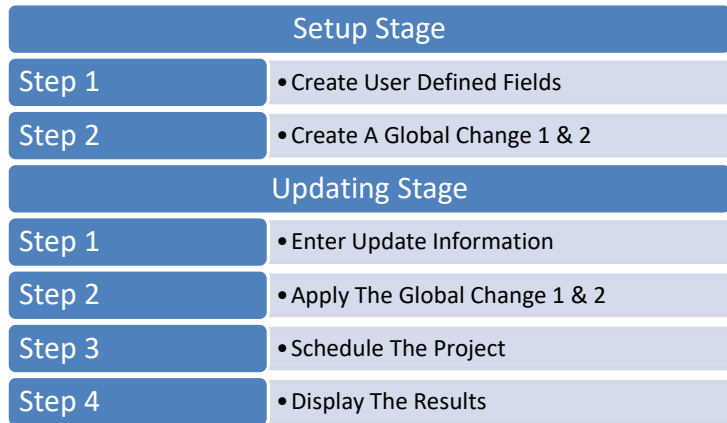
Figure 4-Earned Schedule Demonstration Steps Using P6

Create User-Defined Fields

Select the Enterprise menu, and then choose User Defined Field from the drop-down menu. Create eight user-defined fields, as follows. Some fields are required, and the other are calculated.

- Activity Budgeted Cost (The field type is "cost," and it is required)
- Earned Value Accrued (The field type is "cost," and it is calculated)
- Daily Planned Value (The field type is "cost," and it is calculated)
- Expected Duration (ED) (The field type is "number," and it is calculated)
- Actual Time (AT) (The field type is "number," and it is calculated)
- Earned Schedule (ES) (The field type is "number," and it is calculated)
- SV(t) (The field type is "number," and it is calculated)
- SPI(t) (The field type is "number," and it is calculated)

Budget at completion (BAC) and earned value are already built-in fields in Primavera P6. The program calculates these fields if the schedule is loaded with resources, costs, and/or expenses. But for many reasons, CPM schedules are often not resource loaded, especially if the contract does not require resource and cost loading. To address this problem, the author suggests creating user-defined fields for "Activity Budgeted Cost" instead of "Budgeted at Completion," to be entered during the updating stage, and "Earned Value Accrued" instead of "Earned Value," to be computed during the global change steps. Otherwise, these two fields are equal to the built-in fields in P6, and the required formulas should be added to the global change 1.
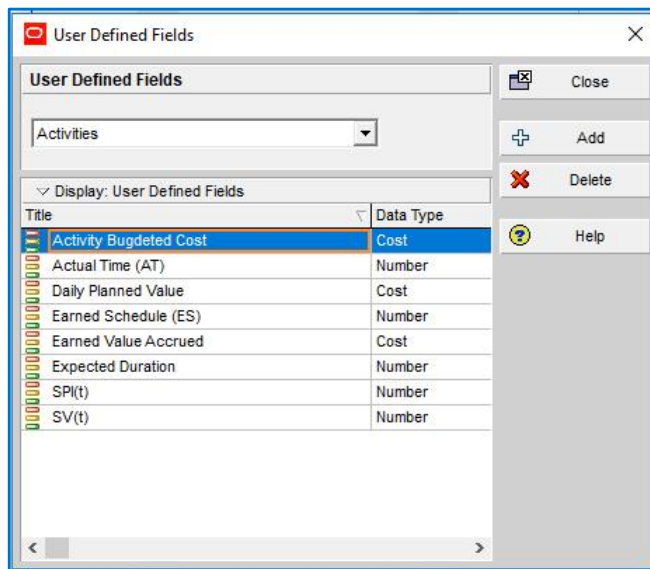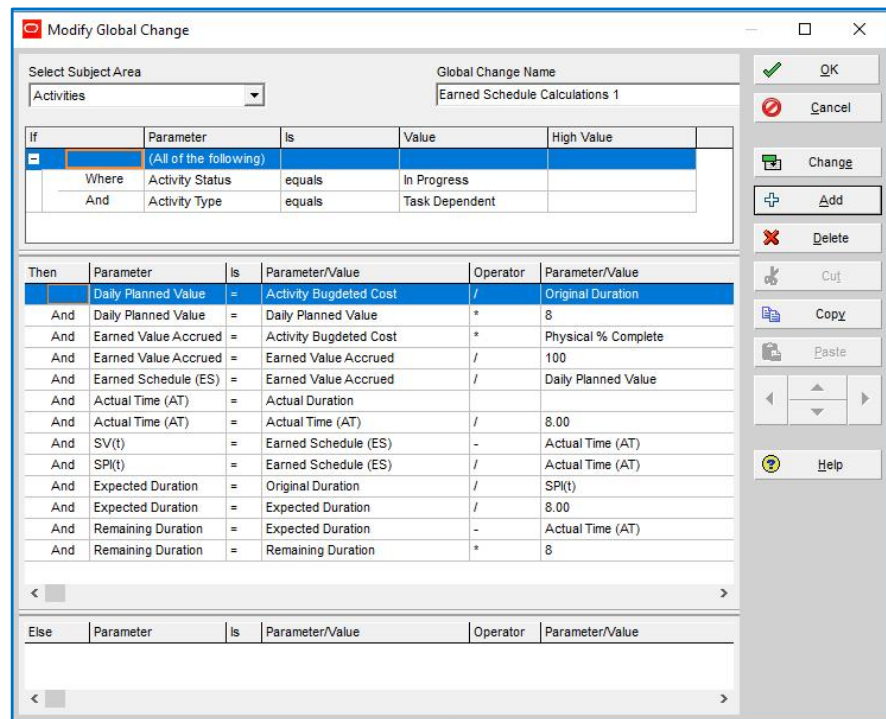

Figure 5-Create User Defined Fields[1]

Create a Global Change 1
Select the Tools menu, then choose Global Change from the drop-down menu. Create a global change under the name "Earned Schedule Calculation 1." In the top section of the global change window, select task dependent activities in progress only (> 0% complete, < 100% complete). In the down section of the global change window, add the formulas required to calculate ES measurements and the remaining duration, as shown in figure 6.

- Daily planned value = activity budgeted cost / original duration
- Daily planned value = daily planned value × 8. This step has been taken because Primavera P6 actually stores durations in its database in the hourly format. Therefore, the figures should be multiplied by the number of hours per day. In this example, the number of hours per day is 8.

- Earned value accrued = activity budgeted cost × physical percent of completion
- Actual time (AT) = Actual Duration
- Earned schedule (ES) = earned value / daily planned value. This step calculates the ES at which the planned value cumulative is equal to earned value accrued.

- Expected duration = original duration / SPI(t)
- Expected duration = expected duration / 8
- Remaining duration = expected duration – actual time (AT)
- Remaining duration = remaining duration × 8

If the schedule is resources loaded, the following steps are required in global changes 1 and 2.

- Activity budgeted cost = budgeted at completion
- Earned value accrued = earned value

Figure 6- Create a Global Change 1[1]

Create a Global Change 2
Select the Tools menu, then choose Global Change from the drop-down menu. Create a global change under the name "Earned Schedule Calculation 2." In the top section of the global change window, select task dependent completed activities (100 % complete) only. In the lower section of the global change window, add the formulas required to calculate ES measurements and the remaining duration, as shown in figure 7.

- Daily planned value = activity budgeted cost / original duration
- Earned value accrued = activity budgeted cost
- Earned schedule (ES) = original duration

- Earned schedule(ES) = earned schedule (ES) / 8
- Actual time (AT) = actual duration
- Actual time(AT) = actual time (AT) / 8
- SPI(t) = earned schedule / actual time (AT)
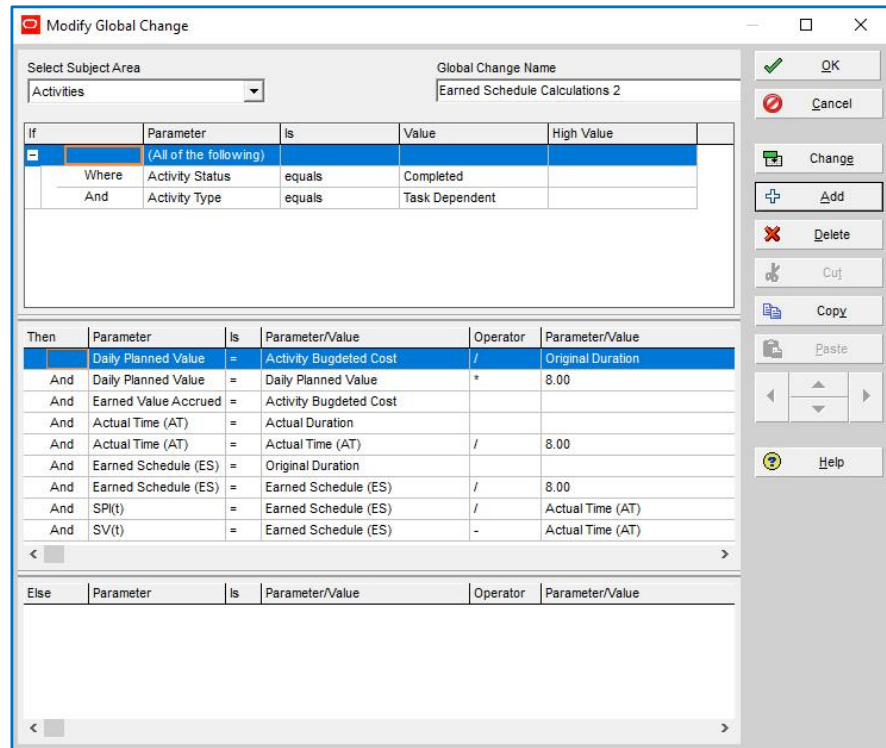- SV(t) = earned schedule − actual time (AT)

Figure 7- Create a Global Change 2[1]

Update Schedule

1. During the updating process, enter the actual start and/or finish and the physical percent of completion for each activity to be updated at the given data date. If the schedule is not loaded with resources, enter the budgeted value alongside the aforementioned data, as shown in figure 9.
2. Enter the remaining duration equal to 1 day for each activity in progress and Schedule the project at the given data date. This intermediate step is necessary to make P6 calculate Actual Duration field which is important to calculate AT later in global change 1.
3. Apply sequentially the previously created global changes 1 and 2 to perform the calculations and determine the remaining duration that is required to forecast the project completion date, as shown in figure 10.
4. Round the remaining duration figures and schedule the project at the given data date to forecast the project completion date, as shown in figure 11.
5. Display the results by adding the columns required, as shown in figure 12.

Looking to the results of the example shown in Figures 8 through Figure 12 leads to two key observations. First, the figures in the remaining duration column are in decimal format, and they could not be rounded to the nearest integer number with the available functions in Primavera P6. Second, Primavera P6 stores the duration in its database as hours, and this makes the software schedule the successor of a finished activity start on the same day. For example, if an activity's remaining duration is 1.75 days, Primavera P6 schedules the finish date of this activity at 14:00 (2:00 p.m.) according to the 8 hours/day calendar and let its successor start on the same finish date at 15:00 (3:00 p.m.). The second finding is that the totals that appear at the top of the columns SPI(t) and SV(t) are simply summations of the figures in those columns. Primavera P6 does not deal with these fields like the ones that are already part of the software system, such as original duration. Thus, these totals do not reflect the overall project indicators.

A further step is required to address these two points. First, the remaining duration figures are rounded manually before scheduling the project again, to determine the project finish date, as shown in figure 9. Second, the overall project indicators can be determined graphically using software such as Microsoft Excel. For instance, Mr. Lipke provides several ES calculations for project indicators based on monthly data on the website www.earnedschedule.com. These calculators are produced using Excel.
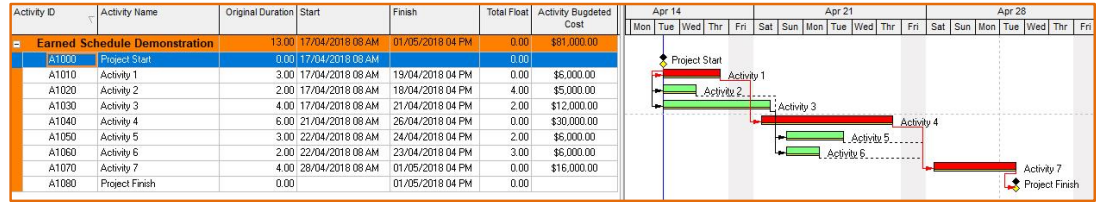

Figure 8 – Baseline Schedule[1]

Figure 9 – Layout for Updating Schedule Step1 and 2[1]

Figure 10 – Layout for Updating Schedule Step 3 and 4[1]

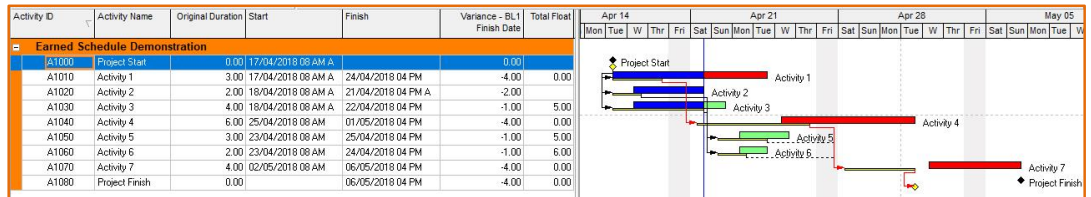Figure 11 – Remaining duration figures rounded manually[1]

Figure 12 – Display the Schedule Results Step 5[1]

EARNED SCHEDULE ON THE PROJECT LEVEL

The final step in this paper is the comparison of the forecasted project completion date derived from using traditional ES on the project level method and using the suggested method that combines schedule analysis and ES on the activity level. The results reveal a significant variance in the expected project completion date between these two methods. The example data shown in Figures 8-12 are used for demonstration purposes. The hypothetical example involves seven activities as show in Figure 8. Activities 1, 4 and 7 are critical while the others are non-critical. The scenario of the first update – at the end of forth working day – is that activity 1 started as scheduled and for four days it progressed more slowly than the planned production rate to reach 65% complete at the given data

date. Activity 2 started one day later than scheduled and for three days it progressed more slowly than the planned production rate and completed at the data date. Activity 3 started one day later than scheduled and it progressed at the planned production rate for three days to reach 75% complete at the data date.

Using schedule analysis and ES on the activity level indicates a four-day delay of the project completion date due to the four-day delay of critical Activity 1 as shown in Figure 12. On the other hand, using traditional ES on the project level indicates an eight- working day delay of the project completion date as shown in Figure 13.

The traditional method of ES on the project level considers all critical and non-critical activities in progress to determine the EV and, subsequently, ES metrics of the project. In the suggested method, ES is used to forecast the remaining duration for each activity in progress and CPM is used to incorporate delays or disruptions of the critical activities only on the project outcome since non-critical activities consume its floats in the case of any delay or disruption before they become critical activities that drive the project completion date.
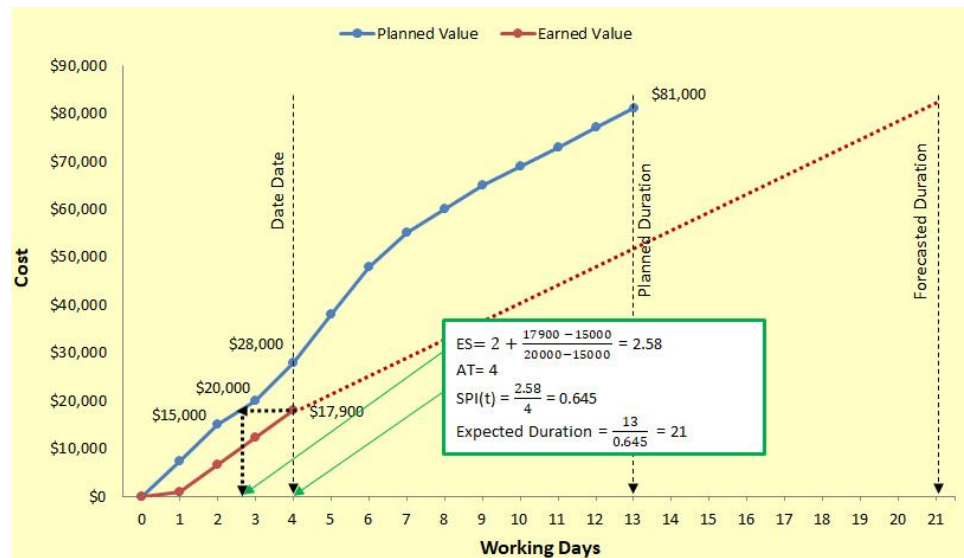

Figure 13 – Earned Schedule on the Project Level

CONCLUSION

This paper has described the method of application for earned schedule concepts on the activity level. Then, by using the advanced features of Primavera P6, namely user-defined fields and global changes, ES metrics are calculated. The remaining duration of the activities are then obtained utilizing the EVM information. Finally, the project completion date is determined based on the current rate of progress. A comparison between traditional ES method and the proposed method shows a significant variance in the expected completion date of the project because the traditional ES considers all critical and non-critical activities in progress to determine EV information and ES metrics. However, the proposed method integrates the ability of ES to provide reliable schedule indicators and the power of CPM, to show the effect of activity delays on project milestones. The method is easy to follow and practicable. However, there are two shortcomings associated with it. First, it is not possible to use global change to round the figure of remaining duration to an integer number; thus, the figure remains in decimal format, which allows some activities to start or finish in a part of one day and successor activities to start later that day. Second, the summation of SPI(t) and SV(t) does not reflect the correct overall project performance. Except for these minor shortcomings, the method helps Primavera P6 users benefit from ES technique for predicting the project completion date.

References

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4) Amos, S. (Ed.), Skills and Knowledge of Cost Engineering, 5th Edition, (2004).