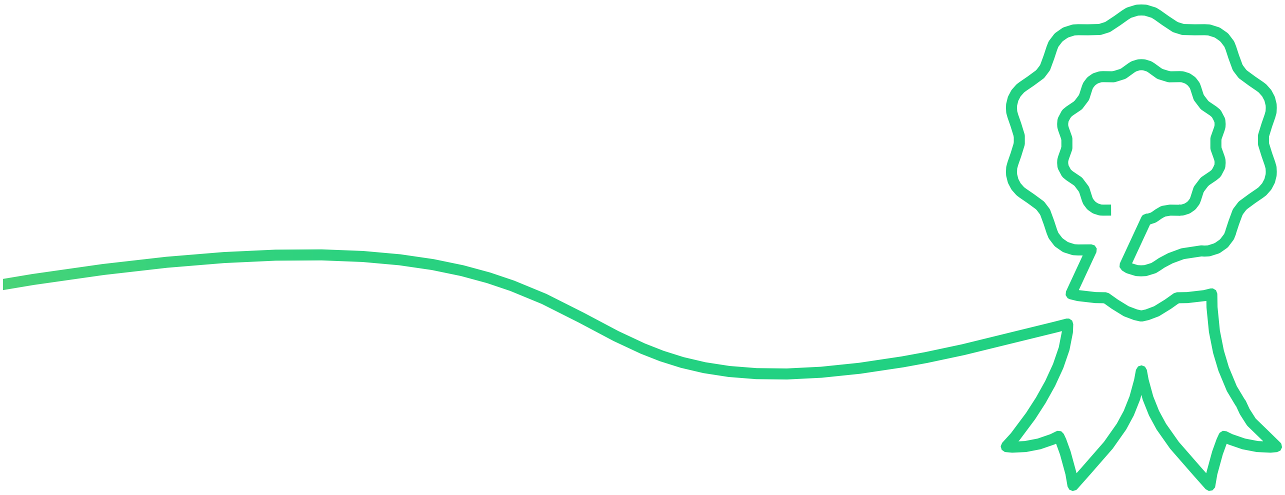
Association for Project Management

Earned schedule analysis appendix



Because when projects succeed, society benefits

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Introduction

A difficulty often levelled at 'traditional' earned value analysis (EVA) is that the common unit is that of currency ($, £, €, etc), even if schedule is being analysed. This can cause confusion and even dismissal of earned value management (EVM) when being discussed with those less knowledgeable of the subject. Furthermore, there are many different leadership and management styles and, while all want confidence in their data, there will be preferred ways of analysing and presenting it.

Earned schedule (ES), or earned schedule analysis (ESA), has been developed as an analysis technique to help overcome this issue and provide a different view of earned value management data to help support decision making and management of projects.

Depending on the accuracy required and the availability of data, there are two primary methodologies for conducting earned schedule analysis:

- **Measured:** Where physical measurements are taken from a printed page and the time variance ascertained from the measurement.
- **Calculated**: Where a mathematical process of linear interpolation is used to calculate the time variance.

It should be noted that the calculated methodology for earned schedule analysis is more complex than the traditional EVA techniques (see the four-step methodology below) and should thus be used with caution.

Both methodologies will be described.

Why use earned schedule analysis?

As noted in the introduction, the use of ESA when discussing schedule may well help to increase the understanding of a wider stakeholder body, resulting in improved input to the decision-making process. Additionally, using time as the unit permits closer co-ordination with other project analysis tools and techniques such as critical path analysis or schedule risk analysis, further increasing the benefit of EVM to successful project delivery.

ESA also retains the traditional benefits of using EVA, for example:

- When based on a validated earned value management system (EVMS), there is a high level of confidence in the data.
- A number of techniques exist that provide forecasts of project outturn.
- It can be used at any level in the project where valid data exists, for example at work package level and at control account level, as well as at project level.

Case study 1: Project behind schedule

This case study will be used to describe and walk through the two methodologies outlined above. A second case study is included after this section to show how the methodologies work with a project that is ahead of schedule.

Figure 1 shows a traditional cumulative earned value graph for a project that is running late and over budget. The project has recently completed and reported on reporting period 7.

Traditional schedule variance, denoted SV(cost), has been identified and is easily calculated on the vertical (cost) axis of the graph. Also marked on the graph is a horizontal, orange dotted line (on the time axis) projecting back from current earned value (EV) line to planned value (PV), and labelled SV(time). The measurement/calculation of SV(time) is the core task of earned schedule analysis.

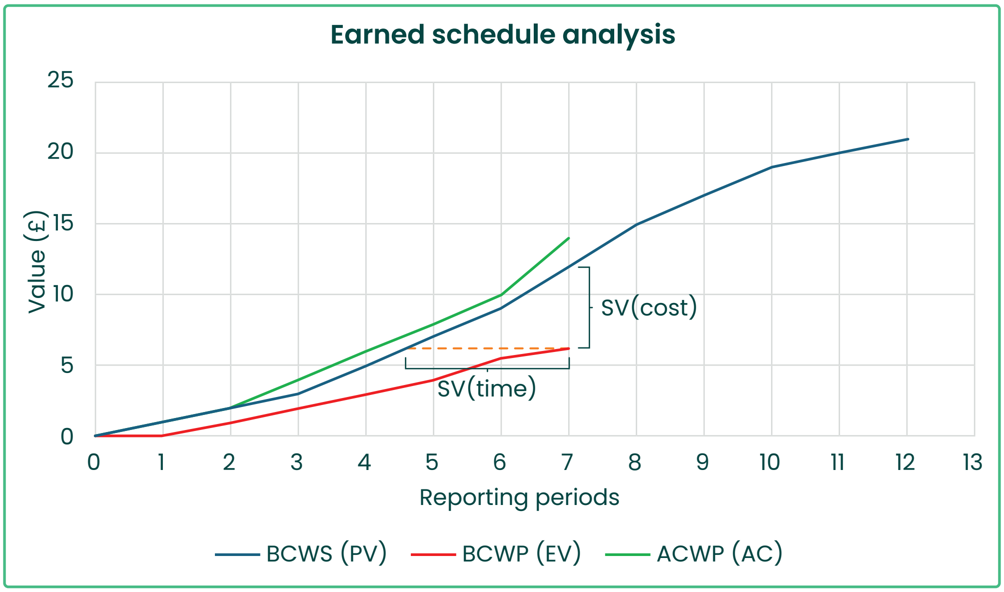

Figure 1 Graphical representation of SV(time)

Case study 1 is based on the data shown in Table 1.

Table 1 Worked example data

Reporting period	Cumulative BCWS PV(cum)	Cumulative BCWP EV(cum)	Cumulative ACWP AC(cum)
0	0	0	0
1	1	0	1
2	2	1	2
3	3	2	4
4	5	3	6
5	7	4	8
6	9	5.5	10
7	12	6.25	14
8	15		
9	17		
10	19		
11	20		
12	21		

It is assumed readers of this appendix already understand traditional EVA and the relationships between BCWS (PV), ACWP (AC) and BCWP (EV). ESA uses equivalent measures, as shown in Table 2.

Table 2 Measures used in ESA

Traditional EVA	Earned schedule analysis	ESA additional comments
Budgeted cost of work scheduled (BCWS) or Planned value (PV)	PV(time)	Uses the project PV curve, taking values from the horizontal (time) axis.
Actual cost of work performed (ACWP) or Actual cost (AC)	Actual time (AT)	For ESA, this is the time against which the analysis is taking place. Mostly this will be at the end of the most recently recorded reporting period; however, any time in the project history can be used.
Budgeted cost of work performed (BCWP) or Earned value (EV)	Earned schedule (ES)	Earned schedule is the point in time when it was planned to have earned the value that has actually been earned.

To ascertain SV(time) the following data points are required:

- **AT – actual time**: The methodology below (both measured and calculated) is used when the AC is at the end of a reporting period, i.e. a set data date. A more advanced method is shown later that enables calculation of SV(time) between reporting period end dates.
- **EV(cum):** Cumulative earned value at the actual time being analysed.
- **PV(cum):** Cumulative planned value baseline.

Measured earned schedule analysis methodology

Once a printed copy of the cumulative earned value management graph (Figure 1) has been obtained, ascertaining SV(time) using the measurement methodology is a four-step process:

Step 1

Measure the physical distance between reporting periods.

Tip: Measure the width of 10 periods and divide by 10 to improve accuracy.

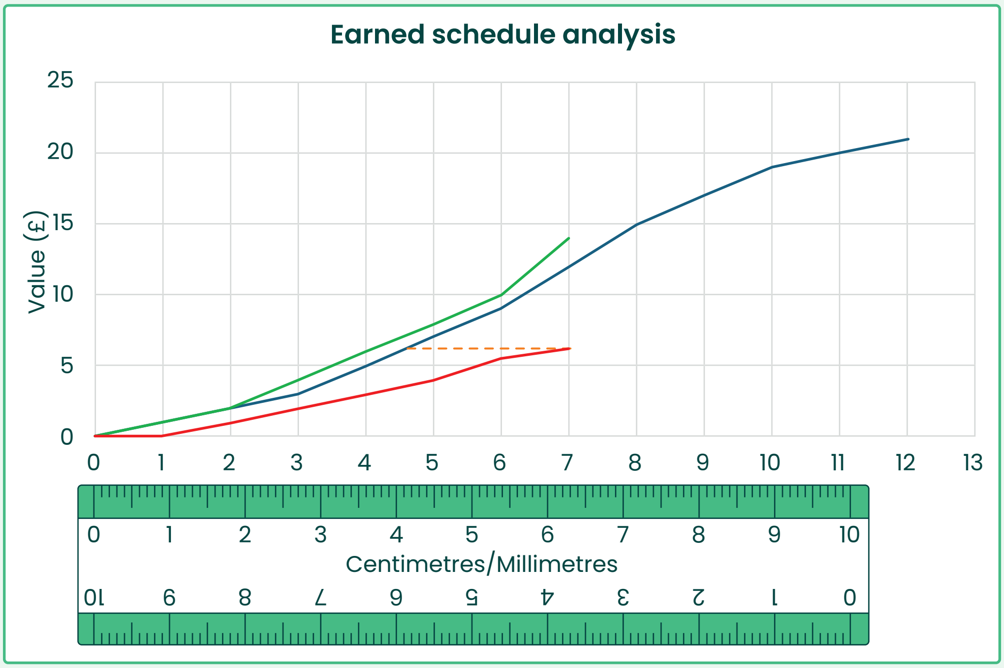

Figure 2 Measuring the length of 10 reporting periods

In this instance, 10 reporting periods are exactly 9cm. Therefore 1 reporting period is 9mm.

Step 2

Measure the horizontal gap between the cumulative EV line and the cumulative PV line for the actual time (AT) you wish to analyse. This is shown by the horizontal orange dotted line in Figure 1, if you were trying to ascertain lateness at the end of reporting period 7.

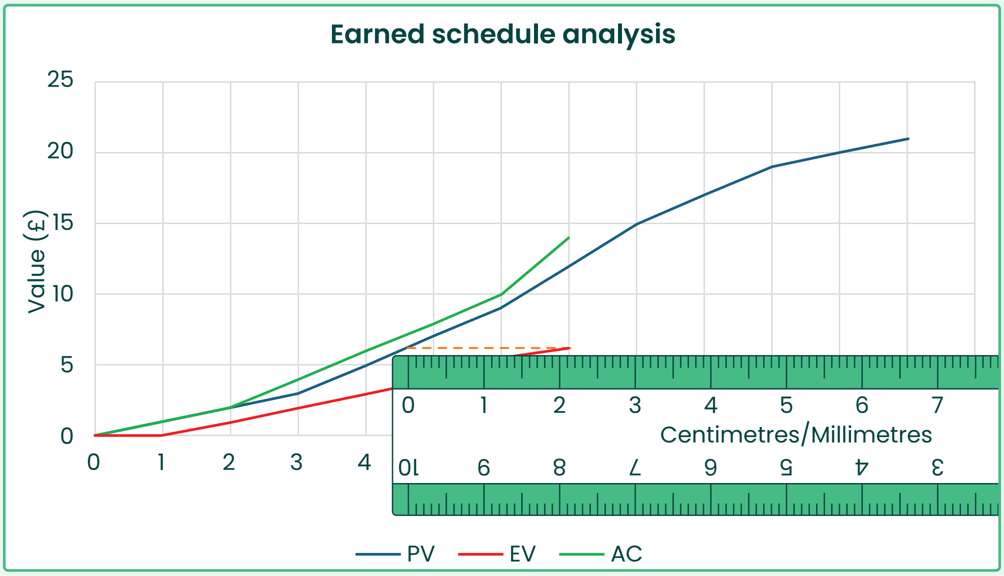

Figure 3 Measuring the gap between earned value and planned value

For the case study, we can see that the gap is 22mm.

Step 3

Divide the outcome of Step 2 by the outcome of Step 1 to calculate the number of reporting periods of schedule variance.

For the case study, this would be: 22 ÷ 9 = 2.44 reporting periods.

Step 4

Multiply the outcome of Step 3 by the duration of a reporting period to find out the time variance in days, weeks or months.

If we assume that each reporting period is 4 weeks, this would give a delay of 2.44 × 28 = 68 days or 9.8 weeks. As this project is **behind** schedule, this is reported as a **negative** number, i.e. -9.8 weeks.

Calculated earned schedule analysis methodology

This section explains the methodology for the calculation of earned schedule using a mathematical technique called linear interpolation. From this, a schedule variance using time as the unit can be calculated, denoted SV(time) from this point forwards.

Using the data from Case study 1, the following steps can then be performed:

Step 1: Establish the boundary conditions for PV and time

This first step identifies the two reporting periods between which the linear interpolation, in Step 2, will take place. In this methodology, these are called the upper and lower boundaries.

Upper boundary

The upper boundary can be defined as the first reporting period where, at the end, PV(cum) is greater than EV(cum).

For this case study, EV(cum) = 6.25, which is the cumulative earned value at the end of period 7.

Starting from reporting period 0, it can be seen that PV(cum) is less than 6.25 until reporting period 5, where PV(cum) = 7, and is thus greater than 6.25. Therefore the upper boundary is reporting period 5.

Lower boundary

The lower boundary can be defined as the last reporting period where, at the end, PV(cum) for that period is less than EV(cum) at the point in time where we are conducting our analysis.

As before, starting from reporting period 0, PV(cum) is less than 6.25 until period 5. Therefore, by definition, the final reporting period when PV(cum) was less than EV(cum) was the period before, i.e. period 4.

Period	PV(cum)	EV(cum)	AC(cum)
0	0	0	0
1	1	0	1
2	2	1	2
3	3	2	4
4	5	3	6
5	7	4	8
6	9	5.5	10
7	12	6.25	14
8	15		
9	17		
10	19		
11	20		
12	21		

Lower boundary

At the end of reporting period 4:

PV(cum) < EV(cum)

Upper boundary

At the end of reporting period 5:

PV(cum) > EV(cum)

EV(cum) = 6.25 for the period being analysed

Figure 4 Showing the upper and lower boundary conditions in the data table

Notes

The lower and upper boundary conditions are always a single reporting period apart and are referred to as PV(x) and PV(x + 1) respectively.

It can be seen that this matches with the horizontal line drawn on Figure 1, which intercepts the planned value line somewhere between reporting periods 4 and 5.

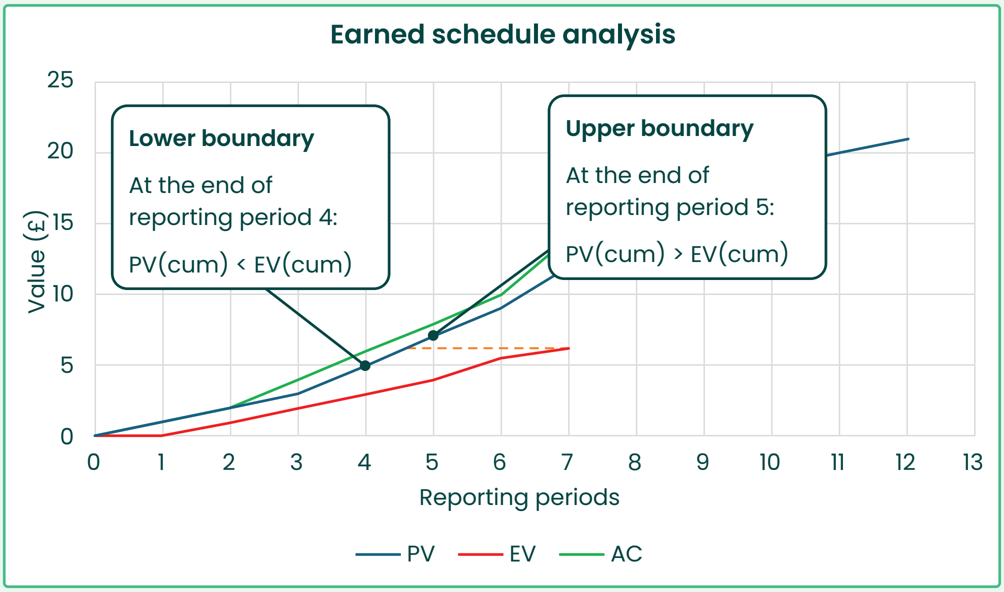

Figure 5 The upper and lower boundary conditions on the graph

Step 2: Calculate where in the period EV(cum) should have been earned

Using the linear interpolation, the fraction through the reporting period that EV(cum) should have been earned is calculated:

$$\frac{EV(cum) - PV(x)}{PV(x + 1) - PV(x)}$$

Note: Linear interpolation assumes PV(cum) is a straight line between PV(x) and PV(x + 1).

Using the results from Step 1 from the case study, this is:

$$= \frac{EV(cum) - PV(4)}{PV(5) - PV(4)}$$

$$= \frac{6.25 - 5}{7 - 5}$$

$$= 0.625 = ES(partial)$$

What this is saying is that the line marked SV(time) on Figure 1 intercepts PV(cum) 62.5% of the way between the lower boundary and the upper boundary (reporting periods 4 and 5 for the case study).

Note: A very simple check to help ensure that this step is correct is that the result must be a positive number between 0 and 1.

Step 3: Calculate the earned schedule

Step 1 established the lower boundary reporting period (x). Step 2 calculated the fraction (ES(partial)) through the reporting period that EV(cum) should have been earned. Therefore:

Earned schedule = x + ES(partial)

For the case study:

Earned schedule (ES) = 4 + 0.625 = 4.625

This means that, although the project has actually just completed reporting period 7, the equivalent value should have been earned 62.5% of the way between reporting periods 4 and 5.

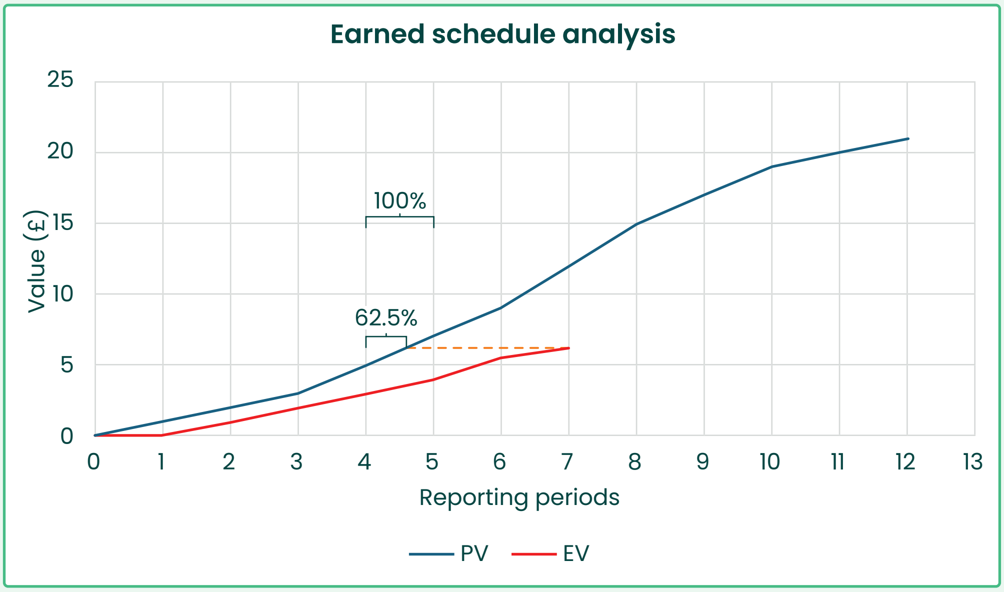

Figure 6 Calculating the earned schedule

Step 4: Calculate schedule variance (time) – SV(time)

SV(time) is calculated as follows:

SV(time) = ES - AT

For the worked example:

SV(time) = 4.625 - 7 = -2.375 reporting periods (or 9.5 weeks, assuming a 4-week reporting period)

This means that the project, according to this calculation, is around 9.5 weeks behind schedule.

Note that, because the project is **behind** schedule, the result of this calculation is a **negative** number.

As can be seen, the results of both the measured and calculated methodologies are very similar. While the result of the calculated method is undoubtedly more accurate, the user must take into account factors such as quality of project data before deciding whether the use of this methodology is worth the additional effort.

Case study 2: Project ahead of schedule

This section will only describe the differences in the methodologies to analyse a project that is ahead of schedule. It assumes a knowledge of the measured and calculated methodologies described above.

Case study 2 is based on the data shown in Table 3.

Table 3 Worked example data

Reporting period	PV(cum)	EV(cum)	AC(cum)
0	0	0	0
1	1	1	1
2	2	1.2	2
3	3	3.5	4
4	5	6	6
5	7	9	8
6	9	12	10
7	12	15.5	14
8	15		
9	17		
10	19		
11	20		
12	21		

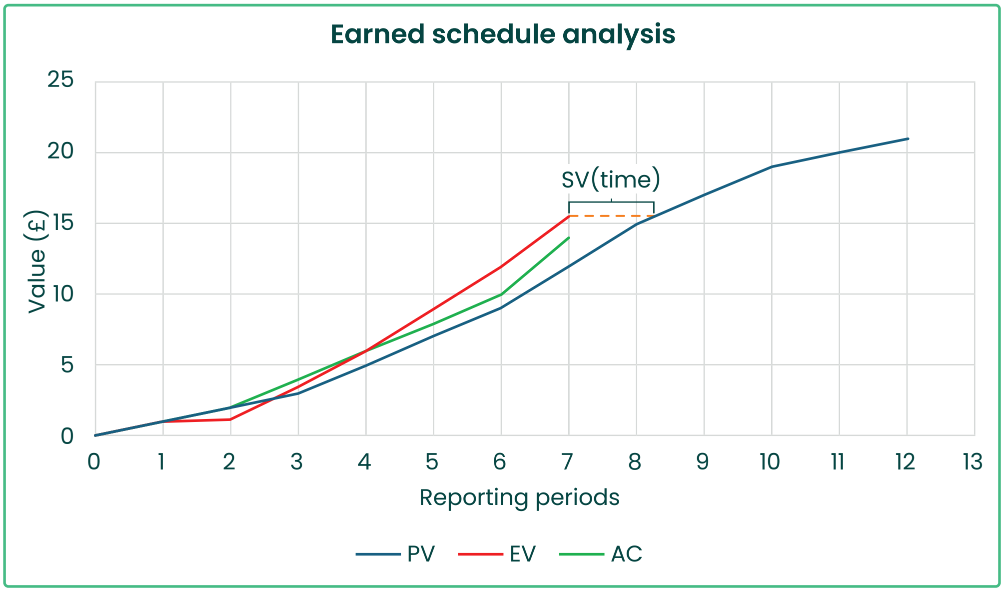

Figure 7 Graphical representation of SV(time)

Measured earned schedule analysis methodology

Step 1

The first step is to measure the physical distance between reporting periods.

As in Case study 1, 10 reporting periods are exactly 9cm. Therefore one reporting period is 9mm.

Step 2

Measure the horizontal gap between the cumulative EV line and the cumulative PV line for the actual time (AT) you wish to analyse.

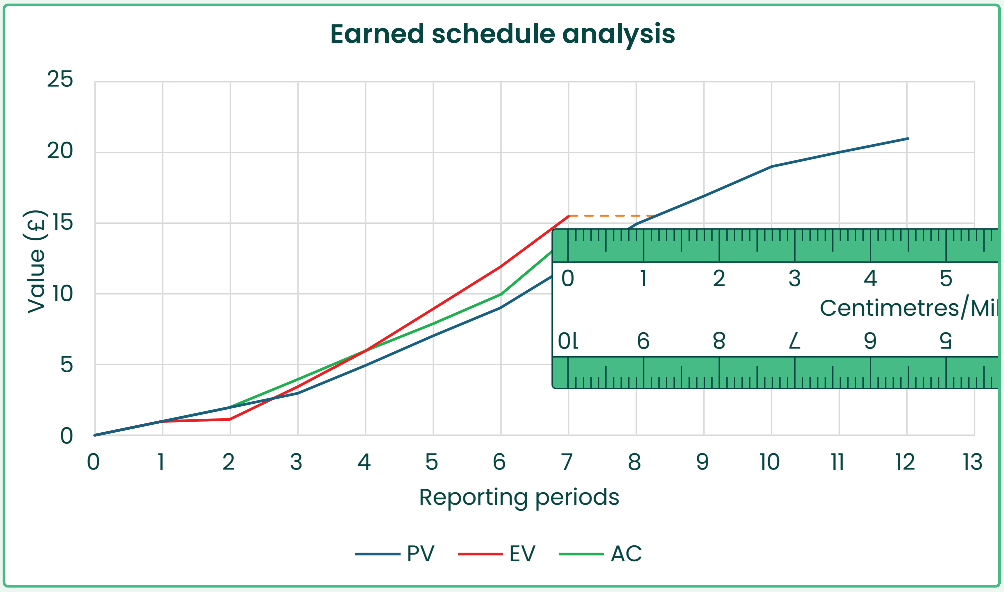

Figure 8 Measuring the gap between earned value and planned value

For the case study, we can see that the gap is 12mm.

Step 3

Divide the outcome of Step 2 by the outcome of Step 1 to calculate the number of reporting periods of schedule variance.

For the case study, this would be: 12 ÷ 9 = 1.33 reporting periods.

Step 4

Multiply the outcome of Step 3 by the duration of a reporting period to find out the time variance in days, weeks or months.

If we assume that each reporting period is 4 weeks, this would give: 1.33 × 28 = 37 days or 5.3 weeks ahead of schedule. As this is **ahead** of schedule, this is reported as a **positive** number, i.e. +5.3 weeks.

Calculated earned schedule analysis methodology

Using the Case study 2 data, the following steps can then be performed:

Step 1: Establish the boundary conditions for PV and time

Upper boundary

For this case study, EV(cum) = 15.5, which is the cumulative earned value at the end of reporting period 7.

Starting from reporting period 0, it can be seen that PV(cum) is less than 15.5 until reporting period 9, where PV(cum) = 17.

Therefore the upper boundary is reporting period 9.

Lower boundary

Starting from reporting period 0, PV(cum) is less than 15.5 until period 8.

Therefore, by definition, the final reporting period when PV(cum) was less than EV(cum) was the period before, i.e. period 8.

Step 2: Calculate where in the period EV(cum) should have been earned

$$\frac{EV(cum) - PV(x)}{PV(x + 1) - PV(x)}$$

Using the results from Step 1 from the case study, this is:

$$= \frac{EV(cum) - PV(8)}{PV(9) - PV(8)}$$

$$= \frac{15.5 - 15}{17 - 15}$$

$$= 0.25 = ES(partial)$$

Step 3: Calculate the earned schedule

Earned schedule = x + ES(partial)

For the case study:

Earned schedule (ES) = 8 + 0.25 = 8.25

Step 4: Calculate schedule variance (time) – SV(time)

SV(time) is calculated as follows:

SV(time) = ES - AT

For the worked example:

SV(time) = 8.25 - 7 = +1.25 reporting periods (or 5 weeks, assuming a 4-week reporting period)

This means that the project, according to this calculation, is around 5 weeks ahead of schedule.

Note that, because the project is **ahead** of schedule, the result of this calculation is a **positive** number.

Challenges associated with applying earned schedule analysis

As with every tool or technique, ESA needs to be used with caution and appropriately. If not, it can lead to spurious data and hence incorrect decisions. Common pitfalls associated with earned schedule analysis are:

- Both the measured and calculated methodologies are based on linear interpolation and therefore have an inherent small degree of inaccuracy. As such, when used in areas of a project where the PV is not stable, the results can be misleading.
- Earned schedule analysis only adds to a plethora of other analysis techniques. The results should only ever be used in conjunction with other techniques to help triangulate the actual position.
- Although earned schedule analysis can be used to drill down, i.e. run on a control account or a work package, it is likely that data at this level is less linear and is thus susceptible to the point about linearity above.
- Re-baselining can make it difficult to identify an accurate lower boundary condition.
- The calculations above work in 'whole' reporting periods and can be amended to work for partial periods; however, this is more complex (see below).
- Out-of-sequence work can make the schedule look better than it really is, and earned schedule analysis will not uncover this.

Advanced calculated earned schedule analysis

Having calculated the earned schedule using the methodology described earlier, it is now possible to conduct further analysis. Table 4 shows several examples and how they might be used to improve decision making.

Table 4 Further calculations and data

Traditional EVA	ESA equivalent	Use
SPI = EV ÷ PV	SPI(time) = ES ÷ AT	If SPI(time) < 1, the project is behind schedule. If SPI(time) > 1, the project is ahead of schedule.
iEAC1 = AC + (BAC – EV)	iEAC1(time) = AT + (PD – ES)	Estimate of the potential completion date, assuming project proceeds to plan from this point.
iEAC2 = AC + ((BAC - EV) ÷ CPI)	iEAC2(time) = AT + ((PD – ES) ÷ SPI(time))	Estimate of the potential completion date, assuming project proceeds at its current cumulative level of performance.
TCPI(BAC) = (BAC - EV) ÷ (BAC-AC)	TCPI(time) = (PD – ES) ÷ (PD – AT)	Estimate of future performance to recover project and deliver on time.

Note: PD = project duration.

Not using start/end for the actual time (AT)

The methodology described earlier to calculate earned schedule is based on using the reporting cadence within a project. This is because the calculations require the date against which the performance data has been collected (referred to as the 'data date').

It is, however, possible to conduct ESA against any point of the history of a project. This requires a further step (also using linear interpolation) to calculate the EV(cum) at the chosen actual time.

The additional step is shown below, along with how it then integrates into the methodology described for Case study 1.

Using the same example as above, we now wish to work out the earned schedule variance for a point in time 10 days into the period between reporting periods 5 and 6 (a 4-week reporting cadence).

Additional step: Calculate EV(cum) on selected date

Find EV(cum) at reporting period 5: EV(lower) = EV(5) = 4 (see Table 1)

Find EV(cum) at reporting period 6: EV(upper) = EV(6) = 5.5 (see Table 1)

Calculate the fraction – AT(partial) – of how far through the chosen period we wish to carry out the calculations:

$$\text{AT(partial)} = \frac{\text{Days into period}}{\text{Total duration of period (in days)}}$$

$$= 10 \div 28 = 0.36 = \text{AT(partial)}$$

$$\text{EV(cum)} = \text{EV(lower)} + \text{AT(partial)} \times (\text{EV(upper)} - \text{EV(lower)})$$

$$\text{EV(cum)} = 4 + 0.36 \times (5.5 - 4)$$

$$= 4.54$$

The EV(cum) calculated in the above step is then fed directly into Step 1 in the basic calculations. Therefore, to continue this example:

Step 1: Establish the boundary conditions for PV and time

For this worked example, it can be seen in Table 1 that the lower boundary is met at the start of reporting period 3 and the upper at the start of reporting period 4.
Thus, where EV(cum) = 4.54:

PV(3) (PV(cum) at start of period 3) = 3 (less than EV(cum))

PV(4) (PV(cum) at start of period 4) = 5 (greater than EV(cum))

Step 2: Calculate where in the period EV(cum) should have been earned

Using the results from Step 1, for the worked example, this is:

$$= \frac{EV(cum) - PV(3)}{PV(4) - PV(3)}$$

$$= \frac{4.54 - 3}{5 - 3}$$

= 0.77 = ES(partial)

Note: A very simple check to ensure that this step is correct is that the result must be a positive number between 0 and 1.

Step 3: Calculate the earned schedule

Earned schedule = x + ES(partial)

For the worked example:

Earned schedule (ES) = 3 + 0.77 = 3.77

This means that, although the actual time (AT) of interest was 36% of the way between reporting periods 5 and 6, the equivalent value should have been earned 77% of the way between reporting periods 3 and 4.

Step 4: Calculate schedule variance (time) – SV(time)

SV(time) = ES - AT

For the worked example:

SV(time) = 3.77 – 5.36 = -1.59 reporting periods

This means that the project, according to this calculation, is around 1.59 reporting periods behind schedule, or approximately 45 days or 6.5 weeks.

Note that, because the project is **behind** schedule, the result of this calculation is a **negative** number.

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