
Programme evaluation and review technique (PERT) in MS Project 7

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Abstract

This paper describes the application of PERT with MS Project 7 software. The method is demonstrated with a representative example. PERT provides a mechanism to explicitly include uncertainty in task durations in a project plan. It is relatively easy to implement, and providing its limitations are acknowledged it can be an effective way to determine the likely duration.

1 Introduction

Programme evaluation and review technique (PERT) is a method for accommodating uncertainty in task durations. It achieves this by assigning three values to each duration: an optimistic, typical, and pessimistic. Then it uses these values to calculate the most likely total project duration.

2 How does uncertainty in task duration arise?

In conventional project management a fixed amount of time is assigned to each task, e.g. 3 days to 'excavate foundation for building'. This is a deterministic estimate, because it does not accommodate uncertainty. It is a nominal allocation of time, and the actual time taken could vary quite considerably.

For example, it might take only 2 days to excavate the foundations if the soil is soft, and the staff work well, and the equipment operates properly, and the weather is kind. This is the optimistic estimate, because it assumes that all these factors are favourable. The more factors the *less likely they will all simultaneously be favourable*, and therefore 3 days might be a more typical estimate. If all the factors were simultaneously unfavourable then it might take a lot more time to complete the task. For example 'excavate foundation for building' may encounter hard ground, sick staff, equipment failures, *and* bad weather, all of which are unknowable before the task starts, and result in a duration of 6 days. This is the pessimistic estimate.

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Thus in our example the three estimates for 'excavate foundation for building' are:

2 days	optimistic or best-case
3 days	typical or nominal
6 days	pessimistic or worst-case

Using some statistical principles, it is then possible to calculate the mean duration. This calculation is not difficult, but is also easily done using MS Project, and it results in:
3.33 days mean duration

But why is the mean duration not equal to the typical? The answer to this is based on statistics, and the fact that the pessimistic estimate is skewing the outcome towards a higher value. If the optimistic and pessimistic estimates were equally spaced about the typical (symmetrical), i.e. as 2 and 4 respectively, then the mean would be 3 and would equal the typical estimate.

Thus three estimates have been combined to give one overall mean duration. This takes into account the uncertainty in durations. Importantly, the three estimates can be used, together with similar estimates for other tasks, to determine the overall project uncertainty in schedule.

3 Making reliable estimates

Ideally the project manager will have prior experience on which to base the three estimates. If this is unavailable, then it is still possible for a novice project manager to estimate the three durations. The novice project manager should be giving a wider range of estimates to accommodate his lack of knowledge, e.g. 1,3,10, and this will flow through to greater uncertainty in the duration of the whole project.

In any estimation process, experience or novice, there is the possibility of bias. Unfortunately novice project managers may be especially at risk of failing to appreciate the variability caused by outside factors, and therefore may erroneously make narrower estimates than they should. Expert project managers can also make bias errors: for example they tend to fixate on a typical value and just add a (small) positive and negative margin around that central value.

4 Weighting within PERT

The PERT method fits a beta statistical distribution to the three estimates. To do this it needs to weight each of the three estimates. The typical weights are 1x optimistic, 4x typical, and 1x pessimistic. PERT analysis relies on the beta distribution analysis to calculate the mean as:

Mean duration = (1x optimistic duration + 4x typical duration + 1x pessimistic duration) /6

However there is *no particularly strong reason for these particular weights* other than common practice, and other weights may be set (Vose, 1996) (see the 'Set PERT weights' button in MS Project). The effect of the weights is to control the central tendency and skew of the beta distribution.

1. Central tendency: If more weight is given to the typical estimate then the distribution will be narrower with a higher central peak. Conversely, less weight to the typical value will flatten the distribution.
2. Skew: If more weight is given to either the optimistic or pessimistic estimate, then the beta distribution will be skewed towards that side, i.e. will have more weight in the tails. Thus the mean value will tend towards whichever side is weighted more.

There is *no strong reason for using the beta distribution*, other than convenience. In particular there is no evidence that real effects closely follow the beta distribution. Other distributions such as the normal (Gaussian) are generally more accurate representations of natural phenomena. However the beta is convenient because it is simpler to manipulate mathematically. Also, its bounded nature makes it easier for project managers to comprehend. Bounded means that it has sharp lower and upper cut-offs. Thus in our example for 'excavate foundation for building' the optimistic (best-case) estimate was 2 days, and the implicit assumption in the beta distribution is that it is impossible to go less than this value. Likewise it is assumed to be impossible to exceed the pessimistic estimate of 6 days. From a purist perspective this is highly problematic, because the distribution is ignoring the obvious fact that it could take more than 6 days to do this task, e.g. if there was some bigger more extreme event (e.g. earthquake, discovering a complete dinosaur fossil at the site, etc.).

5 What is worst-case anyway?

Thus the question arises: what exactly do we mean by optimistic (best-case) and pessimistic (worst-case)? Is it the most utterly worst case conceivable? Is 10 yrs enough? 100 yrs? Or is it just the worst case that the project manager has personally experienced on uneventful similar projects? There are no perfect solutions to these questions. We are better off simply acknowledging that all methods that seek to quantify risk are inherently ambiguous, and we should therefore simply select a meaning and declare it as part of the analysis so that others can scrutinise the basis for our predictions and reconcile those with their own planning and decision-making.

6 Using MS Project for PERT

Applying PERT in MS Project 7 is straightforward.

- A First it is necessary to activate the PERT toolbar (<menu> view\toolbars\PERT analysis). The toolbar appears at the top of the screen, see Figure 1.



Figure 1: PERT bar in MS Project.

- B Next, create a work breakdown structure by entering tasks and nesting them in a hierarchy.
- C Then enter the three estimates of duration for each task, see Figure 2. This can be done in several ways, of which the best is probably <menu> view\ table\ more tables\ PA_PERT entry. Otherwise the PERT toolbar has a >PERT entry sheet=. Only enter data for optimistic, expected, and pessimistic durations, and not for summary tasks (those in bold).

ID	Task Name	Duration	Optimistic Dur.	Expected Dur.	Pessimistic Dur.
1	Develop go-kart	36.17 days	16 days	32 days	73 days
2	Start project	0 days	0 days	0 days	0 days
3	Design the kart	20.17 days	9 days	16 days	48 days
4	Select motor	4.17 days	3 days	3 days	10 days
5	Design power tra	4.17 days	1 day	4 days	8 days
6	Select wheels	3 days	1 day	3 days	5 days
7	Design steering	3 days	1 day	3 days	5 days
8	Design controls &	3 days	1 day	3 days	5 days
9	Design brakes	3 days	1 day	3 days	5 days
10	Design frame	7 days	3 days	6 days	15 days
11	Design fairings a	4.83 days	2 days	3 days	15 days
12	Procure parts	12.33 days	5 days	12 days	21 days
13	Build basic kart	10 days	5 days	10 days	15 days
14	Test kart	6 days	2 days	6 days	10 days
15	End project	0 days	0 days	0 days	0 days

Figure 22: PERT analysis. Three estimates are required for each task, excluding summary tasks (bold): the optimistic (best case), expected (nominal), and pessimistic

- D Set the PERT weights from the PERT toolbar. Typical weights are 1:4:1.
- E Calculate PERT using the button on the PERT toolbar.
- F View the results, e.g. Figure 3. Notice that a new value of >Duration= has been calculated (based on the equation in section 4 previously). Also, you can view the best and worse case project durations, by selecting the appropriate button on the PERT toolbar. However, best and worst case outcomes have limited value, simply because it is highly unlikely that all events will *simultaneously* take best or worst case outcomes.

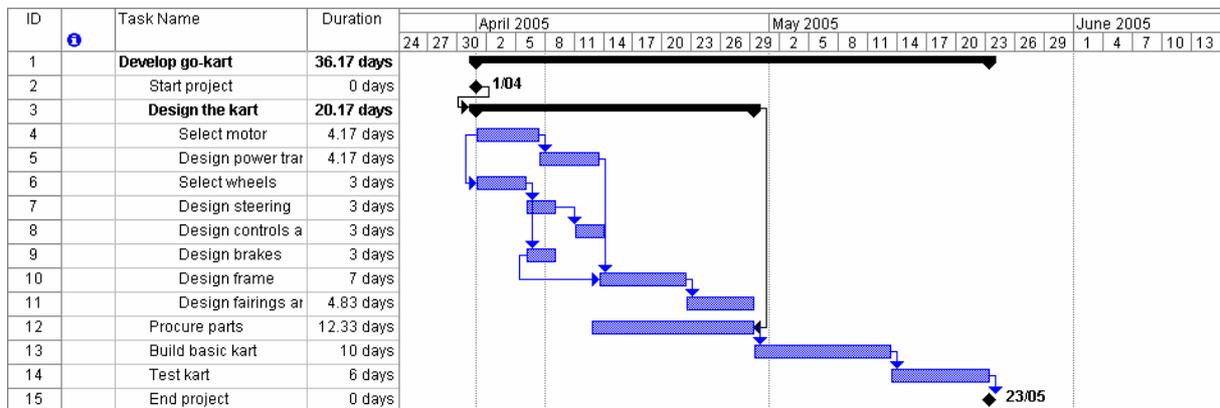


Figure 3: Gantt chart for PERT analysis. Calculated mean durations have been inserted by the software in place of the nominal values first provided (see 'expected dur.' in previous figure). The project duration has become longer than before, because individual task durations have lengthened, in turn due to the effect of the pessimistic estimates.

The Gantt chart now uses the calculated durations rather than the expected, and this will affect the end date and the critical path. So the outcome is a Gantt chart which has taken into account the uncertainty in the durations.

This is useful because it permits the project manager to specifically include uncertain durations in project plans. The process is simple to implement once the basics are understood. In particular it does not require any substantial knowledge of statistics, and this makes it useful for practical applications.

From a statistical perspective, MS Project only uses the mean duration for each task, not the variance, and therefore cannot show the spread in duration for the whole project. However, it is possible to do this calculation, though it is necessary to perform an external calculation of project standard deviation, e.g. with a spreadsheet. This involves calculating the variance of each task duration *on the critical path*, which is easy to do since the variance of the beta distribution is simple. Then the results are summed, and finally the square root taken. This is shown in Figure 4.

The mean expected time is then used in the network as a deterministic value. The variance for each activity is $v = ((c-a)/6)^2$ for the beta distribution. The total project time has a normal distribution (as per the central limit theorem) with variance given by the sum of the variances of the activities on the critical path (Taylor, 1999, p463).

	A	B	C	D	E	F	G
1	Develop go-kart						
2	PERT analysis	<i>Estimates [days]</i>			<i>Calculated results</i>		
3	<i>Critical path</i>	<i>Best</i>	<i>Nominal</i>	<i>Worst</i>	<i>Expected duration</i>	<i>Variance</i>	
4	Formulae				$((Worst+4xNominal+Best)/6)$	$((Worst-Best)/6)$	
5	Select motor	3	3	10	4.17	1.167	
6	Design power trans	1	4	8	4.17	1.167	
7	Design frame	3	6	15	7.00	2.000	
8	Design fairings	2	3	15	4.83	2.167	
9	Build basic kart	5	10	15	10.00	1.667	
10	Test kart	2	6	10	6.00	1.333	
11	<i>Project duration</i>	16	32	73	36.17		
12	Project variance					9.500	Sum of task variances
13	Project standard deviation					3.082	Square root of project variance

Figure 4: PERT analysis for project variance, calculated in a spreadsheet. The project standard deviation (bottom right) may then be used to create a normal distribution and determine likelihood of various scenarios.

For the data used here, the overall project duration is now shown to be 36.17 days with a standard deviation of $s = 3.082$ days.

The standard deviation s shows the spread of the uncertainty: large s corresponds to greater uncertainty. Furthermore, it permits a more robust calculation of the band of uncertainty around the total project duration. See example below which shows for this sample project that there is a 90% probability that the actual project duration will be between:

lower limit 31 day
mean 36 day
upper limit 41 day

7 Limitations

The PERT implementation in MS Project⁷ has some limitations, and these are briefly discussed.

- (1) PERT is unable to accommodate the fact that *the critical path itself may change*, i.e. other tasks may come onto the critical path as durations adjust for the optimistic and pessimistic cases. The critical path is determined by only the calculated durations. MS Project will not recalculate the end date or critical path for the best and worst cases. There is no way around this constraint with MS project. However, in many cases this does not need to be a problem, since the ongoing monitoring of the project will adjust the critical path anyway.
- (2) The calculated worst- and best-case durations for the *whole project* are unreliable. MS Project does calculate optimistic and pessimistic durations for the whole project, but these are unrealistic because it is unlikely that *all* tasks will be simultaneously optimistic (pessimistic). As the number of tasks increases so these extremes cases become increasingly less likely. This can be accommodated by calculating confidence intervals around the mean overall project time as shown above in Figure 4.

Example calculation of band of uncertainty for project duration

Problem

Given an overall project duration of 36.17 days with a standard deviation of $s = 3.082$ days, calculate the possible range of durations for 90% confidence.

Solution

Mean, $D_{\text{mean}} = 36.17$ d

Standard deviation, $s = 3.082$ d

We want to find a range of durations, D_{lower} to D_{upper} that cover 90% of the possibilities. Thus there must be only a 5% chance of the project taking less time than D_{lower} , and 5% chance of exceeding D_{upper} .

We assume the *normal* distribution and find the number of standard deviations (z) for areas under the curve of 0.05 and 0.95. This can be done with statistics tables. Alternatively, use MS Excel to calculate

$$z_{\text{lower}} = \text{NORMSINV}(0.05) = -1.644853627$$

$$z_{\text{upper}} = \text{NORMSINV}(0.95) = 1.644853627$$

Then the lower and upper range points are

$$D_{\text{lower}} = D_{\text{mean}} + s \times z_{\text{lower}} = 36.17 + 3.082 \times (-1.65) = 31.10056112$$

$$D_{\text{upper}} = D_{\text{mean}} + s \times z_{\text{upper}} = 36.17 + 3.082 \times (1.65) = 41.23943888$$

Answer

So the answer is that there is a 90% probability that the actual project duration will be between:

lower limit	31 day
mean	36 day
upper limit	41 day

Compare this to the simplistic project durations calculated by MS Project PERT, which were

optimistic	32 day
mean	36 day
pessimistic	73 day

Notice that the means are the same, but different ranges are predicted. The probability approach (31-41 day) is the more valid.

- (3) The PERT algorithm, which uses the beta distribution, is only an *approximate* probabilistic computation method. It gives some indication of the central tendency (mean) and dispersion (standard deviation), but uses moment methods which are approximate. Nor is there any underlying theoretical justification for using the beta rather than any other distribution, except convenience for the analyst. In many ways this does not need to be a problem, given the large uncertainties in any project. However, if the data support it, and a precision analysis is required for duration, then other methods such as fuzzy theory and Monte Carlo may be necessary, but these are beyond the present scope.

8 Conclusions

PERT provides a mechanism to explicitly include uncertainty in task durations in a project plan. It is relatively easy to implement, and providing its limitations are acknowledged it can be an effective way to determine the likely duration.

References

Taylor, B. W. (1999). Introduction to management science (Sixth edition ed.). New Jersey USA: Prentice Hall.

Vose, D. (1996). Quantitative risk analysis: Wiley.

Appendix 1: Help! PERT analysis toolbar missing from MS Project

According to the help file, this should be easily selectable: "On the View menu, point to Toolbars, and then click PERT Analysis."
However, the toolbar can sometimes be missing, especially in a corporate environment.

Solution 1: Delete profile as per
<http://support.microsoft.com/default.aspx?scid=kb;en-us;329856>.

Solution 2: Find and delete all global.mpt files on C: and your network drive (if your profile is stored on the network). This forces Project to recreate a new global mpt file. See
<http://www.microsoft.com/technet/archive/project98/reskit/011.mspx>
This is not always effective.

Solution 3: Delete the COM Add-Ins for PERT and then reconnect it. This seems to work every time. Here is how to do it:

Open MS Project 2003

<menu> tools/customise/toolbars

<select> commands tab

<select> tools category

<select> commands COM add- ins...

<drag to anywhere on toolbar>

<select> close

Now run the COM Add-Ins off the toolbar, delete the old PERT add-in, and reattach it afresh:

<toolbar select> COMS Add-ins

<select> PERT analysis

<select> remove

<select> add

<browse to C:\Program Files\Microsoft Office\OFFICE11>

<select file> PERTANL.DLL

Return to COM Add-ins

<check> Pert analysis

Shutdown MS project

Restart MS project

Activate the toolbar

<menu> view/toolbars/PERT

PERT toolbar should now be visible. If not, you will need to check with your IT support staff.