Paper Title: ***Project Risk Management – Beyond The Risk Register***

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Summary

This paper examines the fundamental considerations for analysing risks which may contribute to schedule overruns during project execution. Analysing the impact data for schedule risks provides information to the risk owners or project management team to assist them to:

- establish realistic schedule targets:
- determine levels of confidence in achieving, or exceeding, planned delivery timeframes;
- gain maximum benefit to the project through focused effort on the most critical and crucial project tasks; and
- set and agree realistic schedule contingency.

Modelling project risk exposure is beneficial to organisations and allows budgets and schedules to be developed for success. This approach allows organisations and customers to sign up to achievable targets and with contingency set at an appropriate level. More importantly focusing effort in the 'right' place to achieve these targets increases a project's chances of success.

Introduction

Project Risk[1] Management is the process used to manage potential events that might impact the cost, schedule, performance or agreed outputs of a project. The identification, analysis and evaluation of project risks leads to the development of a project risk register which is used for the management of these risks. Those risks with an impact that can be quantified, primarily cost and schedule, may be further analysed with the aim of providing Project Managers with information which can be used to benefit their projects. The generation of this information is a step beyond developing, maintaining and managing a risk register.

This paper examines the fundamental considerations for analysing risks which may contribute to schedule overruns during project execution. Analysing the impact data for these schedule risks provides information to the risk owners or project management team to allow them to:

- establish realistic schedule targets:
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Risk Management Process

A formal process is required to support Project Risk Management in any organisation. The process used in Raytheon Australia, which is aligned to the AS/NZS 4360:2004 Risk Management standard, is shown in Figure 1.

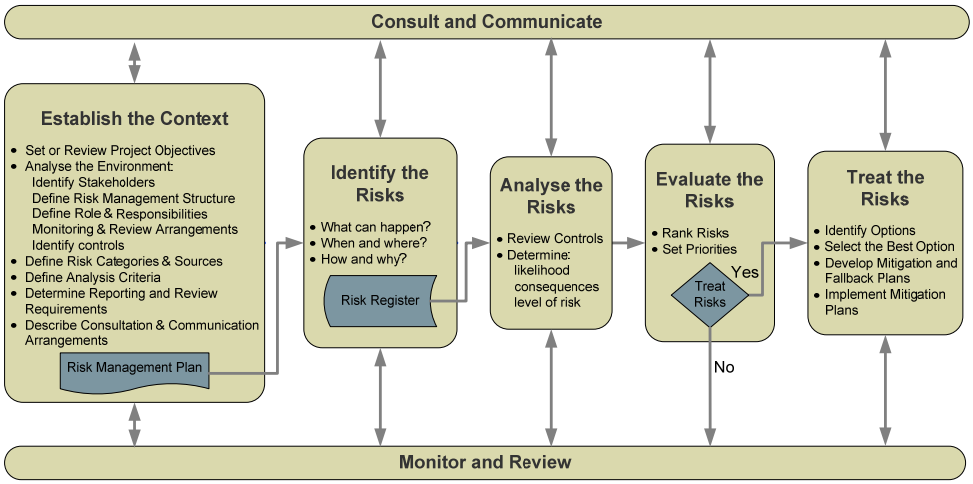

Figure 1 – *Raytheon Australia Risk Management Process*

The outputs from implementing this process within projects are the Project Risk Management Plan and the Project Risk Register, which includes specific Risk Treatment Plans. Before generating treatment plans the risks are first assessed to ensure that they are actually risks to the project's outcomes and not the normal variation which occurs in task duration (uncertainty). This normal variation in task durations should be recorded in the original task estimates and not considered through risk impacts within the risk register.

Uncertainty or Risk ?

Uncertainty and risk must be identified and treated differently to ensure the most realistic modelled outcome. Uncertainty will occur in most task durations, there is almost a 100% chance of this

[1] Where this paper refers to risk/s this is an acknowledgement that this reference includes both risks and opportunities, accepting that one is the converse of the other, but that both can be modelled and analysed using the same methodology.

uncertainty occurring – it is the level of this uncertainty that may vary. Uncertainty can be defined as the variation in estimation caused by the human element in the estimation process or limitations in the quality of estimation data: e.g. uncertainty in duration estimates arise because activities have not been carried out before or because tasks are complex with many variables.

Risks on the other hand may or may not occur. If a risk does occur the size of any schedule (or other) impact will in itself be uncertain. The relationship between risk and uncertainty is demonstrated in Figure 2 and 3 which show that both a task and any associated risk have their own levels of uncertainty of impact and that tasks and risks are separate events.

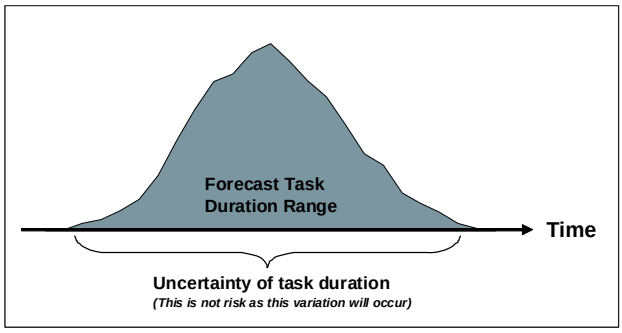

Figure 2 – *Task Modelling*

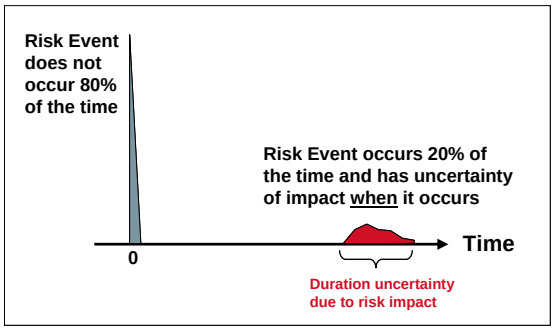

Figure 3 – *Risk Modelling*

3 Point Estimates

The range of uncertainty, for both task estimation and risk impacts, is usually expressed as a three point estimate (3PE) to allow further analysis. Estimates are expressed quantitatively using 3PEs to reflect the range of outcomes that could reasonably be expected. 3PEs support structured analysis and Monte Carlo modelling and can also be used to identify possible risks and opportunities to the project within the 3PE values specified. 3PEs are usually expressed in terms of Minimum, Most Likely and Maximum figures.

- ***Minimum*** – An optimistic assessment that assumes everything goes as well as possible. The estimate should be the minimum reasonable case and excludes miracles or outcomes that are more akin to science fiction than optimism.
- ***Most Likely*** – The value believed to be most likely outcome given the situation and the minimum and maximum bounds recorded. If an activity had been completed many times, the value would be the mode in statistical terms.
- ***Maximum*** – A pessimistic assessment of the time required to complete the task or the impact of a risk on the schedule. It takes account of adverse outcomes that could reasonably occur in completing the task. The Worst Case assessment excludes 'one in a million outcomes' and events that can be identified as risks. This figure represents the maximum reasonable duration impact on the schedule.

Useful 3PEs cannot be 'dreamed up'. They must be based on a reasonable judgment of the available data and take into account the context of the activity being assessed. Some believe that 3PEs are more difficult and time consuming to generate than single point estimates (SPE), however, generating an SPE still requires a thought process through the likely best and worst cases to develop the middle ground SPE. What is needed is for this thought process to be documented as a 3PE. 3PEs may be are informed by:

- Metrics
- Experience or post activity reports
- Results in similar, relevant circumstances
- Extrapolation from similar circumstances
- Modelling and Simulation

To obtain figures based on best judgement for task durations, and also risk impact durations, generation of the 3PEs should be encouraged using the following methodology:

1. First determine the **maximum** reasonable duration – this should exclude risks to completing the task or additional risks which may occur when dealing with a primary risk.
2. Determine the **minimum** reasonable time impact next. If this minimum estimate is derived first it is highly likely that the estimate provided will include an allowance for 'contingency'. However, if the maximum has been defined first then its more likely that the minimum figure will be more realistic.
3. With the minimum and maximum bounds now defined the generation of the **most likely** figure is a relatively easy judgement for estimators to make and they will be comfortable in providing a reasonable estimate within the defined bounds.

Impact Estimation

Using 3PEs for task and risk durations allows the feasible range of project outcomes to be modelled. The result is that the project end date will no longer be a specific date but will become a range of dates. The process of estimating the uncertainty using 3PEs is the same for task durations and risk impact durations – accepting that task duration estimation may have a more solid base level of data as these, or similar tasks, may have been carried out previously. It is acknowledged that 3PEs do not need to be generated where there is certainty in the task duration but this is a rare event in project delivery – applicable generally only to milestone durations (0 days), most other tasks tend to have some level of uncertainty.

Risks and uncertainty must be identified and modelled separately, noting that the outcome of the analysis will be limited by the accuracy of the base data. The review of completed 3PEs assists in the identification of risks or opportunities which have been included within the task estimates. For example in Table 1 if Task 2 really has a best case of 2 weeks the project management team should consider what can be carried out to reduce the most likely and maximum values to capitalise on the opportunity – does it require focused resources, additional equipment, agreement with a sub-contractor/customer etc? Equally if Task 4 really has a 3PE of 4, 5 and 12 weeks it may be that the maximum figure has been skewed by the inclusion of a risk event into the uncertainty estimate. If this is the case then this risk should be removed and treated separately in a risk model where the probability of it happening is taken into account. If this impact is not extracted from the estimate then the modelled figures assumes the risk happens 100% of the time, resulting in a skew to the right of the possible completion dates for the task/project.

	Estimates		
	Minimum (weeks)	**Most Likely (weeks)**	**Maximum (weeks)**
Task 1	5	6	7
Task 2	2	7	9
Task 3	1	1.5	2
Task 4	4	5	12
Task 5	4	5	6
Task 6	3	5	6

Table 1 : *Task Estimate Simple Example*

Pre Analysis Requirements

Experience shows that the majority of schedules proposed for modelling are initially not in a suitable state to generate useful model outputs. Deficiencies in the schedule must be rectified prior to the analysis being run. This point cannot be over emphasised as the information from the model is used to support decision making and as such the underlying data being modelling must be as robust as possible.

Key areas that must be addressed include:

- Full task logic.
- Estimates against tasks which are more than just single points – these may be uniform 2PEs or, as Raytheon encourage, 3PEs.
- Realistic task constraints – ideally all constraints should be removed to model the best possible outcome, however, those that are truly justifiable could be retained. Constraints that can be worked around or have been included to make the schedule look good on a Gantt chart are removed.
- No dangling tasks - all tasks with any associated duration must drive something even if it's the final delivery milestone. Where mid point milestones are in a schedule without successors e.g. a payment milestone then the tasks driving this milestone must be linked to subsequent tasks around the milestone to ensure the schedule is robust.
- Significant leads and lags should be included as tasks – this allows incorporation of the uncertainty associated with these as a 3PE on the duration.
- A suitable level of detail - ideally schedules for analysis should be compiled at a summary level with < 200 tasks. This is a manageable level for analysis, 3PE generation and schedule robustness.
- Minimal interfaces between sections. This eases the modelling process and allows larger schedules to be modelled by sections.
- A risk identification and analysis process to ensure that potential risks to the project schedule are identified and assessed (for probability and impact). These risks must be built into the model against the tasks which may be impacted.

Schedules can be modelled without risks included for an indication of the optimal completion time but ideally they should be modelled with risks attached to the relevant tasks. This provides a more complete review of the possible outcomes.

Monte Carlo Modelling

Monte Carlo modelling is used at Raytheon Australia for schedule modelling and the tool used for this modelling is Predict! Risk Analyser[2]. Monte Carlo simulation allows several hundred or several thousand iterations of a schedule to be run in a few minutes using the data provided in the 3PEs. The output of this iterative modelling is then presented for analysis in a variety of graphical or tabular formats.

The 3PEs are modelled using triangular distributions, as these are easy to understand and specify. Generally estimators will not have available sufficient level of detail to specify the parameters for other distributions: mean, standard deviations etc. In general, given that the base data to be modelled is an estimate, there is little difference between the outcome from modelled normal and triangular distributions as shown in Figure 4.

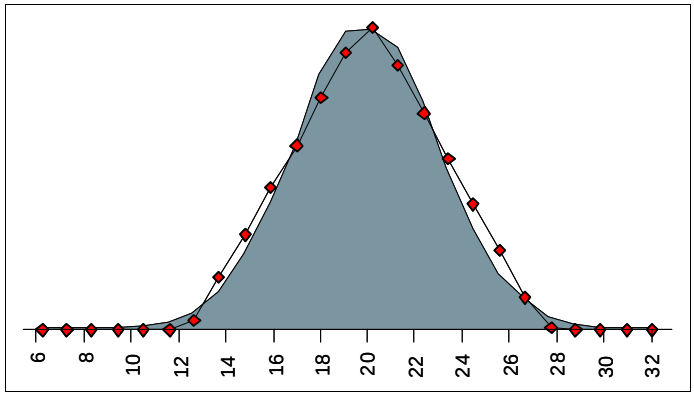

Figure 4 – *Comparison Normal v Triangular Distribution*

[2] Predict! Risk Analyser is a product of Risk Decisions Pty Ltd

The main data outputs available from the Monte Carlo modelling of a schedule, and used by Raytheon to more effectively deliver projects, are:

- levels of confidence in delivering tasks and milestones,
- criticality levels (the chance a task is on the critical path),
- task cruciality (also called sensitivity), and
- schedule contingency.

These modelled outcomes are used to allow 'what-if' modelling of the schedule to focus effort and resources with the aim of increasing the probability of delivering projects on to an agreed timeline. The use of this information is about providing project managers and customers the best possible conditions for success. To demonstrate these outputs the schedule shown in Figure 5 has been utilised[3]. This schedule has 3PEs for all tasks and has risks, along with their individual probability and impact estimates, attached to several of the tasks within the model.

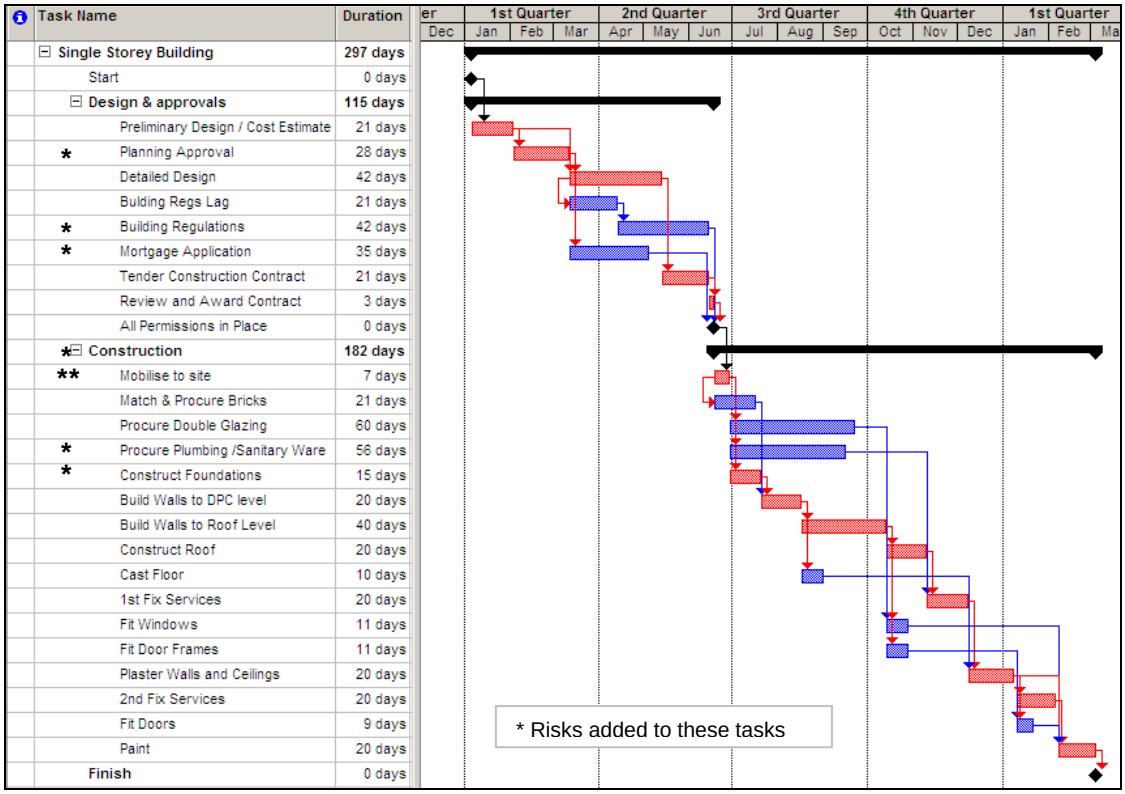

Figure 5 – *House Building Schedule*

Levels of Confidence

Levels of Confidence are calculated from the output distribution of the model. These indicate the probability of meeting a particular date or duration based on the parameters which have been set for the module through the task and risk impact 3PEs combined with the risk probabilities. In the simplest form an 80% level of confidence of achieving a target date of 7 December 2008 means within the model 8 times out of 10 the parameters indicate that the project will be completed by this December date. This is shown in Figure 6.

[3] This schedule has been replicated with the permission of Risk Decisions Pty Ltd and the following graphs, unless indicated, have been generated based on this.

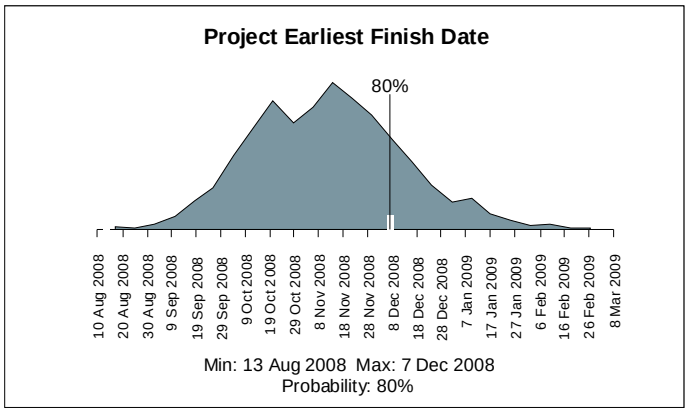

Figure 6 – *Levels of Confidence*

Simply summing the most likely estimates in a schedule will indicate a project completion timeframe that has a low level of confidence, as shown in Figure 7. This is the output of the modelled duration of the simple schedule from Table 2 which assumes these are consecutive tasks.

The graph at Figure 7 indicates the modelled duration for this simple project and the level of confidence of completing this in 29.5 weeks (the sum of the most likely durations) is only 39%. The use of this figure as a target is potentially setting up the Project Manager to fail – customers are unlikely to be happy with 3 chances in 5 of the project being delivered late. The probability of meeting the sum of the best cases (19 Days) is 0.15% - way off the left of the graph. More realistically for a customer, the project can be delivered in 33.7 weeks with a 90% level of confidence.

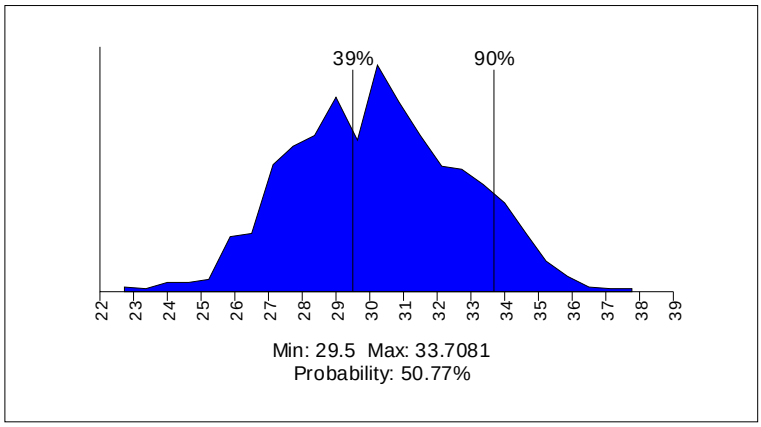

Figure 7 – *Predict! Risk Analyser Output*

	Estimates		
	Minimum (weeks)	**Most Likely (weeks)**	**Maximum (weeks)**
Task 1	5	6	7
Task 2	2	7	9
Task 3	1	1.5	2
Task 4	4	5	12
Task 5	4	5	6
Task 6	3	5	6
Totals	19	29.5	42

Table 2 : *Simple Task Estimates*

Furthermore, once there are parallel paths present within a schedule, which is the norm, summing the most likely durations provides no useful level of detail for managing the project. Modelling the

schedule and utilising the level of confidence outputs of task or project completion are the best method of forecasting the outcome.

Task Criticality

Task criticality is a measure of how often a task will be on the critical path within a modelled schedule. Once a schedule has several parallel paths and the tasks within this schedule have 3PEs outlining their duration uncertainty there is no longer likely to be the one critical path. This is even less likely once identified risks have been added to specific tasks. The result of this analysis is that each task will now have a calculated task criticality % indicating the amount of time it is on the critical path within the modelled schedule. This information can be drawn into a tornado chart to show the tasks which are most critical to the project completion. Figure 8 shows tasks on the critical path over 90% of the time which should be focused on by the Project Manager.

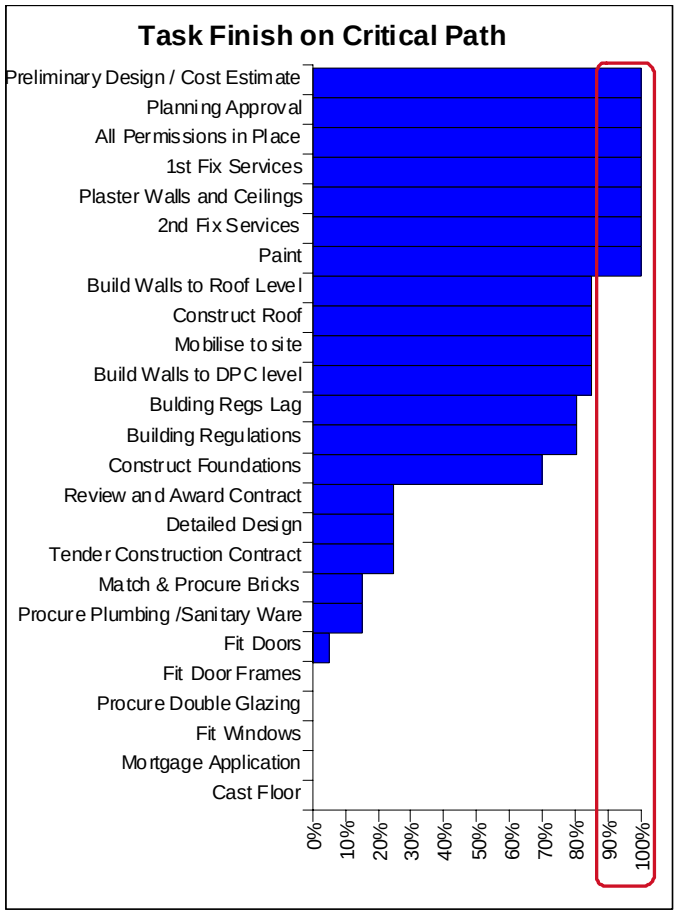

Figure 8 – *Task Tornado Graph*

On its own criticality does not allow sufficient detail to focus scarce resources onto specific tasks. When combined with task cruciality the focus can be narrowed down significantly from these top seven critical tasks shown in Figure 8. This approach also brings other crucial tasks into consideration.

Task Cruciality (Sensitivity)

Task cruciality is a measure of the sensitivity of the project outcome to a particular task. Cruciality is a correlation between a task's duration and the project end date. Simply put, where criticality is a measure of the chance of a task affecting the end date, cruciality is a measure of how much influence each task will have on the project end date.

The largest benefit to Project Managers occurs where criticality and cruciality are used in a combined approach and this is demonstrated in Figure 9 which shows that only one of the original seven 'critical' tasks (Figure 8) is crucial to the project outcome, as well as another two which have high criticality and cruciality. These three tasks are the ones which should be focused on initially to gain maximum benefit to the project.

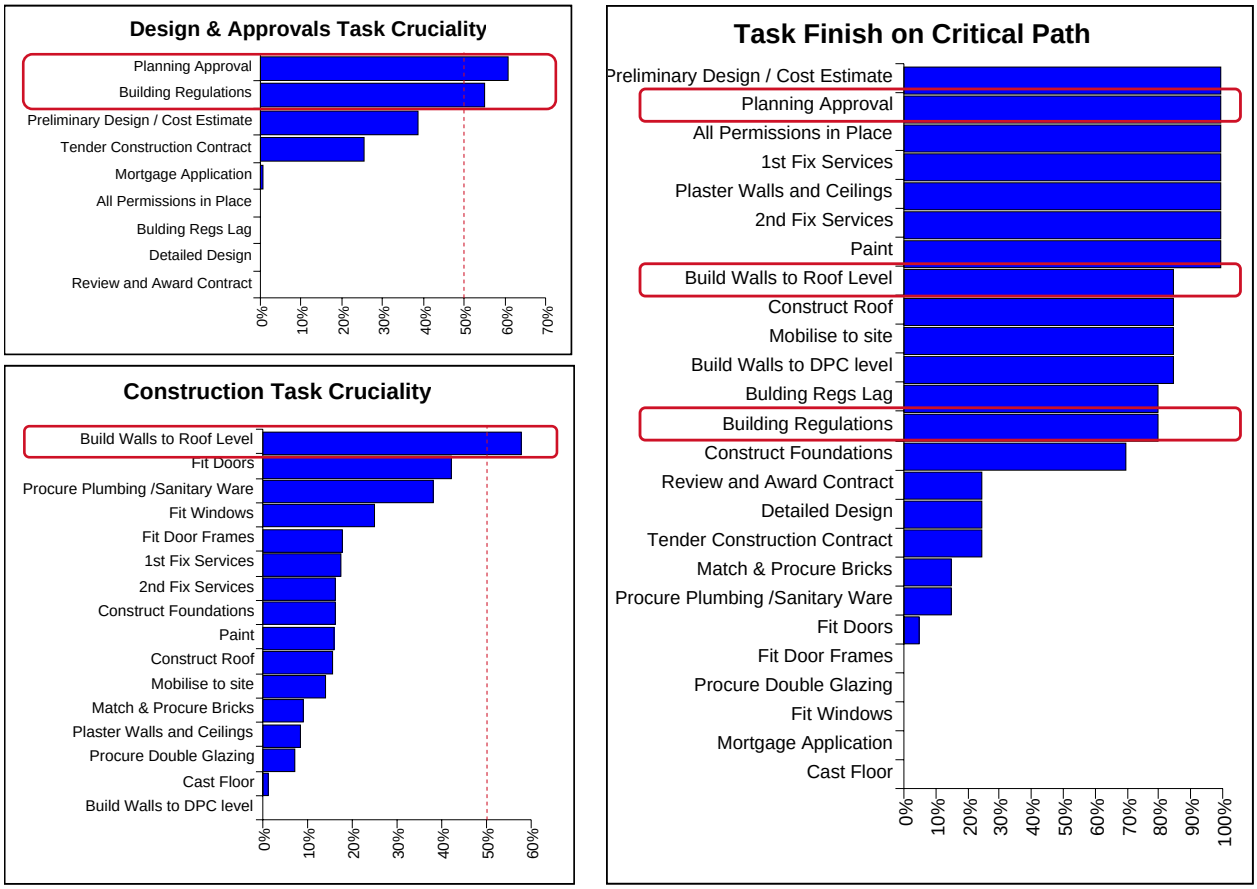

Figure 9 – *Task Cruciality Combined With Criticality*

Schedule Contingency

Historically many projects overrun their initial delivery targets and to help alleviate this schedules should contain contingency, or buffer. Contingency needs to be set at the project level as the uncertainty involved in completing each task should be covered within the realistic 3PEs forecast for that task. Setting contingency at the task level makes the contingency invisible and also makes an assumption that each task will be delayed. This is not the reality in projects, there are regularly 'unders' and 'overs' in the task completion durations.

Setting the contingency at the project level allows organisations to more effectively manage this through regular modelling and review. The data required to carry out this modelling is the estimation of task durations and identification of risks and their impacts both using 3PEs. Possible outcomes of this modelled data from a project management perspective are shown in Figure 10.

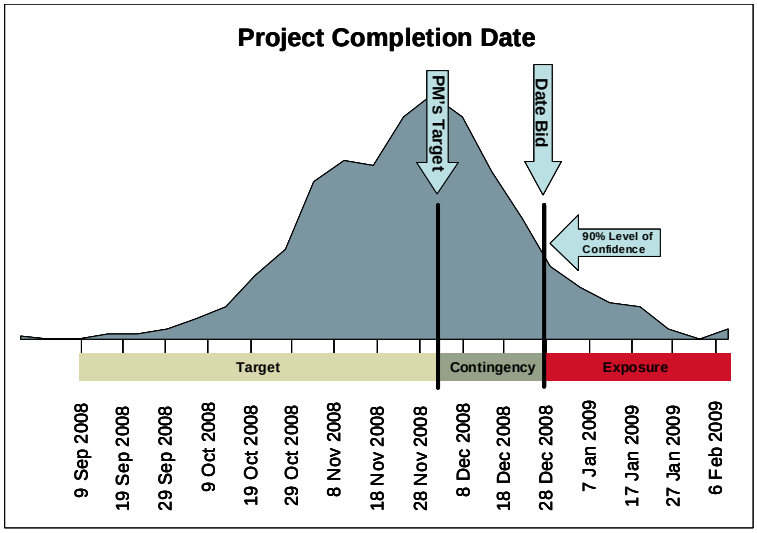

Figure 10 – *Schedule Contingency*

Summary

Projects often fail as the original task estimates were too optimistic – too often the 'most likely' estimates aren't. The use of 3PEs helps overcome this by estimating a range of possible outcomes. Additionally projects fail because events occur which were not planned. A risk identification and management process, including quantification and modelling assists in determining levels of confidence of project delivery. In any competitive environment, project planning must be focused on successful outcomes. The use of 3PEs and Monte Carlo modelling provides organisations with information to assist in this success.

Modelling project risk exposure is beneficial to organisations and allows budgets and schedules to be developed for success. This approach allows organisations and customers to sign up to achievable targets and with contingency set at an appropriate level. More importantly focusing effort in the 'right' place to achieve these targets increases project's chances of success.

Useful Monte Carlo modelling of schedules requires robust schedules, risks to be identified and the task and risk durations to be quantified using 3PEs. If these conditions are not in place you have just identified the first risk on the project risk register.

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