Before using any downloaded PDF version of this guidance note, readers should check the Department’s website at the below URL to ensure that the version they are reading is current. Note that the current version of the Department’s Cost Estimation Guidance supersedes and replaces all previous cost estimation guidance published by the Department, other than that already included in current versions of the NOA and NPA (refer to Overview).

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1: Introduction

1.1: Context and authority

This guidance note – Deterministic Contingency Estimation is one component of the suite of documents that together comprise the Department of Infrastructure, Regional Development and Cities (the Department) Cost Estimation Guidance.

A probabilistic cost estimation process must be used for all projects, for which Australian Government funding is sought, with a total anticipated outturn cost (including contingency) exceeding $25 million. A deterministic methodology to estimate contingency may be used for projects under that threshold. This policy recognises the effort required to conduct a probabilistic assessment and that it may be appropriate to use a deterministic method in certain circumstances, particularly on projects of low value.

Figure 1 on page 8 outlines the expected application of deterministic methods to forecast contingency at the various project phases for which Australian Government funding is being sought.

Further detail on probabilistic methodology, the preferred method in most circumstances, can be found in guidance note 3A - Probabilistic Contingency Estimation.

1.2: Related guidance

This guidance note should be read in the context of the Overview component of the guidance and the specific requirements of the Notes on Administration (NOA).

Additional useful guidance on contingency estimation practices, to the extent that they do not contradict the guidance provided by the Department’s Cost Estimation Guidance, may be found in individual agency cost estimation guidance or manuals, and in the guidance provided by professional associations e.g. AACE International, Project Management Institute or in risk analysis textbooks.

1.3: Objective and scope of Guidance Note 3B

The common methods for establishing contingency are divided into three main groups: Deterministic methods, Probabilistic methods, and Modern mathematical methods. The objective of this guidance note is to provide guidelines for estimating a contingency allowance deterministically with methods most practitioners would consider good practice. It aims to assist practitioners in developing or selecting the most appropriate methods for their situation, and provide a consistent approach to contingency estimation where a deterministic approach has been used. It covers the following topics:

• **Departmental requirements**: outlines the Department’s requirements regarding presentation of project estimates, and the recommended contingency methods to be used at various project phases;

• **Deterministic methods**: description of a selection of the various methods available to estimate a contingency allowance;

• **Application of Department recommended approaches**: describes and provides worked examples of the application of the Department’s recommended techniques; and

• **Definitions and Abbreviations**: refer to Appendix A.

It is expected that the primary users of this document will be jurisdiction public sector organisations (Agencies), including Local Government Authorities and their contractors/consultants that have responsibility for delivering infrastructure projects. However, the guidance may also be relevant to contractors and members of the public with an interest in major infrastructure projects.

### 2: Departmental requirements

#### 2.1: Confidence levels (P50/P90 and deterministic approximations)

For administrative purposes, the Department requires cost estimates for projects seeking Commonwealth funding to be presented as both a P50 and a P90 project estimate defined as follows:

**P50** - P50 represents the project cost with sufficient funding to provide a 50% level of confidence in the outcome; there is a 50% likelihood that the final project cost will not exceed the funding provided.

**P90** - P90 represents the project cost with sufficient funding to provide a 90% level of confidence in the outcomes; there is a 90% likelihood that the final project cost will not exceed the funding provided. In other words, it represents a conservative position; a funding allocation that has only a 10% chance of being exceeded.

Strictly speaking, a true P-value can only be calculated though a probabilistic risk assessment. However, for the purposes of meeting Departmental requirements for funding submissions, approximations to 50% and 90% confidence values may be estimated using a deterministic method for those projects with a total anticipated risk adjusted outturn cost of less than $25 million.

#### 2.2: Recommended approaches at various project phases

Figure 1 shows the recommended application of the different deterministic methods in the various project phases. These methods are explained in full detail at Section 3 of this guidance note. Their key features can be summarised as follows:

- A range based contingency assessment uses an optimistic, most likely and pessimistic assessment of the value of major cost lines in an estimate as well as of major identified...
risks, for each of which a probability of occurrence is also assessed, to estimate the mean and standard deviation of the distribution of the total project cost, from which percentile values can be inferred.

- Factor based methods use a set of factors known to affect a project’s cost performance and, subject to a qualitative assessment of each factor for a given project, allocate a percentage of the base estimate for risk.
- Reference class assessment uses the statistical characteristics of a set of similar projects to assess how much contingency is required for the job in hand.

As indicated in the figure, more than one method may be appropriate in each of the different project phases.

Figure 1: Recommended application of contingency calculation methods when seeking funding for various project phases

In summary, the Department considers the range based approach to be the most realistic and recommends its use, where practical, in each project phase. In particular, as a project moves into the Development and Delivery phases and further information upon which the estimate is based becomes available, a detailed contingency assessment using a range based technique is considered to be most appropriate. This does not preclude the same approach, such as factor based, being used to update the estimate at each phase of the project, provided that the model is

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2 The Department identifies projects as having the following phases “Identification, Scoping, Development, Delivery and Post Completion”. The Department’s cost estimation methodology applies to cost estimates prepared by proponents seeking funding for the Scoping, Development and Delivery phases, noting that while the infrastructure project phase names differ slightly between state/territory government infrastructure delivery agencies, each agency generally defines the project phases similarly. Refer to the Cost Estimation Guidance Overview for more detail.
calibrated accordingly to reflect the greater expected level of certainty as a project moves towards completion.

Note that this guidance note is premised towards those projects for which Commonwealth Government funding is sought for the three phases as per table 1. As such, recommendations for phases prior to the scoping phase do not form part of this guidance note. However, due to the fact that only limited data and information are likely to be available, the Department considers a factor based approach is likely to be the most appropriate method in pre-scoping phase(s), where suitable historical information is available, although the other deterministic methods, as well as a probabilistic analysis, can be applied in the early stages of a project.

2.3: Likely ranges of deterministic P50 and P90 estimates

Indicative contingency levels are often sought by estimators, reviewers, and decision-makers at various project phases to verify that the contingency allowance on a particular project falls within an “acceptable” range. These estimate-type accuracy range expectations have been published historically by independent bodies such as AACE International. Unfortunately, the purpose of these ranges is often misinterpreted, and introduces the temptation to use these figures as an alternative to meaningful analysis.

Quoted ranges have value in conceptually communicating the relative improvement of accuracy that results from developing better scope definition before approving project funding. However, estimators and management may interpret these ranges in an absolute sense assuming that they should apply to every project estimate. While standard, or pre-determined ranges, can be a useful point of reference they cannot be relied upon for a particular estimate as they cannot take account of project specific characteristics. In addition, providing expected ranges implicitly assumes there is a stable pattern among infrastructure projects and the contingency levels required to provide cover at a certain level of confidence. This ignores the variability of projects and the implications of the changing context of major infrastructure investment and delivery.

Assuming that standard ranges specified in terms of the level of scope definition apply, or should apply, to every estimate is a false assumption because the level of scope definition is only one source of uncertainty among many and is not always the most significant. Simply adding a percentage to an estimate as a contingency does not provide managers or decision makers with any useful information on where to focus risk mitigation efforts or understand the potential issues that a project could face during execution.

While it is acknowledged that there may be a desire for published cost estimate accuracy ranges for verification purposes, above all else, what managers and decision makers require are reliable cost estimates that also articulate the existence of project risk.

3 AACE International Recommended Practice No. 18R-97. Cost Estimate Classification System – as Applied in Engineering, Procurement and Construction for the Process Industries
Thus, the Department considers it inappropriate to offer indicative contingency levels. The Department expects that a risk assessment and quantification process be undertaken for all projects.

3: Deterministic contingency methods

Deterministic contingency calculation methods referred to and explained in this guidance note include:

- Deterministic range based method;
- Factor based method; and
- Reference class forecast method.

Further deterministic methods that are sometimes used to estimate contingency but are not recommended and thus not considered further in this guidance note are:

- Simple method, involving the application of an across-the-board percentage to the base estimate (typically standard percentage ranges dependent upon the project phase); and/or
- Item based approach – an allowance for inherent risk is added to the base estimate item by item as a fixed value rather than the ranges used in the range based method, based on an assessment of the likely contingency required at the 50% and 90% confidence levels (P50 and P90 approximations), noting that this is expected to vary between line items. An allowance for project-specific risk is added at the bottom below the base estimate and inherent risk.

3.1: Factor based deterministic method

The factor based approach to quantifying contingencies is most applicable when estimating contingency at the early stages of a project lifecycle, acknowledging that there may be insufficient information, resources or time available at that stage to undertake a more detailed assessment.

The aim of this approach is to achieve a realistic contingency allowance by a strategic review of the factors that will influence the project’s ability to manage its cost outcome. The approach is also intended to promote consistency in assessment of risk across projects using this method by providing a common template for assessment of risk against a set of stated criteria.

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4 Baccarini (Baccarini, D. 2004, Estimating Project Cost Contingency – beyond the 10% syndrome ) notes that contingencies calculated by use of either a simple method or a deterministic item based approach are typically derived from intuition or past experience however, these methods are arbitrary and difficult to justify or defend. They are an unscientific approach and it has been suggested as being one of the reasons why some projects exceed their allocated budget. Further, the addition of a single-figure prediction of estimated cost implies a degree of certainty that is not realistic.

5 While there are some subtle differences, inherent risk is generally analogous to that defined by AACE as “systemic” risk. This distinction is explained in more detail in Guidance Note 3A.
This approach usually does not separately calculate contingency for different risk types, but rather calculates a single overall range of contingency allowance.

The rationale behind a factor based approach is that it attempts to properly identify those items that can have a critical effect on the project outcomes and applies ranges only to those items. In virtually all project estimates the uncertainty is concentrated in a select number of critical items6. This is variously called the Law of the Significant Few and the Insignificant Many, the 80/20 Rule, and Pareto’s Law7. An item is critical only if it can vary enough to have a significant effect on the overall estimate which implies that a very large item in an estimate is not necessarily critical simply because of its magnitude. It is the combination of its possible variation and absolute magnitude that is important.

3.1.1: Factor based approach for road projects

Table 2 is a tool that may be used to estimate the contingency allowance for road projects in the scoping phase. The information applicable to each factor is relevant to the level of planning, design, investigation and estimating work that should have been completed in the scoping (concept) phase.

The example is a derivation8 of the approach used by the then Roads and Traffic Authority of NSW (now RMS and further explained in Appendix B to the RTA Project Estimating Manual 2008), and by the Queensland Department of Transport and Main Roads (QTMR).

By selecting one of three percentage choices, based on the confidence and reliability of the information about each factor and summing them together, an approximation to the 90% confidence level may be found. The model estimates the 50% confidence level by derating the 90% confidence level using a notional factor of 40% (see worked example at Table 2), which agencies may need to modify for their own circumstances.

The percentages in the table were derived by Evans and Peck (now Advisian) based on their exposure to multiple infrastructure projects and broader research. It should be noted that some projects will be more or less risky than others and fall outside the range of these percentages. For these, appropriate adjustments should be made as necessary.

It is stressed that the example percentages in this model need to be further tested and calibrated by agencies by applying their own knowledge, reviewing the historical performance of their projects and sharing information with other agencies. Further, while the percentages are considered appropriate for projects seeking scoping phase funding, they will need to be adjusted, following testing and validation, for subsequent phases.

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6 AACE International Recommended Practice No. 41R-08: Risk Analysis and Contingency Determination Using Range Estimating

7 Ibid

8 Using the six factors adopted by RTA and QTMR, in 2011 Evans & Peck (now Advisian) prepared a factor based table (Table 2) for establishing a Contingency Allowance applicable to most road projects, which was included in previous guidance published by the Department (the Best Practice Cost Estimation Standard for Publicly Funded Road and Rail Construction May 2011), since withdrawn.
### Table 2: Factor based table to determine contingency percentages on road projects

<table>
<thead>
<tr>
<th>Factor Influencing the Estimate</th>
<th>Available information on which the Scoping Estimate is based</th>
<th>Confidence and Reliability level</th>
<th>Adopted Contingency percentage (example only)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Highly Confident &amp; Reliable</td>
<td>Reasonably Confident &amp; Reliable</td>
</tr>
<tr>
<td>Project Scope</td>
<td>A set of well-defined project objectives and related performance criteria</td>
<td>6%</td>
<td>7%</td>
</tr>
<tr>
<td></td>
<td>A design report (with all underlying assumptions and exclusions noted)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A set of concept drawings (covering all the physical scope and staging)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk Identification</td>
<td>Identified significant risks (political, community, technical, financial)</td>
<td>6%</td>
<td>7%</td>
</tr>
<tr>
<td></td>
<td>A detailed risk analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A project delivery method</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constructability</td>
<td>A constructability, staging and construction access review</td>
<td>3%</td>
<td>4%</td>
</tr>
<tr>
<td></td>
<td>A construction timetable (with appropriate start up and handover periods)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Key Dates</td>
<td>A set of project dates (to enable outturn cost to be assessed)</td>
<td>1%</td>
<td>2%</td>
</tr>
<tr>
<td></td>
<td>Timing of the construction phase (for escalation assessment)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site Specific Information</td>
<td>Sufficient and documented investigation for concept design (geotechnical, heritage, environmental, technical, hydraulic)</td>
<td>5%</td>
<td>6%</td>
</tr>
<tr>
<td></td>
<td>Enabling works (adequately identified &amp; allowed in the estimate)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project interfaces</td>
<td>External interfaces (identified and defined in terms of scope, access and risk)</td>
<td>3%</td>
<td>4%</td>
</tr>
<tr>
<td></td>
<td>Project assessment (extended or short site and greenfield/brownfield)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total contingency percentage to be adopted for an estimate with a 90% confidence level of not being exceeded:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total contingency percentage to be adopted for an estimate with a 50% confidence level of not being exceeded: (assessed to be 40% of the contingency percentage for a 90% confidence level of not being exceeded)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### 3.1.2: Factor based approach for rail projects

Whilst the factor-based table for rail projects in Table 3 is similar to that for road projects, there are significant differences in both the information required to support the factor assessment and in the levels of percentages that should be used.

Some of the factors that may have a significantly higher risk on rail projects, particularly those in urban or built up areas are:

- **Project scope:** the industry has difficulty with performance criteria and scoping of works at the concept phase, often through lack of a design report and good concept drawings;
- **Risks:** the risks of designing and constructing new work alongside, near or intersecting with operational rail lines, rail infrastructure or rail systems can be underestimated;
• **Site specific information:** what is available is often outdated. Investigation work is required and this takes significant time and effort, affected by access constraints to rail corridors, resources and budgets to obtain or validate site specific data in the concept phase;

• **Project interfaces:** this is usually not properly understood until the detailed design phase and rail estimates at the concept phase traditionally underestimate the interface requirements;

• **Approval processes:** the design approval processes for an operation railway are complex and can become protracted, potentially delaying the construction commencement; and

• **Lack of resources:** completion and handover of construction work in the rail sector may be affected by a lack of suitably qualified resources. For example, signalling experts.

Note that the model estimates the 50% confidence level by derating the 90% confidence level using a notional factor of 60%, rather than 40% as for road projects which agencies may need to modify for their own circumstances. It is again stressed that the example percentages in this model need to be further tested and calibrated by agencies by applying their own knowledge, reviewing the historical performance of their projects and sharing information with other agencies. They will need to be adjusted, following testing and validation, for subsequent phases.
Table 3: Factor based table to determine contingency percentages on rail projects

For an estimate with 90% confidence level of not being exceeded on a rail project

<table>
<thead>
<tr>
<th>Factor influencing the Estimate</th>
<th>Available information on which the Scoping Estimate is based</th>
<th>Confidence and Reliability level</th>
<th>Contingency percentage adopted for an estimate with a 90% confidence level of not being exceeded:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Scope</td>
<td>A set of well-defined project objectives and related performance criteria</td>
<td>7%</td>
<td>10%</td>
</tr>
<tr>
<td></td>
<td>A design report (with all underlying assumptions and exclusions noted)</td>
<td>10%</td>
<td>16%</td>
</tr>
<tr>
<td></td>
<td>A set of concept drawings (covering all the physical scope and staging)</td>
<td>16%</td>
<td>10%</td>
</tr>
<tr>
<td>Risk Identification</td>
<td>Identified significant risks (political, community, technical, financial)</td>
<td>7%</td>
<td>10%</td>
</tr>
<tr>
<td></td>
<td>A detailed risk analysis</td>
<td>10%</td>
<td>15%</td>
</tr>
<tr>
<td></td>
<td>A project delivery method</td>
<td>15%</td>
<td>10%</td>
</tr>
<tr>
<td>Constructability</td>
<td>A constructability, staging and construction access review</td>
<td>3%</td>
<td>5%</td>
</tr>
<tr>
<td></td>
<td>A construction timetable (with appropriate start up and handover periods)</td>
<td>5%</td>
<td>8%</td>
</tr>
<tr>
<td>Key Dates</td>
<td>A set of project dates (to enable outturn cost to be assessed)</td>
<td>1%</td>
<td>3%</td>
</tr>
<tr>
<td></td>
<td>Timing of the construction phase (for escalation assessment)</td>
<td>3%</td>
<td>5%</td>
</tr>
<tr>
<td>Site Specific Information</td>
<td>Sufficient and documented investigation for concept design (geotechnical, heritage, environmental, technical, hydraulic)</td>
<td>7%</td>
<td>9%</td>
</tr>
<tr>
<td></td>
<td>Enabling works (adequately identified &amp; allowed in the estimate)</td>
<td>9%</td>
<td>14%</td>
</tr>
<tr>
<td></td>
<td>Project assessment (extended or short site and greenfield/brownfield)</td>
<td>14%</td>
<td>8%</td>
</tr>
<tr>
<td>Project interfaces</td>
<td>External interfaces (identified and defined in terms of scope, access and risk)</td>
<td>5%</td>
<td>8%</td>
</tr>
<tr>
<td></td>
<td>Project assessment (extended or short site and greenfield/brownfield)</td>
<td>8%</td>
<td>12%</td>
</tr>
</tbody>
</table>

Total contingency percentage to be adopted for an estimate with a 90% confidence level of not being exceeded: 53%

Total contingency percentage to be adopted for an estimate with a 50% confidence level of not being exceeded: (assessed to be 60% of the contingency percentage for a 90% confidence level of not being exceeded) 32%

3.1.3: Risk Engineering Society factor based approach
An acceptable alternative to the factor based tool presented at Section 3.1, developed by the Risk Engineering Society (RES) of Engineers Australia (Risk Engineering Society 2016, Contingency Guideline – http://www.eabooks.com.au/Risk-Engineering-Society-Risk-Guidelines), lists 10 key factors with a range of contingencies for high level estimates in the early phases of a road project. The 10 key factors are:

- Project scope;
- Status of design;
- Site information;
- Constructability;
- Project schedule;
- Interface management;
• Approval processes;
• Utility adjustments;
• Properties; and
• Other inherent and contingent risks.

The total values for contingency allowance obtained through the application of the RES factor based table are expected to provide results broadly in line with the Evans and Peck prepared tool. Again, it should be stressed that the percentages identified in the RES guideline would need to be tested and calibrated and may not be applicable to all projects or all funding and governance arrangements.

3.2: Range based deterministic method

The range based approach uses a similar structure to an item based approach and aims to improve on it by considering the range of values that the project cost elements (aggregated to a summary level) could take, rather than just assigning a fixed contingency to each one. It is intended to estimate the mean and variance of each item’s cost. Because mean values and variances are statistically additive, so long as the items’ cost distributions are not correlated, the sum of the means and the variances is taken to be an approximation to the mean and variance\(^9\) of the total cost. Assuming the sum of the separate cost items’ distributions will approximate to a normal distribution (see section 3.2.2), a simple statistical analysis using standard Normal variate \(Z\)-values can then be used to find any \(P\)-value.

The range based approach described here requires the project team to estimate a range (comprising best case, most likely, worst case) of values for each high level cost element. For that reason it could be argued that it is not strictly a “deterministic” approach as there is some attempt to calculate the contingency based on an assessment of the range of values a cost element could take. However, because probabilistic approaches (both simulation and non-simulation) should consider all possibilities, using appropriate statistical distributions, and because it does not involve Monte Carlo simulation or equivalent techniques, for the purposes of this guidance note the range based approach is classified as a deterministic method.

3.2.1: Calculation of an approximation to P50

The range based approach uses the Johnson modification\(^{10}\) of the Pearson-Tukey\(^{11}\) formula to quantify the expected value or mean of each cost element. Traditionally in project management, or

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\(^9\) Note: the standard deviation of the total is derived as the square root of the variance.


\(^{11}\) Pfeifer, P., Bodily, S., and Sherwood, C., Pearson-Tukey Three-Point Approximations Versus Monte Carlo Simulation. Decision Sciences; Winter 1991; 22,1
risk management, the estimate of central tendency (the mean or expected value) has been found from the so-called PERT\(^{12}\) formula:

\[
\frac{BC + 4 \times ML + WC}{6}
\]

where BC = the Best Case, ML = the Most Likely, and WC = the Worst Case, and which is based upon triangular approximations to a moderately skewed beta\(^{13}\). The Johnson modification of the Pearson-Tukey formula is claimed to be more accurate than the PERT formula in typical cost estimation applications as it applies to a wide range of beta distributions, particularly those that are considerably skewed\(^{14}\). The formula is as follows:

\[
\frac{3 \times BC + 10 \times ML + 3 \times WC}{16}
\]

When applying this formula, the best case and worse case values should represent the estimator’s opinion of a one in twenty scenario occurrence (P05 and P95 respectively). The range for each cost element should represent the possible variation and subsequent impact to the final cost and consider both rate and quantity uncertainty.

This process is performed for each cost element before the individual results are added together to find the expected value for the project. For the purposes of this technique, the expected value is considered to be equivalent to the P50 confidence level for the project.

Research suggests that in virtually all project estimates, the uncertainty is typically concentrated in 20 or less critical items\(^{15}\). As such it is suggested that the number of base cost inputs should be limited as reasonably as practicable to less than 20 cost elements with subordinate items aggregated such that each cost element is essentially homogeneous and as independent as possible of other elements. Conversely, it is important not to try to model a whole project with only a very small number of cost items, say three or four. Breaking costs down allows us to separate work with distinct characteristics that will be subject to different sources of uncertainty from one another.

Independence is important because the process involves calculating the standard deviation for the project and using it to derive a P90 approximation. Note that mathematically only the variances of independent random variables can be summed to find the total variance (and hence standard deviation). As such in order to find the standard deviation, individual cost elements that are expected to exhibit a high level of correlation with each other should be aggregated together as appropriate such that the remaining inputs are essentially independent.

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\(^{12}\) Further background and detail on PERT can be found in the supplementary material to this Guidance Note.

\(^{13}\) The beta distribution is a general type of statistical distribution which is defined by two positive shape parameters, \(\alpha\) and \(\beta\), which control the shape of the distribution. It is commonly used to describe intervals defined by the maximum and minimum of a variable.


\(^{15}\) AACE International Recommended Practice No. 41R-08: Risk Analysis and Contingency Determination Using Range Estimating
Standard deviations cannot be added together arithmetically. However, provided the cost elements are independent of one another, the total standard deviation is simply the square root of the sum of the variances.

To calculate the allowance for project-specific risks the same method and formula is applied and a range is allocated to reflect the cost impact of each of the residual risks. Again, there should only be a small number of independent risks. However, for project-specific risks the cost impact must be multiplied by the probability of the risk occurring.

The sum of the expected values of each cost element plus the expected value for each project-specific risk represents the P50 approximation of project cost.

### 3.2.1.1 Finding the variance

The Johnson modification of the Pearson-Tukey formula is an empirical formula that takes three values: the best case, most likely, and worst case, and uses them to find the expected value (mean), assuming that the data fit a beta distribution. Hence, an empirical formula is also required to find the variance. The variance may be found as:

\[
\text{Variance} = \left( \frac{WC - BC}{3.35 - k} \right)^2
\]

Where \( k \) is a skewness adjustment of 0.2 \( \left( \frac{WC + BC - 2ML}{v} \right)^2 \)

And \( v = \frac{(WC - BC)}{3.25} \)

The iterative procedure is as follows:

1. Find the value of \( v \) using the following formula: \( v = \frac{(WC - BC)}{3.25} \)
2. Estimate the skewness adjustment, \( k \), using the following formula: \( k = 0.2 \left( \frac{WC + BC - 2ML}{v} \right)^2 \)
3. Finally, find the variance as \( \left( \frac{WC - BC}{3.35 - k} \right)^2 \)

This procedure is iterative, in that the variance found at step 3 could be plugged back into the formula at step 2 to find successively more accurate approximations of the variance. However, the Department considers that one iteration will provide a sufficiently accurate approximation to the variance for the purposes of the range based approach.

Note that for the ease of use for practitioners, the formulae outlined in steps one to three above are embedded within the worked example, “Range based model.xlsx”, that accompanies this guidance note.

### 3.2.2: Calculation of an approximation to P90

An approximation to the P90 confidence level is found by utilising statistical properties of the normal distribution. Each P-value of a Normal distribution can be expressed in the following terms where P\(_n\) is the \( n^{th} \) percentile of the distribution and Z is a factor related to the percentile number n.
For n=50, corresponding to the P50 value, Z=0. For n=80, corresponding to the P80, Z=0.84 (to two decimal places). For n=90, corresponding to the P90, Z=1.28 to two decimal places.

\[ P_n = \text{mean} + (\text{standard deviation} \times Z) \]

Values of the Z-score can be found from the standard normal table or Z-table. This allows for a number of conversions, such as finding the probability that a cost might be less than a certain value, provided the mean and standard deviation are both known.

An estimate of the P90 cost derived using this procedure is simply:

\[ P_{90} = \text{mean} + (\text{standard deviation} \times 1.28) \]

Any other P-value of interest can be found in a similar fashion by using its associated Z-score.

The basis of this procedure rests on an assumption that the sum of the separate cost items’ distributions will approximate to a normal distribution. This is a consequence of the central limit theorem.

The central limit theorem applies to the sum of a large number of independent variables. Even if they have different probability distribution types, the value of the sum of a large number of independent distributions will be approximately normally distributed providing no variable dominates the uncertainty of the sum. While the theorem is based on a large number of independent variables, unless the extreme tails of the distribution of the total are important, say above the P95 and below the P05 values, for practical purposes, half a dozen independent distributions is sufficient to generate a normally distributed total.

As Figure 2 shows, for the normal distribution, the values less than one standard deviation away from the mean account for approximately 68% of the possible outcomes; while the values within two standard deviations from the mean account for approximately 95%. Moreover, the normal distribution is symmetrical so the mean, median (P50) and mode, are all equal to each other.
3.2.3: Worked example – range based deterministic method

An example of the range based approach has been prepared as an accompaniment to this guidance note as an Excel document – “Range based model.xlsx”, with all formulae intact. Practitioners are welcome to utilise this model for training or as a template, modified as appropriate for their own circumstances.

The example uses the Department’s Project Cost Breakdown (PCB) template structure as the basis for aggregating inputs. However, aggregating inputs that reflect the type of risk exposure or other logical model structures such as aggregation based on geographically discrete work packages may be more suitable. Costs representing the most likely, the best case and worst case in this example are hypothetical only. Analysts using this model must consider their particular circumstances and form their own view, confirm that they are using an appropriate item structure and assess ranges to apply to the items based on what they understand about their project.

The steps are as follows:

1. Identify the project cost elements;
2. Aggregate subordinate items as appropriate such that they are, as far as possible, homogeneous and independent;
3. Define the Best Case, Most Likely and Worst Case cost for each element ensuring that the range is a realistic representation of the potential variation and which incorporates both rate and quantity uncertainty;
4. Calculate the expected value for each cost element using the Pearson-Tukey formula presented at Section 3.2.1;
5. Ensure that for project-specific risks, calculations to determine the expected value are factored by the probability of occurrence;
6. Calculate the sum of the expected values of each cost element plus the expected value for each project-specific risk, which represents the P50 approximation of project cost;
7. Calculate the variance, $\sigma_i^2$, for each aggregated item (including the project-specific risks) before summing them together to find the total variance, $\sigma_T^2$ (noting that the variances for independent variables can be arithmetically added);
8. Calculate the standard deviation, $\sigma_T$, by finding the square root of the sum of variances $\sum \sigma_i^2$ (do not add the standard deviations of the individual variances as this sum will not represent the standard deviation of the total); and
9. Add one standard deviation multiplied by 1.28 to the P50 (mean) to find the P90 approximation: P90 = mean + ($\sigma_T \times 1.28$).
Table 4: Project estimate using a range-based deterministic method

<table>
<thead>
<tr>
<th>Item</th>
<th>Best case</th>
<th>Most likely</th>
<th>Worst case</th>
<th>P(x) (%)</th>
<th>Expected Value = (3BC+10ML+3WC)/16 x P(x)</th>
<th>(v)</th>
<th>Skewness adjustment (k)</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Client Management &amp; Oversight Costs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project management</td>
<td>$720,000</td>
<td>$770,500</td>
<td>$850,000</td>
<td>100</td>
<td>$775,938 $ 40,000 0.11 $1,605,058,115</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design and investigation</td>
<td>$125,000</td>
<td>$130,200</td>
<td>$140,000</td>
<td>100</td>
<td>$131,063 $ 4,615 0.20 $22,656,585</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Client supplied Insurances</td>
<td>$95,000</td>
<td>$100,000</td>
<td>$110,000</td>
<td>100</td>
<td>$100,938 $ 4,615 0.23 $23,184,032</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Construction Costs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environmental Works</td>
<td>$90,000</td>
<td>$98,000</td>
<td>$115,000</td>
<td>100</td>
<td>$99,688 $ 7,692 0.27 $66,045,804</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traffic management &amp; temporary works</td>
<td>$1,050,000</td>
<td>$1,131,500</td>
<td>$1,300,000</td>
<td>100</td>
<td>$1,147,813 $ 7,692 0.26 $6,528,182,589</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Public Utilities Adjustments</td>
<td>$16,000</td>
<td>$20,000</td>
<td>$30,000</td>
<td>100</td>
<td>$21,125 $ 4,308 0.39 $22,340,298</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Bulk Earthworks</td>
<td>$850,000</td>
<td>$900,000</td>
<td>$985,000</td>
<td>100</td>
<td>$906,563 $ 41,538 0.14 $1,770,911,161</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drainage</td>
<td>$110,000</td>
<td>$120,000</td>
<td>$135,000</td>
<td>100</td>
<td>$120,938 $ 7,692 0.08 $58,611,204</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Bridges</td>
<td>$3,500,000</td>
<td>$3,829,000</td>
<td>$4,655,000</td>
<td>100</td>
<td>$3,922,188 $ 355,385 0.39 $152,376,730,222</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pavements</td>
<td>$1,955,000</td>
<td>$2,038,500</td>
<td>$2,200,000</td>
<td>100</td>
<td>$2,053,125 $ 75,385 0.21 $6,103,976,077</td>
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<td></td>
</tr>
<tr>
<td>Finishing Works</td>
<td>$155,000</td>
<td>$163,000</td>
<td>$180,000</td>
<td>100</td>
<td>$164,688 $ 7,692 0.27 $66,045,804</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Traffic Signage, Signals and Controls</td>
<td>$188,000</td>
<td>$210,000</td>
<td>$235,000</td>
<td>100</td>
<td>$210,938 $ 14,462 0.01 $197,852,051</td>
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<td></td>
</tr>
<tr>
<td>Supplementary Items</td>
<td>$130,000</td>
<td>$161,500</td>
<td>$210,000</td>
<td>100</td>
<td>$164,688 $ 24,615 0.10 $604,202,827</td>
<td></td>
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<td></td>
</tr>
<tr>
<td><strong>Base Estimate</strong></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td><strong>Contingent Risks</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Risk A</td>
<td>$40,000</td>
<td>$50,000</td>
<td>$75,000</td>
<td>25</td>
<td>$13,203 $ 10,769 0.39 $139,626,860</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Risk B</td>
<td>$72,000</td>
<td>$87,000</td>
<td>$116,000</td>
<td>30</td>
<td>$26,888 $ 13,538 0.21 $196,841,609</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk C</td>
<td>$75,000</td>
<td>$100,000</td>
<td>$160,000</td>
<td>15</td>
<td>$15,984 $ 26,154 0.36 $807,170,725</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Risk D</td>
<td>$220,000</td>
<td>$440,000</td>
<td>$880,000</td>
<td>50</td>
<td>$240,625 $ 203,077 0.23 $4,884,285,564</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Risk E</td>
<td>$125,000</td>
<td>$150,000</td>
<td>$200,000</td>
<td>20</td>
<td>$80,938 $ 23,077 0.23 $579,600,795</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sum of variance (sum of I3:I23)</strong></td>
<td>$216,053,322,323</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>standard deviation (sqrt of B25)</strong></td>
<td>$464,815</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P50 Project Estimate (sum of F3:F23)</strong></td>
<td>$10,146,950</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

When factor based and range based methods are used over a large number of projects, it might be felt that the range based approach tends to result in lower contingency allowances (in terms of a percentage above the base estimate) as well as a reduction in spread between the P50 and P90 of the forecast project cost, than those typically derived using a factor based approach. This is to be expected because a range based approach is more likely to be used in the Development and Delivery phases, rather than the Scoping phase, where there should be less uncertainty in the project (and hence lesser contingency requirements) by this phase.
Note that the range based deterministic approach is not an appropriate substitute for a probabilistic approach on large (>$25M) projects, or on projects for which there is a very high degree of uncertainty.

A useful way to promote realism in the assessment of ranges and record the rationale for the assessment, so that it can be justified and explained to others, is to employ the data table method set out in guidance note 3A. This leads an assessment from a summary of the assumptions on which part of the estimate is based, to noting the sources of uncertainty affecting it, outlining how these sources of uncertainty could play out and then to making a quantitative assessment of pessimistic and optimistic outcomes for a cost item. The method helps to reduce optimism and anchoring biases in assessments, as well as ensures that the results and findings of the risk assessment are well-documented.

3.3: Deterministic method – reference class forecasting

Reference class forecasting takes a statistical view of a project as one of a class of similar projects. Contingency is assessed based on the gap between the initial base estimate and the final costs (less escalation) derived from a set of related previous projects. It does not attempt to understand specific uncertainties causing the gap, but rather simply places a given project in the statistical distribution generated from the reference set. The following steps are required to determine the most appropriate contingency to apply to a given base estimate:

1. A relevant set of reference projects are identified from past data. The set must be large enough to be statistically meaningful but homogeneous enough to be comparable with the project under consideration;
2. A probability distribution is generated of final project cost as a percentage of the base estimate from the selected reference set. This requires access to empirical data for a sufficiently large number of reference projects to make statistically meaningful conclusions; and
3. Comparison of the specific project with the reference set distribution in order to establish the most appropriate contingency for the project based on the assumption that the current project will behave in broadly the same way as the others in the reference set.

Figures 3 and 4 assist in illustrating how the reference class method is used to estimate an appropriate contingency allowance.

Figure 3 is a histogram, or probability distribution, presenting the final project cost as a percentage of the base estimate, and the respective frequency of occurrence, for a reference set of 100 hypothetical projects. Note that in this hypothetical example each “bucket” represents a range of 20 percentage points; 10 percentage points either side of each x-axis value, with the height of each bar of the histogram reflecting the percentage of projects from the reference set that fell within the ranges of the applicable “bucket”. As indicated by the red bar, the final cost for 22 projects within

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this particular reference set was within -10% and +10% of the original base estimate. This choice of range has been arbitrarily chosen for the purposes of this example and can be easily adjusted if desired.

![Probability distribution of reference set of projects](image)

*Figure 3: Probability distribution of reference class data set (hypothetical example only, adapted from Flyvbjerg, 2005)*

Figure 4 is the cumulative distribution of the same set of data. In effect, it becomes the reference class forecast tool, and is presented in the form of an S-curve that represents the actual cost as a percentage of the original base estimate, as determined from the reference set of past projects. The applicable P50 and P90 allowances are determined by selecting the required level of confidence (percentage of projects within a given cost overrun on the x-axis) and reading off the required allowance from the actual cost overrun (y-axis). The percentage allowance is then added to the project base estimate.

In the example shown, a project in the hypothetical reference set would require an allowance of somewhere in the region of 15% (read off the y-axis) to give an approximation to a probabilistically-derived 50% confidence level (read off the x-axis).
This method relies on maintaining an accurate and reliable cost database across many projects, ideally including the impacts of risks that actually occurred. The data will also need to be normalised (including rebasing to a common date and the project’s own base estimate so that the distribution of percentage actual cost versus original base cost can be determined, and from which the S-curve derived), to ensure that costs are comparable. Additionally, use of statistics based on historical precedent will fail to predict the extreme outcomes that lie outside the original set of precedents\(^\text{17}\).

A further subtlety is not only that costs will need to be normalised to a common base date. Ideally, the spread between the final project cost and the base estimate will narrow over time as uncertainty, and hence the contingency allowance, reduces. Therefore the reference set of projects must be comparable not only in terms of scope similarity, and proposed contracting strategy, but also in terms of scope development to ensure that projects with highly detailed estimates are not compared with projects for which only a high-level estimate has been undertaken.

Finally, this method implies that because past efforts to estimate the costs of projects have at times failed, estimators should simply base project cost estimates on the past without regard as to why those past projects failed to accurately predict the final cost\(^\text{18}\). It does not encourage estimators to improve their practice as they will simply refer to past data to estimate the required contingency, and may lead to larger contingency provision than necessary.

The Department considers that deterministic estimation of project contingency via use of a reference class forecast is not the preferred method. However, it may be suitable where sound

\(^{17}\) Newton, S. (n.d.) A Critique of Initial Budget Estimating Practice
data exists and where a factor based or range based approach is not appropriate. It might also offer a useful benchmark against which to compare assessments made using the preferred methods as a means of gaining insight into the sources of risk in a project and how to manage them.

4: Additional contingency approaches

In addition to the techniques described in this guidance note, practitioners may also wish to consider the non-simulation probabilistic techniques or approaches outlined in the Supplementary Material to the guidance notes which provides further detail of how to build a range based approach into a probability distribution of costs for a project using a number of variations of the Method of Moments approach. Method of Moments is an analytic, non-simulation probabilistic approach that may be performed either by hand or in Excel relatively quickly with only a few additional steps.

The strength of Method of Moments is that it allows a probability distribution of cost to be built in Excel without the need for additional software, subject to some assumptions and constraints. Thus, it permits an approximation to any P-value to be generated. It is expected to result in an estimate of contingency very close to that which would have been achieved through running a Monte Carlo simulation based on the same inputs. The weakness is that if one wishes to account for correlation, it starts to become quite cumbersome and arguably more effort than using simulation software with such features already built in. Thus, care is required to avoid correlations and, for this reason, it can only be applied to a relatively high level cost breakdown that has been carefully prepared for the purpose of the analysis. It is easy for a novice to inadvertently build a flawed model using this approach.

Because these approaches are best described as analytical probabilistic techniques, it is not a requirement that they be used to estimate contingency for projects less than $25 million risk adjusted outturn cost included in funding submissions. However, practitioners are welcome to utilise these techniques to explore the uncertainty in a high level estimate of a project’s cost without the need to use simulation software.

In addition to the techniques outlined at Table 1, the Department will accept (upon review and assessment) funding submissions for projects less than $25 million outturn for which the contingency has been determined using a non-simulation analytic approach.

5: Conclusion

This guidance note has described three deterministic contingency estimation methods as well as the Department’s recommended application of those deterministic methods in the various project phases. Application of the guidelines presented in this guidance note is intended to result in a consistent and robust approach to contingency estimation where a deterministic method has been used.
## Appendix A: Definitions and Abbreviations

### Table 5: Definitions and Abbreviations

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agency</td>
<td>A state or territory government body that generally will deliver an infrastructure project.</td>
</tr>
<tr>
<td>Assumption</td>
<td>A documented, cost-related factor that, for the purpose of developing a base cost estimate, is considered to be true, real or certain.</td>
</tr>
<tr>
<td>Base Date</td>
<td>A base date is a reference date from which changes in conditions, (including rates and standards) can be assessed. In the context of a base estimate it is the period when the estimate has been prepared and which reflects the current market conditions.</td>
</tr>
<tr>
<td>Base Estimate</td>
<td>The sum of the construction costs and client’s costs at the applicable base date. It represents the best prediction of the quantities and current rates which are likely to be associated with the delivery of a given scope of work. It should not include any allowance for risk (contingency) or escalation.</td>
</tr>
<tr>
<td>Contingency</td>
<td>An amount added to a base estimate to allow for items, conditions, or events for which the state, occurrence, or effect is uncertain and that experience shows will likely result, in aggregate, in additional costs. These can include, but are not limited to, planning and estimating errors and omissions, price variation as at the date of estimate (other than general escalation), design developments and changes within the scope, and variations in market and environmental conditions.</td>
</tr>
<tr>
<td>Contractor Direct Costs</td>
<td>All contractor’s costs directly attributable to a project element including, but not limited to, plant, equipment, materials and labour.</td>
</tr>
<tr>
<td>Contractor Indirect Costs</td>
<td>Costs incurred by the contractor to perform work but which are not directly attributable to a project cost element. These generally include costs such as preliminaries, supervision, and general and administrative costs.</td>
</tr>
<tr>
<td>Deterministic Contingency Assessment</td>
<td>A deterministic model treats all of the input parameters as constants. In contrast, a probabilistic model treats all input parameters as variables that change according to an assigned probability distribution.</td>
</tr>
<tr>
<td>First Principles Estimate</td>
<td>The method of preparing a cost estimate by calculating the dollar rates and rates of productivity required to complete each of the individual tasks within the Work Breakdown Structure.</td>
</tr>
<tr>
<td>Jurisdiction</td>
<td>An Australian state or territory.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>NOA</td>
<td>The Notes on Administration for Land Transport Infrastructure Projects 2014-15 to 2018-19 (NOA) provide administrative guidance for managing projects to be funded under the National Partnership Agreement.</td>
</tr>
<tr>
<td>Outturn Cost</td>
<td>The sum of the price-escalated costs for each year of a project’s duration. Outturn cost calculation requires the non-escalated project cost to be presented as a cash flow and the application of an escalation factor for each project year to derive the price escalated cost for each year. The Department’s Project Cost Breakdown template can be used to calculate outturn costs. In economic terms non escalated costs are often referred to as real costs while outturn costs are often referred to as nominal costs.</td>
</tr>
<tr>
<td>PCB</td>
<td>Project Cost Breakdown.</td>
</tr>
<tr>
<td>Probabilistic Estimating</td>
<td>A probabilistic method identifies the cost components, determines the likely range and associated probability distribution of each component, and undertakes a sampling process (Monte Carlo or similar process using a computer program) to generate a probability distribution of project costs.</td>
</tr>
<tr>
<td>Project-Specific Risk</td>
<td>Project-specific risks are uncertainties (threats or opportunities) related to events, actions, and other conditions that are specific to the scope of a project.</td>
</tr>
<tr>
<td>Range Estimate</td>
<td>An estimate which reports the best case, worst case, and most likely values.</td>
</tr>
<tr>
<td>Risk</td>
<td>The effect of uncertainty on objectives.</td>
</tr>
<tr>
<td>Systemic Risk</td>
<td>Systemic risks are uncertainties (threats or opportunities) that are an artifact of an industry, company or project system, culture, strategy, complexity, technology, or similar over-arching characteristics.</td>
</tr>
<tr>
<td>Work Breakdown Structure (WBS)</td>
<td>A hierarchical decomposition of the work to be executed to accomplish the project objectives and create the required deliverables. The WBS organises and defines the total scope of the project.</td>
</tr>
</tbody>
</table>