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Department of Infrastructure, Transport,
Regional Development, Communications and the Arts

INFRASTRUCTURE GROUP / INFRASTRUCTURE GROUP ASSURANCE AND ADVISORY BRANCH / INFRASTRUCTURE PROJECT ASSURANCE

Guidance Note 3B – Deterministic contingency estimation

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1. Introduction

1.1. Context

The Department of Infrastructure, Transport, Regional Development, Communications and the Arts (the department) provides and maintains cost estimation guidance intended to inform and assist proponents in improving and establishing cost estimation practices for land transport infrastructure projects, the suite comprises the following volumes:

- Guidance Note – Overview
- Guidance Note 1 — Project Scope
- Guidance Note 2 — Base Cost Estimation
- Guidance Note 3A – Probabilistic Contingency Estimation
- Supplementary Guidance Note to 3A
- **Guidance Note 3B – Deterministic Contingency Estimation**
- Guidance Note 4 – Escalation

Under the policy settings for the Infrastructure Investment Program (IIP), a probabilistic cost estimation process must be used for all projects seeking Commonwealth funding which have a total anticipated outturn cost (including contingency) exceeding $25 million. For projects under this threshold a deterministic methodology can be used to estimate contingency although probabilistic methods are recommended if possible. Deterministic estimates use single values for each component and do not account for the range of possible outcomes for each component of a project. A probabilistic estimate uses a range of possible outcomes for each component and incorporates randomness to model a distributions of possible cost outcomes which are represented by an estimate's probability distribution, which is calculated or simulated through the application of probability and statistics.

Figure 1 in Section 2.2 outlines the expected application of deterministic methods to forecast contingency at the various project phases.

Additional useful guidance on cost estimation practices, to the extent that they do not contradict the department guidance, may be found in individual agency cost estimation guidance or manuals, and in the guidance provided by professional associations such as Engineers Australia, Risk Engineering Society (RES), AACE International, Project Management Institute, or in risk analysis textbooks.

1.2. Objective and scope

The objective of this guidance note is to provide guidelines for estimating a contingency using a determinist approach. This guidance note 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: descriptions of the various methods used to estimate a deterministic contingency allowance.
- Application of department recommended approaches: describes and provides worked examples of the application of the department's recommended techniques.
- Definitions and abbreviations: refer to **Appendix A**.

It is expected that the primary users of this document will be jurisdictional public sector organisations (agencies), including Local Government Authorities that prepare submissions for funding through the IIP.

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

The department requires cost estimates for projects seeking Commonwealth funding to be presented as both a P50 and a P90 project estimate. The 'P' stands for the percentile chance that the cost estimate will not be exceeded.

- 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 this value.
- 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 this value.

A realistic P-value can only be derived through a probabilistic risk assessment, however the department accept approximations to 50% and 90% confidence values using a deterministic methods for projects with a total anticipated outturn cost of less than $25 million.

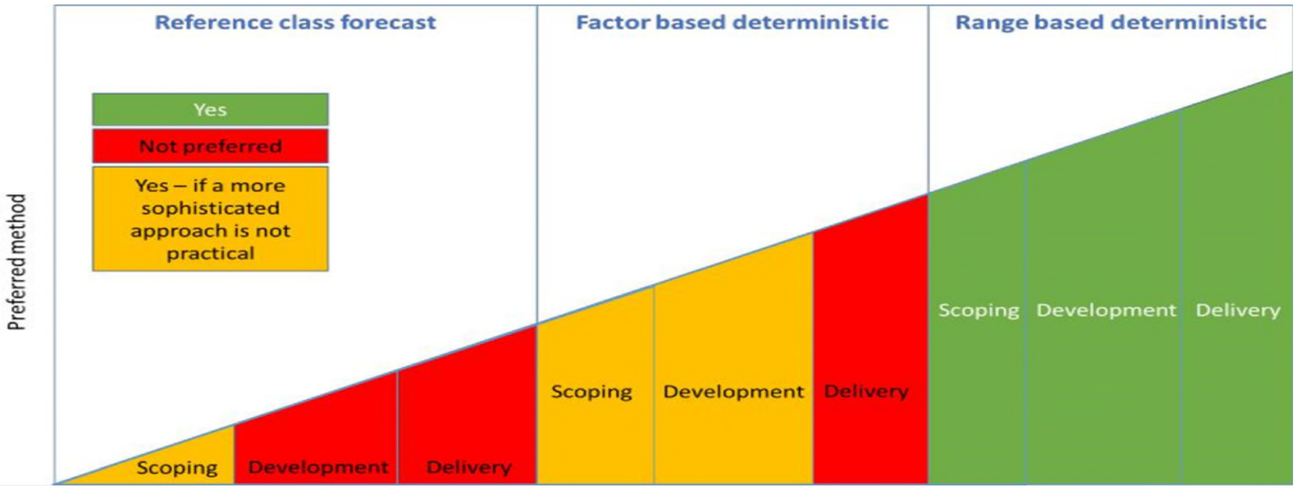
2.2. Recommended approaches at various project phases

Figure 1 shows the recommended application of deterministic methods in the scoping, development and delivery project phases. These methods are further explained in **section 3.0** 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 each major cost elements and the major identified risks. The probability of occurrence of each cost element and risk is assessed and the mean and standard deviation of the total project cost is estimated, from which P50 and P90 values can be inferred. The department considers this method the most appropriate for all project phases.
- Factor-based methods use a set of factors known to affect a project's cost performance and allocate a percentage of the base estimate for risk. A qualitative assessment of each factor is required to tailor to each project.
- 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.

Recommendations for the identification phase does not form part of this guidance note, practitioners should use their judgement to choose an appropriate methodology.

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



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 expected range. These estimate-type accuracy range expectations have been published historically by independent bodies such as AACE International[2]. The purpose of these ranges is often misinterpreted, and introduces the temptation to use these figures as an alternative to meaningful analysis. They apply generally to projects but do not apply to the project you are assessing.

While it is acknowledged that there may be a desire for published cost estimate standard 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. Standard ranges are specific to the data set that they were created from, they can have value in conceptually communicating the reduction of contingency as a project progresses and the scope is further defined. Using standard ranges of similar projects is the basis of reference class forecasting, however, generic standard ranges would be too far removed to be useful, as they are not based on similar projects to what you are assessing and do not take account of jurisdictional or project specific characteristics.

The department considers it inappropriate to support indicative contingency levels that the jurisdictions have not modified to meet their circumstances. It is expected that a risk assessment and risk quantification process be undertaken for all projects.

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[1] 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.

[2] Christensen, P., Dysert, L. R., Bates, J., Burton, D., Creese, R. C., & Hollmann, J. (2005). Cost Estimate Classification system-as applied in engineering, procurement, and construction for the process industries. *AACE International Recommended Practices*, 1-30.

3. Deterministic contingency methods

Deterministic estimating for contingency relies on using a single number value, usually expressed as a percentage of the base cost estimate. Deterministic contingency calculation methods referred to and explained in this guidance note include:

- Factor-based method
- Range-based method
- Reference-class forecast method

There are other deterministic methods that can be used to estimate contingency such as the 'simple method' and the 'item based method' but are not recommended and thus not considered further in this guidance.

3.1. Factor-based deterministic method

The factor-based approach uses a set of factors known to affect a project's cost performance and allocates a percentage value to each item, usually represented as a percentage of the base estimate. A qualitative assessment of each factor is required to tailor to each project. This method is most applicable in the early stages of the project lifecycle, acknowledging that there may be insufficient information, resources or time available at that stage to undertake a more detailed assessment. This approach usually does not separately calculate contingency for different risk types, but rather calculates a single overall range of contingency allowances for each factor. Each factor which could include multiple risks.

This approach aims to achieve a realistic contingency allowance by a strategic review of the factors that have influence on the project's cost outcome. The approach is also intended to promote consistency in assessment of risk by providing a common template for assessment against a set of stated criteria.

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 on a select number of critical items[3]. This is known as the Law of the Significant Few and the Insignificant Many, the 80/20 Rule, and Pareto's Law[4].

An item is critical only if it can vary enough to have a significant effect on the overall estimate. Very large items are more likely to become critical risks as they require less possible variation. It is the combination of possible variation against the absolute magnitude that is important.

Factor-based approach for road projects

Table 1 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.

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 deriving the 90% confidence level using a notional factor of 40% (see worked example at **Table 1**), 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

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[3] AACE International Recommended Practice No. 41R-08: Risk Analysis and Contingency Determination Using Range Estimating
[4] Hardy, M. (2010). Pareto's law. The Mathematical Intelligencer, 32(3), 38-43.

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 through 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. Noting these generally decline as a project progresses.

Table 1: Factor-based table to determine contingency percentages on road projects

P90 - For an estimate with 90% confidence level of not being exceeded on a road project					
Factor influencing the Estimate	**Available information on which the Scoping Estimate is based**	**Confidence and Reliability level**			**Adopted Contingency *(example***
		Highly Confident & Reliable	**Reasonably Confident & Reliable**	**Not Confident & Not Reliable**	
Project Scope	– A set of well-defined project objectives and related performance criteria – A design report (with all underlying assumptions and exclusions noted) – A set of concept drawings (covering all the physical scope and staging)	6%	7%	9%	*7%*
Risk Identification	– Identified significant risks (political, community, technical, financial) – A detailed risk analysis – A project delivery method	6%	7%	9%	*9%*
Constructability	– A constructability, staging and construction access review – A construction timetable (with appropriate start up and handover periods)	3%	4%	5%	*4%*
Key Dates	– A set of project dates (to enable outturn cost to be assessed) Timing of the construction phase (for escalation assessment)	1%	2%	3%	*2%*
Site Specific Information	– Sufficient and documented investigation for concept design (geotechnical, heritage, environmental, technical, hydraulic) Enabling works (adequately identified & allowed in the estimate)	5%	6%	9%	*9%*
Project interfaces	– External interfaces (identified and defined in terms of scope, access and risk) – Project assessment (extended or short site and greenfield/brownfield)	3%	4%	5%	*4%*
Total contingency percentage to be adopted for an estimate with a 90% confidence level of not being exceeded:					*35%*
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)					*14%*

Factor-based approach for rail projects

Whilst the factor-based table for rail projects in **Table 2** has the same structure as 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 under estimated.
- Site specific information: what is available is often outdated. Investigation work is required which 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 be extended, potentially delaying the construction commencement.
- 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 deriving 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 2: Factor-based table to determine contingency percentages on rail projects

P90 - For an estimate with 90% confidence level of not being exceeded on a rail project					
		Confidence and Reliability level			
Factor influencing the Estimate	Available information on which the Scoping Estimate is based	Highly Confident & Reliable	Reasonably Confident & Reliable	Not Confident & Not Reliable	Adopted Contingency *(example only)*
Project Scope	– A set of well-defined project objectives and related performance criteria – A design report (with all underlying assumptions and exclusions noted) – A set of concept drawings (covering all the physical scope and staging)	7%	10%	16%	*10%*
Risk Identification	– Identified significant risks (political, community, technical, financial) – A detailed risk analysis – A project delivery method	7%	10%	15%	*10%*
Constructability	– A constructability, staging and construction access review. – A construction timetable (with appropriate start up and handover periods)	3%	5%	8%	*8%*
Key Dates	– A set of project dates (to enable outturn cost to be assessed) Timing of the construction phase (for escalation assessment)	1%	3%	5%	*3%*
Site Specific Information	– Sufficient and documented investigation for concept design (geotechnical, heritage, environmental, technical, hydraulic) Enabling works (adequately identified & allowed in the estimate)	7%	9%	14%	*14%*
Project interfaces	– External interfaces (identified and defined in terms of scope, access and risk) Project assessment (extended or short site and greenfield/brownfield)	5%	8%	12%	*8%*
Total contingency percentage 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%*

3.2. 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. Considering the items cost distributions are not correlated, the sum of the means and the variances is taken to be an approximation of the mean and variance of the total cost. Assuming the sum of the separate cost items' distributions will approximate to a normal distribution, 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. Example for range-based deterministic method can be found in the **appendix of the Guidance Note 3A - supplementary guidance**.

Range-based approximation to P50

The range-based approach uses the Johnson modification[5] of the Pearson-Tukey[6] formula to quantify the expected value or mean of each cost element. Traditionally in project management, or risk management, the estimate of central tendency (the mean or expected value) has been found from the so-called PERT12 formula:

$$\frac{BC + 4 \times ML + WC}{6}$$

BC = the Best Case

ML = the Most Likely

WC = the Worst Case

This is based upon triangular approximations to a moderately skewed beta. 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[7]. 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.

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[5] Johnson, D. (2002). Triangular approximations for continuous random variables in risk analysis. *Journal of the Operational Research Society*, *53*(4), 457-467.

[6] Pfeifer, P. E., Bodily, S. E., & Frey Jr, S. C. (1991). Pearson-Tukey Three-Point Approximations Versus Monte Carlo Simulation. *Decision Sciences*, *22*(1), 74-90.

[7] Johnson, D. (2002). Triangular approximations for continuous random variables in risk analysis. *Journal of the Operational Research Society*, *53*(4), 457-467.

Research suggests that in almost all project estimates, the uncertainty is typically concentrated in 20 or less critical items[8]. 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 consistent and as independent as possible of other elements. Conversely, it is important not 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.

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.

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:

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

k = skewness adjustment of:

$$k = 0.2\left(\frac{WC + BC - 2ML}{v}\right)^2$$

$$v = \frac{WC - BC}{3.25}$$

The iterative procedure is as follows:

1. Find the value of v using the following formula: $v = \frac{WC-BC}{3.25}$

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[8] Humphreys, K.K., Curran, K.M., Curran, M.W., Gruber, C.O., Patil, S.S., Wells, R.F., & Zhao, J.G. (2008). International Recommended Practice No. 41 R-08 RISK ANALYSIS AND CONTINGENCY DETERMINATION USING RANGE ESTIMATING TCM Framework: 7.6 – Risk Management.

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: $Variance = \left(\frac{WC-BC}{3.35-k}\right)^2$

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.

Range-based 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.

$$Pn = mean + (standard\ deviation \times Z)$$

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:

$$P90 = mean + (standard\ deviation \times 1.28)$$

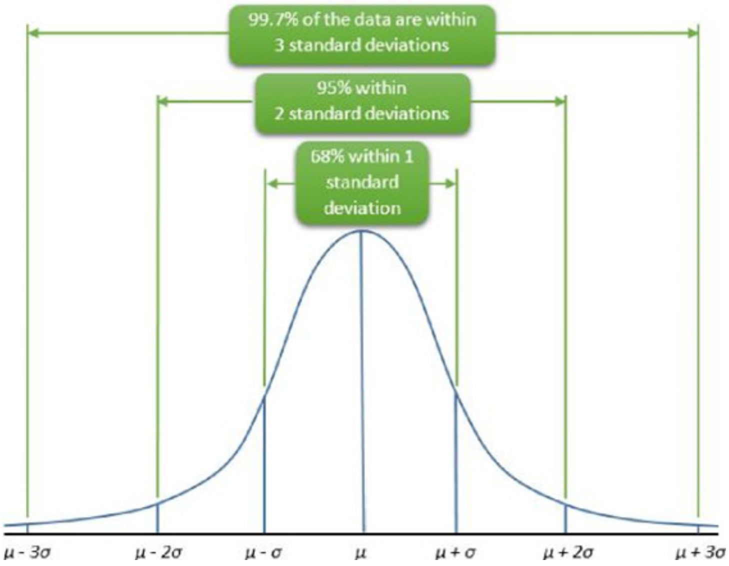
Any other P-value of interest can be found in a similar fashion by using its associated Z-score.

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.

Figure 2: Normal distribution



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.xlxs", 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 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, consistent 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 above in Range-based approximation to P50.
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, σ_i^2, for each aggregated item (including the project-specific risks) before summing them together to find the total variance, σ_T^2 (noting that the variances for independent variables can be arithmetically added).
8. Calculate the standard deviation, σ_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).
9. Add one standard deviation multiplied by 1.28 to the P50 (mean) to find the P90 approximation: P90 = mean + (σ_T*1.28).

Table 3: Project estimate using a range-based deterministic method

Item	Best case	Most likely	Worst case	P(x) (%)	Expected Value = (3BC+10ML+ 3WC)/16 x P(x)	(v)	Skewness adjustment (k)	Variance
Client Management & Oversight Costs								
Project Management	$720,000	$770,500	$850,000	100	$775,938	$40,000	0.11	$1,605,058,115
Design and Investigation	$125,000	$130,200	$140,000	100	$131,063	$4,615	0.20	$22,656,585
Client Supplied Insurances	$95,000	$100,000	$110,000	100	$100,938	$4,615	0.23	$23,184,032
Construction Costs								
Environmental Works	$90,000	$98,000	$115,000	100	$99,688	$7,692	0.27	$66,045,804
Traffic Management & Temporary Works	$1,050,000	$1,131,500	$1,300,000	100	$1,147,813	$76,923	0.26	$6,528,182,589
Public Utilities Adjustments	$16,000	$20,000	$30,000	100	$21,125	$4,308	0.39	$22,340,298
Bulk Earthworks	$850,000	$900,000	$985,000	100	$906,563	$41,538	0.14	$1,770,911,161
Drainage	$110,000	$120,000	$135,000	100	$120,938	$7,692	0.08	$58,611,204
Bridges	$3,500,000	$3,829,000	$4,655,000	100	$3,922,188	$355,385	0.39	$152,376,730,222
Pavements	$1,955,000	$2,038,500	$2,200,000	100	$2,053,125	$75,385	0.21	$6,103,976,077
Finishing Works	$155,000	$163,000	$180,000	100	$164,688	$7,692	0.27	$66,045,804
Traffic Signage, Signals and Controls	$188,000	$210,000	$235,000	100	$210,563	$14,462	0.01	$197,852,051
Supplementary Items	$130,000	$161,500	$210,000	100	$164,688	$24,615	0.10	$604,202,827
Base Estimate		**$9,672,200**						
Contingent Risks								
Risk A	$40,000	$50,000	$75,000	25	$13,203	$10,769	0.39	$139,626,860
Risk B	$72,000	$87,000	$116,000	30	$26,888	$13,538	0.21	$196,841,609
Risk C	$75,000	$100,000	$160,000	15	$15,984	$26,154	0.36	$807,170,725
Risk D	$220,000	$440,000	$880,000	50	$240,625	$203,077	0.23	$44,884,285,564
Risk E	$125,000	$150,000	$200,000	20	$30,938	$23,077	0.23	$579,600,795

Sum of Variance	$216,053,322,323
Standard Deviation	$464,815
P50 Project Estimate	**$10,146,950**

P-value	Z-score	Cost
10%	1.2815515	$9,551,265
20%	0.8416212	$9,755,752
30%	0.5244005	$9,903,201
40%	0.2533471	$10,029,190
50%		**$10,146,950**
60%	0.2533471	$10,264,710
70%	0.5244005	$10,390,699
80%	0.8416212	$10,538,148
90%	**1.2815515**	**$10,742,635**

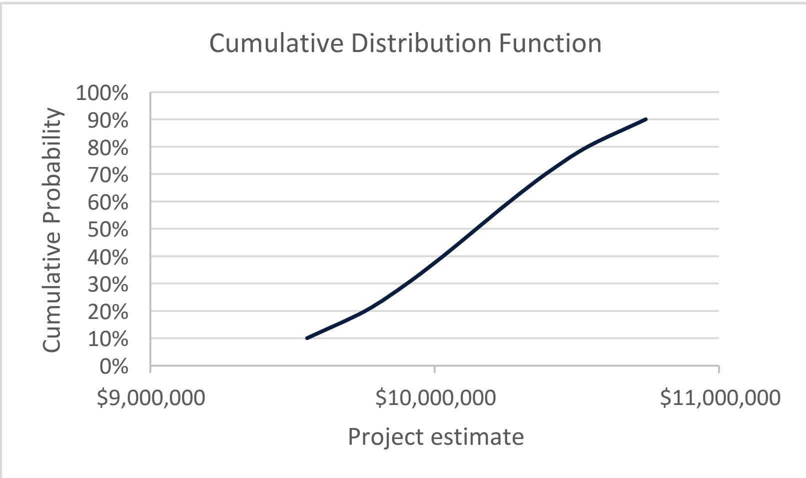


Table 4: Project estimate using a range-based deterministic method

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).

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 from which part of the estimate is based, 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. Reference class forecast deterministic method

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[9]. 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 consistent 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 turquoise bar, the final cost for 22 projects within 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.

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[9] Flyvbjerg, B. (2007). Policy and planning for large-infrastructure projects: problems, causes, cures. *Environment and Planning B: planning and design*, *34*(4), 578-597.

Figure 3: Probability distribution of Reference Class data set (hypothetical example only, adapted from Flyvbjerg, 2005)

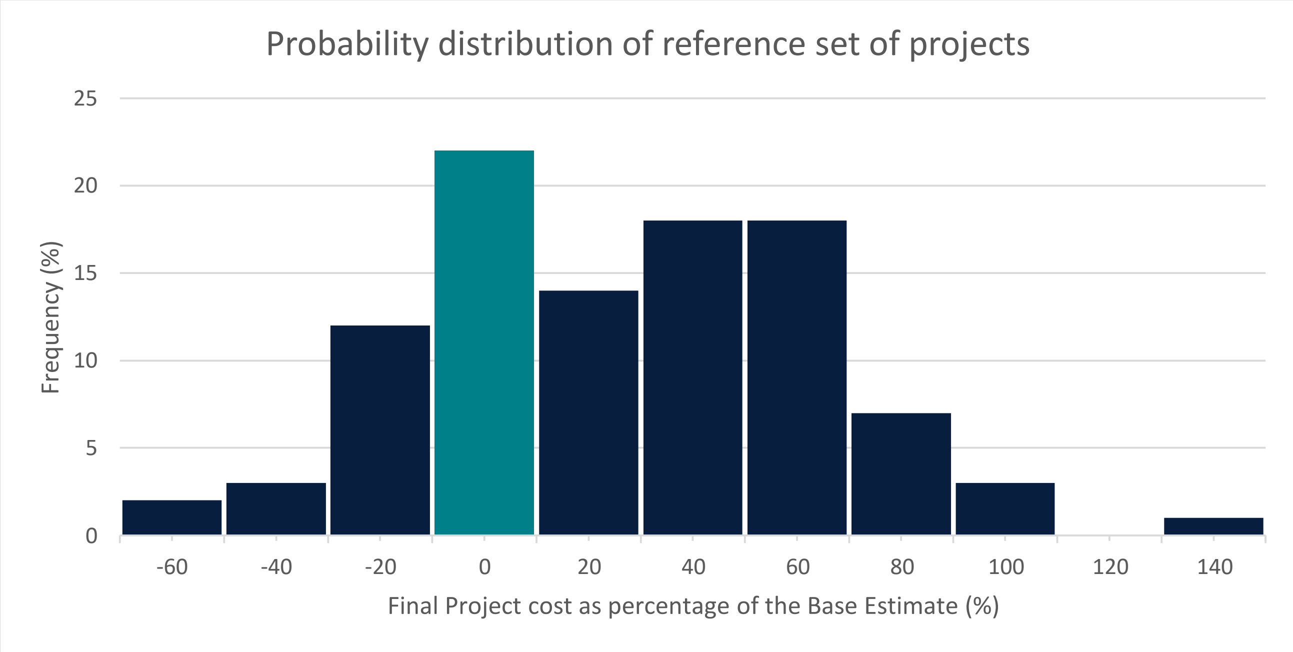
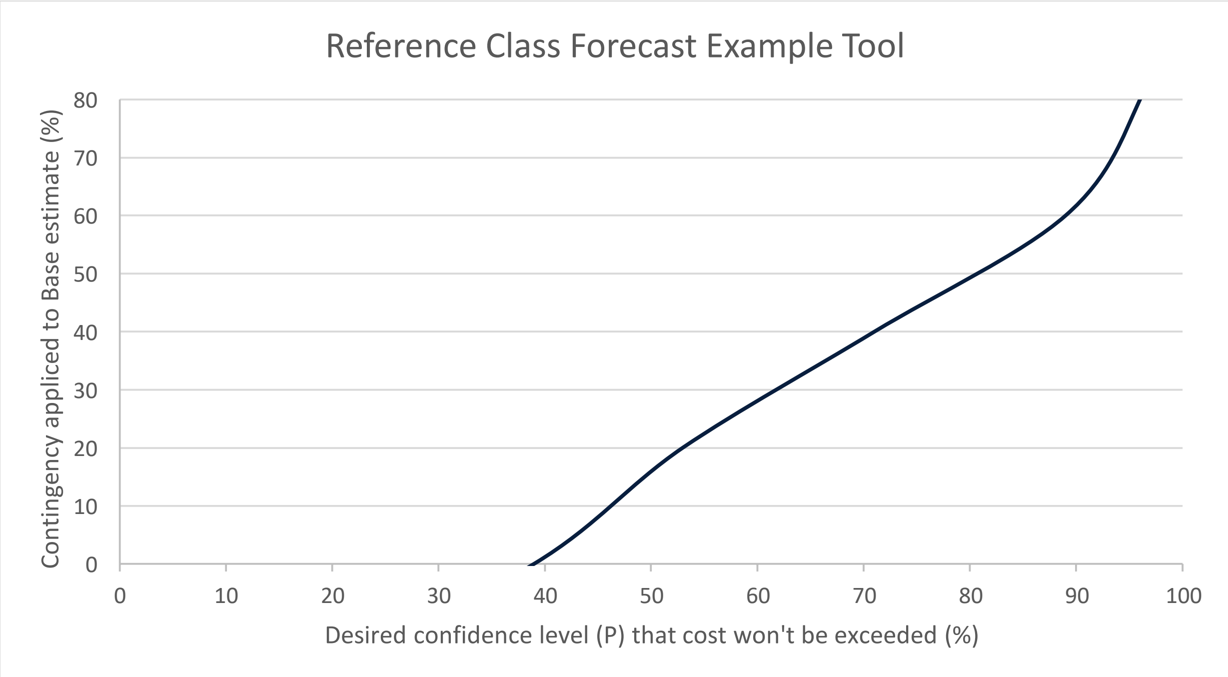


Figure 4 is the cumulative distribution of the same set of data. In effect, it becomes the reference class forecast tool, and is presented in the form of an S-curve that represents the actual cost as a percentage of the original base estimate, as determined from the reference set of past projects. The 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).

Figure 4: A Reference Class forecast (hypothetical example only, adapted from Flyvbjerg, 2005)



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, see **Guidance Note 4**), 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[10].

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 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 guidance note which provides further detail of how to build a range-based approach into a probability distribution of costs for a project using several 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.

These approaches are best described as analytical probabilistic techniques, they can be used for projects with an outturn cost exceeding $25 million. For a high-level estimates practitioners can utilise these techniques to explore the uncertainty of the project cost without the need to use simulation software.

In addition to the techniques outlined at **Figure 1**, the department will accept (upon review and assessment) other non-simulation analytic approach.

5. Conclusion

This guidance note describes 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.

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[10] Newton, S. (n.d.) A Critique of Initial Budget Estimating Practice

Appendix A – Definitions and abbreviations

Term	Definition
Agency	A state or territory government body that is generally responsible for delivering land transport infrastructure project.
Assumption	A documented, cost-related factor that, for the purpose of developing a base cost estimate is considered to be true, real or certain.
Base Date	The reference date from which changes in conditions, (including rates and standards) can be assessed. In the context of a base estimate, it is the date for which the rates included in the cost estimate reflect current market conditions.
Base Estimate	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.
BCR	The Benefit Cost Ratio (BCR) is the ratio that represents the benefits over costs and is represented as a single number. Further guidance on BCR can be found on the Australian Transport Assessment and Planning (ATAP) website.
Client Costs	In this guidance note, 'client' is the project proponent. Client costs are the costs incurred by the proponent (e.g. public sector delivery agency) to develop and deliver a project.
Construction Costs	The costs required to complete the activities or tasks associated with the construction elements of a project.
Contingency	An amount added to an 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[11]. This does not include escalation. As per Appendix B of NoA: *"The component of a Project's cost in excess of the Project Base Estimate that accounts for, or reflects, risk*". For further information on contingency refer to **Guidance Notes 3A and 3B.**
Contractor Direct Costs	All contractor's costs directly attributable to a project element including, but not limited to, plant, equipment, materials, and labour.
Contractor Indirect Costs	Costs incurred by a contractor to perform work that are not directly attributable to a project element. These generally include costs such as preliminaries, supervision, and general and administrative costs.
Escalation	The component of a project's total cost at any point in time that reflects changes in prices and costs since the base cost estimate date. Escalation is

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[11] AACE International, Recommended Practice 10S-90, Cost Engineering Terminology, accessed 19 October 2022 <https://web.aacei.org/docs/default-source/rps/10s-90.pdf>

Term	Definition
	added to the project cost to obtain the outturn cost. Escalation aspects do not form part of the scope of this document. For further information refer to **Guidance Note 4 - Escalation.**
Escalation Rate	The department derives escalation rates from actual or forecast composite index series that reflect the characteristics of infrastructure projects, where the escalation rate in any financial year is calculated from the average of the composite quarterly indexes for that financial year divided by the average of the composite quarterly indexes for the previous financial year.
Estimator	The person or organisation that prepares a cost estimate.
First Principles Estimate	The method of preparing a cost estimate by breaking down the project into a work breakdown structure and determining rates and quantities for each component. The cost estimate is the summation of each component.
Jurisdiction	An Australian state or territory.
Labour	Effort expended by people for wages or salary.
Margin	An allowance that includes the construction contractor's corporate overheads and profit.
Material	An article, material, or supply brought to a construction site by the contractor or a subcontractor for incorporation into the work. Also includes any items brought to the site preassembled from articles, materials or supplies.
NoA	The Notes on Administration for Land Transport Infrastructure Projects 2019-2024 (NoA), provide administrative detail to support the National Partnership Agreement (NPA) and apply to all Projects funded, or proposed to be funded under Part 3 (Investment Projects) and Part 7 (Black Spot Projects) of the National Land Transport Act 2014 (NLT Act).
NPA	National Partnership Agreement on Land Transport Infrastructure Projects (NPA). The NPA supports the delivery of infrastructure projects and sets out how the Australian Government and states will work together to deliver infrastructure projects for the benefit and wellbeing of Australians. The NPA covers projects administered under the National Land Transport Act 2014 (NLT Act) each state has a separately agreed schedule to the NPA which indicate the levels of funding the Australian Government intends to provide for land transport infrastructure investments. These schedules are updated following the Federal Budget each year, and as required.
Outturn Cost	Outturn cost is the summation of the base cost, contingency and the total escalation (it is the nominal total project cost). The department's Project Cost Breakdown (PCB) template can be used to calculate escalation and 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.
Overhead(s)	A cost or expense inherent in the performing of an operation, (e.g. engineering, construction, operating, or manufacturing) which cannot be charged or

Term	Definition
	identified with a part of the work, product or asset and, therefore, must be allocated on some arbitrary basis believed to be equitable, or handled as a business expense independent of the volume of production. These costs are considered when determining the cost of business. (e.g. machine maintenance, company accounting costs etc.)
Project Cost Breakdown (PCB) Template	The PCB template is provided by the department and is updated annually to reflect the latest escalation rates for road and rail projects.
Project Cost	The base estimate cost plus an allowance for contingency and generally prefixed by P50 or P90 to represent the level of contingency included. The project cost reflects costs as of the base estimate date. This does not include escalation.
Plant	All machines, motor vehicles, appliances and things (for example, scaffolding and formwork) used or in use in the execution of the work, but not materials, plant, equipment intended to form part of the final work.
Project Proposal Report (PPR)	A statement detailing the scope and benefits of the project submitted by proponents as part of the project approval process for funding under the Infrastructure Investment Program (IIP).
Project Scope	The work that must be performed to deliver a product, service or result with the specified features and functions.
Subcontractor	A contractor that enters into a subcontract and assumes some of the obligations of the primary contractor.
Sunk Costs	Costs which have already been incurred, such as investigation, research, and design costs. Sunk costs are included in an outturn cost.
Work Breakdown Structure (WBS)	A way of organising a project using a hierarchical breakdown of the activities required to complete the project. The WBS organises and defines the total scope of the project.