ENGINEERS AUSTRALIA | RISK ENGINEERING SOCIETY

Contingency Guideline

3rd Edition, 2025

"A reference for different practical risk-based decision-making approaches to managing schedule and cost contingency allowances throughout the project and program investment lifecycle."

RISK ENGINEERING SOCIETY (RES)

A publication of the Risk Engineering Society (RES) and Engineers Australia

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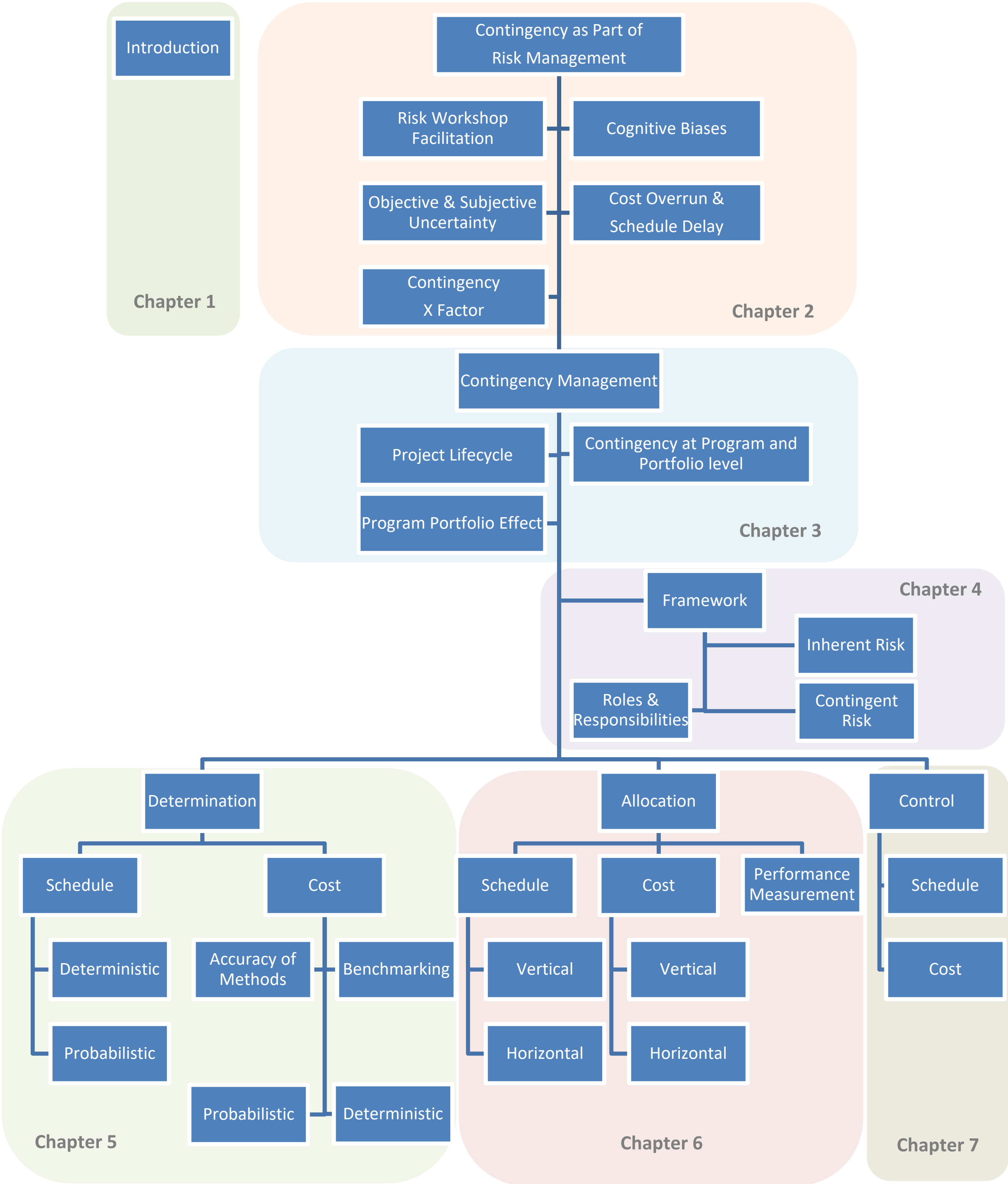
DISCLAIMER

STRUCTURE OF CONTENT



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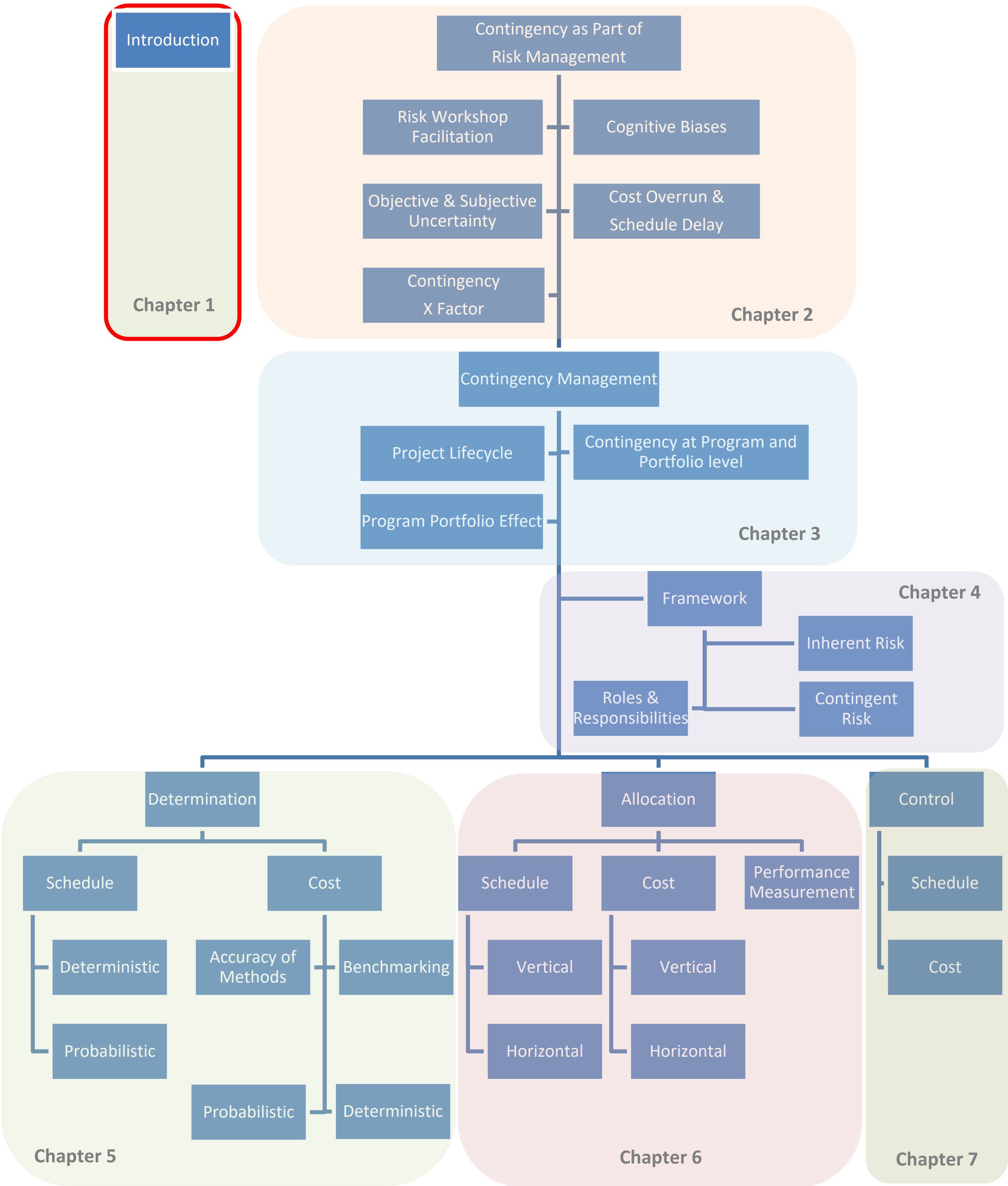
1.1 Structure of Content



1.2 Preamble

The *Institution of Engineers Australia*, trading as *Engineers Australia* ("Engineers Australia") <www.engineersaustralia.org.au> is the Australian forum for the advancement of engineering and professional development of its members and the wider engineering society across Australia and globally. Engineers Australia is the largest professional body for engineers in Australia.

Technical Societies of Engineers Australia provide an important and integral link between the profession and specific areas of technical practice. Technical Societies that function as operating units of Engineers Australia are bound by the Royal Charter and By-Laws, regulations, and policies of Engineers Australia.

As one of Engineers Australia's Technical Societies, the Risk Engineering Society (RES) <Risk Engineering Society | Engineers Australia> contributes to the effective and efficient application of risk engineering methodologies and approaches at every step of the risk management process for strategic, operational, financial or portfolio, program and project management objectives.

Consistent, effective, and efficient engineering approaches to uncertainty and risk assessment help businesses to better understand and quantify the range of possible consequences and the organisation's overall risk exposure. This empowers organisations to proactively manage the treatment and response actions for risks and opportunities, while making informed decisions and optimising their investments.

In May 2013, the National Executive Committee of RES identified the need for a new comprehensive guideline about the topic of 'contingency management' throughout the project / program lifecycle – from its determination at the early stage of business case development to its allocation during contract procurement and contracting and then its control and reporting during the project execution and delivery.

The 1st and 2nd Editions of the ***Contingency Guideline*** were published in May 2016 and February 2019 respectively. The *Contingency Guideline* would address the contingency management requirements in the delivery of major projects, especially for capital projects and government funded investments. Considering the dynamic nature of this important topic – as well as changing public and private requirements and contractual risk allocation practices, the maturity of the risk engineering profession and industry necessities – it is the intent of the RES National Executive Committee to periodically review and update this *Contingency Guideline*, to ensure its quality and to keep it up to date with new developments in contingency management. Following a comprehensive industry consultation, the 3rd Edition of the *Contingency Guideline* was published in May 2025.

The RES National Executive Committee welcomes any feedback, comments, suggestions for future development of this *Contingency Guideline* from its members, corporate and project risk professionals, cost engineers, cost estimators, project planning and scheduling specialists, contract and commercial managers, PMO managers and the public. Please email all communication to res@engineersaustralia.org.au.

1.3 Purpose & Scope

While there are already many publications on different aspects of contingency, the main objectives for publication of this *Contingency Guideline* are:

1. To provide the practitioners with a comprehensive reference for the end-to-end contingency management process, i.e. determination, allocation, control, monitoring and reporting
2. To provide a reference for different practical risk-based decision-making approaches to managing

schedule and cost contingency allowances throughout the project and program investment lifecycle
3. To help reach consensus in the methods used for contingency determination across industry and governments in Australia and globally, by providing comprehensive information on principles and practical methods. It also details when methods are applicable, their accuracy, and how they vary at different stages in the project lifecycle
4. To provide practical details about all key aspects of the contingency management process, e.g. 'determination', 'allocation', 'control', and 'program contingency', not only for cost estimation but also from project planning and scheduling perspective
5. To help practitioners to discuss and select the most suitable method of contingency management while balancing their requirements and constraints. It highlights that there is no one method to suit all situations and provides a framework to assist practitioners and organisations in discussing and selecting the best method for their requirements. Furthermore, practitioners are encouraged to improve the quality of their contingency determination by benchmarking against historical project data as well as the current projects and industry conditions.

The *Contingency Guideline* provides a reference document for different practical approaches and guidance for determining, allocating and managing the most appropriate contingency (time and cost allowances) at different stages of the project and program lifecycle. However, in alignment with Australian Government requirements, it excludes 'escalation' and its interaction with other uncertainties.

Please note that the *Contingency Guideline* is a general guide only. It does not set mandatory or minimum standards or requirements, and it does not comprise professional advice. Any person or organisation seeking to use or rely on the *Contingency Guideline* should obtain independent professional advice. Where the *Contingency Guideline* refers to the views or opinions of any person or association, those views and opinions are not endorsed by *Engineers Australia* or *Risk Engineering Society*, unless expressly stated in the *Contingency Guideline*.

1.4 Applications

Acknowledging that the concepts and definitions may vary by each country and while the concepts and definitions being used in this *Contingency Guideline* can be applied across different industries and sectors – by owners, investors, sponsors, contractors, and consultants – the language of the *Contingency Guideline* may lean more towards capital engineering and construction projects from project to portfolio level from the perspectives of government agencies, asset owners, general contractors or sub-contractors. However, the principles outlined are equally applicable across broader industries, including telecommunications, Information Technology (IT) and other sectors, where robust risk and contingency management practices are critical.

The *Contingency Guideline* aims to establish the characteristics of good industry practices of contingency management throughout project lifecycle. It also seeks to stimulate discussion within organisations and in projects so the required outcomes of risk and contingency management can be agreed and defined. The *Contingency Guideline* highlights that there are three objectives of a good contingency management approach: to accurately quantify uncertainty and risks; to encourage structural thinking; and to support informed decision-making process. Hence, organisations should use risk engineering and contingency determination approaches not only for their explicit results and generated contingency numbers, but also because they force people to share, discuss and validate all key assumptions and outcomes as a team – which is good source of information for decision-makers.

The Guideline is helpful at all levels of the organisation, where there is a need for governance of material impacts of risk such as contingency provisions for cost and schedule impacts. The size and impact of portfolio, program or major provisions could be so significant that they will need to be reported and managed at Board of Directors' level.

The *Contingency Guideline* is predominantly helpful for project engineers, project managers, construction managers, risk managers, cost engineers, estimators, project planners and schedulers, PMO directors, general managers in project development and delivery, contract and commercial managers – in the context of their work on projects and programs. Moreover, effective risk and contingency management directly support strategic investment planning by helping to balance an organization's risk appetite, tolerance, and decision-making processes, ensuring informed and optimized investment outcomes. It also provides a useful overview for business leaders who need to better understand the subject of contingency and its importance in achieving the objectives of project-based organisations, to make informed investment decisions which take risks into consideration.

1.5 Definitions

The *Contingency Guideline* acknowledges that there is a broad range of methodologies for defining, assessing and managing contingencies across different industries, organisations or countries. While a 'one size fits all' approach is not appropriate, there are benefits in constructing a common framework with a uniform set of terminologies and approaches, a high degree of transparency, guidance on clear authorisation arrangements, and fit-for-purpose governance. It should be noted that many of the terms and definitions related to the subject of risk management and contingency are industry, contract, organisation and context specific. However, while it is a difficult task to agree on a common language, the terms defined in Appendix A have been used throughout this document. For comparison purposes and completeness, multiple definitions of some key terms from different sources have been also included.

1.6 Good Industry Practice for Governance

The principles of "good governance" emphasize that it is the role of the board of directors to oversee the setting of its organisation's strategy and risk appetite, with due consideration given to its capacity to bear risk, its purpose and relevant stakeholders. The board should also ensure it has a risk management framework to identify and manage risk, including plans to mitigate the impact of material risks on the organisation. Advisory committees play a significant role in larger organisations, although the ultimate responsibility for risk oversight lies with the full board of directors. (ref: AICD).

AICD also recommends Implementing Enterprise Risk Management to Protect and Create Value - "Enterprise risk management represents a holistic approach to governing risks organisation-wide. Instead of siloed management within functions, enterprise risk management provides integrated visibility enabling trade-offs and interconnections to be managed at the executive and board level. Companies implementing robust enterprise risk management reap benefits including smoother operations, higher performance, informed growth and greater resilience. This article provides guidance for business leaders and directors looking to elevate enterprise risk management."

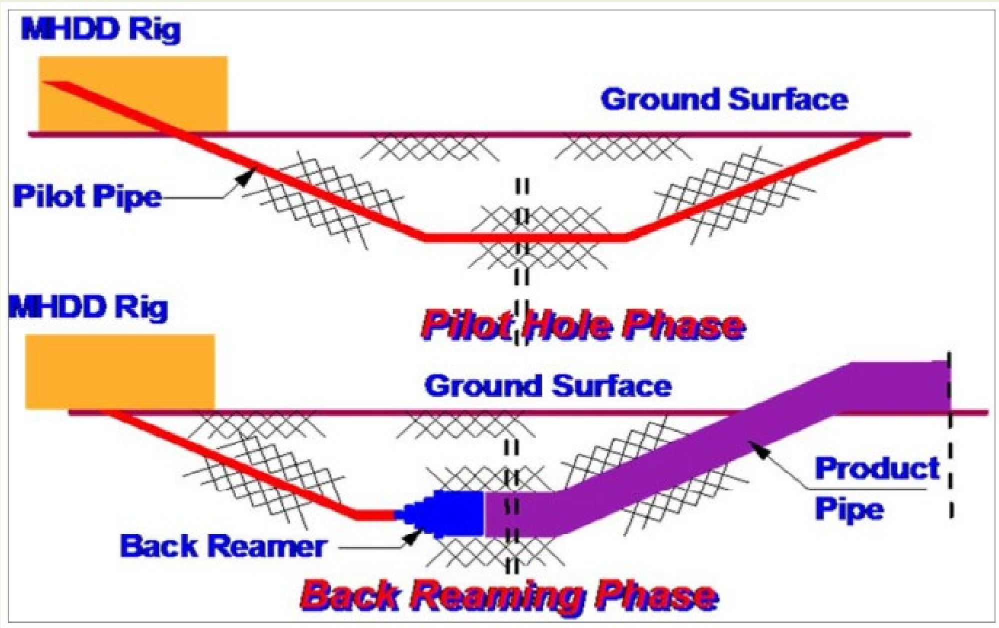
The governance of "Contingency" therefore becomes a key component of the risk management framework and needs to be aligned with the organisation's risk management policy. Also, as part of project cost and schedule estimation, it is essential to acknowledge that any good practice contingency determination should provide a reasonable assurance and forecast – an indicative but reasonably realistic and reliable estimation for organisation or project purposes which uses the latest available information. However, uncertainty does not justify a lack of discipline or integrity in the process. As a defined process including a set of practices, one must govern and ensure the quality of one's performance and activities.

The following are principles of good industry practices that should be considered when developing the risk management policy to cover effectively the allocation of contingency at an enterprise level:

a) Contingency management should address the organisation's risk appetite at strategic levels, the residual risks (i.e. post treatment risks), the organisation's desired confidence level for strategic, organisational and operational specific objectives
b) Objectives of contingency management, e.g. investment decision, tender conditions, change management, and delegation of authority, should be evaluated and communicated
c) Contingency management can be used to develop an overall management of opportunities to provide a positive effect of uncertainty on objectives
d) At any time, the Base Estimate and Base Schedule must:
    i) contain all the cost elements and schedule activities including approved changes
    ii) represent known current most likely assumptions, exclusions and strategies. Also, existing validated trends, e.g. progress performance during the delivery / execution phase of project, should be built into the Base Estimate / Base Schedule prior to any contingency determination
    iii) have a clear and up to date Basis of Estimate (BoE) and Basis of Schedule (BoS) documents
    iv) be supported by relevant data including historical information, when possible.

e) The previously prepared Base Estimate and Base Schedule should be reviewed, updated and escalated for 'Time Now' prior being used for risk assessment and contingency determination
f) The process should reflect overarching quality management principles, e.g. documented, transparent, traceable, defendable and timely
g) The process can support effective decision making on investments, example in Page 16, and as part of change control and integrated project control processes
h) The process should ensure all key risks, including upside risks (opportunities) and downside risks (threats), uncertainties, treatment strategies, and risk responses are explicitly identified, quantified and assessed
i) Key aspects of the organisation's culture and project specific strategies, including cognitive, behavioral, and deliberative biases, risk attitude, risk appetite, and risk tolerance, should be also considered. Additionally, attention should be given to addressing cognitive biases and the organization's risk culture, which may influence how risks are assessed and managed during the contingency management process.
j) Contingency management should address the residual risks (i.e. post-treatment risks), the organisation's desired confidence level, its project portfolio and specific strategic objectives.
k) Objectives of contingency management, e.g. investment decision, tender conditions, change control, and delegation of authority, should be evaluated and communicated
l) Contingency management process should be regularly carried out at every stage of the project
m) The method used for both cost and schedule contingency determination should be consistent with the Base Estimate and Base Schedule estimation methods at any given stage of the project
n) Contingency should not be a replacement for developing appropriate Base Estimate or Base Schedule by using all available information
o) Contingency determination practices should be empirically valid or validated as much as possible: either explicitly in the base methods; or through benchmarking against historical knowledge base; or by undertaking top-down and bottom-up approaches; or by engaging in a wider range of SMEs
p) Post-completion project reviews and lessons learnt sessions should be conducted to assess the effectiveness of the contingency management process, ensuring that lessons are integrated into future contingency determinations and continuous improvement is maintained across projects
q) Cost and schedule risks should be assessed and quantified together, when applicable, and When opportunities are identified, they should optimally be capitalised on by referral to a value management process.

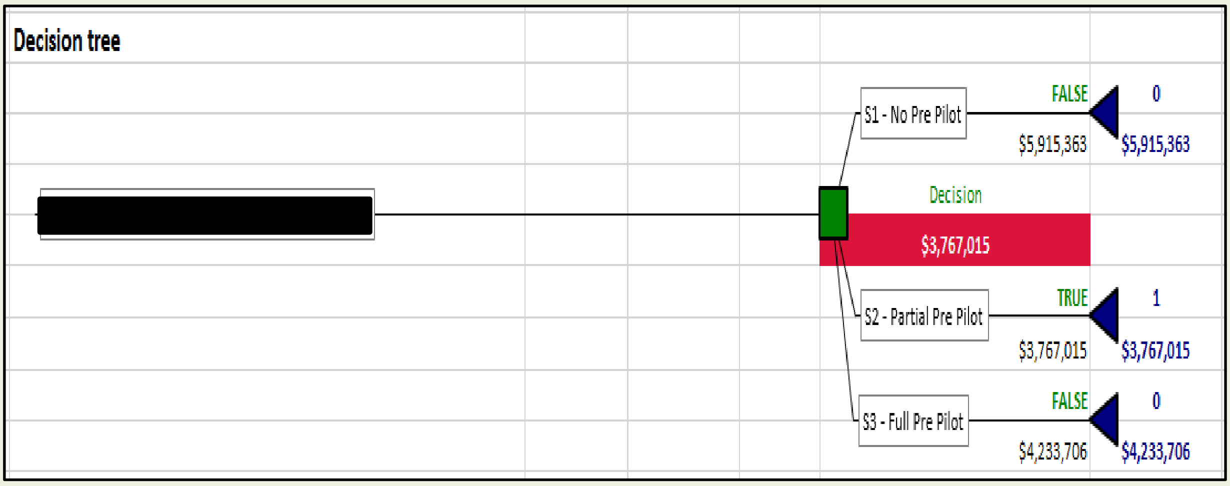
RES Example: KXA Risk Advisory was engaged to undertake a specific risk-based scenario analysis to support their client's decision on the preferred method of Horizontal Directional Drilling (HDD) procurement strategy on a major pipeline project.



To support the decision-making process on the most optimum approach to HDD procurement strategy, KXA Risk Advisory undertook its assessment on 3 different scenarios below.

- Scenario 1 - no pre pilot nor bore holes - in this scenario, no geotechnical investigation or HDD pre pilot activity will be undertaken. All risks will be passed to the Design & Construction contractor.
- Scenario 2 - partial pre pilot and bore holes from one side by Council, then residual risks to be passed to the contractor.
- Scenario 3 - full pre pilot and bore holes from one side to the other side (complete length) by Council, then residual risks to be passed to the contractor.

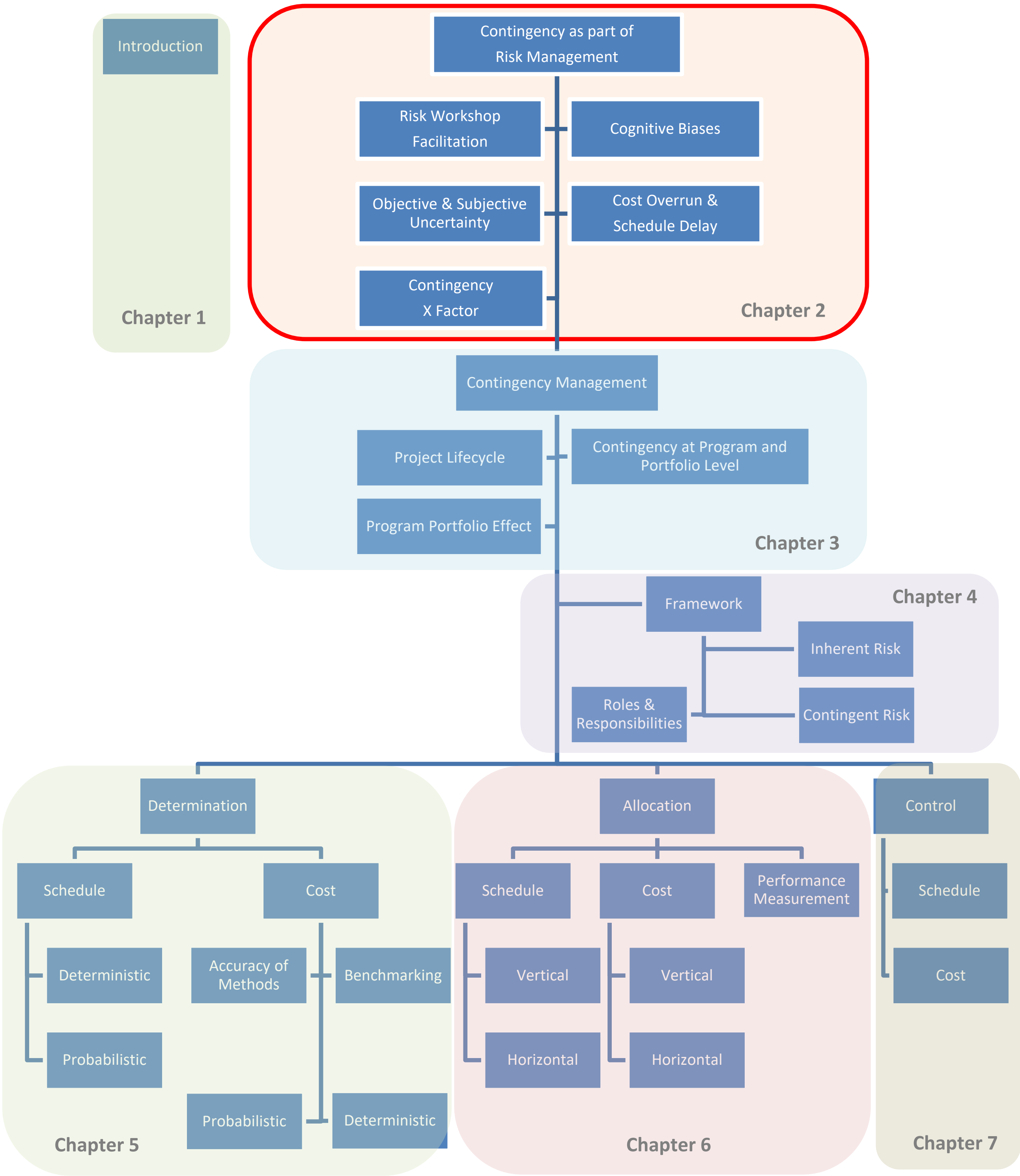
KXA used a combined decision tree methodology and Quantitative Cost Risk Analysis (QCRA) by using First Principles Risk Analysis (FPRA) and a probabilistic decision tree modelling (Monte Carlo).



Through this approach, the Scenario 2 was identified as the most optimum decision. This approach can be also used for assessing contingency for the Long-range, Unclassified / Class 10 estimate.

2. Contingency as Part of Risk Management

2.1 Structure of Content



2.2 Risk Management Process & Contingency

For the purposes of this *Contingency Guideline*, the project risk management process is defined in accordance with ISO 31000:2018 Risk Management – Guidelines, as illustrated in Figure 1. A key factor in the success of projects is the integrated application of value and risk management processes, including systems engineering, throughout the entire project lifecycle. The focus of systems engineering and risk management is to identify and implement solutions that represent the best value over the project's lifecycle while effectively managing associated risks. This approach is distinct from value management, which primarily focuses on fulfilling business requirements.

ISO 31000:2018 asserts that "the purpose of risk management is the creation and protection of value. It improves performance, encourages innovation, and supports the achievement of objectives." To achieve this goal, risk and contingency management should incorporate the expertise and opinions of stakeholders through an iterative, structured process that leverages historical data and high-quality information. High-quality historical data should be combined with current information, and practitioners should conduct additional investigations as needed.

Once an appropriate and fit-for-purpose risk assessment has been conducted, the risk treatment process should begin. This process involves specifying which risk treatment options are appropriate for various conditions, noting that these options may not be mutually exclusive. This ensures that stakeholders understand the process and enables practitioners to monitor progress against the treatment plan effectively.

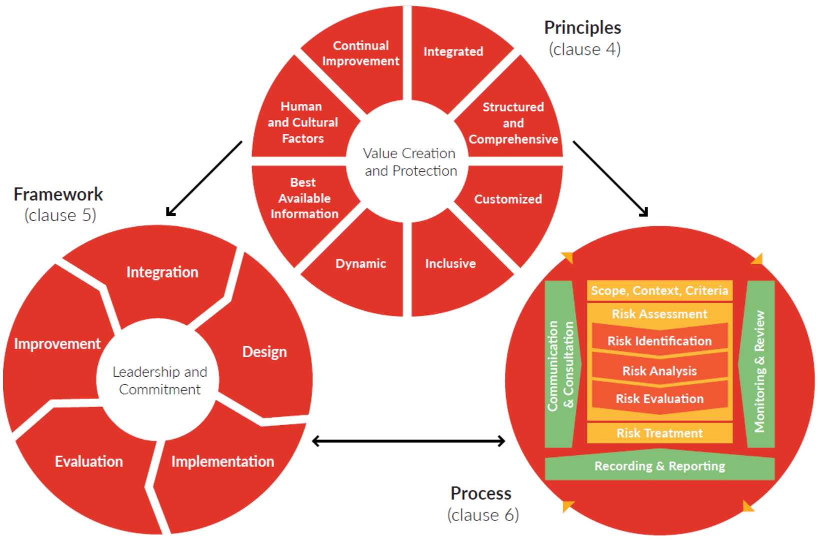


Figure 1: ISO 31000:2018 Risk management – Guidelines (principles, framework and process)

One or more risk treatment options may be selected. Some treatments (as specified by ISO 31000:2018) are listed below:

a) avoiding risk by deciding not to start or continue with the activity that gives rise to the risk
b) taking or increasing the risk to pursue an opportunity
c) removing the risk source
d) changing the likelihood
e) changing the consequences
f) sharing the risk (e.g. through contracts, buying insurance)
g) retaining the risk by informed decision

2.3 Contingency Definition

When further risk treatment is not feasible or justifiable, but the residual risk remains unacceptable (e.g., above the organisation's risk appetite but within its tolerance and capacity), allocating an allowance is an additional treatment option to manage the potential negative impact of the risk if it occurs. As part of the project risk management plan, the team should assess the cost, and time impacts of key risks to determine an adequate contingency allowance. This allowance will be allocated within the cost and schedule plans to cover the potential cost and/or time impacts of uncertainties and identified risks.

This allowance, known as contingency, is designed to address potential variations from the Base Estimate, which may add cost and/or time, and to seize opportunities that may reduce cost and/or time. Contingency management is essential within the risk and change management processes to ensure that risks are effectively identified, treated, monitored, and responded to when they occur.

RES Example: Risk Treatment in a Construction Project with Contingency Allowance

Consider a construction project involving the development of a large commercial complex. One of the identified risks is the possibility of unforeseen ground conditions, such as discovering a large, uncharted underground water source during excavation.

Risk Mitigation Implemented

- To mitigate this risk, the project team engaged in extensive preliminary geological surveys and soil testing before the commencement of excavation. Advanced ground-penetrating radar technology was employed, and geotechnical experts were consulted to assess potential underground anomalies. Additionally, detailed risk assessment workshops and scenario planning sessions were conducted to develop effective responses to a range of possible ground conditions.

Need for Contingency Allowance

- Despite these extensive mitigation efforts, the project acknowledged that unanticipated complexities might still arise during excavation. Such scenarios could lead to delays and additional costs not accounted for in the initial project plan. Therefore, a contingency allowance was included in both the project budget and timeline to account for these unforeseen circumstances.

Contingency for Cost:

- A financial contingency of 10% of the total excavation budget was set aside to cover any additional expenses that might arise from addressing unexpected ground conditions, such as additional excavation work, water removal, and reinforcing the foundation.

Contingency for Schedule:

- A schedule contingency of two weeks was also incorporated into the project timeline. This allowance was meant to absorb any delays resulting from the unforeseen discoveries and necessary additional work to stabilise the foundation without affecting the overall project completion date.

By implementing thorough risk treatment strategies and maintaining appropriate cost and schedule contingencies, the project team ensured that they were well-prepared to handle unexpected challenges, thereby minimising potential impacts on the overall project delivery.

Additionally, practitioners should ensure that contingency assessments consider both objective data and subjective expert insights. When possible, a balance of probabilistic methods, anonymous confidential interviews, and risk workshops should be employed to reflect the true risk exposure of the project. Incorporating a mix of objective data, subjective judgments, reference class forecasting, and scenario analysis will provide a more comprehensive understanding of uncertainties. Emphasis should be placed on historical data, while ensuring that expert views and current conditions are not undermined.

2.4 Objective and Subjective Uncertainties

For the purposes of this *Contingency Guideline*, uncertainty is defined as a potential variation that can occur in any phase or activity of the cost estimating, scheduling process, or other project performance factors. Uncertainty may arise from incomplete knowledge, inherent variability, or inconsistencies within the project's processes. To assess the impact of uncertainty, practitioners should holistically model the associated uncertainties. Uncertainty can be classified as either 'objective' or 'subjective.'

Objective uncertainty stems from measurable variations and quantifiable data, such as historical performance metrics or statistical analysis. Subjective uncertainty, on the other hand, is influenced by personal judgments, expert opinions, and qualitative assessments.

By identifying and categorising these uncertainties, practitioners can better understand their potential implications and develop more robust risk management strategies.

2.4.1 Objective Uncertainty

When practitioners use a replicable process to derive their cost and schedule parameters based on high-quality historical data, the associated uncertainty is termed 'objective.' For example, statistical analysis of historical data or the use of parametric equations can model objective uncertainty. When using statistical data, the relevant data should be carefully normalised to account for significant factors such as currency fluctuations, escalation, and critical risk events.

If empirically based applicable statistical data is used as the basis for cost and time estimates, the practitioner should have access to the required information to incorporate uncertainty into the cost and schedule risk model. This includes definitions of best-case and worst-case boundaries, as well as the nature of the probability distribution. The bounds of the specific confidence interval to be used should be determined by statistical calculations (note: 'level' is not synonymous with 'bounds'). However, it is crucial to ensure that the statistical data does not reflect the impact of critical risk events, escalation, currency fluctuations, or other non-contingency risks in past projects—only nominal variations in performance should be considered.

For instance, site-specific weather data can be used to forecast general conditions and possible disruptions, ensuring that major risk events are separated from nominal variations. Practitioners should collect and normalise relevant historical data before applying appropriate distributions for forecasting. By following these guidelines, practitioners can enhance the accuracy and reliability of their cost and schedule estimates, providing a sound basis for effective risk management.

This *Contingency Guideline* highlights two objective methods for estimating uncertainty:

- Developing Parametric Equations through Regression Analysis: Historical data is analysed to create equations that predict outcomes based on key cost or schedule drivers.
- Fitting Distributions to Normalised Historical Data or Estimates: Statistical distributions are used to represent the variability and uncertainty in project costs or schedules by fitting them to normalised historical data or current estimates.

By relying on these quantitative methods, objective uncertainty offers greater predictability and replicability in determining contingencies, ensuring that decisions are backed by empirical evidence and robust statistical analysis.

RES Example: Cost Estimation for a Major Infrastructure Project

Imagine a major infrastructure project, such as the construction of a new high-speed railway system. One significant aspect of this project is the estimation of its total cost.

- Objective Uncertainty Example - Material Costs:

The total cost of the railway project includes various materials like steel, concrete, and other construction materials. The prices of these materials are subject to fluctuations based on market conditions, supply and demand, and geopolitical factors.

- Historical Data: By analysing historical data on the prices of steel and concrete over the past decade, project managers can identify trends and patterns.
- Price Forecasting Models: Using statistical models and economic forecasts, they can predict future price changes within a certain confidence interval.
- Probabilistic Analysis: They can run simulations, such as Monte Carlo analysis, to quantify the range of possible cost outcomes based on the predicted material price fluctuations.
- Parametric or Reference Class Forecasting from similar projects or adopting industry ranges for defined levels of design maturity

For example, the analysis might show that the cost of steel has a 70% probability of being within ±10% of its current price over the next two years. This quantifiable uncertainty allows project managers to plan their budgets more effectively and include specific contingencies to cover any cost variations.

By acknowledging this objective uncertainty, the project team can make informed decisions about procurement strategies, supplier contracts, and financial reserves, thereby reducing the risk of budget overruns caused by unexpected material cost increases.

2.4.2 *Subjective Uncertainty*

When cost and schedule estimates are primarily based on the judgments of Subject Matter Experts (SMEs) in place of empirical analysis, the associated uncertainties are termed ‘subjective’. Subjective uncertainty cannot be reliably quantified without sufficient supporting data, making it less precise and reliable.

However, it remains significant in contingency estimation, especially when data deficiencies or project constraints limit comprehensive analysis.

Therefore, practitioners must rely on elicitation techniques, which involve gathering expert opinions from project engineers, managers, estimators, schedulers and other stakeholders. Elicitation should be conducted carefully to mitigate biases such as optimism bias or anchoring bias, both of which can skew risk perceptions.

RES Example: During the planning phase of a large infrastructure project, the project manager is uncertain about the exact duration required to complete the construction due to varying opinions from the team. Some experienced engineers believe it will take 18 months, citing past projects of similar scale, while others estimate 24 months, considering potential complications such as weather delays and supply chain issues.

This type of uncertainty is subjective because it heavily relies on individual perspectives, experiences, and judgments rather than precise, objective data. Different stakeholders might have varying levels of confidence and assumptions based on their past experiences, leading to a range of expected outcomes and making planning more complex.

Confidential interviews should be incorporated to reduce social or organizational pressures that may influence expert judgments. Sensitivity analysis can further aid in evaluating how variations in subjective assumptions impact the overall risk profile.

Subjective uncertainties often rely on intuition and qualitative factors but can still be valuable in projects where objective data is scarce. When combined with confidential elicitation techniques, subjective uncertainties can reveal risks and opportunities that might otherwise be missed.

RES Recommendation: Whenever possible, uncertainties should be based on empirical data, such as historical records and reference class forecasting, rather than relying solely on expert opinion. However, subjective insights from anonymous confidential interviews and risk workshops should complement the data-driven approach. Fitted data should be used to select distributions in preference to subjective selection.

2.5 Risk Workshop Facilitation

Despite the wide range of risk assessment software available, conducting a successful risk workshop to identify key areas of uncertainty and capture different views and experiences can be a challenging experience for project teams and organisations. The primary focus of the workshop facilitator is to manage the process effectively, ensuring the group remains engaged in identifying and discussing risks, understanding uncertainties, exploring possible treatments and mitigations, planning risk responses, and considering cost/schedule trade-offs. The goal is to capture ideas and knowledge comprehensively.

Each workshop typically has three phases:

a) Before the Risk Workshop: The key challenge for the facilitator is to understand the context and objectives of the required risk management, guiding participants in necessary preparation actions. The facilitator leads participants in gathering relevant information, including conducting confidential interviews to gain candid insights, particularly on high-risk or politically sensitive aspects of the project. Information gathered during this phase should be provided to participants beforehand while avoiding cognitive biases like anchoring bias and should be included in the final report. The amount of information provided depends on the risk assessment objectives, participants' risk management maturity, available timeframe and resources, and project complexity and scope.

b) During the Risk Workshop and Follow-up Discussions: The facilitator directs discussions on risk identification and classification using various methods such as brainstorming, historical data reviews, and decomposition techniques. Quantitative tools should be introduced to assess both cost and schedule risks. To achieve consistent risk management outcomes and high-quality risk data, the facilitator explains which factors can be defined as risks and which are excluded. Risks can be identified through several methods, including checklists, Risk Breakdown Structure (RBS) templates, brainstorming sessions, relevant historical data, decomposition techniques, process maps, Fault Tree Analysis (FTA), Hazard and Operability Study (HAZOP), Safety in Design (SiD), and Failure Mode, Effects, and Criticality Analysis (FMECA). This phase may also include risk quantification from cost and time perspectives, particularly at key decision gates such as Final Business Case (FBC), Final Investment Decision (FID), or during regular project assurance reviews.

c) After the Workshop: The facilitator creates a draft risk assessment report incorporating relevant data and knowledge gathered throughout the process, including input from all participants. The draft report should be reviewed by key stakeholders to ensure transparency and completeness. Stakeholders are given the opportunity to comment and further analyse the draft before the report is finalised and delivered to the person responsible for managing risk assessment for approval. The final report is then made available to decision-makers and other relevant stakeholders.

Quantitative risk workshops should assess both cost and schedule risks in an integrated manner to address potential trade-offs between cost and schedule objectives. Facilitators should ensure the full participation of all stakeholders, as diverse insights will lead to a more thorough understanding of project risks.

Involving both quantitative techniques, such as historical data analysis and reference class forecasting, along with subjective insights from anonymous confidential interviews and risk workshops, can ensure that hidden risks are surfaced and addressed effectively. Further details and recommendations for facilitating successful qualitative and quantitative risk workshops, and characteristics of good risk workshop facilitators are summarised in Appendix B.

RES Tips & Tricks: Facilitating qualitative and quantitative project risk workshops effectively requires careful planning and execution. Here are several tips to ensure a successful workshop:

Qualitative Workshop Tips:

- Prepare Thoroughly:
  - Gather relevant data and documentation beforehand.
  - Define the scope and objectives of the workshop clearly.
- Diverse Participation:
  - Include a mix of stakeholders—such as PM's, engineers, financial analysts, etc.
- Structured Agenda:
  - Create a detailed agenda with specific topics, timelines, and breaks.
  - Set clear objectives for each session, such as identifying risks or assessing their impact.
- Use Facilitation Techniques:
  - Employ brainstorming methods, SWOT analysis, or Fishbone diagrams to elicit risks.
  - Encourage open communication and make sure every voice is heard.
- Categorise Risks:
  - Classify identified risks into categories (e.g., technical, financial, operational) to organise and prioritise them effectively.
- Assessment of Risks:
  - Use qualitative scales (such as high, medium, low) to assess the likelihood and impact.
- Document Everything:
  - Record all discussions, identified risks, and assessments meticulously.
  - Use tools such as risk registers to keep track of all information discussed.

Quantitative Workshop Tips:

- Data-Driven Approach:
  - Base discussions on real, quantifiable data to assess risks.
  - Ensure all participants have access to the necessary data and tools beforehand.
- Specialised Tools and Techniques:
  - Familiarise participants with quantitative tools such as Monte Carlo simulations, sensitivity analysis, probability distributions, Reference Class Forecasting, etc.
  - Utilise software that can facilitate these analyses.
- Expert Consultation:
  - Involve SME's who can provide insights into complex scenarios and data interpretation.
- Scenario Analysis:
  - Explore different scenarios (best case, worst case, and most likely case) and their impacts.
  - Quantitatively assess the impact of each scenario on project metrics like cost, time, etc.
- Probability Assessment:
  - Use statistical methods to determine the probability and potential impact of risks.
  - Apply probability distributions to model uncertainties more accurately.
- Interactive Sessions:
  - Encourage interactive participation by using workshops and breakout sessions.
  - Discuss potential risk mitigation strategies and their quantitative impacts.
- Review and Follow-Up:
  - Summarise key findings and make sure all data and assessments are properly documented.
  - Plan follow-up sessions to revise and update the risk assessments.

2.6 Contingency X Factor

Cost and schedule contingency allowances are essential for supporting investment and control decisions. For construction contractors, the primary concern is pricing risk, whereas government agencies and asset owners focus on maximising investment returns. Determining the optimum contingency is crucial for both owners and contractors during the project development and delivery phases. This challenge of managing the optimum contingency is referred to as the **Contingency X Factor**.

2.6.1 Project Development Phase

In the project development phase, it is vital to base the contingency allowance on the desired confidence level. Both cost and schedule uncertainties should be considered to avoid underestimating project risks. During this phase—specifically the Initiation, Strategic Assessment, and Concept stages, as outlined in Figure 7 (from the Principal's point of view)—an adequate contingency allowance must be determined for funding allocation and investment planning. This should be done while considering the desired confidence level, such as P80 or P90.

Allocating too much contingency may understate the investment return or even reduce the likelihood of the investment being approved to progress further. Conversely, allocating too little could lead to uncompetitive investments being approved, set unrealistic expectations, or compromise project delivery. This underscores the importance of appropriate and sufficient risk quantification and contingency determination and pricing for principals during the project development phase.

Figure 2 below illustrates the Contingency X Factor for the Principal's contingency pricing during the development phase (i.e., Initiation, Strategic Assessment, and Concept stages). It should be noted that the relationship between contingency and confidence levels may not be linear.

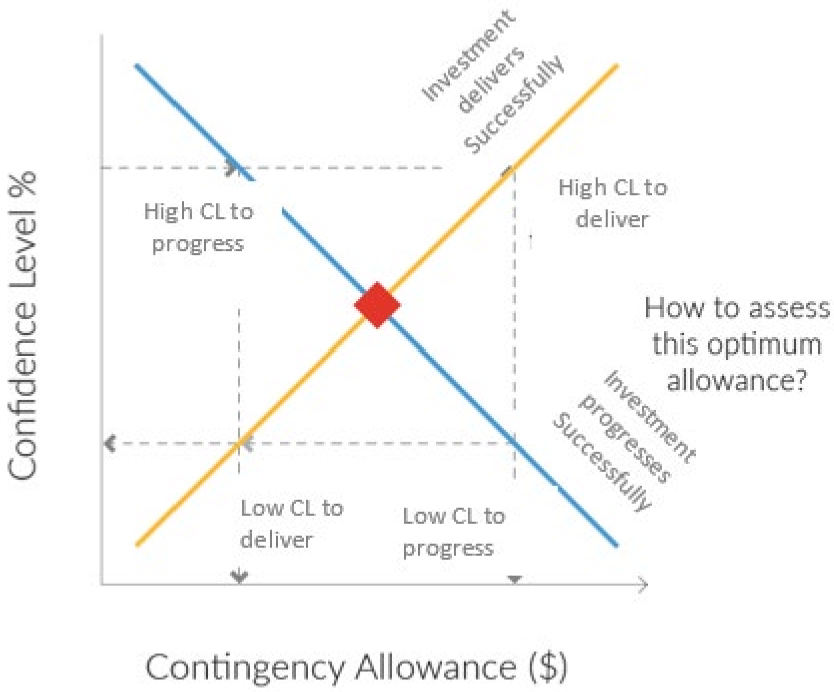


Figure 2: Contingency X Factor during development phase from Principal's point of view

2.6.2 Project Delivery Readiness Phase

From Principal's point of view

Following the Final Investment Decision (FID) or the approval of the Final Business Case—during the Delivery Readiness and Procurement phase as illustrated in Figure 7 — it is common practice to develop a Pre-Tender Estimate (PTE) before going out to the market. An accurate PTE serves multiple purposes: it allows for a final comparison with the budget to ensure that sufficient funds are available before seeking tenders, and it establishes a robust baseline estimate and delivery schedule for better evaluation of the tender responses.

All tender returns will be compared against the PTE, making the development of an accurate and reasonable PTE crucial for the tender evaluation process. If all tender responses significantly exceed the PTE, various issues may arise, including the need for additional funding, complications in the project's commercial assessment (such as the Benefit Cost Ratio, BCR), increased time pressure to meet planned milestones, potential redesign costs, the risk of project abandonment, and reputational and public concerns.

Conversely, an underestimated PTE may result in selecting an unrealistic or incompetent tenderer, which often leads to greater actual expenditure in the future.

Since the PTE is a base cost contract estimate, it should not include any owner's costs and risks (i.e., retained risks). RES recommends a risk-based PTE assessment using the contractor's costs and risks, in line with the latest commercial and contract assumptions (i.e., transferred risks) and current market conditions. A range of contingency allowances (e.g., P10 to P90) should be generated for the PTE. The following notes may be helpful when developing a risk-adjusted PTE from a previously developed estimate or schedule, such as that prepared for the Final Business Case:

- Exclude the Principal's cost items from the PTE.
- Review and update quantities based on the latest design and Scope of Works for the tender.
- Validate, escalate, and update rates to reflect current time and market conditions.
- Include all contractor's inherent risks and validate them.
    - Note that most contract types still involve many shared inherent risks (e.g., utilities, wet weather). Exclude all owner's inherent risks from the PTE model.
- Validate and include all contractor's contingent risks. Identify and allocate all Principal's contingent risks to the owner and then exclude them from the PTE.
- Include all contractor's schedule risks in the PTE, while excluding all Principal's schedule risks.
- Include costs for contractor's risk preventions, mitigations, and risk transfers in the risk-adjusted PTE.

When the owner receives the tender returns, the responses need to be normalised. The normalised tender responses should then be compared to the risk-adjusted PTE range (e.g., P10-P90). For typical market conditions, projects, and tenderers with a balanced risk profile, tender returns between PTE P40 and PTE P70 are generally considered reasonable. Any response below P40 is deemed optimistic, i.e., aggressive or risky, while any response above P80 is considered not to provide good value for money from the Principal's perspective.

It should be noted that selecting the best tenderer requires a thorough assessment of both commercial and non-commercial matters. This *Contingency Guideline* offers only a framework to support the evaluation process from a contingency allowance perspective.

The recommended approach to determine the Contingency X Factor during the Delivery Readiness and Procurement phase is presented in Figure 3 below.

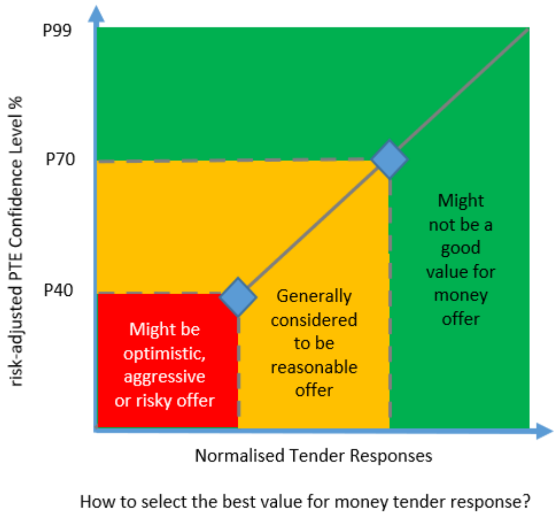


Figure 3: Contingency X Factor during delivery readiness phase from Principal's point of view

RES recommends that a post-tender estimate be produced following the completion of tender evaluation. This involves taking the normalised tender returns and adding other cost items or addressing the latest agreed commercial terms and conditions—including allocated risks and uncertainties—to create a comprehensive post-tender estimate. This will facilitate a full comparison of equalised tender returns on a like-for-like basis.

An appropriate scoring mechanism should then be applied to derive an overall score for the pricing element of the tender, alongside the qualitative assessment part.

The evaluation process and post-tender estimate should also document any unusual circumstances, such as all normalised tender responses being less than PTE P40 or more than PTE P70. In such cases, further assessment and detailed reviews are generally recommended.

From Contractor's point of view

Following the Final Investment Decision (FID) or the approval of the Final Business Case—during the Delivery Readiness and Procurement/Tendering phase as illustrated in Figure 7 — it is crucial from the contractor's point of view to determine the optimum contingency allowance. This should be done while considering the desired confidence level, the organisation's overall risk profile across its current portfolio of projects, and its risk appetite.

Allocating too much contingency may decrease the chance of winning the tender due to market competition, whereas too little could lead to optimistic plans and unrealistic commitments. This challenge underscores the importance of accurate risk quantification and contingency determination and pricing for contractors when tendering for projects.

Figure 4 below illustrates the Contingency X Factor for contractor tender pricing during the tendering phase. It is important to note that the relationship between contingency and confidence levels may not be linear.

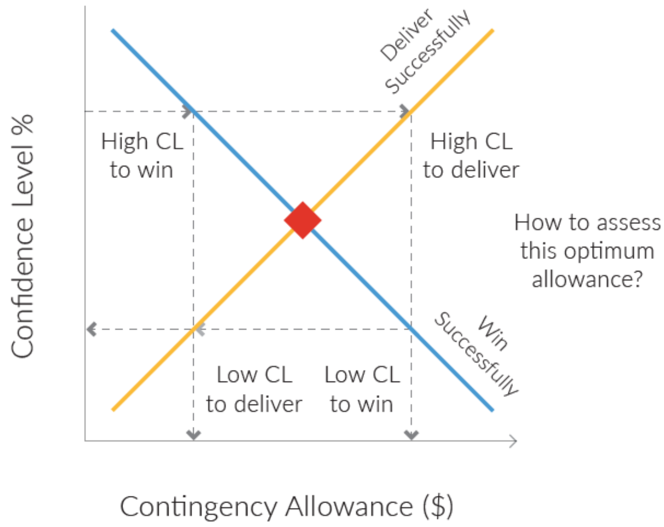


Figure 4: Contingency X Factor during delivery readiness phase from Contractor's point of view

2.6.3 *Project Delivery Phase*

During the project delivery phase, it is essential to regularly and quantitatively monitor and measure the project's risk exposure to ensure that the contingency remains adequate and reasonable for the desired confidence level. For projects encountering many unexpected events or variations, it is quite common to see a continuous decrease in the project confidence level as the project progresses.

When confidence levels drop significantly (below 30-40%), issues such as variations or delays become evident. However, identifying these problems as early as possible is crucial to maximise the opportunities for corrective and/or preventive actions.

The recommended approach to determine the Contingency X Factor during the delivery and execution phase is presented in Figure 5 below.

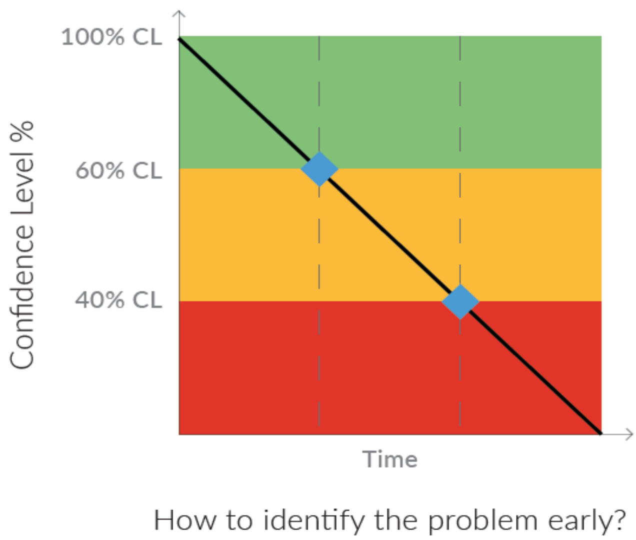


Figure 5: Contingency X Factor during delivery / execution phase from Principal or Contractor's point of view

> **RES Recommendation:** to set up more effective early warning indicators, use a regular (no longer than quarterly) quantitative risk-based confidence level assessment during the delivery phase, with three zones of: GREEN (e.g. from 90% to 60%); AMBER (e.g. from 60% to 40%); and RED (e.g. below 40%) in addition to traditional project progress measurement, traffic lights and performance reporting.

RES Example: AKA Advisory was engaged by XLX Energy who is delivering a major LNG upstream project to carry out a Quantitative Schedule and Cost Risk Analysis (QSRA and QCRA) on the project's current Estimate to Complete (ETC) cost forecast and delivery schedule (from the EPC Contractor). The project cost and schedule status are being reported as 'GREEN' based on the latest monthly project progress report issued by the EPC Contractor.

- the latest approved budget is $14,068m.
- $6,996m of Actual Cost (AC) expenditure has been recorded.
- The estimated cost to complete (ETC) including all current trending and excluding all non-trended contingency is $6,961m.

This indicates an Estimate at Completion (EAC) excluding non-trended contingency of $13,957m (i.e. AC of $6,996m plus ETC of $6,961m).

AKA Advisory undertook a Quantitative Cost and Schedule Risk Analysis. This risk analysis indicated a possible range of required cost contingency from $1,110m with 50% likelihood (P50 Confidence Level) to $1,274m with 90% likelihood (P90 Confidence Level). This highlighted the risk of cost overrun for an Estimate at Completion (EAC) of $15,067m (P50) to $15,231m (P90). **This notes a potential variance of additional $1,163m for P90 confidence level**.

The projected ETC for P50 and P90 levels is given below:

ETC	BASE ESTIMATE $M (EXCL. CONT)	AKA REVIEW P50 ETC ($M)	AKA REVIEW P90 ETC ($M)
Total	$6,961	$8,071	$8,235

2.7 Delays & Cost Overruns

Cost overruns and delays are common issues in major projects. This *Contingency Guideline* defines a cost overrun as the amount by which a project exceeds its initial cost estimate—adjusted for escalation and major business scope changes—at its final decision-making milestone, such as the Final Business Case. A delay refers to a project exceeding its initially forecast completion date. Both cost overruns and delays are often interrelated, as delays frequently lead to additional costs.

When capital is limited, over-budget projects can cause other projects to run overtime or be cancelled altogether. This scenario can adversely affect multiple project budgets and make it more challenging to secure funding for future ventures. Conversely, being under budget (potentially due to excessively high contingency allowances) can lock up capital and may result in under-investment.

Similarly, schedule delay—or slip—is measured by the time by which a project exceeds its initially forecast completion date, as recorded at its final decision-making milestone, such as the Final Business Case. Schedule delays usually lead to cost increases due to factors such as penalty clauses, increased time and effort, escalation, or a combination of these factors. Additional resource costs may also be incurred when attempting to make up for lost time. In worst-case scenarios, efforts to recover the schedule can fail to improve performance, and the added resources can exacerbate cost overruns. This is a risk of trading cost for schedule that practitioners must consider in integrated analysis.

Despite decades of international studies and efforts to predict and reduce project cost overruns and delays, major projects worldwide continue to face significant impacts. Table 1 presents some studies that assess the cost performance of various projects across Australia and globally.

#	Study	Year	Sector	Number of projects	Mean – cost overrun	Standard Deviation (SD) – cost overrun	Note
1	Grattan Institute	2020	Transport		30%		Half of the projects with an initial price tag of more than A$1 billion in 2020 money had a cost overrun. These projects overran their initial costs by 30% on average.
2	Grattan Institute	2016	Transport	836	26%		11% of cost overruns directly attributable to scope changes. 89% attributable to other causes.
3	IHS Herold Global Projects Database	2013	Mining, Oil & Gas and Infrastructure		80%		98% of projects incur cost overruns **or** delays. The average cost increase is 80% of the original value. The average slippage is 20 months behind the original schedule.
4	McKinsey and University of Oxford	2012	IT and software	5400	45%		On average, large IT projects run 45 percent over budget and 7 percent over time, while delivering 56 percent less value than predicted.
4	Bertisen & Davis	2008	Mining	63	25%	30%	
5	Odeck	2004	Roads	610	7.88%	29.2%	
6	Flyvbjerg, Holm, & Buhl	2004	Rail	58	44.7%	38.4%	Key findings: 20-40% average cost overrun; 86% of projects studied exceeded cost estimates; large infrastructure cost estimates "highly and systematically misleading".
7	Flyvbjerg, Holm, & Buhl	2004	Bridges & tunnels	33	33.8%	62.4%	
8	Flyvbjerg, Holm, & Buhl	2004	Roads	167	20.4%	29.9%	
9	Pohl & Mihaljek	2002	World Bank Projects	1015	22%		
10	Gypton	2002	Mining	60	22%		
11	Thomas	2001	Mining	21	17%		
12	Bennett	1997	Mining	16	27%		
13	Odeck & Skjeseth	1995	Toll Roads	12	5%		
14	AGS	1994	Roads	8	86%		
15	AGS	1994	Rail	7	17%		
16	Pickrell	1990	Rail	8	60%		
17	Fouracre, Allport, & Thomson	1990	Metro	21	45%		
18	Merrow	1988	various	47	88%		

19	Department of Industry, Technology & Research (VIC)	1980s	various in Australia and UK	21			Cost overruns of over 20% in 50% of government projects studied.
20	Castle	1985	Mining	17	35%		
Average					**36%**	**37.8%**	

Table 1: A number of studies on cost overrun projects

RES also acknowledges numerous studies conducted by researchers and industry associations, including works by John Hackney (1965 and 1991), Rand Corp, Independent Project Analysis (IPA), the Construction Industry Institute (CII), and others. Several research studies have highlighted that cost overruns and schedule delays are largely caused by measurable practices and inherent project system and scope attributes, which can be quantified using empirical data. Hackney, Rand, CII, and IPA have developed various parametric models to rate and quantify these risks.

Based on research, including the studies mentioned above, this *Contingency Guideline* groups the key factors contributing to cost overruns and schedule delays into two categories: hard and soft factors. Hard factors can include issues such as scope variations and technical problems, while soft factors encompass cognitive biases, strategic misrepresentation, and organisational culture. These factors impact both inherent (including systemic) and contingent risks, which are described further in Section 4.3.

2.7.1 Scope Variations

Scope variation occurs when changes are made to the project's original plan. To mitigate cost overruns resulting from scope changes, projects should incorporate robust contingency allowances. Appropriate contingencies, along with a strong cost-driven design management (i.e., a cost-driven change control process) that aligns with project objectives, can help to reduce these issues. Estimates of the effect of scope changes on cost overruns vary; for example, in 2016, the Grattan Institute found that scope changes accounted for only about 11% of cost overruns in transport projects in Australia.

However, scope variation plays a crucial role during the early stages of project development, such as the Preliminary/Strategic Business Case stage, where the level of scope definition is a major source of uncertainty. This concept underpins project stage-gate assurance systems, which are now considered good industry practice globally. Detailed scope reviews and the use of empirical relationships during project planning stages can reduce reliance on subjective judgments.

This *Contingency Guideline* recommends developing and implementing a Project Assurance Plan early in the project development phase. This plan enables appropriate project assurance activities, such as internal/external gateway reviews, project health checks, and detailed peer reviews (particularly on integrated cost/schedule/risk/contingency assessments at key decision points), to be planned and undertaken throughout the project lifecycle.

RES Example: Scope Variation in a Construction Project

Consider a construction project for a residential apartment building. The original scope included the construction of 50 standard apartments, a basement parking lot, a rooftop garden, and a fitness centre.

Scenario Leading to Scope Variation

During the project execution phase, the developer conducted market research and gathered feedback from potential buyers. The research indicated a high demand for premium apartments with additional amenities. To maximise return on investment and meet market demands, the developer decided to modify the project scope.

Scope Variation

The project scope was revised to include:

- Addition of Premium Apartments: Converting 10 of the standard apartments into luxury apartments with high-end finishes and larger floor areas.
- Enhanced Amenities: Expanding the rooftop garden to include a recreational area with a swimming pool, lounge area, and BBQ facilities.
- Smart Home Features: Integrating smart home technology (e.g., automated lighting, climate control, security systems) into all apartments to appeal to tech-savvy buyers.

Implications of the Scope Variation

Budget Impact: The increase in scope led to a higher overall budget due to the cost of upgraded materials, additional amenities, and smart home technology installation. A detailed cost analysis was performed to ensure the additional expenditure was justified by the potential increase in property

2.7.2 Technical Factors

Technical factors leading to overruns or delays often include inefficient planning, deficient forecasting techniques, and complex internal interfaces. These issues can be mitigated through the use of empirically-based data and more experienced teams. Other examples of inherent risks and uncertainties associated with major projects include:

- Complex internal and external technical interfaces and interdependencies
- Lack of relevant experience and competencies
- Rapidly evolving technology

These challenges can be addressed or eliminated through the adoption of better forecasting models, the application of empirical data and historical performance metrics, and the use of reference class forecasting. Additionally, engaging more experienced teams can significantly improve the management of these technical factors.

RES Example: examples of technical risk factors for a design and construct (D&C) project are:

a) the eventuation or emergence of additional contingent risks as well as those identified
b) all identified risks eventuated, and extra cost changes occurred
c) the worst-case consequences occurred for most of the identified risks
d) uncontrolled change or uncontrolled scope change
e) design development changes including design mistakes, maturity of design information
f) inappropriate procurement (contracting or expediting), or inefficient contract management
g) project complexity, including technical, project size, interfaces, political, cultural, etc.
h) standards and policy changes
i) third party influences, e.g. design costs associated with diversions or utilities adjustments
j) unmeasured items
k) property acquisition requirements, including:
    - permanent project areas (e.g. sub-surface easements)
    - temporary or permanent habitat requirements
    - facilities provided by principal or client for contractor (e.g. traffic diversions, site offices)
    - separate site offices and facilities for principal
    - land requirements for client works within the project
    - landowner compensation
    - residual land value of sites cleared during project demolitions
    - alterations to property access

Section 4.3 delves deeper into inherent risks and offers further insights into mitigation strategies.

2.7.3 Cognitive Biases

A cognitive bias generally refers to a deviation from rational judgement or assumption, leading to illogical inferences about people and situations. These known or unknown psychological factors can affect individuals' ability to make rational decisions based on available evidence and the likelihood of outcomes. In some cases, biases might lead to faster decisions when timeliness is more valuable than accuracy.

Hidden biases often color or distort the perception of risk and its consequences. For example, research indicates that people are generally overconfident in their ability to solve complex issues, despite evidence to the contrary. All project participants are susceptible to different types of biases. Factors that may increase the likelihood of cognitive biases during risk workshops and the contingency planning process include:

- Optimistic single-value estimates and duration of activities
- Pressure to meet predetermined targets due to technical, political, social, financial, or other objectives
- Exclusion of some contingent risks from time and cost estimations
- Unrealistic assumptions about risk allocation to other parties, i.e., transferred risks
- Schedule restraints due to the Merge Bias Effect (MBE), for example:
    - Project schedules have an additional layer of complexity over cost estimates—schedule logic. In complex projects, parallel strands of logic converge at milestones or activities. The probability of achieving those milestones on time is calculated by multiplying the probability of each logic strand being completed according to schedule.

- The Merge Bias Effect (MBE) is one of the main reasons why accelerating projects or recovering lost time is so challenging. It is also why complex projects tend to be overly optimistic when using traditional deterministic scheduling techniques. Simplifying schedules or focusing solely on the critical path does not account for the effects of the MBE and often leads to inaccurate projections.

To enhance the quality of risk management and the accuracy of contingency determination, it is critical to identify, plan for, and mitigate the possible impacts of cognitive biases within the organisation and the project team. Table 2 represents some common biases that may affect contingency determination. Incorporating anonymous and confidential interviews, along with structured risk workshops, can help uncover hidden biases, ensuring that a balanced risk perspective is achieved.

Cognitive bias	**Description**
Anchoring bias	In a risk workshop, participants may base their judgment on the initial estimate of the likelihood of risk occurrence and consequences, causing undue reliance on the first figure presented.
Availability heuristic	People may weigh up recent or easily recalled information too heavily. For example, a project manager may claim that high rainfall will not affect the schedule simply because it hasn't delayed previous projects, ignoring long-term trends.
Group thinking	Individuals tend to conform to the views of the group, leading to a lack of critical examination of risks or alternative viewpoints.
Blind-spot bias	Workshop participants may be less likely to recognize their own cognitive biases than those of others, leading to unacknowledged personal influence on risk assessments.
Confirmation bias	Participants, particularly those with more experience or authority, may overestimate their ability to manage higher risks or foresee outcomes.
Overconfidence	Overconfident workshop participants may believe that they are able to overcome higher risks.
Optimism bias	People tend to underestimate risks and overestimate the likelihood of success, leading to unrealistic projections of cost and schedule.
Recency bias	Participants may place too much importance on recent data, failing to give adequate consideration to long-term patterns or historical evidence.
Attentional bias	The attentional bias describes our tendency to focus on certain elements while ignoring others.
Commitment bias	A psychological tendency to feel tied or committed to things we did or said in the past, even if we recognize the outcomes of doing or saying those same things would not be favorable now.
Expedience bias	Expedience bias is especially likely to occur when people are in a hurry or cognitively depleted; people tend to take the easy path.
Framing bias	Framing bias occurs when people make a decision based on the way the information is presented, as opposed to just the facts themselves.
Sunk Cost Fallacy	The tendency to continue with a project is due to the investment already made, despite new information suggesting it may not be feasible.
Hindsight Bias	The belief that past outcomes were predictable after this fact, which can lead to overconfidence in future risk predictions.
Planning Fallacy	The systematic underestimation of time, costs, and risks, and the overestimation of benefits and ease of project completion.

Table 2: Several different types of cognitive biases

To mitigate the impact of cognitive biases, it is crucial to identify and assess the potential causes of delays and cost overruns using methods designed to explicitly anticipate and objectively address these biases. Utilising anonymous and confidential interviews, structured risk workshops, and scenario analysis can help counteract these biases and provide a more balanced assessment of risk exposure. Additionally, consistently facilitating multiple review meetings and engaging a diverse range of stakeholders in discussions will enhance the overall quality of risk assessments and ensure a comprehensive approach to risk mitigation.

Avoiding bias may also be achieved by:

- Engaging in more thorough inspection and analysis
- Gathering more data
- Comparing the consequences of potential actions
- Envisioning the worst-case scenario
- Seeking alternate and diverse perspectives
- Reinforcing objectivity
- Removing emotions from the discussion
- Encouraging a “growth and change” mindset
- Practicing mindfulness
- Applying critical thinking and critical questioning

RES Example: Two examples of cognitive biases during tendering for a major construction project

Consider a major construction project for the development of a new hospital complex. The project involves a comprehensive tendering process, where multiple contractors submit their bids for the different phases of construction. Example of Cognitive Biases:

1. Confirmation Bias:

Situation: The project owner has a preferred contractor based on previous positive experiences with small-scale projects. During the tendering process, they pay more attention to information that confirms their belief that this contractor is the best choice while downplaying or ignoring any potential drawbacks in the contractor's bid.

Impact: This leads to the selection of the preferred contractor despite the presence of more competitive bids from other contractors that may offer better terms, cost savings, or innovative construction techniques. Consequently, the project may suffer from higher costs or suboptimal execution.

2. Anchoring Bias:

Situation: During the initial stages of the tendering process, the first bid submitted includes a relatively low price compared to historical standards. The selection committee uses this initial bid as an anchor point for evaluating subsequent bids.

Impact: Even though later bids may offer more comprehensive solutions, superior quality, or faster completion times, they are viewed less favorably because their prices are higher than the initial "anchor" bid. This can lead to choosing the lowest-cost option rather than the best value for the project, potentially compromising quality or innovation.

2.7.4 Strategic Misrepresentation

Strategic misrepresentation occurs when project plans are intentionally altered for political, economic, or personal reasons. This can involve underestimating project risks or overstating project benefits to gain approval or funding. Decision-makers should be aware of these risks and ensure transparency in project planning processes to mitigate their impact.

Since 1989, numerous studies have highlighted the negative consequences of strategic misrepresentation on cost overruns. For instance, a Grattan Institute study of 836 Australian transport projects found that cost overruns are, on average, 23% higher for projects announced close to an election than for similar projects announced at other times. This demonstrates how strategic misrepresentation can significantly inflate project costs and timelines.

Below are some examples of strategic misrepresentation in decision-making:

- Premature announcement of projects driven by political agenda: Projects may be announced hastily to gain electoral advantage, often without thorough planning or risk assessment.
- Underestimation of internal and external interfaces and interdependencies: The potential negative impacts of these interfaces and interdependencies are frequently downplayed, leading to underestimated project complexity and risk.
- Organisational pressure to secure more projects: There may be a drive to increase market share or outpace competition, leading to the intentional downplaying of risks.
- Personal objectives to secure more projects: Individuals may misrepresent project viability to achieve personal goals, such as obtaining bonuses or promotions.

RES Example: During a presidential election campaign, a candidate proposes a large-scale infrastructure improvement project aimed at revitalising the country's ageing transportation network. This project promises to create jobs, stimulate economic growth, and address critical infrastructure needs. The proposal quickly gains traction and becomes a central pillar of the candidate's campaign.

To gain public support and secure funding for the project, the candidate and their campaign team present highly optimistic projections concerning the project's costs, timeline, and benefits. They strategically misrepresent several key aspects of the project:

1. **Underestimating Costs**: The candidate claims the total cost of the project will be significantly lower than realistic estimates provided by independent analysts.
2. **Overstating Benefits**: The campaign promises that the project will generate a specified number of jobs, far exceeding the realistic forecasts. Furthermore, they claim the project will lead to unprecedented economic growth and improvements in national productivity, based on inflated assumptions and speculative economic modelling.
3. **Underestimating Project Risks**: The proposal glosses over potential project risks, such as delays due to bureaucratic red tape, the challenges of securing necessary permits, environmental impact concerns, and the complexities of coordinating between multiple state and local jurisdictions.

To counter these practices, it is essential to cultivate a culture of transparency and accountability within project planning and decision-making processes. This includes rigorous risk assessment, third-party audits, and the involvement of diverse stakeholders to ensure a balanced and objective evaluation of project proposals.

2.7.5 Organisational Culture

Political, economic, and psychological factors—often driven by individuals—have been widely assessed in recent studies as significant contributors to project risks. However, there is increasing recognition that organisational culture plays a critical role in shaping project outcomes, particularly regarding project planning, forecasting, and the management of cost overruns and delays. Organisational culture can create systemic issues that undermine risk management processes, drive biassed decision-making, and ultimately result in project underperformance.

In environments where the culture promotes short-term gains, pressure for quick results, or a "win-at-all-costs" mentality, project teams may be incentivized to make overly optimistic forecasts, minimise risks, or suppress important information about potential challenges. This leads to poor risk identification and inadequate contingency planning, exacerbating issues of cost overruns and delays. A culture that places excessive emphasis on meeting predefined deadlines and budget constraints—often at the expense of comprehensive risk assessment—can force project teams to understate risks or overpromise on deliverables.

Consultancy firms provide a notable example of how organisational culture can negatively influence project performance. In some instances, consultants may feel pressured to deliver results that align with the client's expectations rather than providing a true representation of risks and uncertainties. This leads to strategic misrepresentation, where forecasts are adjusted to secure projects or meet client demands, ultimately resulting in unreliable project estimates. Such cultures tend to prioritise client satisfaction over integrity, leading to significant deviations from initial plans as risks materialise during project execution.

Furthermore, a risk-averse organisational culture that discourages transparency and open discussion of potential issues can stifle proactive risk management. When individuals within the organisation are penalised for raising concerns, this leads to information silos where critical data on risks and uncertainties is either not shared or withheld. Consequently, this results in suboptimal decision-making, as leaders are not equipped with the full scope of project risks and opportunities.

Conversely, organisations that foster a transparent, collaborative, and learning-oriented culture are more likely to experience better project outcomes. These cultures encourage open dialogue, even when the information may not align with optimistic projections. Teams are empowered to speak candidly about risks and uncertainties, leading to more robust project planning and the development of realistic contingency measures.

Improving organisational culture can be one of the most effective ways to enhance project performance. By promoting a culture that values integrity, evidence-based decision-making, and cross-functional collaboration, organisations can significantly reduce the likelihood of cost overruns and delays. Leadership plays a crucial role in this transformation by establishing clear risk management frameworks, rewarding transparency, and ensuring that teams are equipped to perform objective, data-driven risk assessments.

Ultimately, aligning the organisation’s culture with the principles of holistic risk management and transparent communication is key to achieving sustainable project success. Embracing a culture that prioritises accurate risk forecasting and contingency planning can help organisations not only avoid pitfalls but also seize opportunities for project optimisation.

RES Example: Impact of Organisational Culture on Successful Major Project Delivery

Example 1: Culture of Transparency and Collaboration

A large-scale urban infrastructure project involves the construction of a new metro line intended to ease traffic congestion and improve public transportation.

Positive Organisational Culture Attributes:

- **Transparency**: The organisation fosters an open culture where team members are encouraged to share information freely about potential issues, risks, and uncertainties.
- **Collaboration**: There is a strong emphasis on cross-functional teamwork, with engineering, procurement, finance, and risk management departments working closely together from project inception to completion.

Impact on Project Outcomes:

1. **Robust Risk Identification**: Team members feel empowered to speak up about potential risks they observe. As a result, the project team can identify and evaluate risks early in the planning phase, leading to comprehensive risk mitigation strategies.
2. **Effective Issue Resolution**: When an unexpected underground obstacle is discovered during excavation, the open communication allows the issue to be quickly reported and addressed.
3. **Realistic Planning**: The collaborative approach and open dialogue lead to more accurate project forecasts, as team members draw from diverse expertise and knowledge bases. This helps create a realistic project schedule and budget with adequate contingencies.

Outcome:
The project is completed on time and within budget, with high-quality outcomes and minimal disruption to the public. Stakeholders are satisfied, and the new metro line significantly improves urban transportation.

Example 2: Culture of Short-Term Gains and Suppression of Negative Information

A high-profile commercial office building is being developed in a rapidly growing business district. The project has a tight deadline to match the influx of new businesses.

Negative Organisational Culture Attributes:

- **Short-Term Gains**: The organisation prioritises immediate results and quick wins, often at the expense of long-term planning and sustainability.
- **Suppression of Negative Information**: There is a prevailing fear of reporting bad news or potential issues, leading to minimisation or concealment of risks and problems.

Impact on Project Outcomes:

1. **Underestimated Risks**: Team members are reluctant to highlight potential risks, fearing reprisal or criticism. This leads to a lack of thorough risk assessment and inadequate risk mitigation planning.
2. **Overly Optimistic Forecasts**: To meet the organisation's demand for impressive short-term results, project managers overpromise on timelines and budget constraints, neglecting realistic projections. This results in a project plan that looks good on paper but is not robust.
3. **Information Silos**: Individuals withhold critical information, leading to fragmented knowledge and poor decision-making. For example, when supply chain issues arise, the problem is not communicated promptly across departments, delaying resolution.

Outcome:
The project faces significant cost overruns and delays due to unanticipated issues that were not adequately planned for. The rushed approach compromises quality, leading to defects that need to be rectified after project completion. Client satisfaction is low, and the building fails to meet the growing business district's demands effectively, impacting the organisation's reputation.

2.7.6 Perspective

Perspective can be described as the lens of analysis or point of view. The outcome of risk analysis is dependent on the perspective from which it is considered; the outcome may well change if a different legitimate perspective is considered. For example, a toll road risk analysis may yield different results from the perspective of a for-profit private operator vs. a public agency serving an urgent infrastructure need.

Perspectives may also differ depending on who is performing the analysis. Risk analysis can be performed by organization employees (internal) or by consultants (external). Internal staff tend to be overly optimistic (see overconfidence bias, above) and may be influenced by management to favor a particular scenario or analysis outcome (see strategic misrepresentation, above). Internal staff have easier access to project and historical data, but independent external consultants have less incentive to distort data.

2.7.7 Ethics

Every decision has an ethical dimension. In the world of project management, there are many relationships and hierarchies that make ethical decision-making difficult. Even the honesty and integrity of the risk analyst can be compromised. All risk analysis steps have an ethical component, including scope definition (and limitation), the identification (or exclusion) of legitimate risks, subjectivity and comprehensiveness in quantification, subjectivity in ranking, and more. At worst, risk analyses are subject to problems of lobbying, opportunism, political influence, self-interest, bias, and perspective.

A moral philosophy that applies well to risk analysis is consequence-based ethics, defined as doing that which produces the greatest good. Consequence-based ethics require a forecast of the results of actions taken, which is satisfied by risk analysis. Members of professional institutions are typically bound by an ethics code, which can serve as a guideline for behaviour. Concepts of honesty, integrity, professional responsibility, and independence/objectivity are often mentioned in such codes. Central is the avoidance of deception, which may occur in false or misleading statements, omissions, and half-truths. Documentation of the risk analysis effort serves as an ethical component of the analysis, satisfying goals of clear communication, accountability, confidence, assurance, rigor, and transparency by capturing comprehensive and substantiated information.

2.8 Further Reading

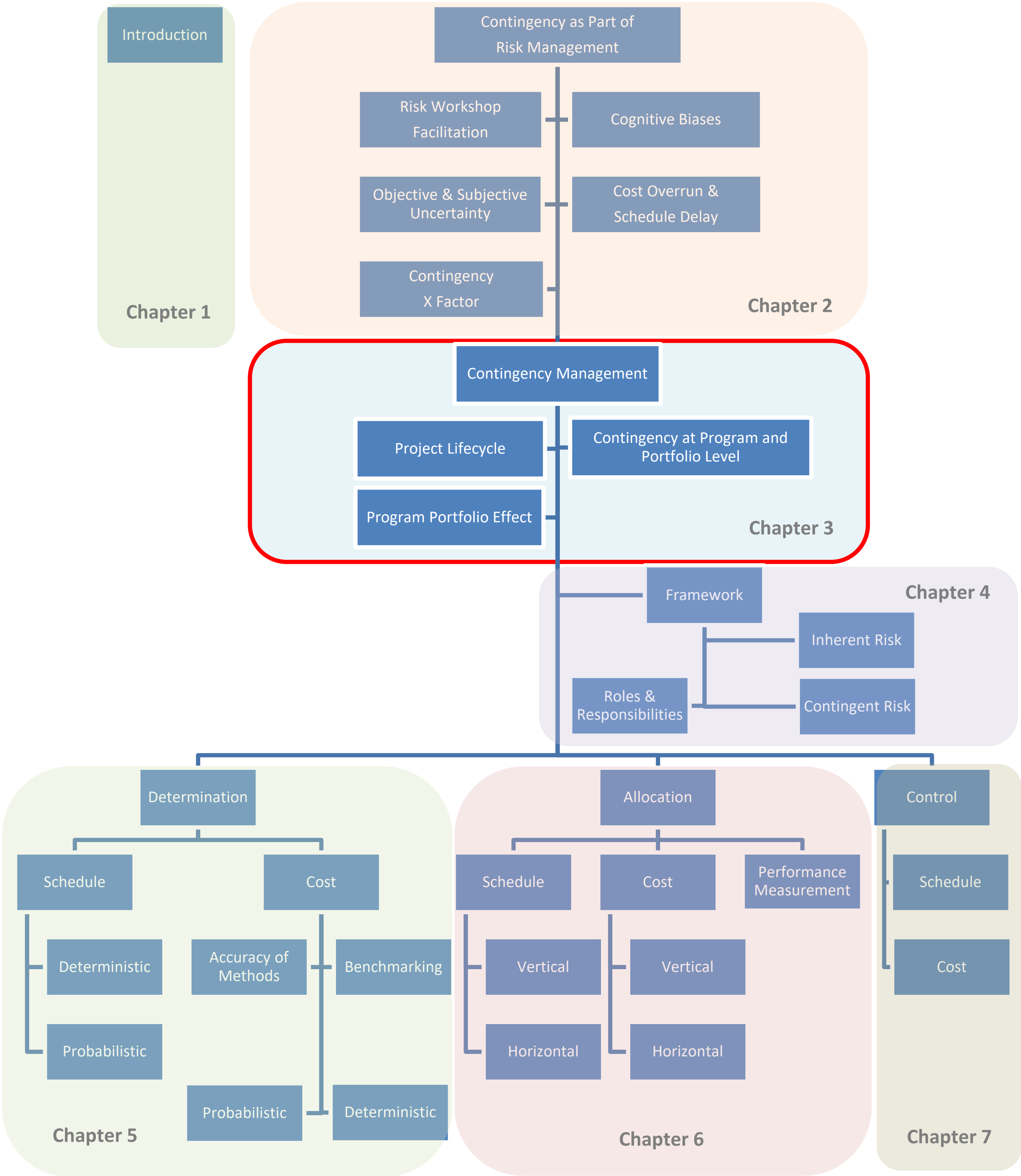
- AACE International, PGD 01 – *Guide to Cost Estimate Classification Systems*, Rev. August 2018, <library.AACE International.org/pgd01/pgd01.shtml>
- AACE International, PGD 02 – *Guide to Quantitative Risk (under development in Feb 2019) Analysis* <web.AACE International.org/resources/publications/professional-guidance-documents>
- AACE International, PGD 03 – *Guide to Cost Estimating (under development in Feb 2019)*
- AACE International, CE-48: *Understanding Estimate Accuracy (DRAFT in Feb 2019)*
- Association for Project Management, *Project Risk Analysis and Management Guide*, APM Publishing, 2nd Edition, 2004
- Flyvbjerg, B., *The Oxford Handbook of Megaproject Management*, Oxford Handbooks, 2017
- Grattan Institute, *Cost Overruns in Transport Infrastructure*, 2016
- Hackney, J.A. "Control and Management of Capital Projects", Wiley, 1991
- ISO 31000:2018 *Risk management – Guidelines (principles, framework and process)*, 2018
- Merrow, E.W, Phillips, K.E. & Myers, C.W.,"Understanding Cost Growth and Performance Shortfalls in Pioneer Process Plants", R-2569-DOE Rand Corporation, 1981
- Naval Center for Cost Analysis, *Joint Cost Schedule Risk and Uncertainty Handbook*, US

Government, 24 April 2013

- Nnadi, E. O. E. , Ezemerihe, A., “Value Management as an Efficient Risk Management Tool”, *International Journal of Advanced and Multidisciplinary Engineering Science*, Vol. 2 No. 1, 2018, pp. 1-6
- PMI, *Practice Standard for Project Risk Management*, Project Management Institute, 2009
- United Kingdom Government, HM Treasury, The Green Book, Appraisal and Evaluation in Central Government, 2003 <www.hm-treasury.gov.uk/d/ green_book_complete.pdf>
- UK Government HM Treasury Green Book Guidance Optimism Bias
- United Nations*, UN Industrial Development Organization, Guidelines for Project Evaluation, Project Formulation and Evaluation Series*, No. 2, UNIDO, 1972

3. Key Concepts of Contingency Management

3.1 Structure of Content



3.2 Expected Accuracy Range

Accuracy is the degree to which a measurement or calculation varies to its actual value; thus, estimate accuracy is an indication of the degree to which the final cost outcome of a project may vary from the single point value used as the estimated cost for the project. Estimate accuracy should generally be regarded as a probabilistic assessment of how far a project's final cost may vary from the single point value that is selected to represent the estimate. The estimate accuracy range should be expressed in terms of a range of values (in absolute terms) for a declared confidence interval. If the estimate accuracy range is expressed as a +/- percentage around a single estimate value, then the confidence level (probability of underrun) of that single estimate value must be identified (e.g., the estimate range is -12% to +18% around the estimate value at a 50% probability of underrun).

There are several similar but different 'single estimate values' that can be used by different industries as the base point when expressing the Expected Accuracy Range. This section provides these relevant definitions and a demonstration of their values from the Expected Accuracy Range perspective.

Base Estimate: Estimated cost of a project that can be reasonably (i.e. current strategies and assumptions) expected if the project materialises as planned. The Base Estimate excludes the escalation, foreign currency exchange, contingency and management reserves.

Central Estimate: As defined by Fellow of the Institute of Actuaries of Australia (FIAA), a Central Estimate of the liabilities is the expected value of the liabilities. In other words, if all the possible values of the liabilities are expressed as a statistical distribution, the Central Estimate is the mean of that distribution. In my experience, the Central Estimate usually lies about the P30-P40 levels in energy and transport projects. FIAA defines risk margin, i.e. contingency or prudential margin, as a provision greater than the Central Estimate to increase the probability of adequacy.

Best Estimate: As per IAS 37 Provisions, Contingent Liabilities and Contingent Assets, provisions should be measured at 'best estimate' (including risks & uncertainties) of the expenditure required to settle the present obligation and reflects the present value of expenditures required to settle the obligation where the time value of money is material. Hence, in reaching its 'best estimate', the entity should consider the risks and uncertainties that surround the underlying events for its desired confidence level.

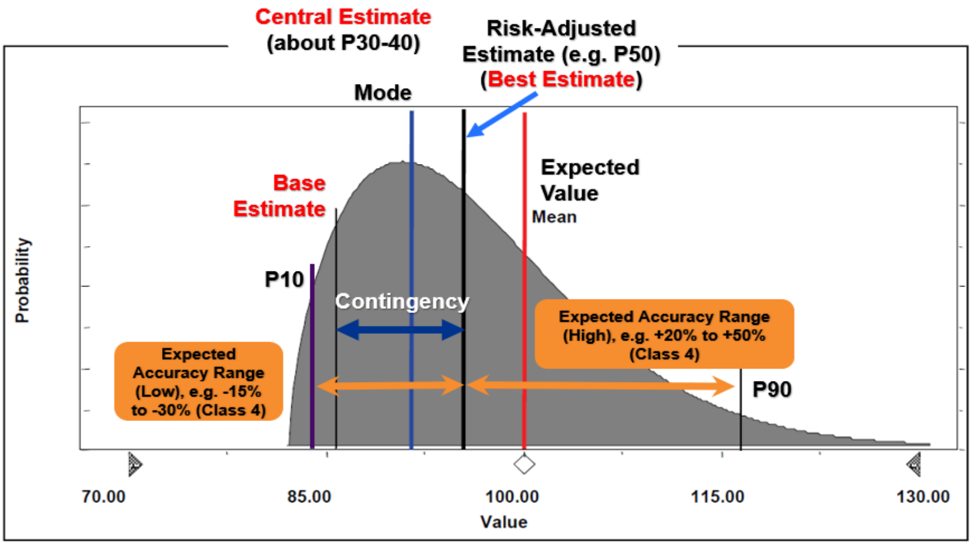


Figure 6: A typical Expected Accuracy Range

3.3 Contingency & Project Lifecycle

Almost all enterprises, public or private, have a level of stage-gate project scope definition processes in place. These gate reviews are part of an effective risk management process, based on research showing that staged funding avoids wasting money on the wrong projects, while increasing chances of success for those that are approved. Incorporating quantitative risk assessments and risk-adjusted cost forecasting at each stage-gate enhances the accuracy and reliability of contingency estimates.

A good practice project lifecycle is divided into phases with decision gates supported by approved procedures and processes. Contingency management must remain a dynamic and adaptive process, evolving as the project moves through different phases and new information becomes available.

As shown in Figure 7, the common six phases will be used in this *Contingency Guideline*, namely: Initiation; Strategic Assessment (i.e. Preliminary Business Case or Initial Business Case); Concept (i.e. Final Business Case or Detailed Business Case); Delivery Readiness or Procurement; Delivery or Execution; and Finalisation. The *Contingency Guideline* also defines six decision gates:

- Gate 0: Project Justification
- Gate 1: Strategic Assessment (i.e. Preliminary Business Case or Initial Business Case)
- Gate 2: Business Case (i.e. Final Business Case or Detailed Business Case)
- Gate 3: Pre-Tender
- Gate 4: Tender Evaluation
- Gate 5: Pre-Commissioning
- Gate 6: Post-Implementation

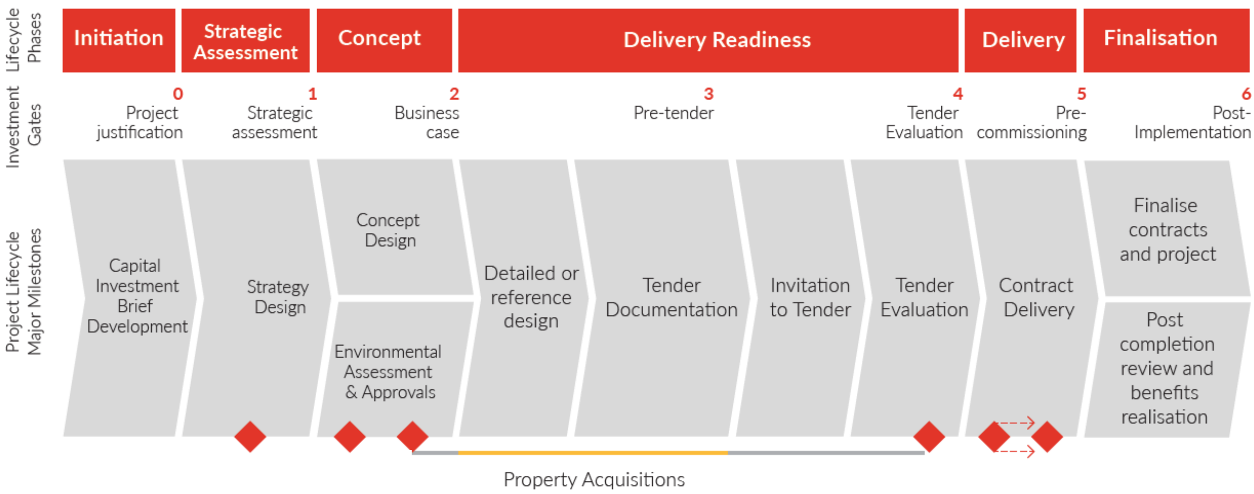


Figure 7: A typical project lifecycle and its key phases and milestones

At each of these decision gates, contingency should be reassessed to reflect new data, risk mitigation actions, and the evolving scope and complexity of the project.

The required contingency for a desired confidence level changes throughout the project lifecycle depending on a variety of factors. Some examples are actual progress of activities against the project plan, scope variations, unforeseen events, public opinion, technology and complexity, political changes, and impacts of internal and external stakeholders.

It is critical to adjust the contingency based on data-driven risk analysis, confidential risk interviews and risk workshops. Risk models should incorporate the impact of these external variables and compare different contingency scenarios to ensure readiness for the unexpected.

It should be noted that the level of scope definition and associated estimate and schedule classifications should also be measured as a basis for objective contingency determination.

RES Recommendation: as a minimum, risk and contingency workshops should be planned at the key points below (with reference to Figure 7):

- at the end of the Initiation Phase
- during the Strategic Assessment Phase:
  - to support assessing the required contingency within the Preliminary Business Case
  - to support Optioneering and Value Engineering for the selection of the preferred option.
- during the Concept Phase: to support the assessment of contingency in the Final Business Case
- during the Delivery Readiness Phase:
  - to support tender documentation, i.e. contingency allocation to different packages
  - to support tender evaluation, i.e. comparing tender responses against risk assumptions
  - to support setting project Performance Measurement Baseline for progress reporting.
- during the Delivery Phase:
  - to support contingency control as well as the change control process
  - to assess the project confidence level against the desired confidence level.

Another approach is to classify cost and schedule estimates according to the level of the project (e.g. Class 1, 2, 3, 4, and 5). However, it should be noted that accuracy and class are not interrelated. Accuracy can only be determined through Quantitative Cost Risk Analysis (QCRA), and each scope and estimate will have its own unique range driven by its unique uncertainties and risk profile. Figure 8 below illustrates the concept of improving accuracy with increased scope definition (as a percentage of the full definition).

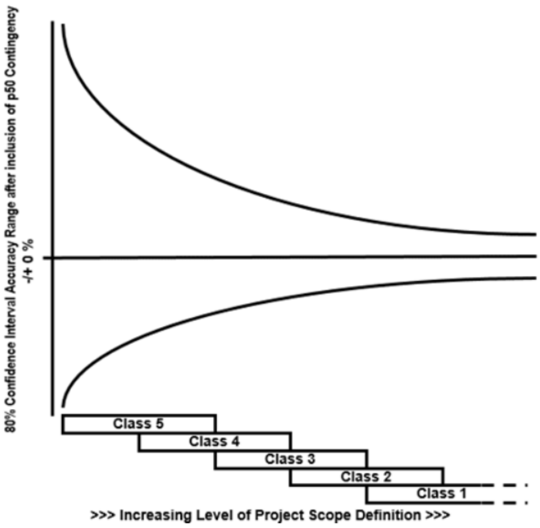


Figure 8: Estimate accuracy improves as the level of project definition improves (RP CE-48, AACE International)

Long-range / Unclassified / Class 10 Estimate

Almost a recently defined terminology, the Long-range / Unclassified / Class 10 estimate is usually referred to an estimate being developed perhaps over several decades or so far in advance that it is virtually assured that the scope will change from even the minimal level of definition assumed at the time of the estimate. Typically, these long-range estimates are based on minimal scope definition as defined for Class 5. Therefore, the Expected Accuracy Range and contingency ranges, as per section 3.2 above, may not be meaningful because the accuracy values explicitly exclude scope change.

The use of "range of P90's" is not recommended by this *Contingency Guideline*, as it might be misrepresented, misinterpreted and hence distorts the accurate risk exposure of the project especially at the FBC stage from the government perspective.

There are four main approaches for addressing the contingency of long-range estimate:

1. To develop a probabilistic decision tree with options and/or scenario variation branches. The highest P90 of all branches will be the estimated P90 for this 'long-range estimate' (recommended approach by this *Contingency Guideline*)
2. The estimate to be split into two parts as below. Total P90 will be calculated by adding two P90s
    A. the scope that can be reasonably estimated as Class 5/4 (risk adjusted). The P90 contingency for the Class 5/4 will be calculated by using the most appropriate method, e.g. the First Principles Risk Analysis (FPRA) method. (Chapter 5)
    B. the uncertain scope, i.e. Long-rang / Unclassified / Class 10. The P90 contingency for this scope will be assessed by using an appropriate top-down method, e.g. Reference Class Forecasting (RCF), parametric, benchmarking, etc.
3. If the long-range estimate is to be updated periodically in a controlled, documented life cycle process that addresses scope and technology changes in estimates over time, the estimate is rated as Class 5 and the accuracy ranges are assumed to apply for the specific scope included in the estimate at the time of estimate preparation. Scope changes are explicitly excluded from the accuracy range. – this approach is more suitable for asset operation and decommissioning, e.g. nuclear decommissioning estimates.

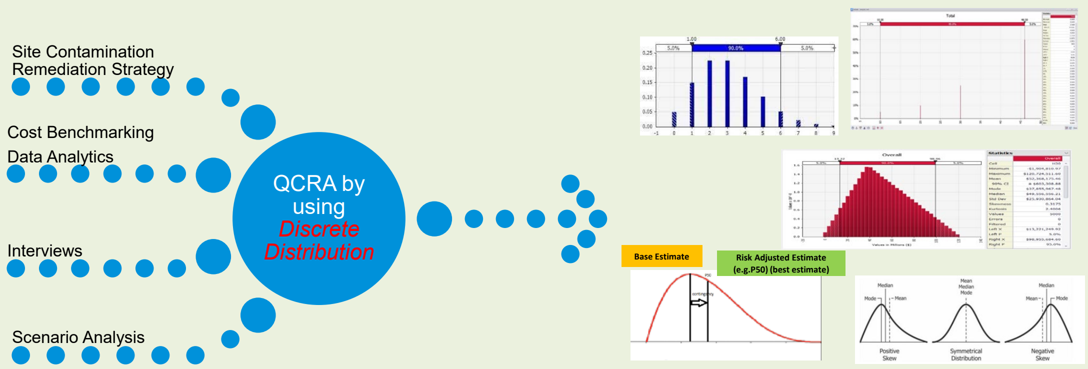
The estimate is rated as Unclassified or as Class 10 without any Expected Accuracy Ranges and P90 contingency. This is specifically used to distinguish these long-range estimates and indicate the order-of-magnitude difference in potential expected estimate accuracy due to the infrequent updates for scope and technology – this approach might not be acceptable for many owners especially for funding purposes from the government perspective

RES Example: ABC, an advisory consultancy, is currently preparing the Site Remediation Strategy Report for addressing environmental site contamination at three former gasworks sites in Victoria, Australia. As part of this report, an appropriate cost estimation (including contingency) should be prepared.

The investigation of soil, groundwater, surface water and sediment at the sites has been relatively limited and occurred many years ago. At the current stage, there is insufficient information available to make informed decisions regarding the longer-term requirements for remediating environmental contamination risks at the sites, the scope and options for undertaking remedial works that may be required, or the potential divestment and use of the sites for other purposes in the future.

At the current stage, there is insufficient information available to make informed decisions regarding the longer-term requirements for remediating environmental contamination risks at the sites, the scope and options for undertaking remedial works that may be required, or the potential divestment and use of the sites for other purposes in the future. Considering these, ABC defined this estimate as a Long-range / Unclassified / Class 10 Estimate. For undertaking the risk-adjusted estimate, ABC undertook:

- further research and cost benchmarking against similar contaminated site remediation for former gasworks sites
- develop a probabilistic decision tree with options and/or scenario variation branches.
    - Scenario 1: Public open space
    - Scenario 2: Cap & contain strategy
    - Scenario 3: Commercial/industrial use
    - Scenario 4: Divestment to council
- selection of the highest P90 of all branches selected as the estimated P90 for this ‘long-range estimate’



The contingency evolution curve (illustrated in Figure 8) emphasizes that as project scope becomes more defined, a narrower range of cost and time uncertainty emerges, leading to more reliable risk-adjusted contingency estimates. This curve demonstrates the correlation between scope development and the reduction in contingency over time.

Research shows that the level of scope definition, i.e. inherent risks (Section 4.3), is the dominant uncertainty in early phases, driving the need for significant contingency. At earlier stages, reference class forecasting and historical data from similar projects should be employed to establish appropriate contingencies. The level of technology and complexity are also major risk drivers that can be identified early, prior to each decision gate.

For most projects, the Base Estimate and Base Schedule evolve as the project progresses through various phases of its lifecycle and additional planning, engineering and design information become available. Revising and updating risk assessments at each decision gate allows for more accurate and responsive contingency allocations. Each possible outcome value of the total project cost can have a P value, or confidence level, which indicates the probability of underrunning that cost. For example, a P50 cost incorporates enough contingency for a 50% probability that the project will not overrun this cost.

As the Base Estimate changes, the estimated contingency requirements for different confidence levels also change. Ideally, the P50 or mean value of the cost distribution will stay constant from phase to phase. In practice, the P90 contingency generally decreases and the P50 contingency increases as the Base Estimate increases and further scope and uncertainties are defined and quantified. This is presented in Figure 9. Definitions of terms used above (including P values, Base Estimate and Base Schedule) are at Appendix A.

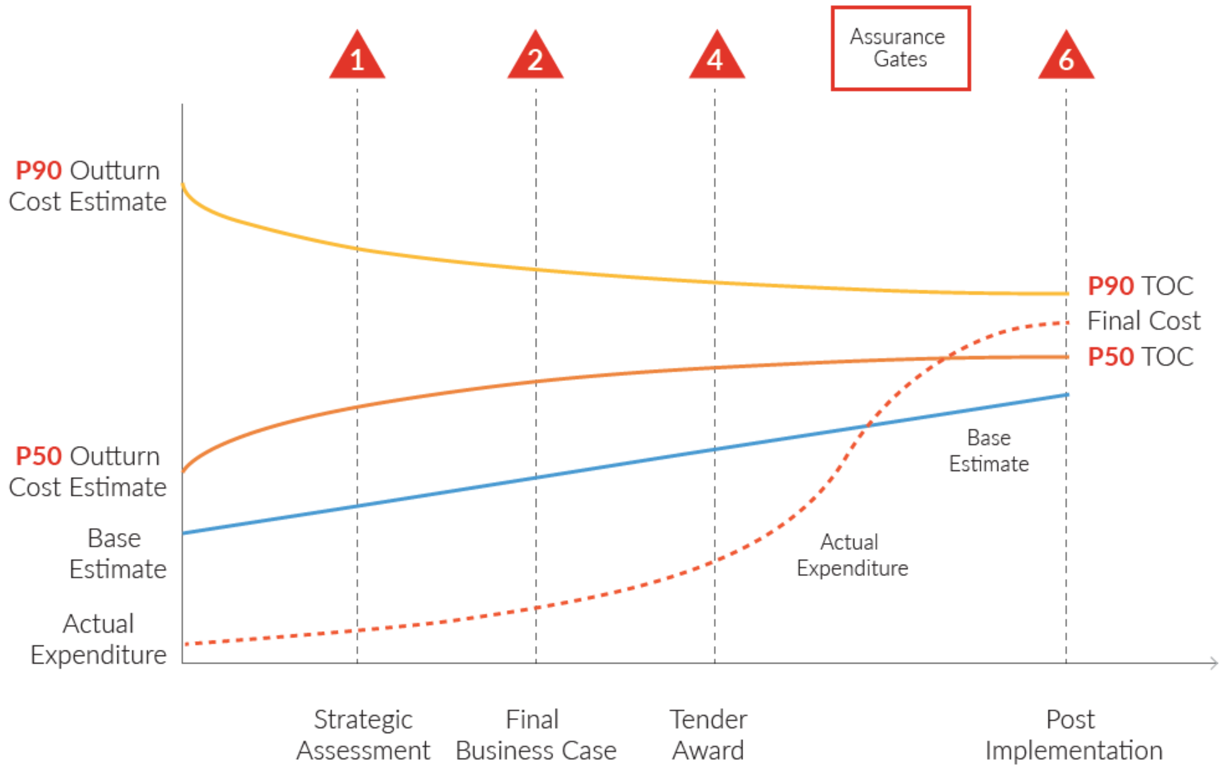


Figure 9: Cash flow and P(X) contingency movement in a typical successful project

It is common for owners to compare the project's Final Actual Cost against the project Total Outturn Cost (TOC) estimate (e.g. TOC P50 and TOC P90) in the Final Business Case (FBC). Three possible scenarios are presented in Figure 10. It should be noted that funding a project at P50-P80 is common in the private sector. For public projects, many government agencies might budget the project at P80/P90 level but only P50 funding will be available to the delivery agency. Access to additional funds, up to P80/P90 amount or beyond, will be subject to a change control process and an additional approval.

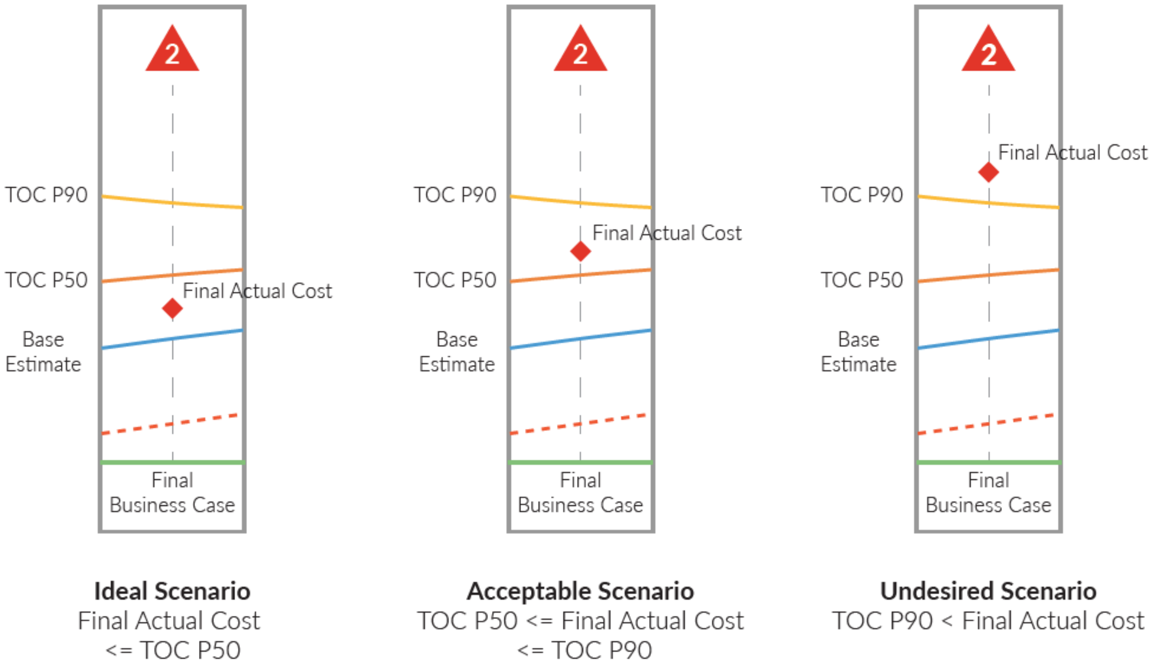


Figure 10: Three possible scenarios of Final Actual Cost against Base Estimate, TOC P50 and TOC P90

Further explanation of the scenarios in Figure 10 is below:

- **Ideal Scenario:** The project's actual cost is less than or equal to the TOC P50 estimate at the Final Business Case (FBC).
- **Acceptable Scenario:** The final actual cost does not exceed the initial Base Estimate plus the budgeted or allocated contingency (e.g., TOC P90). In this situation, any additional costs from risks that occurred or inherent risks are fully covered by the contingency reserve.
- **Undesired Scenario:** The final actual cost significantly exceeds both the initial Base Estimate and the budgeted or allocated contingency reserve (e.g., TOC P90). Despite not meeting cost and timeline expectations, the *Contingency Guideline* notes that such projects may still achieve important objectives, such as satisfying stakeholders, providing valuable community assets, or delivering non-financial community benefits.

In addition, it is important to evaluate the project schedule, and any risks associated with it at each phase of the project. Typically, the uncertainty in the schedule estimate is lower than the uncertainty in the cost estimate. This is partly because of the trade-off between cost and schedule. Often, the business complicates the completion date as the project progresses and new information about the project scope becomes available. As a result, costs tend to increase because achieving the project goals becomes more challenging over time.

3.4 Contingency at Program & Portfolio Level

One effective strategy is to conduct risk and contingency management at the project level, followed by assessing aggregate risks at the program and portfolio levels. This approach includes evaluating additional or secondary risks (e.g., compounding) at higher levels and integrating risk and contingency information. The interdependence of risks across projects necessitates a balanced approach that considers individual project risks alongside broader portfolio-level objectives, especially in organisations with complex project pipelines.

Research suggests that this approach is positively associated with program and overall project portfolio success and provides an effective platform to assess the organisation's risk exposure. Simultaneous risk and contingency management for projects and their parent programs ensure coordination between individual project risks and program-level objectives. This alignment allows for a more strategic allocation of contingency, supporting both project success and overall portfolio performance.

Periodic risk and contingency management at the portfolio level, aligned with overall capital management, offers additional benefits. Although reallocating contingencies between projects within a portfolio may be restricted, particularly in the public sector, having a structured approach for contingency assessment across all organisational levels is extremely valuable. This is especially necessary for programs where projects with common objectives are reported through a program director.

Overall, contingency management focuses on evaluating and utilising funds set aside to cover costs that exceed the Base Estimate across different organisational levels. This structured approach not only enhances the organisation's ability to manage risks effectively but also ensures that resources are optimally allocated to support both project-specific and broader strategic goals.

This is illustrated in Figure 11.

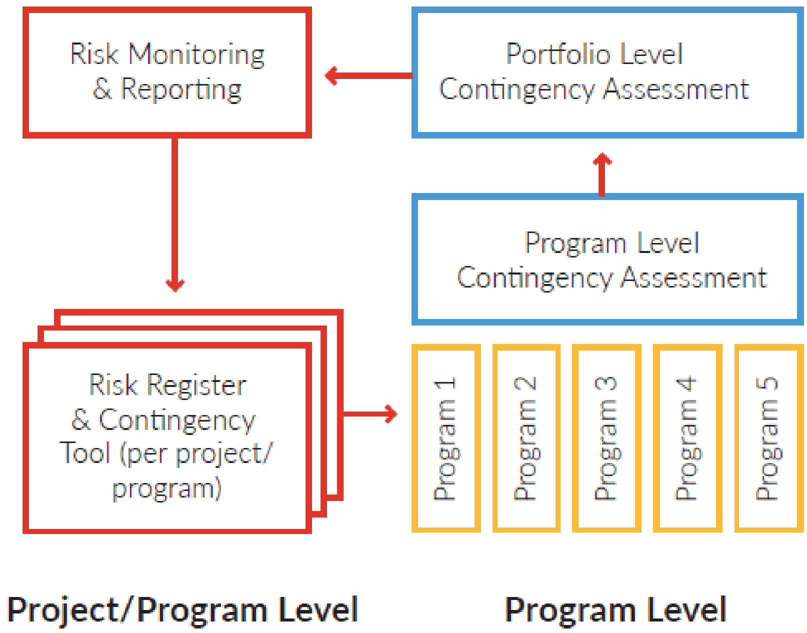


Figure 11: Contingency management at project, program and portfolio levels

RES Tips & Tricks: This Guideline also emphasises the importance of identifying and eliminating any hidden or visible contingencies within the Base Estimate or Base Schedule. To maintain project transparency and accuracy, it is crucial to avoid concealing cost and time contingencies within the base figures as a fallback, should the explicit contingency be underestimated or excluded from the project. Such hidden contingencies can mislead reviewers, creating a false impression that the budget has been inflated due to unwarranted allowances or reduced productivity. The recommended best practice is to ensure all contingencies are explicitly stated and documented, and thus RES does not endorse the use of hidden contingencies.

Contingency management at the project level often focuses on inherent risks from the project's perspective and individual risks that, if they occur, will require more funds or time than initially allocated in the Base Estimates. At the program level, considerations expand to include added or secondary risks arising from the interaction and/or compounding of the component projects.

From the standpoint of the program business sponsor and director, these additional risks need to be evaluated, and specific contingencies must be established to manage them. The program director or a similar authority should oversee this process. Contingencies for these risks should be assessed and managed alongside other relevant information to ensure that the organisation remains comfortably within its risk appetite, even as it considers adding new investments to the portfolio.

RES Recommendation: this Guideline recommends the following approaches when managing contingencies at the program or portfolio levels:

- Develop and implement a standard risk policy for scheduling, estimation, issues, and risk registers, and implement reporting cycles to ensure appropriate contingencies for the project while also considering program and portfolio objectives
- Implement a consistent approach to consolidate and integrate reports from projects to programs and portfolio (note: from a statistical viewpoint, be aware that only the mean value of distributions is additive in a program or portfolio, e.g. P50s are not additive)
- Assess interdependencies such as milestones and resources between projects
- Plan the consolidation of multiple projects using interface relationships (integrated schedule)
- Assess secondary risks (e.g. complexity) that may occur at the program and portfolio level
- Develop and implement a transparent view of issues, risks and change control at the project, program and portfolio levels.

Additional information and interaction risks that need to be assessed at the portfolio or program level may include:

- Risks affecting multiple projects due to their interdependencies, such as shared resources.
- The existing level of risk within the portfolio or program.
- The extent of over-programming.
- The need to provision for potential project cost overruns.
- Constraints on sharing funds between projects, such as Federal funding requirements.

When deciding to invest in a new project, it's important to consider that potential savings will not be realised until the project's completion. Figure 12 illustrates the interrelationship of risks at the project, program, and portfolio levels.

Figure 12: Interrelationship between risks from project to portfolio

Effective portfolio and program risk management involves several key steps:

- Assess all risks at the appropriate levels.
- Centralise risk reporting while keeping the risks and allocated contingencies of projects, programs, and portfolios distinct.
- Develop and implement effective metrics and matrices across all levels.

After these steps, the required overall contingency at the program level for the desired confidence level should be determined. Any surplus between the required overall contingency and the combined available project contingencies can be redirected to other beneficial initiatives.

It's also important to note that internal projects aimed at capability development, such as those managed by the Project Management Office (PMO) or initiatives to improve project management maturity, may be best handled at the portfolio level.

3.5 Program Portfolio Effect

It is theoretically possible to optimise the forecast portfolio return—or keep the risk as low as possible for a given return—by selectively allocating resources. Modern Portfolio Theory (MPT) highlights that diversifying risk across multiple projects within a portfolio can reduce overall risk exposure, leveraging the Portfolio Effect. This phenomenon, known as the Program Portfolio Effect, emerges from managing multiple projects concurrently.

The confidence level of each project, as well as the degree of correlation between projects, can influence the overall confidence level of the parent program. For sufficiently diversified programs, the combined risk tends to be lower than the risk associated with individual projects, allowing for more efficient use of contingency resources.

To fully leverage the Program Portfolio Effect, contingency allowances should be managed at the program or portfolio level. When some projects do not fully utilise their allocated contingencies, any surplus can be reallocated to other projects in need. By actively managing the Program Portfolio Effect alongside an efficient contingency management process, organisations can maintain a high confidence level at the program or portfolio level, even if the confidence levels of individual projects are lower. It is also imperative that the portfolio/program/project contingency are checked on a regular basis for alignment with the strategic contingency and the board's appetite.

Table 3 illustrates the portfolio probability for various numbers of projects, individual project probabilities, and two levels of project correlation. This data underscores the importance of strategic resource allocation and risk management to optimise overall portfolio performance.

One key takeaway from Table 3 is that the portfolio probability for an individual project with a 60% probability remains around 60%, whether there is '25% Correlation' or 'No Correlation,' regardless of the number of projects. This phenomenon occurs because there is no Program Portfolio Effect when projects are funded at the mean. In skewed distributions, the mean is generally greater than P50, with P60 being more typical. This observation underscores that the P50 (median) is not risk-neutral; rather, it is aggressive because the median does not adequately address the skewed reality.

		Portfolio Probability	
# Projects	Project Probability	No Correlation	0.25 Correlation
5	50%	38%	40%
5	60%	61%	59%
5	70%	80%	78%
5	80%	94%	92%
10	50%	32%	36%
10	60%	62%	61%
10	70%	87%	83%
10	80%	98%	96%
20	50%	24%	32%
20	60%	65%	61%
20	70%	94%	86%
20	80%	99%	98%

Table 3: Portfolio probabilities for different levels of project correlation (AFCAA, 2007)

Another important aspect is the impact of reducing individual project probabilities on the overall portfolio probability. A decrease from 60% to 50% project probability for portfolios containing 10 or 20 projects results in a reduction of portfolio probability by 25% and 29%, respectively. This illustrates that even small increases in project risk exposure can significantly decrease the likelihood of meeting funding levels at the portfolio level.

According to the US Air Force Cost Analysis Agency (AFCAA) Handbook (2007), the mean is greater than the median for approximate lognormal uncertainty distributions, leading to low portfolio probabilities for 50% project probability. Therefore, increasing project probability to 60% (which is usually close to or greater than the mean) can elevate portfolio probabilities above the 50% level. Since the median is always lower than the mean, funding projects at 50% results in weak portfolio probabilities. RES suggests that funding projects at 60% (generally near or above the mean) can achieve portfolio success rates above 50%. While raising project probability above 70% can improve portfolio probabilities, it is costly. AACE International defines contingency as "expected to be expended," implying that the expected value is the mean (refer to Hamaker's paper in the Further Reading section for more information).

Figure 13 demonstrates that the program confidence level surpasses individual project confidence levels when project probabilities are greater than 50%. This confidence level continues to rise with the number of projects in the program, highlighting the benefits of strategic resource allocation and risk management.

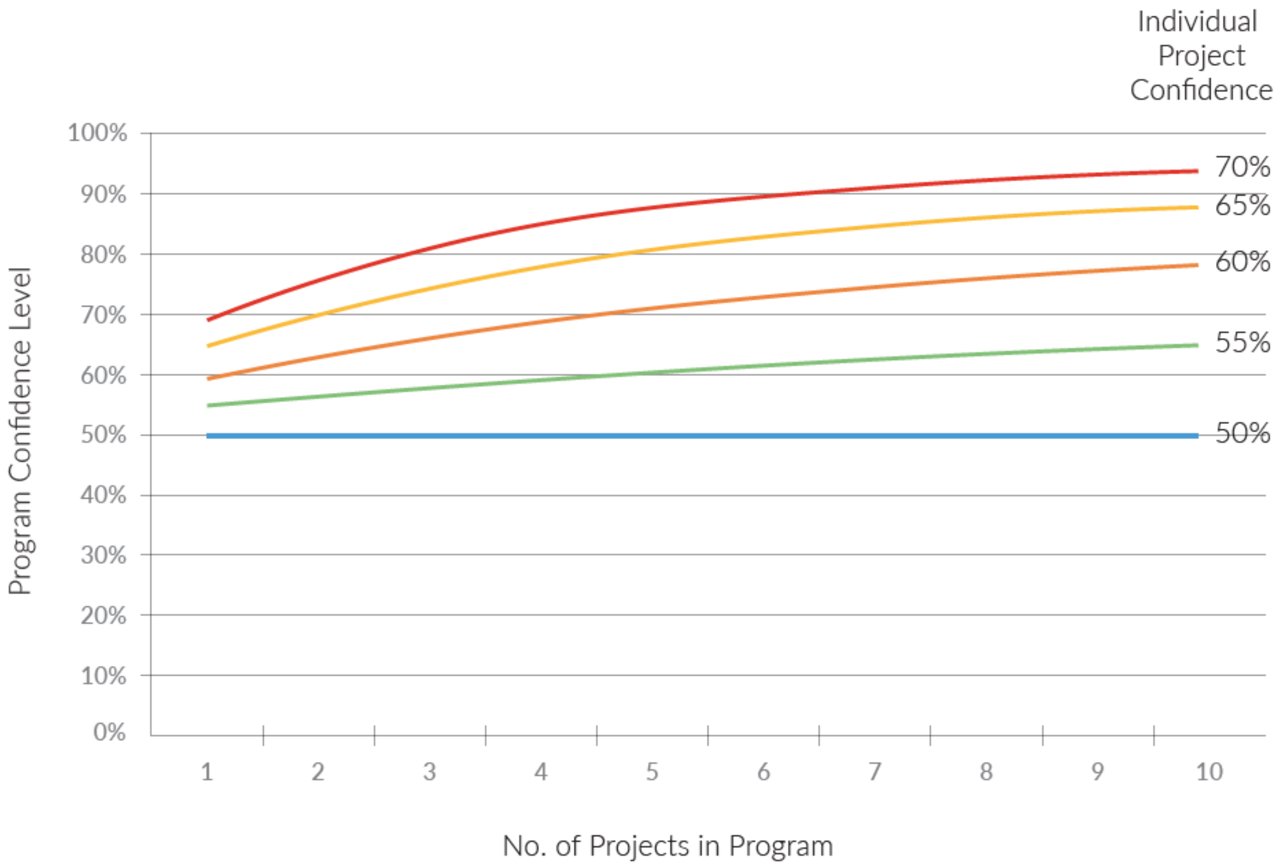


Figure 13: Portfolio probabilities for multiple projects (AFCAA, 2007)

RES Example: ABC, a government agency, is currently managing a portfolio of 20 projects, divided across four separate programs. While funding can be reallocated between projects within each program, it cannot be transferred between programs. The latest progress reports are below:

- Program 1: Comprising 10 projects, each with a remaining P80 contingency of $2 million (totaling $20 million).
- Program 2: Comprising five projects, each with a remaining P80 contingency of $1 million (totaling $5 million).
- Program 3: Comprising two projects, each with a remaining P80 contingency of $5 million (totaling $10 million).
- Program 4: Comprising three projects, each with a remaining P80 contingency of $2 million (totaling $6 million).

The total required contingencies suggest a P80 contingency of $41 million. However, to maximise opportunities for additional projects, ABC developed an integrated risk and contingency assessment platform across the entire portfolio rather than simply summing the project contingencies. This assessment revealed that a contingency of $37 million would be sufficient for an 80% confidence level (P80) at the portfolio level.

This assessment allowed ABC's management to proactively plan to utilise the surplus contingency of $4 million (i.e., $41 million minus $37 million) to advance one additional project within Program 3. As a result, Program 3 will now include three projects.

3.6 Strategic Contingency

In organisations that adopt a framework based on Portfolio Program Project concept and enterprise risk management, the contingency is subject to the same governance as risk and opportunity management. The Figure 14 Strategic Contingency/ Board risk appetite shows the interdependence between the strategic contingency and the board appetite.

Ultimately the risk appetite established by the board of the organisations must inform the strategic contingency of the organisation and the allocation and use of contingency necessary for management of projects, programs and portfolios.

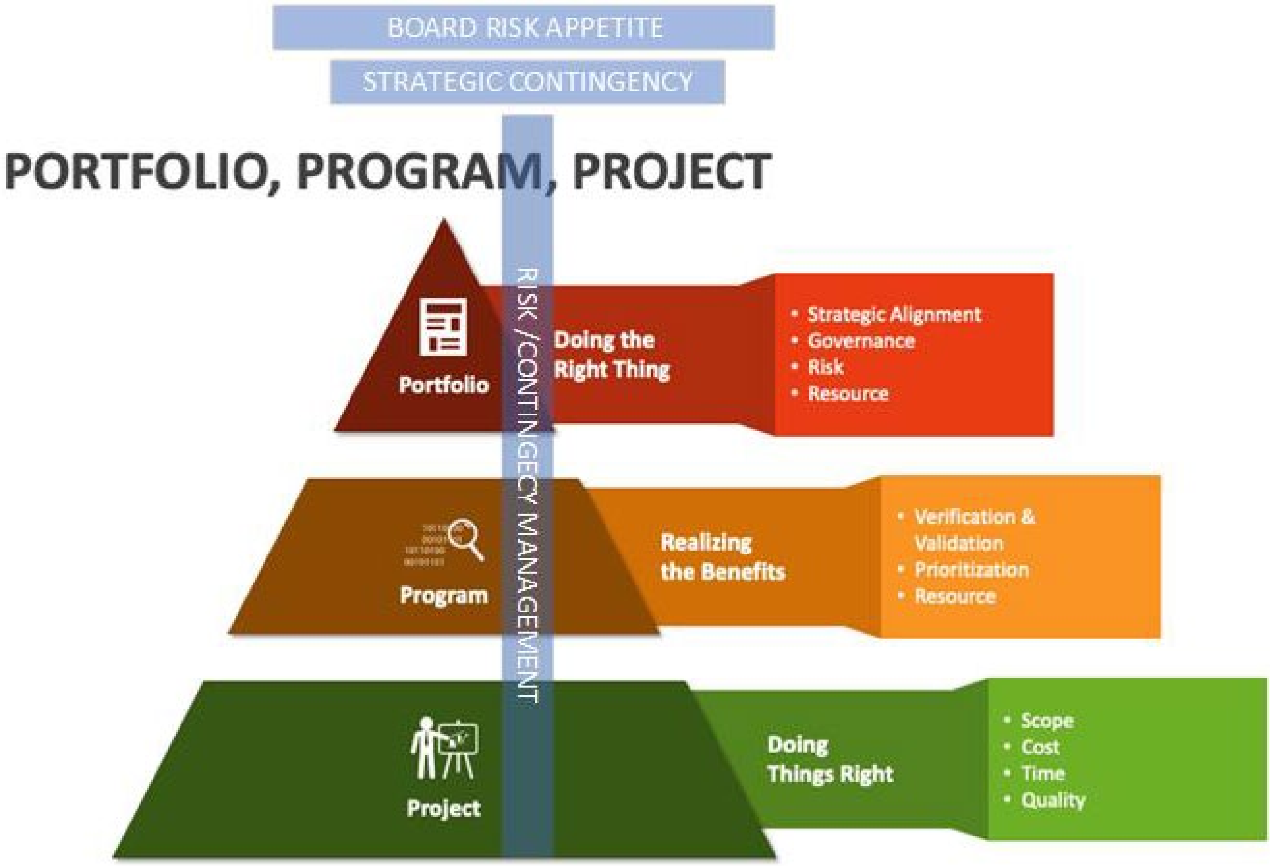


Figure 14: Strategic Contingency / Board risk appetite

3.7 Further Reading

- AACE International RP No. 17R-97 – *Cost Estimate Classification*
- AACE International RP No. 18R-97 – *Cost Estimate Classification System – As applied in engineering, procurement, and construction for the process industries*
- AACE International RP No. 27R-03 – *Schedule Classification System*
- AACE International RP No. 40R-08 – *Contingency Estimating – General Principles*
- AACE International RP No. 46R-11 – *Required Skills and Knowledge of Project Cost Estimating*
- AACE International RP No. 62R-11 – *Risk Assessment: Identification and Qualitative Analysis*
- AACE International RP No. 63R-11 – *Risk Treatment*
- AACE International RP No. 67R-11 – *Contract Risk Allocation As Applied in Engineering, Procurement and Construction*
- AACE International RP No. 70R-12 – *Principles of Schedule Contingency Management – As Applied in Engineering, Procurement and Construction*
- AACE International RP No. 71R-12 – *Required Skills and Knowledge of Decision and Risk Management*
- AACE International RP No. 72R-12 – *Developing a Project Risk Management Plan*
- AACE International RP No. 75R-12 – *Schedule and Cost Reserves within Framework of ANSI EIA-748*
- AACE International PGD 01 – *Guide to Cost Estimate Classification Systems* <library.AACE International.org/pgd/pgd01.shtml>
- AACE International PGD 02 – *Guide to Quantitative Risk Analysis* <web.AACE International.org/resources/publications/professional-guidance-documents>
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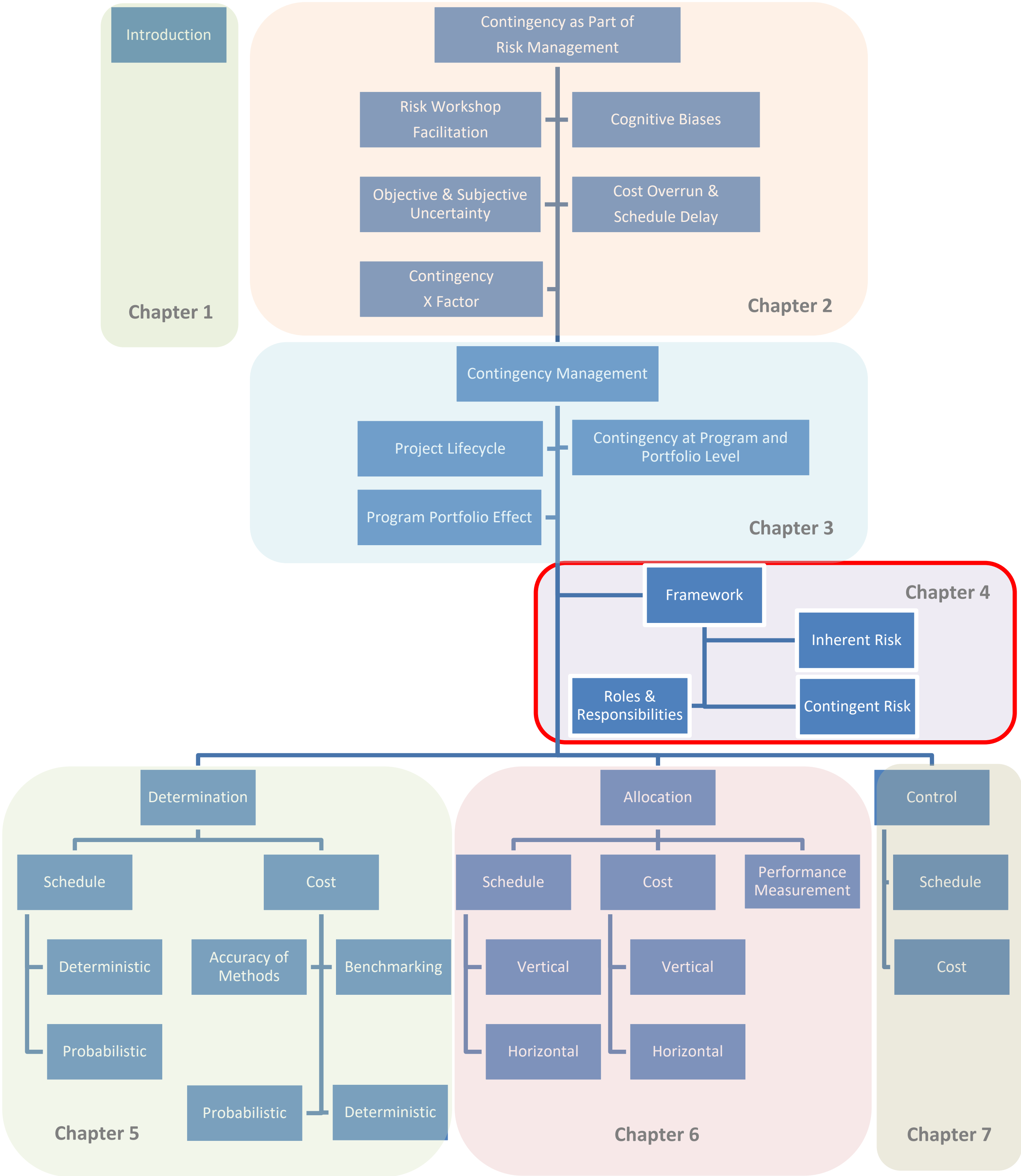
4. Contingency Management Framework

4.1 Structure of Content



4.2 Overview

The primary purpose of the contingency management framework is to serve as a reference document that ensures a consistent, structured and quantitative approach to analysing, determining, allocating, and managing appropriate and reasonable contingency allowances (both time and cost) at various stages of the project lifecycle. It also addresses the risks facing the project, the organisation's risk tolerance, and the Delegation of Authority (DoA) at different organisational levels. The framework outlines a consistent methodology for aggregating contingency data from individual projects to the program level and consolidating it at the portfolio level.

RES Recommendation: for an effective contingency management framework, within an overall risk management framework RES recommends that the key sections below are included within the framework:

a) Objectives
b) Scope, e.g. specific project, program/department or across the organisation
c) Key Definitions, including inherent and contingent risks
d) Internal and external constraints and requirements, e.g. funding allocation, reporting, assurance gates, contingency accessibility and Delegation of Authority (DoA)
e) Scope/Cost/Schedule/Risk/Change Integration Process
f) Roles and responsibilities (Responsible, Accountable, Consulted, Informed (RACI) Matrix)
g) Contingency Determination
h) Contingency Allocation
i) Contingency Controls
j) Monitoring and reporting
k) Tools and infrastructure.

A risk-adjusted approach to contingency management enables more accurate cost and schedule forecasting throughout the project lifecycle, addressing both known risks and residual uncertainties. This framework should integrate both historical data and expert insights, ensuring a balance between empirical data-driven methodologies and quantitative risk assessments.

When selecting a preferred contingency management approach or methodology, a wide range of factors should be considered, including the key elements listed below:

- Complexity of the project or program
- Level of investment assessment (e.g., project or program level)
- Availability and accuracy of information, historical data, combined with reference class forecasting where applicable
- Project and risk management maturity level of the organisation
- Delivery strategy and type of contract, such as:
    - Managing contractor
    - Early contractor involvement
    - Design and construct or construct only
    - Public-private partnership
    - Alliance
    - Joint venture
- Type of project, for instance:

  - Defence
  - Communications
  - Events
  - Organisational change
  - Infrastructure projects
  - Facility management projects, including decommissioning, demolition, or maintenance
- Project classifications:
  - Minor projects (value less than $10 million)
  - Major projects (value more than $10 million)
  - Complex projects (exceptional projects with unique risk profiles)
  - Mega projects (value greater than $1 billion)
- Maturity of risk management systems, use of probabilistic methods for assessing uncertainty, and contingency management at the portfolio level
- Stage of the investment lifecycle, whether strategic, final business case, delivery, or finalisation
- Level of investment, whether at the project, program, or portfolio level)

4.3 Inherent & Contingent Risks

For the purposes of this *Contingency Guideline*, inherent and contingent risks are defined according to the NASA Cost Estimating Handbook (Version 4, Appendix G). Different types of risks require different quantification methods for optimal outcomes, making it crucial for risk practitioners to distinguish between them. This ensures that the risk model and plan incorporate appropriate assessments for risk and uncertainty.

Inherent Risks (or Planned Risks or Uncertainty Risks)

Inherent risks include systemic risks, which acknowledge the interconnected nature of projects and their management systems. A system—comprising processes, people, tools, and resources—is only as strong as their component parts and the cohesion between them. If a system is weak, it can fail in multiple ways, making it challenging to allocate contingency effectively.

Many of the cost impacts of risk events on large and complex projects arise from the cost consequences of delays or disruptions. The trade-off between cost and schedule can be particularly problematic, such as spending money to prevent schedule slippage. When modelling the uncertainty of project schedules and costs, it is important to consider all possible drivers, including risks that impact schedules, and to assess cost and schedule risks together. Project cost drivers can be grouped into five types:

- Uncertainty (i.e., inherent risk or planned risk) around time-independent costs
- Uncertainty (i.e., inherent risk or planned risk) around time-dependent costs
- Uncertainty (i.e., systemic risks) of the project system with non-attributable cost and time impacts
- Risk Event (i.e., contingent risk or unplanned risk) with cost impacts
- Risk Event (i.e., contingent risk or unplanned risk) with time impacts that drive costs

Inherent risks stem from the inability to be certain about the nature and behaviour of the project system and its interaction with external economic, political, and other systems. The likelihood of the occurrence of inherent risks is 100%.

Practitioners should determine probability distributions used to model inherent uncertainty by considering prior experiences of comparable teams on similar projects, supplemented with historical data. Fortunately, many drivers of inherent risks—such as the level of scope definition and team development—are generally consistent across projects, and the uncertainty resulting from these drivers tends to be predictable (e.g., similar poor team development results under comparable uncertainty conditions across projects).

In the early phases of the project lifecycle, empirically based models of inherent risks are often more reliable than team judgement or a limited database (if a risk database is available). Examples of inherent risks include non-uniform construction techniques, pricing and scope uncertainties, and uncertainty over the amount of resources and their cost per unit in the Base Estimate. While these are identifiable technical causes, a more significant concern is the uncertainty about how the system will behave—particularly under the stress of risk events and when compounded by weak practices, skills, and knowledge.

Figure 15 presents two probability distributions (Normal and Triangular) representing point estimates of individual project Work Breakdown Structure (WBS) cost elements. Highlighted on the distributions are the mean (50th percentile), median (expected value), and mode (most likely value).

This version enhances readability and clarity, making the information easier to follow while ensuring all key points are effectively communicated.

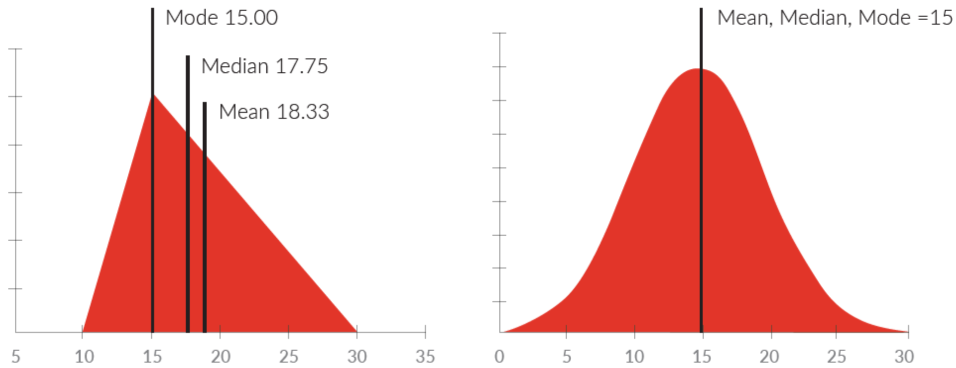


Figure 15: Statistics of Triangle and Normal distributions (NASA Cost Estimating Handbook)

The Central Limit Theorem (CLT) states that the sum of many independent random variables, each with a finite mean and variance, will approximate a normal distribution when averaged. Consequently, the probability of distribution for the combined cost of an increasing number of Work Breakdown Structure (WBS) items can be approximated by a normal distribution, as illustrated in Figure 16.

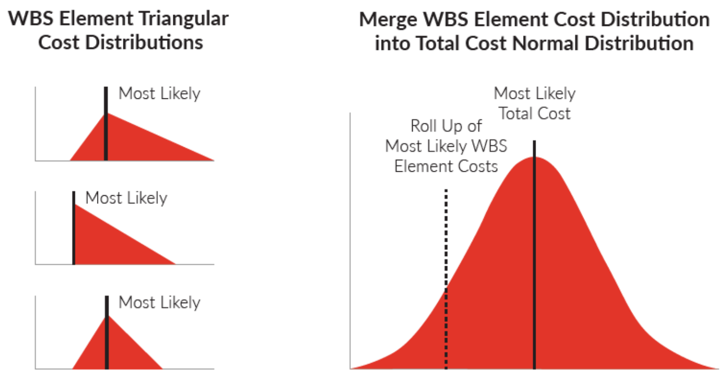


Figure 16: Central Limit Theorem (NASA Cost Estimating Handbook)

The commonly used probability distributions for assessing inherent risks are the Triangular, Normal, PERT, and Lognormal (or their alternative formats) distributions. Both the Triangular and PERT distributions can be defined with three-point estimates, making them widely used in practical risk analysis. In the Monte Carlo Simulation technique, a Triangular distribution requires three inputs: best case (lowest), most likely, and worst case (highest). These inputs can be generated either objectively or subjectively; the objective method defines a probability distribution for each WBS (Work Breakdown Structure) element using these three cost elements, while subjective inputs can be based on expert elicitation by SMEs (Subject Matter Experts, see Section 2.3.2).

It should be noted that many risk analysts prefer to use the alternative formats of Triangular and PERT distributions to address the potential overestimation of best-case scenarios and underestimation of worst-case scenarios.

To represent a broader range of possible outcomes, risk practitioners can adjust the extremes of PERT or Triangular distributions. When the standard deviation and mean are known, practitioners may prefer to use Normal and Lognormal distributions (as shown in Figure 17). This approach does not require best-case or worst-case inputs.

The Lognormal distribution, which cannot go below zero and is asymmetrical, is generally preferred over the Normal distribution by many risk analysts. This preference arises because inherent uncertainties and risks have natural lower bounds at zero. For example, if the Base Estimate assumes three lost days per month due to rain, the best case is zero lost days. However, the worst case could be as many as 30 lost days, a scenario that is skewed similarly to the Lognormal distribution.

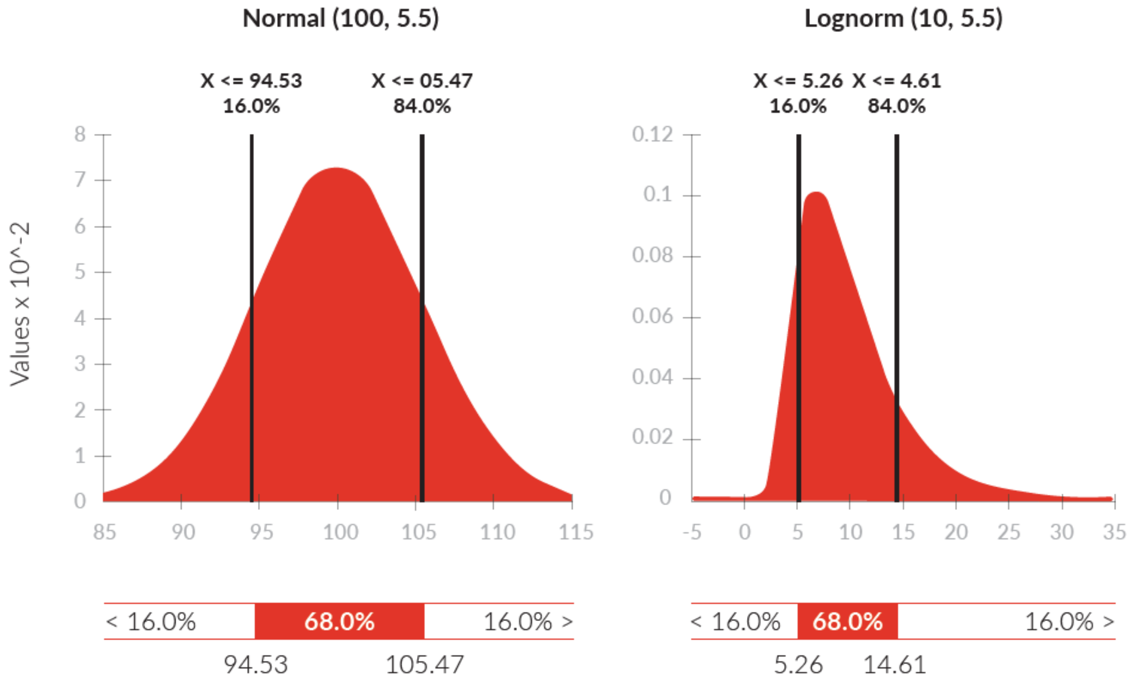


Figure 17: Normal and Lognormal distributions (NASA Cost Estimating Handbook)

Contingent Risks (or Unplanned Risks or Event Risks)

In contrast to inherent risks, contingent risks are generally caused by events or conditions not included in the Base Estimate or Schedule. While inherent risks have a 100% likelihood of occurrence, contingent risks may or may not occur, meaning their likelihood of occurrence is always less than 100%, their cost and/or schedule impact is always greater than zero (noting that the net schedule impact on critical path might be zero if the risk does not affect a critical activity). Examples of contingent risks include delays, or cost increases due to unforeseen bad weather, industrial action, planning approval issues, scope variations, and unexpected site conditions discovered by geotechnical experts. Potential unsubstantiated claims from contractors, which do not result from specific risk events or conditions, are also considered contingent risks.

To realistically assess the various drivers of cost and schedule uncertainty, these drivers should be integrated into a single model—or an integrated set of models—that addresses each type of risk. This approach allows all effects to be simultaneously modelled, enabling the identification and ranking of drivers so that risks can be effectively managed. The selection of the most appropriate approach depends on several factors, including but not limited to:

a) project phase
b) contract type
c) delivery strategy (e.g. self-delivery or subcontracting)
d) internal and external requirements
e) constraints
f) project risk profile
g) organisational risk appetite, contingency management maturity.

RES Tips & Tricks: If all random variables have the same distribution and are perfectly correlated, the percentile of the sum (e.g., the sum of P90s) of each individual project will be the same as the sum of the percentiles (e.g., P90 of all projects combined as a program). In practice, however, this scenario is rare. Therefore, we generally expect the sum of P90s to be greater than the overall P90. This principle also applies when modelling inherent and contingent risks. To determine an optimal contingency allowance, RES recommends assessing both inherent and contingent risks together to calculate the optimum overall contingency.

In addition to the definitions of inherent and contingent risks, several other relevant terms are commonly used in the industry, including "unknown unknowns" or unidentified risks. Traditionally, unknown unknowns have been considered outside the scope of project risk management. However, this *Contingency Guideline* recommends using the definitions provided in Table 4 to consistently integrate these risks into the organisation's risk management framework.

RES also acknowledges that some practitioners argue there are no truly unknown unknown risks, as all risks have materialised in some form in the past. These practitioners believe that unknown unknowns are simply risks that the project team has chosen not to quantify.

Certainty / Identification	Known (i.e. certain)	Unknown (i.e. uncertain)
Known (i.e. identified)	Known Known (i.e. identified knowledge)	Known Unknown (i.e. identified inherent & contingent risks)
Unknown (i.e. unidentified)	Unknown Known (i.e. unidentified knowledge)	Unknown Unknown (i.e. unidentified inherent & contingent risks)

Table 4: Combination of known and unknown uncertainties, ref: Kim, S. D. 2012, PMI Global Congress 2012

		Base Estimate	Inherent Risk	Contingent Risk	Contingency Reserve (CR)	Management Reserve (MR)	Examples
Known	**Known**	X					Cost estimation of a foundation excavation by measuring its size using concept design and current productivity rate assumptions
	Unknown	X	X	X	X		Volume of rock due to lack of geotechnical information. It should be noted that some allowances may be included within the Base Estimate to represent the uncertain, but specific items
Unknown	**Known**			X	X		Possibility of hitting a live electrical cable due to lack of as-built drawings and brownfield nature of project
	Unknown					X	Hurricane Katrina in 2005, COVID in 2019 Also noting that management reserve might be excluded from the project budget.

Table 5: Indicative addressing of known and unknown uncertainties at different allowances for optimum contingency

From the contingency calculation perspective, the indicative approach in Table 5 (above) for assessing and allocating risks and uncertainties against different buckets (i.e. Base Estimate, Inherent Risk, Contingent Risk, CR and MR) can be used to address both identified and unidentified risks while assessing optimum contingency allowance.

While management reserve can be allocated to manage unknown unknowns, RES recommends that the team should aim to convert unknown unknowns to known unknowns through the characterisation of relevant unknown unknowns. This allows these risks to be incorporated into the organisation’s established risk and contingency management processes.

In some circumstances, these risks could be also defined as ‘exclusions’ in the contingency determination process, which would then create a pool of events that contingency has not been allowed for. Hence, these risks would need to be managed externally to the project funding / budget.

As the project progresses through its lifecycle, it is quite common to see changes in the size of the respective contributions of inherent and contingent risks to the required contingency allowance. In the early stages of development, the inherent risks are key drivers (e.g. 60-70%) of required contingency, while contingent risks will be the key drivers at the delivery stage

RES Example: contractor W2F is preparing its submission for a lump sum tender. All packages will be delivered using external subcontractors. In addition to obtaining a number of market quotes, W2F is also using its own internal benchmark data from previous similar projects. As part of the estimate development, W2F assessed and quantified the inherent and contingent risks as per the table below.

Discipline Package	**Quote 1**	**Quote 2**	**Quote 3**	**Internal Benchmark**	**Final Decision**
Design	$500k	$1m	-	$600k	$600k @ Base Estimate with the inherent risk below: Best Case = $500k Most Likely = $600k Worse Case = $1m
Civil Works	$15m	$16m	$20m	$15m	$16m @ Base Estimate with the inherent risk below: BC = $15m ML = $16m WC = $20m
Structural Works	$10m	$12m		Not Available	$10m @ Base Estimate, with possible contingent risk for claim, 50% probability with $2m cost
Mechanical Works	$5m	$7m	$10m	$12m	$12m @ Base Estimate, with possible contingent opportunity for saving, 70% probability (because all three quotes are less) with $2m-$5m-$5m saving. Considering the scope of works, Quote 1 is unrealistic and was excluded.
Electrical Works	$5m	-	-	$7m	$5m @ Base Estimate, with possible contingent risk for claim, 50% probability with $2m additional cost
Internal Resources				$1m	$1m @ Base Estimate with the inherent risk below: Best Case = $$800k Most Likely = $1m Worse Case = $1.5m
Contingency				?	All inputs above should be used to assess the required contingency allowance

4.4 Contingency Management Process Overview

The alignment of risk treatment and contingency management throughout the project lifecycle enhances the value of project risk management. A structured process that integrates contingency management into every stage of the project lifecycle increases confidence in achieving project outcomes.

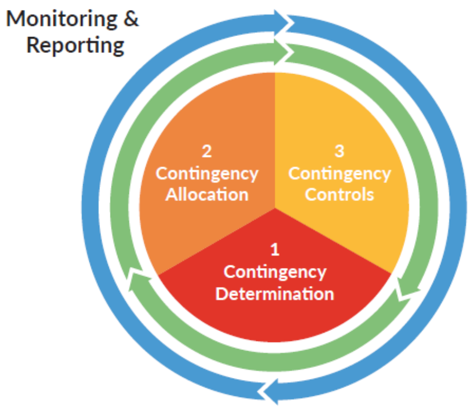


Figure 18: The overall process of the contingency management framework

The overall process (Figure 18) has three key areas, which are applied at various stages throughout project lifecycle:

a) Contingency determination – How much contingency is enough for the desired confidence level?
b) Contingency allocation – Guidance on how to allocate contingencies within the project and at different organisational levels
c) Contingency controls – Guidance on measures to monitor and control contingency use

Figure 19 represents an example of a high-level integrated approach to contingency management applying both quantitative and qualitative techniques, during the project development and delivery phases. The process should be adaptive to new data inputs, allowing for adjustments in contingency allocation as risks are better understood.

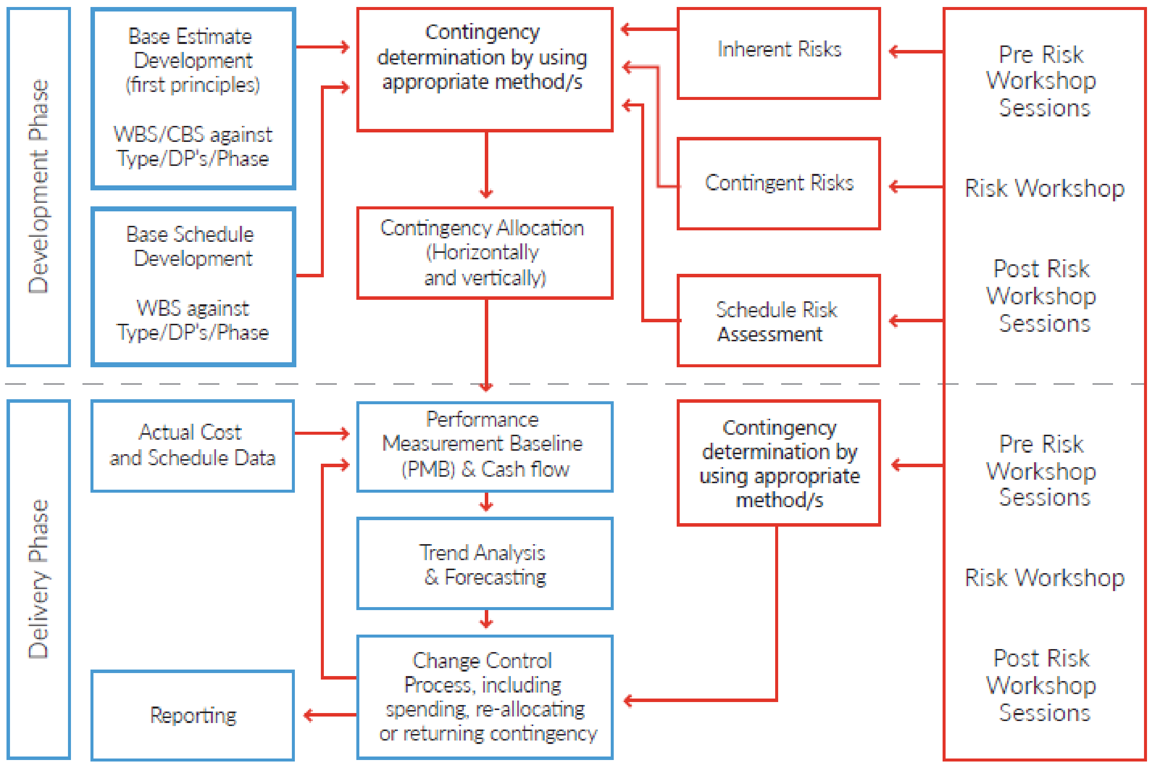


Figure 19: A typical high level contingency management process

4.5 Roles & Responsibilities

The contingency management process involves many teams and stakeholders. For transparency and accountability, a RACI (Responsible, Accountable, Consulted and Informed) Matrix is recommended. This matrix defines the roles and responsibilities of stakeholders in the contingency management process, ensuring clear communication of duties. The red highlighted boxes and interfaces in Figure 19 illustrate the responsibilities of the risk practitioner, including:

- Facilitating risk workshops
- Capturing data inputs for risk modeling
- Developing quantitative risk models
- Reporting on contingency use and adjustments

RES Example: risk related roles in a construction project

A new office building is being constructed in an urban area, involving several phases from planning to completion. The project has multiple stakeholders, including the construction company, subcontractors, finance team, and city regulators. Risk Management Plan has the RACI below.

Task	**Project Manager**	**Risk Manager**	**Construction Team Leaders**	**Finance Team**	**Subbies**	**City Regulators**	**Client**
Risk Workshops	A	R	C	I	C	I	I
Data Inputs for Risk Modelling	A	R	C	I	C	I	I
Developing Quantitative Risk Models	A	R	C	I	I	I	I
Reporting on Contingency Use	A	R	C	I	I	I	I
Implementing Mitigation Strategies	A	R	R	I	R	I	I
Approving Contingency Adjustments	A & R	C	I	C	I	I	I

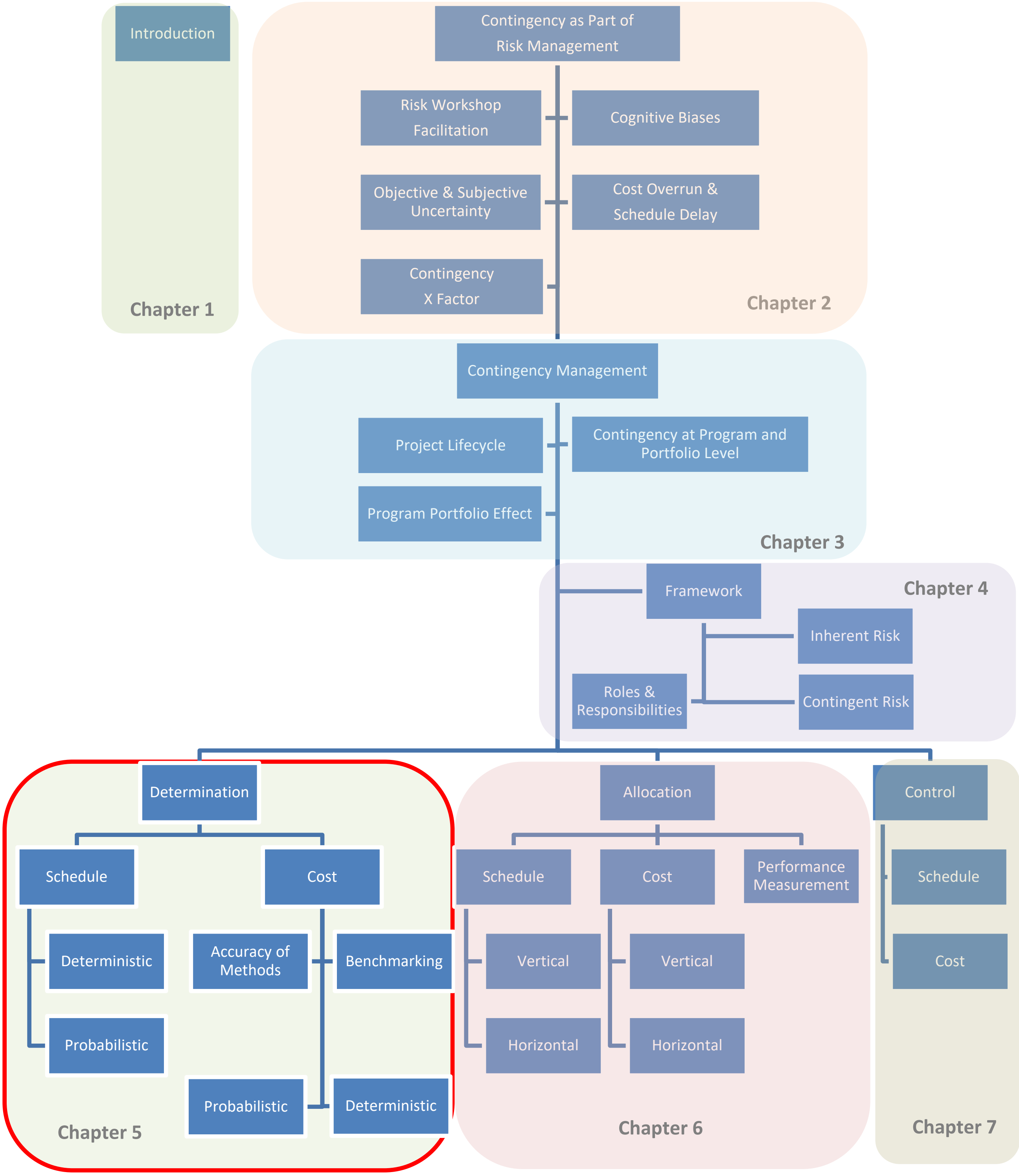
4.6 *Relevant Qualifications and Certificates*

There are a wide range of qualifications and certificates enabling the risk analyst to undertake the required roles and responsibilities, as highlighted in the previous section. Some of these relevant qualifications and certificates are:

- Contingency Masterclass (4-day online training program) and Contingency Management Professional (CMP) Certificate, by Risk Engineering Society (RES) and Western Sydney University, Risk-based Contingency Management Masterclass | Western Sydney University
- Chartered Professional Engineer (Risk Engineering or Cost Engineering), Engineers Australia
- Certified Cost Technician (CCT), Certified Scheduling Technician (CST), Certified Cost Professional (CCP), Certified Estimating Professional (CEP), Earned Value Professional (EVP), Planning & Scheduling Professional (PSP), Certified Forensic Claims Consultant (CFCC), Decision & Risk Management Professional (DRMP), Project Risk Management Professional (PRMP), AACE International
- Project/Program/Portfolio Management Professional (PMP, PgMP, PfMP), Certified Associate in Project Management (CAPM), PMI Risk Management Professional (PMI-RMP), PMI Scheduling Professional (PMI-SP), PMI Agile Certified Practitioner (PMI-ACP), Project Management Institute
- International Certificate in Financial Services Risk Management, International Certificate in Enterprise Risk Management, International Diploma in Enterprise Risk Management, Digital Risk Management Certificate, Institute of Risk Management
- IPMA: International Project Management Association (International Project Management Association) Levels A, B, C and D
- PRINCE2 Foundation and Practitioner
- PRINCE2 Agile Foundation and Practitioner
- 10131NAT Certificate IV in Compliance & Risk Management
- 10184NAT Graduate Certificate in Compliance & Risk Management
- Certified Construction Auditor (CCA) and Construction Control Professional (CCP), National Association of Construction Auditors
- Master of Risk Management (MRM), various universities
- Certified in Risk and Information Systems Control (CRISC), ISACA
- Certified Risk Management Professional (CRMP) and RMCP, RIMS (Risk and Insurance Management Society, Inc.)
- Operational Risk Management Certificate, Global Association of Risk Professionals (GARP)
- Certificate in Quantitative Finance (CQF)
- ISO 31000 Risk Management Certification
- Lean Six Sigma Certification (Yellow, Green, Black Belt)
- Construction Risk and Insurance Specialist (CRIS)
- Certified Business Continuity Professional (CBCP), DRI International (Disaster Recovery Institute) (DRI)
- Certificate in Risk Management Assurance (CRMA), IIA-The Institute of Internal Auditors (IIA)

5. Contingency Determination

5.1 Structure of Content



5.2 Overview

Contingency is never a substitute for proper cost estimating or project planning and scheduling. It must not be added to the Base Estimate in budgets, cost plans, forecasts or the Base Schedule as a replacement for sound, well-founded cost estimating and planning or scheduling.

Contingencies must align with the residual risks in the project's estimated solution and the project's cost estimation and schedule development method. They should be as specific as possible and should match the level of project definition and solution development at each decision gate. At the point of approval, that definition should be fully developed with comprehensive and thorough cost and schedule planning. The primary objective of any contingency management framework is to establish clear procedures that apply to the governance, assessment, allocation and release of contingency.

Even if the contingency determination is based on empirically derived models, any assessed contingency should be verified against appropriate internal and external benchmarks where possible. Multiple risk-based approaches exist for assessing contingency, each with varying degrees of complexity. The appropriate method should be selected based on a range of internal and external factors including:

a) external requirements (e.g. regulations and investment criteria)
b) stage of the investment lifecycle
c) project value and risk profile
d) extent of development of design and scope definition
e) project complexity
f) organisation's strategic objectives
g) organisation's maturity in project, risk and contingency management
h) current risk exposure against the organisations's risk appetite, tolerance and capacity
i) organisation's track record on similar projects
j) market conditions and competition landscape.

If the organisation selects the most appropriate quantitative risk analysis (QRA) method for each set of circumstances, it should address the following five sources of risk:

a) inherent risks associated with the cost estimating and scheduling methodologies
b) inherent risks associated with the technical and programmatic aspects of the system or project being developed, (i.e. systemic risks)
c) contingent risks associated with the key internal and external interfaces
d) inherent risks in the correlation between WBS elements or contingent risks, and
e) specific risks relevant to the project.

RES Recommendation: to improve efficiency, risk and uncertainty data should be collected and assessed for contingency determination. This allows time for modifications and improvements to the plans, and to conduct re-assessments before the decision gate. However, bias in the Base Estimate (which is always present to some extent) must be assessed and addressed using estimate and schedule validation. Hence, RES recommends that the bases should be fully documented and completed before the risk and contingency assessment can be finalised and completed.

5.3 Schedule Contingency Determination

As illustrated in Figure 20, the most common methods for schedule contingency determination are divided into two groups: deterministic and probabilistic. Note that RES **does not recommend** calculating the schedule contingency determination separately to cost contingency. Analysis should always be integrated. This makes it easier to read the discrepancies and correlations between the schedule and cost contingency determination methods. It should be noted that there are also hybrid approaches (i.e. combination of multiple methods or parametric or other to address some deficiencies of various individual methods).

RES strongly recommends an integrated analysis of cost and schedule risk using methodologies like Monte Carlo simulation. This allows for a more holistic view of project risks by linking schedule risks to cost drivers, ensuring interactions between time and cost are effectively captured. Hybrid approaches (i.e. combination of multiple methods, parametric, or others) may be useful to mitigate deficiencies in individual methods.

It should be also noted that different software solutions might use a combination of these methods of schedule contingency determination, e.g. AI-based and Quantitative Schedule Risk Analysis (QSRA). Organisations / Projects are strongly encouraged to carefully assess the capabilities and suitability of each schedule contingency determination solution against their context and requirements.

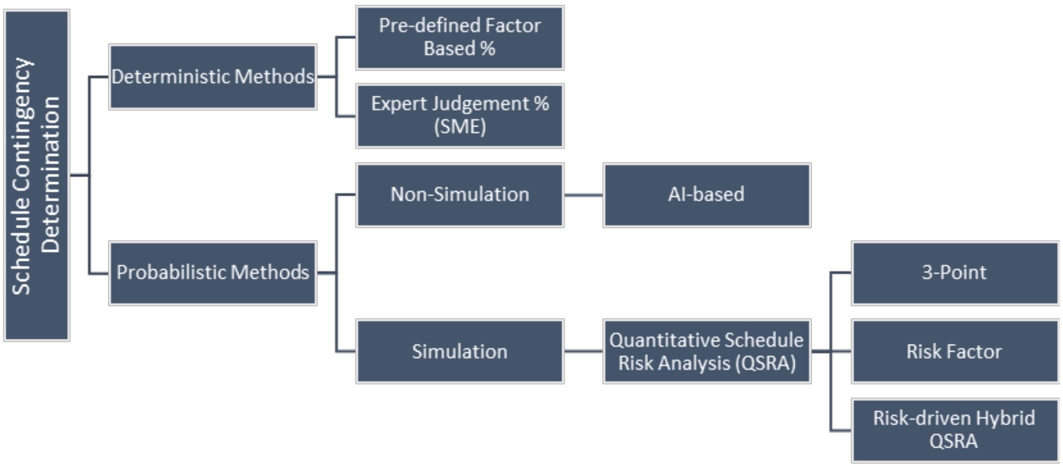


Figure 20: The most common methods of schedule contingency determination

5.3.1 Deterministic Methods

Deterministic methods are the easiest approaches to schedule contingency determination and are mostly used during the early stages of the project lifecycle, or for small projects. During the early stages of project development, insufficient data and time or resource constraints may limit a team's ability to undertake a more detailed schedule contingency assessment. Using appropriate factors for the desired confidence levels facilitates this approach. There are several different applications of deterministic methods for determination of schedule contingency, including predefined factor-based percentage or expert judgment percentage.

Pre-defined Factor Based %

In this method, a predetermined percentage of the project Base Schedule (e.g. 10%) will be added to the project Base Schedule across the board. Some organisations have their own set of guidelines for contingency percentages in addition to the Base Schedule to concurrently address both inherent and contingent risks. Alternative applications may include:

a) predefined percentages of the Base Schedule for different types (or sizes) of projects
b) predefined percentages of the Base Schedule for different project phases
c) predefined percentages of the Base Schedule for different confidence levels (e.g. 10% for P50 and 30% for P90).

Using this technique, practitioners set a single overall contingency allowance for combined inherent and contingent risks for the whole project – or several different key areas. This allowance is based on the organisation's exposure to multiple projects, its experience, and historical project performance. These predetermined percentages will be used consistently across the organisation. An example of the predefined factor-based method is illustrated in Table 6, note that RES **does not recommend** the percentages in Table 6, or any other specific contingency values.

Work Breakdown Structure (WBS)	**Project Value (incl. contingency) PV <= $1m**	**Project Value (incl. contingency) $1m < PV <= $5m**	**Project Value (incl. contingency) PV > $5m**
	% of Base	% of Base	% of Base
Whole scope	5%	10%	20%

Table 6: An example of predetermined contingency percentages for different project sizes

Expert Judgment % (SME)

The method of expert judgment percentage (SME) is similar to the pre-defined factor-based percentage method. However, instead of using predetermined percentages, for the Base Schedule, a group of Subject Matter Experts (SME) determine percentages for each project or phase or discipline – after considering the project specific risks and uncertainties as well as contractual and organisational requirements, stakeholder expectations, and other relevant factors.

RES Example: A construction company is developing a large commercial building. The project involves several phases: planning, foundation work, structural construction, electrical and plumbing installation, and finishing. The project team needs to calculate contingency funds using expert judgement, considering specific risks and uncertainties.

For example, using the expert judgement method, the SMEs determine phase-specific contingency percentages based on their experience and understanding of various project risks and uncertainties. The calculated contingencies were then summed to provide a total contingency amount, which was added to the base project cost to establish the final project budget including contingencies. This method ensures that the contingency calculations are tailored to the specific conditions and risks of the project, making the estimates more robust and reliable.

5.3.2 Probabilistic Methods

For easier understanding, the probabilistic methods of schedule contingency determination have been groups in two categories: Non-Simulation methods and Simulation-based techniques.

Non-Simulation

AI-Based

One of the non-simulation techniques for schedule contingency determination is using Artificial Intelligence (AI) technology, which is growing at a significant speed across all industries. AI based methods generally do not require the manual application of risks and uncertainties to activities in the schedule. Instead, for example the machine learning model trained on past project data automatically generates duration distributions for the activities or disciplines within the schedule. From here, the most impactful activities to the key milestones identified are highlighted in a tornado chart, along with contextual information that helps project teams assessing risk mitigations.

AI-based tools can enhance the assessment of project schedule contingency by leveraging its capabilities in data analysis, pattern recognition, and predictive modelling. Implementation Steps include:

- Data Collection: Gather historical project data, current project details, and any other relevant information.
- Model Development: Develop machine learning models tailored to the specific needs and characteristics of the project.
- Integration: Integrate AI tools with existing project management software for seamless data flow and analysis.
- Testing and Validation: Test the AI models on past projects to validate their accuracy and effectiveness.
- Deployment: Deploy the AI solutions and continuously monitor and update them for ongoing improvement.

Although the concept is at the early stages of development with a limited number of solutions and users, the *Contingency Guideline* highlights there are several ways AI can be utilised for this purpose.

- Predictive Analytics
  - Historical Data Analysis: AI can analyse vast amounts of historical project data to identify patterns and trends. This helps in understanding how past projects have deviated from their schedules and what factors contributed to those deviations.
  - Risk Prediction: By evaluating historical and real-time data, AI can predict potential risks that could affect the project timeline, allowing for better planning and mitigation strategies.
- Machine Learning Models
  - Schedule Optimisation: Machine learning algorithms can optimise project schedules by identifying the most efficient sequence of tasks and predicting potential bottlenecks.
  - Scenario Analysis: AI can simulate various scenarios to assess the impact of different risks on the project timeline. This helps in understanding the probability of delays under

different conditions.

- Natural Language Processing (NLP)
  - Risk Identification: NLP can be used to analyse text data from project documentation, emails, and reports to identify potential risks and issues that might affect the schedule.
  - Stakeholder Communication: NLP can assist in understanding stakeholder sentiment and concerns related to project timelines, ensuring better communication and proactive risk management.
- Real-time Monitoring and Alerts
  - Progress Tracking: AI-powered tools can monitor the project's progress in real-time, comparing it with the planned schedule and identifying deviations immediately.
  - Proactive Alerts: AI can send real-time alerts to project managers about potential delays or issues, allowing for timely intervention and adjustments.
- Integration with Project Management Tools
  - Automated Reporting: AI can integrate with existing project management tools to automate the generation of reports and dashboards that visualise schedule performance and risks.
  - Resource Optimisation: AI can analyse resource allocation and suggest adjustments to minimise delays and enhance productivity.
- Data-Driven Decision Making
  - Informed Adjustments: AI provides data-driven insights that enable project managers to make informed decisions about adjustments to the schedule or contingency plans.
  - Continuous Learning: AI systems can continuously learn from new data, improving their predictive accuracy and the effectiveness of contingency plans over time.

It should be also noted that AI Based methods, e.g. machine learning, can be combined with simulation methos, e.g. Monte Carlo simulation. Machine learning and Monte Carlo simulation are powerful techniques that serve different purposes but can be effectively combined. Monte Carlo methods help in understanding systems under uncertainty, while machine learning provides predictive power and pattern recognition. Together, they can offer robust solutions for complex modelling and prediction tasks.

One common approach to combining these techniques is to use Monte Carlo methods to generate data that can train a machine learning model or to use machine learning to analyse and interpret the outputs of Monte Carlo simulations.

Example Process:

1. **Initial Simulation:** Use Monte Carlo simulation to generate a large dataset representing various scenarios of a system.
2. **Model Training:** Train a machine learning model on this dataset to learn the underlying patterns and relationships.
3. **Prediction and Analysis:** Use the trained machine learning model to predict outcomes of new scenarios or to perform sensitivity analysis.

RES Recommendation: using AI technology for assessing project schedule contingency can improve accuracy, enable proactive risk management, and enhance overall project efficiency. By leveraging predictive analytics, machine learning, natural language processing, and real-time monitoring, risk managers can better anticipate and mitigate potential delays, ensuring projects stay on track. However, given the current stage of AI-enabled tools and data availability, this guideline recommends practitioners exercise additional caution when using AI-based solutions. The risks can be mitigated by using AI in conjunction with other proven techniques, such as Quantitative Schedule Risk Analysis (QSRA).

It should be noted that at the time of this publication, the AI Based techniques for contingency determination are not a replacement for all existing project risk management processes and qualitative / quantitative risk workshops. These in which systemic and project specific risks are identified and assessed are as important as the contingency allowance. RES recommends AI Based methods to be used in combination to other good industry practices, e.g. bottom-up Quantitative Schedule Risk Analysis (QSRA).

Simulation (Quantitative Schedule Risk Analysis QSRA)

The probabilistic simulation-based methods of schedule contingency determination generate a probability distribution of project schedule duration. The critical path method using the Monte Carlo simulation does this by simulating schedule components and their likely ranges using computer software. Regression based parametric modeling does this inherently through the probabilistic attributes of the model algorithm.

Probabilistic simulation-based methods are a form of Quantitative Risk Analysis (QRA). To estimate contingency at the desired level of confidence, common techniques include computer-based Latin Hypercube or Monte Carlo simulations. According to the NASA *Cost Estimating Handbook,* the simulation process will generally produce steady state results after 2,500 to 10,000 iterations. Simulations allow risk practitioners to quantify project risks and provide them with a range of possible outcomes expressed as statistical distributions. For parametric modeling, the algorithm generates the distribution based on the risk factor ratings entered in the model. This is the only viable probabilistic method when there is no Critical Path Model (e.g. at Class 5 as described in Section 3.2).

Three-Point

RES recommends separating inherent uncertainties, such as estimation errors or schedule duration variability, from specific risks. Both inherent uncertainties and contingent risks should be included in the Monte Carlo simulation. This distinction helps clarify the origin of potential delays. The process for the most common approach to this method is represented in Figure 21.

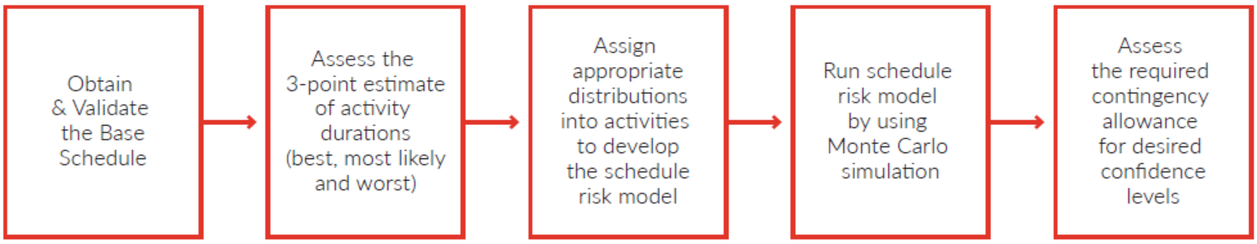


Figure 21: Common process of three-point schedule contingency determination method

A three-point schedule includes three estimates: optimistic, most likely, and pessimistic duration. Commonly, a Monte Carlo simulation provides a probability distribution for the entire project schedule based on SME estimations of range and probability distributions for components of the WBS. Some of the key challenges associated with this method of schedule contingency determination are:

a) selection of an appropriate level of WBS and schedule activities for allocating three-point ranges (i.e. number of schedule items and inputs)
b) determining which risks directly drive crucial activities
c) optimising effective use of the risk register and available contingent risks
d) determination of probability distributions for each activity
e) determination and modelling of the correlations and relationships between inputs
f) visibility of key schedule risk drivers and their rankings
g) accurate estimation of contingent risks (e.g. access delay, wet weather, accidents)

Due to these challenges, the three-point schedule contingency determination method may result in inconsistent and unpredictable results, depending on the level of modelling and its quality. The resulting distribution is almost always too tight, due to inadequate treatment of correlations.

RES Example: A construction company is tasked with building a new office complex. The project involves several critical phases: site preparation, foundation work, structural construction, electrical and plumbing installation, and interior finishing.

Key Phases/Tasks and 3-point estimate

1.1 Site Preparation – 10 / 15 / 25 days
1.2 Foundation Work – 20 30 / 50 days
1.3 Structural Construction – 60 / 80 / 120 days
1.4 Electrical and Plumbing Installation – 40 / 50 / 70 days
1.5 Interior Finishing – 30 / 40 / 60 days

Monte Carlo simulation used to generate a probability distribution for the entire project duration based on the three-point estimates for each task. Monte Carlo simulation results were then reviewed to determine a probability distribution of the total project duration and then an acceptable level of confidence was decided for the project duration (e.g., 80th percentile).

Example result: At the 80th percentile, the project duration is 230 days. The planned duration without contingency is 215 days.

Schedule Contingency Calculation:

- Base Schedule duration: 215 days
- Project duration at 80th percentile: 230 days
- Schedule contingency: 230 - 215 = 15 days

Summary

Using the three-point estimation and Monte Carlo simulation method, the project team calculated the schedule contingency for the construction project. By gathering optimistic, most likely, and pessimistic estimates from SMEs, running a Monte Carlo simulation, and analysing the output, the team established a schedule contingency of 15 days to accommodate uncertainties and risks. This approach helps ensure a more reliable and robust project schedule

Risk Factor

To address some of the gaps within the three-point method (e.g. correlations, narrow ranged outcomes, or identification of key risk drivers) the risk factor top-down approach was introduced to drive the schedule risk with risks previously defined in the risk register. During the early stages of project development, the risk factor method can identify and use several key factors – generally between five to 20 items – representing uncertainties that may affect the Base Schedule. These key factors are often aligned with key scheduling assumptions (e.g. productivity rates and quantities). The key aspects of this method are:

a) set risk factors (e.g. 0.8 for optimistic; 1.0 for most likely; and 1.4 for pessimistic)
b) assign the risk factors to one or more activities and multiply the activity duration by the applicable risk factor
c) if the activity duration is impacted by one or more risk factors, all applicable risk factors should be used to multiply the activity duration.

RES Example: A construction company is tasked with building a residential apartment complex. The project involves several critical phases: site preparation, foundation laying, structural work, electrical and plumbing installation, and interior finishing. Each phase will be subject to various risks as identified in the risk register.

Key Phases/Tasks:
1.1 Site Preparation – 10 days
1.2 Foundation Laying – 20 days
1.3 Structural Work – 60 days
1.4 Electrical and Plumbing Installation – 40 days
1.5 Interior Finishing – 30 days

Key Risk Factors: (values for each risk factor is 0.8 Optimistic, 1.0 Most Likely, 1.4 Pessimistic)

- Labour Productivity (LP)
- Material Availability (MA)
- Weather Conditions (WC)
- Permitting and Regulatory Delays (PR)
- Site Conditions (SC)

Assigned Risk Factors to Activities:

- Site Preparation (Impacted by SC and WC) – optimistic: 10 x 0.8 (SC) x 0.8 (WC) = 6.4 days, most likely: 10 x 1.0 (SC) x 1.0 (WC) = 10 x 1.0 = 10 days, Pessimistic = 19.6 days
- Foundation Laying (Impacted by SC and PR) – 12.8 / 20 / 39.2 days
- Structural Work (Impacted by LP and MA) – 38.4 / 60 / 117.6 days
- Electrical and Plumbing Installation (Impacted by LP and MA) – 25.6 / 40 / 78.4 days
- Interior Finishing (Impacted by LP) – 24 / 30 / 42 days

Monte Carlo simulation then used to generate a probability distribution for the entire project duration based on the three-point estimates for each task. Monte Carlo simulation results were then reviewed to determine a probability distribution of the total project duration and then an acceptable level of confidence was decided for the project duration (e.g., 80th percentile).

Schedule Contingency Calculation:

- Planned duration based on the most likely estimate: 160 days
- Project duration at 90th percentile: 200 days (P90)
- Schedule buffer/contingency: 200 - 160 = 40 days

Risk-driven Hybrid QSRA (recommended by RES)

This method is underpinned by a Critical Path Method (CPM) schedule which incorporates risk drivers as elements of the model (i.e., it is risk driven). The key elements of a realistic and reliable Risk-driven Hybrid QSRA in determination and allocation of a reasonable schedule contingency for different desired confidence levels are:

a) undertake a schedule health check against contractual factors, integrity and structure
b) undertake required rectification of deficiencies (e.g. constraints, missing links, broken logic)
c) for large schedules, create a manageable study schedule
d) allocate the inherent and contingent risks into the rectified schedule model (i.e. determine which activities each risk may impact)
e) assess and model key correlations
f) assess and model key possible scenarios, e.g. directed changes and changes to deal with risk occurrence (i.e. probabilistic branching)
g) run a Monte Carlo Simulation
h) review, validate and finalise the results
i) using results for cost Contingency Determination, if required.

The process for the most common approach of this method is represented in Figure 22.

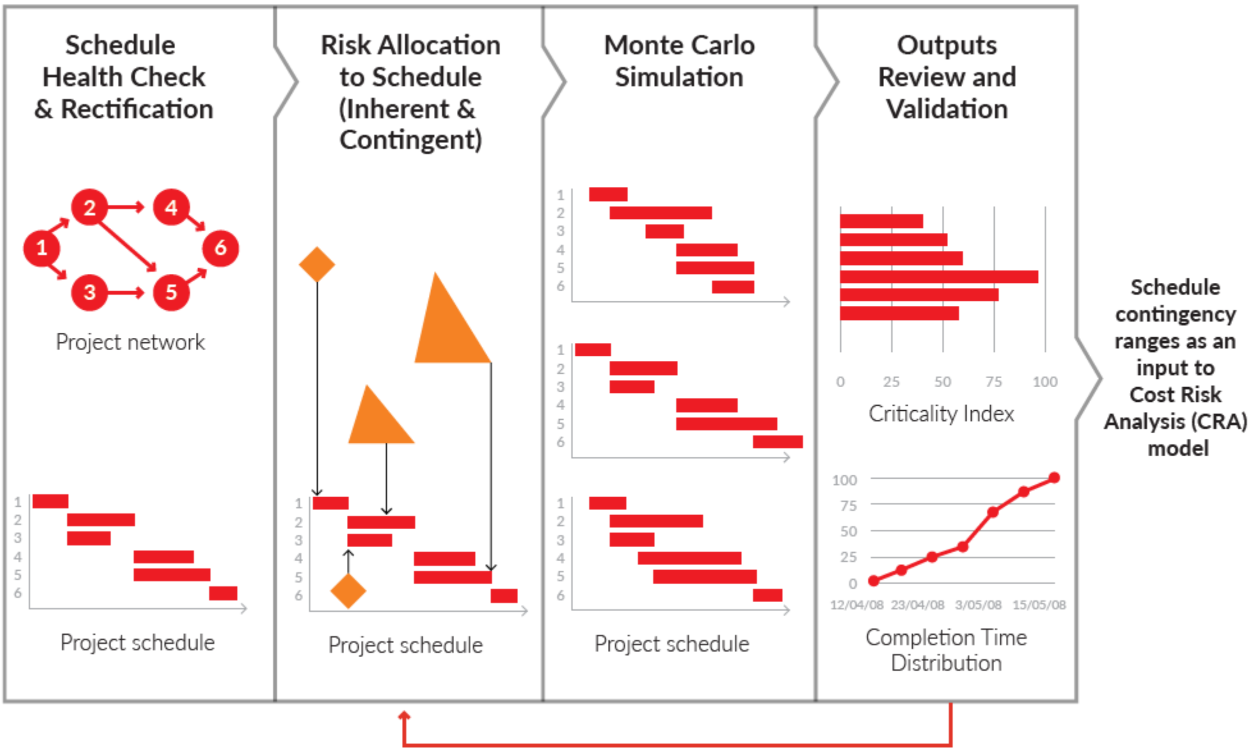


Figure 22: A typical process map for the Risk-driven Hybrid QSRA technique

Further details about this method are included in Appendix C.

5.4 Cost Contingency Determination

As illustrated in Figure 23, common methods for cost contingency determination are divided into two groups: deterministic and probabilistic. RES strongly recommends that practitioners employ the good industry practice of assessing cost and schedule contingency together using an integrated approach. However, to make this *Contingency Guideline* easier to read, schedule and cost contingency calculations have been explained in different sections.

This *Contingency Guideline* also notes that mathematical methods including fuzzy techniques or artificial neural networks, as well as systems dynamics models have been introduced by researchers – mainly for academic purposes. There are also hybrid approaches (i.e. combination of multiple methods or parametric or other to address the deficiencies of various methods).

It should be also noted that different software solutions might use a combination of these methods of schedule contingency determination, e.g. AI-based combined with Quantitative Cost Risk Analysis (QSRA) or Parametric Based combined with QCRA. Organisations / Projects are strongly encouraged to carefully assess the capabilities and suitability of each schedule contingency determination solution against their context and requirements.

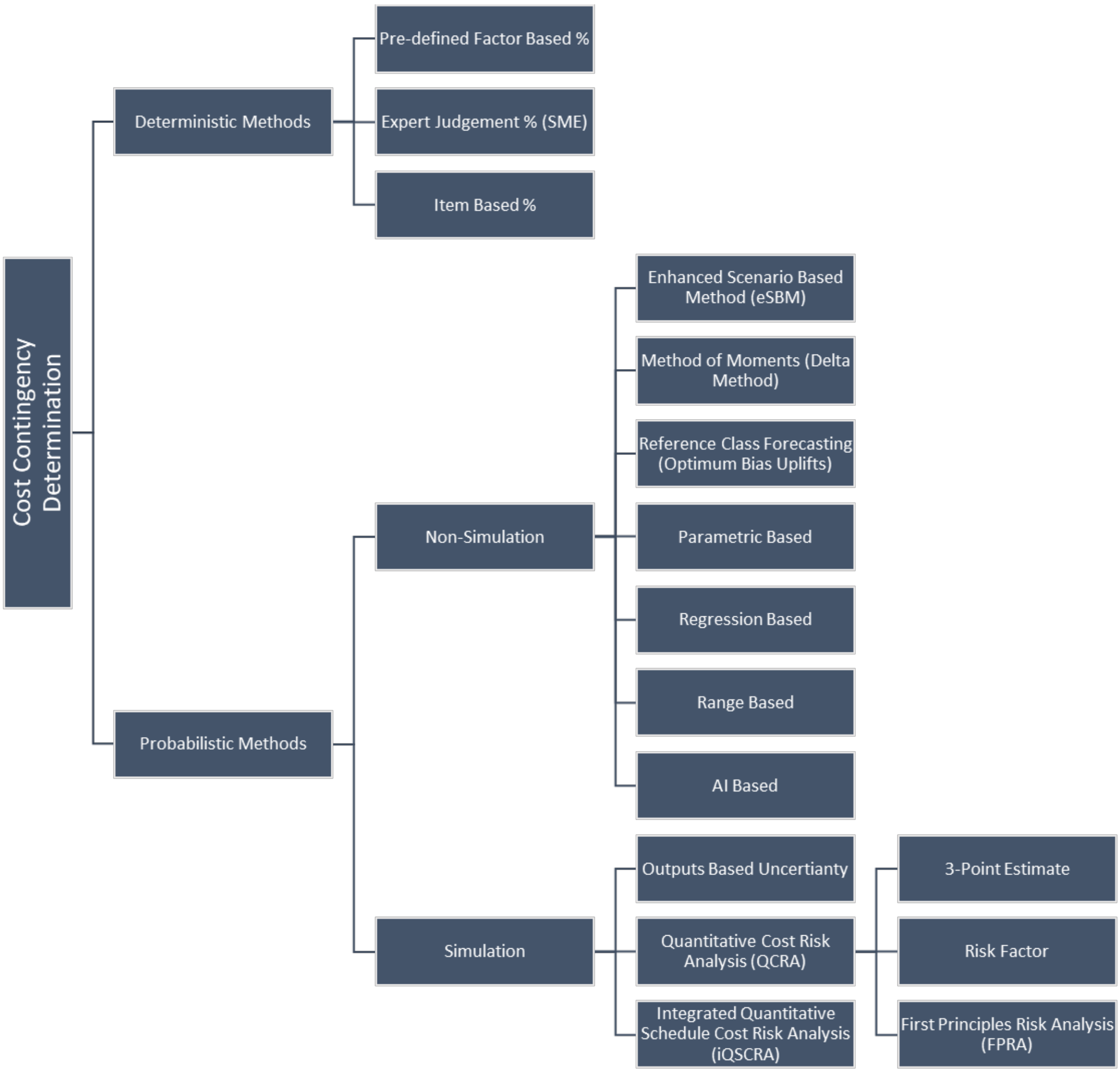


Figure 23: The common methods of cost Contingency Determination

> **RES Recommendation:** while contingency is a form of risk treatment which can be used to mitigate uncertainty or realised risks, it should only be used when incorporated with a comprehensive risk management approach.

5.4.1 Reliability of Methods

Both deterministic and probabilistic methods can be reasonably used to determine a realistic contingency allowance for projects – depending on the phase of the investment lifecycle, availability and quality of project data, historical information, the organisation's maturity, and project specific requirements. While some approaches are more acceptable in the early stages of the project lifecycle, bottom-up probabilistic methods of contingency determination are recommended wherever possible at every decision gate of the phase gate system – particularly at the full funds approval gate. For projects with a value of more than $10m this *Contingency Guideline* recommends simulation or hybrid methods, when practical, at these final decision-making stages.

RES recommends that practitioners use the following evaluation criteria to select an appropriate cost contingency determination method:

a) strength, supporting data and nature of assumptions required
b) ability of the practitioner and project team to understand the technical complexity of the method
c) computational overheads, availability of software, and training required for computational methods
d) consistency, reliability and range boundaries of the method, and its ability to support decision-makers in assisting decision-makers
e) ability and possibility to use a combination of methods to support decision making

The evaluation criteria above can assist practitioners and their organisations to develop an overarching strategy for contingency determination by deciding which method or combination of techniques best fit their internal and external requirements.

The criteria can also help practitioners determine the ability of each of the methods discussed in the *Contingency Guideline* to provide reliable and realistic results for specific needs. This depends on several factors, including the quality and availability of information to support the process.

The *Contingency Guideline* generally recommends the application of MCS, due to its potential capability for consistent and reasonably reliable predictions. It should be noted that there are associated challenges, including: whether historical data is validated; the consistency of probability density functions, their tail shapes, and interdependency; and the relevant risk function.

If a large number of supporting observations are available, practitioners should be able to closely estimate the data with a probability density function which should improve the accuracy of the MCS predictions. While they still depend on the model used, and accurate programming, simulations with a sizeable body of relevant supporting data generally provide the most accurate risk forecasts.

The most common methods of cost contingency determination are explained in this section. The other methods – except the new mathematical methods due to the small number of current practical applications – have been explained in the Appendix D.

5.4.2 Deterministic Methods

Predefined Factor Based %

The factor-based approach is the easiest method of cost contingency determination. It is mostly applicable at the early stages of the project lifecycle or for smaller projects – where time, data and resource constraints make a more comprehensive assessment difficult. Using appropriate factors for the desired confidence levels facilitates this approach.

This technique adds a predetermined, across the board, percentage of the project Base Estimate (e.g. 10%) to the project estimate. Individual organisations have frameworks to determine which percentages best suit their needs. The most common application of this methodology is to set a single overall percentage of the project Base Estimate which incorporates both inherent and contingent risks. Other ways may include:

a) predetermined percentages of base for different types (or sizes) of projects
b) predetermined percentages of base for different key phases of a project
c) predetermined percentages of base for different confidence levels (e.g. 10% for P50, 30% for P90).

Instead of calculating separate contingency for inherent and contingent risks, this technique determines an overarching contingency allowance range for the whole project or a number of different key areas. This is based on the organisation's exposure to multiple projects, experience, and historical performance of projects. These predetermined percentages are used consistently across the organisation. A few examples are illustrated in Tables 7 and 8. Note RES **does not recommend** these, or any other specific values of contingency. It is best to benchmark chosen values against actual company projects.

Work Breakdown Structure (WBS)	**Low confidence level e.g. P10**	**Reasonable confidence level e.g. P50**	**High confidence level e.g. P90**
	% of Base Estimate	% of Base Estimate	% of Base Estimate
Whole scope	20%	30%	40%

Table 7: An example of a predetermined contingency percentages for different confidence levels

Work Breakdown Structure (WBS)	**Project Value (incl. contingency) < = $1m**	**Project Value (incl. contingency) < = $5m**	**Project Value (incl. contingency) > $5m**
	% of Base Estimate	% of Base Estimate	% of Base Estimate
Whole scope	10%	20%	30%

Table 8: An example of predetermined contingency percentages for different project sizes

RES Example: the predefined factor-based method is a common method, especially at the early stages of project development, both in Australia and globally. For example, in the US, the factors below are used by Virginia Department of Transportation to estimate transport projects for different regions.

State	**Factor**
Delaware	5% of estimated construction cost
Kentucky	10% of estimated construction cost
Pennsylvania	10 to 20% of estimated construction cost
Tennessee	10% of estimated construction cost

Expert Judgment % (SME)

The method of expert judgment percentage (SME) method is very similar to the factor-based percentage method. Instead of predetermined levels, percentages are obtained from the Base by a group of experts for each project – after specifically considering its risks and uncertainties. The accuracy of results depends on the experience of the SMEs and their consideration of specific circumstances and risks – and tends to vary from project to project.

Item Based %

The deterministic item-based approach to quantifying contingencies aims to improve the expert judgment approach by applying the deterministic method for a number of items across the project scope – including the inherent and contingent risks – rather than percentages of the Base Estimate and Base Schedule. The structure of items is based on the WBS or Risk Breakdown Structure (RBS). Some applications of this method have been illustrated in Tables 9, 10 and 11.

Work Breakdown Structure (WBS)	**Base Estimate <= $5m**	**Base Estimate > $5m**
	% of Base Estimate	% of Base Estimate
Civil Design	1% of Civil Design $	2% of Civil Design $
Structure Design	1% of Structure Design $	2% of Structure Design $
Soft Soil Treatment	5% of SST $	10% of SST $
Excavation	5% of Excavation $	7% of Excavation $
Structures	5% of Structures $	8% of Structures $
Line Marking	1% of Line Marking $	2% of Line Marking $
Landscape	1% of Landscape $	2% of Landscape $
TOTAL – contingency	**To be calculated**	**To be calculated**

Table 9: An example of the item-based percentage using WBS

Work Breakdown Structure (WBS) / Risk Breakdown Structure (RBS)	Low confidence level e.g. P10	Reasonable confidence level e.g. P50	High confidence level e.g. P90
	% of Base Estimate	% of Base Estimate	% of Base Estimate
Project scope	2%	3%	5%
Status of design	3%	4%	5%
Site information	1%	2%	3%
Constructability	1%	2%	3%
Project schedule	1%	2%	3%
Interface Management	2%	3%	5%
Approval processes	1%	2%	4%
Utility adjustments	1%	2%	4%
Properties	2%	3%	5%
Other inherent & contingent risks	1%	2%	3%
TOTAL – Contingency	**15%**	**25%**	**40%**

Table 10: An example of the item-based percentage using 10 key aspects

With pre-defined factors, research has found that this method is generally optimistic as may not be risk-driven and tends to focus on the estimator's view of the quality of their estimate as opposed to a combination of inherent and contingent risks. It is not usually based on empirical analysis of a company's data.

Values from books and external references generally do not apply well to any specific company or project. Values based on historical projects or benchmarked against actual company projects is best.

RES Example: Table 11 presents an example of the item-based percentage method against WBS and different project confidence levels while approaching the inherent and contingent risks separately. The details presented in Table 11 can be interpreted as described below:

a) Base Estimate of $5,000k
b) Base Schedule of 80 working days
c) For a confidence level of 50%, cost contingency of approximately $720k (14% of Base Estimate) and schedule contingency of an additional 21 working days (26% of Base Schedule) is recommended
d) For a confidence level of 90%, cost contingency of $1,475k (30% of Base Estimate) and schedule contingency of an additional 30 working days (38% of Base Schedule) is recommended. Note that adding P90 values implies all risks are 100% correlated – a very conservative assumption.

WBS / RBS	**P(x) (%)**	**Base Estimate ($)**	**Schedule (day)**	**Low confidence level e.g. P10**		**Reasonable confidence level e.g. P50**		**High confidence level e.g. P90**	
				% of Base Estimate of Item		% of Base Estimate of Item		% of Base Estimate of Item	
INHERENT									
Earthworks	100	$1,000k	20	2%	$20k	3%	$30k	4%	$40k
Pavement	100	$300k	20	1%	$3k	2%	$6k	5%	$15k
Bridge 1	100	$1,000k	20	5%	$50k	10%	$100k	30%	$300k
Bridge 2	100	$2,000k	20	5%	$100k	15%	$300k	40%	$800k
Misc.	100	$700k	-	3%	$21k	5%	$35k	10%	$70k
		$5,000k	**80**						
CONTINGENT									
Extreme weather	30	$500k	20	30% x $500k	$150k	30% x $500k	$150k	30% x $500k	$150k
Extra soft soil treatment	20	$500k	-	20% x $500k	$100k	20% x $500k	$100k	20% x $500k	$100k
Approval & site access	20	-	20						
TOTAL – Contingency				**9%**	**$444k**	**14%**	**$721k**	**30%**	**$1,475k**

Table 11: An example of the item-based percentage method

5.4.3 Probabilistic Non-Simulation Methods

The use of probabilistic non-simulation methods of cost contingency determination is limited within the infrastructure, engineering and construction sector, although AI-based methods and tools are currently growing. These methods have been explained in Appendix D:

a) Enhanced Scenario Based Method (eSBM)
b) Method of Moments (Delta Method)

c) Reference Class Forecasting (RCF)
d) Parametric Based
e) Regression Based
f) Ranged Based
g) AI Based

5.4.4 Probabilistic Simulation Methods

Probabilistic simulation methods generate distributions of possible outcomes. There are two types of practical probabilistic (inferential statistics) methods: regression based and Monte Carlo simulation. Some regression-based methods are discussed in the Appendix D.

Using risk drivers during simulation not only helps assess individual risks but also automatically generates correlations between activity durations. This is crucial in complex projects where manual estimation of correlation coefficients can be error prone. A well-developed model, using quality assumptions validated against historical data, can reasonably reflect the behavior of real projects subject to risks of various types.

The simulation methods start with a model of the project. It may be the estimate with its line items, or a Critical Path Method (CPM) schedule with its activities and logic, or some combination or variation. Note that none of the simulation models depict how a project behaves under the dynamic nature of risks. For example, the CPM network as usually applied is static or fixed. The model is made probabilistic by replacing fixed input values with ranges and probabilistic methods to produce a probability distribution that approximates project schedule and costs. To do this, practitioners need to set a probable range for each identified element of cost and schedule and conduct an iterative sampling process to simulate the distribution using computer software to capture the outputs of the many iterations.

As discussed in Section 5.4.2, probabilistic methods are a form of Quantitative Risk Analysis (QRA).

The quality of simulation methods depends on how realistically the underlying model represents how the project will behave when subject to risk. For example, as a principle, it should be “risk-driven”, i.e., we model the occurrence of each risk and its impact, not just a range of impact without modeling the risk driving that range. When undertaken properly, the method optimally generates all possible scenarios modeled by the analysis and the likelihood of the occurrence of each outcome. Building a realistic yet practical underlying model is the main challenge.

To determine the values of possible outcomes, the simulation calculates which values are reasonably possible for each model variable. If they are included in the model, the simulation includes the risk drivers’ occurrence probability. The results for Monte Carlo simulations and other probabilistic techniques also encompass the confidence levels able to be assigned to each possible value of project cost and duration.

Simulation has an advantage over empirical models in that risk drivers and behaviors not captured in the actual data can be factored into the model. This is particularly relevant to significant contingent risks for which the occurrence and/or impact is specific to the project. However, empirical models have an advantage over simulation models in their objectivity and credible consistency in analysing inherent risks – especially at very early stages of project development. Using empirical and simulation methods together can capitalise on each of their advantages.

RES Recommendation: in the absence of objective data (and unless there is evidence to do otherwise) RES recommends all subjective bounds (i.e. SME opinions) are modelled with confidence intervals of 80% between best case and worst case (e.g. 10% best case and 90% worst case). When using – and when using Triangular, Uniform or Beta-Pert distributions, these confidence intervals should be adjusted for skew

The *Contingency Guideline* provides details for the following probabilistic methods:

- Outputs Based Uncertainty (less common method within the engineering and construction sector. Further details about this method are provided in Appendix D)
- Quantitative Cost Risk Analysis (QCRA)
    - 3-Point Estimate
    - Risk Factor
    - First Principles Risk Analysis (FPRA)
- Integrated Quantitative Schedule Cost Risk Analysis (iQSCRA).

Quantitative Cost Risk Analysis (QCRA)

QCRA generates a cost cumulative distribution (CDF), or S-curve for projects and for various elements of the estimate as needed for allocation purposes. The key activities of QCRA are:

a) Ensure Base Estimate represents the cost strategy established – considering specific circumstances and assumptions
b) Determine the project's cost drivers and risks, using input from key stakeholders and historical data
c) Determine the bias in the estimate by developing the probability of occurrence distributions and correlations for the schedule and technical cost drivers
d) Develop impact distributions and correlations for uncertainties in the cost model
e) Run the cost risk model
f) Generate probabilistic cost distribution
g) Recommend sufficient contingency for the desired confidence level.

QCRA allows practitioners to pinpoint and analyse a project's critical risks according to set technical criteria, key interfaces, and limitations for schedule and costs. It also helps the project team to document and proactively manage the project budget – capturing uncertainty in methodology, systemic factors to shift from a deterministic to probabilistic contingency calculation. QCRA methods can be run in conjunction with empirically based methods to address inherent risks more objectively.

This *Contingency Guideline* provides details for three different methods of QCRA:

a) 3-Point Estimate
b) Risk Factor
c) First Principles Risk Analysis (FPRA)

The following sections will provide further details about these methods as well as recommendations regarding the most appropriate phases of the project lifecycle to put them into action.

3-Point Estimate

In this method, the underlying risk model is the cost estimate with the risk drivers added. It is essential that a risk driven approach is used. For inherent risk, practitioners should replace fixed values with distributions that can be defined with three-point inputs.

For contingent risk, the risk is connected to the impacted estimate items, and the probability of each risk occurring – and its correlation to other risks – is quantified. Note that this is only meaningful when the estimate is reasonably detailed. For Class 5 estimates, this takes the nature of deterministic methods. This method is generally applied to a bottom-up estimate, which is obtained by analysing individual work packages. The process for the most common approach to this method is represented in Figure 24 below.

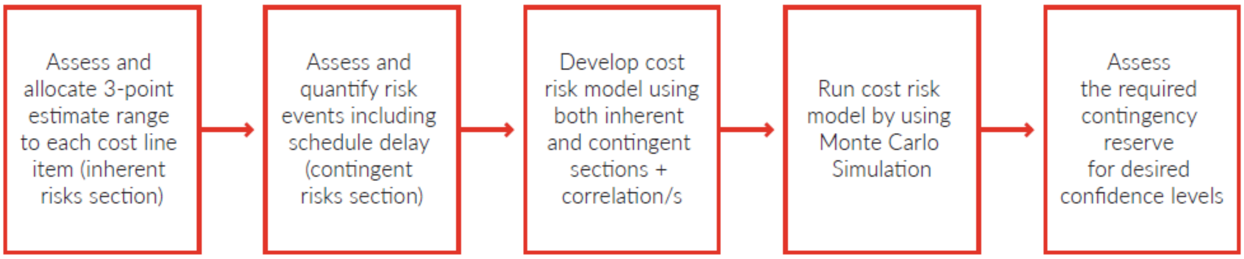


Figure 24: Common process of QCRA 3-Point Estimate methodology

This technique can be used to analyse the costs of multiple projects, with the WBS as a basis. As the WBS includes a breakdown of the project's work packages, components, facilities and services, practitioners can just allocate a cost to each component and calculate the sum for an overall project cost.

For a QCRA 3-point estimate, SMEs are asked to use elicitation to set a range and probability distribution for each WBS element, which is then input into a Monte Carlo Simulation for total cost calculation. As discussed in Section 5.3.2, variations in the elicitation process can affect results. Some of the key challenges associated with this method of contingency determination are:

a) selection of an appropriate level of WBS for allocating three-point ranges (i.e. number of cost items and inputs)
b) determination of probability distributions for each cost element
c) determining the correlations and relationships between model inputs and understanding them clearly
d) accurate assessment of delays
e) narrow range of possible cost outcomes, which increases the likelihood of underestimating the required contingency.

Due to these challenges, the QCRA 3-point estimate may result in inconsistent and unpredictable results, depending on the level of modelling and its quality. This method is **not recommended** by this *Contingency Guideline*, especially at the key investment decision making points, e.g. Final Business Case or Final Investment Decision (FID). Where possible, especially at key decision points (e.g. Preliminary and Final Business Case), RES recommends the use of First Principles Risk Analysis (FPRA). Further details for this method are included in Appendix E.

Risk Factor

To address some of the gaps within the three-point estimate method (e.g. correlations or narrow ranged outcomes) the top-down approach of the risk factor was introduced by some practitioners. At the early stages of project development, the risk factor method can identify and use several key factors – generally between five and 20 items – that represent uncertainties and the cost items which they may affect across the Base Estimate. These key factors are often aligned with key estimating assumptions.

Across different sectors, there are several ways this method can be used – depending on the project requirements and the availability of data. The process of the most common approach to this method is represented in Figure 25.

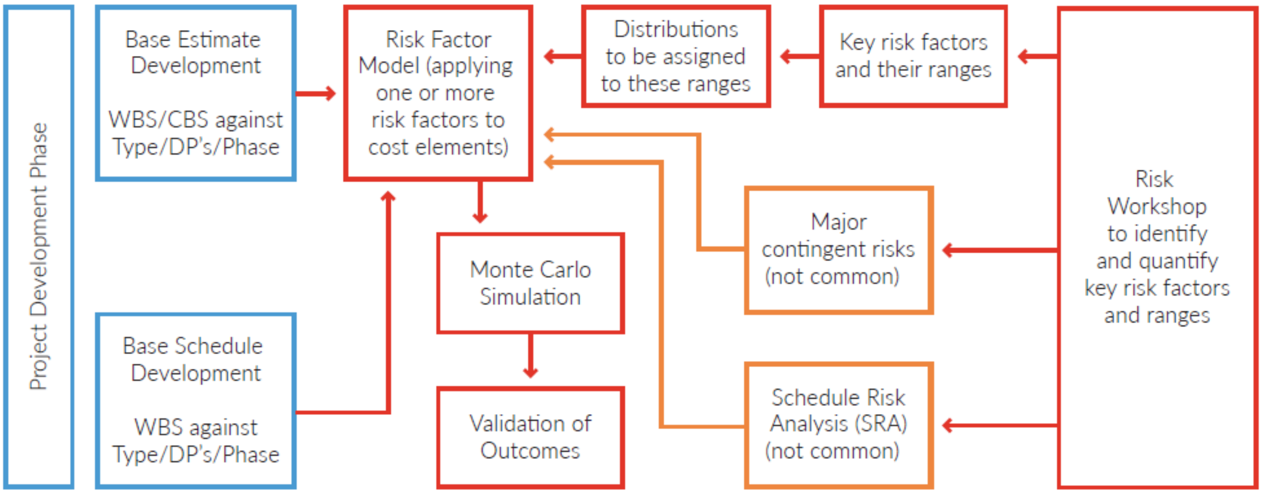


Figure 25: The process for the most common approach to the QCRA Risk Factor method

In practice, organisations generally develop, and use predetermined key risk factors for different types of projects to facilitate quantification during risk workshops. For example, the common key factors for a fly-in-fly-out (FIFO) resource project can be office cost rate ($/month), provisions, schedule, heavy machinery rate ($/month), site accommodation rate ($/month), labor productivity, equipment rate, material quantity, staff rate, productivity, and FIFO rate.

Correlation between risk factor distributions should also be considered, as a single uncertainty factor may affect multiple risk factors.

Like any high-level, top-down approach, the risk factor method may be adequate for projects that are relatively self-contained or at the early stage of development (e.g. projects within the resource sector or at the initiation or Optioneering phase). It may not pass the scrutiny required at key investment decision points (e.g. Final Business Case) particularly in terms of governments demonstrating the best value for public money, hence RES does not recommend this method at key decision points, especially Final Business Case (FBC) of Final Investment Decision (FID).

The risk factor method may not fully address all requirements of infrastructure projects due to the nature of infrastructure cost uncertainties. The HM Treasury Infrastructure UK *Guidance of Cost Estimate* also states that cost contingency estimates should include:

a) uncertainties around the estimate which are defined but unmeasured
b) specific risks that are measured uncertainties
c) uncertainties that are currently unknown or not entirely understood (e.g. interface risks).

RES, as well as several other key references including the UK *Guidance of Cost Estimate*, affirms that (a) and (b) above are the main drivers of contingency for primarily self-contained projects. Point (c) comes into play as a significant risk exposure factor in the early phases of major infrastructure projects – and can result from complex interfaces of the project with the surrounding area, or unexpected stakeholder reactions and needs.

First Principles Risk Analysis (FPRA)

As a bottom-up risk-driven cost contingency determination approach which specifically addresses the critical risk events as well as uncertainties associated with the key assumptions, the FPRA aims to address key deficiencies of the 3-Point Estimate and Risk Factor methodologies, while capturing and validating uncertainties and risks at the lowest meaningful level of the WBS.

The key elements of a realistic and reliable FPRA in the determination and allocation of a reasonable cost contingency for different desired confidence levels are:

a) quality validation of the Base Estimate: preferably a first principles, rigorous, structured and detailed cost estimate – representing the most likely assumptions – structured against equipment, labor, material and sub-contracts
b) quality of the Base Schedule: preferably a logic or resource-driven CPM schedule – representing the current strategies and assumptions
c) alignment and consistency of assumptions between the Base Estimate and Base Schedule
d) identification and quantification contingent risks including schedule risks
e) identification and quantification of inherent risks at the most appropriate level of first principles cost estimate against labor, material, and subcontractor
    - the uncertainties should be then consolidated and aggregated to higher level of CBS for risk modelling – for example, uncertainties might be quantified at Level 5 of CBS/WBS, then aggregated to Level 3 for risk modelling
f) allocation of the inherent and contingent risks into the cost risk model
g) assessment and modelling of key correlations, e.g. by using correlation matrix, aggregation of uncertainties to higher level of CBS/WBS, utilising Risk Factors, etc.
h) running Monte Carlo Simulation (MCS)
i) review, validation and finalisation of the results.

The process for the most common approach to this method is represented in Figure 26. The quality of the method can be improved by validation through an explicit empirical foundation.

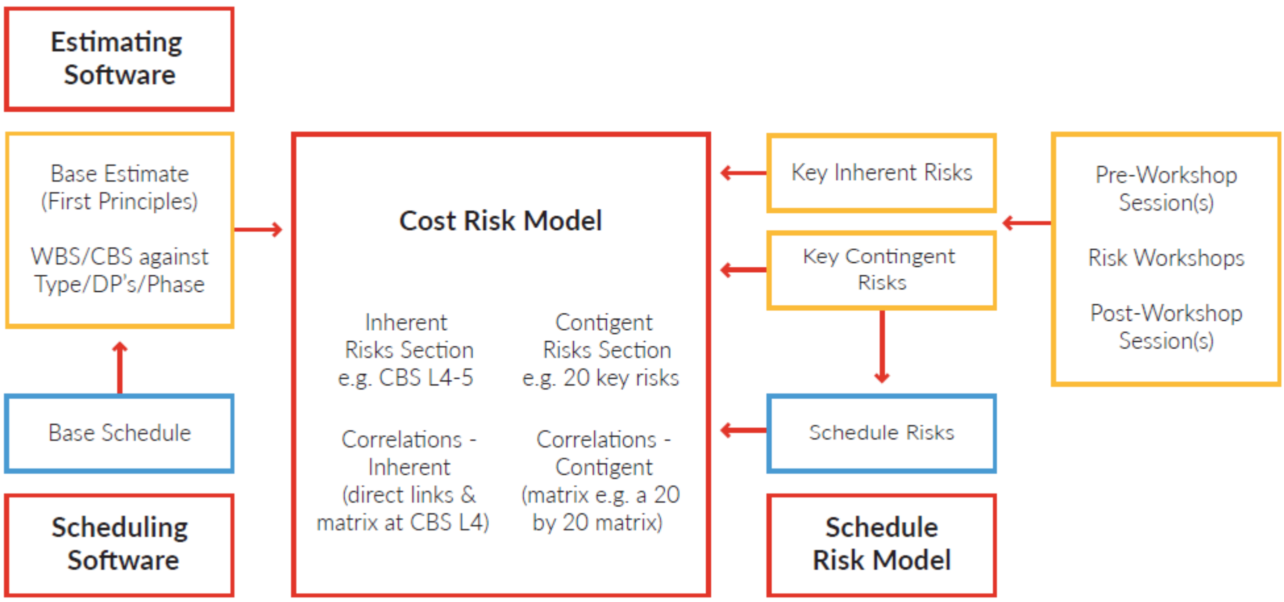


Figure 26: A typical process map for the QCRA First Principles Risk Analysis (FPRA) method

Where possible, especially at key decision points (e.g. Preliminary and Final Business Case), RES recommends the use of FPRA or Integrated Quantitative Schedule Cost Risk Analysis (iQSCRA). Further details for this method are included at Appendix E and F.

Integrated Quantitative Schedule Cost Risk Analysis (iQSCRA)

This method is based on a risk-driven, cost-loaded Critical Path Method (CPM) schedule model. As mentioned earlier, project cost drivers can be grouped into five types:

- Uncertainty (i.e., inherent risk or planned risk) around time-independent costs
- Uncertainty (i.e., inherent risk or planned risk) around time-dependent costs
- Uncertainty (i.e., systemic risks) of the project system with non-attributable cost and time impacts
- Risk Event (i.e., contingent risk or unplanned risk) with cost impacts
- Risk Event (i.e., contingent risk or unplanned risk) with time impacts that drive costs

When attempting to consolidate these five cost drivers within a single model (i.e., a logic-based or resource-based CPM schedule), the Integrated Schedule Quantitative Cost Risk Analysis (iQSCRA) methodology assesses the range of possible outcomes to enhance the quality of project outcomes. This can be achieved using a resource-loaded project schedule, where the project's Base Estimate is assigned to schedule activities or a summary schedule.

An important advantage of this model is that it simultaneously assesses the cost and risk impacts of a given risk, which helps address the cost-schedule trade-off uncertainty. The quality of the method can be improved by validating it through an explicit empirical foundation. The process for the most common approach to this method is presented in Figure 27.

By applying the iQSCRA methodology, project managers can better understand the interplay between costs and schedules, enabling more informed decision-making and increased confidence in project outcomes.

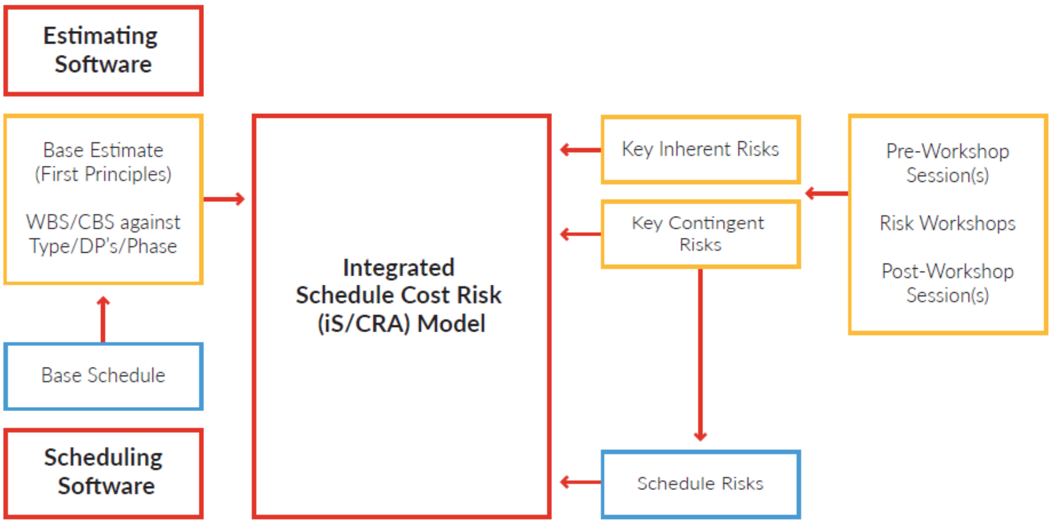


Figure 27: A typical process map for the Integrated Quantitative Schedule Cost Risk Analysis (iQSCRA) model

Further details for this method are included at Appendix F.

5.5 Contingency Determination Tools & Software

Commercial risk assessment tools offer a broad spectrum of technical capabilities and features designed to assist in developing risk-adjusted estimates and schedules, as well as conducting comprehensive risk analysis and management. Table 12 highlights some of the most popular risk assessment software packages available at the time this *Contingency Guideline* was published.

It should be noted that RES does not have any commercial arrangements with these software providers and does not specifically endorse any of these platforms. The inclusion of this list in the *Contingency Guideline* aims to inform organisations and individuals about a wide range of available options. However, RES strongly recommends that organisations undertake a detailed analysis of their specific requirements before selecting and implementing any risk analysis or management tool. This ensures that the chosen product is the best fit for their internal and external needs.

#	Vendor	Product	Applied Method & Application	Reference
1	AACE International	Excel models of the Hackney and the Rand Corp	Probabilistic Non-simulation Parametric Based for cost (FREE)	<web.AACE International.org>
2	ACEIT	Joint Analysis of Cost and Schedule (JACS)	Probabilistic Simulation for schedule & cost	www.aceit.com
3	Nodes & Links	AI QSRA & Risk	Non-Simulation AI Based & Probabilistic Simulation for schedule	https://nodeslinks.com/
4	Barbecana	Full Monte	Probabilistic Simulation for schedule	https://www.barbecana.com/full-monte/
5	Booz Allen Hamilton	Argo	Probabilistic Simulation for cost (FREE)	https://boozallen.github.io/argo/
6	Booz Allen Hamilton	Polaris	Probabilistic Simulation for schedule & cost	<www.boozallen.com/consulting/products/polaris>
7	Deltek	Acumen Risk	Probabilistic Simulation for schedule & cost and iQSCRA	<www.deltek.co.uk/products/ppm/risk/acumen-risk>
8	Frontline Systems	Analytic Solver Simulation	Probabilistic Simulation for cost	https://www.solver.com/
9	Galorath	SEER	Probabilistic Non-simulation Parametric Based for cost	https://galorath.com/seer-for-cost-optimization/
10	GoldSim Technology Group LLC	GoldSim	Probabilistic Simulation for schedule & cost	https://www.goldsim.com/Web/Applications/Areas/BusinessSystems/ProjectPlanning/
11	InEight	InEight Schedule	Non-Simulation AI Based & Probabilistic Simulation for schedule & cost	https://ineight.com/products/ineight-schedule/
12	Intaver Institute Inc.	Risky Project	Probabilistic Simulation for schedule & cost	http://www.intaver.com
13	KGC Consultants S.A. & Validation Estimating LLC	ValidRisk	Probabilistic Non-Simulation Parametric Based & Simulation for cost	https://www.validrisk.com/
14	Lumina	Analytica	Probabilistic Simulation for cost	https://analytica.com/
15	Lumivero (formerly Palisade)	@Risk and the DecisionTools Suite	Probabilistic Simulation for cost	https://lumivero.com/products/at-risk/
16	Lumivero (formerly Palisade)	Schedule Risk Analysis	Probabilistic Simulation for schedule	https://lumivero.com/products/decision-tools/scheduleriskanalysis/
17	Lumivero (formerly Risk Decisions)	Predict! Risk Analysis	Probabilistic Simulation for schedule & cost	<www.riskdecisions.com/predict-risk-management-software>
18	MC FLOsim	MC FLO	Probabilistic Simulation for	https://www.mcflosim.ch/en

			cost	/the-product/faq/
19	Nodes & Links	Nodes & Links	Non-Simulation AI Based	http://www.nodeslinks.com
20	nPlan	nPlan	Non-Simulation AI Based	https://www.nplan.io/
21	Oracle	Crystal Ball	Probabilistic Simulation for cost	https://www.oracle.com/au/applications/crystalball/
22	Oracle	Primavera Risk Analysis (PRA), previously Pertmaster	Probabilistic Simulation for schedule & cost and iQSCRA	NA
23	Oracle	Primavera Cloud Risk Analysis	Probabilistic Simulation for schedule & cost and iQSCRA	https://www.oracle.com/au/construction-engineering/primavera-cloud-project-management/
24	Riskonnect (formerly Sword GRC)	Active Risk Manager (ARM)	Probabilistic Simulation for cost	https://riskonnect.com/solutions/active-risk-manager/
25	Safran Software Solutions	Safran Risk	Probabilistic Simulation for schedule & cost and iQSCRA	<www.safran.com/products/safran-risk>
26	Spider Project Team	Spider Project	Probabilistic Simulation for schedule & cost and iQSCRA	<www.spiderproject.com>
27	Structured Data, LLC	RiskAMP Web	Probabilistic Simulation for cost	https://web.riskamp.com/front-page
28	Trigo White Ltd	White Box	Probabilistic Simulation for cost	https://trigowhite.com/Pages/RiskManagementPages/WhiteBoxRM.aspx#:~:text=With%20White%20Box%20risk%20management,assessing%20risk%20to%20a%20project.
29	Vose Software	Tamara, ModelRisk,	Probabilistic Simulation for schedule & cost and iQSCRA	www.vosesoftware.com
30	XLRisk	XLRisk	Probabilistic Simulation for cost (FREE)	https://github.com/pyscripter/XLRisk?tab=readme-ov-file

Table 12: List of common risk analysis tools and software

5.6 Validation and Benchmarking

While this *Contingency Guideline* acknowledges the value of historical data, it emphasises that such data should be carefully gathered and managed, including making decisions about what to include and exclude. Practitioners should analyse historical data in a consistent manner that supports risk management objectives (and other uses). Ideally, practitioners will embed the learnings from historical data directly into the methods they use.

Regardless of the method used to determine contingency, it is also critical to assess the historical performance of risk assessments, as large projects often exhibit underestimation and small projects overestimation. Practitioners should scrutinise evidence of contingency funds being spent on additional scope or other inappropriate uses. These steps not only help calibrate risk assessment procedures but also enhance the overall performance of organisational and project risk management.

RES recommends using iterative simulation techniques for risk prioritisation. By progressively disabling risks and rerunning simulations, practitioners can identify the risks that most significantly contribute to schedule and cost delays. This allows management to focus mitigation efforts on the most critical risk drivers.

In the absence of internal and external contingency historical data—and for top-down benchmarking purposes only—Table 13 provides guidance on the percentage above the Base Estimate that could represent the common P50 and P90 approximations for different types of transport projects.

Project Phase	**Type of estimate**	**P50 Range**	**P90 Range**
Initiation and Strategic Assessment	Preliminary Business Case	20% to 40%	30% to 70%
Concept	Full Business Case	10% to 15%	25% to 40%
Delivery Readiness	Pre-Tender	5% to 10%	10% to 20%
Delivery	Construction	Up to 5%	Up to 10%

Table 13: Common benchmarking of P50 and P90 contingency allowance (Transport Projects)

RES Recommendation: It should be noted that there is insufficient empirically based and validated historical data (including research-based evidence) to fully support the contingency ranges provided in Table 13.

To mitigate and minimise the risk of bias during contingency determination, RES strongly recommends that these ranges be used only as a final step in the process. Any inconsistencies identified can then be reviewed, validated, and documented. This benchmarking and guidance on contingency ranges should not replace appropriate and sound cost estimating, project scheduling, or contingency determination. These ranges should be used solely for cross-checking and comparison purposes.

5.7 Further Reading

- AACE International, RP No. 41R-08 – *Risk Analysis and Contingency Determination using Range Estimating*
- AACE International, RP No. 42R-08 – *Risk Analysis and Contingency Determination using Parametric Estimating*
- AACE International, RP No. 43R-08 – *Risk Analysis and Contingency Determination using Parametric Estimating – Example Models as Applied for the Process Industries*
- AACE International, RP No. 43R-08 – *Risk Analysis and Contingency Determination using Expected Value*
- AACE International, RP No. 57R-09 – *Integrated Cost and Quantitative Schedule Risk Analysis Using Monte Carlo Simulation of a CPM Model*
- AACE International, RP No. 64R-11 – *CPM Schedule Risk Modelling and Analysis: Special Considerations*
- AACE International, RP No. 65R-11 – *Integrated Cost and Quantitative Schedule Risk Analysis and Contingency Determination using Expected Value*
- AACE International, RP No. 66R-11 – *Selecting Probability Distribution Functions for use in Cost and Schedule Risk Simulation Models*

- AACE International, RP No. 68R-11 – *Escalation Estimating Using Indices and Monte Carlo Simulation*
- AACE International, RP No. 70R-12 – *Principles of Schedule Contingency Management – As Applied in Engineering, Procurement and Construction*
- AACE International, RP No. 75R-12 – *Schedule and Cost Reserves within the Framework of ANSI EIA-748*
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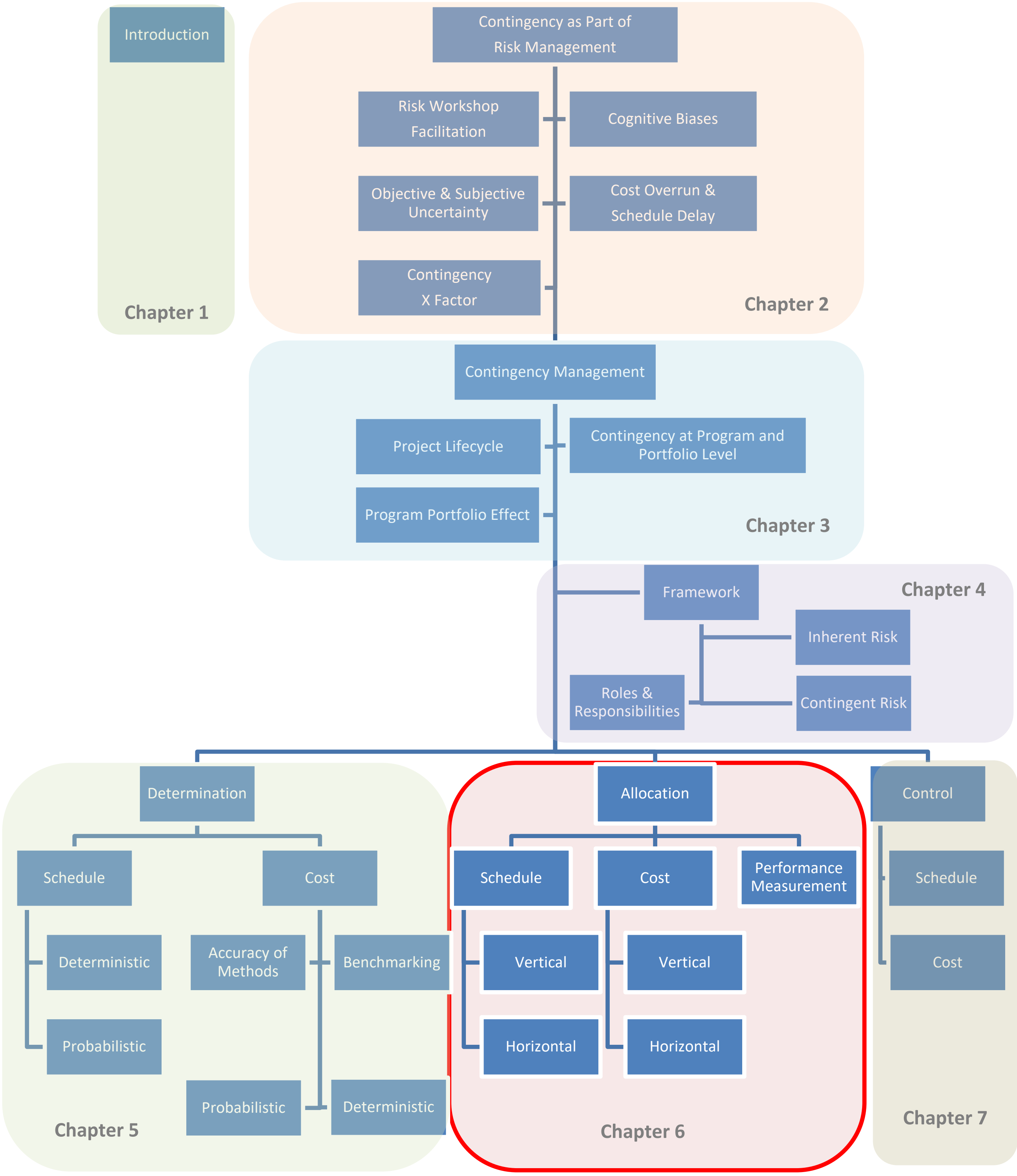
6. Contingency Allocation

6.1 Structure of Content



6.2 Overview

For major infrastructure projects, in the absence of any specific contractual arrangement, a party should assume responsibility for a risk in the following circumstances:

a) its likelihood and/or consequences are within the party's control – noting that 'control' means the party should be able to assess, and treat (e.g. accept, avoid, mitigate or transfer) the risk. From a principal's perspective, the capacity and capability of the team may be limited. Consequently, they might choose to allocate contingency to the contractor.
b) it leads to a greater benefit of the party controlling the risk for any key objective. For example, economic or reputational benefits
c) if the risk occurs, the consequence stays with that party, and it is not practical and/or reasonable to try to transfer the loss to another party
d) it incentivises desired project behaviour, such as risk-based decision making, efficiency, innovation, and value engineering.

In 2005, Engineers Australia and the Chamber of Commerce and Industry of Western Australia conducted a study of effective risk allocation in major construction contracts. It was found that risks were not according to which party was best able to manage the risk. Another study by the Queensland University of Technology highlighted that risk reduction is the most frequently used risk response method, with the use of contingencies and contractual transfer preferred over insurance.

Contingency allocation and control should be planned and managed in alignment with risk allocation agreements as well as broader project performance measurement strategies. For these purposes, proactive planning for contingency allocation and control should enable:

a) establishment of a contract, project or program baseline risk profile and consistent basis for planning
b) establishment of an integrated view of the allocation of contingency for the contract, project or program and the desired confidence levels (or other statistical measure) at each level
c) development of a process for change control, to manage proposed changes to the contingency included within the contract, project or program baseline
d) development of a process to control progressive elaboration of the scope, or rolling wave planning – and the associated transfer of contingency within the contract, project or program baseline
e) monitoring of the contract, project or program risk and contingency profile, measuring deviations from the plan

planning and forecasting by the users of the performance management strategies for assessment of contingency resources (e.g. time, human resources, and money), availability and demand

6.3 Contingency & Contract Type

For major infrastructure projects, cost and risk allocations are typically outlined within the contract. The risk allocation protocol for different types of contracts should be clearly defined, documented and communicated between the commercial team and the cost/schedule/risk teams. Below is an analysis on the different risk allocation types and how they apply to commonly used contracts:

1. **Construct Only**

   - In a construct-only contract, also known as a "build-only" contract, the contractor is primarily responsible for the construction phase of the project without being involved in the design aspect. Under this arrangement, the design risks remain with the owner or principal, who provides the complete design documentation to the contractor. The contractor assumes the construction risks, including ensuring that the work adheres to the design provided, meeting quality standards, and managing construction-related cost risks. It is important to clearly delineate contingencies in the contract to protect the contractor from risks outside their control, such as unforeseen site conditions or scope changes initiated by the owner. This clarity in risk allocation helps to prevent disputes and ensures that both parties understand their responsibilities and liabilities throughout the project.

2. **Design and Construct (D&C)**
   - In D&C contracts, the contractor typically takes on the majority of design risks, construction risks, and related cost risks. The principal retains some risks, such as changes in project scope and site conditions that could not be reasonably foreseen. It is crucial to detail how contingencies are assigned to mitigate the contractor's exposure to risks outside of their control.
3. **Public-Private Partnerships (PPP)**
   - PPP contracts involve long-term collaboration between public and private entities. Risk allocation is shared based on the strengths of each party, where construction, operation, and maintenance risks often fall on the private partner, while regulatory and political risks remain with the public authority. Elaborating on how these risks are quantified and allocated ensures transparency and reduces the potential for disputes.
4. **Fixed-Price Contracts**
   - In fixed-price contracts, the contractor assumes most risks associated with cost overruns and project delays, which makes it essential to allocate sufficient contingency to mitigate unforeseen events. The client bears risks related to changes in scope or project requirements. Elaborating on the contingency provisions in these contracts can help clarify expectations.
5. **Cost-Reimbursable Contracts**
   - In cost-reimbursable contracts, the client assumes more of the cost risk compared to fixed-price contracts. Risk allocation is typically more flexible, with both parties sharing the burden for uncertainties. Providing a detailed risk allocation protocol ensures that both parties understand the division of financial responsibilities.
6. **FIDIC and NEC4 Contracts**
   - FIDIC (International Federation of Consulting Engineers) contracts allocate risks between the employer and contractor using specific clauses, with various editions tailored to different projects (e.g., Red Book, Yellow Book). NEC4 contracts focus on fostering collaboration and effective communication, often incorporating shared risk registers to document risk allocation. Elaborating on specific clauses related to risk allocation helps practitioners understand the contractual mechanisms available to manage and mitigate risks.

6.4 Contingency & Risk Allocation Types

For the purpose of this *Contingency Guideline* and the topic of contingency management, there are three types of risk allocation terms.

- **Retained Risks or Client-Allocated Risks**: These are risks that the client retains due to their ability to better manage or absorb them, such as risks associated with regulatory changes or land acquisition.
- **Transferred Risks or Contractor-Allocated Risks**: These are risks that the contractor manages, usually because they are related to the construction process or means and methods (e.g., labor availability, equipment breakdown).
- **Shared Risks**: In some situations, risks may be shared between the client and contractor. For instance, certain force majeure events may involve shared responsibility, with both parties bearing some level of risk.

RES Recommendation: There is often confusion between 'risk allocation' and 'contingency allocation'. 'risk allocation' is typically established by the contract during procurement and negotiation phases. In contrast, 'contingency allocation'—through horizontal and vertical allocation—is generally undertaken by either party post-contract signing to better manage the budgeted contingency allowance.

From the Principal's perspective, and during the Initial and Final Business Case stages, this Guideline recommends that all project risks (Retained, Transferred, and Shared Risks) be initially included in the schedule and cost risk contingency modelling. This inclusion enables an accurate assessment of overall project risk exposure and the required contingency regardless of risk allocation. Subsequently, the sub-models will be used to assess the required contingency for each party, by using the allocated risks to each party as per the final accepted contractual terms and conditions.

6.5 Contingency and Project Performance Measurement

Projects require a structured performance measurement strategy to assess progress against the latest approved plan and to support accurate forecasting. This is especially crucial for projects with significant risks associated with their cost and/or schedule objectives.

Appropriate performance metrics, including Earned Value (EV), Schedule Performance Index (SPI), and Cost Performance Index (CPI), enable informed decision-making that supports effective management of contracts, projects, or programs. Leading indicators may also be incorporated into performance management strategies. Examples of these leading indicators include safety metrics such as lost time injuries, and quality metrics such as non-conformance reports (NCR), defects, deviations, and waivers. Monitoring these metrics can provide early warnings about whether risk and contingency provisions are sufficient.

The relationship between contingency and project performance measurement is multifaceted and can present both opportunities and risks, along with uncertainties that may adversely affect a project's goals.

RES acknowledges the diverse range of project performance measurement techniques, strategies, and standards available. For the purpose of this *Contingency Guideline*, the "Australian Standard AS 4817-2006, Project Performance Measurement using Earned Value" is explained and recommended. Earned Value Performance Measurement (EVPM) is an integrated methodology that combines cost, schedule, and technical performance data to measure, report, and forecast project performance. The EVPM method allows risk practitioners to obtain a comprehensive view of project health and to adjust as needed.

The EVPM method allows risk practitioners to:

a) measure the performance and status of projects
b) compare project progress to the original plan
c) predict future performance using historical performance data
d) use metrics to measure project performance within an organisation, and against external projects

AS 4817-2006 describes three keys to success when using EVPM:

a) plan work to allow achievements to be measured
b) select objective techniques to gauge 'achievement' for each project component
c) integrate the cost, schedule and technical factors of achievement aspects in a single management system.

The steps below outline the process of applying the EVPM method to a project. For the purpose of this *Contingency Guideline*, steps 1 to 5 have an impact on contingency determination while contingency allocation should be addressed in step 6, as explained in the following section. Contingency control is a key element of EVPM during steps 7 to 11 and will be explained in Chapter 7.

1. Decompose the project scope
2. Assign RACI (Responsible, Accountable, Consulted and Informed) Matrices
3. Schedule the work packages
4. Develop time-phased budget
5. Assign objective measures of performance
6. Set the Performance Measurement Baseline (PMB)
7. Authorise and perform the work packages
8. Accumulate and report project performance data
9. Analyse project performance data
10. Take management action
11. Maintain the baseline.

6.6 Contingency allocation in setting PMB

To establish the PMB, practitioners should create a project baseline which incorporates scope, schedule and cost. This single baseline should be used as a basis to control and manage performance throughout the project lifecycle. As far as possible, the PMB should provide the team with an accurate time-based model of the planned project budget and schedule. Three approaches to contingency allocation for PMB setting purposes are:

1. PMB excludes both Contingency Reserve (CR) and Management Reserve (MR)
2. PMB includes both CR and MR
3. PMB includes CR but excludes MR.

RES Recommendation: the third approach above is preferred in this Guideline – the CR should be a reserve within the PMB managed by the project manager for incorporation of realised risks, while the MR is withheld to cover unforeseen risk events.

Contingency Reserve (CR) is applied to identified and accepted risks and is allocated for planned contingency responses. It is primarily used to implement those responses when risk events occur, financing the execution of contingency plans or necessary risk responses. The main methods for distributing and allocating CR within the Performance Measurement Baseline (PMB) for cost and schedule estimates are explained in Sections 6.5 and 6.6, respectively.

The PMB should provide a realistic, time-phased model of the project budget and schedule that incorporates contingency reserves appropriately. As discussed earlier, this *Contingency Guideline* recommends allocating contingency to relevant risks or project phases when creating the PMB. However, contingency may be removed from the PMB, reallocated, and then managed at the project level during project execution.

Management Reserve (MR) is not part of the cost baseline but can be a component of the project budget or completely external to the project budget. For the purpose of this Guideline, it can be added to the PMB to cover the costs of unforeseen work in accordance with the organisation's change management process.

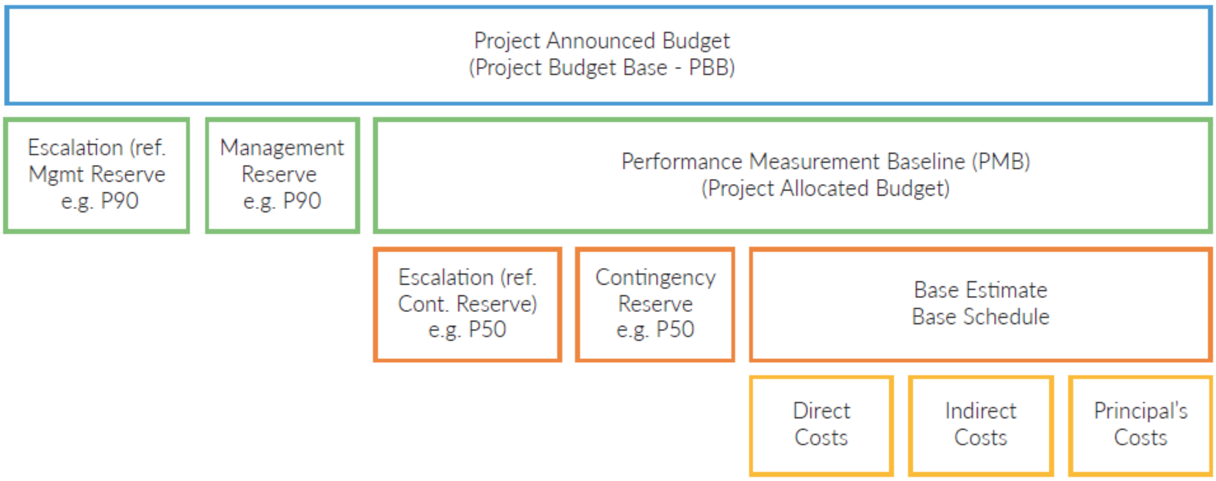


Figure 28: The structure of the project budget base and its elements

To prepare the PMB, this *Contingency Guideline* recommends the process below:

a) Calculate the required cost contingency for the desired confidence level (e.g. P50 cost)
b) Calculate the required schedule contingency for desired confidence level (e.g. P50 schedule):
    - Create additional contingency activities – one before the project Practical Completion (PC) Date and others before the key contractual or critical milestones across the Base Schedule
    - Split and distribute the schedule contingency allowance among these contingency activities
c) Allocate the P50 cost to the P50 schedule to generate the expenditure cost plan (i.e. PMB)
d) Note that additional schedule and/or cost management reserves can be managed as separate 'buckets'
e) To set a tight target PMB, allocate all available schedule contingency before the PC Date, and monitor and compare actual progress against the two cash flows.

This has been illustrated in Figure 29.

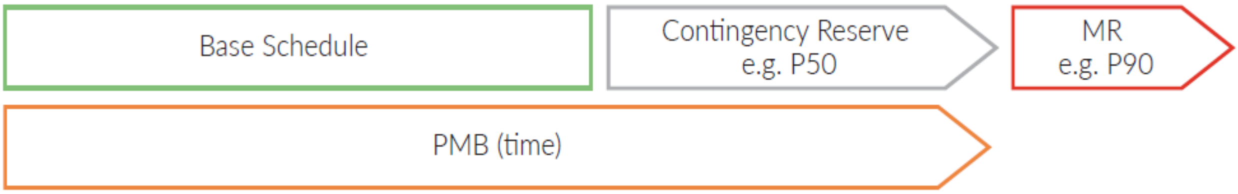


Figure 29: Allocation of schedule contingency for establishment of PMB

For further details regarding project performance measurement, RES recommends *Australian Standard AS 4817-2006, Project performance measurement using Earned Value*.

RES Example: a head contractor, Crown Contractors, has recently won a $300m lump sum Design and Construct (D&C) road project.

Key details are below:

- Base Estimate: $250m
- six-month design, 2.5-year construction, overall schedule duration of three years
- key risks: soft soil treatment, wet weather, availability of import material
- key contractual milestones: SP1 bridge A, SP2 road X and SP3 project Completion Date
- three months of schedule contingency for P70 confidence level.

To maximise the efficiency of contingency control during construction, the management decided to split the available contingency of three months into two buckets as described below:

- allocate two months of available three months schedule contingency, as CR, for the P50 confidence level at the project level. This contingency will be owned and managed by the project manager
- allocate the remaining one-month contingency, as MR, owned and controlled by the general manager.

To establish a reasonable cash flow and the PMB, and considering the associated risks for each key milestone, the project manager created three contingency activities before each contractual milestone and then distributed the available two months contingency between them as shown below:

- two weeks contingency activity prior to SP1
- three weeks contingency activity prior to SP2
- three weeks contingency activity prior to SP3

The Quantitative Cost Risk Analysis recommended a P50 contingency allowance of 10% ($25m) and P70 contingency of 20% ($50m). To achieve reasonable and effective contingency control, the contractor decided to allocate P50 contingency ($25m) as the CR, and the remaining $25m (P70 minus P50 contingency) as the MR.

To establish a reasonable PMB and cash flow and considering the risk profile across the scope and schedule, $25m CR was then distributed to WBS sections (as below) within the project schedule. In summary:

- 10% of $25m, i.e. $2.5m, to be allocated to design activities
- 50% of $25m, i.e. $12.5m, to be allocated to soft soil treatment activities
- 20% of $25m, i.e. $5m, to be allocated to bridge construction activities
- 10% of $25m, i.e. $2.5m, to be allocated to cut and fill activities
- 10% of $25m, i.e. $2.5m, to be allocated across the schedule (on a pro-rata basis for the direct expenditure cost) for other identified risks.

The remaining $25m MR will be kept and controlled as a bucket by the general manager.

For effective and efficient contingency allocation in setting the PMB, it is critical to assess and allocate contingencies appropriately and in accordance with applicable contracts and their terms and conditions as well as Delegation of Authority and funding requirements. To facilitate these considerations, this *Contingency Guideline* discusses two directions of contingency allocation:

a) vertical allocation: the objective of vertical contingency allocation is to appropriately delegate control of contingency for different levels of delegation (e.g. the client, delivery agency, general manager and project manager)
b) horizontal allocation: the objective of horizontal contingency allocation is to appropriately set indicative distribution of contingencies at any level of delegation (e.g. at the project level this would be between different project areas, including procurement, design, and human resources).

The following sections will provide further details on the vertical and horizontal allocation of schedule and cost contingencies.

6.7 Schedule Contingency Allocation

6.7.1 Vertical Allocation

Good industry practice for vertical schedule contingency allocation involves distributing control of contingency to the appropriate delegation level, thereby aligning responsibility with the capability to manage risks effectively. This approach allows contingency owners, in accordance with their Delegation of Authority (DoA), to manage allocations that best match their capability and proximity to the risks involved.

It should also be noted that vertical schedule contingency allocation may be assessed and approached differently depending on the requirements and perspectives of the Principal and the Contractor.

RES Example: a head contractor, Crown Contractors, has recently won a $300m lump sum D&C road project. Key details are listed below:

a) six-month design, 2.5-year construction, overall schedule duration of three years
b) key risks: soft soil treatment, wet weather, availability of import material
c) three months of schedule contingency for P70 confidence level.

To maximise the efficiency of contingency control during construction, management decided to split the available contingency of three months into two buckets as described below:

a) allocate two months of available three months schedule contingency, for the P50 confidence level at the project level. This contingency will be owned and managed by the project manager
b) allocate the remaining one-month contingency, owned and controlled by the general manager.

To establish a reasonable cash flow and the PMB, the project manager then needs to allocate or distribute his two months of schedule contingency across the project schedule. This is the horizontal allocation of contingency (see Section 6.5.2).

6.7.2 Horizontal Allocation

Horizontal schedule contingency should be allocated across the project lifecycle, taking into consideration critical phases, risk categories, and key milestones. This allows schedule contingency to be distributed throughout the schedule or represented by an activity near the completion date. The available options for horizontal schedule contingency allocation include, but are not limited to:

a) Distributing contingency between critical activities on a pro-rata basis – This method can be risky as it embeds contingency directly into critical activities, making it challenging to control and monitor separately. Ensuring transparency and traceability in contingency allocation is crucial, and this method may compromise both.
b) Allocating non-working days within the project calendar – This approach is not ideal when the schedule is used for external communication, such as interfacing with third parties or managing take-and-give milestones. Allocating non-working days may lead to misunderstandings or miscommunications about actual schedule commitments.
c) Representing schedule contingencies as a lag between two activities – This can provide clarity and flexibility in managing potential delays between linked activities.
d) Creating a single activity just before the project's Practical Completion Date (PC Date) – This allows a buffer to accommodate potential delays close to the project's end.
e) Creating multiple activities just before key milestones (i.e., contractual and/or critical milestones) throughout the project schedule – Contingency can be distributed among these activities based on the associated risks for each key milestone, providing targeted risk management.
f) Using risk-adjusted finish dates, such as P50 and P80, for each activity by employing the results of a Quantitative Schedule Risk Analysis (QSRA) – This method integrates risk analysis outcomes to set more accurate completion dates, enhancing the reliability of the project schedule)

RES Recommendation: subject to contractual and project specific requirements, RES recommends a combination of methods (d), (e) and (f) above – as allocating a large portion of contingency to a single activity close to the PC Date is generally preferable. This is because distributing contingency between a number of activities in advance can be problematic because risk practitioners do not know which risks will eventuate, or the magnitude of their outcomes. In addition, dispersing contingency to many activities may cause it to be prematurely or superfluously consumed.

If practitioners choose to distribute contingency between several activities, they should ensure that this does not affect critical path calculations. The allocation of a portion of contingency to key interim milestones should be kept to a minimum – as they should not be associated with scope or resources – or cause a practical delay to successive activities.

The approaches of horizontal schedule contingency allocation are illustrated in Figure 30.

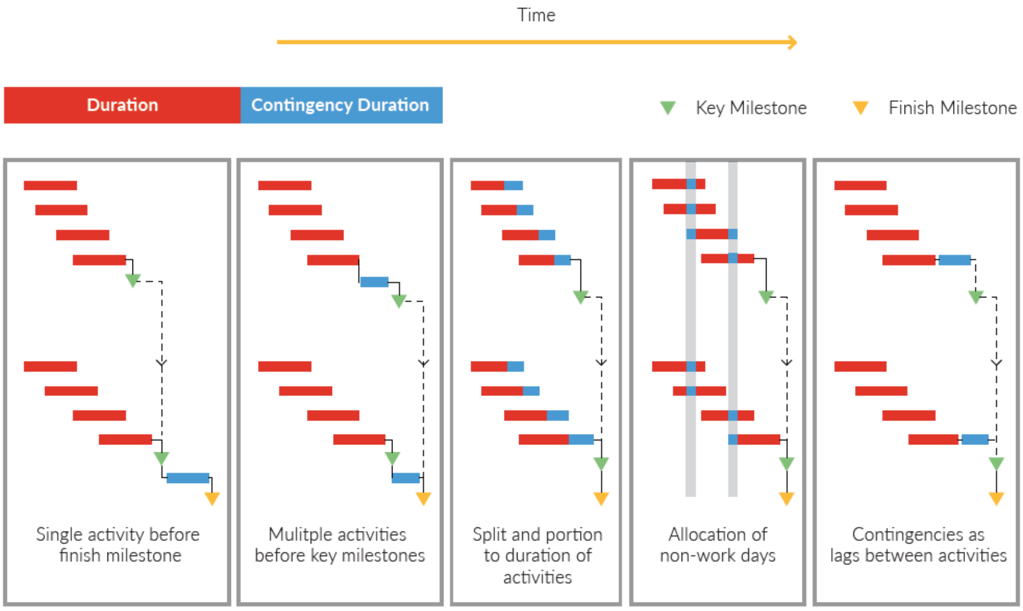


Figure 30: Approaches for horizontal allocation of schedule contingency

RES Recommendation: for practical application of methods (d) and (e) in horizontal allocation of schedule contingency – and depending on contractual and project specific requirements – RES recommends 60-70% of the available schedule contingency is captured as a bucket before the project PC Date. The remaining 30-40% contingency allowance should be distributed and allocated prior to interim key contractual or critical milestones – preferably to less than five milestones – based on their associated risks.

6.8 Cost Contingency Allocation

6.8.1 Vertical Allocation

The vertical allocation of cost contingency should follow the same principles as schedule contingency, namely, separating the contingency allocation into a Contingency Reserve (CR), to be managed at the project level, and a Management Reserve (MR), managed at the program or portfolio level. RES acknowledges that across different sectors and organisations, there are diverse views and approaches to defining, differentiating, assessing, allocating, and controlling CR and MR.

In this *Contingency Guideline*, CR refers to the contingency within the Performance Measurement Baseline (PMB) allocated for identified and accepted risks where responses are planned. MR is a portion of the Project Base Budget (PBB) reserved for management control, specifically for unforeseen work within the project scope or for strategic decisions that require additional funds. Depending on the specific requirements of each organisation and its stakeholders, the MR might represent the budget for unexpected work that falls within the project's scope or for activities outside the planned scope that have been authorised by decision-makers. In special circumstances, the MR might be used to cover items outside the project scope to achieve greater benefits for the customer.

However, the *Contingency Guideline* also acknowledges that some owners, especially within the private sector, may define MR as being outside of the project funding. In the private sector, MR is often regarded as the additional amount that may be required to complete the project if outcomes turn out to be more pessimistic than the overall contingency reserve allows.

MR enables project owners to assess how much extra funding they might need to contribute beyond the allocated budget, including the CR. This allows management to decide the amount of equity they are prepared to hold in a project while protecting their balance sheet from excessive exposure. This determination can influence the maximum percentage of a major project an equity partner may be willing to own.

RES Example: as a head contractor, Crown Contractors, has recently won a $300m lump sum D&C road project. Key details are below:

a) six-month design, 2.5-year construction, overall schedule duration of three years
b) key risks: soft soil treatment, wet weather, availability of import material
c) key contractual milestones: SP1 bridge A, SP2 road X and SP3 PC Date
d) three months of schedule contingency for P70 confidence level.

To maximise the efficiency of contingency control during construction, management decided to split the available contingency of three months to two buckets:

a) allocate two months of schedule contingency, as CR, for the P50 confidence level (at the project level) to be owned and managed by the project manager
b) allocate the remaining one month of contingency, as MR, owned and controlled by the general manager.

To establish a reasonable cash flow and the PMB (considering the risks associated with each key milestone) the project manager created three contingency activities before each contractual milestone and then distributed the available two months of contingency between them as below:

a) two weeks of contingency activity prior to SP1
b) three weeks of contingency activity prior to SP2
c) three weeks of contingency activity prior to SP3.

The assessment of the Management Reserve (MR) should align with the organisation's policies; the overall uncertainty and unknowns associated with the project scope; input from internal and external stakeholders; the organisation's culture and risk appetite; market conditions; and various other factors. The MR can be estimated using an independent deterministic method for the total cost or time of the project (e.g., 5–15%) or probabilistic methods.

This estimation can be made as an additional step after assessing the Contingency Reserve (CR), or even as part of the same contingency assessment with a higher confidence level, using one of the following options:

- Independent Deterministic Method: Estimating a certain percentage (such as 5-15%) of the total project cost or duration as MR.

- Probabilistic Methods: Employing statistical or risk-based models to derive MR based on project uncertainty and variability.

Incorporating these methods ensures a comprehensive approach to managing project risks and uncertainties, providing a buffer to accommodate unforeseen challenges and strategic decisions.

a) selecting CR from a lower confidence level (e.g. P50) and then MR from a higher confidence level (e.g. P90). This method is more common with government organisations, asset owners or investors
b) selecting a portion of the allocated contingency for the desired confidence level, (e.g. 80% of P50), for CR and then the remaining contingency as MR, (e.g. 20% of P50). This method is more common with contractors – especially for lump sum and D&C contracts.

RES Recommendation: in practice, while MR is widely used by government agencies for budgeting purposes, it is rarely set aside in the private sector as many consider the organisation will provide extra funding at the request of the project management team if circumstances require. However, this is **not recommended** by RES. For more effective contingency management, RES recommends a separate MR bucket is reasonably and practically assessed, allocated and managed.

In a government environment, the vertical contingency allowance up to the 'allocated budget' level is controlled by the Government Agency. Any request for access to additional funding, up to the 'announced budget' level, requires approval from the client (e.g., Treasury or the Federal Government).

In a private sector context for a Design and Construct (D&C) project, the allocated budget (e.g., P50 budget) can be managed by the project manager, while the remaining contingency (e.g., P70 or P90 contingency) is allocated and controlled by the project director or general manager as the Management Reserve (MR).

Figure 31 shows an example of project cost and schedule contingency allocation.

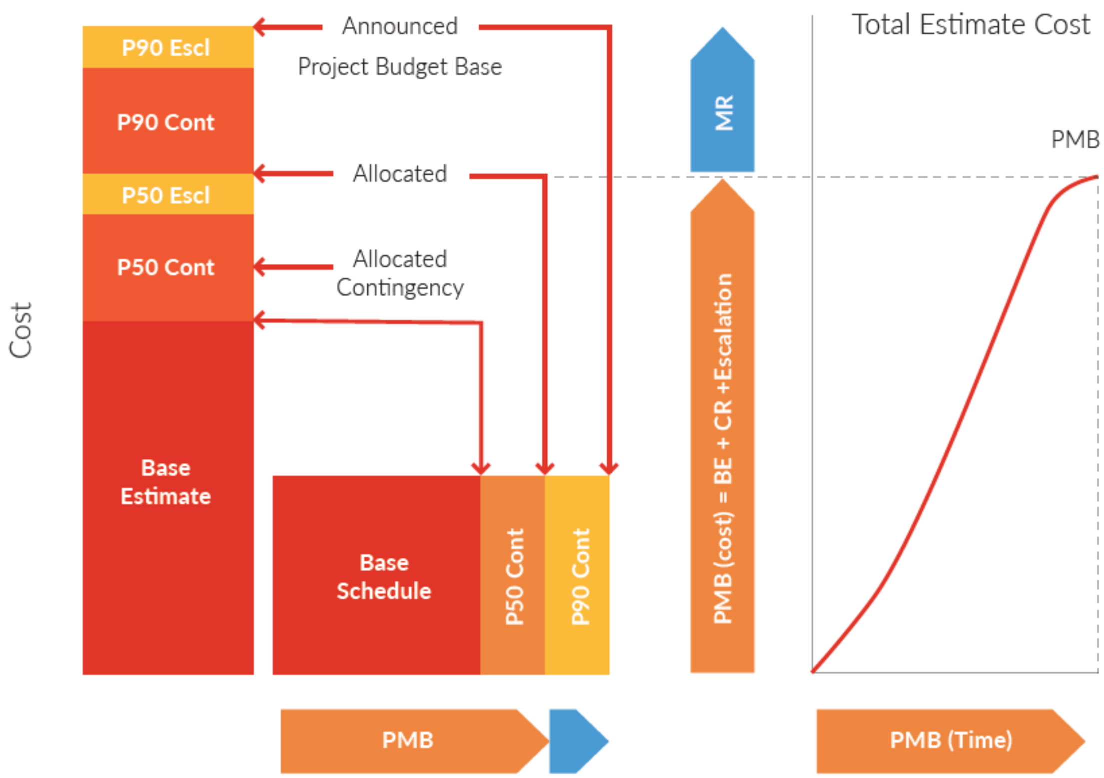


Figure 31: An example of time and cost contingency vertical allocation

RES Example: ABC, a government agency, has prepared a Final Business Case for delivering a major road project with its cost estimate as below:

a) Base Estimate for D&C Contractor: $90m (using the First Principle Estimate methodology)
b) Base Estimate (total including client's costs): $100m
c) P50 Contingency bucket: $20m (using a probabilistic estimation methodology)
d) P90 Contingency bucket: $15m (using a probabilistic estimation methodology
e) no escalation allowance is required.

For budgeting purposes, the P50 Contingency bucket will be allocated within PMB, as the CR. While the additional estimated P90 Contingency bucket (i.e. $15m) will be funded to this project by Treasury, as the MR. This will not be directly accessible by the government agency. A special control process including justification of needs and evidence of proactive risk management is needed as part of accessing this additional funding. Hence, $120m will be allocated to ABC to deliver this project. With this funding approval, ABC progresses with the procurement of a D&C contract through a selective tender.

DEF, as a tier 1 contractor, has prepared and submitted its response to this tender opportunity. For this lump sum contract and considering all internal and external circumstances as well as market conditions, the senior management of DEF decided to proceed with the lump sum tender submission as below:

a) Base Estimate $85m
b) P50 Contingency bucket: $17m
c) Lump Sum submission: $102m.

DEF was selected as the preferred tenderer following a comprehensive tender evaluation including a risk and contingency comparison between the different tenderers. At the commencement of the project, DEF management decided to allocate 80% of the $17m available contingency (i.e. $13.6m) as CR and the remaining 20% (i.e. $3.4m) as MR. As recommended by RES, the CR will be controlled and used by the project manager when establishing the PMB for project performance measurement and Earned Value assessment. MR will be allocated out of PMB and will be controlled and released by senior management, if required.

6.8.2 Horizontal Allocation

The objective of horizontal cost contingency allocation is to appropriately set the indicative distribution of contingencies between different areas of a project or program so a reasonable and achievable PMB can be established. In a D&C project, examples of project areas could include approvals, design and human resources. Cost contingency can be linked to the cost expenditure curve in several ways, including the three approaches below:

1. CR is global to the overall project and will be allocated at the project timeline:
   a) at the beginning of the project
   b) at the end of the project
   c) distributed along the timeline (e.g. linearly).
2. CR is allocated by the project lifecycle phase or risk categories
3. CR is distributed by using a pro-rata approach of cost expenditure per month.

This *Contingency Guideline* recommends that the cost contingency be managed as a single 'bucket' (at the project level). However, indicative distribution to different project areas will improve the effectiveness and transparency of contingency control as well as creating a more realistic project cash flow and PMB. An example of some project areas or subgroups is presented in Table 14.

Approvals	Legal & Commercial
Constructability	Occupational Health and Safety
Community	Procurement
Design	Project Management
Earthworks	Property
Environment, Noise and Heritage	External Stakeholders
Funding	Structures
Government	Utilities
Human Resources	Miscellaneous

Table 14: Some examples of project areas or subgroups

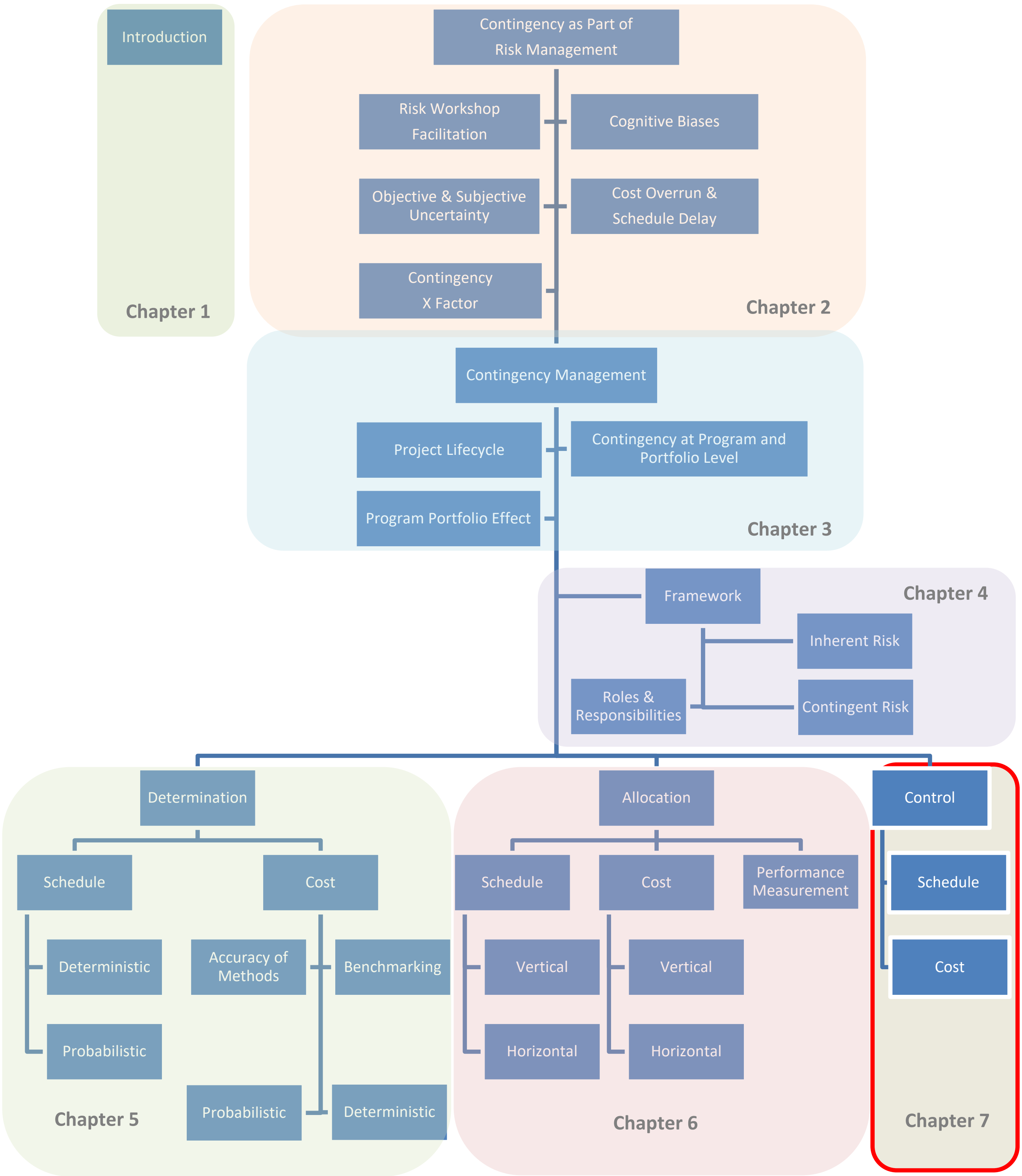
Another approach is to run full, sequential simulations when single (or grouped) costs and tasks – or uncertainty classes – are removed. When each element is taken out of the equation, the simulation models the results of its removal for the probability levels chosen. This process can help organisations decide how best to set priorities to optimise the project's risk response.

6.9 Further Reading

- AACE INTERNATIONAL, RP No. 67R-11 – *Contract Risk Allocation As Applied in Engineering, Procurement and Construction*
- AACE INTERNATIONAL, RP No. 72R-12 – *Developing a Project Risk Management Plan*
- APM, *Project Risk Analysis and Management Guide*, APM Publishing, 2nd Edition, 2004
- AS 4817 – 2006, *Project performance measurement using Earned Value*
- Australian Government Treasury, *Charter of Budget Honesty Policy – Policy Costing Guidelines* <www.treasury.gov.au/PublicationsAndMedia/ Publications/2012/charter-of-budget-honesty>
- Australian Government, *National PPP Guides Volume 4: PSC Guidance*
- Boardman, A.E., Greenberg, D.H., Veining, A.R. and Weimer, D.L., *Cost-Benefit Analysis: Concepts and Practice*, Prentice Hall, 1996
- CIOB, *Guide to Good Practice in the Management of Time in Complex Projects*
- Commonwealth Department of Infrastructure and Transport, *National Alliance Contracting Policy and Guidelines*, 2011
- ISO-31000: 2018 *Risk Management – Principles and Guidelines*
- Lyons, Terry and Skitmore, Martin (2004) Project risk management in the Queensland engineering construction industry: a survey. International Journal of Project Management 22(1):pp. 51-61
- PMI, *Practice Standard for Project Risk Management*
- PMI, *Practice Standard for Earned Value*
- PMI, *Project Management Body of Knowledge (PMBOK)*
- Raydugin, Y., *Project Risk Management*, Wiley, 2013
- United Kingdom Government, HM Treasury, *The Green Book, Appraisal and Evaluation in Central Government*, 2003 <www.hm-treasury.gov.uk/d/ green_book_complete.pdf>
- United Nations, *UN Industrial Development Organization, Guidelines for Project Evaluation*, Project Formulation and Evaluation Series, No. 2, UNIDO, 1972

7. Contingency Control

7.1 Structure of Content



7.2 Overview

As highlighted in Chapter 6, the steps below outline the process of applying the EVPM method to a project. For this *Contingency Guideline*, steps 1 to 5 have an impact on contingency determination while contingency allocation should be mainly addressed in step 6, as explained in Chapter 6. Contingency control covering both schedule and cost, is integral to EVPM from steps 7 to 11. It ensures effective governance over allocated contingencies within the project's integrated management system.

1. Decompose the project scope
2. Assign RACI (Responsible, Accountable, Consulted and Informed) Matrices
3. Schedule the work packages
4. Develop time-phased budget
5. Assign objective measures of performance
6. Set the performance measurement baseline (PMB)
7. Authorise and perform the work packages
8. Accumulate and report project performance data
9. Analyse project performance data
10. Take management action
11. Maintain the baseline.

7.3 Schedule Contingency Control

RES recommends that schedule contingency control should be planned and managed as part of a larger schedule change control plan – which incorporates both Baseline Schedule and current schedule – as well as the contractual terms and conditions in reference to the different types of delays. This ensures that contingency use is documented and transparent, and any variances can be measured.

It is also essential to establish thresholds that determine when a delay warrants using schedule contingency, such as specific durations or events that trigger contingency allocation. The following types of delays are relevant:

- **Excusable Delays (Compensable and Non-Compensable)**: Schedule contingency may be used to accommodate excusable delays, with compensable delays also potentially requiring financial adjustments.
- **Non-Excusable Delays**: These should not be covered by schedule contingency and are the responsibility of the contractor.
- **Concurrent Delays**: Allocation of schedule contingency for concurrent delays may be complex, depending on shared responsibility and contract terms.
- **Critical and Non-Critical Delays**: Schedule contingency should primarily be allocated to cover critical delays which impact the project's overall completion date. Non-critical delays may be managed within available float.

The subject of schedule change control, as part of EVPM, is not the subject of this *Contingency Guideline*, but the section below highlights a few critical aspects of this topic.

7.3.1 Schedule Change Control

A schedule change control process manages the components of the current Updated Schedule, as well as the criteria for applying program and technical changes, and improvements to the Baseline Schedule. This assists organisations to maintain an accurate and reliable current schedule and base. Defining and communicating schedule change measurement criteria to the team ensures that they do not deliberately or unconsciously adjust the planned schedule to correspond with actual or planned performance. This can distort decision-makers' oversight of true performance, reducing the likelihood of project success. Accurate measurement of performance against the original Baseline Schedule and PMB is not possible when changes are uncontrolled or undocumented. Performance measurement, schedule data, and inconsistent versions of the plan can be generated by different project teams or stakeholders.

RES Tips & Tricks: organisations should define the degree to which their project schedules are governed by the schedule change control process. This may be influenced by factors such as complexity, size, scope and risk. For less complex projects, it may be appropriate to restrict the change control process to key contract milestones or high-level WBS components. For complex projects, the level of risk increases, meaning that it may be necessary to manage schedule network dependencies and activities at a lower WBS level under established change management processes.

Management should assign a unique version number to each approved iteration of the Updated Schedule, ensuring accurate tracking and communication across all relevant stakeholders. Consistent version numbers will help management keep track of updates and make sure all parties are referring to a single Updated Schedule. Generally, the Baseline Schedule should not be changed except to accommodate limited scope variations or formal re-planning. One exception is in cases where decision-makers determine that the current Baseline Schedule no longer provides a reasonable estimation to measure performance, hence a need for a new Baseline Schedule. Examples of this case include instructed Variation or an Extension of Time.

In addition to meeting contractual requirements, re-baselining can also provide a more reasonable basis for performance management to help decision-makers regain control. The updated Baseline Schedule generally discards historical variances to efficiently identify and measure new variances. For most projects, there should not be the need for more than two to three baselines over the project duration. Factors leading to more frequent re-baselining can include poor understanding of scope, managers who do not exercise enough discipline to realistically estimate the schedule. In both scenarios, further assessment is urgent to mitigate future risks.

RES Recommendation: for complex projects, schedule contingency control is more efficient and effective if it is being managed as part of a broader schedule change control process. RES recommends that appropriate schedule change control criteria should be defined, implemented and monitored regularly. For example, the criteria below may be used:

a) any change in total number of activities more than 10%
b) any change in original activity duration more than 10%
c) any change in the Schedule Criticality Index (SCI)
d) monitor the Baseline Execution Index (BEI) – the ratio of the number of completed detail activities, compared to those expected to be complete at a point in time. Generally:
    i) the project is performing according to plan if a BEI is equal to 1
    ii) the number of completed activities is less than that planned if the is BEI less than 1
    iii) the number of completed activities is greater than that planned if the BEI is greater than 1.
e) Conduct trend analysis to investigate the effects of mitigation measures (e.g. reducing contingency or decreasing total float).

7.3.2 Schedule Recovery and Acceleration

Several strategies are available to address deviations from the Baseline Schedule, aimed at recovering or accelerating the project timeline. To identify and increase understanding of how individual schedule variances affect the baseline, risk practitioners should analyse several strategies. Variances relate directly to the reliability of the project schedule – so underdeveloped, unrealistic or incomplete schedules may lead to unreliable outputs when measuring them against the Base Schedule.

The list below summarises common general techniques that can be used to reduce (accelerate) the schedule duration, or correct schedule variances (interruptions to the original plan) through schedule recovery.

There are two types of schedules being developed using the CPM technique:

a) logic driven schedules – CPM uses the longest path through the activity network to calculate the shortest project duration or PC Date from events linked by physical relationships
b) resource driven schedules – CPM uses the longest path through the activity network to calculate the shortest project duration or PC Date from the physical relationships of activities, availability of critical resources, and activity priorities.

For logic driven schedules, schedule recovery and acceleration should focus on realistic and achievable critical activities – particularly those with long durations. For resource-driven schedules, emphasis should be placed on optimal resource allocation to ensure efficiency on the critical path.

Some strategies for schedule recovery and acceleration may have contractual or commercial implications. Therefore, any recovery and/or acceleration action should be entirely discussed, assessed and agreed between the project controls, commercial team and project management. Strategies include:

a) reviewing and assessing delays and the causes for possible variations and/or EOTs – any approved EOT may result in schedule re-baselining rather than recovery or acceleration
b) varying construction methodology or logic (e.g. bringing filling material from a closer source)
c) reviewing and adjusting the working calendar (e.g. carrying out activities over the weekend)
d) ‘crashing’ by increasing the resources to time-dependent critical activities
e) performing activities concurrently
f) fast-tracking by substituting partial dependencies between activities with partial dependencies (e.g. reducing Finish-to-Start logic to Start-to-Start plus lag logic)
g) splitting long activities, and undertaking the shorter activities in parallel
h) reviewing schedule logic on critical (and near critical) activities for any improvement
i) reviewing activity durations
j) reviewing any critical constraints and lag/lead assumptions
k) decreasing scope to reduce both duration and costs
l) using available schedule contingency, in accordance with formal change management processes.

7.4 Cost Contingency Control

RES recommends that cost contingency control should be planned and managed as part of a larger change and cost control plan – which incorporates both Baseline Cost and current cost to complete – as well as the contractual terms and conditions in reference to the different types of delays. This ensures that contingency use is documented and transparent, and any variances can be measured.

It is important to define financial thresholds for cost contingency use, such as when additional costs exceed a certain percentage of the baseline estimate or when specific risk events occur. Effective management of cost contingency also requires an understanding of delay types and their potential financial implications:

- **Excusable Delays (Compensable and Non-Compensable)**: Schedule contingency may be used to accommodate excusable delays, with compensable delays also potentially requiring financial adjustments.
- **Non-Excusable Delays**: These should not be covered by schedule contingency and are the responsibility of the contractor.
- **Concurrent Delays**: Allocation of schedule contingency for concurrent delays may be complex, depending on shared responsibility and contract terms.
- **Critical and Non-Critical Delays**: Schedule contingency should primarily be allocated to cover critical delays which impact the project's overall completion date. Non-critical delays may be managed within available float.

7.4.1 Key Objectives

The primary objective of cost contingency control is to manage the expenditure of contingency funds effectively, ensuring that the project is delivered within the approved cost and schedule. Effective governance practices must be implemented to ensure that contingency spending remains within approved limits and is used for its intended purpose.

Change control is a fundamental component of effective cost contingency management. Contingency funds should not be released for any materialising risk or issue without passing through a gated change control process. Risks and issues that arise during the project should be reviewed under this process to confirm and validate that the items are covered by contingency funds. It should be noted that when undertaking this process, both the initial assumptions of inherent and contingent risks should be reviewed.

The key objective of contingency monitoring is to consistently and regularly review the performance and utilisation of contingency funds against the approved provision, enabling proactive management actions and risk mitigation as required. This monitoring should be carried out monthly for qualitative assessment and no less frequently than quarterly for quantitative assessment.

Regular and consistent reassessment of contingency requirements and performance throughout the project lifecycle provides assurance and confidence at all levels of governance and enables proactive risk identification. The objective of regular contingency reporting is to offer consistent and transparent disclosure of contingency management performance information across all levels of governance, enabling optimal fund management across the program and portfolio.

7.4.2 Overall Process

Reviewing performance of cost contingency against initial estimates is a means to identify potential and realised risks and issues early – enabling effective responses and optimising contingency performance across the project and organisation.

For effective and efficient contingency control, change control processes for individual activities should be fully integrated into the project's overall change control process. Any use of contingency should be clearly tracked and categorised into one of the following groups (as illustrated in Figure 32):

a) Scope Change
b) Unforeseen Event
c) Identified Risk (Inherent or Contingent).

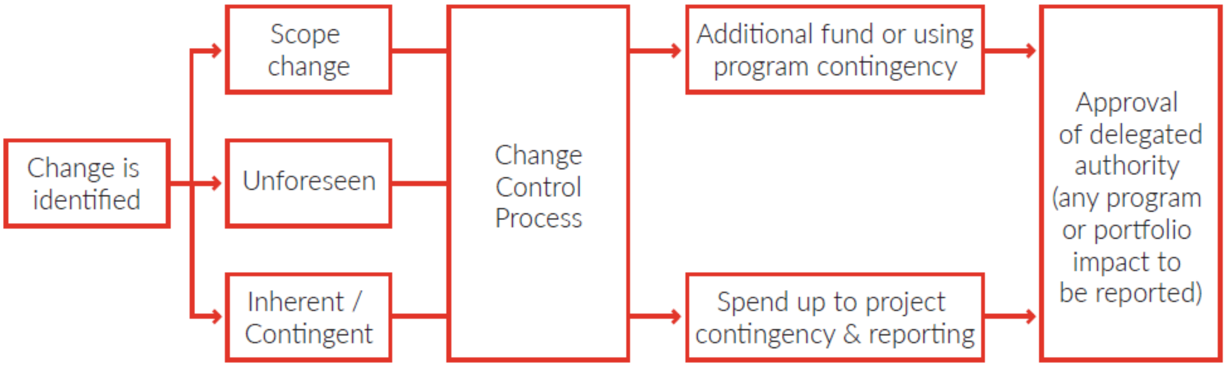


Figure 32: Interface between change control and contingency controls

7.4.3 Delta Contingency

This *Contingency Guideline* recommends the terminologies defined below:

a) allocated (or budgeted) contingency (i.e. P50 contingency)
b) remaining contingency (allocated contingency minus realised contingency minus returned contingency)
c) desired contingency (the contingency needed for the desired confidence level)
d) delta contingency (remaining contingency minus desired contingency).

Decision-makers should assess delta contingency, desired confidence levels, project stage, and delegation authority when determining whether to retain, reallocate, or return contingency. Decision-makers should select from the following actions:

a) retain the contingency
b) reallocate the contingency
c) spend the contingency
d) return the contingency.

Three potential decisions based on the amount of delta contingency are illustrated in Table 15 below.

Scenario	Recommended Decision/s
Delta contingency = 0 (available contingency = desired contingency)	Retain and/or reallocate
Delta contingency < 0 (available contingency < desired contingency)	Retain and/or request for additional contingency (report to the next level of authority)
Delta contingency > 0 (available contingency > desired contingency)	Retain and/or potential return to portfolio (report to the next level of authority)

Table 15: Scenarios for contingency control decisions based on delta contingency

RES Tips & Tricks: considering the subjective nature of contingency determinations and associated uncertainties, for practical use of Table 15, RES recommends the contingency performance indicators below:

a) - 20% =< Delta Contingency / Available Contingency =< +20% – retain and/or reallocate
b) Delta Contingency / Available Contingency > +20% –retain and/or potentially return to portfolio (report to the next level of authority)
c) Delta Contingency / Available Contingency < -20% – retain and/or request for additional contingency (report to the next level of authority).

The key objective of returning contingency is to manage the availability of any surplus contingency funds to enable optimal use of available capital at higher levels. The preferred option to return contingency is to review the delta contingency (see Section 7.4.3 above).

RES Recommendation: return of contingency reviews should be conducted at least every three months throughout the project lifecycle, allowing contingency funds to be released as determined by the delegated authority.

7.5 Further Reading

- AACE International RP 82R-13 *Earned Value Management (EVM) Overview and Recommended Practices consistent with EIA-748-C*
- APM, *Earned Value Management Guideline*
- APM, *Earned Value Management Handbook*
- APM, *Interfacing Risk and Earned Value Management*
- APM, *The Earned Value Management Compass*
- AS 4817 – 2006, *Project performance measurement using Earned Value*
- PMI, *Practice Standard for Earned Value*
- PMI, *Practice Standard for Project Estimation*

8. Appendix A – Key definitions

Term	Definition / Description
Acceleration	AACE International: Conduct by the owner or its agent (either in a directed or constructive manner) in which a contractor is required to complete performance of a contracted scope of work earlier than scheduled. A directed acceleration occurs when the owner formally directs such acceleration completion. A constructive acceleration generally occurs when a contractor is entitled to an excusable delay; the contractor requests a time extension from the owner; the owner declines to grant a time extension or grants one in an untimely manner; the owner or its agent either expressly orders completion within the original performance period or implies in a clear manner that timely completion within the original performance period is expected; and the contractor gives notice to the owner or its agent that the contractor considers this action an acceleration order.
Accuracy	AACE International: "Correctness that the measured value is very close to the true value."
Actual Cost (AC)	1. Actual Cost (AC) refers to the total amount of money that has been spent on a project or a specific activity within a project at a given point in time. This includes all costs incurred for labor, materials, equipment, services, and other expenses directly related to the project's execution. 2. AACE International: The amount of costs that have been incurred and recorded for a particular project, work activity, or cost component during a specific period. This includes all expenditures for labor, materials, equipment, services, and other related costs that have been billed, paid, or accrued.
Allocate	1. Assign contingency funds and associated risks to defined contingency owner or risk categories. 2. AACE International: (i) In planning and scheduling, the process of distributing or assigning work on an activity to specific resources (ii) In cost estimating and budgeting, the process of distributing or assigning cost of an item or activity (often an overhead or indirect cost) to specific cost or budget accounts.
Allowances	1. Queensland Government: Specific allocation of known but undefined resources included in the Base Estimate or Base Schedule to cover a most likely scope that has not yet been fully defined and quantified. The inclusion of these allowances

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	in duration and cost estimates will ensure both the Base Estimate and Base Schedule are presenting the scenario for current strategies and assumptions. 2. AACE International: (i) For estimating, resources included in estimates to cover the cost of known but undefined requirements for an individual activity, work item, account or sub-account (ii) For scheduling, dummy activities and/or time included in existing activities in a schedule to cover the time for known, but undefined requirements for a particular work task, activity, account or subaccount.
Accountability	1. Queensland Government: “Final responsibility for completion of tasks and achievement of results within delegated authority and to established performance standards.” 2. AACE International: “Answerable, but not necessarily charged personally with doing the work. Accountability cannot be delegated but it can be shared.”
Authority	AACE International: (i) Power of influence, either granted to or developed by individuals, that leads to others doing what those individuals direct. (ii) Formal conferment of such influence through an instrument such as a project charter.
Base Estimate	1. Estimated cost of a project that can be reasonably (i.e. current strategies and assumptions) expected if the project materialises as planned. 2.Queensland Government: “the estimator’s best prediction in terms of the quantities and current [productivity] rates which are likely to be associated with the delivery of a given scope of work prior to the addition of inherent and contingent risk values or escalation allowances.” 3. AACE International: “Estimate excluding escalation, foreign currency exchange, contingency and management reserves.”
Base Schedule	1. Expected duration of a project that can reasonably (i.e. current strategies and assumptions) be expected if the project materialises as planned. 2. Queensland Government: “the [scheduler’s] best prediction in terms of the quantities, current [productivity] rates and delivery strategy that are likely to be associated with the delivery of a given scope of work prior to the addition of inherent and contingent risk values. 3. AACE International: Schedule excluding risks (i.e., excluding contingency).
Baseline	1. US Department of Energy: A quantitative definition of cost, schedule, and technical performance

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	that serves as a standard for measurement and control during the performance of an activity; the established plan against which the status of resources and the effort of the overall program, field programs, projects, tasks, or subtasks are measured, assessed, and controlled. Once established, baselines are subject to change control discipline. 2. AACE International: (i) In project control, the reference plans in which cost, schedule, scope and other project performance criteria are documented and against which performance measures are assessed and changes noted. (ii) The budget and schedule that represent approved scope of work and work plan. Identifiable plans, defined by databases approved by project management and client management, to achieve selected project objectives. It becomes basis for measuring progress and performance and is baseline for identifying cost and schedule deviations. (iii) In earned value management systems, the general term to refer to the contractual baseline. See contract budget baseline and performance measurement baseline for the typical earned value management (EVM) definitions of the different baseline levels within the EVM baseline plan.
Baseline Schedule	1. PMI: "the approved time phased plan (for a project, a work breakdown structure component, a work package, or a schedule activity), plus or minus approved project scope, cost, schedule, and technical changes." 2. AACE International: (i) A fixed project schedule that is the standard by which project performance is measured. The current schedule is copied into the baseline schedule that remains frozen until it is reset. Resetting the baseline is done when the scope of the project has been changed significantly, for example after a negotiated change. At that point, the original or current baseline becomes invalid and should not be compared with the current schedule. (ii) Version of schedule that reflects all formally authorised scope and schedule changes.
Basis of Estimate (BoE)	A document which records the evidence used to develop the key elements of the project cost estimate. It includes factors such as assumptions, reference analyses, availability of resources and personnel. BoE and Basis of Schedule (below) should be developed and aligned together.
Basis of Schedule (BoS)	A document which records the evidence used to develop the key elements of the project schedule. It includes factors such as delivery strategy, productivity rate estimates, long lead times, deviations and assumptions, and reference analyses.

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	BoE and Basis of Schedule (below) should be developed and aligned together.
Benchmark	1. US Department of Energy: "A standard by which performance may be measured." 2. AACE International: A measurement and analysis process that compares practices, processes, and relevant measures to those of a selected basis of comparison (i.e., the benchmark) with the goal of improving performance. The comparison basis includes internal or external competitive or best practices, processes or measures. Examples of measures include estimated costs, actual costs, schedule durations, [and] resource quantities.
Best Estimate	As per IAS 37 Provisions, Contingent Liabilities and Contingent Assets, provisions should be measured at 'best estimate' (including risks & uncertainties) of the expenditure required to settle the present obligation, and reflects the present value of expenditures required to settle the obligation where the time value of money is material. Hence, in reaching its 'best estimate', the entity should take into account the risks and uncertainties that surround the underlying events for its desired confidence level.
Best Practices	AACE International: "Practical techniques gained from experience that have been shown to produce best results."
Bias	1. US Department of Energy: "A repeated or systematic distortion of a statistic or value, imbalanced about its mean." 2. AACE International: Lack of objectivity based on the enterprise's or individual's position or perspective. Systematic and predictable relationships between a person's opinion or statement and his/her underlying knowledge or circumstances. Note: There may be "system biases" as well as "individual biases".
Bid	AACE International: "To submit a price for services; a proposition either verbal or written, for doing work and for supplying materials and/or equipment."
Brainstorming	1. US Department of Energy: "Interactive technique designed for developing new ideas [within a group]." 2. AACE International: [Process in which] a group of people, selected for their creativity and knowledge, are brought together to seek solutions to particular problems or simply to find better ways of meeting objectives. Suggestions, however outlandish, are encouraged and pursued during a

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	creativity session. From this, many ideas, some entirely new, are brought forward for analysis and ranking.
Budget	1. Amount of money available for spending that is based on a schedule for how it will be spent. 2. PMI: "the approved estimate for the project or any work breakdown structure component or any schedule activity." 3. AACE International: "A planned allocation of resources. The planned cost of needed materials is usually subdivided into quantity required and unit cost. The planned cost of labor is usually subdivided into the work-hours required and the wage rate (plus fringe benefits and taxes)."
Budgeting	AACE International: "A process used to allocate the estimated cost of resources into cost accounts (i.e., the cost budget) against which cost performance will be measured and assessed. Budgeting often considers time-phasing in relation to a schedule or time-based financial requirements and constraints."
Buried contingency	US Department of Energy: Costs that may have been hidden in the details of an estimate to protect a project from the removal of explicit contingency and to ensure that the final project does not go over budget. To reviewers, buried contingency often implies inappropriately inflated quantities, lowered productivity, or other means to increase project costs. Buried contingency should not be used.
Business Case	AACE International: Defines a project's or other investment's justification for business decision making purposes. Depending upon the business' decision making criteria, it typically includes an outline of objectives, deliverables, time, cost, technical, safety, quality and other attributes in respect to how the project or investment addresses the objectives and requirements of the business. May include information on project risks (either threats or opportunities), competitive impact, resource requirements, organizational impacts, key performance indicators (particularly profitability) and critical success factors.
Calendar	1. AACE International: "Defined work periods and holidays that determine when project activities may be scheduled. Multiple calendars may be used for different activities, which allows for more accurate modeling of the project work plan e.g. 5-day work week calendar vs. 7-day work week." 2. PMI: a table or register of dates containing the days of each month and week

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	in one or more years. In project management, each date may be identified as a time span for performing work (work period) or as a time span for not performing work including designated holidays (non-working period) and each date may be further subdivided into segments such as shifts, hours, or even minutes that may be designated as work periods or non-work periods.
Cash Flow	AACE International: “Inflow and outflow of funds within a project. A time-based record of income and expenditures, often presented graphically.”
Central Estimate	As defined by Fellow of the Institute of Actuaries of Australia (FIAA), a Central Estimate of the liabilities is the expected value of the liabilities. In other words, if all the possible values of the liabilities are expressed as a statistical distribution, the Central Estimate is the mean of that distribution. The Central Estimate usually lie about the P30-P40 levels in energy and transport projects. FIAA defines risk margin, i.e. contingency or prudential margin, as a provision greater than the Central Estimate to increase the probability of adequacy.
Client	Accountable entity for the successful selection, approval and delivery of the projects to be funded. The client is the owner of the completed asset.
Change	Alteration or variation to the cost and schedule baseline. For business, scope change is limited to changes to the basic premises of the business case.
Change Control	1. The system for managing alterations to a project’s baselines. 2. US Department of Energy: “a process that ensures changes to the approved baseline are properly identified, reviewed, approved, implemented and tested, and documented.” 3. PMI: “identifying, documenting, approving or rejecting, and controlling changes to the project baseline.” 4. AACE International: (i) Process of accepting or rejecting changes to the project's baselines. Lack of change control is one of the most common causes of scope creep. (ii) Process of implementing procedures that ensure that proposed changes are properly assessed and, if approved, incorporated into the project plan. Uncontrolled changes are one of the most common causes of delay and failure. (iii) Risk abatement process of accepting or rejecting changes to the project's baselines, based on predetermined criteria or "trigger points.”
Confidence Interval	Probability that the value of a parameter e.g. project actual cost or completion date falls within an expected or specified or expected range.

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Confidence level	1. US Department of Energy: "Confidence level is the probability that a cost estimate or schedule can be achieved or bettered. This is determined from a cumulative probability distribution." 2. AACE International: The probability: (i) That results will be equal to or more favorable than the amount estimated or quoted; or (ii)) That the decision made will achieve the desired results; or (iii) That the stated conclusion is true. Note: Confidence level may also be expressed as "equal to or less favorable". If that is the case, it should so be noted. Without such a note, the definition shown is assumed. 3. PMI: a measure "of how reliable a statistical result is, expressed as a percentage that indicates the probability of the result being correct."
Consequence	1. The outcome of a contingent risk. (Normally includes scope, schedule, and cost.) 2. AACE International: "In risk management, the impact or effect of a risk event or condition."
Contingency	1. Specific allocation of resources (capital cost, resources, and time) required in addition to the Base Estimate or Base Schedule as a provision for inherent and/or contingent risks for the desired confidence level. 2. AACE International: (1)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. Typically estimated using statistical analysis or judgment based on past asset or project experience. Contingency usually excludes: 1) Major scope changes such as changes in end product specification, capacities, building sizes, and location of the asset or project; 2) Extraordinary events such as major strikes and natural disasters; 3) Management reserves; and 4) Escalation and currency effects. Some of the items, conditions, or events for which the state, occurrence, and/or effect is uncertain include, but are not limited to, planning and estimating errors and omissions, minor price fluctuations (other than general escalation), design developments and changes within the scope, and variations in market and environmental conditions. Contingency is generally included in most estimates, and is expected to be expended. (2) In earned value management (based upon the ANSI EIA 748 Standard), an amount held outside the performance measurement baseline for owner level cost reserve for the management of project uncertainties is referred to as contingency.

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Contingency Allocation	Appropriately delegating control of contingency between the client, delivery agency and project manager.
Contingency Controls	Controls to effectively and efficiently manage the movement of contingency, based on delegated authority.
Contingency Determination	Quantification and assessment of required contingency funds or time for inherent and contingent risks to achieve desired confidence level.
Contingency Management Framework	Establishes how the contingency management process (i.e. determination, allocation and controls) is to be performed at project, program and portfolio levels.
Contingency Owner	Governance authority responsible for the use or return of contingency (or part thereof) throughout the project lifecycle.
Contingency Plan	AACE International: "A risk response plan made to address identified residual risks if they occur."
Contingency Reserve (CR)	1. Allowance incorporated in the Performance Measurement Baseline (PMB) to fund management of accepted risks, or risks with planned contingency responses. 2. PMI: "budget within the performance management baseline that is allocated for identified risks that are accepted and for which contingent or mitigating responses are developed." 3. Australian Government Department of Finance: (in relation to budgeting) A provision within the Budget and forward estimates for items that either cannot or should not (generally for reasons of commercial sensitivity) be allocated to specific programmes at the time of publication. For example, allowance for the expected receipts from the sale of assets, or measures that require negotiation by the government where publication of estimates would adversely affect the government's negotiating position. The amount of the contingency reserve is not a general policy reserve, and it is not appropriated.
Contingent Risk	Type of risk caused by unmeasured items outside the Base Estimate, which may or may not materialise. Examples of contingent risks are delays or cost increases due to bad weather and other incidents which have not been predicted, industrial action, planning approvals, scope variations, or unexpected site conditions detected by geotechnical engineers. The likelihood of occurrence of a contingent risk is always less than 100%.
Control Gate	AACE International: "A major project milestone at which the project client has the opportunity to exercise a 'go/no-go' decision upon continuation into the succeeding phase."

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Correlation	1. US Department of Energy: “relationship between variables such that changes in one (or more) variable(s) is generally associated with changes in another. Correlation is caused by one or more dependency relationships. Measure of a statistical or dependence relationship existing between two items estimated for accurate quantitative risk analysis.” 2. AACE International: “The measure of the relationship between two or more quantitative elements.”
Cost Estimate and Schedule Classification System	AACE International: recommends classification categories are primarily defined according to the project level. For projects, the estimate class designations that follow below are labeled Class 1, 2, 3, 4, and 5. A Class 5 estimate is based upon the lowest level of project definition, and a Class 1 estimate is closest to full project definition and maturity. This “countdown” approach considers that estimating is a process whereby successive estimates are prepared until a final estimate closes the process. **CLASS 5 ESTIMATE** – (Typical level of project definition required: >0% to 2% of full project definition.) **CLASS 4 ESTIMATE** – (Typical level of project definition required: 1% to 15% of full project definition.) **CLASS 3 ESTIMATE** – (Typical level of project definition required: 10% to 40% of full project definition.) **CLASS 2 ESTIMATE** – (Typical level of project definition required: 30% to 75% of full project definition.) **CLASS 1 ESTIMATE** – (Typical level of project definition required: 65% to 100% of full project definition.)
Cost to Complete (CTC)	1. Forecast costs to complete the project in addition to actual cost already spent or accrued. 2. AACE International: “The amount that an in-progress activity or group of activities will cost to complete."
Critical Path	1. US Department of Energy: A logically related sequence of activities in a critical path schedule having the longest duration. The total float is zero. A delay in any activity will have a corresponding impact on the completion date of the project. 2. PMI: “generally, but not always, the sequence of schedule activities determining the duration of the project. Generally, it is the longest path through the project. However, a critical path can end, as an example, on a schedule milestone that is in the middle of the schedule model and that has a finish-no-later-than imposed date schedule constraint.” 3. AACE International: “longest continuous chain of activities (may be more than

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	one path) which establishes the minimum overall project duration. A slippage or delay in completion of any activity by one time period will extend final completion correspondingly. The critical path by definition has no 'float'."
Cumulative Distribution Function (CDF)	US Department of Energy: A statistical function based on the accumulation of the probabilistic likelihood of occurrences. In the case of the DOE risk analysis, it represents the likelihood that at a given percentage the project cost or duration will be at or below a given value. As an example, the x-axis might represent the range of potential project cost values evaluated by the Monte Carlo simulation and the y-axis represents the project's probability of completion.
Direct costs	1. Expenses specifically attributable to a project cost object, such as materials or labor. 2. US Department of Energy: "Costs identified with a particular project or activity; includes salaries, travel, equipment, and supplies directly benefiting the project or activity." 3. AACE International: Costs of completing work that are directly attributable to its performance and are necessary for its completion. 1) In construction, the cost of installed equipment, material, labor and supervision directly or immediately involved in the physical construction of the permanent facility. 2) In manufacturing, service, and other non-construction industries: the portion of operating costs that is readily assignable to a specific product or process area.
Duration	1. AACE International: The amount of time estimated to complete an activity in the time scale used in the schedule (hours, days, weeks, etc.). Planned production rates and available resources will define the duration used in a given schedule. The following four types of duration are used: 1) Original duration: Duration input by the planner; 2) Current duration: Duration based on latest progress date for in-progress activities. Calculated rate of progress provides a new completion estimate; 3) Actual duration: Duration based on activity's actual start and actual finish. Applies only to completed activities; and 4) Remaining duration: The expected time required to complete an activity. It is calculated as the difference between the data date and the expected finish date for in-progress activities. (Equal to the original duration for non-progressed activities. Equal to zero for completed activities). 2. PMI: "the total number of work periods (not including holidays or other

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	nonworking periods) required to complete a schedule activity or work breakdown structure component or project. Usually expressed as work-hours, workdays or workweeks. Sometimes incorrectly equated with elapsed time."
Escalation	1. Queensland Government: Anticipated increase in project costs over time as a result of various factors such as inflation or market conditions. It is the provision in actual or estimated costs for an increase in the cost of equipment, material, labor, etc., due to price level changes over time. Inflation may be a component of escalation, but non-monetary policy influences, such as supply-and-demand, are often components. 2. AACE International: "A provision in costs or prices for uncertain changes in technical, economic, and market conditions over time. Inflation (or deflation) is a component of escalation."
Estimate	1. Queensland Government: "Document recording the calculated cost prediction to undertake a specific amount of work. It is prepared in a systematic manner appropriate to the size and complexity of the work, and to a level of accuracy commensurate with the available information and the intended use of the information developed." 2. AACE International: "A prediction or forecast of the resources (i.e., time, cost, materials, etc.) required to achieve or obtain an agreed upon scope (i.e., for an investment, activity, project, etc.)." 3. PMI: "A quantitative assessment of the likely amount or outcome. Usually applied to project costs, resources, effort, and durations and is usually preceded by a modifier (i.e. preliminary, conceptual, feasibility, order-of-magnitude, definitive). It should always include some indication of accuracy (e.g., +- % percent)."
Estimate at Completion (EAC)	1. PMI: The expected total cost of completing all work "expressed as the sum of the actual cost to date (AC) and the estimate to complete (ETC). EAC = AC + ETC" 2. AACE International: "Estimate of the total cost an activity or group of activities will accumulate upon final completion."
Estimate to Complete (ETC)	1. PMI: "The estimated cost of completing the remaining work." 2. AACE International: (1) In general terms, the estimated resources (i.e., work hours, costs, time, and/or materials) required to complete a scope of work. (2) In earned value management, an estimate of the remaining costs required to complete an activity or group of activities. ETC = estimate at completion (EAC) – actual cost (AC), is often used to calculate the estimated cost to complete the project or program under discussion.

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Estimate uncertainty	US Department of Energy: The accuracy of the cost or schedule estimate. Represents a function of the level of project definition that is available, the resources used (skill set and knowledge) and time spent to develop the cost estimate and schedule, and the data (e.g., vendor quotes, catalogue pricing, historical databases, etc.) and methodologies used to develop the cost estimate and schedule.
Expected Value Method	AACE International: "In quantitative risk analysis and contingency estimating, a method that employs the product of a risk's probability times its impact as the primary approach to quantifying risks."
External Risk	Risk related to factors external to an organisation, including: the political and physical environment; the public and other external stakeholders; and global influence.
First Principles Estimate	Method of preparing a cost estimate at the lowest level of first principles estimate, i.e. material, labor, equipment and sub-contractor for each cost code within the Work Breakdown Structure.
Indirect Costs	1. Queensland Government: Costs "not directly attributable to work items. For construction activities these costs include on-site overheads (such as site supervision) and off-site overheads (such as contractor's corporate and business costs)." 2. AACE International: Costs not directly attributable to the completion of an activity, which are typically allocated or spread across all activities on a predetermined basis. (1) In construction, (field) indirect are costs which do not become a final part of the installation, but which are required for the orderly completion of the installation and may include, but are not limited to, field administration, direct supervision, capital tools, startup costs, contractor's fees, insurance, taxes, etc. (2) In manufacturing, costs not directly assignable to the end product or process, such as overhead and general-purpose labor, or costs of outside operations, such as transportation and distribution. Indirect manufacturing cost sometimes includes insurance, property taxes, maintenance, depreciation, packaging, warehousing and loading.
Inherent Risk	1. Inherent risks stem from the inability to be certain about the nature and behavior of the project system and its interaction with external economic, political and other systems or any other project or organisation system element

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	or attribute. The inherent risk also covers the 'engineering uncertainty' driven by maturity of the design, i.e. how much engineering risk should be designed into the project scope. The likelihood of the occurrence of inherent risk is 100%. Inherent risks may also include systemic risks. 2. "AACE International: A risk that exists (but may or may not be identified) due to the very nature of the asset, project, task, element, or situation being considered."
Internal Risk	Internal risks are related to factors within the organisation such as employees and internal stakeholders, governance policies, contract management, and organisational culture.
Issue	AACE International: "In risk management, a risk that has occurred or an unplanned question or decision that needs to be addressed by a process other than risk management."
Known Unknown	Uncertainties whose cause and nature are reasonably known and quantifiable. AACE International: "An identifiable quantity or value having variability or an identifiable condition lacking certainty."
Management Reserve (MR)	1. PMI: "An amount of the project budget base (PBB) withheld for management control purposes. These are budgets reserved for unforeseen work that is within scope of the project. The management reserve is not included in the performance measurement baseline (PMB)." 2. AACE International: (1) An amount added to an estimate to allow for discretionary management purposes outside of the defined scope of the project, as otherwise estimated. May include amounts that are within the defined scope, but for which management does not want to fund as contingency or that cannot be effectively managed using contingency. (2) In earned value management according to the ANSI EIA 748 standard, an amount held outside the performance measurement baseline to handle unknown contingency at the total program level. Management reserve has no scope, is not identified to specific risks, and is not time-phased. It is typically not estimated or negotiated and is created in the budget development process. Note: The MR is not included in the Performance Measurement Baseline (PMB).
Monte Carlo Simulation	AACE International: "A computer sampling technique based on the use of "pseudo-random numbers" that selects samples for a simulation of a range of possible outcomes."
Opportunity	AACE International: "Uncertain event that could improve the results or improve

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	the probability that the desired outcome will happen."
Optimism bias	Queensland Government: "Tendency for people to be overly optimistic regarding project costs and planned durations."
Out-turn dollars	Queensland Government: Value in dollars of the project cost at the end of the "period in which the work will be performed. Estimates prepared at a particular date can be converted to out-turn dollars by applying the appropriate escalation rates to the project's planned cash flow."
Parametric Estimate	AACE International: In estimating practice, describes estimating algorithms or cost estimating relationships that are highly probabilistic in nature (i.e., the parameters or quantification inputs to the algorithm tend to be abstractions of the scope). Typical parametric algorithms include, but are not limited to, factoring techniques, gross unit costs, and cost models (i.e., algorithms intended to replicate the cost performance of a process of system). Parametric estimates can be as accurate as definitive estimates.
Parametric Risk Analysis	AACE International: "Methods using parametric estimating wherein the input parameters are risk drivers, and the outputs are a quantification of risk. Typically applied for systemic risks."
P(x) estimate	Estimate of the project cost based on a percentage of x% (e.g. P50 for 50% or P90 for 90%) probability that the cost will not be exceeded at project completion.
P(x) schedule	Estimate of the project schedule based on an x% probability that the schedule will not be exceeded (e.g. P50 for 50% or P90 for 90%).
Performance Measurement Baseline (PMB)	1. AS 4817-2006: The total time-phased BUDGET plan against which project performance is measured. It is the schedule for expenditure of the resources allocated to accomplish project scope and schedule objectives and is formed by the BUDGETS assigned. The PERFORMANCE MEASUREMENT BASELINE also includes BUDGET for future scope assigned to UNDISTRIBUTED BUDGET. MANAGEMENT RESERVE is not included in the PMB as it is not yet designated for specific work scope. 2. AACE International: (1) The time-phased budget plan against which contract performance is measured. (2) In earned value management according to the ANSI EIA 748

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	standard, the assignment of budgets to scheduled segments of work produces a plan against which actual performance can be compared. The PMB is the time-phased project execution plan against which performance is measured. It includes direct and indirect costs and all cost elements. It also contains undistributed budget. PMB + management reserve (MR) = contract budget base (CBB) unless an over target baseline (OTB) has been implemented.
PERT	AACE International: "Project Evaluation and Review Technique, Along with CPM, PERT is a probabilistic technique for planning and evaluating progress of complex programs. Attempts to determine the time required to complete each element in terms of pessimistic, optimistic, and best-guess estimates."
PERT Analysis	AACE International: "A process by which you evaluate a probable outcome based on three scenarios: 1) Best-case; 2) Expected-case; and 3) Worst-case. The outcome in question may be duration of a task, its start date, or its finish date."
Portfolio	AACE International: "An array of assets—projects, programs, or other valuable and often revenue-producing items—that are grouped for management convenience or strategic purpose. When strategically combined, the portfolio assets serve to create synergies among and otherwise complement one-another."
Portfolio Management	AACE International: (1) Direction and oversight of an array of assets grouped together for strategic purpose or convenience. (2) In total cost management (TCM), this is considered an aspect of strategic asset management (SAM).
Portfolio Risks	Project and program risks that cannot be effectively managed at their originating level may be also escalated to the portfolio level if they require responses unavailable at the project or program level. The capital portfolio management process itself may be a cause of risk to the projects and programs. This risk may seriously damage the organisation's operations.
Principal	Also known as "delivery agency", is the body that will generally deliver a project.
Principal's Costs	Queensland Government: Costs that the principal (i.e. the delivery agency) "incurs to conceptualise, develop, deliver and finalise a project. These may include community consultation, environmental assessment, design planning, services relocation, resumptions, accommodation, site investigations and principal supplied material."

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Probabilistic Estimating	Queensland Government: "Method of generating estimates which takes into consideration the fact that quantities measured (or allowed for) can change, rates assumed can vary and risk with a probable outcome can materialise."
Probability Distribution Function (PDF)	A representation of the probability of specific project costs or durations (i.e. the number of times particular outcomes are likely to be achieved). Also known as a probability density function.
Program of Works (PoW)	1. Queensland Government: Group of related projects, or projects within the same program office, "managed in a coordinated way in order to obtain benefits and control not possible when managing them individually." 2. AACE International: (1) A grouping of related projects usually managed using a master schedule. (2) A set of projects with a common strategic goal. (3) In Europe and elsewhere, the term 'program' or 'programme' may be used to mean a network schedule.
Program risks	Risks that should be managed at the program level. These may include resource allocation, project interactions, cumulative project risks, and quality of change management processes.
Project	1. Queensland Government: Temporary endeavor "undertaken to create a unique product, service or result. It has a clearly defined scope, start and end time, a structured set of activities and tasks, a budget and a specified business case." 2. AACE International: "A temporary endeavor with a specific objective to be met within the prescribed time and monetary limitations and which has been assigned for definition or execution."
Project Control	AACE International: A management process for controlling the investment of resources in an asset where investments are made through the execution of a project. Project control includes the general steps of: 1) Project planning including establishing project cost and schedule control baselines; 2) Measuring project performance; 3) Comparing measurement against the project plans; and 4) Taking corrective, mitigating, or improvement action as may be determined through forecasting and further planning activity.
Project lifecycle	Queensland Government: "The activities necessary for a project throughout its life – from beginning to end – normally dissected into a number of sequential

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	phases."
Project Manager	1. Queensland Government: "Person responsible for managing a project and achieving its objectives to the required quality standard and within the time and cost constraints." 2. AACE International: "An individual who has been assigned responsibility and authority for accomplishing a specifically designated unit of work effort or group of closely related efforts established to achieve stated or anticipated objectives, defined tasks, or other units of related effort on a schedule for performing the stated work funded as a part of the project. The project manager is responsible for the planning, controlling, and reporting of the project." 3. PMI: "The person assigned by the performing organisation to achieve the project objectives."
Project risks	Individual risks that, should they occur, will affect the project's objectives.
Project schedule	PMI: "Model used in conjunction with manual methods or project scheduling software to perform schedule network analysis to generate the schedule for use in managing the execution of a project."
Quantitative Risk Analysis (QRA)	1. Method of risk analysis used to numerically assess the nature, sources, and impact of the identified risks, and to assess and quantify the overall impact of uncertainties. 2.AACE International: "Risk analysis used to estimate a numerical value (usually probabilistic) on risk outcomes wherein risk probabilities of occurrence and impact values are used directly rather than expressing severity narratively or by ranking as in qualitative methods."
RACI	AACE International: "Acronym for a chart or matrix indicating which individuals on a team responsible, accountable, consulted and informed are regarding identified project deliverables."
Requirement	AACE International: (1) An established requisite characteristic of a product, process, or service. A characteristic is a physical or chemical property, a dimension, a temperature, a pressure, or any other specification used to define the nature of a product, process, or service. (2) A negotiated set of measurable customer wants and needs.
Residual risk	1. IBM Centre for the Business of Government: "Risk remaining after risk treatment. Residual risk can contain unidentified risk and can also be known as 'retained risk'". 2. AACE International: "That portion of risks that remain after risk responses are

Term	Definition / Description
	implemented in full or in part." Note: Residual risk present at the time of the gate review is typically the risk being quantified.
Returned contingency	Refund of unutilised contingency funds, preferably not in a way to diminish the project confidence level.
Risk	1. ISO 31000: "Effect of uncertainty on objectives." 2. AACE International: (1) An ambiguous term that can mean any of the following: a) All uncertainty (threats + opportunities); or b) Undesirable outcomes (uncertainty = risks + opportunities); or c) The net impact or effect of uncertainty (threats – opportunities). The convention used should be clearly stated to avoid misunderstanding. (2) Probability of an undesirable outcome. (3) In total cost management, an uncertain event or condition that could affect a project objective or business goal.
Risk Allocation	AACE International: "In risk treatment, the process of transferring threats or sharing opportunities between parties, most commonly expressed in association with the contracting process."
Risk Appetite	AACE International: "A component of the risk management plan that expresses the risk management objective in terms of a confidence interval or level for selected outcome measures."
Risk Breakdown Structure (RBS)	AACE International: "A framework or taxonomy to aid risk identification and for organizing and ordering risk types throughout the risk management process."
Risk event	Refer to "contingent risk".
Risk Response	AACE International: "Strategies or actions identified and planned in the risk treatment process to address risks."
Schedule	AACE International: (1) A description of when each activity in a project can be accomplished and must be finished so as to be completed timely. The simplest of schedules depict in bar chart format the start and finish of activities of a given duration. More complex schedules, general in CPM format, include schedule logic and show the critical path and floats associated with each activity. (2) A time sequence of activities and events that represent an operating

Term	Definition / Description
	timetable. The schedule specifies the relative beginning and ending times of activities and the occurrence times of events. A schedule may be presented on a calendar framework or on an elapsed time scale.
Schedule Contingency	AACE International: (1) Duration added to a schedule activity to allow for the probability of possible or unforeseen events. Use in this manner is not recommended as the contingency is hidden and may be misused. (2) A unique activity used to model specific float available to a project phase. Used in this manner gives ownership of float to those activities and or responsibility entity. (3) The amount of time added to specific activities of a project (or program) schedule to mitigate (dampen/buffer) the effects of risks or uncertainties identified or associated with specific elements of that schedule.
Scope	1. PMI: "The sum of the products, services, and results to be provided as a project." 2. AACE International: The sum of all that is to be or has been invested in and delivered by the performance of an activity or project. In project planning, the scope is usually documented (i.e., the scope document), but it may be verbally or otherwise communicated and relied upon. Generally limited to that which is agreed to by the stakeholders in an activity or project (i.e., if not agreed to, it is "out of scope"). In contracting and procurement practice, includes all that an enterprise is contractually committed to perform or deliver.
Severe Weather	AACE International: A weather event, which is in itself severe and can be of violent nature. If the average weather over time is significantly different from the normal then it is said to be other than normal. In either case, if such weather affects the job and causes a delay, it may be excusable and form the basis for a contract adjustment for time and possibly money once all relevant contract clauses are considered.
Spend of contingency	Approval of use contingency.
Systemic Risks	AACE International: "Uncertainties (threats or opportunities) that are an artifact of an industry, company or project system, culture, strategy, complexity, technology, or similar over-arching characteristics."

Term	Definition / Description
Total Outturn Cost (TOC)	Department of Infrastructure, Regional Development and Cities: 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 … In economic terms non-escalated costs are often referred to as Real costs while Outturn Costs are often referred to as Nominal costs.
Trend Analysis	AACE International: "Mathematical methods for studying trends based on past project history allowing for adjustment, refinement or revision to predict cost. Regression analysis techniques can be used for predicting cost/schedule trends using historical data."
Uncertainty	AACE International: (1) The total range of events that may happen and produce risks (including both threats and opportunities) affecting a project. (Uncertainty = threats + opportunities.) (2) All events, both positive and negative, whose probabilities of occurrence are neither 0% nor 100%. Uncertainty is a distinct characteristic of the project environment.
Unknown unknowns	1. Events whose probability of occurrence and effect are not foreseeable by the project team at the time of risk assessment. Unknown unknowns are typically averse to a program or project's objectives. 2. AACE International: "A quantity, value or condition that cannot be identified or foreseen, otherwise referred to as unknowable."
Unplanned risk	Refer to "contingent risk".
Validation	AACE International: "Testing to confirm that a product or service satisfies user or stakeholder needs. Note difference from verification."
Work	1. PMI: "Sustained physical or mental effort, exertion, or exercise of skill to overcome obstacles and achieve an objective." 2. AACE International: Any and all obligations, duties, responsibilities, labor, materials, equipment, temporary facilities, and incidentals, and the furnishing thereof necessary to complete the construction which are assigned to, or undertaken by the contractor, pursuant to contract documents. In addition, the entire completed construction or various separately identifiable parts thereof required to be furnished under the contract documents. Work results from performing services, furnishing labor, and furnishing and incorporating materials and equipment into the construction, all as required by contract documents.

Term	Definition / Description
Work Breakdown Structure (WBS)	1. AACE International: “A hierarchical structure by which project elements are broken down or decomposed.” 2. PMI: A deliverable-oriented hierarchical decomposition of the work to be executed by the project team to accomplish the project objectives and create the required deliverables. It organises and defines the total scope of the project. Each descending level represents an increasingly detailed definition of the project work. The WBS id decomposed into work packages. The deliverable orientation of the hierarchy includes both internal and external deliverables.

For more definitions, the *Contingency Guideline* recommends AACE International Recommended Practice No. 10S-90, Cost Engineering Terminology – [10S-90: Cost Engineering Terminology]

9. Appendix B – Risk Workshop Facilitation

9.1 Phase 1 – Before Risk Workshop

Establishing the risk context is a critical first step in developing the risk register and facilitating meaningful conversations among project stakeholders prior to any risk workshop. This ensures that the appropriate stakeholders and subject matter experts attend and contribute effectively to the risk management process. Key actions for the workshop facilitator include:

- **Early Engagement**: Contact and discuss the requirements with key stakeholders and attendees as early as possible.
- **Define Objectives**: Clearly understand and confirm the key objectives of the risk workshop. For example, running a strategic risk workshop at the Preliminary Business Case stage has different objectives compared to running a quantitative risk workshop to assess cost contingency for an Engineering, Procurement, and Construction (EPC) bid submission. These may include risk identification for project activities and mitigation controls or providing risk analysis to support a project submission.
- **Review Existing Information**: Examine relevant documents including the Risk Management Policy or Framework, any pertinent guidelines, the latest risk register (if available), the Organisational Chart, Project Management Plan (PMP), Basis of Estimate, Basis of Schedule, and Work Breakdown Structure (WBS).
- **Capture Initial Insights**: Document key risks, uncertainties, and concerns during meetings or conversations with stakeholders, and understand their expectations of the risk workshop. Share these details with the team prior to the workshop.
- **Distribute Information**: Consolidate and disseminate all critical captured information before the workshop, including a pre-populated risk register, background information, key constraints, major internal and external interfaces, and specific data (e.g., rain data for assessing severe weather risk for a civil engineering project).
- **Identify Stakeholders**: Proactively identify and plan for an appropriate list of internal and external stakeholders (e.g., regulators, the public, alliance partners) who could be affected by project risks or treatment actions. These can be groups or individuals.
- **Mitigate Groupthink**: Be aware of and plan for the risk of groupthink, for example: "I'll follow the others, they know more than me."
- **Document Assumptions**: Identify any assumptions made by the team during risk identification to better understand the risks as well as any exclusions, issues, dependencies, etc.
- **Identify Constraints**: Outline project constraints, such as political, regulatory, environmental, social, economic, technical, and logistical factors. Also, define internal and external boundaries within which the risk assessment will be conducted, such as geographical, operational, interface, and project phase limitations.
- **Prepare the Venue**: Arrange an appropriate room for the workshop with sufficient natural light, adequate temperature control, suitable size, presentation capabilities, and appropriate seating arrangements.
- **Furniture Layout**: Arrange the furniture to support group discussions, such as round tables.
- **Select Attendees**: Nominate the best group of attendees, usually fewer than 7-10 people per

workshop.

- **Support Personnel**: Plan to have a support person during the workshop for tasks like notetaking, changing slides, and other logistical support.
- **Identify Speakers**: Select subject matter experts and stakeholder speakers.

By following these steps, you can ensure that the risk workshop is productive and that all key areas of concern are addressed effectively.

RES Tips & Tricks: It's better not to walk into a risk workshop with a blank risk register!

9.2 Phase 2 – During Risk Workshop

For running an efficient and productive risk workshop and brainstorming session, RES recommends considering the following notes:

- **Right Mix of Stakeholders**: Ensure a diverse group of stakeholders is present to extract high-quality risk information.
- **Controlled Group Activity**: Conduct the workshop in a structured manner to avoid issues like groupthink or cognitive biases.
- **Seating Arrangement**: Invite participants to sit around the room rather than at the back or in sub-groups to foster collaboration.
- **Introduction**: Start with a brief introduction covering objectives, the workshop schedule (including breaks), key facilities, and safety items.
- **Presentation**: Deliver a concise (15-30 minute) presentation on the project scope, current status, risk management process, specific stakeholder requirements, workshop objectives, and agenda. Include periodic short breaks to keep the group refreshed.
- **Prioritise Risks**: Focus on top risks first, then low risks. Also consider very low probability risks with high consequences.
- **Time Management**: Avoid spending too much time on any one risk. Plan offline discussions and designate a responsible person for further details if needed.
- **Facilitate Discussions**: Encourage group discussions rather than reading and filling in the risk register word by word.
- **Consistent Risk Identification**: Plan a consistent approach for identifying risks and opportunities (e.g., Project Management Institute (PMI) Risk Work Breakdown Structure).
- **Use Workshop Time Wisely**: Focus on risk identification and high-level analysis during the workshop. Conduct detailed risk analysis, evaluation, and treatment discussions with individuals or smaller teams outside the workshop.
- **Differentiate Issues and Risks**: Distinguish between issues and risks. Document issues in a separate Issues Register and move on. Clarifying that issues are current problems, while risks are potential future problems.
- **Action-Oriented Risk Definitions**: Ensure risk definitions include an action verb.
- **Assign Risk Owners**: Assign an owner to every risk for follow-up before concluding the workshop and document the due date for follow-up actions.

- **Consider Internal and External Risks**: For external risks, focus on the consequences; for internal risks, focus on the causes.
- **Summarise Discussions**: Use the participants' words when summarising discussions to ensure they can read and understand the notes later.
- **Positive Body Language**: Maintain positive body language, look at participants when they speak, use hand gestures to enliven your presentation, and smile.
- **Benchmarking and Elicitation**: Use benchmarking and structured elicitation processes.
    - do not initially share these with the team to avoid unintended anchoring
    - as the process progresses, this will provide further context for the discussion
    - do not use it to blame the team, but to positively challenge or support estimates
- **Cultural Awareness**: Be mindful of cultural factors and differences, such as the impact of seniority among participants.
- **Conflict Management**: Be aware of potential conflicts between participants, which may lead to hidden agendas.
- **Group Size**: Keep the group at a manageable size, typically fewer than 10 people.
- **Key Risk Focus**: Concentrate on identifying and addressing a few key risks rather than many trivial ones.
- **Managing Dominance**: Be attentive to participants with higher authority or dominant personalities and manage their influence appropriately.
- **Clear Objectives**: Set clear objectives for the workshop without starting with predetermined outcomes.
- **Inclusivity**: Do not rely solely on the input of the smartest or most dominant people in the workshop. Encourage contributions from all participants

By following these guidelines, you can ensure that the risk workshop is both efficient and productive, addressing all key areas of concern effectively

RES Tips & Tricks: Remember, "facilitation" is different from "teaching." As a facilitator, your role is to guide the flow of information from participants to achieve the workshop objectives.

Be mindful that people have varied learning and engagement styles, such as:

- Auditory (hear only)
- Visual (see only)
- Auditory-Visual (hear and see)
- Auditory-Tactile (hear and talk)
- Multimodal (see, hear, talk, and do)

Bring a diverse set of engagement tools to accommodate these different styles. Keep the workshop lively and engaging; dull and boring sessions can disengage participants and waste their time.

By understanding these distinctions and employing various engagement techniques, you can create a dynamic and productive workshop environment

9.3 Phase 3 – After Risk Workshop

RES recommendations for post workshop actions are:

a) Schedule follow-up sessions with individuals after the workshop as early as possible
b) Discuss, evaluate and further develop the risk register, then share it with the whole team
c) Circulate the updated risk register to everyone for review and comment no later than a week after the workshop
d) If a quantitative risk analysis is undertaken, a short group meeting is also recommended to share the draft results and assumptions (including key risk drivers) before you finalise the assessment.
e) Capture, document and communicate any identified risk treatment, mitigation, action owner, action due date, etc.

A good balance of time allocation between the three phases (before, during and after the risk workshop) will considerably increase the likelihood of success in achieving the team's risk workshop objectives.

9.4 Good Risk Workshop Facilitator

While RES acknowledges that there is no singular approach to being a successful risk workshop facilitator, certain practical and helpful characteristics commonly contribute to success. These include:

- Relevant and Appropriate Domain Knowledge: A thorough understanding of the subject matter ensures the facilitator can add value, guide discussions effectively, and answer technical questions that arise during the workshop.

- Strong Emotional Intelligence and Communication Skills: Effective facilitators demonstrate high emotional intelligence, enabling them to manage group dynamics sensitively. They also possess strong communication, listening, and presentation skills to convey information clearly and engage participants.

- Proper Body Language and Appropriate Appearance: Maintaining confident and professional body language, along with a suitable appearance, helps build credibility and trust among participants.

- A Wide Range of Facilitation Tools and Techniques: Equipped with various facilitation tools and methods, including brainstorming sessions, SWOT analysis, and risk assessment matrices, facilitators can adapt their approach to suit different workshop needs and participant preferences.

- Management of Cognitive Biases: Skilled facilitators are aware of common cognitive biases and can implement strategies to mitigate their impact, ensuring a balanced and objective risk assessment process.

- Ability to Utilise a Range of Behaviour Types: The capacity to switch between different behavioral styles—such as being directive, collaborative, or supportive—allows the facilitator to handle various situations and participant personalities effectively.

- Leadership Skills Supported by Process and People Management Capabilities: Strong leadership abilities, coupled with solid process and people management skills, enable facilitators to guide the workshop efficiently while fostering a productive environment.

- Conflict Management Skills: Effective facilitators are adept at resolving conflicts that may arise during discussions, ensuring that disagreements are handled constructively and do not derail the workshop.

- Time Management Skills: The ability to manage time effectively is crucial, as it ensures that the workshop remains on schedule, covers all necessary topics, and achieves its objectives without rushing through important discussions.

In summary, successful risk workshop facilitators combine technical expertise with interpersonal skills and practical facilitation techniques. By doing so, they can create a collaborative and productive environment that enhances the quality of risk assessment and decision-making processes.

9.5 Quantitative Risk Register

A quantitative risk register is the output of risk workshop facilitation for the purpose of contingency management. This register is a record of all key risks with potential time and/or cost impacts. These will include mainly contingent risks, but the quantitative risk register can also have some references to inherent risks identified and quantified by the project team. Inherent risks may have either a positive or negative impact on the cost estimate and/or the project schedule.

The quantitative risk register includes information such as:

a) a description of the risk or consequence as well as a description of the cause(s)
b) the risk owner, who is responsible for the quality of its qualitative and quantitative information
c) key risk treatment strategies and associated costs (if applicable)
d) the probability that the residual risk, or consequence, will occur
e) the range of schedule impacts of the event if it should it occur. It is important to note that the impact of the event could be an unfavorable result (negative), or a favorable result (positive)
f) the validation and determination supporting each element of the schedule impacts, i.e. best cost impact, most likely cost impact and worst-case cost impact
g) the range of cost impacts of the event if it should it occur. It is important to note that the impact of the event could be an unfavorable result, i.e. negative, or a favorable result, i.e. positive
h) the validation and determination supporting each element of cost impacts, i.e. best cost impact, most likely cost impact and worst-case cost impact
i) specific reference in the risk register to the affected activity (or activities) which will be impacted if the risk occurs
j) other key notes, e.g. possible correlation of risks or consequences.

The information above is generally laid out in columns as presented in Table 16. It should be noted that risk registers generally have other columns as well, which are used for risk management purposes: for example, triggers, controls, risk owner and treatment action.

#	Description of risk or consequence	Cause	Risk Owner	Probability of residual risk or consequence	Schedule Impact				Cost Impact				Notes
					BC (d)	ML (d)	WC (d)	Quantification validation	BC ($)	ML ($)	WC ($)	Quantification validation	
1													
2													

Table 16: Key columns of quantified risk register

The project risk manager needs to prepare the quantitative risk register and determine which contingent risks not captured by the cost model are significant enough to add to the model. However, the sources of discrete risk items to be modeled are not limited to the risk register. Opportunities to reduce costs should also be captured and discussed.

Each item in the quantitative risk register needs to be carefully assessed to properly augment the cost and schedule uncertainty model. Additional effort may be required to properly interpret the cost and schedule consequences – as the team may only provide impacts to the program's current or pending contract. The register should be archived and attached to the final contingency report for future reference.

RES Tips & Tricks: when identifying the risks with schedule/cost impacts, it is useful to consider:

a) both risks and opportunities, i.e. negative impacts as well as positive impacts
b) only key risks and opportunities. According to the Pareto Principle (80-20 rule), about 80% of outcomes result from 20% of the causes. You should focus on 'rocks' not 'sand'!
c) the schedule and cost impacts together to increase the accuracy of assessment
d) the inherent and contingent risks together for the optimum contingency
e) the potential relationship and interfaces not only between risks and uncertainties but also between key internal and external stakeholders, i.e. correlation
f) human and organisational aspects, behaviour and organisational culture.

10. Appendix C – Risk-driven Hybrid QSRA

10.1 Purpose

The purpose of this appendix is to provide detailed information on the Risk-driven Hybrid QSRA approach used to develop, assess, and allocate a reasonable schedule contingency for a desired confidence level. In the context of contingency planning, quantitative risk analysis refers to various techniques that offer a numerical estimate of the overall impact of risks on project objectives. These risks stem from the combined effects of all residual risks and their potential interactions.

Risk-driven Hybrid QSRA is a form of quantitative risk assessment that uses a probabilistic process, most commonly the Monte Carlo simulation technique—to evaluate the reliability of the Base Schedule. The premise of Risk-driven Hybrid QSRA is that, due to potential risks, the projected final duration of a project is better represented by a range of values with associated probabilities rather than a single, deterministic schedule value.

Schedule contingency is quantified in terms of percentile (or 'P') values, which indicate the percentage confidence that work will be completed on or before a specific date. Various techniques can then be employed to identify the primary drivers of schedule risk, often referred to as 'schedule sensitivity' to risks. By using these methods, the QSRA approach provides a more accurate and realistic projection of project timelines, enabling more effective risk management and contingency planning.

10.2 Risk-driven Hybrid QSRA overall process

The key elements of a realistic and reliable Risk-driven Hybrid QSRA in determination and allocation of a reasonable schedule contingency for different confidence levels are below, as illustrated in Figure 33.

a) schedule health check and rectification
b) identification of risks, both uncertainties (or inherent) or contingent
c) allocation of risks to the Base Schedule
d) scenario analysis to ensure all possible risks will not change schedule fundamentally, for example do not change the project delivery strategy
e) Monte Carlo Simulation
f) output review and validation.

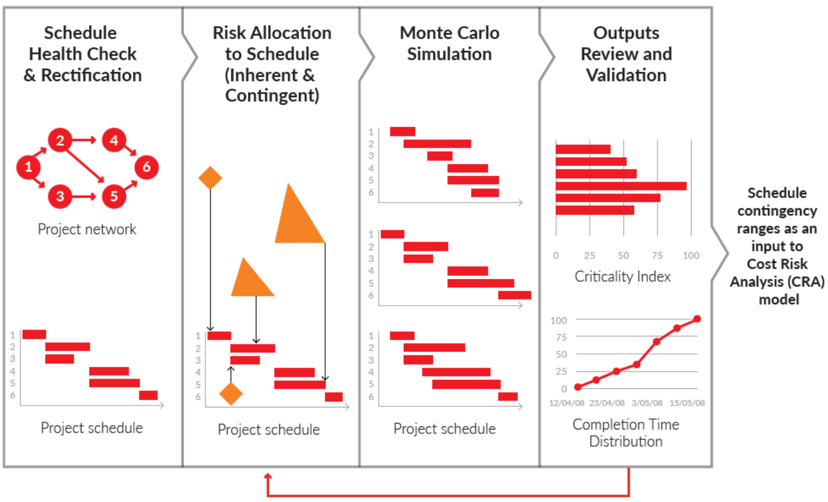


Figure 33: A typical process map for probabilistic Risk-driven Hybrid QSRA

10.3 Schedule Health Check and Rectification

The Base Schedule should represent the most likely delivery strategy of a project, based on the assumption that the project will proceed as planned. This schedule is developed to determine the expected duration of the project before accounting for any risks. While the Base Schedule may include some embedded allowances to represent the most reasonable scenario, it should not contain any contingency.

Conducting a comprehensive health check of the Base Schedule is crucial, as it forms the foundation for Risk-driven Hybrid QSRA and influences all its outcomes. Several factors should be considered when preparing a schedule for QSRA, generally aligned with good planning principles. These factors include:

- **Contractual Obligations**: Ensuring the schedule meets all contract requirements.
- **Schedule Structure**: Organising the schedule logically and coherently.
- **Schedule Integrity**: Verifying the schedule's accuracy and completeness.

These concepts are discussed in more detail in the following sections. Ensuring a robust Base Schedule is essential for reliable and effective quantitative schedule risk analysis.

10.3.1 Contractual Obligations

The key considerations for contractual obligations when conducting a Risk-driven Hybrid QSRA health check include:

a) The Base Schedule must meet all contractual obligations including, but not limited to, level of details, delivery strategy, separable portions, durations, key contractual milestone dates and interim milestones
b) The Base Schedule must represent all known scope – both included or missing from the drawings
c) The Base Schedule must be representative of the latest approved project execution strategy or plan
d) The Base Schedule must include the key activities of all stakeholders that may influence contractual milestone dates
e) The Base Schedule should clearly include the internal and external dependencies that involve a relationship between project activities and non-project activities

10.3.2 Schedule Structure

Depending on project requirements, various approaches can be used to develop the project scheduling plan. These include, but are not limited to, the Critical Path Method (CPM), the Critical Chain Method, and the Line of Balance (LoB).

Critical Path Method (CPM) is the most used project scheduling technique. It involves creating a schedule network that represents the project's time management strategy. In this method, activities that need to be accomplished are represented and linked to each other by relationships (e.g., finish-start, start-start, finish-finish, start-finish). These relationships depict physical or resource constraints (e.g., limited resource availability) that determine the sequence of work.

Using a logic-driven or resource-driven approach, CPM algorithms calculate the earliest and latest dates for all activities. The difference between these dates for any activity, before affecting the project's end date or a key milestone, is known as the "Total Float." Critical activities have the least amount of float, meaning any delay in these activities typically results in a delay of the same duration at the project's end date. Activities with low Total Float are termed "near critical" because they can quickly become critical if their float is exhausted due to unanticipated delays. Therefore, managers must closely monitor both critical and near-critical activities by employing sound scheduling practices.

To ensure an accurate and valid critical path, the Base Schedule must represent the entire scope of work and be correctly sequenced through network logic. If it does not, the scheduling software may report an incorrect or invalid critical path, which will not accurately reflect the activities impacting the project's finish date. Without an accurate critical path, the Risk-driven Hybrid QSRA cannot effectively identify the activities that could jeopardise key milestones and the overall project timeline if delays occur.

By adhering to these principles, project managers can develop a reliable scheduling plan and perform effective Risk-driven Hybrid QSRA to manage risks and stay on track.

There are two types of schedules developed using the CPM technique:

1. Logic driven schedules – CPM calculates the shortest project completion duration and/or project completion date from the longest path through the network of activities linked by physical relationships
2. Resource driven schedules – CPM calculates the shortest project completion duration and/or project completion date from the longest path through the network of activities set not only by their physical relationships but also the availability of required resources and priority of activities.

It is important that the correct schedule structure be adopted to ensure the Risk-driven Hybrid QSRA is reliable and robust, and its results are reasonable. The CPM schedule represents one possible scenario of how a project may be delivered, hence there is a need for a detailed Risk-driven Hybrid QSRA to assess the confidence level of this scenario.

10.3.3 Schedule Integrity

The key considerations for schedule integrity include:

a) Scope Representation:

- The Base Schedule must accurately reflect 100% of the project's scope, as defined in the Work Breakdown Structure (WBS). This includes all necessary work to achieve the project objectives, involving key activities of both the owner and contractors.

b) Schedule Logic:

- The Base Schedule logic should be correctly established to predict impacts on the project's planned finish date due to misallocated resources, delayed activities, external events, scope changes, and unrealistic deadlines.

c) Predecessors and Successors:

- Generally, every activity within the Base Schedule should have at least one predecessor and one successor. The exceptions to this rule are the project start milestone (which has no predecessor) and the project finish milestone (which has no successor).

d) Constraints and Lags:

- Minimise the use of hard constraint dates (e.g., "must start on," "must finish on") and lags, or provide justification if they are used. This helps ensure the interdependence of activities is accurately represented.

e) Lead Time:

- Establish and use lead time to events or milestones to guide work and measure progress.

f) Summary Activities:

- Avoid logic relationships on summary activities because their start and finish dates are derived from lower-level activities. In a properly networked schedule, there's no need for logic relationships on summary activities.

g) Path Convergence:

- Path convergence occurs when several parallel activities join with a single successor activity. This can represent an unrealistic plan, implying many activities must be completed on time for a major event to occur as planned. Such points should be a key schedule management concern because the risk at the merge point is multiplicative. In complex projects, convergent paths are unavoidable, but QSRA can help recognise and manage merge bias effect (MBE).

h) Path Divergence:

- Path divergence occurs when a single activity joins with several parallel successor activities, presenting a similar schedule risk as path convergence.

i) Resource Allocation:

- The Base Schedule must reflect the resources (labor, materials, overhead) needed to undertake the work, their availability, and any funding or time constraints. Depending on the type of schedule (logic or resource-driven), this aspect is crucial before any QSRA assessment.

j) Activity Durations:

- The Base Schedule must realistically reflect the duration of each activity. Durations should be reasonably short, meaningful, and allow for discrete progress measurement.

k) Critical Paths:

- Depending on the type of schedule, the Base Schedule must identify schedule critical paths, which are the longest duration paths through the sequence of activities leading to key milestones. Establishing a valid critical path is necessary for QSRA to examine the effects of any activity slipping along this path. Reviewing activities with large total floats is also recommended.

l) Critical Path Ratio:

  - Assessing the Base Schedule quality by counting critical activities is generally not useful. The number of critical activities depends on the visibility required to manage the schedule and the project's risk profile. If the ratio of critical activities to total activities (schedule criticality index) exceeds 50%, the schedule might be overly serial, and resource limited. A further review and development of the base schedule are recommended before undertaking QSRA.

m) Long Duration Activities:

  - Re-evaluate long-duration, non-level-of-effort activities to determine if they can be broken down into more manageable pieces, especially if they appear on the critical path.

n) Calendar Changes:

  - For projects with a multi-phase lifecycle, calendar changes are generally unavoidable. Note that changes in working periods per day and/or week can result in criticality gaps when determining driving critical paths through a schedule risk model. These gaps occur when calendars attached to predecessor and successor activities differ.

By adhering to these key considerations, project managers can enhance schedule integrity, ensuring a robust foundation for accurate QSRA analysis and effective project management.

10.4 Level of Schedule WBS for Risk-driven Hybrid QSRA

Depending on the requirements and objectives, Risk-driven Hybrid QSRA can be undertaken at different levels of the schedule. These levels include the detailed master schedule, a rolled-up schedule, or even a separate summary schedule. Engaging the right stakeholders in the assessment process is crucial for developing the most reasonable Base Schedule with an appropriate structure, tailored for Risk-driven Hybrid QSRA.

Mapping risks to the schedule is one of the most challenging steps of the Risk-driven Hybrid QSRA process, as it necessitates a detailed understanding of both the nature of the risks and the schedule tasks involved. The integrity of any schedule risk model heavily depends on the validity and accuracy of risk allocation. It is essential to ensure that the impacts of risks are neither overstated nor understated, maintaining a balanced perspective.

For a reliable Risk-driven Hybrid QSRA, it is fundamental to meticulously identify and map all potential risks to their respective activities within the schedule. This precise mapping allows for a more accurate assessment of how risks could affect the timeline and overall project objectives. Several key elements contribute to the success of this process:

- **Comprehensive Risk Identification:** A thorough identification process that considers all possible sources of risk, including technical, resource, environmental, and stakeholder-related risks.

- **Engagement of Subject Matter Experts:** Collaborating with subject matter experts to gain insight into specific risks and their likely impacts on various schedule activities. Their knowledge is invaluable in ensuring accurate risk mapping.

- **Detailed Task or Work Discipline Analysis:** A careful examination of each schedule task to understand its dependencies, duration, and criticality, aiding in the precise allocation of risks.

- **Calibration of Risk Impacts:** Ensuring that the potential impacts of risks are appropriately calibrated against historical data and realistic assumptions. This avoids exaggerating or minimising the effects and helps in developing a credible risk model.

- **Continuous Validation and Review:** Regularly validating and reviewing the risk mapping and analysis process to incorporate any new information or changes in project scope, ensuring the Risk-driven Hybrid QSRA remains relevant and accurate.

In conclusion, a well-executed QSRA offers significant insights into potential schedule risks and their impacts, enabling better-informed decision-making and enhanced project planning. By ensuring that risks are accurately identified, mapped, and calibrated by using the most appropriate level of schedule WBS, project teams can develop more effective mitigation strategies and improve overall project resilience.

10.4.1 Common Sources of Schedule Uncertainty

There are many factors that contribute to schedule uncertainty (inherent risks) in a project. The key contributors to schedule uncertainty are:

a) 100% scope uncertainty – uncertainty that 100% of scope will be covered in the Base Schedule
b) delivery strategy uncertainty
c) activity duration uncertainty – due to uncertainty about quantity, productivity rate or efficiency of resources.
d) contingent risks – events that may or may not occur – but if they do, will impact the schedule positively or negatively
e) schedule logic uncertainty – including the dependencies that may or may not exist between activities or the alternative situations or pathways for completing an objective
f) calendar related uncertainty – these uncertainties usually determine the times in which certain work can be performed (e.g. inclement weather).

10.4.2 Workshops and Review Meetings

Several workshops and meetings should be conducted with the relevant stakeholders to review the scope, the Base Estimate and the Base Schedule to identify and quantify all sources of schedule uncertainty as explained in the previous section. Depending on the size of the project and its scope and complexity, it may also be necessary to seek expert input at these meetings from outside the project team.

The relevant people to attend workshops and review meetings include:

a) the estimators and cost planning team
b) the schedulers and programming team
c) the engineers, designers, planners and other advisors or service providers who prepared the material which the estimators used
d) work stream leads and delivery strategy personnel who understand how the work will be procured and delivered on the ground
e) leads from functional groups and other external experts, when required.

10.4.3 Schedule Risk Model Development

Following the completion of risk workshops, a schedule risk model should be developed. Key steps include:

a) collect and further assess the identified risks (e.g. from the latest risk register)
b) review and assess the latest assumptions with the basis of estimate and basis of schedule for areas of concern and potential variances
c) determine the overall range of risk impacts for areas of concern or uncertainty – uncertainty typically refers to a three-point estimate of how a risk may impact activity durations:
    - best case or optimistic duration – if everything goes as well as could be expected
    - most likely duration – under most likely conditions
    - worst case or pessimistic duration – if everything goes towards worst case scenario.
d) select and allocate the most appropriate probability distribution type to risk impacts (further details about distribution types can be found at Appendix D)
    - The most commonly used types of distributions include Triangular; Trigen – similar to the Triangular distribution, but with the corners cut off; uniform – a simple constant probability distribution for which every value in the range between the minimum and maximum limit is equally likely to occur; Alt-Pert – best described as a Normal distribution that allows for positive or negative 'skewness'
    - Depending on availability of historical data and actual performance benchmarks (e.g. within the road and rail sectors), this *Contingency Guideline* recommends that the Alt-Pert (10, 90) distribution be used for modelling uncertainty. In the absence of actual data, an application of a more conservative distribution, e.g. Trigen (10, 90) is recommended
e) include and model the likelihood of occurrence and range of schedule impacts for key risks
f) assess risk factors and include them in the Risk-driven Hybrid QSRA model
g) model inclement weather:
    - most construction activities will be subject to some kind of weather conditions that may dictate working and non-working periods for all or part of the workforce. In deterministic plans, this is usually accounted for by making an allowance for downtime in the relevant plan calendars. However, the weather is often more complex and may require special probabilistic techniques to be able to model its potential effects appropriately
h) assess and model the potential correlations between risks (if required) – further details about correlation have been provided at Appendix E
i) assess and model probabilistic links and branching (if required)
j) review and finalise the schedule risk model for the first iteration of simulation with consideration to optimism bias.

10.5 Probabilistic Links and Branching

As highlighted earlier, the Base Schedule should represent the most likely assumptions including required activities, productivity rates, resources, logic, relationships, etc. However, the occurrence of some specific contingent risks may require a new sub-schedule to be introduced within the schedule. This is called 'probabilistic branching' and represents a branch, or branches, that happen only with some probability.

> **RES Example:** below are a couple of examples of events which may need probabilistic branching within Quantitative Schedule Risk Analysis model:
>
> a) the source of fill material may need to be changed from one quarry to another due to the final geotechnical results and unsuitability of the assumed quarry
> b) failure in the final test of an integrated software may require additional activities for cause analysis, further consultation, recovery actions and re-test.

In some QSRA tools, another advanced technique known as 'conditional branching' is also available. For example, if a commissioning activity takes two weeks more than planned, then a recovery plan should be developed and implemented.

10.6 Monte Carlo Simulation

The Monte Carlo Simulation (MCS) is a mathematical technique that uses repeated random sampling within specified distributions to calculate the probability of defined outcomes. As applied to Risk-driven Hybrid QSRA, MCS involves the random sampling of uncertainties within a project schedule. Against each item in the model, uncertainties are randomly sampled for duration and/or probability.

Normal forward and backward pass critical path method calculations are then made, and the resulting early and late start and finish dates for each of the tasks and milestones in the schedule are recorded, as are the activity durations. Following multiple iterations, the results are collected – ready for interpretation.

10.7 Output Review and Validation

Risk-driven Hybrid QSRA results are derived from date and duration information collected across multiple iterations of a schedule risk model. When interpreting this data, it is important that it can be conveyed in a simple and meaningful form. The commonly accepted means of presenting MCS results uses a histogram overlaid with a cumulative curve to display percentile data. Some of the reports of Risk-driven Hybrid QSRA results are described in the following sections.

10.7.1 Histogram and Cumulative Curve

The histogram shows the results for all iterations ('hits') of the simulation for any activity or milestone within the schedule risk model. The cumulative curve adds up the number of hits in each bar progressively to represent the number of iterations up to a particular date.

An interception of the curve to the horizontal axis represents the percentage of iterations up to that date, or the probability of the selected activity or milestone finishing on or before that date. This result is usually referred to as a 'P value'. The most common P values are summarised below:

a) P10 – this is the best-case figure, and is often referred to as the stretch target
b) P50 – this is the median schedule and is often used as the target schedule. However, targets may be set at other percentile values due to various reasons including commercial considerations
c) P90 – this is a conservative position and is often used for government announcements to the public.

10.7.2 Tornado Graph

A tornado graph is another typical output of sensitivity analysis. It provides a ranking of the inputs with the greatest regression sensitivity (in simple terms, it shows which risks have the greatest effect on the variability in the output). It will not necessarily include the items of the greatest value, particularly where they have low risk ranges applied or do not affect activity durations directly, such as probabilistic branching and calendar-based risks. The tornado graph should be combined with a sanity check, to verify that what the model is calculating as the greatest risks meets reasonable expectations. It is recommended that the tornado graph be used to prepare a qualitative description of greatest risks to be listed in the probabilistic assessment report.

It should be noted that Correlation based Tornado graphs are not representative of risks at a specific confidence level, and do not indicate a quantum of risk impacts in duration or cost, but rather as a degree of correlation between variables.

10.7.3 Risk By Exclusion

Another approach to determining the sensitivity of risks to the Risk-driven Hybrid QSRA results is known as the Risk by Exclusion technique. In this method the Risk-driven Hybrid QSRA is undertaken to determine the results for all or a selection of identified risks. A specific activity (or milestone) and a specific "P" confidence level are then chosen to monitor. The Risk-driven Hybrid QSRA is then repeated excluding each risk at a time to determine how the results vary for the chosen activity at the chosen confidence level by excluding each risk. The risk that results in the greatest variance in results is therefore the driving risk. This process can then be repeated to identify the risk producing the next greatest variance and so on.

10.8 Updating and Documenting Risk-driven Hybrid QSRA

The Risk-driven Hybrid QSRA should be performed periodically as the schedule is updated to reflect actual progress and the reforecasting of remaining activity durations and sequences. As the project progresses, risks will retire or change in potential severity and new risks may appear. The length of time between Risk-driven Hybrid QSRA updates will vary according to project length, complexity, risk, and availability of management resources. This *Contingency Guideline* recommends that Risk-driven Hybrid QSRA should be undertaken:

a) on a minimum quarterly basis, or
b) at key decision points for major projects, or
c) When project scope variation impacts risks, or
d) When major risks are identified

The Risk-driven Hybrid QSRA and its updates should be documented to include the risk data sources of risks and techniques used to validate the risk data. Key outputs should also be documented, including: the risk list; the likelihood of the project meeting its completion date; activities that most often ended up on the critical path, and the driving risks produced from the analysis.

11. Appendix D – Other Methods of Cost Contingency Determination

11.1 Probabilistic Non-Simulation Methods

These non-simulation methods generate probabilistic output without the use of simulation techniques such as Monte Carlo Simulation. Most of these methods are empirically based to some extent (e.g., regression analysis), providing distribution information (e.g., standard error) with varying degrees of statistical rigor. An advantage of an empirical basis is that the base risk model is grounded in real-world data rather than being purely theoretical.

In contrast, the distributions for simulation models, which will be discussed later, are derived from software-generated data based on risk models. These models are often theoretical representations of project behaviour to varying degrees. In either approach, achieving empirical validity is essential. Combining both methods can offer a balanced approach, leveraging the strengths of empirical data and theoretical modelling to achieve more accurate and reliable results.

11.1.1 Enhanced Scenario Based Method (eSBM)

The Scenario-Based Method (SBM), initially introduced in 2008, offered a simpler analytical deterministic method – as an alternative to advanced statistical methods or simulation – for generating measures of cost risk. Since 2008, enhancements to SBM have included integrating historical cost performance data into its Quantitative Cost Risk Analysis algorithms. These improvements define the enhanced scenario-based method (eSBM), which was published in 2012.

The objective of an eSBM is to assess the impact of various scenarios against a project baseline. Consequently, the baseline scenario is often based on the Cost Analysis Requirements Description (CARD) parameters. Rather than building up risk and uncertainty element by element as in a Monte Carlo simulation, eSBM instead shifts attention to the identification and quantification of what can go right and what can go wrong with the project from a high-level management point of view. Hence – like other deterministic methods – eSBM is more of a top-down approach.

The key benefits of the eSBM are its visibility, defensibility, and the cost impacts of specifically identified risks. The SBM specifies a well-defined set of conditions or scenarios (i.e. Protect Scenario or PS) that would create a condition that management would like to protect against. The eSBM assumes specified scenarios that – if they occurred – would result in costs higher than planned or budgeted levels. These scenarios do not have to represent worst cases. Rather, they should reflect a set of conditions a project manager or decision maker would want to budget for, should any or all those conditions occur.

These are the eight steps associated with an SBM:

a) Step 1: Generate/Obtain Base Estimate, i.e. most likely estimate
    - Assess Base Estimate Probability, i.e. α, the probability that Base Estimate will not be exceeded. This probability is mainly calculated from the analysis of project cost growth histories in the past.
    - Select the Coefficient of Variation (CV), i.e. the ratio of a probability distribution's standard deviation to its mean. The CV is a way to examine the variability of any distribution at plus or minus one standard deviation around its mean. An appropriate realistic, historically based, CV for use in generating a probability distribution should be selected

b) Step 2: Drive the project's cumulative cost probability distribution
c) Step 3: Define the Protect Scenario (PS)
   - A PS captures the cost impacts of major known risks to the project – those events the project must monitor and guard against occurring. The PS is not arbitrary, nor should it reflect extreme or worst-case events. It should be a possible project cost that – in the judgment of the risk modeler – has an acceptable chance of not being exceeded. In practice, it is envisioned that a few iterations of the process may be needed for defining the final PS
d) Step 4: Cost the PS
   - Once the PS is defined, its cost should then be estimated.
e) Step 5: Derive Cumulative Density Function (CDF), i.e. eSBM S-Curve
   - with values assessed for α and CV, the project's cumulative cost probability distribution, i.e. CDF or eSBM S-Curve, can then be created. This distribution is used to view the probability level associated with the PS cost, as well as probability levels associated with any other cost outcome along with this distribution.
f) Step 6: Determine Confidence Levels, i.e. Probability Levels
g) Step 7: Perform Sensitivity Analysis
   - to identify critical drivers associated with the protect scenario and the project's Base Estimate cost. It is recommended that the sensitivity of the amount of Contingency Reserve be assessed with respect to variations in the parameters associated with these drivers
   - on key assumptions or conditions expressed in the protect scenario(s), as well as uncertainties in values chosen for α and CV. This allows a broad assessment of probability level variability, which includes determining a range of possible program cost outcomes for any specified probability level.
h) Step 8: Finalise assessment and select required contingency allowance for desired confidence level.

The non-statistical eSBM described above has limitations. As mentioned earlier, cost risk – by definition – is a measure of the chance that the planned or budgeted cost of a program will be exceeded due to unfavorable events. A non-statistical eSBM does not produce confidence measures. Also, the chance that the cost of the PS – or the cost of any defined scenario – will not be exceeded is not explicitly determined.

The lack of reasonable historical data for similar projects may also create challenges in selection of α and CV, impacting the accuracy of the assessment. Considering the minimum practical application of this method in the construction and infrastructure sectors, this *Contingency Guideline* refers its readers to other references (e.g. 'A Scenario-Based Method for Quantitative Cost Risk Analysis' by Paul R Garvey or USA's Joint Agency Cost Schedule Risk and Uncertainty Handbook, 2014) for further guidance on this method.

11.1.2 Method of Moments (Delta Method)

Method of moments also goes by a variety of other names such as the Delta method or the mean-value first-order second-moment method. It is a deterministic cost-risk analysis approach that allows the risk analyst to statistically sum WBS element costs, which are represented by probability distributions. The method is a technique for finding approximations to the moments (particularly the variance) of functions of random variables when these moments cannot be directly evaluated (Oehlert, 1992).

From this, it is possible to obtain a probability distribution of total cost. Summation of WBS element costs is done not by Monte Carlo sampling, but by fitting a lognormal probability distribution to the mean and variance of total cost. Specific percentiles of the lognormal distribution of total cost can be displayed (e.g., 10^{th}, ..., 90^{th}, 95^{th}).

This method tries to estimate a total-level mean and variance from the sum of the subordinate elements. The mean and variance are the first and second moment of a random variable, hence the name method of moments. With knowledge of the mean and standard deviation for each element and how they are correlated, the mean and standard deviation at the parent levels can be calculated without simulation.

It must be noted that – due to its reliance on normal and lognormal distributions – this method may underestimate risk in certain situations. Method of moments is a convenient approach when the model is a simple sum of uncertain elements, particularly if there are a large number of them. However, there are several complications, including:

a) challenges to develop a custom method of moments for every estimate
b) mean and variance of subordinate elements should be supported by reliable historical data
c) the variance sum must be adjusted for correlation
d) distributions at the parent levels are assumed rather than derived
e) efforts to combine uncertainties can lead to complex calculations.

This *Contingency Guideline* does not recommend the method of moments for general use, especially for the building, construction and infrastructure projects.

11.1.3 Reference Class Forecasting (RCF)

The reference class forecasting (RCF) method was introduced, by Kahneman and Tversky (1979) and later Lovallo and Kahneman (2003), Bent Flybjerg and Cowi (2004), to overcome human bias and the resulting inaccurate forecasts. RCF – also known as *Optimism Bias Uplifts* or *Comparison Class Forecasting* – is a method of predicting the performance of future projects by referring to the performance of similar past projects. A concern with this method is that by setting budgets based on past performance, which is mediocre at best, one forecloses on the opportunity for improvement (repeating history by design). That is contrary to risk management principles which seek to support continuous improvement.

RCF is generally adopted to mitigate two main factors which cause persistent cost overruns in infrastructure projects – optimism bias and strategic misrepresentation as described in Chapter 2 earlier. This can be more properly considered a validation or benchmarking practice for quality management and governance, not a contingency determination method.

By using data from previous projects, this method aims to divide projects into several distinct groups. For example, groups for transport projects may include road, rail, tunnel, bridge, buildings and Information and Communication Technology (ICT) projects. For each category, the probability distribution for cost overrun – as the share of projects with a given maximum cost overrun – should be then created.

RES Recommendation: organisations should establish and regularly capture as much accurate real life project data as possible. Organisations should make a point of capturing, validating and recording their projects' assumptions, conditions, progress and performance data in a structured and systematic approach. This data then can not only be used for cost/schedule contingency forecasting, but also to improve their risk management practices.

By establishing an empirical cumulative probability distribution, uplifts will be then set up as a function of the confidence level (i.e. risk appetite) that the organisation is willing to accept. Uplift (i.e. contingency reserve) represents the required additional amount on top of the Base Estimate required to achieve the desired confidence level. The process for the most common approach of this method is represented in Figure 34 below.

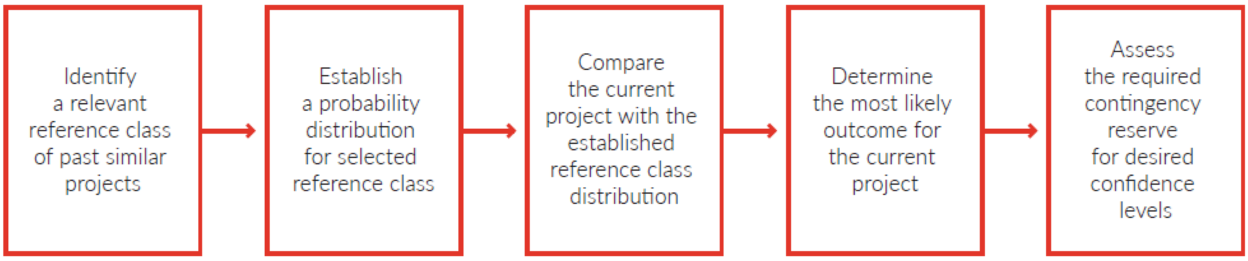


Figure 34: The process of reference class forecasting (RCF) methodology

The key challenges associated with this method are:

a) The method assumes that future projects will perform similarly to past projects. Considering the influences of internal and external factors on project performance, there are a number of uncertainties associated with this assumption
b) By assuming that future performance will be similar to past performance, the method is discouraging good industry practice of project risk and contingency management, as well as opportunities for improvement
c) Most organisations do not have good data from a large number of their past projects. This may cause a significant error in the determination of the contingency reserve (uplifts)
d) While the selected projects should be broad enough to be meaningful, they should be as similar as possible to the current project – so comparison can provide reliable results
e) The RCF does not involve any serious attempt to identify, mitigate and quantify any specific major contingent risks (events) that may affect the project considered. In other words, while using historical data is a great initiative, the key objective is not to repeat the past, but to improve it by reduced residual risks
f) Although the project cost estimate and duration forecast are perhaps the two most important objectives of the RCF method, this method ignores other key risks such as safety, quality, environment and reputation which have time and/or cost impacts which should be identified, quantified and assessed
g) From a number of studies, it has become apparent that the RCF method needs a reference class consisting of projects that are highly similar to the project at hand, as forecasting accuracy considerably diminishes with decreasing similarity level.

There are several references that provide adjustment percentages for generic project categories that can be used in the absence of more robust evidence. One example presented below is based on Supplementary Green Book Guidance – Optimism Bias.

Project Type	Optimism Bias (%)			
	Works Duration		Capital Expenditure	
	Lower	Upper	Lower	Upper
Standard Buildings	1	4	2	24
Non-Standard Buildings	2	39	4	51
Standard Civil	1	20	3	44

Engineering				
Non-Standard Civil Engineering	3	25	6	66
Equipment / Development	10	54	10	200
Outsourcing	N/A	N/A	0*	41*

* The optimism bias for outsourcing projects is measured for operating expenditure.

Table 17: Supplementary Green Book Guidance – Optimism Bias %

The following steps can be adopted, and the results should be reviewed for reasonableness.

Step 1 – select the project type
The definitions of the project types are as follows:

- **Standard building projects** are those which involve the construction of buildings not requiring special design considerations i.e. most accommodation projects e.g. offices, living accommodation, general hospitals, prisons, and airport terminal buildings.
- **Non-standard building projects** are those which involve the construction of buildings requiring special design considerations due to space constraints, complicated site characteristics, specialist innovative buildings or unusual output specifications i.e. specialist/innovative buildings e.g. specialist hospitals, innovative prisons, high technology facilities and other unique buildings or refurbishment projects.
- **Standard civil engineering projects** are those that involve the construction of facilities, in addition to buildings, not requiring special design considerations e.g. most new roads and some utility projects.
- **Non-standard civil engineering projects** are those that involve the construction of facilities, in addition to buildings, requiring special design considerations due to space constraints or unusual output specifications e.g. innovative rail, road, utility projects, or upgrade and extension projects.
- **Equipment & development projects:** Projects that are concerned with the provision of equipment and/or development of software and systems (i.e. manufactured equipment, Information and Communication Technology (ICT) development projects) or leading-edge projects.
- **Outsourcing projects** are those that are concerned with the provision of hard and soft facilities management services e.g. ICT services, facilities management or maintenance projects.

Step 2 – calculate upper bound (table above)

Step 3 – assess reasonableness of upper bound optimism bias – consider any mitigations and factors that can reduce the upper bound. The main strategies for reducing optimism bias are full identification of stakeholder requirements (including consultation), accurate project cost estimation, comprehensive project and risk management.

Step 4 – apply the mitigated optimism bias % on the Base Estimate – this provides the risk-adjusted cost estimate, or sometimes defined as the 'Base Case', as defined in the Green Book is the best estimate of how much a project will cost in economic terms, including an allowance for risk and optimism.

It should be noted that RES recommends this method to be used to complement rather than replace the good practice quantitative risk assessment, e.g. First Principles Risk Analysis (FPRA) supported by Quantitative Schedule Risk Analysis (QSRA) which is recommended to be undertaken to identify and assess project specific risks and inherent uncertainties, e.g. systemic risks.

11.1.4 Parametric Based

The parametric method determines and applies the correlation of systemic risk drivers and cost growth and schedule slips outcomes. The inherent regression diagnostics (i.e., error of prediction) provides the basis for probabilistic model outcomes. Regression and MCS are the only two practical inferential statistical methods available. One is based on distribution of an actual dataset, the other on distribution of a theoretical dataset generated by sampling. The method aims to develop a relationship between a cost overrun or schedule slip (normalised to percentages) and systemic risk drivers by using historical data. This method uses parameters which are risk factors such as project definition, size of the project, complexity, team development, bias, existing historical data, etc. This method uses linear relationships between dependent (cost increase or schedule slip) and independent variables (the systemic risk factors).

Parametric models can be classified as simple or complex. For this *Contingency Guideline*, simple models are cost or schedule estimating relationships consisting of one risk driver. Complex models, on the other hand, are models consisting of multiple relationships, or algorithms, to derive cost overrun and schedule slip estimates. The following present the typical forms of simple parametric estimating formulas used in risk quantification:

Outcome = Base * (1 + Parameter A Factor + Parameter B Factor + …)

$ % cost overrun or schedule slip = a + b*V1 + c*V2 + … (Linear Relationship)

% cost overrun or schedule slip$ = a + b*V1^x + c*V2^y + … (Non-Linear Relationship)

Parametric based methods, as the name suggests, are based on parameters that define the inherent (including systemic) drivers of uncertainty including complexity, risk, schedule, cost and risk of a program, project, service, process or activity. Some of the most common parameters are:

a) maturity of design
b) maturity of estimate and schedule
c) type of technology
d) process system complexity
e) site conditions
f) team experience and competency
g) cognitive biases.

The process for the most common approach to this method is represented in Figure 35.

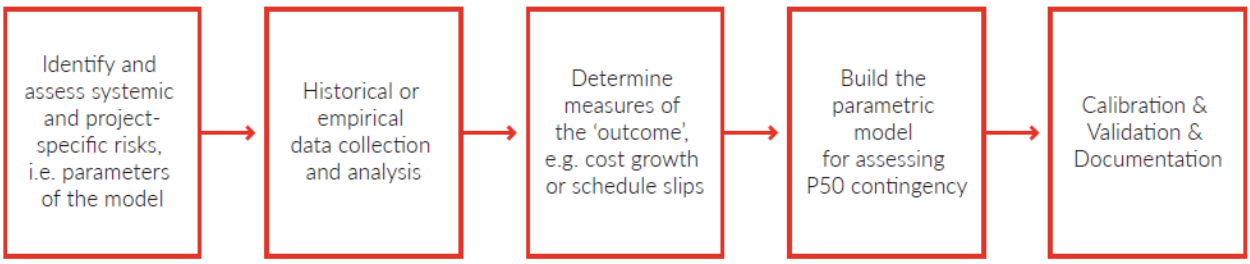


Figure 35: Common process of Parametric based methodology

The development of parametric cost models generally occurs through the steps below:

a) database development
b) model requirements
c) resolution of model architecture and data availability
d) model development
e) model calibration and validation

f) model documentation
g) model updating.

Usually, a series of regression analysis cases (linear and non-linear) will be run against the data to determine the best algorithms to eventually comprise the parametric model. The data application stage of the development process involves establishing the user interface and presentation form for the parametric cost model. Using the mathematical and statistical algorithms developed in the data analysis stage, the various inputs to the cost model are identified. An interface is then developed to provide the estimator with an easy and straightforward way in which to enter this information.

The process above generally generates the mean or P50 contingency. To generate a probabilistic range of outcomes, e.g. from P10 to P90 range, it is quite common to assume that the contingency is normally distributed when expressed in the form of estimate/actual and is equal to the standard deviation of the distribution of that ratio. With these assumptions, the normal cumulative distribution can be generated using the NORMINV function within Microsoft Excel. The probabilistic distribution can be refined as one obtains better data for validation.

RES Example: utility owner DAXA, is planning to expand one of its commercial buildings. As part of the required preliminary business case, a Class 5 estimate and schedule has been developed. A parametric based method as shown below has been used to assess the required cost contingency.

a) Base Estimate excluding contingency (1,000 square meters × $10,000/m2) = $10m
b) Parameters: A=1.15, B=1.1, C=1.05, D=1.0
c) Luxury Factor (Parameter A) = 1.15
d) Complexity Factor (Parameter C) = 1.05
e) Site Conditions Factor (Parameter C) = 1.05
f) Maturity of Design Factor (Parameter D) = 1.0
g) Total Cost Estimate (TCE) including contingency = $10m × (1+0.15+0.05+0.05+0.0) = $12.5m
h) P50 Contingency = $2.5m
i) NORMINV (probability, mean, std. dev)
    - TCE P10 = NORMINV (0.1, $12.5m, $2.5m) = $9.3m
    - TCE P50 = NORMINV (0.5, $12.5m, $2.5m) = $12.5m, i.e. $2.5m or 25% contingency
    - TCE P70 = NORMINV (0.7, $12.5m, $2.5m) = $13.81m, i.e. $3.81m or 38% contingency
    - TCE P90 = NORMINV (0.9, $12.5m, $2.5m) = $15.7m, i.e. $5.7m or 57% contingency

The strengths of parametric based methods are:

a) reasonable at the early stages of project development (e.g. preliminary business case)
b) probabilistic results
c) data-based (all this happened before and all of it will happen again)
d) simple and quick assessment
e) repeatable.

The weaknesses of parametric based methods are:

a) may not be reasonable and accurate at final stages of project development, e.g. FBC
b) access to sound historical and empirical data
c) quality of project data including Base Estimate and Base Schedule
d) complex to create
e) do not address project specific risks
f) generally, do not address the importance of good industry practice risk management to identify

and mitigate risks.

Parametric based methods can be a reasonable method in preparing early conceptual estimates, e.g. at the stage of Preliminary Business Case development. They are often used during both the concept screening and feasibility stages of a project. Parametric estimating models can be developed using basic skills in estimating, mathematics, statistics, and spreadsheet software.

RES Tips & Tricks: Make sure your project data is collected, validated, cleansed and maintained in order to provide a complete audit trail with expenditure dates so that costs can be adjusted for escalation. You should identify and capture non-recurring and recurring costs separately, preferably through project Work Breakdown Structure (WBS).

It is important to understand that the quality of results can be no better than the quality of the input data, and great attention should be taken during the data collection and analysis stage to gather appropriate and accurate project scope and cost data.

Based on several studies, the relationship between parameters and cost growth and schedule slip as percentages (output) have proven reliably consistent for projects of all types and sizes involving construction from simple pipelines to nuclear projects. In other words, the models from industry research can be used with confidence by anyone, though one should validate the outcomes over time with one's own data.

RES Recommendation: Parametric based methods are generally reasonable and adequate at very early stages of project development (e.g. Preliminary Business Case with Class 5 estimates) – given the dominance of systemic risk impacts and wide range of inherent risks associated with assumptions as well as lack of knowledge of project specifics including possible contingent risks.

For key decision points at the later stages of project development (e.g. Final Business Case with Class 4 estimates or better) or during project delivery – RES recommends other methods of Contingency Determination (such as First Principles Risk Analysis (FPRA) as described in Appendix E) are used in combination with the parametric based methods.

11.1.5 Regression Based

Regression based analysis is a probabilistic (non-simulation) method used to find relationships between variables for the purpose of predicting future values. In project cost estimating, this method is used to develop CERs between a dependent variable (project cost) and one or more independent variables (e.g. cost drivers such as weight, power or volume) from historical completed project data.

By a statistical relationship, it is meant that the observed variation of the dependent variable (project cost) across similar projects can be explained or predicted by one or more independent variables (e.g. technical, performance, or programmatic). The objective is to find a functional relationship that most accurately estimates the cost of a particular element in a project WBS. There are several different approaches to this method including the list below:

a) Ordinary Least Squares (OLS)
b) Minimum Unbiased Percentage Error (MUPE)
c) ZPB/MPE Method (or ZMPE Method)

d) Iterative Regression Techniques.

Considering the limited application of this method in industry, especially construction and infrastructure projects, this *Contingency Guideline* refers its readers to other references (e.g. AFCAA Quantitative Cost Risk Analysis Handbook or JA CSRUH Handbook) for further guidance on this method.

11.1.6 Range Based

A single-point cost estimate can be improved by using a range: the optimistic (best case); the most likely; and the pessimistic (worst case) estimate for each cost element – instead of one forecast. These three-point estimates will be determined for both inherent and contingent risks by SMEs; validated by actual historical data from previous projects; and will be then combined into one number by using an appropriate average formula (e.g. the triangular or beta distribution formulas, as shown in Figure 36 below).

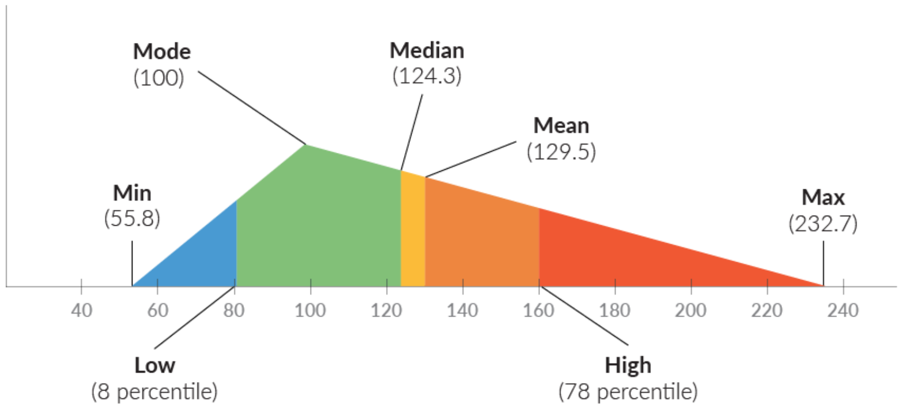


Figure 36: Distribution parameters of a Notional Triangle

The range-based approach to quantifying contingencies aims to improve on other non-simulation probabilistic approaches by using a validated range of possibilities for each item across the project scope for the inherent and contingent risks. Like the item-based method, the structure of items might be based on the WBS, contract packaging, commodity types or other groupings. The process for the most common approach to this method is represented in Figure 37.

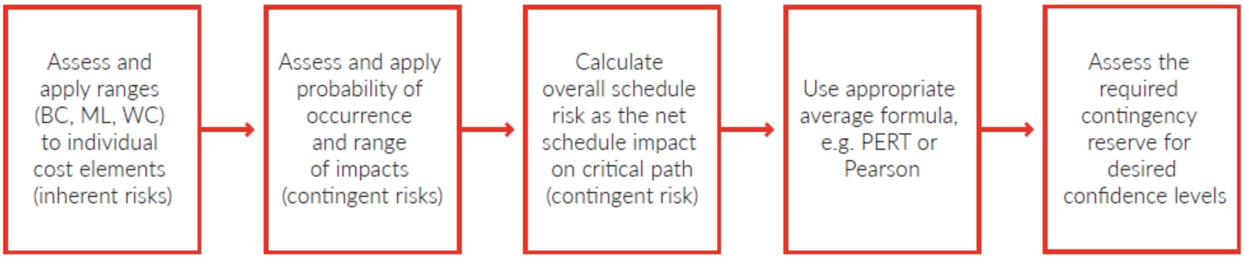


Figure 37: the process for probabilistic range based methodology

In assessing the best case, most likely and worst-case ranges, several factors including estimating judgment, previous experience, historical data, risk appetite and the organisation's previous performance should be considered. The example below illustrates the required steps further:

a) For inherent risks: apply a range (best case, most likely and worst case) to individual cost elements (recommended at project WBS level 4), then use any weighted average formula to turn the range

into a number. Examples include:
- PERT formula: (BC + 4 X ML + WC)/6
- Johnson modification of the Pearson-Tukey formula for assessing a 50% confidence level: (3 X BC + 10 X ML + 3 X WC)/16

b) For contingent risks: apply the probability of risk occurring and range of time and cost consequences for residual risks

c) Calculate total schedule contingency as the net schedule impact of inherent and contingent risks on the completion date

d) Calculate total cost contingency as:
- for a 50% confidence level:
  - P50 contingency = P50 contingency for inherent risks + P50 contingency for contingent risks
- for a 90% confidence level (noting that the P90's of each item are not additive so overall will be conservative. Only the means are):
  - P90 contingency = P90 contingency for inherent risks + P90 contingency for contingent risks
  - A reasonable multiplier to P50 contingency may be used for determination of P90 contingency for each item, e.g. P90 = P50 + Standard Deviation. (Noting that in a normal distribution, approximately 95% of the data falls within two standard deviations of the mean.

Table 18 presents the range-based method using the weighted average Pearson-Tukey formula.

	Range of potential impact			Weighted average formula (e.g. Pearson)			
P(x) (%)	Best case	Most likely	Worst case	Standard Deviation /2	W.Av=(3*BC+10*ML+3*WC)/16 P50=P(x)*W.Av		P90=P50 + (SD x P(x))
35	$100,000	$500,000	$2,500,000	$524,934	$800,000	$280,000	$647,453
50	$2,500,000	$3,000,000	$6,000,000	$772,802	$3,468,750	$1,734,375	$2,507,176
75	$100,000	$110,000	$300,000	$46,007	$143,750	$107,813	$176,823
5	$200,000	$220,000	$500,000	$68,475	$268,750	$13,438	$20,285
35	$125,000	$150,000	$500,000	$85,594	$210,938	$73,828	$133,744
80	$2,500,000	$3,000,000	$6,000,000	$772,802	$3,468,750	$2,775,000	$4,011,482
12	$100,000	$110,000	$500,000	$93,125	$181,250	$21,750	$44,099
10	$200,000	$220,000	$600,000	$92,014	$287,500	$28,750	$47,152.90
80	$125,000	$150,000	$300,000	$38,640	$173,438	$138,750	$200,574
90	$2,500,000	$3,000,000	$6,000,000	$772,802	$3,468,750	$3,121,875	$4,512,917
10	$100,000	$110,000	$500,000	$93,125	$181,250	$18,125	$36,749
75	$200,000	$220,000	$600,000	$92,014	$287,500	$215,625	$353,646
60	$125,000	$150,000	$500,000	$85,594	$210,938	$126,563	$229,275
40	$2,500,000	$3,000,000	$6,000,000	$772,802	$3,468,750	$1,387,500	$2,005,741
100	$100,000	$110,000	$500,000	$93,125	$181,250	$181,250	$367,499
						$10.2m	**$15.3m**
						P50	**P90**

Table 18: An example of the range-based method by using the Pearson-Tukey formula

11.1.7 *AI Based*

One of the non-simulation techniques for cost contingency determination is using AI technology, which is growing at a significant speed across all industries. AI-based tools can enhance the assessment of project schedule contingency by leveraging its capabilities in data analysis, pattern recognition, and predictive modelling. Implementation Steps include:

- Data Collection: Gather historical project data, current project details, and any other relevant information.
- Model Development: Develop machine learning models tailored to the specific needs and characteristics of the project.
- Integration: Integrate AI tools with existing project management software for seamless data flow and analysis.
- Testing and Validation: Test the AI models on past projects to validate their accuracy and effectiveness.
- Deployment: Deploy the AI solutions and continuously monitor and update them for ongoing improvement.

Although the concept is at the early stages of development with a limited number of solutions and users, the *Contingency Guideline* highlights there are several ways AI can be utilised for this purpose.

Predictive Analytics

- Historical Data Analysis: AI can analyse vast amounts of historical project data to identify patterns and trends. This helps in understanding how past projects have deviated from their costs and what factors contributed to those deviations.
- Risk Prediction: By evaluating historical and real-time data, AI can predict potential risks that could affect the project timeline and/or cost, allowing for better planning and mitigation strategies.

Machine Learning Models

- Schedule and/or cost Optimisation: Machine learning algorithms can optimise project schedules/costs by identifying the most efficient sequence of tasks and predicting potential bottlenecks.
- Scenario Analysis: AI can simulate various scenarios to assess the impact of different risks on the project timeline/cost. This helps in understanding the probability of delays under different conditions.

Natural Language Processing (NLP)

- Risk Identification: NLP can be used to analyse text data from project documentation, emails, and reports to identify potential risks and issues that might affect the schedule.
- Stakeholder Communication: NLP can assist in understanding stakeholder sentiment and concerns related to project timelines/costs, ensuring better communication and proactive risk management.

Real-time Monitoring and Alerts

- Progress Tracking: AI-powered tools can monitor the project’s progress in real-time, comparing it with the planned schedule/cost and identifying deviations immediately.

- Proactive Alerts: AI can send real-time alerts to project managers about potential delays or issues, allowing for timely intervention and adjustments.

Integration with Project Management Tools

- Automated Reporting: AI can integrate with existing project management tools to automate the generation of reports and dashboards that visualise schedule performance and risks.
- Resource Optimisation: AI can analyse resource allocation and suggest adjustments to minimise delays and enhance productivity.

Data-Driven Decision Making

- Informed Adjustments: AI provides data-driven insights that enable project managers to make informed decisions about adjustments to the schedule or contingency plans.
- Continuous Learning: AI systems can continuously learn from new data, improving their predictive accuracy and the effectiveness of contingency plans over time.

It should be also noted that AI Based methods, e.g. machine learning, can be combined with simulation methos, e.g. Monte Carlo simulation. Machine learning and Monte Carlo simulation are powerful techniques that serve different purposes but can be effectively combined. Monte Carlo methods help in understanding systems under uncertainty, while machine learning provides predictive power and pattern recognition. Together, they can offer robust solutions for complex modelling and prediction tasks.

One common approach to combining these techniques is to use Monte Carlo methods to generate data that can train a machine learning model or to use machine learning to analyse and interpret the outputs of Monte Carlo simulations.

Example Process:

1. **Initial Simulation:** Use Monte Carlo simulation to generate a large dataset representing various scenarios of a system.
2. **Model Training:** Train a machine learning model on this dataset to learn the underlying patterns and relationships.
3. **Prediction and Analysis:** Use the trained machine learning model to predict outcomes of new scenarios or to perform sensitivity analysis.

RES Recommendation: using AI technology for assessing project cost contingency can improve accuracy, enable proactive risk management, and enhance overall project efficiency. By leveraging predictive analytics, machine learning, natural language processing, and real-time monitoring, risk managers can better anticipate and mitigate potential delays, ensuring projects stay on track. However, given the current stage of AI-enabled tools and data availability, this guideline recommends practitioners exercise additional caution when using AI-based solutions. The risks can be mitigated by using AI in conjunction with other proven techniques, such as Quantitative Cost Risk Analysis (QCRA).

11.2 Probabilistic Simulation Methods

11.2.1 Outputs Based Uncertainty

The outputs-based method applies uncertainty directly to the cost model results rather than to the model's inputs. The approach relies on historical data to estimate the overall uncertainty at output levels of indenture within the estimate. The assumption is that the aggregate uncertainty of both the methodology and the inputs is addressed using uncertainty distributions on the outputs.

RES Recommendation: upon completion of the Base Estimate, the risk analyst will examine the WBS and determine the level at which to apply uncertainty. Application at every WBS child element is recommended though circumstances may lead to application at WBS parent levels instead. For example, in a model where a WBS parent element is the sum of many low-cost WBS child elements, it may be appropriate to simply treat uncertainty at the level of that parent.

The simulation model is set up such that the distributions are defined with a most likely value of "1" (or in the case of Lognormal, the median) to be multiplied by each element's Base Estimate. Each simulation pass will draw a sample of the distribution and multiply the drawn value times the Base Estimate value – the simulation need not execute the entire cost model upon each draw. Since the objective is to model combined effects in one distribution, the shape and bounds of the distribution will often by necessity be subjective unless the bounds were derived from a data set or from a more detailed series of simulations.

The subjective selection of uncertainty can often be enhanced by the use of risk score mapping – this is often used in outputs-based simulations. Risk score mapping is a technique consisting of a risk scoring matrix and a map of uncertainty distribution bounds against risk scores. Figure 38 (after the US Air Force Cost Risk and Uncertainty Analysis Handbook) depicts this method conceptually. The risk scoring matrix at the top of the figure consists of uncertainty-causing categories by row. By column, the attributes of those categories are listed that are deemed low risk, high risk, etc. Separate matrices may be developed for different types of cost elements.

The matrices are used to elicit judgments from technical personnel as to the technical and schedule risk associated with a particular cost element. The columns are quantified with assigned scores of increasing values from low to high risk. The average score from the matrix across the categories is the overall risk score for that cost element. The categories may be weighted if desired. The risk scores are converted to distribution bounds as shown in the bottom of Figure 38. Although this method has merit in formalising the assignment of subjective risk and providing a mechanism for eliciting participation from the technical personnel in judging risk, this *Contingency Guideline* does not recommend application of this method at key project investment decision-making points, (e.g. Final Business Case).

	Risk Scores		
Risk Categories	Low	Medium	High
Category 1	Reference text describing attributes of low risk of each category	Reference text describing attributes of medium risk of each category	Reference text describing attributes of high risk of each category
Category 2			
Category 3			
Category 4			
Category 5			

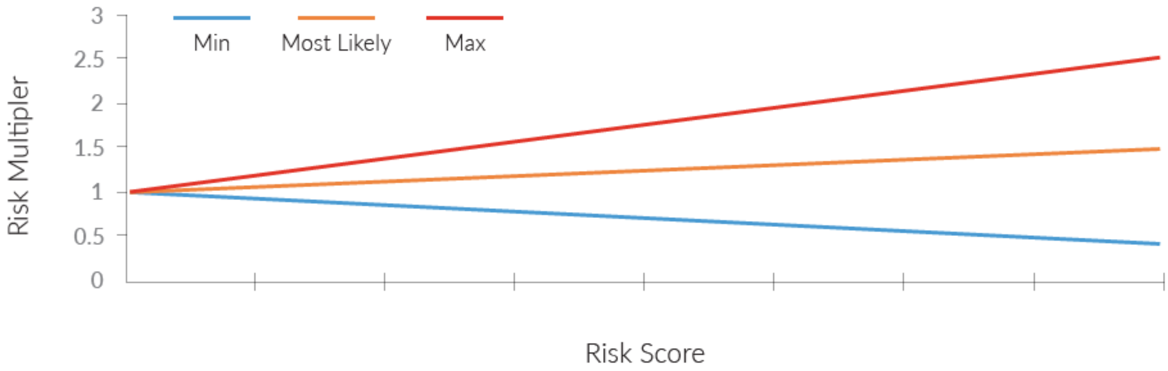


Figure 38: Risk score mapping concept

11.3 Further Reading

- AACE International, RP 41R-08 Risk Analysis and Contingency Determination Using Range Estimating
- AACE International, RP 42R-08 Risk Analysis and Contingency Determination Using Parametric Estimating
- Garvey, Paul R., Book, Stephen A., and Covert, Raymond P., *Probability Methods for Cost Uncertainty Analysis*, 2nd Edition
- Hollmann, John K., *Project Risk Quantification*, 2016, Probabilistic Publishing
- Johnson, D., “Triangular Approximations for Continuous Random Variables in Risk Analysis”, *Journal of the Operational Research Society*, vol. 53, no. 4, pp. 457-467, 2002
- NASA, *Joint Cost Schedule Risk and Uncertainty Handbook, 24 April 2013*
- US Air Force, *Cost Risk and Uncertainty Analysis Handbook*

12. Appendix E – First Principles Risk Analysis (FPRA)

12.1 Purpose

The purpose of this appendix is to provide information on First Principles Risk Analysis (FPRA) – as a method of Quantitative Cost Risk Analysis (QCRA) – to develop, assess and allocate a reasonable risk based contingency allowance (time and cost) for the desired confidence level.

12.2 FPRA Overall Process

The key elements of a realistic and reliable FPRA in determination and allocation of a reasonable cost contingency for different desired confidence levels are:

a) quality validation of the Base Estimate: preferably a first principles, rigorous, structured and detailed cost estimate – representing the most likely assumptions – structured against equipment, labor, material and sub-contracts
b) quality of the Base Schedule: preferably a logic or resource-driven CPM schedule – representing the current strategies and assumptions
c) alignment and consistency of assumptions between the Base Estimate and Base Schedule
d) identification and quantification contingent risks including schedule risks
e) identification and quantification of inherent risks at the most appropriate level of first principles cost estimate against labor, material, and subcontractor
    - the uncertainties should be then consolidated and aggregated to higher level of CBS for risk modelling – for example, uncertainties might be quantified at Level 5 of CBS/WBS, then aggregated to Level 3 for risk modelling
f) allocation of the inherent and contingent risks into the cost risk model
g) assessment and modelling of key correlations, e.g. by using correlation matrix, aggregation of uncertainties to higher level of CBS/WBS, utilising Risk Factors, etc.
h) running Monte Carlo Simulation (MCS)
i) review, validation and finalisation of the results.

The process for the most common approach to this method is represented in Figure 39.

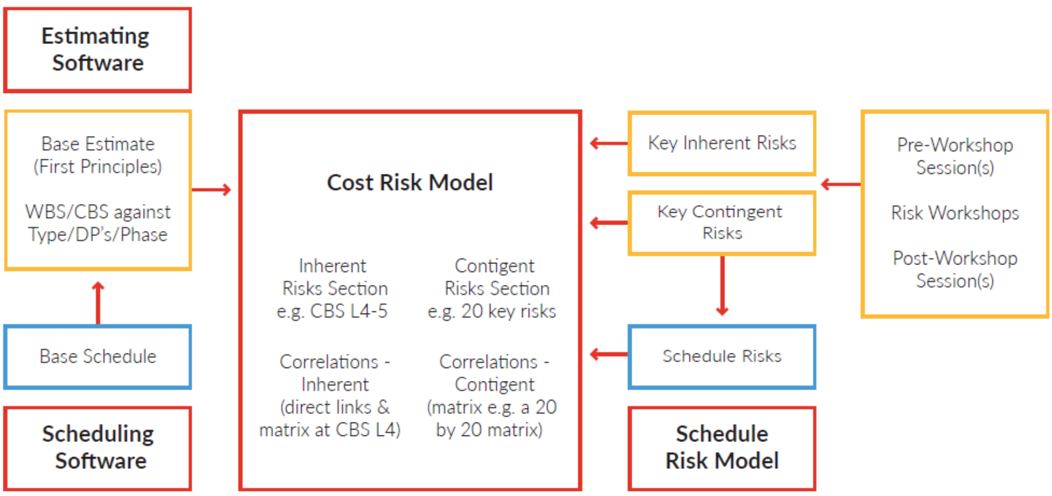


Figure 39: A typical process map for the FPRA method

These key elements are further explained in the sections below or other chapters of this *Contingency Guideline*.

12.3 Base Estimate

To prepare an effective probabilistic risk assessment, it is important that the following items can be identified from the Base Estimate:

a) the relationships between different cost line items, rates and quantities
b) the relative uncertainty in the estimate of different line items, rates and quantities
c) the key assumptions that underpin the base estimate
d) the best structure of the first principles Base Estimate, e.g. material, equipment and labor.

These aspects will determine the design of the risk model, and the approach taken to quantify risks. The approach taken should be consistent with inherent and contingent risk models – that is, where an allowance is made in the Base Estimate, it should not 'double up' with further ranges or risks in the risk models.

12.4 Base Schedule and Schedule Risks

Key notes for consideration include:

a) ensuring appropriate integration of schedule risk (by using a range of schedule impacts) within the cost model
b) ensuring the residual risk exposures are not double counted or missed between the cost and schedule risk assumptions and overall model
c) ensuring that the Base Schedule on which the QSRA is to be performed is fit for purpose – with the appropriate level of detail and logic contained within it
d) ensuring there has been reasonable assessment of inherent risk within the Base Schedule as well as the possibility of discrete risk events (contingent risks).

In addition to the above, application of a fully integrated schedule cost risk model may be considered depending on the availability of early design and Base Estimate data (as detailed in Appendix E).

12.5 Risk Workshops and Review Meetings

Several risk workshops and meetings should be conducted with the relevant stakeholders to both review the estimate and schedule and populate the risk model. Considering the size of project and its scope, it may also be necessary to elicit expert input through other means. The relevant people to attend workshops and/or review meetings include:

a) the estimators and cost planning team
b) the schedulers and programming team
c) the engineers, designers, planners and other advisors or service providers who prepared the material which the estimators used
d) work stream leads and delivery strategy personnel who understand how the work will be procured and delivered on the ground
e) leads from functional groups and other external experts, when required.

> **RES Tips & Tricks:** While workshops and reviews can help to record many risks in the risk register, it is important to note there may be other discrete risk sources that need to be assessed and modelled.

For further details about risk workshop facilitation, please refer to Appendix B.

12.6 Optimism Bias

It is important to recognise that people tend to be consistently optimistic and overconfident in assessing uncertain outcomes, such as probabilities and ranges. This optimism bias can lead to setting unrealistically low contingencies, which may inadequately prepare the project for potential risks. To mitigate this impact, several control approaches are recommended:

a) Benchmarking:

- Compare your estimates to other cost estimating procedures. This involves understanding the contingency range expected at each project phase based on the estimator's experience and taking into consideration insights from the wider industry. This benchmarking helps ensure that contingencies are neither overly optimistic nor pessimistic.

b) Cross-Checking Assumptions:

- Verify your assumptions by consulting with different people across several separate meetings. This cross-checking process provides diverse perspectives, helping to identify and correct any biases that might have been overlooked by relying on a single viewpoint.

c) Multiple Short Risk Reviews:

- Conduct multiple short risk reviews involving a significant number of participants rather than longer risk workshops with a limited group. Frequent, shorter sessions can keep discussions focused and productive, while the diversity of participants ensures a broader range of insights and mitigates groupthink or bias from a smaller, homogeneous group.

d) Using Wide Ranges:

- Apply wide ranges for estimates, generally biassed on the upside to account for unforeseen risks. By assuming a broader spectrum of potential outcomes, this approach acknowledges the inherent uncertainty in project estimates and helps set more realistic contingencies.

Additional Mitigation Strategies

e) Historical Data Analysis:

- Utilise historical data from past projects to inform current risk assessments. By examining previous outcomes, you can identify patterns of underestimation and adjust current assumptions accordingly.

f) Continuous Monitoring and Adjustment:

- Implement ongoing monitoring of project progress and regularly adjust risk estimates as more information becomes available. This dynamic approach ensures that contingencies are continually aligned with the current project status and emerging risks.

g) Risk Management Training:

- Provide training on risk management principles to all project stakeholders. Educating the team about optimism bias and its effects can heighten awareness and encourage more realistic assessments.

h) Use of Expert Judgement:

- Involve industry experts in the risk assessment process. Their seasoned judgement can provide valuable insights and help counterbalance the innate optimism bias of less experienced team members.

i) Scenario Analysis:

- Conduct scenario analyses to explore various 'what-if' situations. By considering extreme cases and their implications, you can better prepare for a range of outcomes and set appropriate contingencies.

j) Independent Reviews:

- Engage independent third-party reviewers to assess the project risk and contingencies. External reviewers can offer unbiased perspectives and highlight potential blind spots within the project's risk management plan.

By employing these strategies, the practitioners can mitigate the impact of optimism bias and set more realistic and resilient contingencies, thereby enhancing the overall robustness of the project planning process. For further details about optimism bias and other possible cognitive biases influencing risk and contingency assessment, refer to Section 2.6.3, Chapter 2.

12.7 Correlation

A critical component of the simulation model is defining the correlation between each of the distributions included in the model. Correlation describes the degree to which variables move in relation to one another. For instance, if a random sample from one distribution is taken from the high end, is there a reason to expect other samples to also be drawn similarly? The level of correlation in a model profoundly influences the results, which will be addressed in the following sections.

Understanding Correlation

Correlation refers to the degree to which variables are related or associated, but it does not imply a cause-and-effect relationship between them. In risk analysis, it is crucial to account for the relationships between cost elements during risk simulation. This interrelationship between Work Breakdown Structure (WBS) elements is commonly known as dependency or correlation. For example, if an increase in the cost of WBS element A causes an increase in WBS element B (positive correlation), it might also result in a decrease in WBS element F (negative correlation). Including correlation between random input variables in input-based analyses is essential where significant.

Types of Correlation for FPRA Modelling

For the purpose of FPRA (Full Project Risk Analysis) modelling, consider and model two different types of correlation:

a) Functional Correlation:

- This type of correlation is based on a direct, calculable relationship between variables. For example, if the completion time for Task A directly affects Task B, this functional relationship needs to be represented in the model.

b) Applied Correlation:

- Applied correlation considers the empirical relationships observed in historical data or expert judgement. This type of correlation is not directly calculable but is based on observed trends and behaviour within similar projects or scenarios.

By understanding and incorporating these two types of correlation, you can achieve a more accurate and realistic risk simulation, thereby improving the reliability and robustness of the model's outputs.

> **RES Tips & Tricks:** The FPRA analysis is not complete until both functional and applied correlation is addressed. If correlation is ignored, the variance at the total levels in the estimate may be understated – in many cases considerably.

12.7.1 Functional Correlation (Implicit)

Correlation is a statistical measure that indicates the extent to which two or more variables rise and fall together. A positive correlation (e.g. +1) indicates the extent to which those variables increase or decrease in parallel; a negative correlation (e.g. -1) indicates the extent to which one variable increases as the other decreases. It should be noted that correlation does not necessarily imply causation. Research and guidelines show that correlations must be included in Monte Carlo simulations, otherwise the analysis leads to an incorrect assessment of the overall risk profile. Studies also suggest that the effect of excluding correlations from the model is more profound than the effect of the choice between different probability distributions.

The term functional correlation has been around since at least 1994 and yet it is largely misunderstood. Essentially, it is referring to the correlation that is developed in the simulation due to the mathematical (functional) relationships within the elements of the risk model. Uncertainty that is defined on a variable or assigned to a cost element will be inherited by any relationship that uses them in its equation. Functional correlation can exist between:

a) cost element inputs if these inputs are in fact a function of each other
b) cost elements if these elements share one or more common input variables. With this variable's uncertainty modeled only once, these elements will be inadvertently correlated in the model
c) two or more cost elements if one element is related to other elements (for instance through a factor relationship).

> **RES Recommendation:** if the relationship between uncertain elements in the Base Estimate is known, then capturing that in the functional relationships within the risk model should be attempted. For instance, if the cost of design is known to be a function of the direct construction cost, then this relationship should be explicitly implemented in the FPRA model rather than allowing the elements to behave independently in the model. This simplifies what-if analysis and improves the chances of the simulation behaving properly.

If there are no known functional relationships to employ, every simulation tool will allow correlation to be applied. Applied correlation is when the risk analyst specifies a correlation between two or more uncertainty distributions. It is also possible to apply additional correlations across functionally correlated items. Applied correlation does not replace functional correlations. The net effect in the simulation is the combination of the applied and functional correlation, and it is not a simple sum. It is necessary to measure correlation in the simulation result before and after applied correlation to determine the applied correlation impact. Most simulation models contain a mix of both functional and applied correlation. Functional correlation is a result of model functional relationships, while applied correlation is specified by the risk analyst.

There are two main ways to define and model the required Functional Correlation/s within the cost risk model:

1 By using links and formulas between variables to model functional correlation – this is probably the easiest and most effective way to reflect a direct relationship between variables
2 By grouping the smaller elements together and assessing their risk together. This is useful when there are many smaller variables that are similar in nature but are difficult to relate directly to each other.

12.7.2 Applied Correlation (Explicit)

Applied correlations are those specified by the user and implemented within a model. Before specifying any additional correlations among the WBS elements, RES recommends that the user measure the correlations already present in the cost risk model. Correlations (or dependencies) between the uncertainties of estimates for the WBS elements are determined by the structure of the project. These correlations should not be estimated by the cost-vs-cost correlations in the historical database from which the CERs are derived. In other words, strong correlations between cost elements in a database should not be mistaken for evidence that residuals or percentage errors of the CERs derived from the same database are correlated.

A correlation matrix is an efficient way to define key correlations amongst a group of uncertainty distributions built into the FPRA model. The diagonal of the correlation matrix should be populated with '1's to define the correlation between each distribution in the group and itself. Only half the matrix need be modeled, as the other half (on the other side of the diagonal) is a mirror image. An example of correlation matrix presented in Table 19.

	A	B	X	Y
A	1			
B	0.5	1		
X	0.3	0.5	1	
Y	0.8	0.3	0.8	1

Table 19: An example of a correlation matrix for 4 variables

In developing the correlation matrix, there are several key items that should be considered:

a) Correlation Coefficients
   - correlation coefficients range in value between -1 and +1
   - a value of 0 indicates there is no correlation between the two variables – this is called 'independence
   - a value of +1 is a perfect positive correlation between the two variables – when the value sampled for one variable input is 'high, the value sampled for the second variable will also be high
   - a value of -1 is a complete inverse correlation between the two variables – when the value sampled for one input is high, the value sampled for the second will be 'low'. This is called 'perfect correlation'

- coefficient values between -1 and +1 are known as ‘partial correlation’. For example, a coefficient of +0.5 specifies that when the value sampled for one input is high, the value sampled for the second value will tend to, but not always, be high. A 0.5 correlation can also be read as 50%. In other words, the second variable will be high in only 50% of iterations

b) Consistent Matrix: correlations between multiple variables should be consistent. For example, if X:Y and Y:Z are highly correlated in a positive direction, then assigning a strong negative to X:Z would cause an inconsistency in the FPRA model

c) Inconsistent Matrix: most current risk modelling software, e.g. Lumivero @RISK, detects and highlights a correlation matrix that is inconsistent enough to prevent the simulation from running. The software will then offer the option to adjust correlations enough to allow the simulation to proceed

d) Empty Cells: be aware that different software treats empty cells within the correlation matrix differently, e.g. Lumivero @Risk requires all cells to be populated

e) Note that correlation is a measure of the linear relationship between random variables. It does not prove a cause-and-effect relationship

f) Often the correlation coefficients will be calculated from actual historical data on which the risk analyst is basing the distribution functions in the cost risk model. In this case, data needs to be collected on correlated items and used to compute the correlation coefficient.

In the absence of objective data, risk analysts are encouraged to make subjective correlation assessment and matrix following the process below:

1. Apply functional correlations within the risk model whenever possible. Most Base Estimates contain many cost elements that are functionally related through linear and non-linear methods. This often causes uncertainty distributions to be multiplied, divided or exponentiated
2. Measure the correlation present in the model due to functional correlations and identify those elements with a low level of correlations, e.g. less than or equal to 0.3
3. Determine if specific elements that are currently uncorrelated should move together, that is, be correlated either negatively or positively
4. Assign additional correlation using a correlation value between -1 and +1 at an appropriate level of the Cost Breakdown Structure or WBS. Table 20 provides guidance on default correlation values
5. Measure and review the correlations again to ensure elements are properly correlated.

Level of Correlation	Positive	Negative
Full	1.0	-1.0
Strong	0.8	-0.8
Medium	0.5	-0.5
Weak	0.3	-0.3
Nil	0.0	0.0

Table 20: RES recommended correlation factors in the absence of objective data

RES Recommendation: several references suggest a default correlation of 0.25 to 0.3 when there is no other information available. However, others provide evidence that 0.45 or 0.63 may be more appropriate. As a compromise between all the published recommendations, RES recommends 0.3 as the default correlation value – and discourages perfect correlation of +/-1.0.

12.8 Probability

Probability is the relative frequency of an outcome of a repeatable, observable experiment. Probability is measured on a scale between 0 and 1. Probability is assigned to each outcome of an experiment based on its relative frequency – where 1 represents always and 0 represents never.

Probability Distribution

A probability distribution is a mathematical formula that describes how the relative frequency of occurrence is assigned to the real numbers in the range of a random variable. The distribution may be described by either a density function p(x) or a cumulative probability function F(x). These functions are two different representations of the same data. In Figure 40, the dark, curved line represents the statistical distribution underlying the sample data shown in the table at the left. This type of curve is also called a Probability Density Function (PDF).

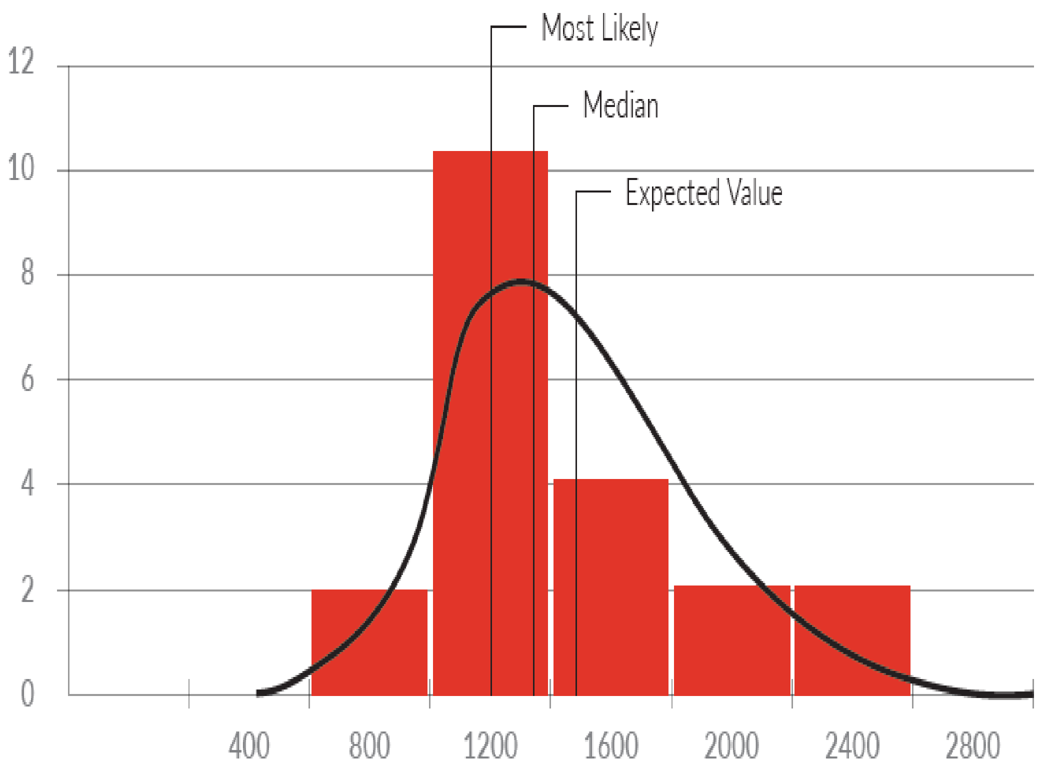


Figure 40: Distribution example

Probability Density Function (PDF)

A continuous PDF is the ‘smoothed out’ version of a histogram. The area under any PDF is equal to 1. A PDF identifies the probabilities associated with specific values or intervals of values of the random variable (see Probability Distribution). If there is a finite probability associated with a specific value x, then the PDF will have a ‘spike’ at that value of x.

Cumulative Distribution Function (CDF)

The CDF is a mathematical curve that for any given possible value of an item, identifies the probability that the actual value will be less than or equal to the given value. When shown graphically, the CDF is an S-shaped curve. The term S-curve is used synonymously with CDF. The value of a cumulative distribution function is bound between 0 and 1, with 0.5 indicating the median of the population (see Figure 41).

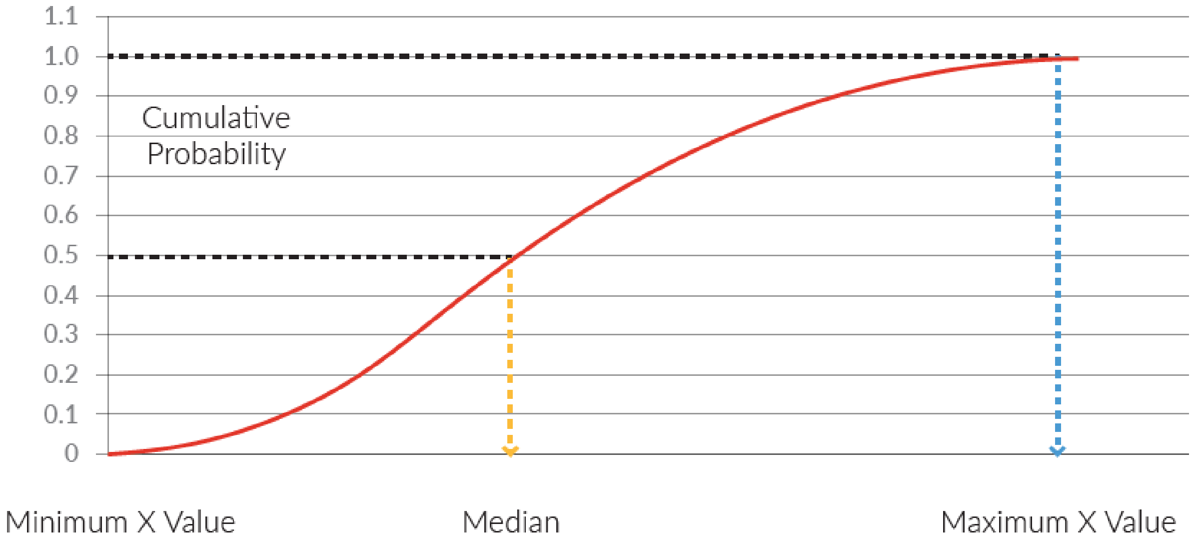


Figure 41: Cumulative Probability Distribution (CPD)

Probability and FPRA

FPRA differentiates two probabilities when assessing and setting the assumptions within the model:

1. Probability of risk occurrence
2. Probability of a range of consequences due to risk occurrence

While many risk analysts insist on aligning the qualitative risk assessment and probabilities within the risk matrix with the probability assumptions within the Quantitative Cost Risk Analysis. The example below represents this approach:

a) Risk: fire may happen at site during construction
b) Probability of occurrence based on risk matrix: likely or 50%
c) Range of consequences: $1m (Best Case), $3m (Most Likely) and $6m (Worst Case).

RES Recommendation: While this approach may be reasonable for low risk and less complex projects, it may not appropriately address the likelihood of possible consequences. From a FPRA perspective, RES recommends that the probabilities in the model should be also aligned with the likelihood of consequence as well as the likelihood of risk occurrence.

All the percentages and impacts above should be modelled within the FPRA risk model. In other words, both the likelihood of risk occurrence and probability of consequences are important to ensure that an accurate and reasonable contingency allowance is calculated.

Another issue is how to maintain consistency in probability and consequence assumptions between a qualitative risk assessment (risk matrix) and FPRA. In practice, this Guideline highlights that qualitative risk assessment using a risk matrix should only be used as a starting point to select the key risk items that need further assessment –including quantitative analysis. There are many references highlighting the issues associated with the sole use of a risk matrix and its assumptions (probabilities and range of consequences) to drive Quantitative Cost Risk Analysis. RES does not recommend this course of action.

RES Example: Modelling schedule risk is a good example. Assuming that we have the Base Schedule, right and representing the most likely circumstances, the probability that the schedule will be delayed is 100%. To assess the best-case scenario, we are 90% sure that we will finish the project within a one-month delay. With 50% probability, we will finish the project within a two-month delay – but there is only a 10% probability that we will need more than five months' delay. This is summarised below:

- Risk: schedule delay compared to the Base Schedule – likelihood of 100%
- Best Case: 90% sure the delay will be less than one month
- Most Likely: 50% sure the delay will be less than two months
- Worst Case: 10% chance that we will need more than five months' delay.

RES Tips & Tricks: in the absence of an internal probability table for FPRA purposes, RES recommends the table below. To minimise optimism bias, RES recommends the project team uses the "Qualitative Descriptive" column during risk workshops and the "Probability Ranges" column for risk quantification and modelling purposes.

Qualitative Descriptive	Probability of Occurrence	Probability Ranges
Almost Certain	The event is almost certain to occur within the planning period	90% < P(x)
Likely	The event is likely to occur within the planning period.	70% < P(x) < 90%
Possible	The event may occur within the planning period.	40% < P(x) < 70%
Unlikely	The event is not likely to occur in the planning period.	10% < P(x) < 40%
Rare	The event will only occur in exceptional circumstances.	P(x) < 10%

12.9 Statistical Measures

Expected Value, Average or Mean

The expected value is the arithmetic average or mean of the distribution of possible values for a variable. For a given set of n values (y1, y2, …, yn), the mean (y) is defined to be the arithmetic average of these n values. In mathematical notations, it is given by the equation:

$$\bar{y} = \frac{\sum_i y_i}{n}$$

RES Tips & Tricks: Expected values have an important mathematical property: the sum of the expected values of a set of variables is equal to the expected value of the sum of the set of variables. In other words, when summing the expected values of a number of WBS items, the result will be the expected value of the sum of the WBS items. This is not true for percentiles or most likely values.

Median

The median is the point in a distribution where half the observed values will be lower, and half will be higher (the 50th percentile). In other words, this is the point where the actual cost is just as likely to be higher as it is to be lower. For a finite number of observations – if the sample size is odd – the median is the middle value. If the sample size is even, the median is the average of the middle two values. The sum of the medians of several WBS items is not equal to the median of the sum of the values, except in the unusual cases in which the distributions of all the WBS items are symmetrical.

Most Likely Value (Mode)

The mode is the most probable single value for a variable (the peak of the distribution). The output of the primary estimating methodology (i.e. the point estimate) for a WBS item is typically interpreted as the most likely value. The sum of the most likely values of several WBS items is not equal to the most likely value of the sum of the values, except in the unusual case in which the distributions of all the WBS items are symmetric.

Skewness

A distribution is skewed if one of its two tails is longer than the other. For example, if there is a long tail to the right of the distribution, then it is positively skewed (or skewed right). This means that the distribution has a long tail in the positive direction. Similarly, if there is a long tail to the left, then the distribution is negatively skewed (or skewed left). If the distribution is symmetrical, then the distribution has no skew. For example, the normal distribution has a skewness value of zero as it is a symmetric distribution.

Variance

To calculate the variance, first calculate the arithmetic mean and then for each data point, then find the difference between the point and the mean. Next, square all these differences and sum them. Divide this sum by the number of items in the data set (if the data is from a sample, the sum is divided by the number of items minus one). The variance is a measure of the average squared distance of each value from the mean, but it is not expressed in the units of measure of the mean or the original data. The measure of variance is greatly affected by extreme values.

Standard Deviation (SD)

The standard deviation is one of the most widely used statistics for measuring the spread, or dispersion, of values in a population of data. For a given set of n values (y1, y2, ..., yn), the standard deviation (Stdev or S) is defined by the equation:

$$S = \begin{cases} \sqrt{\dfrac{\sum_{i=1}^{n}(y_i - \bar{y})^2}{n-1}} & \text{if data is from a sample} \quad - \text{Std. Dev. (Sample)} \\ \sqrt{\dfrac{\sum_{i=1}^{n}(y_i - \bar{y})^2}{n}} & \text{if data is from a population} \quad - \text{RMS (Population)} \end{cases}$$

Coefficient of Variation

The coefficient of variation (CV) of a distribution is defined as the ratio of the standard deviation to its mean (i.e., SD/Mean). It is a relative measure of dispersion because it expresses the standard deviation as a percentage of the mean. CV is fast becoming one of the more recognised metrics to characterise the spread in a CDF (S-Curve).

12.10 Distributions and Ranges

There are two different types of distributions that may be applied to each input: continuous and discrete distributions. Common continuous distributions include Triangular, PERT, and Uniform distributions, as illustrated in Table 21 and Figures 43 and 44. The choice of a particular distribution depends on the nature of the risk being considered and any supporting data available. For specific risk modelling scenarios (e.g., predicting rainfall) where statistical data is available, other empirically fitted distributions should be considered if appropriate.

Continuous Distributions:

These include the Triangular, PERT, and Uniform distributions. They are used when the potential outcomes can take any value within a specified range.

Discrete Distributions:

These are used when the potential outcomes are limited to specific, distinct values.

The decision to use a particular distribution should be based on the nature of the risk and the available data. For instance, empirical fit distributions might be more suitable for specific risk modelling scenarios with ample statistical data.

Recommendations by RES

RES generally recommends using an alternative form of distribution (e.g., AltPert distribution rather than PERT distribution) whenever possible, especially for modelling inherent risks and estimate ranges. The rationale is that the assessment of minimum and maximum outcomes is usually approximated based on the participants' experience and is unlikely to consider the absolute worst or best-case scenarios thoroughly.

By adopting the Alt configurations of these distributions, the model can more accurately represent the potential variability and uncertainty, resulting in more realistic risk assessments.

RES Tips & Tricks: It is worthwhile suggesting that practitioners at a workshop should not attempt to estimate the Most Likely value of an event risk prior to other values. Everyone will have a different image of the consequences. It is best for the workshop to come to grips with the maximum possible cost, then consider the smallest possible costs.

Distribution	Application	# of Parameters	Parameters
Lognormal	Not enough info available	2	Median, High
Triangular	SME, labour productivity rate, quantum	3	Low, Mode, High
BetaPert	Similar to Triangular with more weighting to mode	3	Low, Mode, High
Beta	Similar to Triangular, but min/max boundaries known better than mode	4	Min, Low, High, Max
Normal	Equal likelihood for Low and High	2	Mean/Median/Mode and High
Uniform	Equal likelihood over uncertainty range	2	Low, High

Table 21: Recommended uncertainty distributions

RES Recommendation: in the absence of better information, RES recommends the Lognormal distribution shape. When the distribution is known to be left-skewed, RES recommends BetaPert.

Some agencies include failure analysis mathematics in their operations and support cost models to estimate the number of spares and/or maintenance actions. A few of these distributions are introduced here. Distributions include:

a) Poisson distribution: which can be used to define the number of failures in a specified time when the average number of failures is small. It is also a useful distribution to estimate testing, inventory levels, and computing reliability. The Poisson distribution is a discrete distribution that requires only a single parameter – the mean – to define the distribution. A common use of the Poisson distribution is to simulate the number of failures per year using the inverse of the mean time between failures as the parameter
b) Exponential distribution: which is a continuous distribution that can be used to estimate the time between failures. The parameter in this case is the mean time between failures
c) Weibull distribution: which is a continuous distribution often used to estimate time between failures. A common approach is to assume a high failure rate at the beginning of the lifecycle due to manufacturing errors (infant mortality), reducing to a constant (the design failure rate), and then increasing at the end of life (wear out). Infant mortality and wear out phases are often modelled with the Weibull distribution.

Figure 42, sourced from the US Air Force Cost Risk and Uncertainty Analysis Metrics Manual (CRUAMM), illustrates the frequency of each distribution found across 1,400 fits of various cost data and other factors.

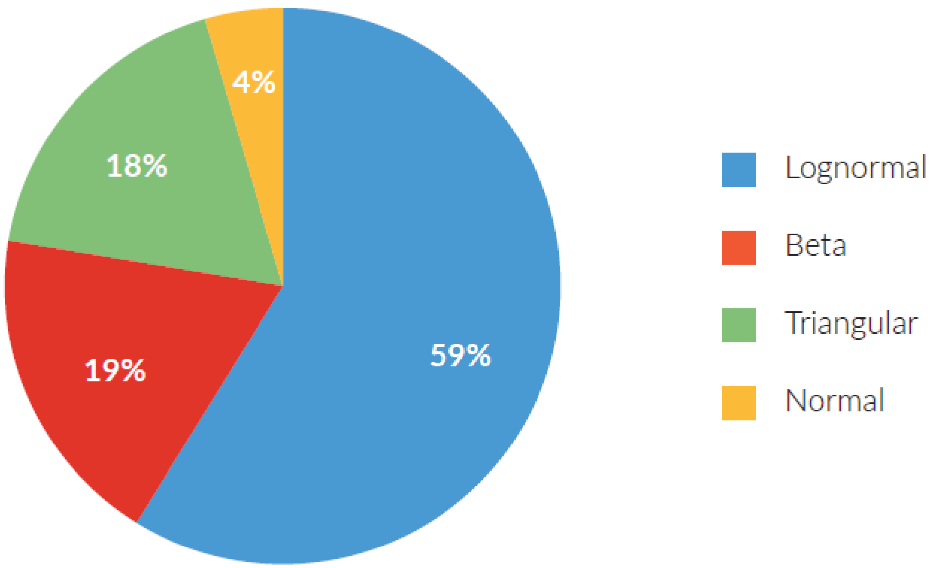


Figure 42: Relative frequencies of distribution shapes (US Air Force CRUAMM)

Some examples of common continuous distributions are represented in Figure 43.

Figure 43: Common continuous distributions (Lumivero @Risk)

The most commonly used discrete distribution is the binomial distribution – which returns either a single value or zero, depending on a percentage input to the formula. This can be used to model the likelihood of a contingent risk occurring. Some examples of discrete distributions are represented in Figure 44.

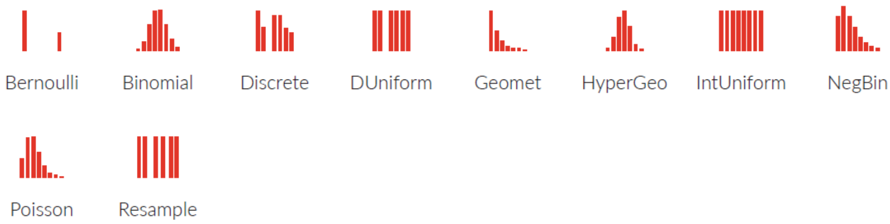


Figure 44: Common discrete distributions (Lumivero @Risk)

12.11 Truncated Distributions

In cost risk modelling, it is not unusual to obtain objective or subjective bounds that cause the distribution shape to get into the negative region (i.e. below zero) despite never observing a value in that region. In the circumstances that the distribution will result in having non-logical outputs, the risk analyst may choose to force a lower bound when performing the distribution fit for modelling.

Alternatively, an unconstrained fit that stretches into the negative region can be truncated when used in the simulation tool. All risk analysis tools provide the ability to truncate distributions at either a low point, high point or both. Establishing the lower limit of the distribution to be zero will avoid irrational situations of negative values in cost or schedule.

There are two significant impacts to be considered when truncating at low point, e.g. zero:

a) First, the distribution variance will be reduced
b) Second, the mean will shift to the right, i.e. higher value.

Care should be taken to determine the impact of these settings and if it is acceptable and make sense. However, in situations when negative tails would represent irrational results, the risk analyst is encouraged to either truncate or select another distribution, e.g. lognormal, that does not require truncation to simplify the explanation of the risk model. Alternatively, another solution is to not use these Alt forms of distributions for risks and use SMEs or historical data to determine what the minimum value should be.

12.12 Number of Inputs: Ranges and Distributions

The FPRA approach uses two different numbers of inputs for setting cost ranges and simulation modelling:

a) number of cost ranges: to ensure uncertainties are identified and accurately quantified, the ranges on cost items should be quantified and assessed at the lowest level of first principles estimate, e.g. against quantum, productivity rates, or equipment
b) number of distributions: the information from previous cost ranges should then be aggregated to a higher level of the WBS. The distribution will be then applied against those items.

The rule of thumb when preparing a FPRA risk model is that the number of simulation inputs should be reasonably limited, and commensurate with the level of detail applied in the Base Estimate. In other words: the level at which inherent risks can be reasonably quantified and also well understood in terms of possible correlations. The model can have as many variables and inputs as needed so long as the way they interact is well understood and any correlations that exist are included within the model.

This *Contingency Guideline* recommends the assessment of uncertainties and ranges (for productivity rates and quantities) at the lowest level of estimate based on a first principles estimate. The overall impact of these ranges should then be aggregated to a higher level of the project WBS (e.g. WBS Level 4) before appropriate distributions and correlations are introduced, and a Monte Carlo modelling simulation is undertaken.
Figure 45 (below) illustrates the process.

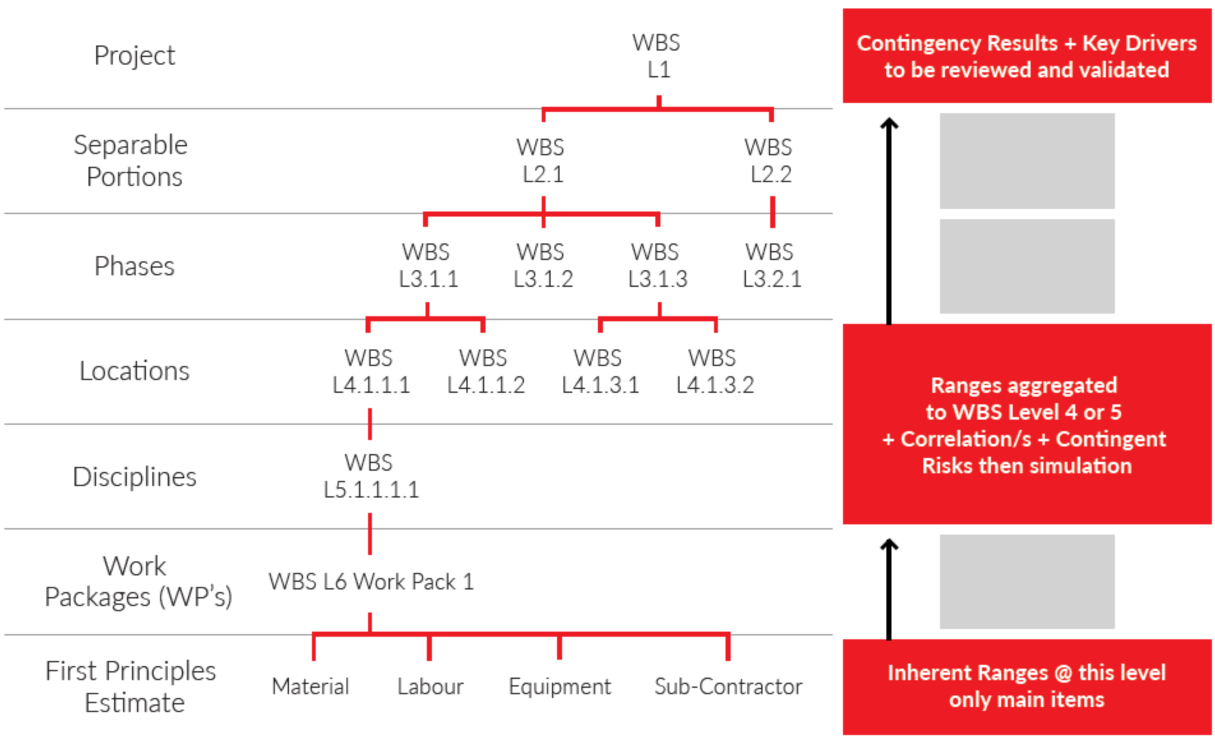


Figure 45: Brief illustration of FPRA flow of information

12.13 Sunk Costs

Sunk costs are the costs that have been incurred and cannot be recovered. For many acquisition decisions, funds that have been allocated and obligated in prior years are often deemed sunk though they have not been totally expended.

Sunk costs are often part of a lifecycle cost model because current and prior years are part of a project's total cost. Prior years' costs (and often current year's costs) should not have uncertainty distributions associated with them. In any event, it is essential to report both sunk and remaining Cost to Complete (CTC) when reporting cost to facilitate comparisons to project Cost at Completion (CAC) and previous estimates.

When sunk costs are in play, cost risk modelling can be complicated. There are many ways to approach the modelling task. The uncertainty about the initial estimate is generally based on an analysis of the Base Estimate resulting in Total Outturn Cost (TOC), not on costs-to-go from some point in the project. Subtracting the sunk costs from the total cost estimate to arrive at CTC may make sense. But defining how much of the uncertainty remains in the CTC portion is more difficult to assess.

This *Contingency Guideline* recommends the process below when addressing sunk costs assigned to a specific element in the risk and uncertainty model:

a) Every effort should be made to estimate the CTC based upon the best assessment of performance so far and current and most likely circumstances ahead:
   - noting that the CTC should be the Base Estimate of remaining work at the time of assessment. Other methods of forecasting (e.g. trend analysis) may be also used to ensure CTC is representing the most likely circumstances similar to the Base Estimate at the beginning of the work
   - noting that the total point estimate changes (sunk plus cost-to-go) may not equal the original total point estimate cost. This should not discourage risk analysts from using this approach.
b) Divide the original uncertainty parameters by the point estimate cost to convert parameters to a percentage of the original total point estimate
c) For cost items or activities with objective uncertainty:
   - use the results from the previous step to calculate the uncertainty parameters for the uncertainty on the CTC. Use a distribution of the same shape, but scaled to the CTC
d) For cost items or activities with subjective uncertainty:
   - consult with SMEs to assess uncertainty parameters
   - compare these ranges with the results from the previous step
   - select the most reasonable uncertainty parameters – RES recommends using conservative ranges.
e) If possible, obtain evidence to determine if the sunk costs are consistent with progress to date. Ideally, this assessment should be data-driven – for instance through analysis of earned value data. If the evidence is convincing, consider multiplying the scaled uncertainty by a positive or negative adjustment factor
f) Review the latest updated risk register and determine if any contingent risks associated with the element have been retired or changed – or whether they need to be included in the assessment of the CTC risk model
g) Complete the risk model with other key elements, e.g. correlations
h) Run the risk model
i) Review the results, revise the model (if required), and then finalise.

12.14 Simulation

Before finalising the risk model for simulation, there are other influences on simulation results that need to be reviewed and addressed properly.

12.14.1 Random Seed and Number Generator

The random seed is a number that sets the selection of numbers from a random number generator. Given the same seed, a random number generator will generate the same series of random numbers each time a simulation is run. For example, Lumivero @RISK software – by default – picks a different random seed each time the simulation runs.

To avoid this, an initial random seed may be set by the user. However, if the location of various assumptions is changed on the worksheet, answers will still vary. Additionally, if other workbooks are open that contain separate risk models, this can influence the random seed assignments. Changing the random seed (either manually or by allowing the tool to do so) will cause the percentile results to vary on the order of 0.5%.

Furthermore, it is not possible to get precise matches across tools since each uses a different random number generator and different methods for assigning random seeds.

RES Recommendation: where possible, let the simulation software select a random seed initially and then fix this seed in the FPRA model. It is important to document the random seed selected and if choices are available, the random number generator selected. To promote consistency, RES recommends organisations define a set random seed and random number generator.

12.14.2 Sampling Method

Some tools allow the user to choose either Monte Carlo or Latin Hypercube sampling. Latin Hypercube draws random numbers more evenly and it will generally require fewer trials to obtain the same level of accuracy. RES recommends that the number of partitions equals the number of trials when using Latin Hypercube sampling. Doing so helps to ensure that the entire distribution is sampled with fewer trials.

RES Tips & Tricks: Lumivero @RISK and ACE do not have a user setting for the number of partitions; both fix the number of partitions to the number of trials.

12.14.3 Number of Iterations

The number of iterations required to achieve reasonable accuracy is a function of many factors including:

a) the complexity of functional relationships
b) the number of distributions being defined in the model
c) the degree of uncertainty applied
d) the number of defined functional and applied correlations.

Several references suggest that 10,000 iterations are sufficient for most cost risk models and this number is a common practice in the cost and risk communities. However, most simulation tools have a feature to stop the simulation when selected convergence criteria are met. For instance, both Crystal Ball and @RISK will test the mean, standard deviation or a selected percentile to determine when the statistic is estimated to be within a user defined percentage of its actual value for a specified probability level.

Risk modelling software like Crystal Ball and Lumivero @RISK provide a feature to run the simulation until predefined criteria are met on one or more of the model forecasts. The concept is to have the tool measure the chosen statistics and stop the simulation when the difference is less than a specified interval at a defined confidence level.

RES Recommendation: RES recommends that the 10,000 iterations be considered. While there is no reference for defining standard deviation convergence, 1.5% seems like a reasonable target as it generally takes at least a 1.5% change in standard deviation to impact percentile results by 0.5%.

RES Example: the criteria recommended by an organisation was: 95% confidence that the mean, standard deviation and 90 percentiles are stable within 3% of their value. If this type of feature is to be used, this Guideline recommends that organisations should specify the required settings for their risk modeling across the enterprise.

RES Tips & Tricks: simulation settings such as sampling type (Monte Carlo vs. Latin Hypercube), random seed, correlation on/off and similar settings will have an impact on the simulation results. These and similar settings may not be saved with the model file. Organisations are encouraged to publish recommended settings for each tool that is used. Perform a convergence analysis to verify the number of iterations required to develop a stable result.

12.15 Escalation

An escalation allowance is essential for providing adequate capital funding to compensate for likely cost increases, mainly within the construction sector, during the project's life span. The estimate of escalation is typically determined by applying an assumed rate of escalation for each financial year from the estimate's base date through to practical completion. However, it is crucial to recognise that overall escalation—expressed as a percentage of the base estimate plus contingency—is a function of the specific cost profile of the project and the yearly escalation rate.

The escalation is based on the project's cash flow estimates for both P50 (most likely) and P90 (conservative) scenarios. Industry best practices dictate that escalation is calculated on cash flow by financial year, using forecast annual percentage increases that are compounded year-on-year. If a project includes a contingency based on risk, and those risks have associated costs, the same base-year dollars are typically used, and the performance periods for these risks often correlate with project components. Consequently, escalation may also apply to contingency.

However, if:

- Contingency cannot be easily broken down by Work Breakdown Structure (WBS) elements or cost elements
- The contingency cannot be associated with a specific time period

Then it may not be appropriate to apply escalation to the contingency. The accuracy of an escalation forecast can also be a significant risk, with the associated cost impacts included as part of the contingency.

Components of the Base Estimate

The Base Estimate includes the sum of construction costs and principal's costs but excludes contingency and escalation. Escalation represents the anticipated increase in project costs over time due to factors like inflation and market conditions. Most major projects require three to six years to complete, making escalation a crucial factor in planning, as the value of money changes over time, which can result in an underestimated project cost if not accounted for.

Requirement for Out-Turn Dollars

Most organisations require estimates to be expressed in out-turn dollars, based on the project's development and delivery schedule. While determining escalation is not within the scope of this *Contingency Guideline*, the relationship between contingency and escalation is vital.

Assumptions and Future Price Changes

When developing a project budget, estimators must make assumptions about future prices of goods and services, which fluctuate due to inflation, market conditions, demand cycles, and legislative impacts. These future price changes must be applied to the project's cash flow. Escalation is particularly sensitive to market conditions, systemic changes, and supply and demand dynamics for specific project inputs. Key historical indices or cost movement measures, available in industry publications and produced by the Australian Bureau of Statistics, provide data for future rate estimations.

Use of Historical Data

These indices are derived from observed historical data for various project components such as concrete, cement, sand, petroleum and coal products, and steel. Estimators must exercise judgement to determine appropriate escalation factors for specific components and overall project escalation. In volatile conditions, escalation should be prominently factored into the project budget presentation so that management fully understands the underlying assumptions.

Impact of Project Progression

As the project advances, the cash flow will affect the cost base, and teams must consider the impact of lead times, as escalation compounds each year. This consideration is particularly crucial for major infrastructure projects in their early development stages (e.g., preliminary and final business cases) for government and owners' budgeting purposes.

By thoroughly addressing these factors, the project can achieve a more realistic and robust budget, better preparing stakeholders for future financial requirements and risks.

While the subject of escalation determination is not part of this *Contingency Guideline*, the example below is provided for some clarity regarding the relations between the contingency and escalation allowances.

RES Example: there are different approaches to address determination and management of escalation allowance. RES recommends the practical approach below to address determination, allocation and control of escalation (this depends on factors including: the project specific requirements; project risk exposure to commodity price changes; and stage of the project (i.e. development or delivery):

Determination:

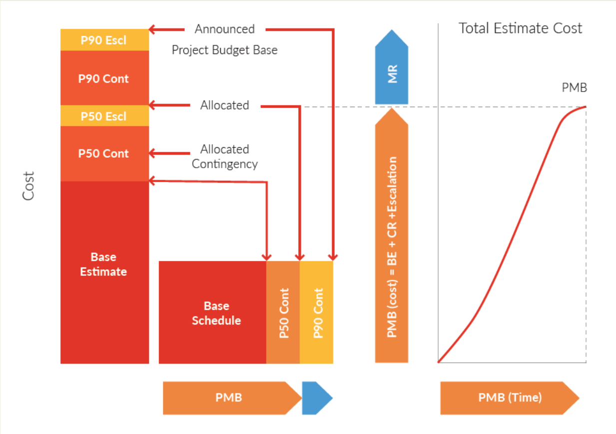
a) for small projects: the most likely escalation rates can be used reasonably

b) for major projects at the preliminary business case: most reasonable escalation rates can be used to produce the P50 escalation, and the pessimistic escalation rates as well as a full probabilistic escalation method can be used. For further details please refer to AACEi's RP 58R-10 "Escalation Estimating Principles and Methods Using Indices" and RP 68R-11 "Escalation Estimating Using Indices and Monte Carlo Simulation".

Allocation:

a) for small projects: escalation and contingency allowances can be added together to create the overall project contingency. This allowance can be split in two buckets (e.g. 60% and 40%) The first bucket should be added to the Base Estimate to generate the PMB for progress measurement and reporting. The second bucket should be kept and controlled outside the PMB.

b) for major projects:
    - Depending on the delegation of authority and access to project funding, appropriate allowances (e.g. P50 escalation and P50 contingency) should be added to the Base Estimate, then cash flowed against the P50 Schedule to generate PMB. Project progress will be then measured and reported against this PMB
    - This has been shown in the diagram below.



Controls:

a) for small projects: the second bucket (as explained above) will be kept and controlled outside PMB.

b) for major projects: after establishing the PMB, both P50 Escalation and P50 Contingency allowances will be taken out and will be controlled by using two distinct buckets. The remaining P90 Escalation and P90 Contingency will be managed as a MR by higher levels of delegation.

12.16 Exclusions

Attempting to account for all possible outcomes in a project is likely to be futile, as a risk model is inherently limited in its ability to predict every extreme event. Instead, the assessment should focus on quantifying the necessary contingency to achieve the project's objectives in most scenarios, rather than trying to provide contingency for every possible eventuality. Consequently, it may be appropriate to exclude certain risks from the probabilistic model. Examples of such exclusions include:

- **Additional Scope**: Changes that would alter the nature and objectives of the project.
- **Acts of God**: Unpredictable natural events such as earthquakes or floods.
- **Project Funding Delays**: Interruptions in the funding schedule that are beyond the project's control.
- **Changes to Delivery Strategy**: Modifications to the delivery approach that are significant enough to affect project outcomes.

By focusing on the most relevant and probable risks, the risk model can be more effective in providing a realistic contingency plan, thereby enhancing the project's likelihood of success.

12.17 Other specific areas of concern

There are several other items that need to be assessed separately and in detail, then included within the FPRA risk model if required. These may include (but are not limited to):

a) risks related to property acquisitions
b) risk of foreign exchange variations
c) risks of financing costs and interest rate variations
d) organisational risks.

12.18 FPRA Report

The key elements of the FPRA report are:

a) key assumptions, model parameters and settings
b) exclusions
c) high consequence, very low likelihood risks – noting that in most projects, if these cannot be mitigated by insurance, should be clearly documented and presented to the Client as risks which have not been modelled, but which the Client must consider separately, not by setting money aside, but by deciding whether to take on the commercial risk
d) the process undertaken and workshops and review meetings held
e) probabilistic S-curve (e.g. P10, P50, and P90)
f) tornado graph (sensitivity analysis on both schedule and cost)
g) overall contingency and its allocation across work packages
h) supporting evidence – including risk model inputs and outputs, data sheets, correlations and interface matrix (if applicable), details of workshops and meetings held and attendees.

The final FPRA report should also present the overall contingency distribution (for both P50 and P90) between contract package breakdown (based on the delivery strategy) and interface risks between packages.

The required tasks for undertaking a QCRA process should be discussed, agreed and included within the master development program. The program should include timing and responsibilities as well as inputs and outputs of the process. Key activities should include:

a) timing of key inputs (e.g. base estimate, base schedule, workshops)
b) cost risk modelling process and validation and sanity checks for iterative inputs
c) schedule risk modelling process and validation and sanity checks for iterative inputs
d) interface risk assessment between work packages (contract packages)
e) reviews (internal and external)
f) reports.

12.18.1 Output review and validation

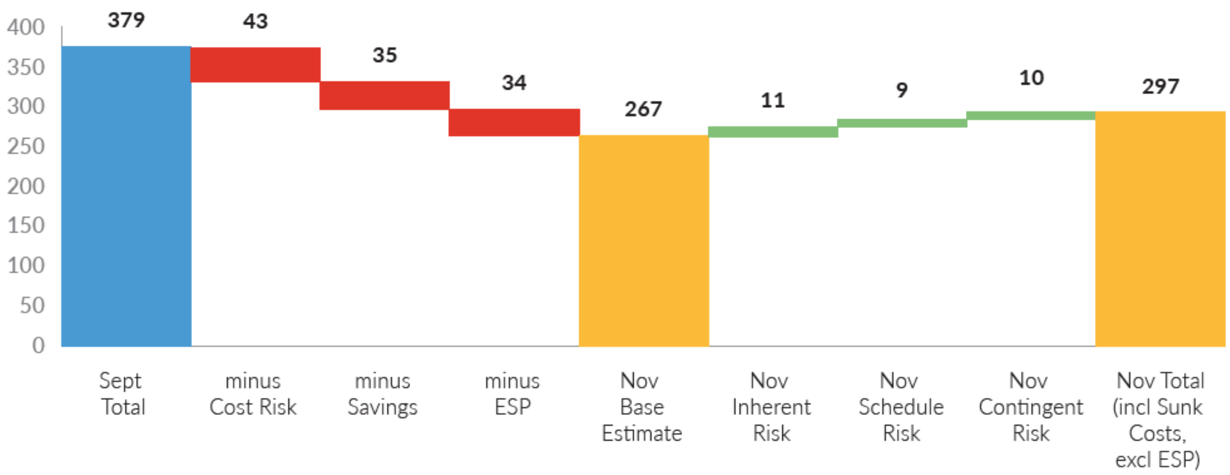
Key outputs and their interpretations should be validated through the iterative nature of the QCRA process (as explained in the section above), so assumptions and inputs can be reviewed and revised if required.

Following the final iteration of the probabilistic model and subject to the review and acceptance of key stakeholders, a report should be prepared to document the probabilistic assessment undertaken. The key probabilistic assessment outputs and their interpretations are:

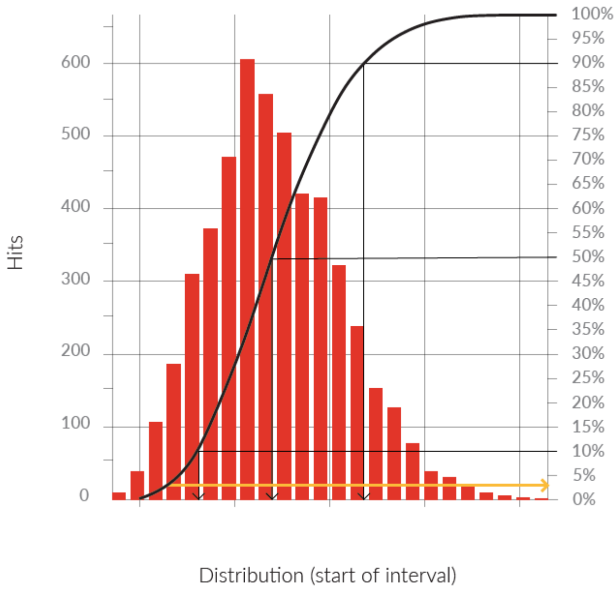
a) probabilistic S-curves
b) tornado graphs.

The most common probabilistic assessment output is a cumulative probability distribution graph (also known as an S-curve) or a histogram. This S-curve presents the final cost against probability of occurrence, while the histogram graphs the final cost against the number of 'hits' returned during the simulation. A very flat S-curve may suggest a project with a lot of risks. Conversely, a project with only a small number of risks has a very steep S-curve. A tornado graph can also be used to report QCRA outputs.

Different reports may be used to communicate the results of FPRA not only for management decision making but also to ensure the information being effectively communicated and understood by the project team. Figure 46 illustrates a few examples of reports.

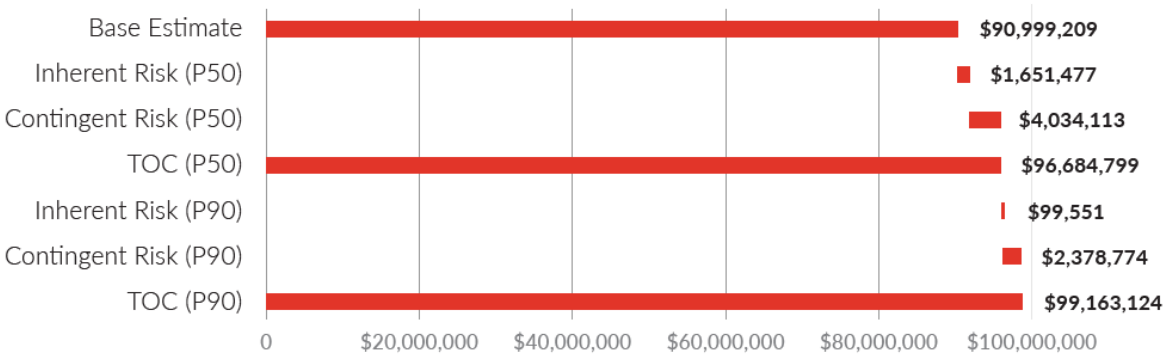


MM.GEN.1090 - Feed On : Finish Date



Schedule Sensitivity Index: Entire Plan - All tasks

Contingency Breakdown



PSC Contingency Summary				
Confidence Level	P_{10}	P_{50}	P_{90}	
Capex Retained Uncertainty	$3,064,438	$3,287,956	$3,492,693	37%
Capex Transferred Uncertainty	$ -	$ -	$ -	0%
Capex Retained Contingent	$1,707,211	$3,406,863	$5,850,736	63%
Capex Transferred Contingent	$ -	$ -	$ -	0%
Total Capex Contingency*	$4,771,649	$6,694,819	$9,343,429	100%
	5%	8%	11%	

*Note all costs are in DD/MM/YY

TOTAL CAPEX			
Base Estimate (Total Capex Excl. Contingency & Escalation) $86,865,335			
	P_{10}	P_{50}	P_{90}
Total Capex Incl. Contingency	$91,636,984	$93,560,154	$96,208,764
Escalation*			
Total Capex Incl. Contingency & Escalation	$91,636,984	$93,560,154	$96,208,764

OUTPUT 3 - PSC State Event

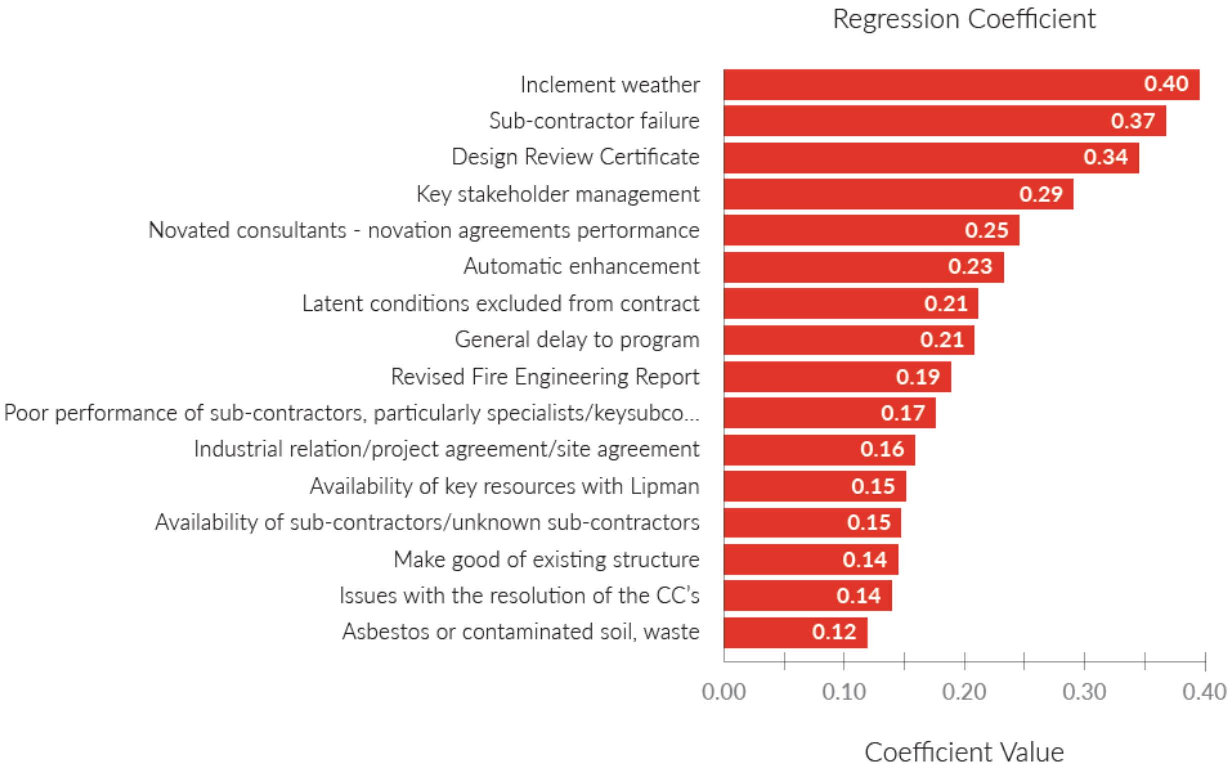


Figure 46: Several different contingency reports of FPRA outcomes

12.19 Updating and documenting FPRA

A FPRA should be performed periodically as both the cost and schedule are updated to reflect actual progress on activity durations, sequences and costs. As the project progresses, risks may retire or change in potential severity and new risks may appear. The length of time between FPRA updates will vary according to project length, complexity, risk, and availability of management resources. This *Contingency Guideline* recommends that FPRA should be undertaken on a quarterly basis as well as at key decision points for major projects.

The FPRA and its updates should be fully documented to include the risk data, sources of risk data, and techniques used to validate the risk data. In addition, the methodologies used to perform the simulation should be detailed – and outputs such as a prioritise risk list; the likelihood of the project completion date; the activities that most often ended up on the critical path; and the derivation of contingency sufficient for risk mitigation should be documented.

RES Recommendation: RES recommends that a regular, no longer than quarterly, FPRA be undertaken for major projects during delivery phase, as well as key decision points during development, i.e. Preliminary and Final Business Case.

As well as providing an effective early warning indicator, as highlighted in Section 2.5.2, another benefit is identifying the confidence level trend as evidence for future claims and disputes.

13. Appendix F – Integrated Quantitative Schedule Cost Risk Analysis (iQSCRA)

13.1 Purpose

In Integrated Quantitative Schedule Cost Risk Analysis (iQSCRA), the risk analysis of the cost estimate is conducted using the cost and resource loaded project CPM schedule, where the project cost estimates (excluding contingency) are assigned to the schedule activities or summary groups. Then, the schedule and its cost expenditure are modelled using the MCS.

Generally, there are 4 approaches to address schedule risks for the purpose of cost contingency determination.

1 undertaking QSRA first, then quantifying the adequate cost impact and then adding this to the result of a separately undertaken QCRA

2 undertaking QSRA first and then including its results into the QCRA model and then simulate using MCS, i.e. two separate models.

3 allocating cost information (including their associated inherent and contingent risks) as the 'expenses' within the QSRA model (which also includes the schedule risks and uncertainties), and then simulate using MCS, i.e. one model

4 loading/assigning time-independent and time-dependent costs and resources to the relevant activities of the schedule within the QSRA model. Then apply the inherent and contingent risks (for both cost and time) creating one model of iQSCRA and then simulate using MCS. In this model of iQSCRA both time and burn rate can be modeled simultaneously and the time uncertainty helps drive the cost uncertainty together

While in good industry practice, all cost risk modelling should consider and quantify schedule risks, for a better grouping of methods of contingency determination, RES defines **option 4** above as the **Integrated Quantitative Schedule Cost Risk Analysis (iQSCRA).**

In the iQSCRA model, time-depending costs (e.g. design costs) will increase if their activities take longer because of risks to the schedule. These include labor resources assigned to the activities, and supporting resources – including the project management team, who continue working until the schedule is complete. The typical process is illustrated in Figure 47.

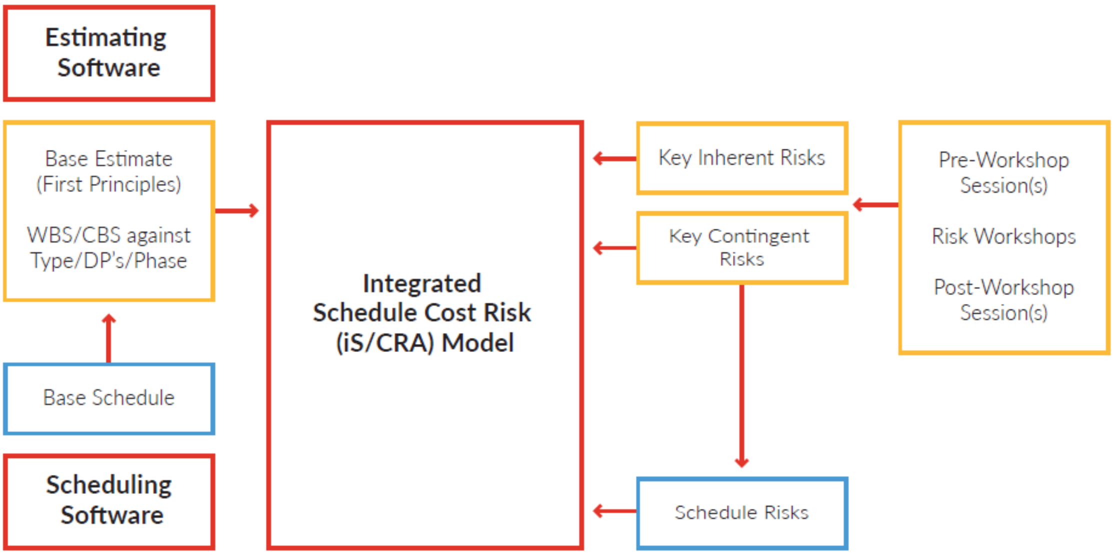


Figure 47: A typical process map for the Integrated Quantitative Schedule Cost Risk Analysis (iQSCRA) model

13.2 Overall process

The key elements of a realistic and reliable iQSCRA in determination of a reasonable schedule and cost contingency for desired confidence level are:

a) schedule health check and rectification
b) Base Estimate
c) risk mapping to Base Schedule
d) cost mapping to Base Schedule
e) correlation and relationships between model inputs
f) building the iQSCRA model
g) integrated analysis
h) output review and validation.

An example is illustrated in Figure 48 which assumes a construction project with weather risk exposure.

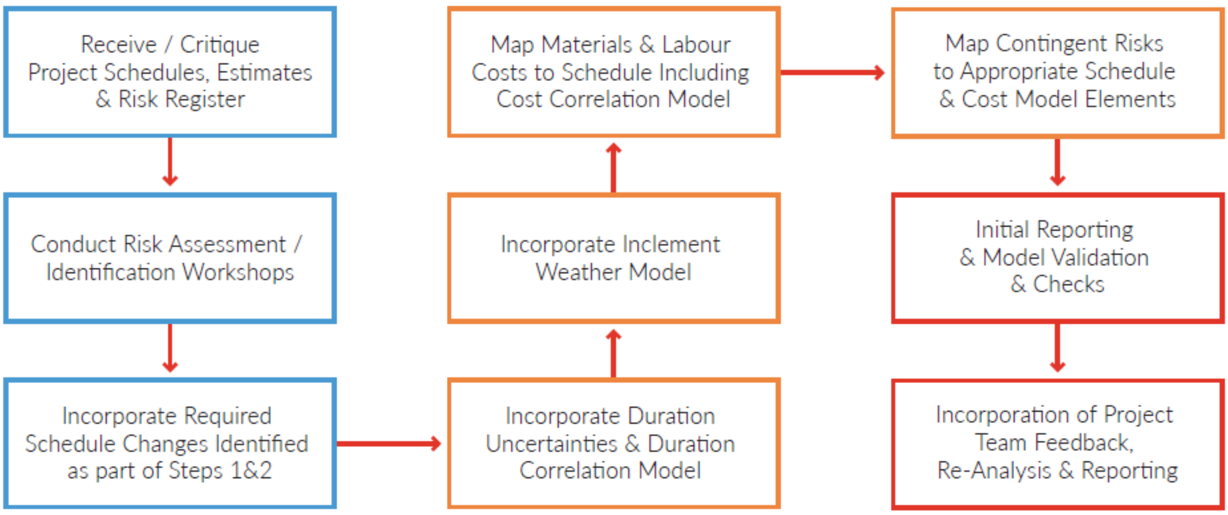


Figure 48: An example of iQSCRA process for a construction project with wet weather risk exposure

The benefits of iQSCRA include:

a) enabling the simultaneous analysis of probabilistic schedule and cost distributions incorporating all known and possible sources of time and cost uncertainty
b) enabling the probabilistic method of the cost consequences of schedule changes based on where and when they occur in each iteration
c) enabling the quantification and ranking of all driving sources of uncertainty.

13.3 Schedule health check and rectification

Refer to Appendix C.

13.4 Base Estimate

Refer to Appendix C.

13.5 Risk mapping to Base Schedule

Refer to Appendix C.

Depending on the capabilities of the software, different approaches may be used for mapping risks into the schedule, including:

a) put ranges against activity durations for representing inherent risks
b) create quantified risk register within the software then mapping the risks to relevant activities
c) create additional activities logically linked within the schedule
d) define risk factors, then mapping them to relevant activities
e) use a combination of risk factors, range of activity durations and contingent risks.

13.6 Cost/Resource loading to Base Schedule

The project estimate can be overlaid on the project schedule in a series of hammock activities (tasks that change in duration according to the durations of the tasks to which they are linked without taking part in critical path calculations).

The line-item costs are a mixture of variable (time dependent) and fixed (time independent) costs, all of which are uncertain at the start of the project. The proportions (or splits) of fixed and variable costs must be accurately known or estimated for each line item. This is necessary so that the summarised variable costs – when spread over the applicable groups of tasks in the schedule – can vary realistically due to duration changes. Variable costs can vary due to task duration changes and due to uncertainty in their rates. For example, labor and equipment hire rates may be uncertain at the start of the project. Costs and/or resources can be loaded into different schedules or levels depending on available data and project specific requirements. These requirements could include:

1. allocating costs and/or resources into activities within the detailed schedule
2. allocating costs and/or resources into hammock/summary activities within the detailed schedule
3. allocating costs and/or resources into a high-level schedule built from the detailed schedule.

13.7 Correlation

Correlation models are developed to ensure that groups of activities and resources that behave in related ways are represented realistically in the iQSCRA model. This extends to risk factors that vary in related ways, such as productivity risk factors for different disciplines. Correlation inputs are essential instructions to the modelling tool to correct the inherent assumption of the complete independence of all inputs, and to enable the model to forecast realistic probabilistic spreads of schedule and cost. A more detailed discussion of correlation is provided in Appendix E.

13.8 Building the iQSCRA Model

The iQSCRA model is built from the following:

a) a carefully reviewed and technically corrected schedule, or a model network constructed for the purposes of the risk analysis
b) an overlaid summarised estimate
c) schedule and cost ranges inputs
d) schedule and cost correlation models
e) mappings of the treated cost and schedule impact risk events and risk factors
f) probabilistic calendars e.g. wet weather (usually derived from historical data) assigned to appropriate tasks where the project involves risk-exposed activities.

13.9 Integrated Analysis

The analysis is usually performed at least twice and sometimes three or more times. The number of analyses depends on the complexity of the model and how much the client wants to optimise the risk profile of the iQSCRA model and thus the project. The key point is that changes in inputs to the model depend on the wishes of the project team in reviewing the results and what the sensitivity rankings reveal about the schedule drivers and the underlying logic.

13.10 Output review and validation

The iQSCRA report should include the following sections:

a) executive summary
b) description of methodology
c) assumptions and exclusions
d) deterministic and probabilistic results for key milestones and summary costs
    - drivers of key results
    - discussion of results
    - conclusions and recommendations
    - appendices of inputs and outputs of the analysis.

13.11 Software requirements

Software for iQSCRA must offer fast simulations, be able to handle resource-loaded schedules of several thousand tasks and run simulations of required iterations efficiently.

Good planning capabilities are also essential – as complex models take significant time to build. The software should be able to perform changes to schedule logic for the treated risk-mapped and cost-loaded schedule model and not require complete rebuilding of the model from an external planning tool. The software should have a comprehensive range of modelling capabilities, including:

a) percentage probability of task existence, which can be correlated with the existence of other tasks
b) probabilistic branching and probabilistic links
c) percentage lags (where the lag in a dependency becomes a percentage of the duration of the predecessor or successor, or both)
d) resource and duration uncertainty with a wide range of distribution types
e) ability to create chains of multiple threats and opportunities with link to a parent task.

The software must also have sophisticated and statistically reliable correlation models which can be applied to the iQSCRA model – both duration and cost and preferably multi-level. The assignment of correlation should be performed using coding and not be restricted to individual assignment at the task level.

The software should be capable of building time and cost impact risk factors, with families of risk factors able to be correlated to each other – for example, the productivity of different disciplines within a project.

It should be possible to assign probabilistic weather calendars to weather-exposed tasks. Preferably, the weather distributions should be able to be built as discrete distributions based on historical weather data.

Finally, it is preferable that the software selected for the iQSCRA includes an application programming interface (API) that enables the user to add analysis and reporting functionality to the software, and to incorporate decision making within iterations, without slowing the iterations unacceptably.

14. Appendix G – Australian Government and Contingency

This appendix contains information quoted from government websites and documents accessed on the date of publication of this *Contingency Guideline*. It is recommended that the sources be regularly checked for any updates.

14.1 Federal Government

14.1.1 Parliamentary Budget Office

The Budget Explainer released by Parliamentary Budget Office on 24/Apr/2024 updated its 2021 report, The Contingency Reserve, to include the impact of COVID-19, which led to a sharp increase in the reserve to a record level of $57 billion (2.7% of GDP) in 2020-21. The explainer outlines what influences the Contingency Reserve's size and provides insights into an otherwise opaque component of the budget papers.

The Contingency Reserve is an allowance within the government's budget estimate forecasts for items that either cannot or should not be allocated to specific programs at the time of publication. It is a tool to account for uncertainty and improves the accuracy of the aggregate budget estimates. This in turn supports the goals of responsible fiscal policy and sustainable economic development.

At any time, the Contingency Reserve includes a variety of provisions. However, the two main provisions are the Conservative Bias Allowance (CBA), which is an allowance for the historical tendency for expense estimates to be under-forecast; and Decisions Taken But Not Yet Announced (DTBNYA), which is the value of policy decisions that have not yet been disclosed, along with policies that have been announced but whose costs cannot be published.

The CBA is generally the largest component of the Contingency Reserve and was introduced to take account of an observed tendency for budgets to underestimate future expenses, even after allowing for changes in policy and economic forecasts. It is designed to account for all the changes in estimates of expenses from 'program specific' factors. The provision scales up over the forward estimates to reflect greater uncertainty into the future and is unwound at subsequent updates as uncertainty reduces. PBO analysis of the past 30 years shows the CBA generally improves the accuracy of budget estimates in practice.

DTBNYA covers expenditure and non-tax revenue decisions that have been included in the budget aggregates but not yet announced, as well as policies that have been announced but whose costs cannot be disclosed. DTBNYA amounts have been published consistently since 2004-05, with their total size increasing significantly over the years since then. Policies may not be announced, or their amounts left undisclosed, for a variety of reasons.

Whilst the use of the Contingency Reserve does improve the accuracy of aggregate budget estimates, it also reduces transparency. As an aggregate provision, it is not always possible to see the annual funding profile for important expenditure and non-tax revenue decisions.

Introduction

This Budget Explainer examines the definition and use of the Contingency Reserve in the Australian Government budget. It outlines what influences the Contingency Reserve's size and provides insights into an otherwise opaque component of the budget papers.

This Explainer is part of a series that seeks to improve understanding of key parts of the budget that are not well understood. Other topics include indexation and its impact on the budget, and various taxation topics including superannuation, fuel excise and bracket creep.

What is the Contingency Reserve?

The Contingency Reserve is an allowance within the Commonwealth budget for events that the government reasonably expects to eventuate but has not allocated to specific programs or detail. By including these items on an aggregate basis, rather than omitting them, the Contingency Reserve improves the accuracy of aggregate budget estimates at the time of their publication.

Overall accuracy in the aggregate budget estimates is an important component of responsible fiscal management. Including items within the Contingency Reserve is a key accountability provision and supports the efficient allocation of resources and management of risks. As funding needs to be appropriate at fixed times, it is important that the estimate reflects the expected appropriation needed to meet the Government's policy goals.

Although its name may imply that the Contingency Reserve is a stock of funds, which would be expected to appear on the government's balance sheet together with cash deposits and other assets, it is a flow on the expense side of the government's operating and cash flow statements.

Since the Contingency Reserve was introduced in 1987, it has included a variety of items which generally fall within the following groups:

- The Conservative Bias Allowance (CBA), which makes provision for the historical tendency for the estimates of expenses for existing government policy to be under-forecast, and hence revised upwards later. The CBA is discussed further in this explainer.

- Expense and non-tax revenue policy decisions that were not announced in the fiscal update. These are classified as Decisions Taken But Not Yet Announced (DTBNYA). The Contingency Reserve contains the cumulative impact of funding for outstanding and new DTBNYA. These policies are usually announced and published in a future fiscal update.1 Budget aggregates can also include DTBNYA that relates to taxation, but these are included elsewhere in the budget in the tax revenue estimates, as opposed to the Contingency Reserve. DTBNYA are explored in more detail later in this explainer.

- Items that are too sensitive to be disclosed separately, such as those that are commercial-in-confidence or affect national security. In some cases, a description of the item is disclosed in the fiscal update while the funding allocated to it is not. In other cases, no information is disclosed. The 2021-22 Budget, for instance, included a provision for the manufacturing of messenger RNA vaccines in Australia, but funding was not disclosed as the exact price negotiated with pharmaceutical companies was commercial-in-confidence.

- An aggregate provision for underspends in the budget year, reflects the tendency for budgeted expenses for some entities or functions not to be met.

- Information that is received too late during the preparation of the fiscal update to be allocated to estimates of individual items, such as policy decisions or changes to the expected economic outlook.3 The information is instead included at the aggregate level in the Contingency Reserve and allocated to the individual program estimate at the next update.

- Provisions for items that have a significant amount of uncertainty at the time of publication, such as programs still under negotiation with state and territory governments, or for the establishment of new agencies whose legislation has not yet passed Parliament.

Figure 49 below shows how the components of the Contingency Reserve and DTBNYA are related, highlighting that the Contingency Reserve includes more than just DTBNYA, but does not include tax revenue DTBNYAs. These measures are instead incorporated into the revenue forecasts in Budget Paper 1.

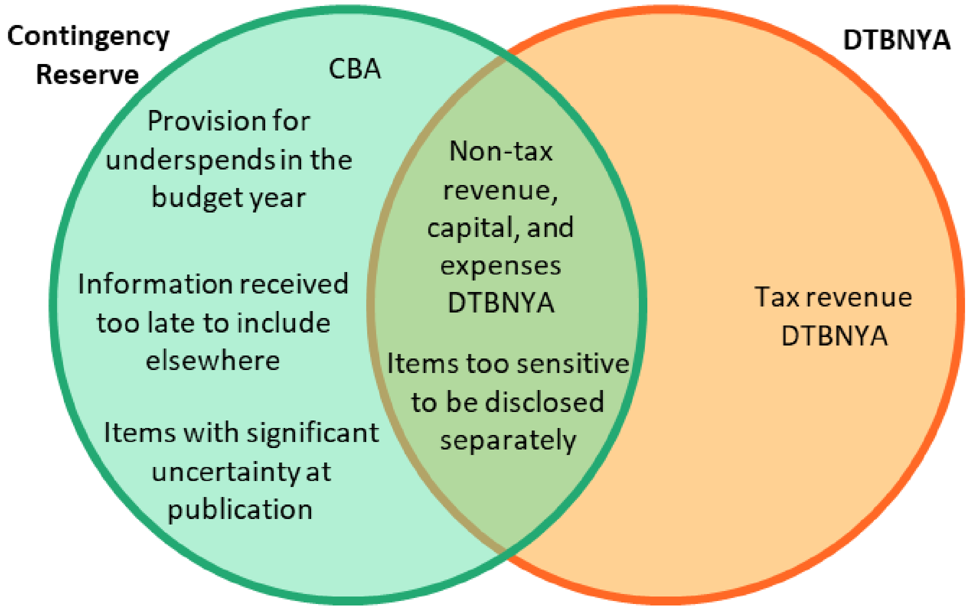


Figure 49: Contingency Reserve and DTBNYA components

The description of the Contingency Reserve in a fiscal update will occasionally provide information on other specific items included. An example is the 2009-10 Budget, where the Contingency Reserve amounts were relatively large, and included: provisions for future equity investments in the National Broadband Network (subject to an implementation study); estimates of revenue and expenses related to the then proposed Carbon Pollution Reduction Scheme (where the timing was dependent on the actions of other major economies); and provisions for future increases in Australia's Official Development Assistance yet to be allocated to specific aid programs.4 See Appendix A for a complete list of all items that have been included in the description of the Contingency Reserve throughout history.

What is the Conservative Bias Allowance?

The CBA is an allowance for the historical tendency to underestimate expenses over the forward estimates. The amount of this provision is calculated as a certain percentage of total expenses, excluding GST payments to the states and territories (the 'CBA percentage'). The current CBA percentage is zero in the Budget year, 0.5% in the first year of the forward estimates, 1% in the second year, and 2% in the final year. An example of a calculation of the CBA is shown below.

Consider the estimates for the year 2019-20 in the 2018-19 Budget. Total expenses were estimated to be $504,171 million and GST payments to the states were estimated to be $69,790 million. The CBA percentage for this year was 0.5 per cent, so the total amount provisioned in the CBA may be estimated as:

$$0.5\% \times (504{,}171 - 69{,}790) =$$

$$\$2{,}172 \text{ million.}$$

The CBA does not account for all possible reasons why expense outcomes may differ from their budgeted forecasts. The budget specifies the following five reasons why forecasts for expenses vary from one update to the next:

- new policy decisions
- revisions to economic parameters, such as economic growth, prices and unemployment
- revisions to other parameters, specific to particular programs
- changes to the amount of interest the government is expected to pay on its borrowings
- other variations not captured otherwise.

The CBA percentage is intended to compensate for only a third of these factors, referred to in the budget as 'program specific parameter variations'.

Does the Conservative Bias Allowance improve the accuracy of budget estimates?

Medium term expenditure frameworks (MTEF)18 aims to overcome the limitations of the annual budget cycle by adopting a medium-term perspective for achieving government fiscal objectives. They generally span the budget year and at least 3 years beyond. In Australia, this 4-year period is known as the forward estimates. MTEF's improve budget formulation by framing expenditure plans based on existing resources and link the annual budget to multi-year policies. They also increase budget stability by decreasing uncertainty in expenditure flows. To be effective, the expenditure estimates need to be based on high quality projections, which facilitates planning and fiscal discipline, and ultimately efficient resource allocation and sustainable economic growth.

The CBA is a key tool to address uncertainty to support sound budget estimates over the forward estimates. The PBO has reviewed the past 30 years of budget program variations. This analysis indicates that, on average, there is a historical tendency to underestimate aggregate expenses, and that the CBA does work as intended to improve the accuracy of aggregate expense estimates.

- While some individual years vary significantly, the long run average of the sum of program specific variations is approximately 2%, the same size as the current CBA.
- The positive long-run average of program specific variations confirms that there is a historical tendency to underestimate aggregate expenses.
- The consistency between the size of this tendency and the CBA percentage in this high-level test means that the CBA does improve the accuracy of aggregate expense estimates.

Since its introduction, the size of the CBA has varied. Sometimes this reflects that the relevant annual budget was part-way through a year (for example the 2022-23 October Budget), or different views about how much inherent uncertainty there was in the estimates. The current settings for full year budgets have applied since 2009-10.

What are 'Decisions Taken But Not Yet Announced'?

Over time, the Government has increasingly made decisions with financial impacts outside of the annual budget process. Some of these may be announced ahead of a fiscal update, but some may not. Most fiscal updates include some new policies, the details and costs of which have been calculated but not announced.

The fiscal impacts of all these unannounced policies are aggregated and presented as a single line DTBNYA in Budget Paper No 2, in the tables showing the receipts, payments and capital measures.19

The total published DTBNYA amount includes new policies not yet announced as well as policies that have been announced but whose costs cannot be published. In the latter case, short summaries of policies, known as 'measure descriptions' are still published for these policies, but the amounts are replaced by 'nfp' (not for publication).

The financial impacts of unannounced and not for publication policies are generally included in the Contingency Reserve. An important exception to this is tax policies, where the impacts are explicitly incorporated into the estimates for the relevant taxes, rather than within the Contingency Reserve.

Both unannounced tax and non-tax revenue policies are included in the aggregate figure for revenue DTBNYA in Budget Paper No 2, but only the unannounced non-tax revenue policies are included in the Contingency Reserve.

There are several reasons why policies may not be announced, or amounts cannot be published.

- Information may be commercial-in-confidence, or its disclosure could prejudice national security. For example, the cost of the 2023-24 Budget measure, Energy Price Relief Plan, was listed as 'not for publication (nfp) due to commercial sensitivities.'20 Similarly, the fiscal impact of new listings to the Pharmaceutical Benefits Scheme is usually reported as nfp.

- Some policies may have been finalised very late in the budget process, and it is not possible to allocate the financial impact in detail.

The government, who choose the timing of their policy announcements, may include some policies within DTBNYA in order to announce them later.

If a subsequent fiscal update announces a policy which has previously been included within DTBNYA then the measure tables show no impact on budget estimates, because the budget estimates have already included the impact at the aggregate level. This is often reflected with a note such as 'Funding for this measure has already been provided for by the Government.' The description of the policy in Budget Paper No 2 may also include the cost of the policy which has already been accounted for. However, it usually does not include the detailed funding profile for the decision and in some cases the funding profile is never disclosed.

Concluding comments

The Contingency Reserve provision seeks to improve the reliability of the budget forward estimates by taking account of some known uncertainty risks related to program specific issues. The key ones being the tendency to underestimate future outlays (the CBA) and DTBNYA.

The benefit in improving the estimates at an aggregate level is somewhat offset by the loss of fiscal transparency at a more detailed level, especially the funding profile for policy decisions that are eventually announced.

For additional information and more insights on the impact of another significant variation to the budget estimates – changes in prices and how they flow through to the budget via indexation, see https://www.pbo.gov.au/.

It should be also noted that the information below might not be relevant to contingency for individual projects or portfolios of projects as it relates more to aggregate budget estimates.

14.1.2 Department of Finance

Contingency Reserve

(in relation to budgeting) A provision within the Budget and forward estimates for items that either cannot or should not (generally for reasons of commercial sensitivity) be allocated to specific programmes at the time of publication. For example, allowance for the expected receipts from the sale of assets, or measures that require negotiation by the government where publication of estimates would adversely affect the government's negotiating position. The amount of the contingency reserve is not a general policy reserve, and it is not appropriate.

Defining P50 and P80

P50 and P80 refer to a confidence level regarding the probability of the cost not being exceeded and does not indicate a quantum of cost or proximity to the actual cost realised. That is, P80 is not a cost plus/minus 20% but instead it is a cost that will not be exceeded 80% of the time.

Risk profiles take the shape of the asymptotic ‘S’ curve shown below.

The curve shown is for a fictional representative project with an arbitrary parametric cost estimate of $1,000 and a simplified risk profile. This demonstrates the position of the P50 and P80 confidence level estimates and risk allowances (contingencies). Note that to reach P100, all risks would be identified and allowed for at their estimated cost, leading to an impractically large contingency allowance (observe the asymptotic nature of the probability curve) or require an excessive time to deliver the project. Conversely, if the parametric estimate (in this example $1000 with P15 confidence) was all that was allowed for, that is with no contingency allowance, then the cost will be exceeded in almost every circumstance. Clearly, prudent project management and informed investment decision requires a consistent confidence level applied to all projects. It is for this reason that the entities must use a P50 confidence level in the cost estimate at First Stage of the Two Stage Capital Works Approval Process and requires a P80 confidence at Second Stage Approval.

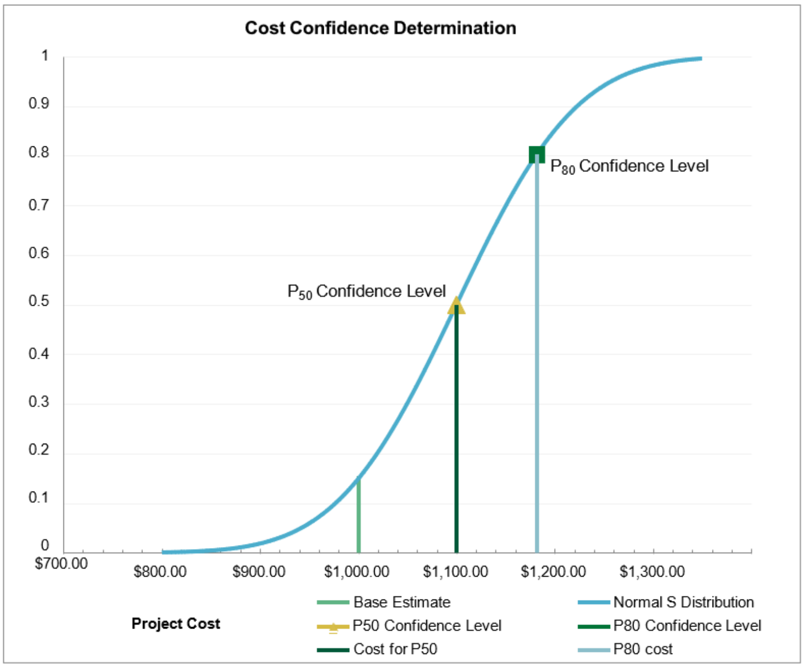


Figure 50: A typical risk profile with the shape of the asymptotic ‘S’ curve

Note that base estimate is a parametric cost with 'most likely' values for inherent risks (range risks). This value is not P0 as a consequence of range risks which have the potential to result in a lower cost (though unlikely). Where this line intersects the S curve indicates the cost confidence associated with that estimate on the represented risk profile (in this case the parametric estimate is approximately P15 – the other way to consider this confidence level is that the parametric estimate will be exceeded by some amount 85% of the time).

The S Curve is a cumulative probability curve arising from the normal distribution analysis of the risks identified.

Note that the graph above demonstrates the difference in risk allowance between a P50 and a P80 cost estimate. However, this is only at a moment in time – the refinement, realisation and retirement of risks through the due diligence investigations between First and Second Stage approvals will change both the base case and the standard deviation on the normalised distribution of risk, changing the placement of P50/P80 points on the cumulative probability curve.

In practice the progression from P50 at First Stage Approval P80 at Second Stage Approval involves the refinement, retirement and realisation of many identified risks. This usually results in the base case estimate increasing and the contingency allowance decreasing commensurately. However, if the estimate was in fact P50, this should be the case in only half of all projects, while the other half have budget estimates that decrease through maturity. The reality shows this not to be the case indicating probable optimism bias in the estimates or inadequate recognition/assessment of risks.

It is also critical to 'lock-in' the scope of the project at Second Stage Approval, as any further changes to the project scope and performance will also have flow on effects to the project cost and risk. Should the scope or performance change, the assumptions and estimates would affect the overall cost and risk profile for the project and would certainly alter the project from what was agreed by Government at Second Stage Approval.

Ascertaining your P50 or P80 confidence level cost

Deriving the appropriate cost confidence requires a cumulative assessment of the applicable risks. There are two different risk categories that form the risk profile: inherent (range) risk and contingent risk.

Range risk involves assessing the highest likely, lowest likely and most likely cost impact of an event that will occur (probability =100%). This may be a range of both quantity and rate separately or combined.

Example

The bulk earthworks are assessed as 200,000m3 at $25 per m3 with the quantity and rate combined range being -20%, 100%, +40%. The range of costs for this is:

Lowest likely = (200,000 x $25) -20% which equals $5.0m x 0.8 = $4.0m
Highest likely = (200,000 x $25) +40% which equals $5.0m x 1.4 = $7.0m
Most Likely = (200,000 x $25) -0% = $5.0m

The mean value is then considered the base estimate plus risk and so the risk allowance to include is the mean minus the most likely.

Contingent risk is an assessment of, and allowance for, unmeasured items. These may include items such as weather, geotechnical problems, political issues, design/owner requirements and other similar unknowns. These risks have a probability of less than 100% chance of occurring. As such, the risk needs to be allowed for in the contingency in a probabilistic manner. That is: cost ($) x likelihood of occurrence (probability %).

To ascertain the appropriate risk allowance, the risks and costs are viewed as a normalised cumulative cost probability as shown in the graph above.

Ascertaining the normalised cumulative cost probability curve is done by use of the Monte Carlo simulation method where all identified risks are simulated over a number of projects probabilistically to ascertain the normal distribution of risk costs. This can be completed using a random number generator in a spreadsheet application to determine the mean and standard deviations of costs derived from the simulation. This represents the application of the accumulated risks (both inherent and contingent).

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

Information in this section is quoted from two sources:

a) The Notes on Administration for Land Transport Infrastructure Projects provide administrative guidance for managing projects to be funded under the National Partnership Agreement. https://investment.infrastructure.gov.au/sites/default/files/documents/notes-on-administration-january-2021.pdf
b) The Cost Estimation Guidance https://investment.infrastructure.gov.au/resources-funding-recipients/cost-estimation-guidance

The department's cost estimation guidance outlines the principles that are expected to be followed by proponents in preparing cost estimates accompanying Project Proposal Reports, submitted in accordance with the Notes on Administration (NOA), for projects seeking Australian Government funding.

Guidance notes

The cost estimation guidance, published following a thorough public consultation process, comprises the following key components which are available for download:

- Guidance Note — Overview, Version 2.0, November 2023 PDF, https://investment.infrastructure.gov.au/sites/default/files/documents/guidance-note-overview-v2.pdf
- Guidance Note 1 — Project Scope, Version 2.0, November 2023 PDF, https://investment.infrastructure.gov.au/sites/default/files/documents/guidance-note-1-project-scope-v2.pdf
- Guidance Note 2 — Base Cost Estimation, Version 2.0, November 2023 PDF, https://investment.infrastructure.gov.au/sites/default/files/documents/guidance-note-2-base-cost-estimation-v2.pdf
- Guidance Note 3A — Probabilistic Cost Estimation, Version 2.0, November 2023 PDF, https://investment.infrastructure.gov.au/sites/default/files/documents/guidance-note-3A-probabilistic-cost-estimation-v2.pdf

- Supplementary Guidance Note 3A — Probabilistic Cost Estimation, Version 2.0, November 2023 PDF, https://investment.infrastructure.gov.au/sites/default/files/documents/supplementary-guidance-note-3A-probabilistic-cost-estimation-v2.pdf
  - Risk Factor Model 1 XLSX, https://investment.infrastructure.gov.au/sites/default/files/documents/Risk-factor-model-1-V2.xlsx
  - Risk Factor Model 2 XLSX, https://investment.infrastructure.gov.au/sites/default/files/documents/Risk-factor-model-2-V2.xlsx
  - Risk Factor Model 3 XLSX, https://investment.infrastructure.gov.au/sites/default/files/documents/Risk-factor-model-3-V2.xlsx
  - Risk Factor Model 4 XLSX, https://investment.infrastructure.gov.au/sites/default/files/documents/Risk-factor-model-4-V2.xlsx
- Guidance Note 3B — Deterministic Contingency, Version 2.0, November 2023 PDF, https://investment.infrastructure.gov.au/sites/default/files/documents/guidance-note-3B-deterministic-contingency-v2.pdf
  - Range Based Model XLSX, https://investment.infrastructure.gov.au/sites/default/files/documents/Range-based-model.xlsx
- Guidance Note 4 — Escalation, Version 3.0, November 2023 PDF, https://investment.infrastructure.gov.au/sites/default/files/documents/guidance-note-4-escalation-v3.pdf

Under the policy settings a probabilistic cost estimation process must be used for all projects, for which Commonwealth funding is sought, with a total anticipated outturn cost (including contingency) exceeding $25 million.

For projects with a total anticipated Outturn P90 cost (including contingency) under $25 million, a deterministic methodology may be used; however, the Department recommends using a probabilistic cost estimation method where possible.

The Department will review and assess the project cost estimate (including the cash flows by financial year and project phase) provided in the associated Project Proposal Report (PPR), before making a recommendation to the Minister.

Guidance on the preparation of the PPR and associated cost estimation requirements are outlined in the Notes on Administration for Land Transport Infrastructure Projects (the NOA) which provides administrative guidance for managing projects to be funded under The National Partnership Agreement on Land Transport Infrastructure Projects (the NPA). The NPA requires project proponents to provide access to underpinning data, and to cooperate with any review undertaken. As such, proponents must maintain an electronic library of all documentation consulted in determining the Project Estimate.

As specified in the NOA, cost estimates accompanying a PPR must be prepared in accordance with the principles outlined in the Department's Cost Estimation Guidance and presented using the Department's Project Cost Breakdown (PCB) templates.

The Department's cost estimation Guidance Notes which, in aggregate, will constitute the Cost Estimation Guidance referred to in Appendix B to the NOA, are progressively developed and, following public consultation, will be published on the Department's website.

14.2 States & Territories

14.2.1 New South Wales (NSW)

NSW Treasury and Infrastructure NSW (INSW)

Information in this section is quoted from key sources below:

a) NSW Treasury
https://www.treasury.nsw.gov.au/sites/default/files/pdf/TC14-29_Management_of_Contingency_Provisions_for_Major_Projects.pdf
b) INSW Cost Control Framework for the Infrastructure Program, 26 April 2022
https://www.infrastructure.nsw.gov.au/media/vg2d0f5p/cost-control-framework-approved.pdf

Agencies seeking approval for new major infrastructure projects (with an estimated total cost over $100 million) are required to identify the amount of contingency provision, controls and delegations proposed to manage those funds and monitoring and reporting arrangements.

In addition to organisation's internal assurance processes, it is a mandatory requirement of the NSW Treasury that all General Government agencies and Public Trading Enterprises (PTEs), except State Owned Corporations (SOCs), are required to identify the amount of contingency provision and the controls/delegations proposed to manage the release of the provision for new major infrastructure projects when seeking project approval through the Cabinet Standing Committee on Expenditure Review (ERC).

The Treasurer (as the Chair of ERC) will approve:

a) the amount of contingency provision allocated with regard to the project risk profile
b) the controls and delegations proposed to manage the release of the provision.

A major project that is considered high risk might warrant the Treasurer controlling/holding a proportion of the contingency funds or delegating this responsibility to the Portfolio Minister. Other projects with a lower risk profile could be managed with delegations for the use of contingency funds set at lower levels (including Head of Agency and or Project Director/ Manager).

Infrastructure NSW (INSW) provides advice to the Treasurer as to the adequacy of the contingency funds allocated and the controls proposed. INSW also reports on the use of contingency for major projects to the Cabinet Standing Committee on Infrastructure (CIC) every two months.

To enable Treasury and where requested by the Treasurer, INSW, to assess the proposed amount of contingency and the controls and delegations, project business cases or project identification submissions should:

a) provide details of how the contingency has been determined with reference to the determination method (e.g. deterministic or probabilistic), risk profile of the project, the investment lifecycle stage, the delivery method, the risk allocation and other key aspects of the business case
b) propose and provide a rationale for the delegations and controls, consistent with the risk profile, the business case and the governance arrangements for the relevant project, delivery entity and

owner

c) provide details of arrangements for regular monitoring and reporting contingency requirements and performance throughout the investment lifecycle.

As per INSW, the preferred approach for the estimation of the Contingencies for any projects within the scope of the INSW Cost Control Framework is probabilistic risk impact assessment. It can be undertaken through either or both of the following two processes:

- Monte Carlo Analysis. This is the minimum requirement for all HPHR projects and is encouraged to be conducted, as best practice, for Tier 2 and below projects, particularly where the project has a unique risk profile or features major risks that do not have a deterministic (single point) outcome.
- Expected Value Analysis. This approach may be utilised for Tier 2 projects or below, particularly where there are many recent and similar projects to benchmark against.

Clusters may employ both approaches as a further check on the robustness of the contingency. Some probabilistic risk assessment methodologies are resource, and time, intensive and may not be justified for Tier 3 projects and below. Clusters may determine the appropriate method determining the Contingency for Tier 3 and below projects. The use of generic risk percentages is to be avoided wherever practicable. Risk percentages must be determined by appropriate benchmarking against similar projects or projects in other infrastructure sectors with similar risk profiles.

Key points to note from the diagram on the following page include:

- Gate 1 - The Estimated Total Cost of the project includes Construction Costs and Client Costs (see Section 6 – Estimation of Project Costs), a probabilistic Contingency and a determinative Design Contingency (see Section 7 – Contingencies) and a project wide escalation (see Section 8 - Escalation).
- Gate 2 - The determinative Design Contingency should be retired by Gate 2, placing the onus on the project teams to define the scope and identify and quantify the risks to be included in the Contingency. It would be expected that both the Construction Costs and probabilistic Contingency would increase through this process. The project wide escalation should also be benchmarked by calculating escalation by element where possible. Provision for environmental disasters should be considered based on the location of the project. Clusters are not required to provision for potential future pandemics and options to identify funding to mitigate potential impacts will be considered in the unlikely event of another pandemic. Clusters are required to highlight known risks with potential unknown impacts to ERC at Investment Decision for HPHR projects.
- Gate 3. The draft contract should provide a risk allocation that will be modelled in the Contingency. The Contingency should be split by reference to whether the draft contract transfers the risk, or it is retained by the cluster, such that the Risk Adjusted Construction Costs include the risks to be transferred to the contractor. This figure is the cluster's best assessment of the likely contract sum. Escalation should be calculated by element. Note that escalation should be applied to the Risk Adjusted Construction Costs, the Client Costs and Contingency. For some collaborative contracts, escalation risk for the Direct Costs may be retained by the cluster, in which case it should be addressed in the retained Contingency. Clusters are required to provide regular updates to the relevant Cabinet Committee on the sufficiency of provisions for unknown risk provisions and effectiveness of mitigations through procurement.
- Gate 4. The overall Construction Costs are locked in, and the retained risk should be updated based on the outcomes of negotiations. The Approved Contract Budget should reflect the contract price at Contract Award and the Contingency should include provision for any retained risks.

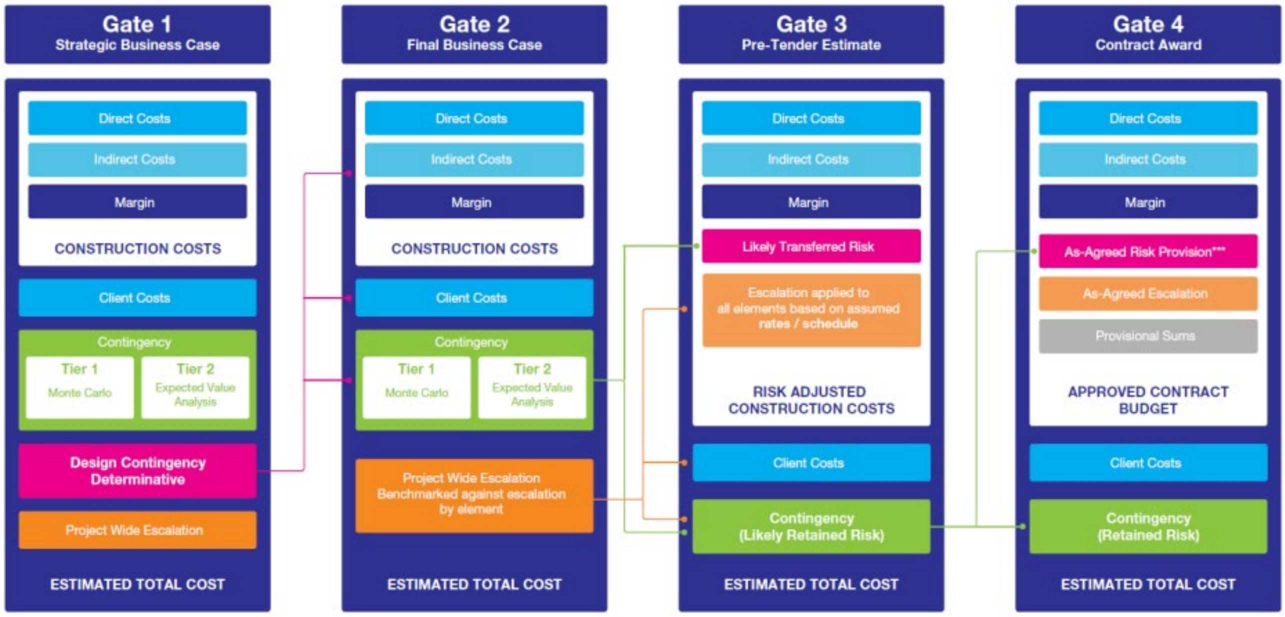


Figure 51: Contingency movement as per INSW Cost Control Framework for the Infrastructure Program

Clusters may seek approval from ERC for the apportionment of a **Portfolio Reserve**. Approval of a Portfolio Reserve will be considered where:

- The cluster has demonstrated a track record of rigorous and effective cost estimation and control
- Processes for the funding, oversight, management and transparent reporting of the Portfolio Reserve have been agreed with Infrastructure NSW and Treasury
- The cluster's cost control processes have been reviewed through an Infrastructure NSW Cost Control Deep Dive and all critical recommendations have been closed

The Portfolio Reserve is generally designed to protect against unforeseen project cost overruns on designated projects across the portfolio. Where clusters are elected, and are approved to maintain a Portfolio Reserve, the reserve will be internally funded from within project budgets as approved by the ERC. The funding earmarked for the Portfolio Reserve will be determined at Gate 1 and reviewed at Gate 2 for High Profile, High Risk and Tier 2 projects. Infrastructure NSW will undertake the review and provide advice on the cluster's ability to manage the Portfolio Reserve at Gate 2.

Where clusters are approved to maintain a Portfolio Reserve, it will be held and managed by the cluster or agency centrally. The Portfolio Reserve will be available to address risk events on any project in accordance with cluster guidelines. The cluster's cost control processes should include details on the cluster's plan to fund, manage and utilise the Portfolio Reserve, including governance arrangements. Clusters may nominate to split the Portfolio Reserve so that programs within the portfolio have their own separately managed Portfolio Reserve Fund. For example, the Portfolio Reserve for Commonwealth-funded projects may be managed separately in order to avoid potential issues with Commonwealth funding being transferred to non-Commonwealth funded projects.

Transport for NSW (TfNSW)

The Project Cost Estimation Template has been developed by Transport for NSW (TfNSW) to support councils in developing a mandatory project cost estimate. It is a template for applicants to populate with itemised data to ensure all costs, including contingencies to P50 and P90, are accounted for to the best available knowledge at the time of submission.

It is a mandatory requirement of the Road Safety Program for project submissions to provide a cost estimate which includes P50 and P90 contingency. This is to ensure that successful projects have multiple layers of contingency to enable good financial management at the project level and to reduce the likelihood of projects requesting additional funding from the Program.

Within the Project Cost Estimation Template (Road-Safety-program-Project-Cost-Estimation-Template.xlsx), the contingency for Strategic Estimates that have been derived using TYPICAL rates such as the ones indicated below should be in the range of 40-70% depending on the confidence and reliability of the of the information used in preparing the estimate. Please note that the estimating manual recommends a range of 35-70%, the 35-40% should be used only if the project has been advanced to concept but for some reason is titled strategic. While the suggested values are based on Strategic Estimates, the applicant can assign much lower contingency values against the task/activity (or even 0%, if no contingency is required). Any number (from 0% to 100%) can be assigned to the contingency value in the table. The table simply adds all contingencies assigned to a total amount at the bottom.

14.2.2 Victoria (VIC)

Department of Treasury and Finance

Several documents refer to the topic of contingency determination, including key references below:

- The Reference Management Framework, Resource-Management-Framework-2023-2024.docx
- High value high risk framework, High value high risk framework | dtf.vic.gov.au

As per the Reference Management Framework, the funding is released incrementally during a project's lifecycle as follows:

- Project approval: project budget is typically set at a P90 estimate (or equivalent). Development, procurement and early works funding is released to the delivery agency (10 per cent or an identified amount) with the balance held in central contingency.
- Contract award: project risk and contingency provision is reset and the project funding up to the P60 estimate (or equivalent) is released to the delivery agency with the balance held in central contingency if or until required.
- Project completion: a full reconciliation of project expenditure will occur, and all unused project budget is either:
  - retained (for outstanding claims or warranties)
  - reallocated to other government priorities
  - returned to the Consolidated Fund.

Office of Projects Victoria

The Office of Projects Victoria (OPV), an administrative office within the Department of Treasury and Finance (DTF), has developed these Risk, Time, Cost and Contingency (RTCC) technical guidelines to assist project teams as they plan, propose and deliver projects through DTF's Investment Lifecycle. They are applicable to investments funded through the Budget process where a business case must be prepared, with additional requirements applicable to High Value High Risk (HVHR) projects.

Risk,-Time,-Cost-and-Contingency-Guidelines.docx

14.2.3 Queensland (QLD)

QLD Treasury

Information in this section is quoted from the Queensland Government Treasury.
https://www.treasury.qld.gov.au/growing-queensland/project-assessment-framework/

The Government's decision makers, primarily Cabinet, the Cabinet Budget Review Committee (CBRC) and the Ministers and Chief Executive Officers of Departments, require consistent, transparent and accurate information to:

a) align agencies' policies, projects, programs and activities to the Government's stated priorities
b) prioritise individual projects within programs
c) ensure that their project procurement and resource allocation decisions achieve maximum value for money
d) benefit for the State.

Rigorous and robust project evaluation will materially help in delivering on these requirements. In this context, the purpose of the Cost-benefit analysis guidelines is to assist analysts, across the whole of the Queensland Government by providing:

a) a standard methodology and approach for cost-benefit analysis
b) a guide to undertaking the analysis

Department of Transport and Main Roads (DTMR)

Information in this section is quoted from:

- estimating policy.

https://www.tmr.qld.gov.au/business-industry/Technical-standards-publications/Project-cost-estimating-manual.aspx

- Project Risk Management and Contingency Development Process Manual, 1st Edition March 2023, Project Risk Management and Contingency Development Process Manual (2).pdf

The Infrastructure Cost Estimating Policy (estimating policy) requires all cost estimates for Department of Transport and Main Roads infrastructure projects to be completed in the format prescribed by the Project Cost Estimating Manual (PCEM). This includes all state and federally funded projects including road and rail, black spot and bridge renewal programs. The purpose of this policy is to maintain consistency, accuracy and high level of confidence required in transport infrastructure project cost estimates.

DTMR estimating policy has been founded on five key principles to achieve these objectives:

a) Estimates are created in accordance with the requirements of the department's Program Management Framework (PMF), OnQ project management methodology, Work Breakdown Structure (WBS) and Main Roads Specifications (MRS).
b) All estimates are prepared on an "unlikely to be exceeded but not excessively conservative" basis for various stages of the project lifecycle to provide confidence in project priority, affordability and strategic fit.
c) Estimates are to be presented using the prescribed estimate document format which highlights the elements of the estimate structure and relevant project cost attributes.
d) Estimates are subject to a review and approval process to ensure accountability, responsibility,

cost standards and controls are applied to any budget that is to be released.
e) Estimate performance will be ascertained at all funding approval points.

DTMR's Project Cost Estimation Manual (8th Edition, Dec 2021) provides some guidance as to contingency percentage above the base estimate. The project managers, estimators and designers are expected to follow appropriate processes on risk identification, evaluation and management. Contingency allowances outside of these ranges or larger contingencies must be justified by a detailed risk analysis approach using tools such as a project risk management workshop or a Monte Carlo analysis.

Base estimate stage	Level of project definition	Typical contingency ranges
Strategic estimate	1% to 15%	40% to 70%
Project proposal estimate	1% to 15%	40% to 70%
Options analysis estimate	N/A	N/A
Business case estimate (P90)	10% to 40%	30% to 40%
Development Phase Stage 1 Design estimate	30% to 65%	20% to 30%
Development Phase Stage 2 Design estimate	40% to 80%	10% to 20%

Table 22: DTMR's Project Cost Estimation Manual, Contingency %

These contingency ranges were in use by the department since the Second Edition released of this manual in 2004. The Association for the Advancement of Cost Engineering International's Cost Estimate Classification Matrix provides ranges of expected accuracy wider than those shown, however departmental experience has not yet indicated a need to modify these ranges.

QTRIP projects receiving Australian Government funding are subject to additional conditions over and above OnQ and PAF requirements.

- Transport and Main Roads projects are required to submit a completed Queensland Project Proposal Report template and required attachments (see Annexure D of this manual) for all projects seeking Australian Government funding approval. Project cost estimates are to include a Project Cost Breakdown (PCB) for the whole project, not just the phase or phases that the PPR relates to – the exception being the identification phase PPR, and when the commitment is less than $25 million.

- PCBs must include a P50 and P90 scenario.

- Project cost estimates should include actual costs for phases already complete.

- The Department of Infrastructure, Transport, Regional Development and Communication and the Arts (DITRDCA) escalation rates are to be applied to cost estimates, noting that, for projects with a total commitment greater than $25 million, a PCB spreadsheet must be completed – the PCB spreadsheet will determine the escalation rates to be used.

It is a mandatory requirement that a probabilistic cost estimation process be used for projects for which federal funding is sought, with a total outturn P90 cost (including contingency) greater than $25 million.

14.2.4 Western Australia (WA)

Department of Treasury

Information in this section is quoted from the Department of Strategy Strategic Asset Management Framework – Business Case. Strategic Asset Management Framework - Policy , 2022

Business Case Guidelines, Business Case Guidelines – cost estimates will also cover associated impacts on other State Government agencies. For high value, high risk proposals, probabilistic (P90 or P50, depending on the nature of the project) estimation methods may be required for the financial analysis of the business case to determine an appropriate level of contingency.

Clearly document the levels of contingency.

Department of Finance, Building Management and Works (BMW)

Information in this section is quoted from the Project Cost Planning & Management Guideline, January 2019.

BMW Project Cost Planning Guideline

This guideline contains information specifically written to assist cost consultants in preparing and reporting on project costs for Building Management and Works (BMW) managed non-residential building projects. The cost plan pro formas provide a consistent reporting format and shall be used when presenting cost plans and estimates for review, analysis, evaluation and key performance measurement. They also provide background and guidance to project stakeholders to understand the BMW requirements for cost planning and cost management of projects.

Generally defined as, sums allocated within a budget or cost plan to cover the cost of unplanned activities or risks that are necessary to deliver project outcomes and require additional funds. Contingency is not intended for changes to project scope outside the business case for which the investment was approved (Contingency Management Guidebook, Guidelines for optimising capital investment funding, February 2014, Infrastructure NSW). Also refer to specific definitions and applications of:

- Planning Contingency - The Planning Contingency is an allowance to cover the risk of not being able to design the spatial relationships and achieve the desired Functional Area and Travel / Engineering allowances (Australian Cost Management Manual, Volume 1, 2nd Edition, 2013, Australian Institute of Quantity Surveyors). This contingency is to be set at 5% for planning projects / evaluation phase and is usually reduced to zero by the Schematic Design stage. Note: How any residual Planning Contingency remaining at the Schematic Design stage can be used will require negotiation between the Agency and Department of Treasury.

- Design Contingency - The Design Contingency is an allowance to cover the risk of the estimator / cost planner not adequately foreseeing the correct design or the complexity of the design. The amount of the Design Contingency will depend on the amount of detail available. (Australian Cost Management Manual, Volume 1, 2nd Edition, 2013, Australian Institute of Quantity Surveyors). This contingency is to be set at 10% for planning projects / evaluation phase and is usually reduced to zero by the Construction Documentation stage. Note: How any residual Design Contingency remaining at the Construction Documentation stage can be used will require negotiation between the Agency and Department of Treasury.

- Construction Contingency - The Construction Contingency is an allowance to cover the risk of variations and unforeseen items encountered during construction (Australian Cost Management Manual, Volume 1, 2nd Edition, 2013, Australian Institute of Quantity Surveyors). This contingency is not to be used for changes in scope and is to be set at 10% for planning projects / evaluation phase. Note: How any residual

Construction Contingency remaining at Practical Completion stage can be used will require negotiation between the Agency and Department of Treasury.

14.2.5 South Australia (SA)

Department of Treasury and Finance

Information in this section is quoted from the Department's Guideline for the evaluation of public sector initiatives – Part A: Overview.
https://www.treasury.sa.gov.au/__data/assets/pdf_file/0006/515292/ti17-guidelines-part-a.pdf

These guidelines provide the evaluation framework for assessing public sector initiatives pursuant to Treasurer's Instruction 17: Evaluation of and Approvals to Proceed with Public Sector Initiatives (Treasurer's Instruction 17). These guidelines are an update of the previously released 'Guidelines for the evaluation of public sector initiatives' by the Department of Treasury and Finance (DTF).

In accordance with Treasurer's Instruction 17, approval to proceed with a proposal can be granted by the lead agency chief executive, minister and/or Cabinet depending on the total estimated cost of the proposal as detailed in table below.

Total estimated cost (plus GST)[a]	Approval required
Less than \$1 100 000 or Chief Executive delegation	Chief Executive
Greater than \$1 100 000 or Chief Executive delegation and less than \$11 000 000	Minister
Equal to or greater than \$11 000 000	Cabinet

Table 23: South Australia Department of Treasury Approval Requirements

Full compliance with these guidelines is required where a proposal has an estimated cost equal to or more than \$11 million unless otherwise exempt from Treasurer's Instruction 17 approval requirement.

The Department of Planning, Transport and Infrastructure (DPTI) is the government leading agency responsible for providing an assurance comment on the time and cost estimates of construction projects. The business case requires assurance that the cost, cash flow and timeframe estimates are within +/- 10 per cent. This assurance comment should be included in the business case for all building and infrastructure proposals. DPTI is required under the DPC Circular PC028 — Construction Procurement Policy Project Implementation Process to provide project, risk and procurement management services to agencies for all infrastructure projects of cost exceeding \$150 000 (exclusive of GST). This requirement is to ensure that the project implementation process and all relevant policies and guidelines for construction procurement are followed. The lead agency should seek advice from DPTI regarding the scope, estimated costing and timeframes of an infrastructure proposal.

Department's 'Guideline for the evaluation of public sector initiatives – Part B: Investment Evaluation Process, (https://www.treasury.sa.gov.au/__data/assets/pdf_file/0007/515293/ti17-guidelines-part-b.pdf) requires that for each risk, the probability of the risk occurring and its potential cost impacts should be assessed and quantified. Note the project budget (step 4 in the investment evaluation process) requires the determination of a monetary amount to be held as a contingency to cover the potential costs incurred should an identified risk eventuate.

The details associated with determining the budget impact should be included in the business case in an appendix. For example, typical cost elements that should be sufficiently detailed (including contingency amounts) are shown below in table below.

Type	Discussion
Direct costs	The estimated cost of labour, plant, materials and specialist subcontract work required to deliver the asset based on calculated quantities derived from proposed design solutions and construction methodologies.
Indirect costs	Other estimated costs necessary to support the direct costs such as site facilities, project insurance, professional fees etc.
Contingency amounts – project risks	Amounts to be included in the budget estimate to accommodate various project risks (refer step 3.6), for example, they should not be incorporated into estimated construction or equipment costs. Note it is bad practice to 'load up' the project risk estimate to compensate for absent or poor project planning. The practice of 'budget padding' should be avoided.
Contingency amounts - escalation	An escalation allowance that provides adequate compensation for potential cost increases beyond the estimate for inflation already included in the cost estimates. Construction costs typically are highly sensitive to market conditions. While various measures for cost movements in construction cost components such as concrete, cement and steel are available from industry publications and the Australian Bureau of Statistics, these are only based on observed historical data. Any future cost estimate requires the use of judgement regarding future market volatility and the supply and demand for construction input costs.

Table 24: South Australia Department of Treasury, typical cost elements

Determining risk estimates is best based on a combination of professional judgment and previous project data where available. A number of different risk estimate techniques are well documented ranging from simple scenario analysis to Monte Carlo simulation technique. The extent to which risk analysis is undertaken and the potential contingency amounts required depend on the complexity of the proposed solution. Generally:

a) for most routine public sector projects such as school buildings and simple road developments, reference can be made to corporate history and the contingency amount for project risks would typically be between 5 to 10% of the total project budget estimates
b) for more complex or larger projects that are not regularly undertaken by agencies, expert advice may be required for assessing the project risks which would typically be between 15 to 20% of the total project budget estimates
c) for other one-off and high-risk projects, the project risks may be greater than 20% of the total project budget estimates.

Agencies should ensure that they do not over-identify and over-estimate the risks associated with delivering the preferred solution. An informed and experienced view should be taken of the construction and design industry's capability and expertise in delivering such projects and advice within the time and cost estimates should be sought accordingly.

Consideration of which party, that is, the investor (government), client (lead agency) or supplier, is best able to manage the risk may also be required for developing strategies designed to reduce and manage each risk and determining the potential budget impacts should the identified risk eventuate.

The key project specific risks that should at a minimum be considered are detailed below in the table below.

Type	Discussion
Planning risks	The risk that critical issues have been overlooked and costs, benefits and projected outcomes are overstated or understated. Examples include the risk that projected outcomes will not adequately address the service need problem, and the risk that technological changes will make the proposed mode of service delivery out-dated early in the life cycle of the proposal.
Technical specification risks	The risk that individual characteristics of the project do not meet the solution specification.
Completion risks	The risk that design, construction and completion issues including supply side constraints, site availability, contamination and remediation issues, and industrial action will delay or even prevent the project from being implemented.
Demand risks	The risk that the forecasted service need demand projections are inaccurate.
Implementation risks	The risk that the preferred solution will not deliver the targeted outcomes and outputs as projected.
Management risks	The risk that the lead agency will fail to deliver on the expected outcomes of the preferred solution due to lack of expertise, resources and/or other factors.
Operations risks	The risk that implementation of the preferred solution will not occur as planned due to issues such as the inability to source labour and materials as required and interruptions to operations as a result of failure of equipment.
Cost overrun risks	The risk that during design and construction, the actual project cost will exceed the estimated costs.
Environmental risks	The risk that adverse impacts on the natural environment will be identified that extend the project time with potential consequence and delays in implementation and the provision of services, resulting in additional costs and loss of user support and, subsequently, demand for services.
Private sector risks	Where a proposal involves participation by the private sector, major risks include the ability of the private entity to obtain finance and provide the other expected outcomes regarding implementation, management and operations.

Table 25: South Australia Department of Treasury, project specific risks

Department for Infrastructure and Transport

Master Specification Part PC-PL5, Cost Estimation, September 2024
https://www.dit.sa.gov.au/__data/assets/pdf_file/0006/1423797/PC-PL5-COST-ESTIMATION.pdf

Cost estimation must comply with the Reference Documents, including:

- Department EST600 Estimating Manual, Transport Infrastructure Projects (found at: https://thinkroadsafety.sa.gov.au/__data/assets/pdf_file/0003/173532/Estimating-Manual-Roads-Rail.pdf); and
- Department EST600-2 - Standard Estimating Spreadsheet, Levels 2, 3, 4, 5 and 5B (where prepared by

estimating consultants) template (as referenced in the Department EST600 Estimating Manual, Transport Infrastructure Projects).

Cost Estimate level	Nominal design stage	Intended application
Level 2	Longlist Concept Design	Long list of options in the proving phase of a planning study
Level 3	Shortlisted Concept Design	Approved shortlist of Concept Designs in the proving phase of a planning study
Level 4	Reference Design to Preliminary Design	Refined version of preferred Concept Design in the proving phase of a planning study
Level 5	Detailed Design to IFA with cost estimate revisions as the design progresses	Project delivery

Table 26: South Australia Department for Infrastructure, levels of cost estimate

Cost estimates must incorporate assessment of risk items using probabilistic risk methods to determine P50 and P90 cost estimate values calculated in accordance with the Department's EST 600 Estimating Manual, Transport Infrastructure Projects. All cost estimates must include the development of Project programs, cash flows, staging diagrams, and risk assessment tables, which clearly link to the derived P50 and P90 values, with the exception of Level 2 cost estimates which are permitted to include a simplified or generic risk assessment table when deriving P50 and P90 values.

As per the Manual, the estimates are defined in three ways; Options Estimates, Project Estimates and Formal Estimates.

Options Estimates are produced for each alternative project option being considered. Options Estimates are expressed as follows:

<table>
<tr><th>Estimate Level</th><th>Level 1</th><th>Level 2</th><th>Level 3</th><th>Level 4</th><th>Level 5</th><th>Level 5A</th><th>Level 5B</th><th>Level 6</th></tr>
<tr><td>Expressed As:</td><td>Cost Range (Mid to High)</td><td colspan="4">P50/P90 (or equivalent P50/P90)</td><td>Out-turn $ (tendered values typically include escalation to completion)</td><td>P50/P90 (or equivalent P50/P90)</td><td>Actual $</td></tr>
</table>

<table>
<tr><th>Estimate Level</th><th>Level 1</th><th>Level 2</th><th>Level 3</th><th>Level 4</th><th>Level 5</th><th>Level 5A</th><th>Level 5B</th><th>Level 6</th></tr>
<tr><td>Where Prepared by Estimating Consultants</td><td rowspan="2">Factor Based Deterministic Analysis</td><td colspan="6">Probabilistic Risk Analysis</td><td rowspan="2">Not applicable</td></tr>
<tr><td>Where Prepared by DIT Staff</td><td colspan="6">Range Based Deterministic Analysis</td></tr>
</table>

Table 27: South Australia Department for Infrastructure, Options Estimates

Project Estimates generally have the same characteristics as Options Estimates except that they represent the highest most realistic Options Estimate prior to the addition of cost escalation and Senior Responsible

Owner approval (the Formal Estimate).

Formal Estimates are required at defined times in the project life cycle and are based on the highest most realistic Options Estimate (the Project Estimate) at that point in time. Note: when seeking delivery funding the project estimate must represent the defined option/scope of work which is to be implemented.

14.2.6 Tasmania (TAS)

Department of Treasury and Finance

Information in this section is quoted from the Department of Treasury and Finance.
http://www.treasury.tas.gov.au/budget-and-financial-management/guidelines-instructions-and-legislation/budget-guidelines/structured-infrastructure-investment-review-process-(siirp)

The Department's 'Structured Infrastructure Investment Review Process (SIIRP)' is a review and assessment process for General Government Sector infrastructure investment proposals. Infrastructure investment proposals will be subject to a series of decision points prior to being considered for funding and will be required to meet reporting requirements during the development, and following the completion of, the project.

At each of the points an assessment is made as to whether the project should: proceed to the next stage; require further details to be provided for further assessment or not proceed if the project is not supported at the present time. The SIIRP consists of four decision/reporting points:

a) Investment Concept and Options Analysis
b) Business Case
c) Budget Committee Consideration
d) Project Review – Closure and Benefits Realisation.

Agencies should confirm the processes to be used for estimating, monitoring and controlling project expenditure as well as any provisions for contingencies factored into the Budget.

All capital and recurrent cost estimates must be detailed in the business case as the business case is the basis for the Treasurer's and Budget Committee's decision making. The processes to be used for estimating, monitoring and controlling project expenditure should be confirmed as well as any provisions for contingencies factored into the Budget.

14.2.7 Northern Territory (NT)

No specific reference to contingency management within Northern Territory (NT) was identified at the time of this publication.

14.2.8 Australian Capital Territory (ACT)

The Capital Framework (https://www.treasury.act.gov.au/capital-framework) is the policy framework used by the Territory to support the successful delivery of capital projects in the ACT. It is managed by Infrastructure and Commercial Advice (ICA) in Treasury and provides consistent, structured and fit-for-purpose guidance to support you in methodically undertaking robust analysis of infrastructure projects and helps inform Government in making investment decisions, tracking outcomes and benefits.

Capital Framework within the Infrastructure Investment Lifecycle

The Infrastructure Investment Lifecycle is the staged lifecycle of an investment - from planning, proposing and delivering investments, together with measuring their benefits in practice and feeding lessons learnt to future projects.

The Capital Framework covers Stage 1 - Develop, Stage 2 - Prove and Stage 5 - Measure of the Infrastructure Investment Lifecycle.

Although the Capital Framework does not cover Stage 3 - Procure and Stage 4 – Implement, it has intrinsic implications for these stages, particularly in relation to the monitoring and reporting of risk, contingency and benefits realisation. Procurement ACT supports the activities within Stage 3 - Procure. Major Projects Canberra (MPC) administers the Project Delivery Framework which supports Agencies through Stage 3 – Procure and Stage 4 – Implement. For more information on the Project Delivery Framework contact the MPC Project Management Office.

Tier identification

The Tier assessment applies to a tailored, risk-based approach to project analysis for proposed investments.

To identify a proposed investment's appropriate Tier, the Project Team needs to have an indicative understanding of the project's cost and risk profile, based on the outputs of the activities undertaken in Stage 1 – Develop of the Capital Framework (preliminary scope, risk and delivery analysis, the ILM process and the EPP).

The role of risk in identifying the Tier is to ensure that the level of assessment is appropriate for each project and to mitigate the potential for significant additional work or rework. For more information on the preliminary risk assessment, refer to the next section.

The Project Team should assign the project's Tier in accordance with the matrix shown in the diagram below. The Tier assessment of some projects, Programs or Precincts may differ from the matrix shown below if agreed in the EPP (refer to the EPP Guidelines).

Tier classification matrix

Value >>	< $25m	$25m - $100m	> $100m
High Risk	Tier 2	Tier 1	Tier 1
Medium Risk	Tier 3	Tier 2	Tier 1
Low Risk	Tier 3	Tier 2	Tier 1

Figure 52: Tier classification matrix, ACT Government

The Project Team should identify the risk level of the project based on the descriptions provided in the table below. Each risk level may include a combination of risk types. The Consequence, Likelihood and Impact of each risk type will designate the risk level of the project.

Risk level	Description
High Risk	Projects generally should be classified as high risk if the Territory has limited or no experience developing, delivering and operating a project with similar characteristics. Additionally, the project should be classified as high-risk when the project includes new, complex or unique characteristics. This may include projects that: • Use a new financing strategy (financial risk) • Are located on a site within a designated area (which has special characteristics of the National Capital) (planning risk) • Have significant stakeholder interest and requires extensive community engagement (stakeholder risk) • Use a new, or an Alliance, Managing Contractor or Public Private Partnership (PPP), delivery model • May result in, or be related to, political, reputational or strategic issues • Require integration with surrounding or interrelated projects (design and integration risks).
Medium Risk	Projects may be classified as medium risk when the Territory has some experience developing, delivering and operating projects with similar characteristics. The project may also involve medium-level risks related to: • Integration with surrounding or interrelated projects (design and integration risks) • Some stakeholder interest (stakeholder risk) • The location or site of the project (site or planning risks) • The approval process for the project.
Low Risk	Projects should be classified as low risk when the Territory has extensive experience developing, delivering and operating projects with similar or the same characteristics. This may include 'business as usual' projects.

Figure 53: Risk Levels, ACT Government

Tier requirements

The Project Team should undertake the risk analysis process documented in these Guidelines for projects in all three Tiers, to the level of detail appropriate for the project's Tier. However, the risk quantification methodology used by the Project Team depends on the project's Tier.

For Tier 1 projects, the Project Team should quantify risks using stochastic techniques based on quantifications of the Consequences of risk events and of their Likelihoods (probabilities) of occurrence, in order to develop a project contingency allowance. The Project Team should develop a contingency allowance for each shortlisted project option. It is likely that the Project Team will be able to use much of the analysis for the recommended project option to estimate the contingency allowances for the other shortlisted project options.

For Tier 2 projects, the Project Team is also recommended to quantify risks using stochastic techniques. However, the Project Team should tailor the approach to suit the requirements of the project. Projects that are 'Business-as-Usual' may instead elect to use a deterministic approach if there are good data on project cost outturn compared to budget for similar projects. If the Project Team wishes to use a deterministic method to quantify risks, the team should discuss this with MPC, FABG and ICA during the Early Presentation of Project.

For Tier 3 projects, the Project Team normally can quantify risks using deterministic techniques.

For Programs and Precincts, the Project Team must undertake the risk analysis process documented in these Guidelines for the full Program or Precinct, including the development of a Risk Register. The Project Team should discuss the method to develop contingency allowances for the Program and Precinct with MPC, FABG and ICA.

15. Appendix H – International Practices of Contingency Management

This review of publicly available information on contingency management outside of Australia focused on the top five export markets for Australia plus a selected common law jurisdiction at the time of this publication. It is recommended that the sources be regularly checked for any updates. The search utilized generative artificial intelligence and traditional research techniques.

Generally, the research found that the approach of China, Japan, Korea, India, Singapore relied on ISO standards for quality management systems and risk management and either adopted these without localization or, in some cases, local versions of the standards have been developed. ISO standards for quality management systems and risk management do not specify prescriptively how to calculate and manage contingency.

1.1 China

No specific reference to contingency management was identified at the time of this publication.

1.2 Japan

No specific reference to contingency management was identified at the time of this publication.

1.3 Korea

No specific reference to contingency management was identified at the time of this publication.

1.4 India

No specific reference to contingency management was identified at the time of this publication.

1.5 USA

Guidelines for contingency management are published by industry bodies such as the Project Management Institute and AACE International. Specific guidelines have been located for U.S. DOT Federal Railroad Administration & Federal Transit Administration who have procedures on the monitoring and oversight of Risk and Contingency, salient points include:

- Requirement for projects to have a Risk and Contingency Management Plan (RCMP) which contains topics on primary and secondary mitigations, insurance, risk management, risk review process, cost and schedule contingency management.
- Requirements for projects to have monitoring and oversight of the RCMP by independent parties.
- Methods used for assessing the level and adequacy of contingency include:
    - Assessing that minimum requirements of RCMP are established. i.e. appropriate risk register, associated mitigations are in place and being monitored, clear identification of cost and schedule contingencies, process for tracking and managing current minimum levels of contingency and contingency drawdown and governance is established.

- Validation of basic project elements such as scope, design quality, cost estimate and schedule. The known projects elements are required to be validated, and if necessary, adjusted before attempting to assess the project's uncertain elements.

- Assess the process of risk identification and risk modelling. Including the establishment of risk-range cost estimates and distribution. That an appropriate risk modelling method has been used such as, stochastic (Monte Carlo), risk range or expected value.

- Use bottom-up cost risk assessment (Monte Carlo approach) and top-down approach (beta range model) together to test a project's risk exposure.

- Beta range models use broad parameters derived from historical project information to create a beta range factor. These factors are applied to the lower bound cost estimate for an element to create lower and upper bounds of a cost element.

- The lower bound is established by a review of project's cost estimate, removing contingencies (Stripped Cost Estimate) and adjusted by reviewing scope, cost, contract packaging, or other information through prior reviews, analyses, and/or workshops to create an Adjusted Cost Estimate). The Adjusted Cost Estimate, stripped of its contingencies, establishes a highly optimistic level of cost forecast (the lower bound) useful for assessing risk.

- Minimum levels of contingency are recommended

  - At nominal 15% design level, 40% contingency;

  - At nominal 30% design level, 33% contingency;

  - At nominal 60% design level, 26% contingency;

  - At nominal 95% design level (pre-bid), 20% contingency;

  - At nominal 100% design level (post-bid/construction start), 13% contingency;

  - At nominal 20% construction completion, 9% contingency;

  - At nominal 50% construction completion, 7% contingency;

  - At Revenue Service Date (RSD), 1% contingency.

Source: Oversight Procedure 40 – Risk and Contingency Review, U.S. Federal Transit Administration. TPM-20 Office of Capital Project Management, Project Management Oversight.

- Cost contingency draw down curves are used to monitor contingency adequacy during project execution. The curves indicate minimum contingency levels that must remain in the project budget at any given point in time. The draw-down curve is used to protect from inappropriately early draw down of contingency funds.

- Schedule contingency is managed in a similar fashion.

- Other

  - Risks mitigations are classified as either primary or secondary mitigations. Primary mitigations may include items such as completing design or conducting a geotechnical survey. Secondary mitigations are pre-planned, potential scope or process changes that may be triggered when risk events occur that cause the overuse of project contingencies. The process enables the project to make cost reductions in a planned and orderly process and preserves contingencies for use later in the project. It is not value engineering.

- Contingencies are set aside amounts (cost and time) that are included in the overall cost and schedule targets. The amounts are used to overcome increases in cost or schedule that are due to potential risks, and for which no other mitigation measure is available.

References:

- U.S. DOT Federal Railroad Administration. Office of Passenger and Freight Programmes, Monitoring Procedure 40 – Risk and Contingency Review

- U.S. DOT Federal Transit Administration TPM-20 Office of Capital Project Management, Project Management Oversight.

1.6 Singapore

No specific reference to contingency management was identified at the time of this publication.

1.7 New Zealand

Guidelines for contingency management are published Ministry of Business Innovation and Employment with limited guidance on how to calculate and / or appropriate levels of contingency.

New Zealand Gateway Reviews, Lessons Learned Report 2017 recommends:

- Conduct a Quantitative Risk Analysis (QRA) of costs and schedule. QRA is an inexpensive tool to reduce uncertainty around risk and cost estimates. If carried out during the Indicative Business Case stage, it can give early visibility of risks that may affect planning.

- There is a ministerial expectation that major high-risk projects will use QRA in the Detailed Business Case to determine contingency and identify the two or three risks with the greatest likelihood of affecting schedule and cost.

References:

- Risk Management, Construction Procurement Guidelines, October 2019 v2.0, New Zealand Government Procurement.

- New Zealand Gateway Reviews, Lessons Learned Report 2017, Fourth Lesson Learned Report: New Zealand Gateway Reviews 151 -200, New Zealand Government.

1.8 United Kingdom

The Infrastructure and Project Authority publishes guidance that covers cost estimating, project development, amongst others. The salient points include:

- Project risks and mitigations should be used to inform overall project contingency which should be included in the anticipated final cost. Contingency should be used to address the risk that materialize on the project. As a project becomes more defined, the size and allocation of contingency must be revised. Further, projects should not reallocate or repurpose contingency even if they stay within the same project cost envelope.

- Allocation of contingency should be driven by the risk ownership of the project management, whilst sponsors may hold "unallocated contingency" across projects and portfolios.

Anticipated Final Cost (AFC)

The AFC is the value that the project should expect as the target out-turn, addressing the various cost components. It is the aggregate of the value of the base cost estimate, adjusted to address cost estimating uncertainty, plus an allowance for project contingency to address expected risks. The cost estimate must present the "Median Scenario/P-50 equivalent" cost, meaning that the estimator believes that there are comparable probabilities of the actual outcome to be higher or lower than this threshold.

The expected accuracy range presents the cost estimate as three values which establish a probable cost envelope. They present the most-likely out-turn cost, reasonably optimistic and pessimistic out-turn costs based on the level of scope definition and taking into consideration some contingency for unknown risks threats.

Project Development Guidance

Project Development Guidance recommends as good practice to confirm uncertainties are progressively locked down through the project lifecycle including:

- use gateways to lock down uncertainty. This is most difficult on novel or highly complex schemes, where there is a lack of benchmarking or reference class data.
- It is crucial the estimates for cost and time are prepared with a clear strategy for dealing with all residual uncertainties, otherwise the actual cost and time might vary significantly from the estimates
- Where early-stage uncertainties are unlocked (because of poorly defined benefits or user requirements), significant and unexpected variation can remain in the delivery stage.
- Project Development Routemap recommends good practice:
    - Applying different techniques to calculate the project's risk exposure
    - Reference class forecasting (RCF) + Quantitative Risk Assessment (QRA) can be used to quantify risk exposure and to inform level of project contingency required.
    - RFC is a top-down approach that uses past project results and relates them to the project in question
    - QRA is generated bottom-up by identifying specific risks, costing their impacts
    - The degree of project definition and organizational maturity (in term of capability and processes) will determine at what point the risk model will change from top-down RFC to a bottom-up QRA. The more mature an organisation is, the earlier the transition point.
- Alternative models for allocating contingency
    - Contingency allocated in accordance with exposure

- Contingency allocated to overall project confidence levels
- Contingency held at portfolio programme and project levels

- Contingency should be allocated based on accountability for managing risk ensuring:
  - Accountability for managing risk should be clear at each level of the project governance structure

References

- Cost Estimating Guidance - GOV.UK
- Project Development Routemap - GOV.UK

1.9 Hong Kong

The Development Bureau of Hong Kong is responsible for publishing guidance on the administration of government projects, that cover cost estimating, project development, amongst others. The salient points include:

- Quantitative analysis methods such as expected value, simulation, sensitivity analysis, decision trees can be used to refine contingency setting and monitor contingency draw down.
- The most common methods in the construction context are simulation and expected value.
- All quantitative risk analysis methods rely on information from a qualitative risk management process which must be robust for the qualitative methods to be effective.
- Sensitivity analysis can be carried out on both the expected value and simulation techniques. Sensitivity analysis involves altering the parameters of a particular set of probability or impact variables for a particular activity and then re-running the simulation.
- Decision trees assess the level of risk associated with various courses of actions following a decision and therefore, may be used for risk-based decision making.

The Hong Kong Government has published a practice note Estimating using Risk analysis (WBTC No. 22/93 Appendix A). The purpose of the practice note is to provide a structured, logical, accountable, traceable process for determining the amount of contingency in an estimate. The salient points include:

- There are two types of estimates:
  - (a) Base Estimate. The "risk free" part i.e. the certain features, the work that is unlikely to change, prepared by pricing the known features using current rates and prices and standard techniques appropriate to the stage of the project.
  - (b) Average Risk Estimate. The total of all Average Risk Allowances plus the Base Estimate.
- There are two types of Risk Assessment:
  - (a) Fixed Risk Assessment. A risk which will be incurred as a whole or not at all. Although an "all or nothing" allowance, the likelihood of it occurring can vary and this likelihood or probability also needs to be assessed.

- (b) Variable Risk Assessment. A (usually certain) risk relating to an event or feature which can occur in varying degrees, with correspondingly varying probabilities.

- There are two types of Risk Allowance:
  - (a) Maximum Risk Allowance The estimated sum of money required if a risk were to occur to its full extent. It is only used as the basis of comparison with the Average Risk Allowance and is not added into the estimate build-up.
  - (b) Average Risk Allowance (i) For a Fixed Risk, it is the product of the Maximum Risk (ii) For a Variable Risk, it is the estimated sum of money which is assessed as having a fifty/fifty chance (ie. 50% probability) of being exceeded.
- Iterative approach to re-estimating, as each resolved risk becomes a known requirement, its cist allowance is added to the Base Estimate. Increases are funded from contingencies; savings are returned to the contingency. Generally, the Average Risk Estimate is not reduced except where there is a relatively low total of unresolved risk.
- Project contingency normally represents about 10% of the project cost.

References:

- Risk Management for Public Works, Risk Management User Manual, May 2021, The Government of Hong Kong special Administrative Region, Development Bureau.
- Appendix 4.15 Estimating Using Risk Analysis (ERA) Practice Note, Project Administration Handbook for Civil Engineering Works, 2022 Edition.
- Note for Public Works Subcommittee of Finance Committee, Estimation of Project Cost (PWSCI (2013-14)10.

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