



HM Treasury

# **The Aqua Book:**

guidance on producing quality  
analysis for government

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March 2015





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guidance on producing quality analysis  
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# Foreword

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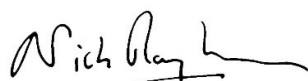
Analysis and the use of evidence informs every decision we make as civil servants. It also underpins the civil service values of integrity, honesty, objectivity and impartiality by which we are held to account. The breadth of topics on which the civil service provides advice is extraordinary – from the health of the public finances to predicting the spread of pandemic flu, from forecasting our future energy needs to the complex commercial decisions that underpin our infrastructure ambitions. High quality analysis is therefore fundamental to the civil service's effectiveness.

I see high quality analysis all the time as I look at the complex and varied issues with which civil servants grapple. But since the difficulties with the Intercity West Coast franchise competition, the quality of our analysis has, rightly, been scrutinised.

In October 2012, I was commissioned to review the quality assurance of analytical models across government. The recommendations of that review were written with the aim to extend best practice across the whole of government. They focus on quality assurance, governance and accountability, culture, capacity, capability and control.

Continuous challenge and improvement is essential to ensure that the people we serve – ministers and, of course, the public – have trust in our analysis. Following the *Review of quality assurance of government analytical models*, a cross-departmental working group on analytical quality assurance was established. The Aqua Book is one of the products this group has developed. It outlines a sensible, achievable set of principles. These principles will help ensure that our work can be trusted to inform good decision making. I'm grateful to all those who contributed to it.

As the Aqua Book points out, we need to create an environment where the skills and time to deliver analysis is respected, and a culture that values it is encouraged. I commend it to you.



Nick Macpherson

Permanent Secretary to the Treasury





# 1 Introduction

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## Fit-for-purpose analysis in government

**1.1** Analysis is vital to the success of policy development and the delivery of programmes, projects and operational services. Analysis helps to shape and appraise options, provides insight into how complex systems work and behave, measures system performance and improves efficiency.

**1.2** However, if analysis and any supporting models, data and assumptions are not fit-for-purpose then the consequences can be severe ranging from financial loss through to reputational damage and legal challenge. In the most severe of consequences, lives and livelihoods can be affected.

**1.3** The InterCity West Coast franchise competition of 2012 illustrated both the importance of analysis and modelling in delivering a major government project and the consequences when things go wrong. The subsequent *Review of quality assurance of government analytical models*<sup>1</sup> found significant variation in the type and nature of quality assurance used within, and between, departments. Much of this was to be expected given the differences in organisations' remits, and the levels of risk in question.

**1.4** The review's work highlighted the benefits of creating a work environment that expects thorough quality assurance – including allocating clear responsibility for key models and how they are used, and giving specialist staff adequate time to manage quality assurance effectively. The review provided headline recommendations for departments and their arm's length bodies, including:

- All business critical models in government should have appropriate quality assurance of their inputs, methodology and outputs in the context of the risks their use represents. If unavoidable time constraints prevent this happening then this should be explicitly acknowledged and reported;
- All business critical models in government should be managed within a framework that ensures appropriately specialist staff are responsible for developing and using the models as well as quality assurance;
- There should be a single Senior Responsible Owner for each model ("a Model SRO") through its lifecycle, and clarification from the outset on how quality assurance is to be managed. Key submissions using results from the model should summarise the quality assurance that has been undertaken, including the extent of expert scrutiny and challenge. They should also confirm that the Model SRO is content that the quality assurance process is compliant and appropriate, that model risks, limitations and major assumptions are understood by users of the model, and the use of the model output is appropriate.

**1.5** The review found that the many components of best practice in quality assurance fall under 2 headings: the modelling environment, which can be generalised to cover the wider environment in which analysis takes place, and process.

**1.6** The right modelling environment involves a culture where leaders value and recognise good quality assurance. It requires adequate capacity, including specialist skills and sufficient time to

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<sup>1</sup> Review of quality assurance of government models, <https://www.gov.uk/government/publications/review-of-quality-assurance-of-government-models>, Accessed February 2015.

conduct quality assurance effectively. It also needs a set of controls, including a clear internal chain of responsibility and a route for challenge where analysts have concerns

1.7 The process side, on the other hand, is about a systematic approach to make quality assurance accessible, easy and comprehensive. It requires clear guidance on quality assurance and clear documentation for every model.

## Quality principles

1.8 Following the review, the cross-government working group on analytical quality assurance was established to identify and share best practice across government. The Aqua Book is one of the products this group has developed. It draws together existing practice from departments and best practice from analysts across a variety of analytical professions within government. The Aqua Book builds upon the *Review of quality assurance of government analytical models* and expands the principles to cover all types of analysis as there is much common ground.

1.9 The Aqua Book sits underneath the *Review of quality assurance of government analytical models* as supporting material to help those implementing the review's recommendations and more generally to promote analytical quality. It should be read in this context: as providing further advice rather than making specific or binding recommendations.

1.10 No single piece of guidance can provide a route to a definitive assessment of whether a piece of analysis is of sufficient quality for an intended purpose. However, the Aqua Book sets out the following principles of analytical quality assurance that will help to support commissioning and delivery of fit-for-purpose analysis:

- **Proportionality of response:** The extent of the analytical quality assurance effort should be proportionate in response to the risks associated with the intended use of the analysis. These risks include financial, legal, operational and reputational impacts. In addition, analysis that is frequently used to support a decision-making process may require a more comprehensive analytical quality assurance response.
- **Assurance throughout development:** Quality assurance considerations should be taken into account throughout the life cycle of the analysis and not just at the end. Effective communication is crucial when understanding the problem, designing the analytical approach, conducting the analysis and relaying the outputs.
- **Verification and validation:** Analytical quality assurance is more than checking that the analysis is error-free and satisfies its specification (verification). It must also include checks that the analysis is appropriate, i.e. fit for the purpose for which it is being used (validation).
- **Analysis with RIGOUR:** Quality analysis needs to be repeatable, independent, grounded in reality, objective, have understood and managed uncertainty, and the results should address the initial question robustly. In particular, it is important to accept that uncertainty is inherent within the inputs and outputs of any piece of analysis. It is important to establish how much we can rely upon the analysis for a given problem.

## Accountability

1.11 Following the *Review of quality assurance of government analytical models*, all business critical government models should have a single *model* Senior Responsible Officer ("a Model SRO") through their lifecycle. The key prerequisites are that this should be a named individual

with sufficient seniority to take responsibility for the model throughout its life cycle and sign-off that it is fit-for-purpose, prior to its use.

1.12 This principle can be generalised to cover any business critical *analysis* and there may be a need for interaction between a model SRO and those responsible for a wider analytical project to ensure that quality assurance considerations are fit-for-purpose and are appropriately communicated.

1.13 Not all analysis will be business-critical or use business-critical models. However, it remains good practice to ensure that there is a single accountable individual with ultimate responsibility for the overall quality of the analysis, at all stages of the analytical cycle. For business-critical analysis, the single accountable individual should be of sufficient seniority for the associated risks.

#### Box 1.A: Accountability, responsibility and authority

It is important that departments and agencies have a cascade of accountability and responsibility from their senior management teams down throughout their organisation.

At the senior management level (e.g. the senior civil service), it is important that the accountability and responsibility for establishing the analytical quality assurance environment and processes are clearly defined. In addition, a mechanism should be established that determines the senior manager accountability for the analytical quality assurance activities supporting business critical analysis.

The senior accountable person for analytical quality assurance must ask the right questions and satisfy themselves that appropriate analytical quality assurance is being provided – but they do not need to be a specialist (or have an analytical background) to ask these questions. Instead, when assigning roles and responsibilities, departments must give careful thought as to the nature of the project, and ensure that those providing analytical quality assurance are sufficiently senior and sufficiently experienced to take responsibility for the analysis in question.

## Roles and responsibilities

1.14 To support those responsible for providing analytical quality assurance, and to deliver the quality principles set out above, it is useful to consider the wider activities that are involved:

- commissioning analysis
- providing analytical assurance
- delivering the analysis itself

1.15 Those accountable for the analysis may, or may not, be directly involved in the above activities, but they need to ensure that all 3 are being carried out to a suitable standard. In either case, governance arrangements for the wider programme requiring the analysis should consider analytical quality assurance needs.

## Commissioning analysis

1.16 The person **commissioning analysis** must ensure that those doing the analysis understand the context of the question being asked so that they understand the likely risks and can determine what the appropriate analytical and quality assurance response should be. The commissioner has a role to ensure that there is sufficient time and resource for the required level of assurance to be delivered and that they understand the associated risks when time and resource pressures are unavoidable. When using the analysis, the commissioner must

understand the strengths, limitations, inherent uncertainty and the context of the analysis so that the results are interpreted correctly.

## Analytical assurance

1.17 The person responsible for **providing analytical assurance** must ensure they receive evidence that appropriate analytical quality assurance activities have been conducted and that residual uncertainties and risks are understood and are communicated. Typically this would be done by a senior analyst or analytical project manager who is not one of the analysts delivering the analysis. This activity takes place throughout the life cycle of the analysis from understanding the problem, through designing the analytical approach, conducting the analysis and relaying the outputs. The analytical assurer is responsible for advising the commissioner on whether appropriate analytical quality assurance has taken place and advising them of any outstanding risks. The Aqua Book presents examples of the different type of assurance activity that can be undertaken including analyst-led testing, peer review and audits. For business critical analysis, more thorough assurance activities may be required.

## Delivering analysis

1.18 The people responsible for **delivering the analysis** frequently assist the commissioner in structuring the question in order to ensure the appropriate analysis is performed. Some analysis may require external specialists and therefore analysts may also have responsibilities as part of the procurement process. Analysts, including those 3<sup>rd</sup> parties providing analysis, should also provide proportionate documentation that outlines the verification and validation activities undertaken and the associated conclusion. In addition, analysts should determine and communicate the uncertainty associated with the outputs of their analysis so that commissioners and users of analysis can make informed decisions.

### Box 1.B: Local business practices and nomenclature

Each department and agency will require its own business processes and nomenclature to reflect their organisation's needs. Whilst the Aqua Book refers to commissioners, analysts and analytical assurers, it is the responsibilities identified that are important, not the name of the role. In addition, the Aqua Book makes no statement of the particular level of seniority or grade of each of the occupiers of the roles: this will vary from project to project and between departments and agencies.

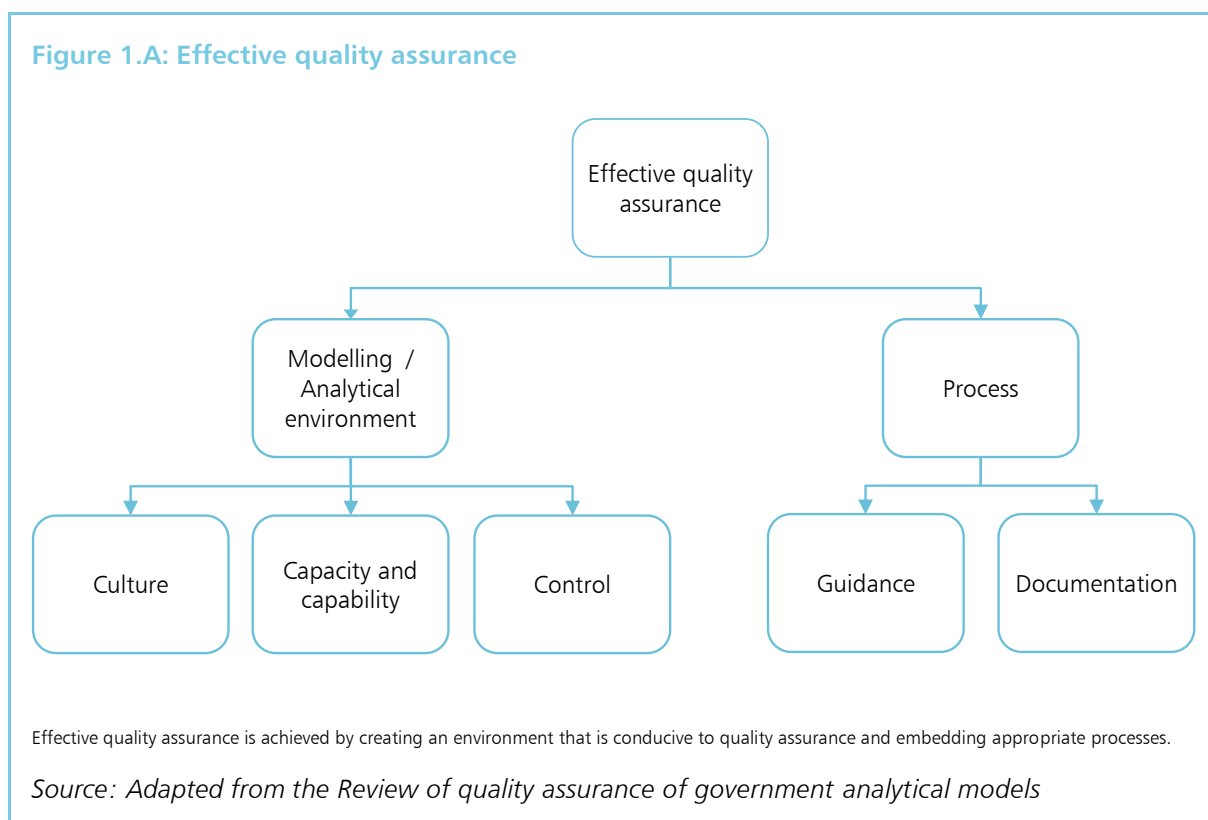
At any time, analysts should refer to and operate in adherence to their local business processes and existing guidance on analytical quality assurance.

## Quality assurance

1.19 Quality assurance is a key aspect of the effective risk management of analysis and the decisions it helps inform. Sitting above the many principles and techniques which ensure good quality assurance, there are 2 main requirements:

- **environment:** creating the conditions in which quality assurance processes can operate effectively, facilitated by a culture that values quality assurance and welcomes effective challenge, a well understood chain of responsibility and sufficient time for quality assurance; and

- **process:** establishing a clear process for every stage of the analytical life-cycle. This includes working alongside the commissioner and any other users to ensure there is a shared understanding about the purpose and any limitations of the analysis.



### 1.20 Environmental considerations includes creating:

- a culture where quality assurance is highly valued, and there are strong incentives to deliver appropriate quality assurance, backed by effective scrutiny of analysis, supporting models, assumptions and data
- capacity and capability where specialist staff have sufficient time built-in for quality assurance, and are able to draw on expertise and experience across government and beyond
- adequate controls, including a clear governance framework

1.21 An effective **process** involves on-going engagement between specialists and customers to ensure there is a shared understanding about the purpose and any limitations of the analysis. This includes understanding the consequences of sensitivity analysis, and the impact of the uncertainty associated with inputs, assumptions and outputs. This needs to be backed by:

- clear guidance that sets out the key considerations driving the approach to quality assurance
- clear documentation about the analysis and the quality assurance process

1.22 Further details can be found in the *Review of quality assurance of government analytical models*.

## The Aqua Book and other resources

1.23 Combining the high-level principles of analytical quality assurance, together with clarified roles and responsibilities, the Aqua Book will help ensure that analysis is fit-for-purpose. For

those who commission or use analysis, a short overview provides sufficient depth to be able to ask the right questions about quality. Specific information targeted at the analyst and the analytical assurer covers more technical considerations.

1.24 The Aqua Book is a cornerstone of a suite of resources aimed at improving analytical quality assurance. A range of templates and guidance on specific analysis topics and analysis techniques that are frequently encountered within government analysis will supplement the resource. The aim of these resources is to:

- help departments and agencies embed an analytical environment that will assist the delivery of quality analysis by strengthening existing processes
- deliver greater consistency in the approach to analytical quality assurance processes across government
- ensure commissioners of analysis have greater confidence in analysis

1.25 The Aqua Book is divided into 3 parts:

- Part A is designed for the commissioners of analysis and those who have accountability for a programme in which analysis is used. It provides an overview of the each of the topics that are important for ensuring that analysis is fit-for-purpose.
- Part B is designed for the analytical assurer and the analyst and expands that material presented in Part A. It provides additional guidance on verification, validation and uncertainty.
- The Aqua Book draws together information that will be of benefit to all departments, agencies and analysts. However specific guidance covering verification and validation of particular types of analysis, as well as example templates and documentation, are also beneficial. Part C introduces the additional supporting resources that accompany the Aqua Book.

# Part A

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This part of the Aqua Book is written for commissioners of analysis and those that have accountability for programmes where analysis is important to successful delivery.

Chapter 2 explains how commissioning analysis relates to the problem under investigation and the decision the analysis is helping to inform. This chapter provides an overview of the types of analysis that may be commissioned in order to support the decision-maker. Analytical projects follow a similar cycle to other projects encountered in government, and a simplified analytical cycle is presented before 2 key themes are introduced: delivering quality analysis and working with uncertainty.

Chapter 3 provides an overview of how to commission analysis that will be fit-for-purpose. The commissioner of analysis plays an important role in the quality assurance of the analysis and this role throughout the analytical cycle is explained. To support the commissioner, the analytical assurer is there to provide the assurance that the analysis is fit-for-purpose.

Chapter 4 introduces the two main questions to be asked of any piece of analysis: is it the right analysis and has it been conducted correctly. This chapter provides an overview of the types of activity that can be undertaken to give the assurance required.

Chapter 5 explains that uncertainty is inherent in all analysis and needs to be acknowledged, understood, managed and clearly communicated. This chapter outlines why the commissioner of analysis should request an estimate of the uncertainty inherent within the analysis in order to make better informed decisions.





# Decision-making and analysis

## Box 2.A: Decision-making and analysis – key points

Decision-makers rely on various forms of analysis to inform their decisions.

Understanding the rationale for a decision enables the identification and appraisal of options. We can determine whether our desired outcome has been achieved by monitoring the impact of a decision and, if necessary, take further action as appropriate.

A variety of analytical approaches are used to build the evidence base that supports the decision-maker throughout the process. Different analysis may be used at different stages.

In order to ensure that the responsibilities required to deliver analysis that is fit-for-purpose, we identify a framework with 3 important roles: the commissioner of analysis, the analyst and the analytical assurer. Departments and agencies will wish to tailor these roles to meet their local business needs. Each has a role in ensuring the analysis is fit-for-purpose.

Some decisions are more important than others and the underlying analysis will require greater scrutiny. Departments and agencies may determine that a piece of analysis is business critical; in this situation, the governance arrangements and the seniority of the 3 responsibilities outlined in this framework – particular that of the analytical assurer – should be appropriate for the level of risk.

Analysis projects follow a similar life-cycle to that of other projects. Understanding the requirements enables planning and execution of the analysis. The analysis provides results that can be delivered and interpreted against the original requirements. In doing so, the requirements may evolve and further iterations of analysis may be commissioned.

Analysis should be fit-for-purpose. This is to say that there is sufficient confidence that the right analysis has been performed and appropriate analytical quality assurance activities have been conducted.

Even with the knowledge that the right analysis has been performed and appropriate analytical quality assurance activities have been completed, one artefact of analysis remains: the inherent uncertainty of the outcome of the decision. Uncertainty analysis helps to quantify and communicate the results of the analysis.

The analysis should be communicated to the commissioner with appropriate reference to the analytical quality assurance and statements of the residual uncertainty.

## Introduction

2.1 This chapter provides an overview of the decision-making process and how it relates to analytical projects. It also includes an overview of the analytical cycle alongside an introduction to the topics of quality analysis and uncertainty.

## Decision-making

2.2 Policy development and the delivery of programmes, projects and operational services frequently require identified issues to be overcome. The Green Book outlines the policy development cycle<sup>1</sup> – ROAMEF – which can be generalised to support any kind of decision-making and not just that associated with policy development. For any given decision, the rationale and objectives must be understood. Following appraisal of the options and implementation of the decision the outcome should be monitored, evaluated and the original rationale reconsidered with the completion of the feedback.

2.3 Each part of the ROAMEF cycle involves gathering and appraising evidence. Different analytical approaches will supplement the evidence base at each stage of the cycle. Examples of different analysis are provided in section 2.4.

## Types of analysis

2.4 Evidence bases contain a variety of facts, figures and analysis all of which must be correctly sourced, appraised and referenced. The analysis can vary widely between situations and many different types of analysis may be used to form the evidence base that supports the decision-making process. Examples of types of analysis that are frequently encountered in government are:

- actuarial analysis
- economic analysis
- financial analysis
- operational research / analysis
- scientific, technical and engineering research
- social research
- statistical analysis

2.5 Many branches of analysis make use of analytical models. Some analytical models can be used to inform several pieces of analysis and this flexibility and utility introduces the need for further quality considerations. Models are used for a variety of purposes including to:

- test systems under a variety of scenarios
- carry out investigations to understand a problem in more detail
- enable the monitoring of processes to facilitate risk management
- compare and appraise options
- understand past behaviour to better prepare for the future

2.6 Analytical tools – related to models – are frequently developed that allow the repetition of calculations to be performed in a more resource efficient manner.

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<sup>1</sup> The Green Book: appraisal and evaluation in central government, <https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-government>, Accessed February 2015.

### Box 2.B: Types of model

**Policy simulation:** to better understand policy options that drive government decisions. Ministers make policy decisions based on assessments of the likely cost and impact of policy choices. For example, the Intra Government Tax Benefit Model is used to analyse the distributional impact of tax and benefit changes.

**Forecasting:** to predict the future and inform today's policy choices. For example, demographic projections are essential to understand future cost pressures for education and healthcare. Equally, DECC use the updated Energy and Emissions Model to forecast the energy demand and emissions by fuel type and business sector under existing firm and funded policies.

**Financial evaluation:** to better understand future liabilities or costs. For example, modelling to understand the future cost implications of current pension commitments or the future cost of decommissioning existing nuclear energy plants.

**Procurement and commercial evaluation:** for the letting and management of large contracts, and to ensure value for money – for example, where a key service is to be contracted out as in the case of railway franchises or where a major IT upgrades/ new system is being introduced.

**Planning:** to make workforce decisions which affect the delivery of future services. For example, these models may be used to assess the number of trainee teachers, doctors and nurses required to deliver education and healthcare into the future.

**Science based:** to better understand and simulate the physical environment, in order to evaluate possible solutions or to mitigate potentially devastating impacts – for example, climate change and flood risk.

**Allocation of funds:** to determine how funds allocated to departments are then distributed to, for example: local authorities, schools or across the health service. These models are essential to ensure funds are allocated properly across the country to underpin local service delivery.

**Conceptual:** to help understand the key influences that are important to a system being modelled. A variety of problem-structuring techniques are used to develop conceptual models.

## Roles and responsibilities in analytical modelling projects

2.7 The *Review of quality assurance of government analytical models* introduced an important quality assurance role: all business critical models should have a single Senior Responsible Officer (a "Model SRO") throughout their development and application. The key prerequisites are that the Model SRO should be a named individual with sufficient seniority to take responsibility for the model throughout its life cycle and to provide sign-off that it is fit-for-purpose, prior to its use i.e. the Model SRO provides analytical assurance for the model and its outputs in each piece of analysis where that model is used.

2.8 Not all analysis will involve business-critical models so there may not be a formal requirement for a "Model SRO". However, it remains good practice to ensure that there is a single accountable individual with ultimate responsibility for the overall quality of the model, at all stages of the modelling cycle.

2.9 The concept of the Model SRO can be widened for any analytical project, whether it utilises modelling or other forms of analysis, that is used to draw conclusions that inform the decision making process. Good practice is to identify a single accountable individual with ultimate

responsibility for the overall quality of a piece of *analysis* that supports a specific decision making process (e.g. an *Analysis SRO*). For business critical analysis, the seniority of the person accountable for the analytical quality assurance should be determined based upon the risks associated with the analysis.

2.10 It is important that there is a clear cascade of accountability and responsibility from senior management teams down throughout the organisation so that the roles of a Model or Analysis SRO are understood within local governance arrangements.

#### Box 2.C: Accountability, responsibility and authority

Each department and agency will wish to review their local practices and guidance to ensure that there is an appropriate mechanism in place for determining the necessary accountabilities, responsibilities and authorities for the provision of analytical quality assurance. It is important that departments and agencies consider the complete cascade of accountability and responsibility from their senior management teams down throughout their organisation.

At the senior management level (e.g. the senior civil service), it is important that the accountability and responsibility for establishing the analytical quality assurance environment and processes are clearly defined. In addition, a mechanism should be established that determines the senior manager accountability for the analytical quality assurance activities supporting business critical analysis.

Departments and agencies will wish to tailor their accountability mechanism to accommodate local business practices and requirements, such as project risks, the need to work across organisational boundaries, and the interaction with other functions such as a *programme* Senior Responsible Owner and any existing analytical leadership structure.

The senior accountable person for analytical quality assurance must ask the right questions and satisfy themselves that appropriate analytical quality assurance is being provided – but they do not need to be a specialist (or have an analytical background) to ask these questions. Instead, when assigning roles and responsibilities, departments must give careful thought as to the nature of the project, and ensure that those providing analytical quality assurance are sufficiently senior and sufficiently experienced to take responsibility for the analysis in question.

To support the above, departments and agencies will wish to consider how those who manage, conduct and review business critical analysis should interact with the senior accountable person.

## Roles and responsibilities in analytical projects

2.11 The Aqua Book presents a framework for addressing the responsibilities required to ensure analysis is fit-for-purpose and builds upon the role of the Model SRO that was outlined in the *Review of quality assurance of government analytical models*.

2.12 While analysts play a large role in the successful delivery of analytical projects, there are 2 other important responsibilities: commissioning analysis, noting that this responsibility may be on the behalf of the ultimate customer or decision-maker, and assuring analysis.

2.13 The **commissioner** must ensure that the analyst understands the context of the question being asked. This is so that the latter understands and can assess the likely risks and determine what the appropriate analytical and quality assurance response should be. The commissioner has a role to ensure that there is sufficient time and resource for the required level of assurance to

be delivered and that they understand the associated risks when time and resource pressures are unavoidable. When using the analysis, the commissioner must be confident in the quality of the outputs and understand the strengths, limitations and contexts of the analysis so that the results are correctly interpreted.

**2.14** The **analytical assurer** – typically a senior analyst or analytical project manager, who is not one of the analysts delivering the analysis – must ensure they receive evidence of appropriate analytical quality assurance activity. These activities must take place throughout the life cycle of the analysis, from understanding the problem, through designing the analytical approach, conducting the analysis and relaying the outputs. They must ensure that the governance arrangements for the wider programme requiring the analysis consider analytical quality assurance needs. The analytical assurer is responsible for advising the commissioner on whether appropriate analytical quality assurance has taken place.

**2.15** The analytical assurer may or may not be the same person as the Analysis or Model SRO if the analysis uses a business critical model.

**2.16** The analytical assurer need not be an analyst. Projects that depend on highly complex and sophisticated analysis or modelling techniques may choose an analytical assurer with the ability to understand the technical or analytical considerations in order to “sense check” the outputs. Similarly, projects dependent on complex project or programme knowledge or theories may need an analytical assurer who can understand the sensitivities and uncertainties with the subject matter of the problem being addressed. The key requirement is that commissioners of analysis and analysts work closely together to ensure the analytical assurer is able to ask the right questions, fully understands the uses and limitations of the analysis and supporting model and is therefore able to sign-off to confirm it is fit-for-purpose.

**2.17** Analysis is frequently used to inform business critical decisions. In such situations, it is important that the decision-maker has sufficient assurance from a senior level within the organisation before taking the decision. For business critical analysis and modelling, the commissioner should be satisfied with the seniority of the analytical assurer.

**2.18** The analytical assurer sign-off provides confidence that:

- the quality assurance process used is compliant and appropriate
- analysis risks, limitations and major assumptions are understood by the users of the analysis
- the use of the analysis is appropriate

**2.19** The sign-off covers both development and output use, and potentially straddles analytical and policy disciplines. Therefore the analytical assurer may need to seek appropriate assurances from the other disciplines, to ensure there is a single coherent confirmation.

**2.20** Reconfirmation of the sign-off would be required if the analysis or supporting model was subsequently used for a purpose other than that for which it was originally designed or if the circumstances surrounding its use have changed. Where a supporting model is being used for a new purpose or project, the analytical assurer should obtain confirmation from the Model SRO that the model is suitable for the proposed use.

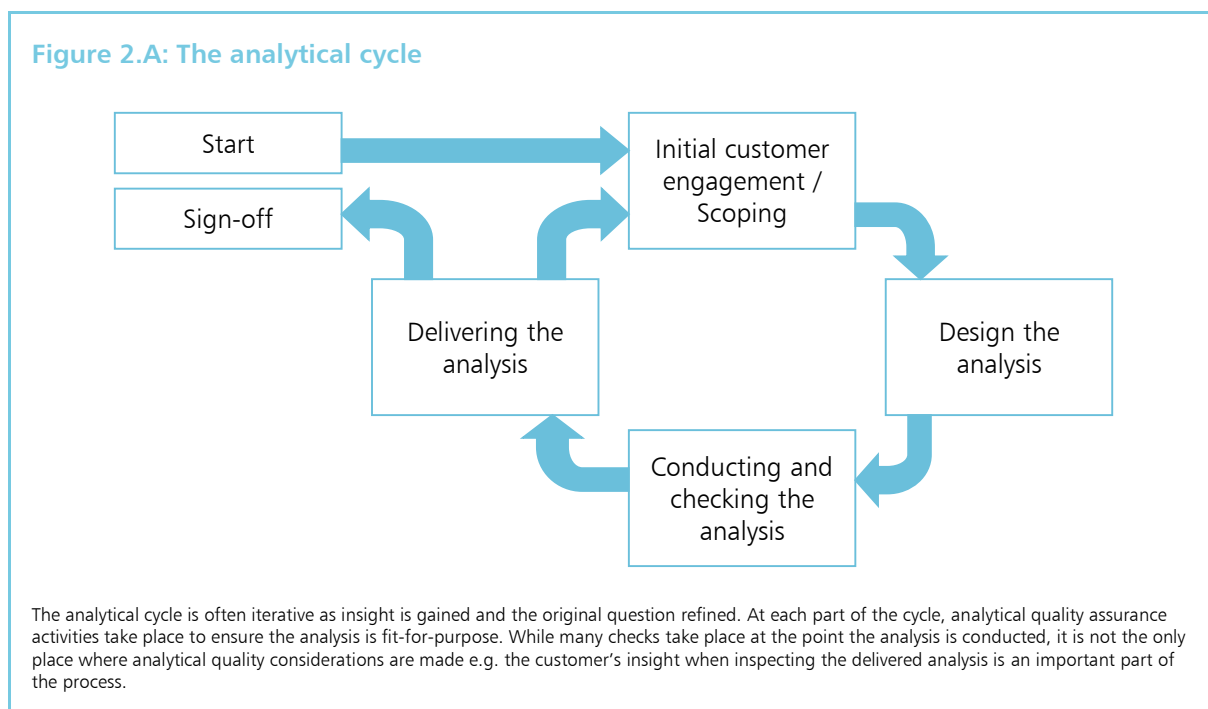
**2.21** If the analytical assurer cannot give their sign-off, this signals the analysis is not fit-for-purpose. In this case, the analysis should not be used until any specific issues are rectified. This may entail additional and / or alternative analysis or amending / re-developing any supporting model. In addition, further verification and validation checks may be required.

2.22 In addition to conducting the analysis, the **analyst** should also provide proportionate documentation that outlines the verification and validation activities that their analysis has been subjected to, in most cases by an analyst independent of the original analysis. In addition, the analyst should determine and communicate the uncertainty associated with the outputs of their analysis so that the commissioner can make informed decisions.

2.23 Departments and agencies will wish to tailor the presented framework to meet local business needs and the responsibilities may be distributed differently between organisations. It is the responsibilities that are important.

## The analytical cycle

2.24 For analysis to be used to effectively inform the decision-making process, it should be fit-for-purpose. When commissioning a piece of analysis, a project is established and the typical project trade-offs between time, resources and quality must be made, recorded and communicated to the analyst. The analyst may also have a role in working with the commissioner to establish the optimal balance of these constraints. The analytical process, outlined in Figure 2.A, provides a simplified outline of the main steps in the delivery of an analytical project. It is worth noting that local business practices may require additional stages to be included, such as formal approval stages, or use different terminology. However the core stages below can be found in most versions of the analytical cycle.



2.25 The first stage of the analytical cycle presented above is **initial customer engagement and scoping**. The commissioner plays an important role in communicating the commission and working with the analyst to ensure that an appropriate understanding of the problem is captured. There should be a clear understanding of the requirements and scope between the commissioner and the analyst at the commissioning stage.

2.26 During the **design** phase, the analyst will convert the commission into an analytical plan and will consider the inputs, possible analytical methods, and the expected outputs that will be produced. A degree of iteration between commissioner and analyst is to be expected as the analytical solution develops over time. The analytical assurer should at this stage check that the proposed design meets the commissioner's requirements.

2.27 When the analyst is **conducting** their analysis, they will work through their analytical plan and will maintain a record of their analysis noting any deviations. In addition, they will be performing their own tests to check their analysis and they will commission other verification and validation activities as required.

2.28 During the **delivery** phase, the commissioner has additional important roles, both in providing feedback to assist in the correct interpretation of the results and to determine whether the analysis has addressed their commission. Analytical projects frequently require further iteration, as the original question is often refined in the light of initial results, and so the risk of further extensions to the analysis should be taken into account and managed constructively.

## Delivering quality analysis

2.29 Before analytical output can be used to inform a decision, an appreciation of its fitness-for-purpose must be gained. This requires assuring that:

- the analysis undertaken aligns with its intended purpose and is relevant to the original problem
- the correct analysis has been performed
- the analysis has been conducted correctly and it is accurate
- the analytical output was provided in time to be useful and was presented in an accessible and clear manner
- the analysis is comparable and repeatable

2.30 By considering quality from the start of the analysis, the analysis is more likely to be right first time and thus save time and resources overall. However, quality management and control processes are also deployed to manage mistakes, handle changes to the analysis requirements and ensure the appropriate re-use of analysis for different purposes.

## Working with uncertainty

2.31 Uncertainty is all around us and takes a variety of forms and so it should be acknowledged, understood and managed. All analysis contains inherent uncertainties and there are implications for the commissioner as well as the analyst.

2.32 Understanding the sources of uncertainty and the impact it has on the analysis will enable the decision-maker to apply appropriate weight to the results of the analysis.

2.33 Where practicable, uncertainty should be quantified. However, even where this is impossible or impracticable given time and resource constraints, a qualitative assessment of the uncertainty should be made. This must be communicated alongside the results of the analysis.

2.34 Further detail is set out in Chapter 5.





# 3

## Commissioning analysis

### Box 3.A: Commission analysis – key points

Commissioners play a vital role in assuring that analysis is fit-for-purpose.

At the initial engagement phase, the commissioner must share knowledge and contextual information that will support the analyst, and vice versa.

When interpreting the results of a piece of analysis, the commissioner provides constructive challenge and, with the analyst, explores whether further analysis is required.

When analysis is business critical or may become so in the future, the commissioner will wish to ensure that the analytical assurer is of an appropriate seniority.

### Introduction

**3.1** This chapter provides an overview of what commissioners of analysis will experience when working with an analyst to develop a commission, through to taking delivery of the analytical output.

### Commissioners of analysis

**3.2** People at all levels of seniority commission analysis. For large programmes, where business critical decisions may be taken, the commissioner may be a programme senior responsible owner or someone acting on their behalf. This chapter provides guidance for the commissioner of analysis that will assist in ensuring that they receive fit-for-purpose analysis.

### Roles and responsibilities

**3.3** During the **engagement** phase of the analytical cycle, see Figure 2.A on page 18, the commissioner and the analyst shape the analysis by developing a shared understanding of the problem and the context. The commissioner is responsible for ensuring that:

- key aspects of the problem, scope and complexities, including programme constraints, are captured and clearly communicated
- they are available to actively engage with the analysts in order to appropriately shape the work
- appropriate resources, including specialists, are commissioned for the analysis
- they work with the analyst to ensure that the scope of the project is proportionate to the issue being addressed and that the criticality of the analysis is understood by the analyst and the analytical assurer
- there is proportionate governance in place to support the analysis and its role in the wider project or programme – this is particularly important if the analysis is supporting business critical decisions

**3.4** During the **design** and **conduct of analysis** phases, the commissioner may need to provide the analyst with important information for the analysis to proceed or be asked for other essential input. While it is not possible to provide an exhaustive list, the following are to be expected:

- identification of where the boundaries are between the problem in question and other topical issues or problem areas, including any dependencies
- agreement to the use of specific data and assumptions and provide agreement and sign-off to any assumptions that are developed as part of the project
- details of any changes to the scope and intended use of the analysis or change of importance of the analysis
- the level of precision and accuracy required

**3.5** As part of the **delivery** phase, once the analysis has been interpreted and the results have been provided, the commissioner should:

- ensure that there is an assessment of the level of analytical quality assurance of the analysis, making note of where there has been a trade-off between time, resources and quality
- ensure that an assessment of uncertainty has been provided and that the implications of the uncertainties are understood
- provide constructive challenge and scrutinise the analysis against other evidence that has been gathered
- ensure that the views of the analytical assurer on the level of analytical quality assurance and the residual uncertainty are considered clearly and effectively when the analysis is used. In particular, the onward communication of the analysis should include the context of the problem being considered and include information on residual uncertainty, risks, limitations and constraints

**3.6** The commissioner may also expect to take delivery of a variety of products that support and communicate the analysis. What is required will depend on the intended uses of the analysis.

# 4

# Quality analysis and quality assurance

## Box 4.A: Delivering quality analysis – key points

The process of ensuring that analysis is fit-for-purpose must be delivered in partnership across the suggested roles of commissioner, analyst, and analytical assurer. It is vital that the commissioner is confident that appropriate assurance is undertaken.

Effective communication and transparency are crucial throughout the whole analytical process: in understanding the problem, designing the analytical approach, conducting the analysis and relaying the outputs.

The scale and scope of the applied assurance needs to be proportionate to the purpose and constraints of the analysis – one size does not fit all analytical projects.

The need for assurance applies both to the whole analytical process and to smaller pieces of analysis or modelling that form part of a wider analytical programme.

Without a record of analytical assurance activities that have taken place, confidence in the analysis by the commissioner is reduced.

## Introduction

4.1 This chapter provides a high level summary of what is meant by quality analysis and places it in the context of the project trade-off between quality, time and resources.

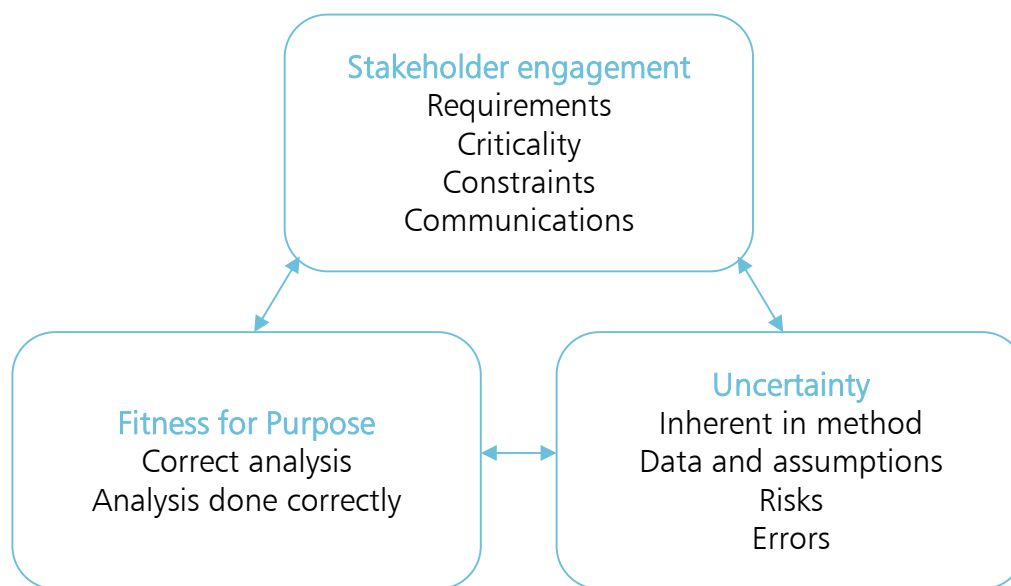
## Requirements for quality analysis

4.2 To deliver quality analysis means the following have been addressed:

- the interactions between the analyst and the stakeholders have been effectively managed to ensure an proportionate amount of effort goes into an analytical project
- confidence has been provided that the analytical output is fit-for-purpose
- uncertainty and risks associated with the analysis have been quantified, where appropriate, and managed actively

4.3 The above are linked strongly. If there is an increase in the time available for the analysis project, then more time may be available for analytical quality assurance activities or for quantifying the residual uncertainty. However, in situations where the requirements of the commission increase but more time is not available, there is a pressure which may result in a less than ideal level of analytical quality assurance and/or an insufficient understanding of uncertainties.

Figure 4.A: Analytical project



There is usually a trade-off between the available resources and time for the project and the level of analytical quality assurance activities that can be completed. With any analytical project, the competing aspects of the project need to be considered.

## Proportionate quality assurance

4.4 A wide range of factors will contribute to the overall quality of analysis. These include the skill and expertise of the analysts and users, the quality of the data and assumptions, the communication of the outputs and the understanding of the limitations and simplifications to the decision makers. All these factors play an important role in developing good quality analysis, and using it appropriately.

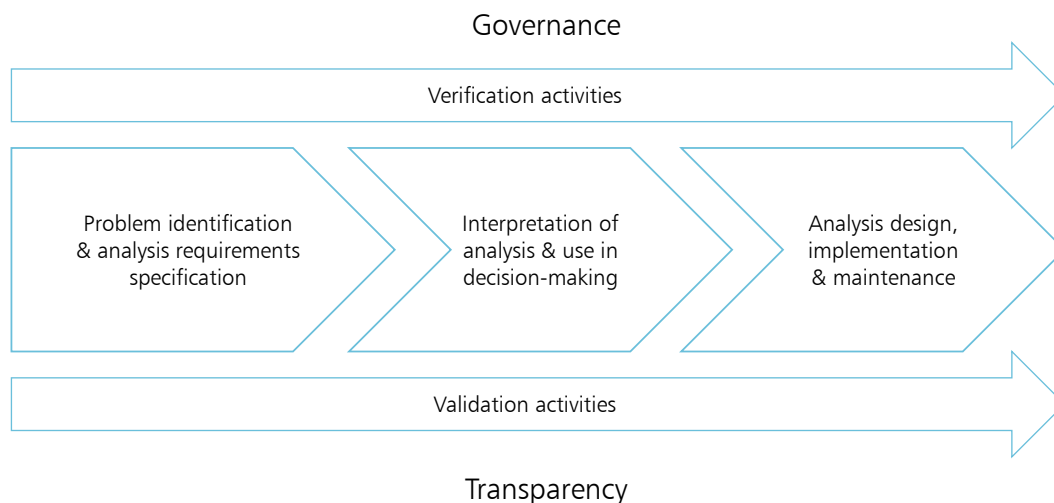
4.5 As the analysis progresses through the analytical cycle, there are various checks performed to ensure that the analysis is fit-for-purpose. Checks that confirm that the right analysis has been performed (known as validation) and that the analysis has been carried out correctly (known as verification) cover:

- the purpose for which analysis is developed
- the quality of any data inputs, and any assumptions that drive the analysis, including the estimation of parameters
- the use of the analysis' outputs
- the degree of risk and uncertainty in the analysis and its outputs

4.6 To support these activities, appropriate governance and transparency between the analyst, the commissioner and the analytical assurer is required as is illustrated in Figure 4.B.

4.7 A governance framework should identify clear lines of responsibility and accountability, and transparency can help to ensure analysis benefits from external scrutiny. Effective governance and transparency can be particularly important where analysis is highly complex, and a level of expertise is required to understand the analysis and the risks associated with its complexity. An organisation's culture can also play a role in ensuring that appropriate quality assurance is highly valued and seen as fundamental to analysis, model development and use.

**Figure 4.B: Quality assurance**



Quality assurance combines both verification and validation activities throughout the life cycle of the analysis and are supported through appropriate governance and transparency between analyst, commissioner and the analytical assurer.

*Source: Adapted from Review of quality assurance of government analytical models*

**4.8** There is no single “quality assurance” activity. Rather, quality assurance is delivered through a variety of different activities, each of which adds to the overall level of quality assurance. There can be no ‘one size fits all’ approach to determining what level of quality assurance is appropriate. There are good reasons why the approach to quality assurance will vary. These include the:

- type and complexity of the analysis
- novelty of the approach
- importance of the issue
- role and criticality of the analysis to the decision making process
- required precision of the analytical outputs
- amount of resource available for the analysis and the supporting assurance activities

**4.9** This illustrates the importance, at all stages of model or analysis development, that analysts and their customers take a conscious decision on the amount and type of quality assurance that is appropriate. When there are time or resource constraints, analytical quality assurance activities should not be ignored. In such situations, the analyst should use a risk-based approach to highlight the areas of greatest potential error and focus assurance efforts on these areas. It is also important that the impact of any reduction in the thoroughness of analytical quality assurance activities is understood by the commissioner.

## Quality assurance activities

**4.10** There are many different analytical assurance activities that can be undertaken. These include:

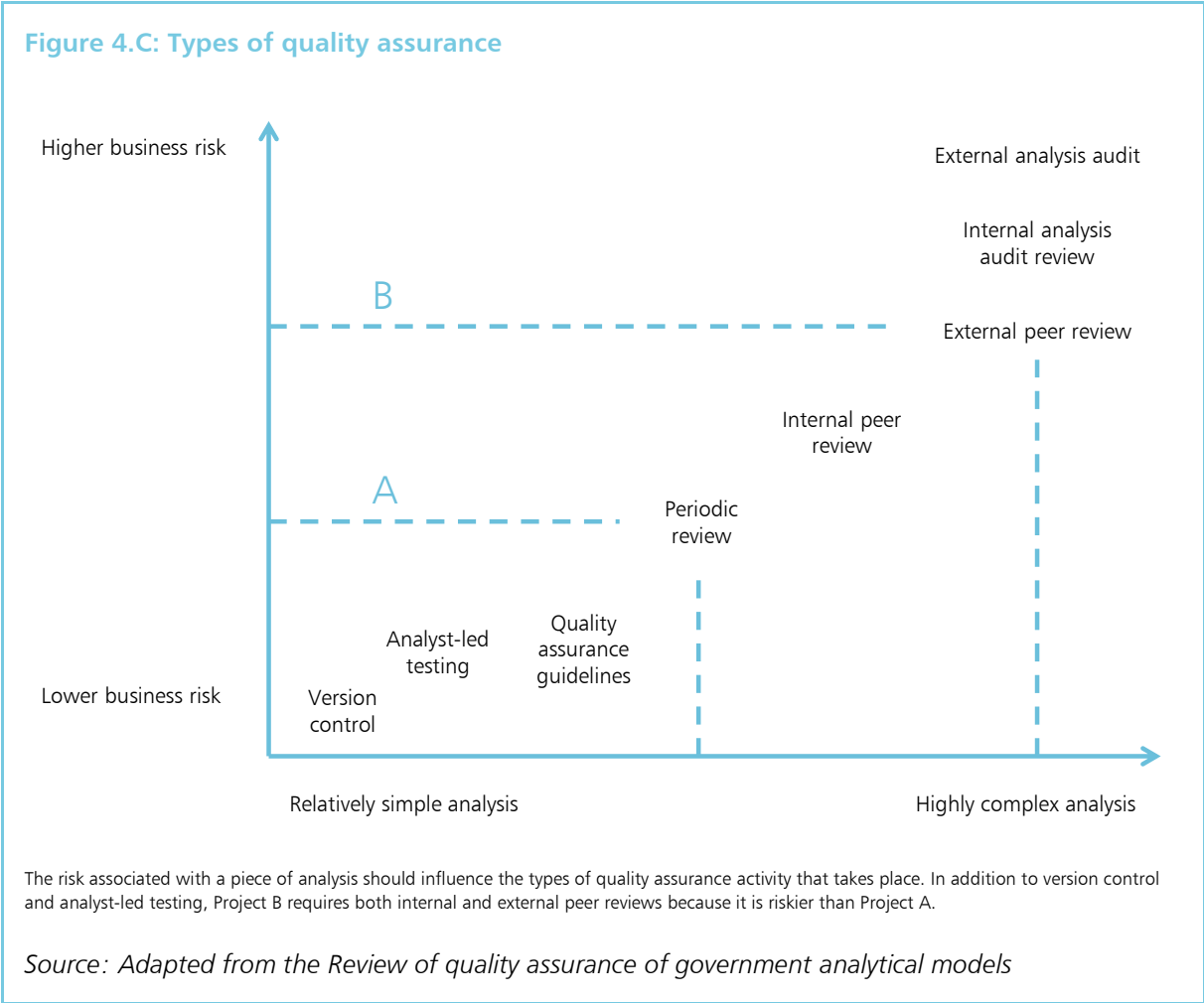
- analyst testing
- peer review
- analytical audits

4.11 Analyst testing covers those activities where the analyst builds in checks and processes to ensure that their analysis is correct.

4.12 Peer reviews may use internal or external parties to provide critical challenge of the analysis. The peer reviewer might consider the entire analytical process from the user requirements through to the interpretation of the results, or focus on particular aspects of the project. Peer review provides constructive challenge and a fresh perspective on an analytical project. The peer reviewers should be unfamiliar with the detail of a piece of analysis.

4.13 An independent analytical audit focuses on the processes that were followed and the evidence gathered to provide the analytical assurance. The use of version controls and the adherence to guidance and checklists would form part of an audit.

4.14 In Figure 4.C, 2 projects (A and B) that carry different levels of risk are shown as an example of what types of quality assurance activity are required. It would be typical for all projects to include those activities to the left and below the most intensive quality assurance activity.



#### Box 4.B: Commissioning peer reviews and audits

In the cases of very complex analysis or analysis that drives a significant business critical decision, commissioners of analysis or analytical assurers may wish to request a formal peer review or analytical quality assurance audit of a piece of analysis. In doing so, consideration of the requirements should be carefully developed to ensure the appropriate assurance is obtained. If commissioning an external peer review or audit, it may be beneficial to obtain an internal peer review or audit first to establish the appropriate specification. A formal peer review or audit should also be accounted for in the time and resource needs of the analysis and the impact on the wider programme should be understood and managed.

### Other supporting activities

**4.15** Governance arrangements can be used to improve the analytical quality assurance activities. For example, formally agreeing assumptions will reduce the need for reworking of the analysis and provides greater time for assurance.

**4.16** Greater transparency, e.g. through publication of inputs, assumptions and analysis, may enable wider engagement from experts who can provide external analytical assurance activities.





# 5 The importance and implications of uncertainty

## Box 5.A: The importance and implications of uncertainty – key points

Analysis is used to inform decision-makers about which option to choose, often in unique situations. For each option, a range of real outcomes may occur – the actual outcome is uncertain. Uncertainty will always exist and is inherent in any analysis and real-world decision.

Decision-makers aim to achieve their desired outcome by adopting strategies which increase the chances of better outcomes occurring while decreasing the chances of less favourable outcomes occurring. This requires good information on uncertainty, such as the range of outcomes that may occur together with the likelihoods for each option they can choose. “Best estimates” are not usually enough.

In the proposed responsibilities framework, commissioners should always expect information on uncertainty from analysts, and challenge them when it is absent, inadequate or ambiguous.

Analysts often describe uncertainty in qualitative terms, e.g. moderate uncertainty, high confidence, etc., that do not express the range or likelihood of alternative outcomes. Commissioners should request further information, however project constraints and practicalities may limit what can be achieved.

If the uncertainties are too complex for analysts to quantify, even approximately, the analysts should say so in order that the commissioner can take this into account.

When communicating with decision-makers and stakeholders, commissioners of analysis need to describe the extent to which outcomes are uncertain and the reasons for this.

## Introduction

5.1 This chapter discusses why understanding uncertainty is important and its implications for commissioning analysis and for communicating the analysis to decision-makers and stakeholders.

## The importance of understanding uncertainty

5.2 Decision-makers aim to choose options that lead to good outcomes. It is for this reason that commissioners request analysis: to assess the prospective outcomes of alternative options.

5.3 However, the outcome of a decision is never known perfectly in advance. For each option, a range of real outcomes is possible: **the outcome is uncertain.**

5.4 Many different factors can contribute to the uncertainty of outcomes. These include uncertainty about the resources available to implement the decision, uncertainty about how the implementation will unfold, uncertainty about its immediate effects and uncertainty about its wider or longer-term consequences. They also include the potential for unexpected events, which should be considered as ‘risks’, or changes in the contextual environment.

5.5 Analysis seeks to take account of these factors, but is itself subject to uncertainties in the evidence, data and assumptions that are used and how they are combined. In addition, there

may be errors in analysis, though these should be mitigated by appropriate quality assurance. All of these factors contribute to the overall uncertainty about the decision outcome.

**5.6 “Best estimates” of outcomes are not enough.** For example, the best estimate of an outcome might be better for option A compared to option B, but if the uncertainty of A is greater it might carry an unacceptable chance of much worse outcomes.

**5.7** To select the best option, decision-makers need to take account of the range of outcomes that may occur for each option and their relative likelihoods. In other words, they need information on uncertainty.

**5.8** Information on the overall uncertainty is needed to inform choices between options. In addition, information on the main sources of uncertainty is useful for identifying risks that can be mitigated and areas where the data or analysis can be improved. This should be discussed between the commissioner and the analyst and should form part of the quality assurance process.

**5.9** Uncertainty is generally increased in situations where there are time or resource pressures. This is accentuated in crisis situations, because they tend to involve new or unexpected problems and there is less time for investigation and analysis. Commissioners should expect to see greater levels of uncertainty in these situations.

## Implications for commissioners

**5.10** Commissioners should request and expect information on uncertainty from analysts, and challenge them when it is absent, inadequate or ambiguous. This information should go alongside details of the quality assurance effort that has been undertaken. In addition, commissioners of analysis may have identified sources of uncertainty as part of their wider considerations and should communicate these to the analyst.

**5.11** Analysts may describe uncertainty in qualitative terms, e.g. moderate uncertainty, high confidence, etc. This does not express the range or likelihood of alternative outcomes, which need to be taken into account in decision-making. Furthermore, qualitative expressions are by their nature relatively ambiguous and subjective. The same expression, e.g. “moderate”, is interpreted in different ways by different people, so commissioners and decision-makers may over- or under-interpret the degree of uncertainty and consequently take inappropriate decisions. When more quantitative expression of the range and likelihoods of alternative outcomes would be useful, commissioners should request it.

**5.12** Uncertainty can be analysed at different levels of detail, with analytical methods of increasing sophistication, and requires time, resources and specialist expertise. It is therefore important to conduct analysis at the level required to support decision-making, and avoid spending resources on excessive detail and sophistication. If it is possible for the commissioner to indicate in advance the consequences for decision-making of different degrees of uncertainty, this may enable the analyst to conduct their analysis at a proportionate level. If this is not possible an efficient alternative is for the analyst to start by providing a simple analysis, which can then be refined over time until it provides a sufficient basis for decision-making.

## Implications for decision-making

**5.13** Information on uncertainty helps decision-makers take decisions that are more likely to achieve their desired outcome. They may wish to adopt a risk-averse or risk-taking strategy depending upon the assessment of uncertainty alongside other considerations such as legal, economic, social and political factors.

**5.14** Commissioners of analysis should also consider whether it may be beneficial to commission more refined analysis of uncertainty, or evidence-gathering aimed at reducing uncertainty. Through discussion with the analyst, this can be targeted on those areas of the analysis where there is the best prospect of reducing uncertainty in a cost effective way. If there is a need for urgent action, such as a precaution against unacceptable but uncertain risks, the commissioner may request further analysis or evidence-gathering be commissioned in parallel to inform subsequent adjustments of the policy response when uncertainty is reduced.

**5.15** If any source of uncertainty is so deep that nothing can be said about its impact on the policy outcome, this implies that the outcome could be anything, i.e. is totally uncertain. Deep uncertainties have major implications for decision-making: they are likely to require strategies that are precautionary and/or flexible, coupled with evidence-gathering and monitoring of emerging outcomes.

**5.16** Decision-making should also take account of the quality of the analysis, which should be qualified alongside the analysis. When there have been time or resource constraints that have a negative impact on the quality of the analysis, the commissioner needs to consider, preferably in discussion with the analyst, whether this implies additional uncertainty about the outcomes, beyond that indicated by the analysis. If so, this additional uncertainty should be taken into account when considering the decision strategies outlined above.

#### **Box 5.B: Further resource on risk**

More detailed discussion of risk appetite and options for addressing risk is provided in the HM Treasury's Orange Book that is available at: [www.gov.uk/government/publications/orange-book](http://www.gov.uk/government/publications/orange-book). Accessed February 2015.

## **Communicating uncertainty**

**5.17** Commissioners of analysis often have to further communicate the results of analysis to decision-makers or other stakeholders. In doing so, the commissioners should consider:

- the consequences of communicating certainty when there is an uncertainty, as credibility will be damaged if things turn out differently
- a balanced picture of the analysis covering what is known and what is uncertain
- describing the range of possible outcomes and their relative likelihoods
- identifying key risks or uncertainties that have a large impact on the predicted outcome, and explaining the reasons for the uncertainties and the circumstances in which the risks might be realised
- identifying options for managing risk and uncertainty
- being open about the existence of any deep uncertainties whose impact cannot be assessed, and explain how they are managing those uncertainties
- avoiding implying unwarranted confidence in particular outcomes. Focus instead on communicating the level of confidence in the appropriateness of the proposed decision, and explain how this is justified by the quality of the analysis and by the measures that can be taken to address risk and uncertainty



# Part B

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The Aqua Book clarifies the responsibilities required to ensure that analysis is fit-for-purpose: it presents a framework for addressing these responsibilities through the roles of the commissioner of analysis, the analytical assurer and the analysts throughout the life cycle of the analytical project. Departments and agencies will wish to ensure that responsibilities are met, though the roles may vary locally.

This part of the Aqua Book is written for analytical assurer and the analyst.

Chapter 6 provides a more detailed coverage of the principles of verification and validation and describes the activities that can provide analytical quality assurance. In addition, there is a helpful mnemonic to assist analysts in challenging their own analysis and that of others: RIGOUR. This chapter also outlines suggested activities and whether the commissioner, analyst or analytical assurer is best place to take ownership.

Chapter 7 outlines the responsibilities of the analytical assurer, who should provide the confidence to the commissioner that an appropriate amount of quality assurance has been performed on the analysis.

Chapter 8 discusses the approach to understanding uncertainty and how to go about quantifying, where possible, the uncertainty that inherently affects the output of any analysis. This chapter highlights the many different sources of uncertainty and offers approaches to help understand them.



# 6 Verification and validation

## Box 6.A: Verification and validation – key points

Analytical quality assurance involves verifying and validating the analysis, i.e. that the analysis has been conducted as planned and that it is the right analysis, and it is delivered through a partnership of the commissioner, the analyst, and the analytical assurer.

Effective communication and transparency are crucial throughout the whole analytical process; in understanding the problem, designing the analytical approach, conducting the analysis and relaying the outputs.

The scale and scope of the verification and validation activities applied need to be proportionate to the purpose and constraints of the analysis – one size does not fit all analytical projects. Engagement between the commissioner, analyst and analytical assurer helps to identify the appropriate proportionate response.

While the results of the analysis is an important focus of any scrutiny, the need for verification and validation applies to the project as a whole as well as to the application of analytical techniques that deliver the analytical output.

Applying the principles of RIGOUR (repeatable, independent, grounded in reality, objective, uncertainty-managed, and robust) ensures that the key aspects of verification and validation are addressed.

## Introduction

**6.1** This chapter provides an account of the verification and validation measures that should be applied in order to provide analytical quality assurance. It describes approaches that are applicable to all types of analysis, although some may be more appropriate than others for a given piece of analysis and the available time and resources. This chapter focuses on those activities that are performed throughout the analytical cycle by the commissioner, analyst and analytical assurer, however an overview of additional assurance activities provided by third parties is presented for reference.

## Quality analytical projects

**6.2** Providing quality assured analysis means that the following must all be appropriately addressed:

- that the engagement between the analyst and the stakeholders have been effectively managed to ensure an proportionate amount of effort goes into an analytical project
- that confidence has been provided that the analytical output is fit-for-purpose and that there needs to be verification and validation of the analysis
- that the uncertainties and risks associated with the analysis have been understood, quantified where appropriate and managed actively

**6.3** For analysis to be used to inform a decision it must be possible to assess its utility, reliability, and the degree of validation and verification to which it has been subjected:

- the utility of the analytical output can be assessed through gathering feedback from the end users about its practical benefits
- reliability refers to how consistent the analysis is in ensuring that it adds value to the commission and the intended purpose of the analysis
- verification activities ask whether the analysis has been conducted correctly
- validation activities ask whether the correct analysis has been performed

## Verification and validation and the analytical cycle

**6.4** To understand what utility, reliability, validity and verifiability mean in practice, it is worth considering the simplified analytical process presented in Figure 2.A on page 18 and expanding on each of the stages.

**6.5** Analytical projects typically start with **customer engagement** although it is possible that other events trigger analytical projects. The commissioner plays an important role in communicating the questions to be addressed and working with the analyst to ensure an appropriate understanding of the problem is communicated. The commissioner is in fact verifying the understanding of the analyst, and the analyst is:

- validating that the analysis requested is actually what the commissioner requires in order to answer the problem
- identifying what form the findings need to be in to be of use to the commissioner

**6.6** In this stage of the project it is important for there to be transparency of the understanding between the commissioner and the analyst. Best practice is to record the customer engagement process in scoping documentation, which forms a living document to record the details of the work requested originally plus any changes made to the commission later.

**6.7** During the **design phase**, the analyst will convert the commission into an analytical plan. Key considerations include the inputs, possible methods of conducting the analysis and the outputs that will be produced. Throughout, it is important to validate that the analysis will deliver against the commission and to verify the conduct of the work against the aim. Some iteration between the commissioner and the analyst is to be expected as the analytical solution develops. The analytical assurance role assists in the identification and consideration of the validation evidence, as well as in reviewing the audit of the verification material. The commissioner also has an important role, since they may well be more an expert in the subject than the analyst. As such, their contribution towards the input assumptions, data requirements and the most effective way to present the outputs can prove invaluable.

**6.8** The design phase requires that the conversion of the commission into an analytical plan is transparent. This transparency helps expose the assumptions that have been made and highlight any known limitations of the proposed approach. Best practice is to document the design process which should record how the proposed analytical process is intended to generate the requested insights. The concept of analysis should, if appropriate, be supported by design documentation.

**6.9** When the analysts are undertaking their analysis, they will ensure that they are conducting the analysis correctly and will record any changes to their plan that they have had to make, such as if they encounter any difficulties or unexpected limitations. The analytical assurer can then comment on whether the analysis is still meeting the needs of the commission to ensure best use of the results.



**6.10** Regular contact with the commissioner, for example through regular update reports on large projects, provides an opportunity for the commissioner to be able to advise on whether the analysis is still meeting their needs or whether there are any new requirements.

**6.11** When conducting the analysis, it is important that it is transparent that the analytical plan has been followed and, if deviations have been necessary, any changes have been recorded. Best practice includes:

- maintaining a record of the work that has been done in a technical report
- logging the data and assumptions used in the analysis which should detail the source, ownership and a fitness-for-purpose risk assessment
- recording the verification and validation activities that have been undertaken, document any activities that are outstanding, and note what remedial action that has been taken and its impact on the analysis

**6.12** During the **delivery phase**, the commissioner has another important role when they receive the interpretation of the results and determine whether it has addressed their request. However, as analytical projects frequently involve further iteration or extension this consideration may be the trigger for additional analysis.

**6.13** Effective delivery requires a transparent translation from the results of the analysis to the conclusions presented to the commissioner. Best practice is to record this process in a customer report. The insights must also be presented in the most accessible form that can be achieved – the details of which should be determined on a case-by-case basis.

#### **Box 6.B: RIGOUR of analysis**

Throughout all the stages of an analytical project, the analyst should be asking questions of their own analysis. The helpful mnemonic “RIGOUR” may assist:

Repeatable

Independent

Grounded in reality

Objective

Uncertainty-managed

Robust

**Repeatable:** For an analytical process to be considered ‘valid’ it might reasonably be expected that for the “same” inputs and constraints the analysis produces the “same” outputs. It is important to note that different analysts will consider the analytical problem differently, potentially resulting in differing results, however if any one approach is repeated the results should be as expected.

**Independent:** To produce analysis that is free of prejudice or bias. In doing so, care should be taken to appropriately balance the views across all stakeholders and experts.

**Grounded in reality:** Quality analysis takes the commissioner and analyst on a journey as views and perceptions are challenged and connections are made between the analysis and its real consequences. Connecting with reality in this way guards against failing to properly grasp the context of the problem – which is being analysed.

**Objective:** Effective engagement and suitable challenge reduces potential bias and enables the commissioner and the analyst to be clear about the interpretation of the analytical results.

**Uncertainty-managed:** Uncertainties have been identified, managed and communicated throughout the analytical process.

**Robust:** Provide the analytical result in the context of residual uncertainty and limitations in order to ensure it is used appropriately.

## Verification and validation roles and responsibilities

**6.14** For each part of the analytical development cycle, there are multiple activities that help deliver quality analysis. Each analytical project will require more or less effort against each activity depending upon the complexity of the analysis and the familiarity of the analyst with the problem area.

**6.15** The following tables list several verification and validation activities for each part of the analytical cycle. An indication is made as to whether the commissioner, analyst or analytical assurer has responsibility for that activity and which other roles may be involved (noting that departments and agencies may wish to tailor this framework to meet local business needs and processes). Additional activities may be required depending upon the specific analysis being covered. Within each table the term ‘method’ is used and should be interpreted to apply equally to analyses, tools, experiments or models.

### Customer engagement

**6.16** Successful engagement between the commissioner of analysis and the analyst will help identify the question that analysis can address and establish the context that the analyst needs to be aware of before they start the analysis.

Activity (to be tailored as appropriate to accommodate local practices)	Suggested ownership (to be tailored as appropriate to accommodate local practices)		
	Commissioner	Analyst	Analytical assurer
Ensure key aspects of the problem, scope and complexities are captured and clearly communicated.	Owner	Involved	Involved
Be available to engage with the analysts in order to appropriately shape the work.	Owner	Involved	
Clearly record the perceived purpose of the analysis and/or modelling and the levels of quality and certainty that are required for this purpose.	Involved	Owner	Involved

Activity (to be tailored as appropriate to accommodate local practices)	Suggested ownership (to be tailored as appropriate to accommodate local practices)		
	Commissioner	Analyst	Analytical assurer
Challenge and test the understanding of the problem.	Involved	Involved	Owner
Ensure appropriate resources are commissioned for the analysis.	Owner	Involved	Involved
Ensure appropriate stakeholders have been identified so that the scope and boundaries of the problem can be appropriately explored.	Owner	Involved	Involved
Explore the requirements, boundaries, and scope with all of the stakeholders ensuring a wide range of perspectives are sought.	Involved	Owner	
Challenge the requirements, boundaries and scope and assess whether sufficient views have been considered.	Involved	Involved	Owner
Ensure expectations are managed to keep stakeholders expectations aligned with what can be delivered.	Involved	Owner	Involved

## Designing the analysis

6.17 The analyst is responsible for planning their analysis including how they will demonstrate that they have considered analytical quality assurance throughout the 'conducting analysis' phase.

Activity (to be tailored as appropriate to accommodate local practices)	Suggested ownership (to be tailored as appropriate to accommodate local practices)		
	Commissioner	Analyst	Analytical assurer
Record and review the decision process from structuring the problem to developing the analytical plan. Check that the process reflects due RIGOUR.	Involved	Owner	Involved
Plan appropriate resources to deliver the analysis.	Involved	Owner	Involved
Capture the specification of any necessary methods. This must be adequate to allow subsequent verification testing / validation of the analysis. It should also specify what approaches will be used to identify, quantify and communicate uncertainty.		Owner	Involved
Produce appropriate design documentation. Best practice can include a concept of analysis, user requirements, design specification, functional specification, data dictionary, and test plan.		Owner	Involved

Activity (to be tailored as appropriate to accommodate local practices)	Suggested ownership (to be tailored as appropriate to accommodate local practices)		
	Commissioner	Analyst	Analytical assurer
Dry run the proposed approach to see if it delivers as intended. Then consider if the overall approach adequately addresses the complexities of the customer issue for this purpose. It is good practice to engage subject matter experts in this review.	Involved	Owner	Involved
Ensure the accuracy and limitations of the chosen methods are understood – and where appropriate tested (where possible baselining their response against independent reference cases).		Owner	Involved
Ensure the basis of the work is accurate, transparent (so that the basis of the findings can be understood) and well recorded.		Owner	Involved
Ensure the approach to the analysis is well-structured for the purpose, data driven, and reflects a robust overall design.		Owner	Involved
Ensure the level of quality checking of the analysis will be appropriate for the decision being supported.	Involved	Involved	Owner
Ensure that, if required, formal ethical approval is provided.	Involved	Owner	Involved

## Conducting the analysis

6.18 As the analyst manages their analysis and follows their analytical plan, they are ensuring that the analytical assurer has sufficient evidence that proportionate quality assurance activities have taken place.

Activity (to be tailored as appropriate to accommodate local practices)	Suggested ownership (to be tailored as appropriate to accommodate local practices)		
	Commissioner	Analyst	Analytical assurer
Collect and manage data. Understand data accuracy and uncertainties. Capture, manage and understand implicit assumptions made.		Owner	Involved
Engage appropriate Subject Matter Experts, at the appropriate time, when collecting data. NB: The commissioner may be a subject matter expert.	Involved	Owner	Involved

Activity (to be tailored as appropriate to accommodate local practices)	Suggested ownership (to be tailored as appropriate to accommodate local practices)		
	Commissioner	Analyst	Analytical assurer
Record data and assumptions, including uncertainties and accuracy, in a master data and assumptions list to record the origin of all data used.		Owner	Involved
If applicable undertake parametric analysis to understand the consequences of missing or uncertain data and assumptions.		Owner	Involved
Ensure data formats, units, and context are properly understood and handled.		Owner	Involved
Ensure implications of any data dependencies or relationships to other analysis or methods are understood.		Owner	Involved
Ensure the level of quality checking of the analysis is appropriate for the decision being supported: All analysis requires some checks, at some level, by another competent person wherever and whenever practicable.	Involved	Involved	Owner

## Delivery of the analysis

6.19 Communication of the results and the associated uncertainties and limitations is very important. The analytical assurer must be content that the analyst is presenting a true representation of the analysis that has been undertaken. The commissioner must be confident that the results of the analysis are fit-for-purpose in the context of the original question asked. They must also ensure they have sufficient statements of assurance and understand the uncertainty associated with the analysis.

Activity (to be tailored as appropriate to accommodate local practices)	Suggested ownership (to be tailored as appropriate to accommodate local practices)		
	Commissioner	Analyst	Analytical assurer
Ensure the results of the analysis are communicated clearly and effectively to the commission with statements of the degree of assurance associated with the analysis alongside a statement of the residual uncertainty.	Involved	Owner	Involved
Ensure that onward communication of the results beyond the commissioner are communicated clearly and effectively in the context of the problem being considered.	Owner	Involved	Involved

Activity (to be tailored as appropriate to accommodate local practices)	Suggested ownership (to be tailored as appropriate to accommodate local practices)		
	Commissioner	Analyst	Analytical assurer
Ensure uncertainty, risk, limitations, and constraints are communicated clearly, along with the results, to the study commissioner.	Involved	Owner	Involved
Ensure uncertainty, risk, limitations, and constraints are communicated clearly, along with the results, to the decision-makers and stakeholders.	Owner	Involved	Involved
Ensure an analytical record is provided to i) facilitate access to the analysis by broader stakeholders, ii) make the analysis exploitable for wider decisions, and iii) inform continual improvement.	Involved	Owner	Involved
Ensure a suitable audit trail is in place that clarifies the level of validation, scope, and risks associated with the analysis. Best practice includes the production of validation log books.		Involved	Owner
Undertake reflective learning to capture successes and difficulties and ensure these lessons are available to improve future analysis.	Involved	Owner	Involved

## Documenting the assurance effort

**6.20** Local business practices and processes will determine the appropriate form and format of those resources and templates that facilitate the verification and validation process supporting the delivery of quality analysis. The need for appropriate proportionality of analytical response and of the verification and validation efforts needs to be kept in mind.

**6.21** The following templates should be considered:

- **Specification documentation:** this documentation captures the initial engagement with the commissioner and identifies the question, the context, and any boundaries of the analysis. It provides a definition of the scope and a mechanism for agreeing the project constraints, e.g. deadlines, available resources, etc., and capturing what level of assurance is required by the commissioner.
- **Design documentation:** this document outlines the design of the analysis, including conceptual models to illustrate the analytical problem, and forms an important tool for ensuring that the analytical assurer has the confidence that the analyst can deliver quality analysis.
- **Assumptions and data log:** a register of assumptions whether provided by the commissioner or derived by the analysis and data that have been risked assessed and signed-off by an appropriate governance group or stakeholder.
- **Quality assurance plan:** a detailed plan of what verification and validation activities are to be undertaken can also form the basis of a log for those analysts conducting

the verification and validation checks. Any additional verification and validation checks that have been performed should be recorded on the quality assurance plan.

- **User / technical documentation:** all analysis should have documentation for the user, even if that is just the analyst leading the analysis. This is to ensure that they have captured sufficient material to assist them if the analysis is revisited in due course. For analysis that is more likely to be revisited or updated in the future, documentation should be provided to assist a future analyst and should be more comprehensive. This documentation should include a summary of the analysis including the context to the question being asked, what analytical methods were considered, what analysis was planned and why, what challenges were encountered and how they were overcome and what verification and validation steps were performed. In addition, guidance on what should be considered if the analysis is to be revisited or updated is beneficial.
- **Customer reports:** a report that provides a detailed summary of the analysis outlining the commission through the design, conduct of analysis and delivery phases. The report should outline the decisions taken in order to complete the analysis and provide detailed descriptions of the analytical assumptions, levels of uncertainty etc.
- **Assurance statement:** a brief description of the analytical assurance efforts that have been performed to assure the analysis. The statement should make reference to known limitations and conditions associated with the analysis.

#### Box 6.C: Additional Aqua Book resources

Accompanying the Aqua Book is a suite of resources that include generic templates that can be adopted and tailored as required. For further information on templates, please see Part C. At any time, analysts should follow local guidance.

## Proportionality

6.22 There is no “one size fits all” for the verification and validation process. The level of time and resource spent on demonstrating fitness-for-purpose should also be balanced against the criticality and urgency of the decision being supported. It is likely that more effort will be required in the following situations:

- when complex analytical techniques are used
- when a novel approach is adopted
- when the analysis is business critical or addresses a potentially controversial issue
- when there is limited evidence to provide challenge of the results of the analysis
- when the results are required to a high level of precision and accuracy

6.23 Quality assurance activities should be considered for every piece of analysis, including:

- analyst testing
- peer review
- analytical audits

**6.24 Analyst testing** covers those activities where the analyst builds in checks and processes to ensure that their analysis is correct. This may be supplemented by “dual running” where the analysis is repeated by a different analyst to ensure it is consistent and “sense checks” where alternative calculations are performed, often to a reduced accuracy for ease and speed, to improve confidence.

**6.25** Activities that an analyst may perform under this strand of assurance checks include:

- adopting standards, e.g. spreadsheet or coding standards, to assist peer review checks through standardisation of approach
- comparison to other analysis, models or real events (e.g. historical data)
- applying “built in” checks to the analysis to highlight areas of concern
- test the analysis with alternative input data or assumptions to check the analysis behaves as expected
- run the analysis with extreme values to facilitate the identification of errors or unexpected behaviour

**6.26 Peer reviews** may use internal or external parties to provide critical challenge of the analysis. They might consider the entire analytical process from the user requirements through to the interpretation of the results, or focus on particular aspects of the project.

**6.27** The views of others – whether in an expert capacity or not – can provide constructive challenge to the analytical approach, application of a methodology or interpretation of the analysis. Peer review enables:

- knowledge transfer
- “lessons learnt”
- a fresh perspective to test the logic and analytical approach adopted

**6.28** An **analytical audit** focuses on the processes that were followed and the evidence gathered to provide the analytical assurance. The use of version control and the observations of guidance and checklists would form part of an audit. To assist an audit, recognised best practice is to:

- maintain a log of the analysis and the verification and validation checks that have been performed
- keep track of changes and modifications – and the reasons for doing so – alongside the analysis for ease of reference
- establish an appropriate version control system for both the analysis as a whole and for the supporting data and assumptions
- maintain a risk register and issues log for the analytical project

## Quality under time and resource constraints

**6.29** In some situations, such as for analysis that is needed under significant time constraints, it may not be possible to do as much work as is usual in order to understand and improve the verification or validation of the analysis as desired. In these situations:

- verification and validation efforts should focus on those areas of the analysis that are likely to have the largest impact on the analytical output and that are associated with the greatest risk



- the analysis should be communicated with appropriate caveats outlining what has and, importantly, has not been through verification or validation together with a practical interpretation of the associated risk
- when time allows, further assurance activities should be performed after the event so as to capture lessons learnt



# 7 Analytical assurance

## Box 7.A: Analytical assurance – key points

In the proposed responsibilities framework, analytical assurance provides the sign-off that a piece of analysis is fit-for-purpose. Departments and agencies will each ensure that this is done, however the specific role and seniority may vary locally.

For analysis that is business critical, the seniority of the analytical assurer should be appropriate to the risks associated with the analysis and the wider project or programme it supports.

## Introduction

7.1 This chapter provides an outline of the analytical assurance role and how it provides the commissioner with the required assurance, specifically that there has been proportionate and appropriate verification and validation of the analysis.

## The analytical assurer

7.2 The concept of analytical assurance is not new: it is commonplace for someone with responsibility for the delivery of analysis to request that an independent analyst provides an appropriate review before the analysis is communicated.

7.3 However, this important responsibility requires greater acknowledgement to help create an appropriate environment for the quality assurance of analysis.

7.4 The analytical assurer should produce a report outlining their view of the level of analytical assurance checks that have been completed. The report should include a short assurance statement that can be carried alongside the output of the analysis for the benefit of the commissioner. An assurance statement could include a summary of the assurance activities that have been undertaken and any important risks that have been identified.

7.5 Departments and agencies may wish to consider formalising the reporting of such assurance statements and include them in formal ministerial or senior official submissions, board papers and reports.

## Business critical analysis and the seniority of the analytical assurer

7.6 The proportionality of the quality assurance response, such as the number and type of verification and validation checks that are necessary to provide assurance, will vary by project. However, business critical analysis is more likely to require:

- verification and validation that are formally project managed with a formal governance arrangement
- external subject matter experts to validate the approach and assist with the interpretation of the findings such as through academic peer review
- verification checks performed by an analyst who has had no involvement in the design and execution of the analysis in order to ensure that a fresh pair of eyes considers the analysis and the adopted approach

7.7 To provide the appropriate assurance, the senior responsible officer must be satisfied that the analytical assurer has appropriate seniority for the risks associated with their wider project or programme.

7.8 The analytical assurer should expect to review evidence confirming the following have been completed over the life cycle of the analysis:

- evidence that the requirements have been captured, agreed through an appropriate governance process and shared with the commissioner, analysts and other stakeholders
- supplementary evidence of agreement and scrutiny of assumptions, analytical requirements and design considerations, including an analytical appraisal of options with considerations to uncertainty, limitations and weaknesses
- evidence that the commissioner and the analysts have discussed options and have agreed the verification and validation activities that are proportionate to the business critical risks
- supporting material confirming the suitability of the deployed analytical resources to both conduct the analysis and to carry out the verification and validation activities
- evidence that there has been sufficient networking between analysts as the providers of data and other evidence sources
- detailed descriptions of the verification and validation activities and their conclusions with supporting documentary evidence of the conduct of the work

7.9 The analytical assurer should provide a formal report that communicates the proportionality of the verification and validation checks. It is important that information covering the scope of the analysis, and relevant caveats, are communicated. In addition, an assessment of the residual uncertainty should be provided.

# 8 Analysing uncertainty

## Box 8.A: Analysis of uncertainty – key points

Decision-makers need information on the uncertainty of decision outcomes, i.e. the range of outcomes that may occur and their relative likelihoods, in order to act appropriately and be confident with the messages they communicate.

To provide this, analysts need to:

- identify sources of uncertainty, i.e. the reasons why outcomes may differ
- assess the impact of the uncertainties, i.e. the range of outcomes they may cause and the relative likelihoods of those outcomes
- communicate the analysis of uncertainty clearly

Causes of uncertainty of the outcome include: uncertainties associated with data and assumptions used in the analysis; changes in the wider environment; and unexpected events or risks that may influence the outcome.

Uncertainty should be expressed as the range of possible outcomes and their likelihoods, as this is what commissioners need to communicate to the decision-maker. It is important to express this quantitatively if possible, even though it may be approximate.

A range of quantitative methods is available for analysing uncertainty, including sensitivity analysis to explore the range of possible outcomes and probabilistic modelling to estimate their likelihoods.

Analysts also need to use expert judgement to assess any additional uncertainties that are not quantified by modelling, because it is the overall uncertainty that is important for policy-making. In doing this, analysts need to guard against overconfidence and other biases that commonly affect such judgements.

Uncertainty analysis requires time and resource and should be proportionate to the commission.

## Introduction

**8.1** This chapter describes how analysts can identify sources of uncertainty and risk, and how they can assess the impact on the analysis that supports decision-making. The importance of communicating the uncertainty associated with the analysis is highlighted.

## Objectives for uncertainty analysis

**8.2** Analysis is used to inform decision-making by predicting and understanding the likely outcomes. For example, a decision may be required today in order to achieve a desired outcome in many years' time. The actual outcome of a decision is inherently uncertain: many other events could occur that will affect the actual outcome. Decision-makers need information on the range of outcomes that may occur and their relative likelihoods.

**8.3** To provide this, analysts need to:

- **identify sources of uncertainty**, i.e. the reasons why actual outcomes may differ from those presented

- **assess the impact of the uncertainty**, in terms of the range of outcomes they may cause and the relative likelihoods of those outcomes

## Identifying sources of uncertainty

8.4 Many different factors can contribute to the uncertainty of outcomes including:

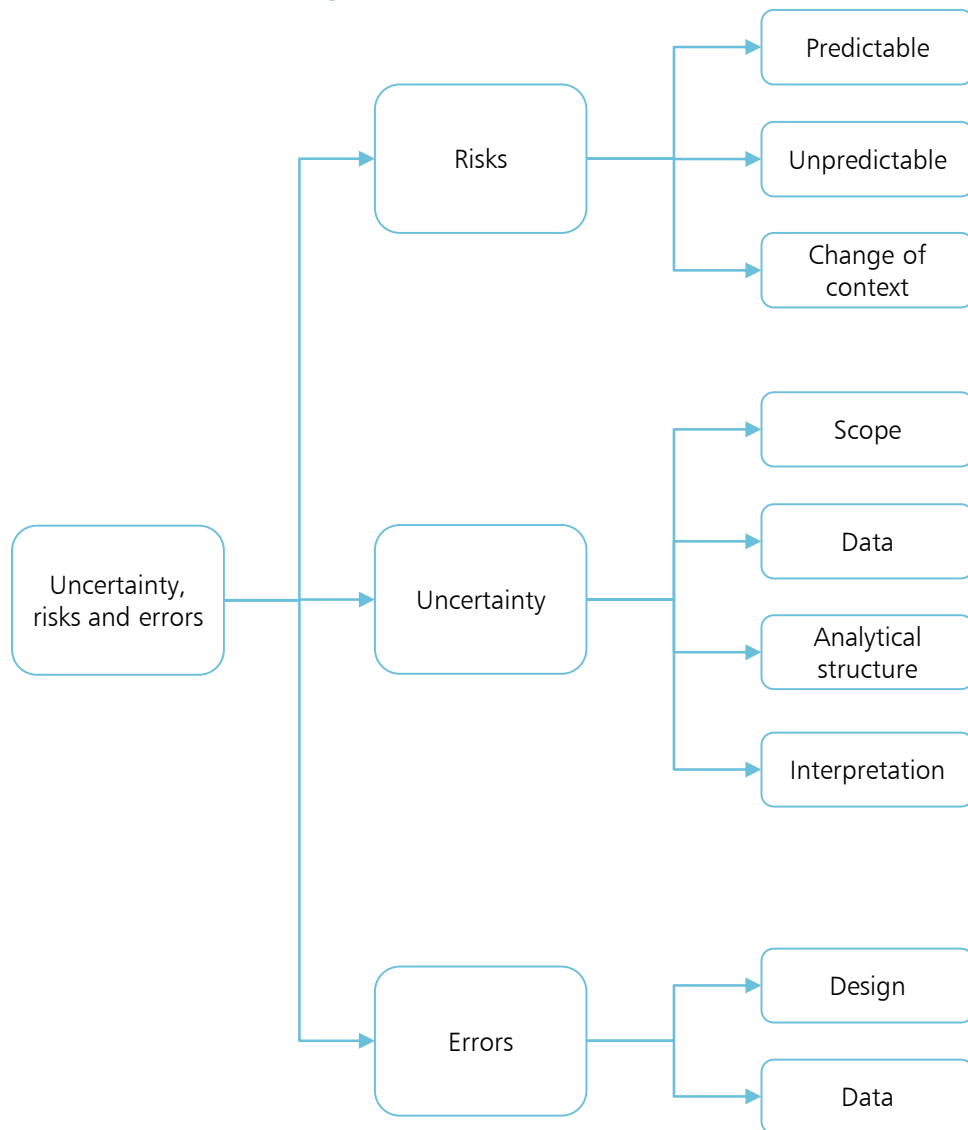
- the resources available to implement the decision
- how the decision will be implemented and its immediate effects
- the wider or longer-term consequences of a decision
- the potential for unexpected events, which might be considered as the realisation of 'risks', or changes in the contextual environment

8.5 Analysis seeks to take account of the above factors, but is itself subject to uncertainties, see Figure 8.A on page 51. Aspects of the analysis where uncertainty may arise include:

- inputs, including numerical data, evidence, intelligence and assumptions
- structural considerations, such as the logical flow and choice of analytical techniques for the problem in question, or the use of models beyond the defined scope
- external risks, influences and behaviours that may affect the outcome but are not taken into consideration within the analysis

8.6 In addition, there may be errors in analysis, though these should be limited by appropriate quality assurance. All of these factors contribute to overall uncertainty of knowing the outcome of a decision.

Figure 8.A: Sources of uncertainty



An overview of the risks, errors and uncertainties that may contribute to the overall uncertainty within a piece of analysis.

**8.7** Analysts should examine their analysis systematically for all possible sources and types of uncertainty, to minimise the chance of missing any that might be important. Tips that may help with this include:

- Develop a list of types of uncertainty encountered related to the field of work, or adopt a general list. This list can be used as a checklist when searching for uncertainties affecting a piece of analysis.
- Make a list or table of all the input data, evidence and intelligence used in the analysis and then consider each type of uncertainty that could affect it. It may be useful to maintain an assumptions and data log for this purpose.
- Write down each step of the analysis and/or draw diagrams that represent the structure of the analysis. For each step, consider what additional factors might act at that point and affect the analysis outcome.
- Identify any external risks and potential changes in the wider policy landscape that might affect the outcomes of interest.

- Review the structure of the analysis as a whole and consider carefully whether there are any other ways in which it could have been approached.

**8.8** Document all the sources of uncertainty and risk that are identified, including any considered negligible and/or tolerable. This provides a transparent record of what has been considered and contributes to the credibility of the analysis.

## Expressing the impact of uncertainty

**8.9** It is not sufficient to identify and describe risks and uncertainties. It is essential also to assess their impact on the outcome of the analysis and their contribution to the range and likelihoods of possible outcomes.

**8.10** If this is not done explicitly as part of the analysis, it will be done implicitly when decisions are made. For example, the decision may be based on the best estimate, which would imply that the combined impact of all the uncertainties is assumed to be negligible.

**8.11** If the analyst does not evaluate the impact of the uncertainties, it will be left to the commissioner or decision-maker to do this. This is undesirable, because they will generally be less familiar with the details of the analysis and therefore less able to evaluate the impact of the uncertainties.

**8.12** Qualitative expressions of uncertainty, e.g. 'moderate' or 'high', are ambiguous and mean different things to different people, so the degree of uncertainty may be misunderstood by others and decision-makers may over- or under-interpret the degree of uncertainty and consequently take poorly informed decisions. In addition they do not describe either the range or likelihood of alternative outcomes.

**8.13** Therefore, it is recommended to express the impact of uncertainty quantitatively when possible in terms of the range of outcomes and their likelihoods, even if this is approximate and/or subjective.

## Quantifying uncertainty about the structure of the analysis

**8.14** Sometimes there is uncertainty about the structure of the analysis, such as the equations or logic used to combine the analysis inputs. The impact of this may be quantified by implementing different versions of the analysis, for example using alternative formulations and examining how this changes the outputs. This can be applied both to uncertainty about specific steps in a single piece of analysis and to different approaches to the problem, which require wholly different analysis.

**8.15** This process will result in one set of alternative outputs for each alternative piece of analysis. If relative likelihoods can be assigned to the different versions of the analysis, and hence to their outputs, this will provide better information for decision-making.

## Quantifying uncertainty about additional factors, risks and external changes

**8.16** If it is uncertain whether a particular factor should be included in the analysis, then **repeating the analysis** with and without it will show the range of alternative outcomes. Once key factors have been identified, their uncertainty can be assessed.

**8.17** A similar approach using **alternative scenarios** can be used to quantify the impacts of external risks and potential changes in the policy landscape. Repeating the analysis with and without a risk event, or with and without an external change, will show their impact on the range of alternative outcomes.



**8.18** If relative likelihoods can be assigned to the alternative scenarios and their impacts with and without the additional factor, risk or policy change, then this will provide better information for decision-making.

**8.19** If it is not possible to add a potentially relevant factor, risk or external change into the analysis, this must be made clear. Approaches for addressing uncertainties that are not included in the analysis, or which cannot be quantified, are discussed below.

## Quantifying uncertainty associated with the use of data in the analysis

**8.20** When an input or parameter is estimated from data, this will often rely on **statistical methods** and theory to identify the most appropriate estimate. Further statistical methods may be used to directly quantify the uncertainty in the estimate. Whilst this output may provide an estimate of uncertainty within the context of the statistical method being used, it is important to realise that the underlying statistical methods are in themselves a form of model and may introduce further uncertainty.

### Box 8.B: Uncertainty associated with statistical techniques

Where parametric techniques are used, for example by assuming a statistical distribution, there may be uncertainty about the applicability of this assumption or about the value of the parameters of the distribution.

Where non-parametric methods are used, for example using bootstrapping techniques to re-sample from the data, the resulting estimates of variance will themselves be uncertain, especially if the quantity of data is limited.

**8.21** It is important to consider how well available data meet the needs of the analysis. Often, no data are available that are directly and precisely relevant to the parameter and conditions of interest. In such cases, it is often possible to use **surrogate data**. These are measurements of another parameter, or of the parameter of interest under different conditions, that are related to the parameter and conditions of interest. This implies an **extrapolation** between parameters, or between conditions for the same parameter, which introduces further uncertainty, additional to that associated with the data themselves. It may be possible to quantify this additional uncertainty using expert knowledge of the relationship between the surrogate and the parameter of interest.

### Box 8.C: The limitations of data

It is rare to have the perfect dataset for an analytical commission. Reasons for this include:

- the data is not available in the time frame required for the ideal analysis
- the data definition does not perfectly align with the commission
- there are data or coverage gaps
- the data may be experimental or there are other reasons why it is not 'mature'

As a consequence it may be necessary for an alternative dataset to be used as a proxy and further uncertainty must, unfortunately, be introduced into the analysis. The impact of using a proxy dataset should be explored and, if the uncertainty associated with the dataset has a large impact on the analysis, its appropriateness should be revisited. This exploration, and the decision to use a particular dataset or input, should be recorded for the benefit of the analytical assurer.

## Quantifying uncertainty with expert knowledge

**8.22** When neither direct nor indirect data are available for a parameter needed in the analysis, **expert judgements** about that parameter may be sought from people with relevant knowledge.

**8.23** Expert judgement may be used to estimate uncertainties associated with data, as well as in the absence of data. Examples might include estimating the size of adjustment needed for extrapolating from surrogate data to a parameter of interest, or to correct for biases in sampling or measurement.

**8.24** When using expert knowledge it is important not to rely on the expert's 'best estimate', as this gives no indication of the generally large uncertainty involved. Rather, experts should be asked to provide a range or a range plus a central estimate, or a distribution representing both the range of alternative values and their relative likelihoods.

**8.25** There are various formal methodologies for eliciting knowledge from experts such as the Cook, Sheffield or Delphi methods. These are designed to reduce the influence of cognitive biases that affect expert judgements, including over-confidence which can give too narrow a range or distribution, anchoring in which one fixes too strongly to an initial estimate and 'group think' whereby there is a lack of critical challenge in order to quickly reach a consensus. They also include standardised procedures for selecting the experts, training them in the elicitation process, and combining judgements from multiple experts.

**8.26** Judgements of different experts will differ to some degree. This is another source of uncertainty, which needs to be taken into account. If there is considerable disagreement among experts, one option is to repeat the analysis using alternative expert judgements to show how much they affect the outcome.

**8.27** Formal expert elicitation is costly in time and resource. It is therefore efficient to use simpler, less formal expert judgements to provide initial, approximate estimates and use these to identify the more critical parameters or uncertainties that may merit the expense of more formal elicitation. However, less formal methods should still guard against cognitive biases, such as by requiring experts to review their initial ranges and ask themselves why they could not be wider, to guard against over-confidence.

## Quantifying the impact of uncertainties on the analysis outcome

**8.28** It is not sufficient to quantify the uncertainty of individual components within an analysis. It is necessary to also quantify their impact on the overall outcome, because this is what matters for decision-making.

**8.29** The impact of individual uncertainties on the analysis outcome may be quantified by sensitivity analysis or probabilistic modelling:

- Ranges or alternative point estimates representing a range of alternative values or scenarios may be propagated by simply repeating the calculation with each estimate in turn. This is a simple form of **sensitivity analysis**.
- Distributions may be propagated by repeating the calculation many times, sampling different values from the distributions each time: often referred to as stochastic or **probabilistic modelling**. This is often done by Monte Carlo simulation.
- If the form of a parameter distribution is uncertain, the impact of this can be quantified either by repeating the analysis with alternative distributions or by using imprecise probability approaches such as probability boxes, which envelope sets of potentially relevant distributions.

**8.30** When quantifying the impact of multiple uncertainties, it is important to take account of potential dependencies between them. In sensitivity analysis, this means excluding implausible or impossible combinations of input values. In probabilistic modelling, it means specifying correlations between input distributions so as to take account of how the likelihoods of combinations of values deviate from the products of their individual probabilities. This is a critical challenge because wrongly assuming independence or mis-specifying dependencies can lead to highly misleading results, for example combinations of extreme values that rarely or never occur together in practice. Uncertainty about the form and magnitude of dependencies needs to be captured either within the model, such as using imprecise probability methods, or outside it.

**8.31** Once the impact of uncertainties on the analysis output has been established, their relative contributions to overall uncertainty can be quantified, such as the percentage of overall variance. This is particularly valuable if time and resources allow further work to be done to reduce the most important uncertainties, but it can also provide guidance for future research.

## Evaluating uncertainties that are not quantified by modelling

**8.32** Even when many uncertainties are quantified by modelling, there will always be other uncertainties that affect the analysis outcome but are not included in the analysis. These must also be evaluated, because it is the overall uncertainty that is important for decision-making.

**8.33** The basic requirements for evaluating uncertainties outside the analysis are the same as apply for quantifying uncertainties within the analysis. First it is necessary to evaluate the individual sources of uncertainty, and then it is necessary to evaluate their combined impact on the analysis outcome.

**8.34** This can be undertaken in a stepwise manner:

- 1 List all identified sources of uncertainty in a table, including uncertainties relating to the structure of the analysis; uncertainties associated with data, evidence and intelligence used in the analysis; additional factors; external risks; and potential changes in the policy landscape.

- 2 Evaluate the impact of each uncertainty on the analysis outcome, when considered in isolation. For uncertainties affecting input data, it may be helpful first to evaluate the uncertainty of the data themselves, and then consider the consequences of this for the analysis outcome.
- 3 Evaluate the combined impact of all the uncertainties on the analysis outcome, when considered together. In this step it is important to consider potential dependencies between the different sources of uncertainty, just as is necessary when uncertainties are quantified within the model.

8.35 The evaluations at steps 2 and 3 should be expressed in quantitative rather than qualitative terms if possible, to avoid the ambiguity associated with qualitative expressions. Ideally one would use formal expert judgement to obtain these quantitative estimates, but generally there will be too many uncertainties for this to be practical. Instead, it is efficient to start by performing the evaluation using less formal expert judgements. If decision-makers require a more refined analysis of the uncertainty, formal expert judgement could be introduced progressively, such as first assessing the combined uncertainty, step 3, and then, if needed, for the individual impacts of the most important individual uncertainties.

## Dealing with deep uncertainties that cannot be quantified

8.36 Quantifying uncertainty is difficult. Quantifying it statistically from data requires significant statistical expertise, and experts often find it very challenging to express subjective judgements in a quantitative form. If an uncertainty really cannot be quantified it is vital to communicate this to commissioners and decision-makers, as such **'deep' uncertainties** have special implications for the interpretation of analysis outputs and for decision-making.

8.37 If even one source of uncertainty is so deep that nothing can be said about its impact on the decision outcome, this implies that the outcome could be anything, i.e. is totally uncertain. This will have major implications for decision-making. Therefore, before concluding that an uncertainty is really unquantifiable, it is recommended to consider very carefully whether absolutely nothing can be said about it. For example, it is rare that a parameter could literally take any value from plus infinity to minus infinity, which is implied if one states it is unquantifiable.

8.38 If it is too difficult to express an uncertainty as a distribution, try to identify an approximate minimum and maximum or a range of alternative scenarios. Even when this results in a very wide range of estimates, it is still useful for decision-makers because it is essential for them to understand the magnitude of the uncertainty involved.

8.39 If even an approximate range cannot be given, bring the deep uncertainty to the attention of decision-makers at an early stage and describe its nature and causes as fully as possible.

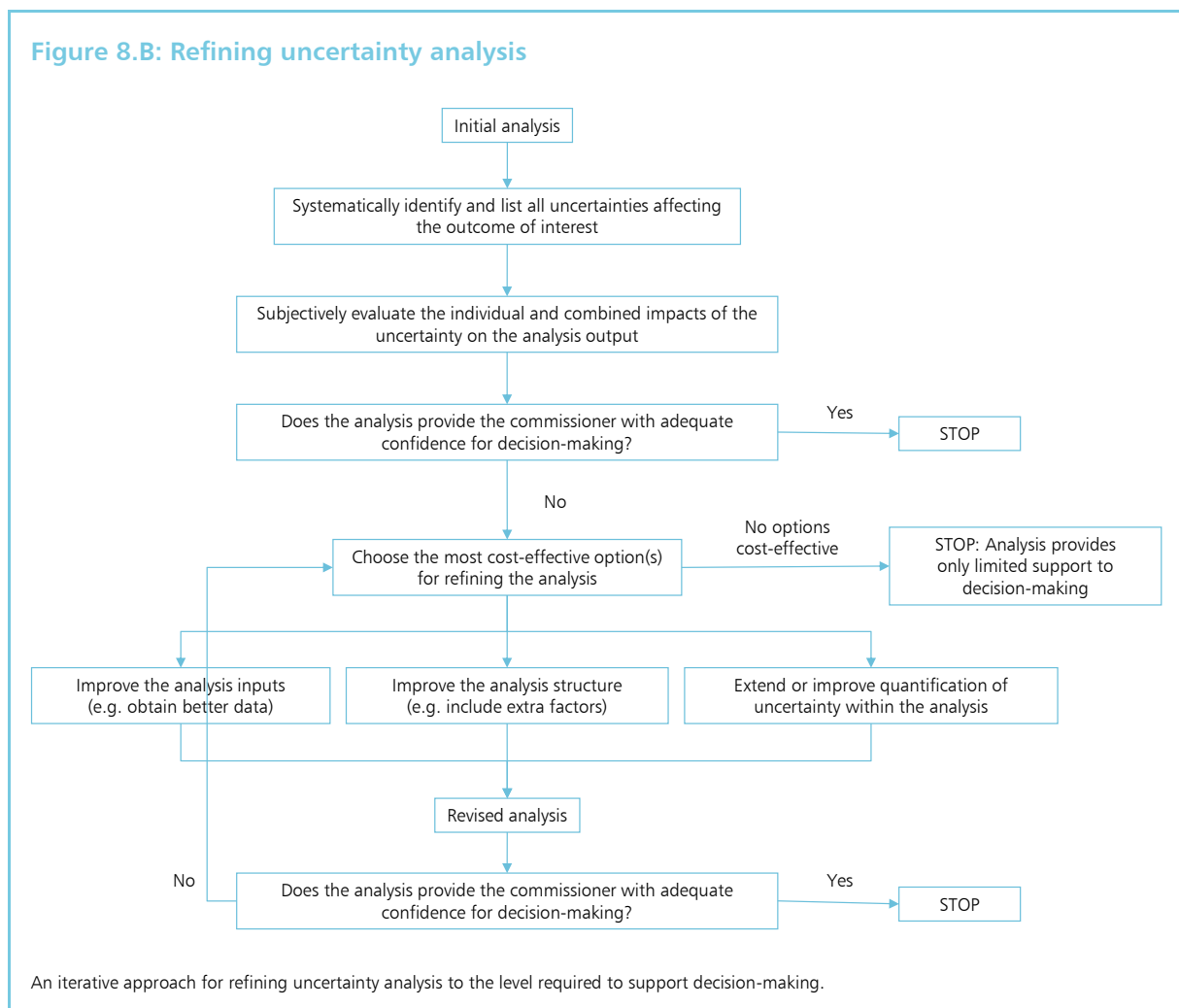
## Making the uncertainty analysis proportionate to the problem

8.40 Uncertainty can be analysed at different levels of detail with analytical methods of increasing sophistication, and requires time, resources and specialist expertise. It is therefore important to conduct analysis at the level required to support decision-making, and avoid spending resources on excessive detail and sophistication.

8.41 If it is possible for the commissioner to indicate in advance the consequences for decision-making of different degrees of uncertainty, this may enable the analyst to conduct their analysis at a proportionate level.

8.42 If this is not possible then an efficient alternative is for the analyst to start with simple and approximate methods and progress gradually to more refined approaches only when this is needed for decision-making, see Figure 8.B below:

- 1 Initially, do not attempt to quantify any uncertainties by modelling. Instead, systematically identify all the uncertainties, evaluate their combined impact on the analysis outcome by informal expert judgement, and communicate the result to the customer, making clear its approximate and subjective nature.
- 2 If the initial evaluation of uncertainty is not sufficient for the decision-maker to reach a decision, use the approximate initial evaluation to identify the most important sources of uncertainty, and consider quantifying them more rigorously. This can either be by using more formal methods of expert judgement, or by quantifying them by sensitivity analysis or probabilistic modelling. Revise the analysis and communicate it to the customer.
- 3 If the customer requires still more refinement of the analysis, repeat step 2 iteratively, progressively extending more rigorous methods to more and more of the uncertainties in order of their importance. Continue this until the customer is able to reach a decision.



## Communicating the outcome of the uncertainty analysis

8.43 The principal output of uncertainty analysis is information on the range of alternative outcomes and their likelihoods. It is important to communicate this in ways that are accessible

to commissioners and decision-makers and minimise the risk of misunderstanding. The analytical assurer may wish to insist this information goes alongside any communication of the analytical assurance, see paragraph 7.5.

**8.44** A tiered approach to communication may be helpful; a concise headline conclusion in narrative form, accompanied by one or more levels of more detailed information which the recipient may consult if they wish.

**8.45** If the likelihoods are quantified, such as by probabilistic modelling or expert judgement, the range of outcomes and their likelihoods can be presented in tabular form or as a probability distribution or bar graph.

**8.46** It is important to provide an overall characterisation of the uncertainty, combining any that have been quantified by modelling with the contribution of any additional uncertainties that were evaluated outside the model. This may be achieved by first giving the estimates provided by modelling, and then indicating how much this is increased by uncertainties evaluated outside the model.

**8.47** Depending on the complexity of the analysis, communication of results can be a challenging and may require separate approaches for different audiences. This will have to be determined on a case-by-case basis and if appropriate, seek assistance from communication specialists.

# Part C

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This part of the Aqua Book provides an overview of the accompanying resources that will help turn high-level guidance and principles into embedded practice.

Chapter 9 introduces the templates and checklists that have been developed. They can be tailored to complement existing business processes or to act as a starting point for the development of new business processes. Supplementary guidance on particular analysis problems will complement the Aqua Book.





# 9

## Aqua Book resources

### Box 9.A: Aqua Book resources – key points

The Aqua Book forms part of a suite of resources that will help analysts deliver quality analysis with analytical quality assurance. Additional resources include templates, checklists and specific guidance for specific analytical techniques and common areas of analysis.

Templates and checklists can be adapted to meet local business processes or specific analytical project needs.

### Introduction

**9.1** To support the Aqua Book, a series of templates, checklists and supporting guidance and more have been created and can be found alongside the Aqua Book on the civil service 'collaborate' workspace on analytical quality assurance.

### Quality assurance resources

**9.2** Templates and checklists are often used to facilitate the adherence to business processes. A suite of templates and checklists have been developed that cover topics such as scoping out analysis and recording assumptions.

**9.3** Spreadsheets are commonly used for a variety of analysis. A spreadsheet template has been developed that helps structure project and analytical quality assurance information alongside clearly structured calculations.

**9.4** A series of supporting resources delve deeper into the concepts of analytical quality assurance and uncertainty and what they mean in principle when implementing specific analytical techniques or addressing common analytical problems. The supporting resources are not intended to provide a detailed explanation of the theory and methodology behind each of the techniques, for which there will be numerous textbooks and training courses available. Instead they will provide a point of reference for analysts setting out on a project using the technique, providing guidance on:

- analytical quality assurance considerations
- common pitfalls to avoid
- project considerations and what additional information needs to be communicated to the analytical assurer and to the commissioner



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