A Joint Report by the Nuclear Energy Agency
and the International Atomic Energy Agency

Addressing Uncertainties in Cost Estimates for Decommissioning Nuclear Facilities

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The mission of the NEA is:

– to assist its member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for a safe, environmentally sound and economical use of nuclear energy for peaceful purposes;

– to provide authoritative assessments and to forge common understandings on key issues as input to government decisions on nuclear energy policy and to broader OECD analyses in areas such as energy and the sustainable development of low-carbon economies.

Specific areas of competence of the NEA include the safety and regulation of nuclear activities, radioactive waste management, radiological protection, nuclear science, economic and technical analyses of the nuclear fuel cycle, nuclear law and liability, and public information. The NEA Data Bank provides nuclear data and computer program services for participating countries.

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Foreword

The OECD Nuclear Energy Agency (NEA) and the International Atomic Energy Agency (IAEA) have long been concerned about the need to promote greater transparency in decommissioning costing and have therefore been collaborating on a number of initiatives in pursuit of this goal. Together with the European Commission, the NEA and IAEA published in 2012 the *International Structure for Decommissioning Costing (ISDC) of Nuclear Installations*, which proposes a harmonised approach to the presentation of decommissioning cost estimates. This approach has been gaining general acceptance as a means of facilitating comparison between different cost estimates.

The ISDC presents a common reporting format for decommissioning costing undertaken on a deterministic basis, including the reporting of contingency within the defined project scope as part of the project baseline estimate (PBE). Over the years, a number of different approaches have been developed to perform uncertainty analyses and incorporate the results into decommissioning cost estimates. However, while the ISDC may be used as a good foundation for cost calculations relating to out-of-scope uncertainties, the ISDC itself does not address probabilistic methods or associated presentation formats for their inclusion in decommissioning estimates. Developing a consistent and comparable treatment of risk and uncertainty in decommissioning cost estimation would further facilitate comparison between different cost estimates and enhance the overall understanding of and confidence in the estimates themselves.

Accordingly, the NEA and the IAEA have initiated a joint activity with the aim of building upon the ISDC to facilitate the preparation and presentation of nuclear decommissioning cost estimates that explicitly include consideration of uncertainties in an integrated manner. This report complements the ISDC cost presentation format, describing approaches to estimating uncertainty and to risk analysis, as well as their treatment and presentation in decommissioning cost estimates, based on experiences gained through projects in participating countries.

The opinions expressed and arguments employed herein do not necessarily reflect the official views of the international organisations concerned or of the governments of their member countries.

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List of abbreviations and acronyms

ACM	Asbestos-containing materials
BoE	Basis of estimate
BWR	Boiling water reactors
DRiMa	Project on Decommissioning and Risk Management (IAEA)
GAO	General Accountability Office (United States)
IAEA	International Atomic Energy Agency
ISDC	International Structure for Decommissioning Costing
ISFSI	Independent spent fuel storage installation
NAO	National Audit Office (United Kingdom)
NEA	Nuclear Energy Agency
NPP	Nuclear power plant
OECD	Organisation for Economic Co-operation and Development
WBS	Work breakdown structure

Chapter 1. Introduction

Decommissioning cost estimates may serve a variety of purposes and be produced under various circumstances and at different points in time. Therefore, each estimate needs to be considered in context, and the supporting information made available should reflect the intended purpose and target audience (NEA, 2015). Accordingly, decommissioning cost estimates should identify the purpose for which the estimate is prepared and describe the nature of the estimate, including the source data, degree of detail and level of reliability of the information used to prepare the cost estimate. This description should be supported by the provision of sufficient information for a reader to understand the necessary limitations of the estimate.

Uncertainties have different characteristics and may need to be addressed in distinctive ways within a decommissioning cost estimate since they arise in the cost estimate for a number of reasons. Uncertainties can be described as falling into three broad categories:

- "routine variability", e.g. of environmental or working conditions, due to the dynamic and hands-on nature of many decommissioning activities;
- "insufficient knowledge", e.g. due to lack of relevant experience or insufficient data;
- external events or "risks" that are unpredictable, but whose likelihood and impact can be examined through risk analyses.

It is clear that uncertainties and risks need to be considered in decommissioning projects and that a cost estimate should reflect the understanding of the potential impacts of such uncertainties in financial terms. However, the appropriate level of detail for such analyses and the degree to which provisions for such uncertainties and risks should be factored into a cost estimate will be context specific and based on several considerations. Developing a consistent and comparable treatment of risk and uncertainty in decommissioning cost estimation would facilitate comparison between different cost estimates, and enhance the understanding of and confidence in the estimates themselves.

1.1. Objective and scope of the report

The purpose of this report is to describe the treatment and presentation of uncertainty and risk in nuclear decommissioning cost estimates, based on experience in participating countries and current good practices. The report describes the different elements of a decommissioning cost estimate and provides suggestions for incorporating and presenting uncertainty and risk in a way that is compatible with the International Structure for Decommissioning Costing (ISDC).

Although the report mainly focus on single-unit nuclear power plants, the approach is nevertheless applicable to multiple-unit sites and may be extended to any nuclear facility including research reactors, fuel fabrication facilities, reprocessing plants, accelerators or other sites, provided the appropriate adjustments are made.). More specifically, it will describe how related uncertainties in decommissioning cost estimation can be contextualised and addressed using standardised methods of estimating uncertainty and risk analysis. Recommendations are provided to enable better consistency in the treatment of uncertainty and risk when preparing decommissioning cost estimates.

The report uses the term "uncertainty" to describe in general the cause, and the term "financial provision" to refer to the outcome of addressing uncertainty and risk in the estimate. Under these umbrella terms, certain key terms are used in a more precise way.

This report does not repeat large sections of other reports on decommissioning cost estimations, such as the ISDC and practices reports (NEA, 2015, 2012b), but is complementary to these reports and should be used in conjunction with them. Moreover, the report does not address monitoring of expenditures during a project, or the tracking of costs against progress towards completion in relation to estimate/budget. Such topics are addressed elsewhere (see, for example NEA, 2012a).

1.2. Structure of the report

The report is structured as follows:

- **Chapter 2. Key terms and basic elements of a cost estimate**: Key terms used in identifying components of a cost estimate are identified and defined. To illustrate how these fit together in the estimate, a generic figure based on the ISDC structure is included. An introductory section discussing the relationship between elements of the estimate is included.
- **Chapter 3. Provision for estimating uncertainty within the defined project scope**: This chapter describes and illustrates provisions for uncertainty within the defined project scope and explores the estimating uncertainty ("ISDC contingency") value used to establish the project baseline estimate. The concept of incorporating risk mitigation scope within the project baseline estimate is explained.
- **Chapter 4. Provision for risks beyond the defined project scope**: This chapter describes and illustrates identification and analysis of risks beyond the defined project scope and the concept of risk appetite in deriving a funded risk provision.
- **Chapter 5. Other considerations relevant to enhancing the understanding of and confidence in an estimate**: This chapter discusses the development of a cost estimate over time with increasing maturity of scope, the role of information on additional considerations, and supporting analyses in enhancing the understanding and interpretation of the cost estimate.
- **Chapter 6. Conclusions and recommendations**

Appendices include:

- **A** and **B**: Two specific examples are presented to illustrate different aspects related to the treatment of estimating uncertainties and risk in cost estimates for actual decommissioning projects.
- **C**: The IAEA Project on Decommissioning Risk Management (DRiMa) through the project lifecycle.

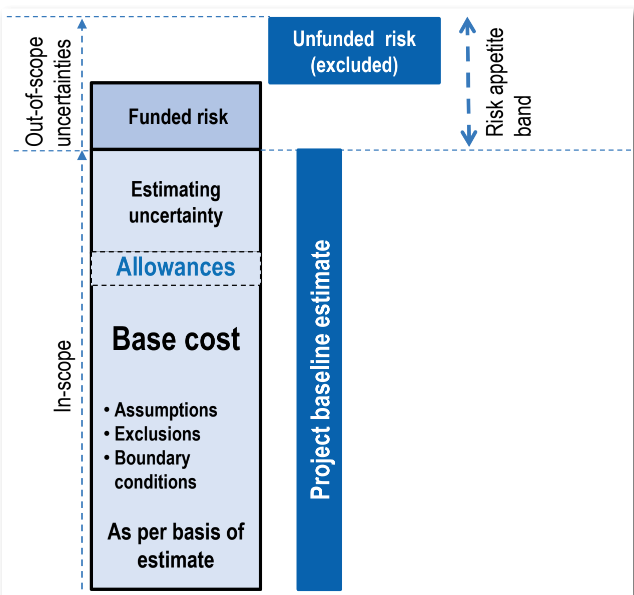
Chapter 2. Key terms and basic elements of a cost estimate

Many different terms are used when discussing uncertainties in cost estimation, and there is much variation in their use and meaning depending on preferences and traditions developed over time in a variety of contexts and countries.[1] The terms "risk" and "uncertainty" are often interchangeably used according to the specific application, the language used and the approach taken. This report is specific in using "uncertainty" (the cause) and "financial provision" (the outcome) as umbrella terms under which it defines certain key terms that are used in a more precise way. The term "estimating uncertainty" refers to in-scope uncertainties and the term "risk" refers to out-of-scope uncertainties. This report defines and uses these terms in order to communicate concepts unambiguously (see Section 2.2). It also illustrates how these relate to the existing International Structure for Decommissioning Costing (ISDC).

2.1. Illustrating basic elements of an estimate

Figure 2.1 illustrates the basic elements of a cost estimate. This is an example based on the ISDC structure, with risk elements added. The figure is intended to facilitate understanding of how the main terms used in this report relate to the various components of a cost estimate.

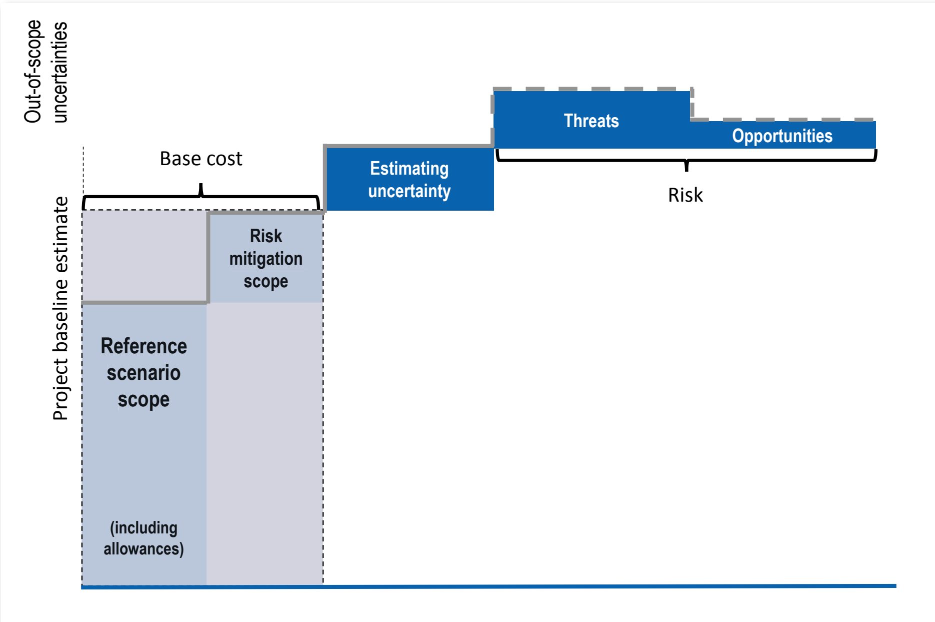
Figure 2.1. Basic elements of a cost estimate



1. For a discussion of the challenges posed by the variety of terminology used around the world, see, for example Smith, 2014.

This report uses an ISDC-based example for presenting the various elements of a cost estimate. However, there are a wide variety of approaches for presenting the different elements of a cost estimate currently in use, and the details may differ considerably between countries, organisations and estimators. Nonetheless, despite the multiple variations, all these approaches necessarily have some core elements in common. These common elements are illustrated in Figure 2.2. The figure shows the cumulative impacts as cost components are added or subtracted. Such a presentation is useful for understanding how an initial value (for example, the reference base cost) is affected by a series of positive and negative cost elements.

Figure 2.2. Generic example of the elements of a cost estimate



2.2. Definition of key terms

In Table 2.1, a number of key terms are listed and the ways they are used in this report are defined. How these terms are used in the context of a decommissioning cost estimate is further described in Section 2.3.

The definitions set out herein are not intended to be a comprehensive glossary; rather, they are intended to enable the reader to understand the terms and how they are used in the context of this report. As much as possible, the terminology and definitions used in this report are consistent with the ISDC and the other reports cited. However, countries and organisations may need to interpret and "translate" the present report and its recommendations in light of the terminology and definitions they currently use.

Table 2.1. Key terms

Term	Definition
Allowances	Provisions for known activities included in the base cost but whose exact values are not presently known.
Assumptions	Postulated activities and conditions that are expected to occur. Assumptions are necessary to define boundaries of the project scope and describe the basis on which the project is planned.
Basis of estimate (BoE)	A detailed description of the assumptions and exclusions, constraints, boundary conditions, sources of data and methodology to be used in the cost estimate (including how estimating uncertainty and risk analysis will be addressed). See NEA, 2015.
Base cost	Estimated cost of the base scope of the project as defined by the BoE, without any provision for estimating uncertainty or out-of-scope uncertainties.
Boundary conditions	Legal and technical limitations and regulations under which decommissioning work is expected to be performed.
Estimating uncertainty	A provision for uncertainties that are associated with the defined project scope (i.e. are considered to be in-scope), as identified by the BoE, and are part of the project baseline estimate. Specifically, this is a provision for uncertainties associated with conduct of work under other than the ideal (theoretical) conditions used to derive the project base cost. Within ISDC, this is referred to as the "contingency" and it is assumed to be fully spent during execution of the project.
Exclusions	Specific assumptions which are not to be considered in the project. Risks associated with exclusions are defined as being out-of-scope.
Funded risk	An additional funding provision calculated for identified risks above the project baseline estimate. This is a provision which may or may not be spent during execution of the project, but is funded according to the risk appetite.
In-scope	Activities and costs that comprise the project baseline estimate and are described in the BoE. This includes the estimating uncertainty.
Out-of-scope uncertainties	Uncertainties which lie above the project baseline estimate as they are considered beyond the defined project scope. In this report, these are referred to as risk. Out-of-scope uncertainties can be funded or remain unfunded (see: risk appetite).
Project baseline estimate	Estimated cost of the base scope of the project as defined by the BoE, including provision for the estimating uncertainty. It **excludes** provision for any risks considered beyond the defined project scope, but **includes** any added risk mitigation scope.
Risk appetite	The amount of risk above the project baseline estimate that an individual, group or organisation is prepared or required to fund in order to complete the project objectives.
Unfunded risk	Identified risk above the project baseline estimate for which funding is not provided within the project, according to the risk appetite.

2.3. Relationships between the elements of an estimate

The basis of estimate (BoE) is the foundation upon which the cost estimate is developed. As per NEA, 2015, the BoE provides a detailed description of the project including:

- assumptions and exclusions, including the reference year and currency used;
- boundary conditions and limitations – legal and technical (e.g. regulatory framework);
- decommissioning strategy description;
- end point state;

- stakeholder input/concerns;
- facility description and site characterisation (radiological/hazardous material inventory);
- waste management (packaging, storage, transportation and disposal);
- spent fuel management (the activities included in the decommissioning project);
- sources of data used;
- methodology used in the cost estimate;
- discussion of techniques and technology to be used;
- the basis for determining allowances, estimating uncertainty and risks;
- description of computer codes or calculation methodology employed;
- schedule analysis.

A well-documented BoE should fully reflect the current applicable decommissioning plan for the nuclear facility, and highlight any relevant variation between the plan and reference scenario used for calculating the decommissioning cost estimate. At the working level in the work breakdown structure (WBS), scope statements and assumptions are used to clearly define the scope of work to be executed. The sum of all WBS scope statements represents the project scope as set out in the BoE. The use of the ISDC list of activities is a way to facilitate understanding the project scope, establish a WBS, and ensure that all relevant activities within the project scope are reflected in the cost estimate.

Assumptions can be *strategic assumptions* – supporting establishment of boundary conditions for the overall project; or *working assumptions* that are specific to aspects of the WBS and scope definition.

The BoE should fully define boundaries of the project scope and set out the basis for the cost estimating process and the consideration of estimating uncertainty and risk. To avoid unintended gaps or overlaps between the characterisation of estimating uncertainty as *in-scope* and risks as *out-of-scope*, a well-developed BoE is required which clearly delineates this boundary. Consistent with the ISDC, allowances are a specific provision within the base cost for an activity or expense that will be incurred, but whose actual cost is not precisely determined at the time the estimate is being prepared.[2] Such allowances would be included in the estimate based on the estimator's best judgement or currently best available information. Assumptions and exclusions are used in the cost estimate to define boundaries of the project scope as described in NEA, 2015.[3] Exclusions must reflect deliberate scope omissions, for example where the scope is undertaken elsewhere by others externally and is therefore outside the project baseline estimate. Other relevant details should be explicit, such as the reference year of the estimate, the currency used, and a clear statement on the treatment of escalation/inflation. All of this needs to be clearly documented in the BoE.

Boundary conditions are usually derived from legal and technical limitations under which the decommissioning work is expected to be performed. This includes the regulatory framework and other limitations like criteria for clearance, personnel exposure limits or specifications for radioactive waste packages. These are usually stated at a project level.

2. See also the discussion in NEA, 2015 and Section 3.13 of NEA, 2014.

3. See in particular the discussion of assumptions and exclusions in Section 2.3.1 of NEA, 2015.

The base cost is the estimated cost of the base scope of the project as defined by the BoE, without any provision for estimating uncertainty or risk.

While "contingency" is a commonly used *generic term* in cost estimation for any financial provision that is above an estimated base cost, contingency may also be given a specific, more limited meaning in particular contexts, for example in the ISDC. Therefore, in order to reduce possible ambiguity and confusion, instead of the term "contingency", the terms "estimating uncertainty" and "funded risk" are used in this report.

- The term "estimating uncertainty" is used in this report for the provision related to uncertainties within the defined project scope ("*in-scope*") which are associated with conduct of work under other than the ideal (theoretical) conditions used to derive the project base cost. The estimating uncertainty is considered as part of the project baseline estimate and its derivation is described in more detail in Chapter 3. In the ISDC (NEA, 2012b), the estimating uncertainty is called "contingency". It is important to note when using the ISDC approach that ISDC cost estimates *do not* include a provision for risk beyond the defined project scope ("out-of-scope"). Nonetheless, using the ISDC approach for producing the project baseline estimate provides a good basis for subsequently proceeding on to the additional analysis and cost calculations relating to provision for risk beyond the defined project scope.
- The term "funded risk" is used in this report for the provision related to risks outside the defined project scope ("out-of-scope"). The funded risk provision is an additional provision above the project baseline estimate calculated to cover the costs of such eventualities should they occur. Chapter 4 of this report describes how analysis of out-of-scope risks can be used to provide a basis for quantitatively accounting for any project risks beyond the defined project scope. The calculated value of the funded risk is to be determined for each project, taking into account that such risk events, if they occur, may impact positively (opportunity) or negatively (threat) on the costs of achieving the defined project scope. The amount determined for the funded risk provision is related to that portion of the aggregated impact of the defined risk events for which funding is made available according to the risk appetite. Conversely, the term "unfunded risk" is used in this report to refer to risks outside the defined project scope for which no financial provision is made within the project budget.

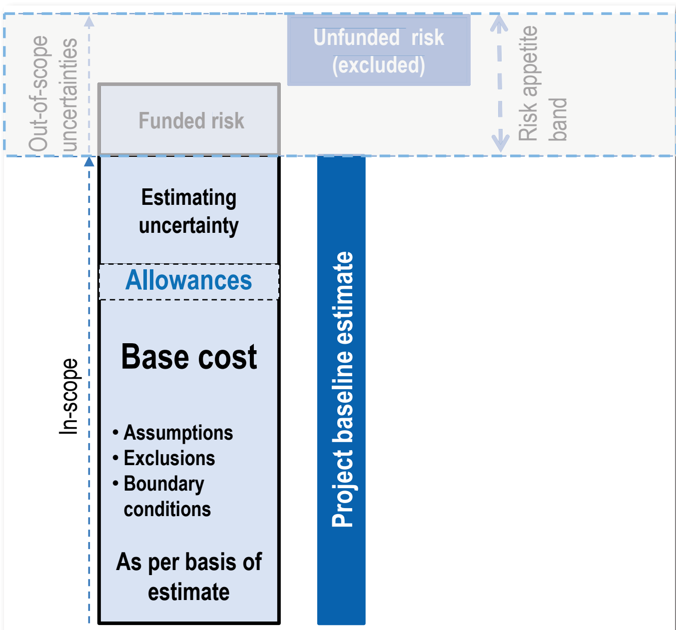
Consistent use of these specific estimating uncertainty and funded risk provisions in cost estimating will support derivation of a quality project budget estimate. This requires care in setting out the approach in the BoE to ensure that each step of the base scope, in-scope estimating uncertainty and the treatment of out-of-scope funded risk is documented, and that the outcomes are integrated and logically presented. It might appear that explicitly including these provisions may add additional costs or seem to generate a budget that is higher than needed; however, this is neither the intent, nor the reality. In developing a quality cost estimate, one must take into account scope maturity, assumptions, known uncertainties and all risks that can materially affect the costs of the project. If estimating uncertainty and risk are not adequately provisioned for, then it is highly likely that final project costs will at some stage exceed the assigned decommissioning budget.

Chapter 3. Provision for estimating uncertainty within the defined project scope

Estimating uncertainty is a provision related to uncertainties within the defined project scope ("in-scope"). Estimating uncertainty is considered as part of the project baseline estimate and its derivation is described in this chapter. The estimating uncertainty is called "contingency" in the ISDC (NEA, 2012b).

The basis of estimate (BoE) should clearly specify what is to be considered within the defined project scope and create the framework for calculating the project baseline estimate. The impact of uncertainties within the defined project scope creates a need to include an estimating uncertainty provision as part of the project baseline estimate, as illustrated in Figure 3.1.

Figure 3.1. Estimating uncertainty as part of the project baseline estimate



3.1. Including risk mitigation within the base scope

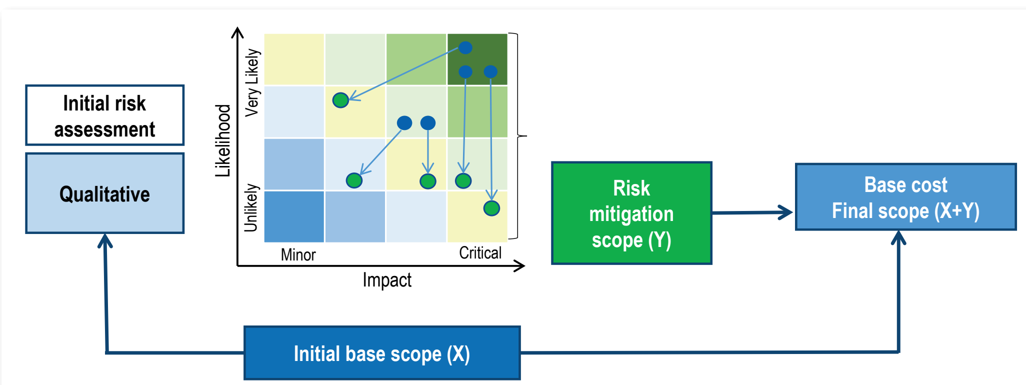
As described in the BoE, all scope is defined by a set of scope statements and bounded by use of assumptions, exclusions, etc. While very repeatable projects and sub-projects may simply adopt a lump sum cost estimate based on a parametric approach, this approach rarely works for complex decommissioning projects. Instead, attention needs to be given to an iterative process of scope refinement or optimising of the initial project scenario. It may take several iterations of scenario development to optimise the base scenario for the project, with an understanding of the potential impacts of alternative decommissioning strategies. This iterative development of the base scope is part of the scope maturity process and can be undertaken progressively at any time in the cost assessment process. Scope maturity is discussed further in Chapter 5 and the case study set out in Appendix B.

Figure 3.2 illustrates how an initial base scope can be adjusted by adding additional scope in order to mitigate potential risks. This additional risk mitigation scope is associated with expert judgement being applied to the original reference scenario for the project. The decision to include or exclude risk mitigation scope (and how much) is a matter of some subjectivity as it is tied to risk appetite and the perspective of the estimator and the client. This process of including risk mitigation in a revised base scope can generate a significant increase in base cost value and is one reason that base costs for a given decommissioning project can increase. Failure to adequately explain in the cost estimate the process and decision making related to inclusion of risk mitigation scope may therefore generate doubts on the quality of the estimate.

Where an initial assessment reveals potential events and outcomes that may be seen as intolerable or undesirable, these may be better dealt with by adding appropriate risk mitigation scope to the original base scope, rather than by being addressed separately as potential out-of-scope risks. Accordingly, potential risks to be mitigated are treated as in-scope issues and therefore included in the BoE, for example by including insurances, permits, new technologies, etc. The additional cost for the risk mitigation scope should then be estimated as part of a revised base cost for the project.[1]

In order to simplify the presentation of this report, it is generally assumed that the project scope as defined in the BoE is post-mitigation scope, which has been optimised by this iterative method.

Figure 3.2. Adding risk mitigation scope to the initial base scope



3.2. Estimating uncertainty within the defined project scope

The cost estimate for the activities within the BoE, as discussed in Section 2.3, needs to accommodate all known uncertainties within the defined project scope. These uncertainties arise from events that are likely to occur, and include events which occur during the execution of a project such as equipment breakdown, inclement weather, logistical delays, etc. Estimating uncertainty can be specifically evaluated and should be provisioned for in the estimate as part of the project baseline estimate. Consistent with

1. While the addition of risk mitigation scope increases the base cost, it should also reduce the calculated amount for the funded risk provision, as discussed in Chapter 4.

the ISDC approach, it is assumed that the estimating uncertainty would be expected to be fully spent during project execution.

The ISDC notes three groups of sources of uncertainty within the defined project scope that can influence decommissioning costs (Appendix C.2.2 of the ISDC [NEA, 2012b]). These are:

- uncertainty related to input parameters;
- uncertainties related to the extent of decommissioning;
- uncertainty related to the nature of documents for which evaluation of decommissioning cost is performed and objectives of the estimate.

In the context of this report, the first of these is generally treated as allowances,[2] whereas uncertainties relating to the extent of decommissioning activities would be considered as estimating uncertainty. For the third category, the situation may vary.[3] However, it should be noted that currently there exist a range of approaches to addressing allowances and whether these are considered as part of the base cost or calculated as estimating uncertainty. This makes it essential that the definitions used and approach taken be fully explained and documented in the estimate.

Uncertainties vary in whether and to what extent they may be reduced over time in the light of additional information or more in-depth analysis. Some may be addressed by additional effort (research, measurements, planning, elaboration of the regulatory requirements, etc.). The methods may vary but narrative and supporting analyses should be used to make transparent how uncertainties have been addressed in a particular cost estimate (also see NEA, 2015). The choice of analysis methods, or whether such methods are used at all, depends on the specific context for a given estimate.

The following is an illustrative list of factors influencing the level of estimating uncertainty:

- variability in input data (physical parameters on the objects, radiological parameters, etc.), some of which may be adjusted through the use of allowances in the base cost;
- differences in the estimating methodology or process (bottom-up vs. parametric);
- quantity variability due to level of design maturity, also adjusted by allowances;
- variability of labour productivity and/or cost rates assumed;
- labour availability/skills;
- post-contract award price variability.

2. In the context of this report, allowances are typically a provisional quantity or value for something that is expected to be known with greater precision at a later date (e.g. when a contract is signed, or item purchased).

3. For example, in the case of conceptual decommissioning plan cost estimates, an incomplete inventory database or radiological inventory should be supplemented with allowances as noted earlier, for example by using relevant proxy information from other similar facilities, or a value based on the estimator's experience. Conversely, where there is complete and sufficiently detailed documentation used to support the implementation of a decommissioning plan, the estimating uncertainty would be calculated as described in Section 3.3 of this report and in the ISDC (NEA, 2012b).

3.3. Calculating the "estimating uncertainty"

As the base cost is generally calculated in the first instance on the basis of standard conditions and mean efficiencies of activities, the estimating uncertainty[4] is needed in order to improve the realism of the estimator's assumptions, and to account for events that will occur during project execution. The estimating uncertainty value may be derived deterministically, by percentages or by probabilistic means, or by combination of these techniques as described in NEA, 2012b. It should be noted, however, that cost estimation approaches vary in how they calculate and factor in estimating uncertainty. The approach used will impact on the relationship between base cost and project baseline estimate. Care is needed to ensure that the estimating uncertainty does not overlap with the provision made for risks beyond the defined project scope.

As recommended in NEA, 2015, a reference year value cost approach should be used in cost estimation. It should be noted that the estimating uncertainty does *not* account for price escalation and inflation in the cost of decommissioning over the remaining operating life of the nuclear installation and during the period covered by the decommissioning project itself. It is expected that issues such as price escalation and inflation would be addressed as risks beyond the defined project scope, as described in Chapter 4.

Allowances includes a provision for currently uncertain elements which should be related to the level of design or scope maturity, and the quality/reliability pricing level of given components at the time the estimate is calculated.

Estimating uncertainty addresses uncertainties relating to the degree of technological advancement and work conducted outside of ideal (theoretical) working conditions. However, the estimating uncertainty does *not* include any provision for potential scope change from external factors (out-of-scope), such as impacts of changing regulations, major design or project scope changes, catastrophic events (force majeure), labour strikes, variation in site conditions (expected vs. actual), or external project funding (financial) limitations. These need to be separately considered as risks beyond the defined project scope for which additional provision (funded risk) might be required (see Chapter 4).

Estimating uncertainty is determined through analyses of the input data, e.g. physical, radiological, decommissioning process and economic parameters. The next section describes approaches for evaluating the estimating uncertainty based on an analytical evaluation of the impact of input data uncertainties (potential exposure, labour, amount of radioactive waste, etc.) on the cost.

Several approaches may be used for calculating the estimating uncertainty:

- application to an entire decommissioning project;
- application to groups of decommissioning activities;
- application to individual decommissioning activities.

The basis for adding estimating uncertainty, as well as its relation to allowances, also needs to be established from the outset and clearly communicated to all parties in order to ensure consistent interpretations of how it is to be derived for a particular estimate.

4. Appendix C.2 of the ISDC (NEA, 2012b) describes an approach for applying a provision for the estimating uncertainty ("ISDC contingency") to decommissioning cost estimates.

Application to an entire decommissioning project

The first of these approaches would be to apply a single estimating uncertainty provision to an entire decommissioning project. Here, the estimating uncertainty is defined on the basis of expert judgement or by means of other methods as a percentage of the base cost (NEA, 2010). This methodology is based on the expert judgement of the estimator and to do this they need prior knowledge of the type of activity and typical outcomes or benchmarks.

Applying a single estimating uncertainty provision to an entire decommissioning project is arguably the simplest of the three approaches. However, it should be noted that the estimating uncertainty derived in this manner may itself be quite variable from estimator to estimator. This approach has been used historically because of limited experience of using analytical methods for calculating estimating uncertainty provisions.

Application to groups of decommissioning activities

The second of these approaches requires that the estimator addresses the impact of input parameter uncertainty in the application of estimating uncertainty provisions to a specific group of activities. This approach reflects the fact that different uncertainties in input data can be identified for different groups of activities in the decommissioning process. These uncertainties may also have different weight of influence. For example, separate percentages for estimating uncertainty for highly radioactive component removal (reactor vessel and internals), lower percentages for less radioactive piping, components and building demolition. Where this approach is followed, estimating uncertainty for individual activities may vary widely, depending on the specific methodology used, the experience of the estimator and the groupings of the activities (NEA, 2010; Taboas et al., 2004). These also depend on the accuracy of the inventory and of the site characterisation/mapping.

This is an elaboration of the first approach and offers more level of detail. However, it is subject to similar limitations as the first approach.

Application to individual decommissioning activities

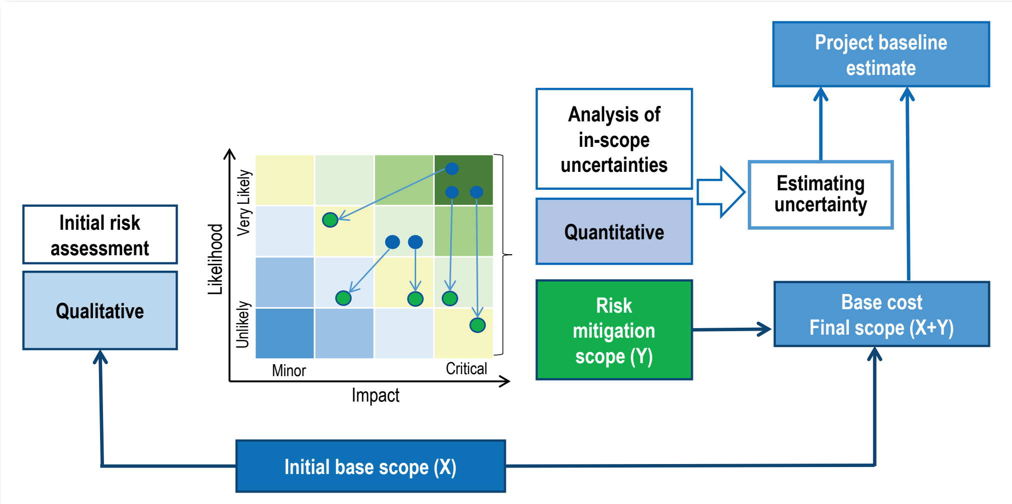
The basis of the third approach is an application of estimating uncertainty for each decommissioning activity on a line item basis using a bottom-up estimating method. This approach relies on the data being available during execution of the calculation in a detailed structure. For example, specific values for decontamination, removal, packaging, transport and storage/disposal, project management, and both clean and contaminated equipment and structure removals (see Atomic Industrial Forum, 1986 for additional details and examples of the use of such values).

Application of estimating uncertainty for each decommissioning activity on a line item basis using a bottom-up estimating method is the most detailed of the three approaches. This approach ensures consideration of individual conditions and characteristics of specific decommissioning activities. However, this approach requires considerable effort, detailed information and knowledge about the planned decommissioning project.

3.4. Estimating uncertainty as part of the project baseline estimate

Figure 3.3 illustrates the processes described in this chapter for including risk mitigation scope and estimating uncertainty in the calculation of a project baseline estimate.

Figure 3.3. Project baseline estimate, including risk mitigation scope and estimating uncertainty



The project baseline estimate is the estimated cost of the base scope of the project, as defined by the BoE, which includes risk mitigation scope, and the estimating uncertainty for uncertainties within the defined project scope. As the project baseline estimate is specific to the scope as defined at that point in time, the relative maturity and completeness of the scope definition also needs to be taken into consideration in the assessment of risk beyond the defined scope of the project.

The project baseline estimate *excludes* provision for any risks considered beyond the defined project scope. The analysis of and provision for risks beyond the defined project scope are described in Chapter 4.

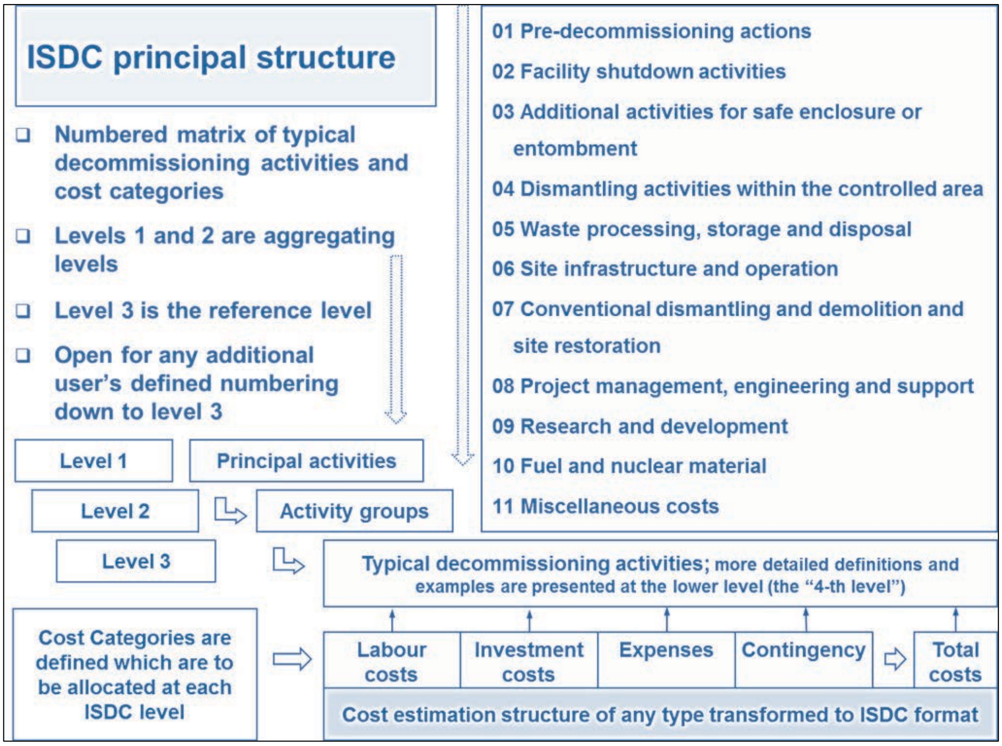
3.5. Relating the estimating uncertainty to the ISDC structure

The ISDC (NEA, 2012b) provides a harmonised approach to the presentation of decommissioning cost estimates. The format is applicable to the decommissioning of nuclear installations of any type, size and operational history. Costs are presented in a hierarchical framework at three levels, with levels 1 and 2 providing aggregation of the costs associated with the typical decommissioning activities represented at level 3. Each cost item comprises four separate cost categories: labour, investment, expenses and contingency (which translates to “estimating uncertainty” in this report). The typical representative decommissioning activities are organised into 11 groups of similar activities – principal activities – which broadly reflect the main phases of a decommissioning project (see Figure 3.4).

The list of typical decommissioning activities represented by the ISDC may also be used to define the scope of decommissioning projects by the indication of which ISDC activities are included within the defined project for costing purposes.

For each individual activity, the estimating uncertainty (or “ISDC contingency”) provision is applied to the three sub-cost categories: labour, investment and expenses. The ISDC cost presenting format also has additional levels of detail of analysis (levels 2 and 3).

Figure 3.4. ISDC principal structure



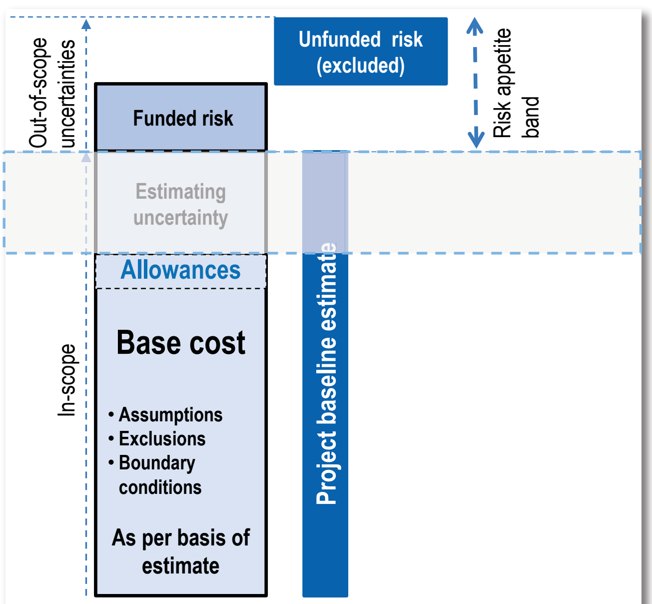
The ISDC also provides a list of boundary conditions and assumptions intended as guidance for users concerning the completeness of the scope of work to be included in the cost estimate (see Appendix B of the ISDC report [NEA, 2012b]). These are grouped according to similar activities and decommissioning phases. The purpose is to address specific work activities in each phase to ensure that all elements of the estimate are properly covered and to facilitate comparison between different cost estimates.

Chapter 4. Provision for risks beyond the defined project scope

This chapter describes and illustrates identification and analysis of risks beyond the defined project scope, as shown in Figure 4.1.

For uncertainties beyond the defined project scope, risks can be either funded or unfunded. This is a decision point in developing the decommissioning cost estimate which is tied to the defined risk appetite, for which the logic and basis should be clearly set out in the basis of estimate (BoE). How this calculation is subsequently conducted is determined by the nature of the decommissioning project, the uncertainties being considered, the impact of proposed risk events, and last but not least, the perspective of those analysing this data.

Figure 4.1. Consideration of risk in a cost estimate



The concept of out-of-scope uncertainties is fundamentally driven by risk perspective. The consequence is to address the need for an additional cost provision for risk above the project baseline estimate. As we are dealing with a potential range of outcomes, it is logical to consider both deterministic and probabilistic means to derive a further funding provision to tackle the issue of funding shortfall against out-of-scope risks.

It should be noted that a prerequisite of addressing risk beyond the defined project scope requires understanding of the BoE, assumptions and exclusions; and how estimating uncertainties within the defined project scope have been treated. For example, as described in Section 3.1, for the purposes of this report it is assumed that risk mitigation scope is included in the base scope, and such activities are therefore not included when considering risks beyond the defined project scope. If the base scope has not been optimised by the process of addressing risk mitigation scope, then these risks would need to be taken into consideration within the analysis of risks beyond the defined project scope, and a larger risk provision would need to be incorporated in order to balance the outcome.

The completeness and maturity of the scope definition also needs to be taken into account in the risk analysis process.[1] Risk associated with incomplete or poorly defined scope should be considered in the risk analysis.

4.1. Risk framework

A clear framework is an essential prerequisite to address the definition and the related methodologies and processes relevant to the management of cost uncertainties.

The IAEA has developed a risk analysis framework specifically for risk management in decommissioning projects in the context of a project on Risk Management for Decommissioning (DRiMa).[2] This is based on the IAEA Safety Standards on *Decommissioning of Facilities* (IAEA, 2014) and ISO Standards on risk management (ISO, 2009a, 2009b and 2009c). DRiMa provides recommendations on how to perform such risk analyses by considering the decommissioning plans, from initial to final versions, up to the implementation of the decommissioning and dismantling actions.

Three different categories or bands of risk are often separated out for consideration. The first of these is that of well-defined higher frequency and medium or high-impact risks. Such risks are usually treated as a priority in some way via the risk appraisal steps. The second band is that of well-defined low-frequency but medium- or low-impact risks. Such risks are often "accepted" and not mitigated through the risk appraisal steps. The assumption is that these are among the main small impact events that may affect individual scope packages but even a significant volume of these occurring would not challenge the project boundary assumptions or materially change the overall project cost by more than a few percent. The third category includes much more significant single initiating events that are often poorly understood or characterised in terms of consequences and frequency of occurrence. Often they are referred to as the high-impact low-probability events, and usually result in changes to project boundary conditions and a consequent step change in project scope requirements. In DRiMa these would be considered as a type of strategic risk. They tend to be generated by a "top-down" review taking into consideration the external environment and how this relates to decommissioning cost drivers. Where certain high-impact low-probability events are excluded from consideration or explicit financial provision, the basis for excluding these should be documented in the estimate.

The risk identification and assessment process is subsequently used to generate a project cost for risks beyond the defined project scope; and in the process of doing so can be associated with a level of probability. It is the analysis of these out-of-scope risk elements that provides the basis to justify an additional provision for risk in the cost estimate. The risk appetite is the factor that determines which point in a range of cost outcomes is to be used for the funded risk provision. While a mid-point assessment is a realistic starting point, assessing how much of this risk should be funded or remain unfunded requires intelligent assessment of the actual implications of the risks.

The greatest area of subjectivity in the funded risk calculation is the quality of underpinning of the input data to the risk register for the risks beyond the defined

1. This issue is discussed further in Section 2.5 and the case study set out in Appendix B.
2. See IAEA, forthcoming and Appendix C of this report for additional details.

project scope. While the estimating uncertainty assessment is a professional judgement based on knowledge of past practice and performance on real work, this out-of-scope risk register contains judgements on initiating events, judgements on their probability and judgements on their impact. A consistent and fully documented approach to risk appetite should enable a more reliable funding estimate value to be generated. Without this, factors such as optimism bias (artificially high risk appetite), or a nuclear site operator's desire to simply exclude scope that is difficult to estimate or provision for, may appear and can generate misleading estimates. The basis for excluding particular risks should be documented in the estimate, and the implications discussed.

4.2. Step-wise approach to risk assessment and analysis

The following sections describe a step-wise approach to the analysis of out-of-scope risk and how this can be used to derive a cost provision in the final cost estimate.

Stage A: Risk review and prompt lists

In determining what would constitute a reasonable set of risks, both bottom-up and top-down approaches are considered useful. While bottom-up can be time consuming it captures all of the key risks at various work breakdown structure (WBS) levels (as per DRiMa). This is a rigorous and exact process that will generate a complete knowledge and understanding of scope and the risk. The purpose of the review is to challenge the scope assumptions and boundary conditions for the project.

The top-down approach on the other hand is a less constrained review, and often a less robust process. This is because senior management articulation of risk is rarely as rigorous as the bottom-up process, as the participants may only have a high-level perspective to properly identify the detailed risks, impacts and mitigation options. To help facilitate top-down risk identification it is useful to develop an initial or 'prompt' list of issues for consideration. It can be focused on boundary condition breaches (as outcomes) and external factors (as initiating events) as well as being largely unconstrained in approach.

There are a number of ways to run a top-down risk review process. In practice, a risk workshop or similar process would be undertaken to identify and explore possible risks. The participants would list all risks on a risk register (or log) and examine all risk events qualitatively to determine the low-, medium and high-risk events. Table 4.1 lists typical categories of risks and issues to consider as part of the risk workshop qualitative and subsequent quantitative risk analysis. The categories are intended to initiate discussion and raise new potential risks for consideration and analysis.

Stage B: Opportunity review

The process described above is used to generate negative impacts (risks), and it is vital that beneficial outcomes (opportunities) are also generated. The subsequent treatment of opportunities can be integrated with the risk process or added as a further step in adjusting the estimate downwards – i.e. reducing the risk provision previously derived.

Stage C: Generating scenarios

The development and use of scenarios is an important but optional step. This is an essential feature of project decision making such as technology selection or evaluating options as part of preparation for work on a decommissioning project (see also discussion in Section 5.1). It can be particularly useful to conduct risk based scenario analyses at an enterprise level.

Table 4.1. Suggested list of risks and issues to consider

Category of risk	Issues to consider
Permitting	Permitting process longer than expected.
Costs/funding	Decommissioning trust fund investments lose money in stock market; funding profile for project reduces; fuel shortages cause cost of fuel increases.
Spent fuel	More damaged fuel than anticipated; fuel transfer to pool; dry storage transfer delayed; casks do not meet regulatory review; cask fabrication delays.
Technical approaches	Primary system components more difficult to remove; reactor vessel and internals segmentation more difficult from radiation hardening; disposal cask turnaround time longer than anticipated; building demolition more difficult because of stronger concrete than anticipated; foundation structures to be removed.
Waste disposition	Waste disposal site closes; interveners block roadways preventing transport of wastes; disposal site increases rates significantly; local governments prohibit transfer of trucks through their region.
Site release criteria	Unexpected reduction in site release criteria requiring more material removal.
Schedule	Beginning of project delayed by government/owner/licensee; extended inclement weather prohibits work on project for extended period; delivery of critical dismantling equipment delayed.
Environmental	Owner/licensee prohibits fossil-fuelled dismantling equipment within buildings; local government prohibits disposing of clean concrete on-site for fill; clean water discharges to local tributaries prohibited.
Regulatory	Regulator reviews take longer than anticipated; regulator changes exposure limits to workers/public.
Safety	Worker injury/death shuts down project for extensive safety re-training; additional post-removal asbestos discovered causing additional abatement programme.
Stakeholder concerns	Local public object to increase in heavy trucking on local roads; demolition noise objectionable; clean demolition dust drifting to unrestricted areas, homes, businesses; local homeowners demand reimbursement for loss of home value, loss of jobs.
Political	Government changes policy on deep geological repository availability; delays start-up of low-level waste and intermediate-level waste disposal facility.
Legal	Unexpected lawsuits regarding contractor's terms and conditions of contract with owner/licensee.
Insurance costs	Insurance rates not dropping as work progresses.
Local socio-economic	Local government demands establishment of special fund to compensate for loss of taxes/jobs/social services (fire rescue/police, etc.).
Contract issues	Contractor change orders challenged by owner/licensee; owner-delivered services not provided per contract.
Procurement uncertainties	Heavy equipment (cranes, tractor/trailers, excavators) not available in local area; cost of equipment from distant source greater than anticipated.
Site risks	Site characterisation inadequate causing delays; historic relics discovered on-site; unexpected legacy waste discovered; groundwater contamination discovered.
Subcontractor issues	Subcontractor strikes; major subcontractor declares bankruptcy.
Property taxes	Higher than negotiated; state intervention to support local economy.

Stage D: Out-of-scope risk analysis

The starting point for the analysis is a risk (and opportunity) register with impacts and probabilities that have been reviewed, agreed and assigned. These risks can impact on cost, or schedule or both. As previously mentioned, these risks should be associated with an optimised base scope and hence are considered "post-mitigation". In addition to the risk register analysis, alternative scenarios may also have been derived, based on foreseen alternative project or sub-project outcomes.

A number of analysis approaches may be applied:

Option 1 – Probabilistic risk assessment

The benefit of a probabilistic approach is that it should facilitate conduct of an unbiased analysis. The quality of the output data is however greatly dependent on the input data and for that reason it is often not a recommended approach for projects of low scope definition and maturity. A further issue is how this method treats high-impact low-probability events and whether these events may dominate the s-curve (cumulative probability) shape and in doing so mask more realistic outcomes.

Option 2 – Apply a factor tied to past experience of similar activities

The nuclear decommissioning industry has a limited history of recent nuclear power plant (NPP) dismantling work. Completed project cost data is currently very limited and unreliable, as owners and contractors consider the completed detailed cost data to be proprietary. Some costs of dismantling work have been reported in the literature, but in general they contain only summary level cost data.[3] As the NPP decommissioning industry matures, it may be anticipated that more of this detailed information will become available.

Option 3 – National factors (custom and practice)

For some project types and for some countries it is normal to apply a multiplying factor or lump sum additional provision to cover the costs associated with out-of-scope uncertainties, e.g. the addition of a 20% or 30% uplift. This is typically done to address issues of potential funding shortfalls and/or experience of project cost overruns, for example relating to incomplete or immature definition of scope, and where there is a limited basis for the detailed analysis of specific risks. However, as this approach is likely to be inaccurate and misleading as to project outcomes since it is arbitrary and not related to an analysis of the specific risks that may impact the project. Accordingly, this practice is being phased out in most countries, and is being replaced by use of appropriate specific risk analyses.

Option 4 – Qualitative risk assessment

Qualitative risk analysis is the process of assessing and combining risk probability of occurrence and impact; in this kind of analysis risks are "manually" classified by raw types of impacts and probability (and not by really computed values with respect to the whole project and the side effects of other risks).

Option 5 – Quantitative risk analysis

The main objective of the quantitative risk analysis is to appraise the cost value coming from negative risk or the revenue of positive risk. Not all the identified risks are

3. See NEA, 2016 and also the discussion of benchmarking in Section 5.5.

considered in the quantitative analysis, and the focus is on strategic risks.[4] A first selection is done by the qualitative analysis results.

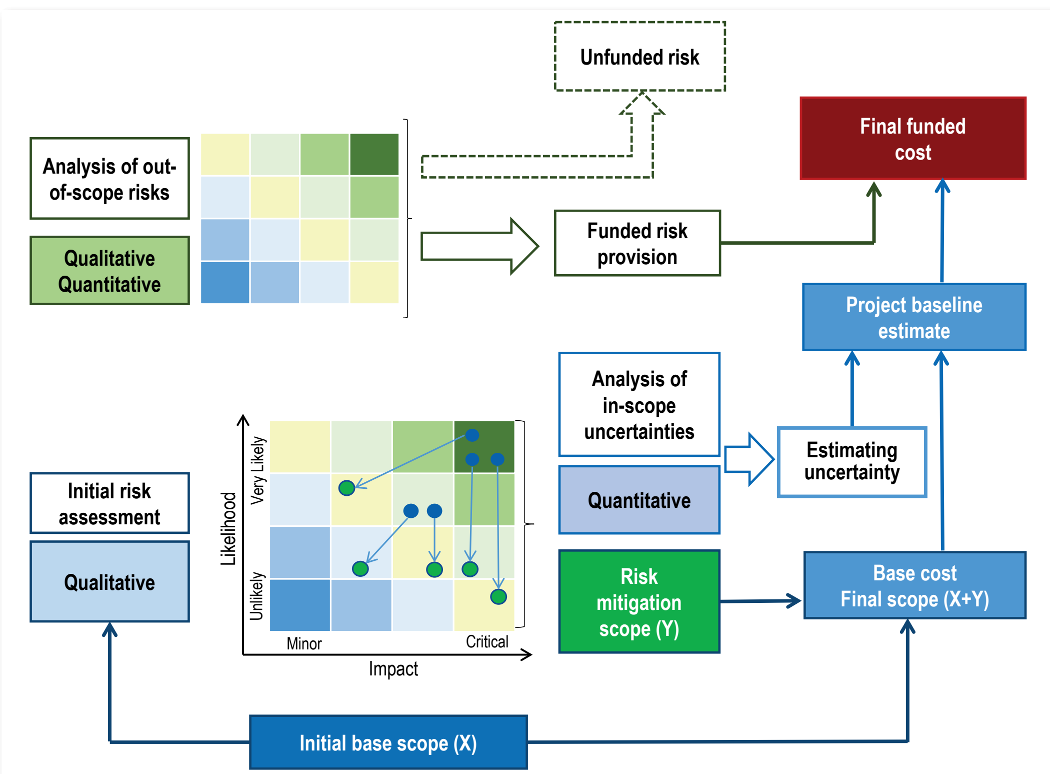
Within this step the risk effect is costed as the calculated expected monetary value (EMV), i.e. the expected monetary value of the risk: EMV = cost impact × probability.

4.3. The funded risk provision

This chapter has described a process which involves risk identification, assessment and analysis to generate a set of outcomes for several different scenarios (and hence a range of additional cost provisions) that are directly tied to a probability of occurrence. Taking the risk appetite into consideration allows a determination to be made of which of these risks are to be funded or not, as funded risk and unfunded risk elements respectively. The additional cost provision for funded risk above the project baseline estimate can now be included in the estimate to yield a final funded cost.

Figure 4.2 illustrates this by including the process for calculating a funded risk provision in the earlier Figure 3.3 for a project baseline estimate, including risk mitigation scope and estimating uncertainty. The exclusion of certain risks from a funding provision is shown in the figure as unfunded risk.

Figure 4.2. Final funded cost, including addition of a funded risk provision to the project baseline estimate



4. See IAEA, forthcoming and Appendix C of this report.

Chapter 5. Other considerations relevant to enhancing the understanding of and confidence in an estimate

Estimates are more than just numbers, and understanding of an estimate also requires consideration of a range of factors beyond the process by which cost estimates are calculated, such as when it was prepared, for whom and in which context. It also requires consideration of the quality of the underpinning data and calculation processes. This chapter identifies and discusses a number of these issues in the context of analysis of uncertainties and provisions for them.

5.1. Evolution of an estimate and a basis of estimate over time

Decommissioning cost estimates are produced at different points of time, spanning the period from conceptual design prior to construction of a facility, through to the execution of decommissioning. They are updated periodically throughout the facility's operation, following plant shutdown and during the period in which decommissioning activities are undertaken. Estimates will evolve over time as knowledge is accumulated and planning for the decommissioning project develops. It is important to recognise that no simple pattern of progression applies to all projects and thus the development of cost estimates over time will vary from project to project. Changes may occur for example as a result of modifications made to the defined project scope, increasing maturity of project scope, and developments in the definition and analysis of risks at different points in time.

Figure 5.1 illustrates how relationships between different components of an estimate may be expected to evolve over time.[1]

In this figure, a mid-point of risk appetite is assumed to be the objective and hence the actual costs should converge to this mid-point over time through the project execution phase. In the figure:

- **Column (A)** is associated with the very early stages of decommissioning planning and typically is the case for most of the operational period of the nuclear installation. It is based around a reference scenario and involves boundary conditions deemed to be true at that point in time and fully considered in the basis of estimate (BoE). As these can change with time, they are a major source of uncertainties. This includes external factors such as regulatory requirements and waste disposition assumptions as well as selected project execution techniques and outcomes. Scope definition can be low, hence this is reflected in the relative size of the estimating uncertainty and funded risk provisions. These provisions can be determined in a range of ways as discussed in this report.
- **Column (B)** reflects the point in time much closer to where decommissioning activities start. This column is representative of a more mature scope definition and an associated detailed estimate of uncertainty and risk analysis. While boundary

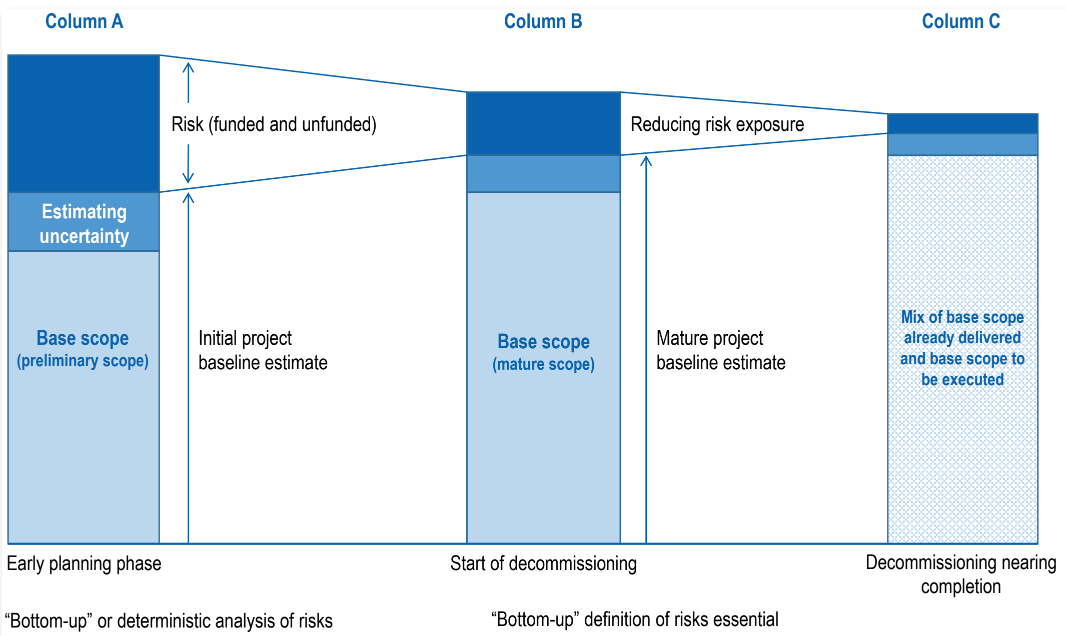
1. Note that escalation (i.e. the changing value of money) is excluded as a contributory factor in the illustrated cost growth in this figure.

conditions are less likely to change through the project execution phase, some scope assumptions may have changed and uncertainties will be re-determined as part of the project base-lining for the execution phase. A detailed risk register is usually also developed at this stage which enables risk mitigation strategies to be fully documented.

At this stage, project execution strategies need to be fully developed. A better understanding of contamination and radiation levels and other characterisation aspects of the nuclear facility undergoing decommissioning is also needed. Previous assumptions are sometimes shown to be wrong during project execution and if this results in a change of approach, it may mean a step change in the project base cost and a change to the provisions for project uncertainties. During this stage, allowances may be refined upwards or downwards as more complete process and technological definitions are available.

- **Column (C)** reflects the point in time where the decommissioning project is nearing completion. At project completion, it is assumed that the estimating uncertainty provision will have been fully spent. In this column it has been assumed that the boundary conditions and scope assumptions as per column B were broadly correct. A proportion of the funded risk provision will have been used to accommodate out-of-scope uncertainties that materialised during the decommissioning project execution.

Figure 5.1. Change in-scope maturity and relationships between elements of a cost estimate over time



From a funder (client) perspective, a range of potential cost outcome scenarios is not unreasonable for projects with low scope definition (low project maturity). Multiple cost estimate scenarios may be prepared to explore the cost impacts of modifying single or multiple variables to fully assess their relative significance. Ultimately, funds are made available to align with the approved project baseline estimate, the uncertainties assessed and the associated cost provisions appropriately established. This will enable the project to be funded to the most realistic mid-value (or risk-appetite-led value) at all times.

5.2. Scope completeness and maturity

Figure 5.1 also clearly illustrates an increase in project base scope over time. There are many project-dependent issues that can manifestly change scope over time and therefore impact directly on the project baseline estimate.[2]

The implications of scope change with increasing maturity of project definition, and the associated need for progressive evolution of a cost estimate over time are important considerations. This process is an important factor that may drive costs beyond agreed budgets unless financial provision is made for the impact of all related uncertainties. Experience suggests that many early decommissioning project forecasts did not address adequately the maturity of the definition of scope when considering provision for both in-scope and out-of-scope uncertainties. To address this, therefore, the completeness and maturity of the scope definition needs to be explicitly considered in the estimate. As the project baseline estimate is specific to the scope as defined in the BoE at that point in time, the relative maturity and completeness of the scope definition needs to be taken into consideration in the assessment of risk beyond the defined scope of the project.

Estimates developed at an early stage are usually to explore decommissioning strategies, and establish future funding requirements. This can be compared with cost estimates produced at a later stage during facility or plant operation to assess progress towards future funding requirements, and with estimates further developed immediately prior to decommissioning into a performance measurement baseline. The processes for conducting these estimates should be similar and the basic analytical techniques do not vary. Therefore, it is good practice to ensure that the estimating process is defined in a BoE and is made as transparent as possible. Irrespective of the purpose for which a particular cost estimate might be developed, estimates are prepared at a particular time and reflect the stage of scope development at that time (sometimes called "an overnight estimate"). The maturity of the definition of the scope of work to be undertaken will evolve through a series of staged developments.

As updated estimates are produced with increased scope completeness and maturity, the newer estimates should include a detailed comparison between the new estimate and the previous one (reconciliation step) to explain what is changed and why.

5.3. Project context and differing perspectives

The circumstances or "context" in which a project takes place are important considerations for understanding an estimate, as facts and data do not exist in a void, unconnected from other information. Project context will vary from project to project and country to country. It may also change over time as a function of national strategies and organisational accountabilities. Some countries have adopted standards (and created associated project control procedures) to enable better transparency and consistency in cost estimating, and to generate the need for cost and schedule integrated decommissioning baselines. Some countries mandate production of "owner's estimates" and third party (independent) assurance while others rely more on the supply chain to provide budget prices and use these to create reference cases and extrapolate from these on a site by site basis.

2. See also the case study in Appendix B.

It is important that a cost estimate BoE clearly provides the specific conditions and perspectives which apply. These may include:

- External considerations (political, economic, societal) – this should encompass the overall policy framework governing nuclear energy in the country where the estimate was produced, as well as the level of public and stakeholder acceptance.
- The regulatory framework for decommissioning – regulatory practice may introduce key approval or hold points or introduce confidence checks. Considerations include licensing conditions and regulatory approaches to oversight of dismantling activities. Legislative conditions will form some of the boundary conditions and hence are likely to be a key area of uncertainty analysis.
- The maturity of the budget prices and levels of risk that can be assigned by the supply chain.
- The volume of available supporting information and confidence in this information. This includes any experience gained from similar decommissioning projects or benchmarking data.
- Whether any top-down views or third party biases exist in response to budgetary approvals.
- The structure of the nuclear fleet to be decommissioned[3] and whether there is a possibility to develop a national or programmatic approach to decommissioning across multiple sites.[4]
- Whether waste management and disposal is integrated with the decommissioning project – this will affect boundary conditions and associated risk analysis.

Perspectives are very important to understand. Those with responsibility for undertaking the project and those with responsibility for funding allocation often apply biases (consciously or sub-consciously) that can materially impact both the base scope and additional funding provisions.

While some projects will adhere to the theoretical relationship illustrated in Figure 5.1, many will not. It is therefore necessary to better understand why this under-provisioning occurs, and ensure a more systematic approach to the analysis of decommissioning uncertainties. In doing this, one also has to consider different perspectives and their associated cost drivers.

- external perspectives – political or regulatory;
- fund owner – adequacy of fund build-up; returns on investments;
- operator/owner/licensee – decommissioning inexperience;
- supply chain perspectives – vendor decommissioning experience[5];
- technical considerations – use of unproven technologies and novel approaches.

3. E.g. degree of variation in the design of the plants, number of plants owned by the same operator, power of the plants, number of plants on the same site, etc.
4. These include, for example, the possibilities to develop a national programme (such as the UK's Nuclear Decommissioning Authority or Spain's Enresa) or multiple site or fleet-wide approaches (such as that of EDF in France). Other considerations range from the financial (e.g. possibilities to mutualise investments), to the technical (research and development on technologies) or conducting engineering studies across a number of sites to be decommissioned with transfer of both equipment as well as knowledge and experiences across sites and from one project to another.
5. External contracting of work packages brings a further dimension to cost profiles and risk appetite.

These perspectives can generate very diverse outcomes for the estimate, in particular where provision for uncertainties outside of the defined project scope is being considered, taking account of different risk appetites.

5.4. Sensitivity analysis and scenario planning

Sensitivity analysis is the study of how the output of a mathematical model or system (numerical or otherwise) can be related to variances in its input variables. By means of this analysis, insight is provided into how and to what extent changes in particular variables may influence the model outputs. The BoE is designed around a set of boundary conditions that defines what work packages are to be produced. This is based on a single reference scenario and results in a project baseline estimate cost covering the in-scope elements. Cost modelling can therefore be used to conduct a sensitivity analysis of the project baseline estimate to particular input parameters such as labour rates or waste package disposition costs. By changing key parameters one at a time, this will reveal what the key cost drivers are and enable more analysis of options, opportunities and risk mitigation. For example, a sensitivity analysis for an NPP decommissioning project might consider variation of key input parameters related to alternative arrangements for *inter alia*:

- organisational transition activities (operations to decommissioning);
- make versus buy (supply chain) decisions;
- waste packaging, treatment, storage optimisation and accessibility of waste disposition routes;
- critical path analysis of the reactor and any other decommissioning schedule optimisation;
- labour costs for different staffing options.

A further sensitivity analysis can be conducted specific to risks and out-of-scope events. In this case, a useful insight might be obtained as to where it may be possible to prioritise effort to reduce risk and hence reduce cost and schedule durations associated with the baseline.

Scenario planning may be used where the reference scenario is adjusted to consider alternative options. These may be risk- or opportunity-driven, but the initial concept should be that the same outcome is achieved (i.e. working within the same boundary conditions and scope assumptions). If so, these new scenarios can be built and directly compared with the reference scenario. This is particularly useful in early (concept design) baseline estimates where options can be laid out side by side and tested for robustness and benefit. In the case of nuclear decommissioning, two time-based strategic scenarios are internationally recognised:

- immediate dismantling;
- deferred decommissioning.

At a lower level in the work breakdown structure (WBS) it may also be possible to change scope assumptions and generate detailed scenarios at sub-project level. Examples are waste container selection or decontamination levels that can be achieved. This generates options for waste quantities/storage capacity and waste handling plant design, and several scenarios developed under the “waste project” scope. Baseline maturity will progressively require scenario planning to be conducted lower into the WBS and, in doing so, increase scope definition and cost underpinning.

5.5. Benchmarking

Systematic approaches to benchmarking costs and enabling comparison with other estimates and assumption sets may be invaluable in understanding risks and possible cost outcomes. It requires the collection and analysis of data relating to cost estimates and/or actual (incurred) costs. A major challenge for benchmarking in the context of NPP decommissioning costing at present is that key project and cost data typically is not readily available (NEA, 2016).

Even on the basis of such limited data as is currently available, careful comparisons of estimates and outcomes may be valuable and give useful insights. These include comparisons with costs from other decommissioning projects, as well as other projects that offer relevant useful data. Comparing estimates with actual costs from completed or ongoing projects can be used to support or challenge the results of a cost estimate in light of actual experience. Such comparisons should ensure that the differences between the estimate scope and the actual decommissioning project have been taken into account, and include information about relevant specific contexts or conditions and other factors that may impact on costs. Systematic approaches to benchmarking and enabling comparison with other estimates and assumption sets is valuable.

5.6. Interdependencies between cost and schedule

A quality cost estimate is sufficiently detailed, with WBS costs assessed for each activity determined at the lowest working level, and a schedule that aligns the cost block in a logical and interdependent way. This is the process of building an integrated resource loaded schedule on a software platform. The interdependencies are fully mapped and logically linked, and the consequent impact of estimating uncertainty and risk analysis in cost and time. Risk mitigation scope can be added or deleted and opportunities explored. Several iterations are often used to optimise the final baseline.

The interdependency of cost and schedule is very important for nuclear decommissioning projects as many costs are time dependent and hence duration-related planning assumptions can directly influence the baseline cost.

An integrated Monte Carlo probabilistic tool is often used by a risk expert to analyse the resource loaded schedule. This analysis allows the determination of risks impacts and whether these should be against cost or schedule or both. In some cases, one risk or two specific risks may dominate the statistical analysis and use of a tornado diagram or other software analysis tools are useful to understand these outputs. All techniques have advantages and disadvantages, and the selected approach can depend on the purposes of cost estimates, the customer or requesting organisation, and the use and expected result of the estimate.

5.7. Quality assurance analysis and review

It is vital for all decision makers to understand that the quality of the analyses of estimating uncertainty and risk are tied to the quality of the input data and the analysis of specific uncertainties and impacts. In order to enhance understanding of the process and confidence in the results, the analyses and calculations underpinning these provisions need to be traceable, the processes understandable and able to be referenced to the input data. The following paragraphs identify a number of guides which examine aspects of quality assurance issues and how these can be addressed in an estimate.

OECD: The NEA has published a guide which sets out a detailed process to describe quality decommissioning cost estimates in relation to the maturity of scope definition; the basis of estimates; the structure of estimates; risk analyses of costs and schedules and estimating uncertainty; and quality assurance requirements followed by the licensee to ensure the estimate conforms to the requirements of its quality assurance programme (NEA, 2015). It offers international specific guidance in preparing quality cost and schedule estimates to support detailed budgeting for the preparation of decommissioning plans, for the securing of funding and for decommissioning implementation. The guide is based on current practices and standards in a number of NEA member countries.

United States: More generally, the US General Accountability Office (GAO) has produced a cost estimating guide which provides an assessment of the processes, procedures and practices needed for ensuring development of high-quality – that is, reliable cost estimates (GAO, 2009). In this context, a high-quality cost estimate helps ensure that readers are given the information they need to make informed decisions and conclusions concerning the cost estimate. The GAO guide identifies the following four characteristics of a high-quality cost estimate. Specifically, such an estimate is:

- **credible** when it has been cross-checked with an independent cost estimate (ICE), the level of confidence associated with the point estimate has been identified, and a sensitivity analysis has been conducted;[6]
- **well-documented** when supporting documentation is accompanied by a narrative explaining the process, sources, and methods used to create the estimate and contains the underlying data used to develop the estimate;
- **accurate** when it is not overly conservative or too optimistic and based on an assessment of the costs most likely to be incurred;
- **comprehensive** when it accounts for all possible costs associated with a project, it contains a cost estimating structure in sufficient detail to ensure that costs are neither omitted nor double-counted, and the estimating teams' composition is commensurate with the assignment.

United Kingdom: The UK National Audit Office (NAO) has published a report (NAO, 2016) on performing audits of models, which is applicable to cost estimation models. It lays out a seven-stage plan which can be used for auditing estimates and the foundation on which the cost estimate is built, starting with the model concept and design, and ending with making use of model outputs and all overseen by a governance and assurance structure.[7] The steps involved in performing the NAO's approach to a model audit are shown in Figure 5.2.

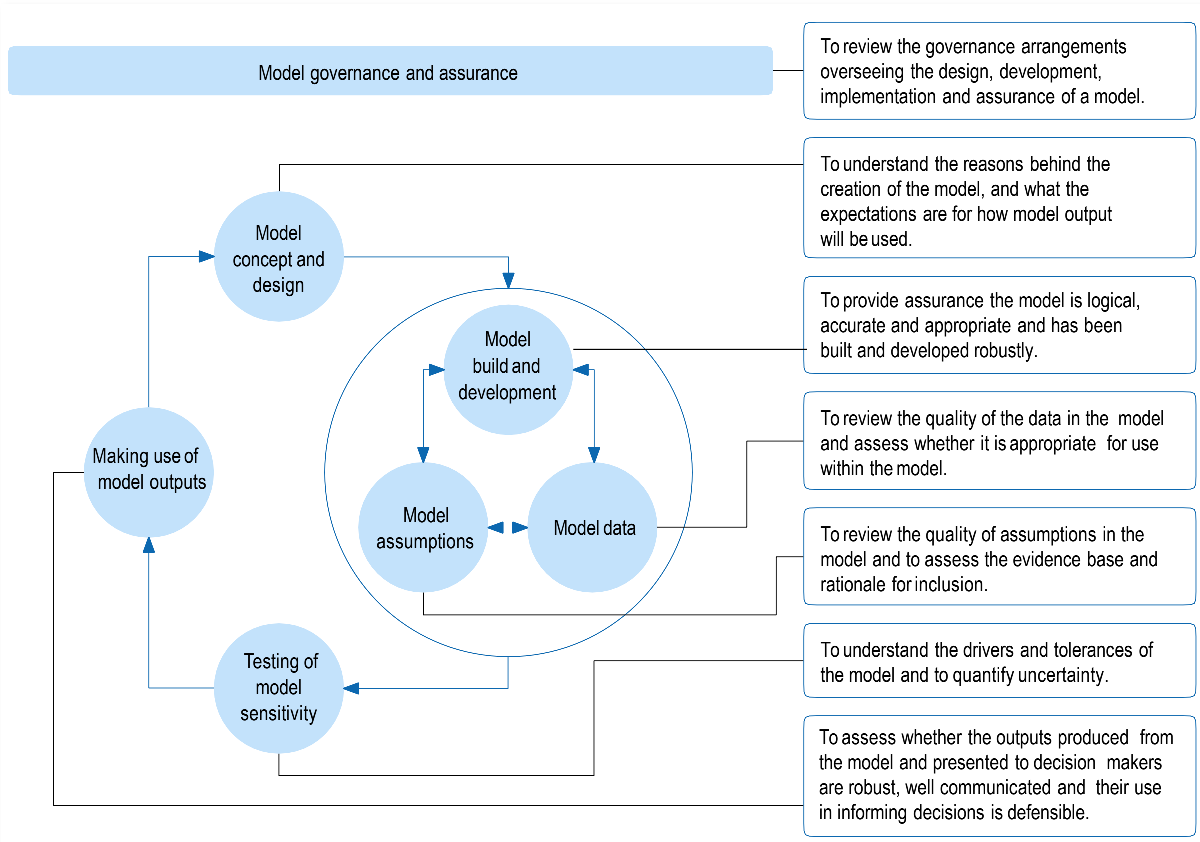
Specifically, the NAO's approach to a model audit addresses the outputs produced by the model to ensure they are robust, well communicated and used by decision makers. It covers issues such as governance arrangements, and the quality of data and assumptions. It has the flexibility to be used for models of all levels of complexity and business risk.

The application of the NAO approach can be tailored according to time and resources available, and the level of assurance needed to reach a judgement. The framework is based on that used by the NAO when reviewing organisations' models and builds on good practice guidance, including from HM Treasury (2004) and international standards. Reviews of cost estimate models, including allowances, estimating uncertainty and risks

6. According to the GAO framework, the risk and uncertainty analysis assesses the variability in the cost estimate from such effects as schedules slipping, missions changing, and proposed solutions not meeting users' needs. A sensitivity analysis examines the effect of changing one assumption related to each project activity while holding all other variables constant in order to identify which variable most affects the cost estimate.
7. The NAO report notes, in addition, that the questions in the framework are not exhaustive, meaning there will be other checks that can be applied.

using the NAO framework can enhance the credibility of the model and provide confidence in its output. This is perhaps best done by an independent auditor who has not been directly involved with the creation of the model.

Figure 5.2. NAO framework for a model audit



Source: © NA0 2016.

Chapter 6. Conclusions

The process of decommissioning cost estimation is continually evolving, in line with national requirements and practice, taking into account experiences from other sectors. It is essential to have a clear understanding of costs, including the associated uncertainties, so as to demonstrate that the full range of relevant potential cost outcomes has been considered in the decommissioning cost estimate. There has been a general trend towards showing greater levels of detail in such estimates and more explicit representation of the uncertainties bearing upon the final cost. Issues of current concern include the ability to accurately calculate and demonstrate the validity of decommissioning cost estimates, the capacity to ensure adequate decommissioning funding and the need to control costs during the decommissioning phase.

Ensuring that adequate funds are available, when needed, to implement decommissioning activities relies on two interrelated factors:

- that the full range of potential costs, including the associated uncertainties, are considered in determining the extent of the resources required;
- that a system is established which ensures that finances are set aside to conduct decommissioning activities, and that these funds are managed in an appropriate way.

Neither of the above factors are static. Cost estimates, for example, evolve over time, in line with increased knowledge of the plant behaviour, and as the eventual decommissioning strategy becomes more firmly established. Changes to the cost estimate would then need to be reflected in changes to the required contributions to the financing system. This process normally takes place at regular intervals over the plant's lifetime (e.g. every three years, with oversight mechanisms generally being applied in accordance with national legal frameworks).

The report thus enumerates the major components of decommissioning cost estimates, distinguishing those elements that are "in-scope" from those that are "out-of-scope" in relation to the originally established basis of estimate (BoE). In-scope uncertainties are associated with situations and events that, based on past experience, can be considered sufficiently likely to occur, and thus should be fully reflected in the cost estimate. Associated costs are determined by taking into account assumptions, boundary conditions, exclusions and constraints specified in the BoE.

By following a rigorous approach based on the BoE, the different elements of uncertainties can be identified and distinguished in a project/site-specific way. This report highlights the need to address both in-scope and out-of-scope uncertainties comprehensively in order to get a full picture of the potential costs. Fully addressing uncertainties also requires careful consideration of the relative completeness and maturity of the scope definitions themselves.

It is recommended in this report that out-of-scope uncertainties, irrespective of their origin and nature, be designated as risk events and treated as such, since they relate to situations which, though not expected to occur, could impact the total project cost. The extent to which fund provisions are set aside to deal with these situations depends on the assessed probability that they might occur as well as the "risk appetite", or the extent to which those responsible for a project are prepared (or allowed) to proceed without having made specific provisions in advance. It may be appropriate to exclude certain risks, but the basis for exclusion and the implications for the overall estimate and funding provisions need to be fully described.

Cost estimates should therefore contain a number of specific elements:

- the cost as it relates to the "base scope";
- the estimating uncertainty;
- the funded risk.

Estimating uncertainty can be calculated using either a deterministic approach, or by using a probabilistic approach, where a Monte Carlo analysis is performed. Fully documenting the approach used to calculate the estimating uncertainty provision will allow for a better understanding of and confidence in the overall cost estimate.

The funded risk provision also needs to be carefully defined and communicated. Ensuring that the approach to applying a funded risk provision is clearly linked to the project baseline estimate, and that the identification and assessment of risks is fully presented, enhances confidence in the overall cost estimate. Part of this process involves addressing risks associated with the completeness and maturity of the scope definition, on which the estimate is ultimately based. Where there is unfunded risk, particular care should be given to describing the basis for excluding the provision for these risks.

Adopting a consistent means for deriving estimating uncertainty and risk provisions, and having a consistent approach to risk appetite should enable a more reliable funding estimate value. Without such measures, optimism bias (inappropriately high risk appetite) or a nuclear site operator's desire to simply exclude scope that is difficult to estimate may generate misleading estimates. Care and consistency must therefore be exercised by the estimator when setting out the approach in the BoE so as to ensure that each step of the base scope, risk mitigation scope adjustment, estimating uncertainty and the treatment of risk is integrated and that the outcomes are fully and logically presented. In order to enhance understanding of the estimate and confidence in the results, the analyses and calculations underpinning these provisions need to be traceable, the processes need to be comprehensible and the estimate output needs to be able to be referenced to the input data. It is thus important to also consider aspects of quality assurance and how these aspects are addressed in an estimate.

Taking a systematic approach to the benchmarking of costs, and enabling comparison with other estimates and assumption sets, is invaluable in understanding project uncertainties and risks, as well as the range of possible cost outcomes. It requires the collection and analysis of data relating to both the decommissioning cost estimates and actual costs. The industry will need to address the challenge of making relevant project and cost data available for analysis if it is to avail itself of the insights that such benchmarking initiatives can offer in relation to the analysis and management of decommissioning project costs. Such initiatives can also provide useful input into processes for demonstrating the adequacy of decommissioning funding and ensuring value-for-money in the execution of decommissioning projects.

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Appendix A. Case study – Calculating the final funded cost for a reactor decommissioning project

Introduction

To illustrate the step-wise process described in this report, this case study presents the calculation of the final funded cost for a single unit 1 100 MWe pressurised water reactor (PWR) nuclear power plant (NPP) decommissioning cost estimate.

This case study sets out a simplified basis of estimate (BoE) which is used to determine the project base cost. This is followed by a determination of estimating uncertainty (ISDC contingency) to calculate the project baseline estimate. The final stage is the conduct of a risk analysis to determine the funded risk provision for the project. Screen shots of the raw outputs from the computer analyses are included to show the practical steps involved. Note that this is an illustrative example, which should not be taken as a typical or expected outcome.

The example used is from an actual NPP immediately prior to the start of decommissioning, but with the description simplified and condensed in order to more clearly describe the application of the principles without going into unnecessary degrees of detail.[1] The decommissioning strategy selected was immediate dismantling, with the site to be returned for alternative use after site restoration. The estimate is assumed to be based on a complete and fully mature scope definition, and incorporate risk mitigation scope in the project baseline.

Basis of estimate

Scope of work

- To estimate the cost to decontaminate, dismantle, terminate the licence and restore the site.

Assumptions

- Spent fuel will be stored wet until an independent spent fuel storage installation (ISFSI) is constructed on-site. Fuel will then be transferred to dry storage casks on the ISFSI until a geological repository is available.
- Decommissioning will be performed to meet the radiological “clearance level” for termination of the license as imposed by the regulator as of the date of the study.
- Building structures will be demolished to a depth of one meter below grade, where applicable.

1. In an actual site-specific analysis, a much more comprehensive uncertainties’ assessment would be performed, resulting in potentially hundreds of in-scope and out-of-scope uncertainties to consider.

- As low as reasonably achievable principles are implemented through the use of work difficulty factors (productivity factors) to take into account worker safety, use of protective clothing, respiratory protection, confined space/scaffolding work areas, work breaks and mock-up training.
- Labour costs are representative of the local labour contracted labour rates. Labour rates for project management and administrative personnel were obtained from the owner/licensee.
- Radiological levels of contamination and activation of components and structures was taken from the facility and site characterisation report.
- Liquid filled systems not required to support decommissioning activities have been drained and disposed of by the facility operations personnel prior to the start of decommissioning. Similarly, legacy wastes of spent resins, filters, and hazardous/toxic materials will have been removed prior to the start of decommissioning.
- Asbestos-containing materials (ACMs) are removed immediately prior to radiological dismantling, and is considered part of the decommissioning scope of work and cost.
- Clean components that have potential reuse (large pumps, valves, diesels, etc.) as their original function will be made available for resale as salvage. Clean components with no potential for reuse will be made available for scrap. No credit for salvage or scrap is included in the estimate as the value is small.
- Costs for energy consumption during decommissioning are assumed to be the same as consumption during refuelling outages.

Exclusions

- Electrical switchyards and switchgear are not part of the decommissioning scope, and will remain in service for transmission purposes.
- The cost for on-site spent fuel storage is included in this estimate. The cost for spent fuel transport and disposal in a geological repository is excluded, as it is covered as an operations cost and funded separately.

Boundary conditions and limitations

- There were no off-site radiological contamination conditions reported in the characterisation report, so none were considered in this estimate.

Decommissioning strategy

- The decommissioning strategy is immediate dismantling.

End point state

- The end point state will be "greenfield."

Stakeholder input

- The local citizens advisory panel considerations have been included with respect to safety to the community, as requested.

Facility description

- The facility physical inventory was developed from detailed as-built drawings, equipment specifications and facility confirmative walk downs.

Site characterisation

- The facility and site characterisation report was used as the basis for determining the radiological and hazardous/toxic inventory.

Waste management

- All waste will be packaged, transported and disposed of or stored in accordance with all federal and local regulations.
- Low-level (LLW) and intermediate-level waste (ILW) will be disposed of at a licensed disposal facility within a distance of 1 000 kilometres. High-level waste (spent nuclear fuel and highly radioactive reactor vessel components) will be stored on-site in the ISFSI until a geologic repository is available.
- Off-site waste processing (conditioning) will be used to the maximum extent possible to reduce material disposed of in the LLW and ILW disposal facilities.

Sources of data used

- Actual physical data was used to develop the inventory. No "proxy data" (from a similar sized and type plant) was used.

Decommissioning cost estimating methodology used

- The bottom-up estimating methodology using unit cost factors was used for all activity-dependent (hands-on) tasks. Level-of-effort estimating was used for period-dependent project management estimates. No parametric ratio estimating was used.

Description of techniques and technology used

- Reactor vessel and internals will be fully segmented to fit containers/casks for transport and disposal using remotely operated cutting tools.
- Large components (steam generators, pressurisers and reactor coolant pumps) will be removed intact and sealed as their own containers for transport and disposal.

Work breakdown structure

- The work breakdown structure (WBS) is sufficiently detailed so as to be able to convert it into the ISDC WBS structure as needed.

Description of computer codes or calculation methodology

- The estimator's proprietary computer code was used to develop the cost estimate. The code was developed under a rigorous quality assurance programme, and the code validated for accuracy.

Schedule analysis

- A decommissioning schedule has been developed for all work activities with the goal of minimising the critical path activities for efficient work practices.

Allowances

- Allowances are included in the base scope of work to account for the estimated cost of special tooling for segmentation of the reactor vessel and internals. As actual decommissioning activities commence, these allowances will be refined as needed, e.g. using actual vendor quotes for the equipment.

Estimating uncertainty and risk

- Estimating uncertainty is calculated for the in-scope activities using a probabilistic Monte Carlo analysis computer program. A three-point distribution is used to develop the contingency amount.
- A risk analysis is performed to determine additional funding provision for the out-of-scope risks. The post-mitigation residual risks is analysed using a probabilistic Monte Carlo analysis computer program. A three-point distribution is used to develop the funded risk amount.

Quality assurance programme

- A decommissioning-specific quality assurance programme and quality assurance plan was followed for the development of the cost estimate.

The project base cost

As noted earlier, for simplicity a condensed list of decommissioning activities is considered for this case study. For each of the main categories of activities, the "likely cost" was determined.

As shown in Table A.1, the total base cost estimate is about 421.6 million.

This base cost excludes estimating uncertainty and any provision for risk. As noted in the BoE, it does include allowances and is assumed to include risk mitigation scope.

Table A.1. The base costs for major categories of activities

Description	Dist	Likely cost
Spent fuel	Tri	64 312 000
Project management	Tri	132 812 000
General plant operation and maintenance	Tri	13 723 000
Site preparation and characterisation	Tri	10 173 000
Asbestos removal and disposal	Tri	8 632 000
Large component removal	Tri	6 001 000
Segmentation and removal of reactor vessel internals and reactor	Tri	21 877 000
Component and piping disposition	Tri	20 838 000
Containment building demo.	Tri	13 987 000
Other building demo.	Tri	16 042 000
Final status survey and licence termination	Tri	2 607 000
Waste management	Tri	93 266 000
Soil remediation	Tri	742 000
Clean material disposition	Tri	1 087 000
Site restoration	Tri	15 466 000
Totals		**421 565 000**

Calculating the estimating uncertainty

The method used to develop the in-scope estimating uncertainty is a Monte Carlo probabilistic computer program employing a three-point distribution for each of the major categories of activities identified earlier.[2]

In order to create the three-point distribution for the Monte Carlo analysis, for each category of activity a "lowest" percentage value (% below the "likely cost") and "highest" value (% above the "likely cost") for each category of activity were selected by the estimator based on actual decommissioning experience.

Table A.2. Estimating uncertainty input data

Description	Dist	Likely cost	% below	% above	Exp cost
Spent fuel	Tri	64 312 000	5.0	25.0	68 599 467
Project management	Tri	132 812 000	5.0	15.0	137 239 067
General plant operation and maintenance	Tri	13 723 000	5.0	15.0	14 180 433
Site preparation and characterisation	Tri	10 173 000	5.0	25.0	10 851 200
Asbestos removal and disposal	Tri	8 632 000	5.0	25.0	9 207 467
Large component removal	Tri	6 001 000	5.0	25.0	6 401 067
Segmentation and removal of reactor vessel internals and reactor vessel	Tri	21 877 000	5.0	75.0	26 981 633
Component and piping disposition	Tri	20 838 000	10.0	20.0	21 532 600
Containment building demolition	Tri	13 987 000	5.0	30.0	15 152 583
Other building demolition	Tri	16 042 000	5.0	25.0	14 111 467
Final status survey and licence termination	Tri	2 607 000	5.0	25.0	2 780 800
Waste management	Tri	93 266 000	5.0	25.0	99 483 733
Soil remediation	Tri	742 000	10.0	35.0	803 833
Clean material disposition	Tri	1 087 000	5.0	15.0	1 123 233
Site restoration	Tri	15 466 000	5.0	20.0	16 239 300
Totals		**421 565 000**	**5.7**	**26.7**	**447 687 883**

The Monte Carlo analysis was then run, yielding the following outputs: a probability distribution for estimating uncertainty (Figure A.1); a cumulative probability curve for estimating uncertainty (Figure A.2); and accompanying statistical data (Table A.3).

2. C.f the process described in Section 3.3.

Figure A.1. Probability distribution for estimating uncertainty

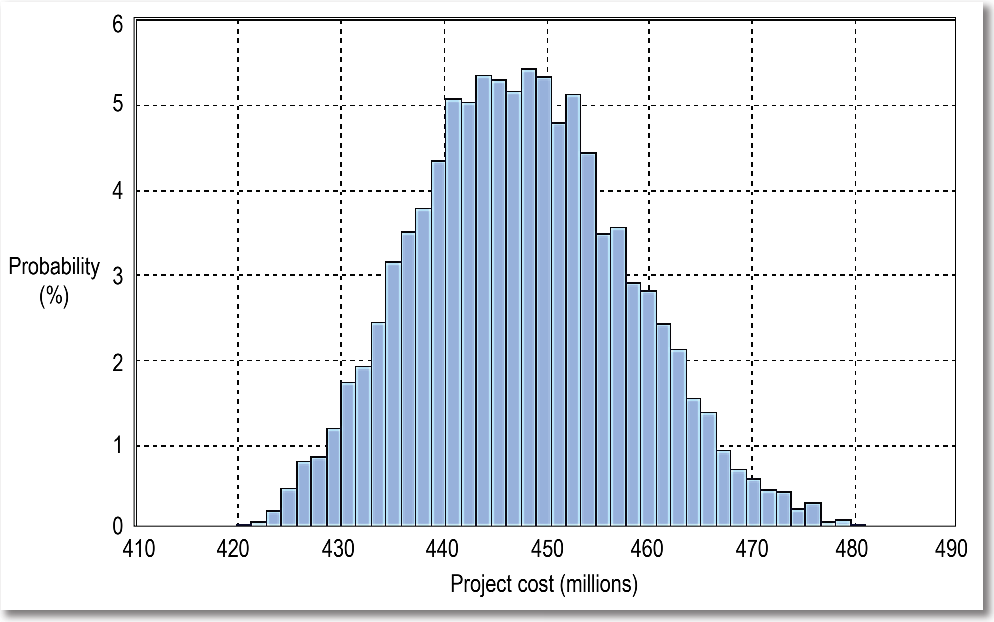


Figure A.2. Cumulative probability for estimating uncertainty

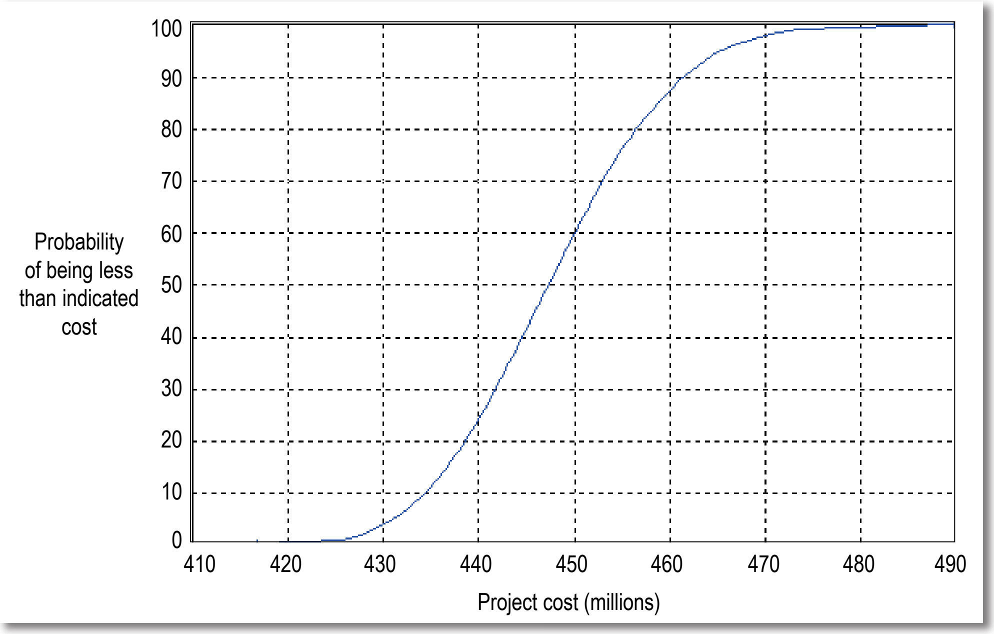


Table A.3. Basic statistics for estimating uncertainty

Basic statistics		
Lowest cost	4.2e8	
Highest cost	4.9e8	
Standard deviation	10 475 156	
Iterations run	10 000	
Kurtosis	2.848[a]	
Skewness	0.217[b]	
Averages		
Median cost	4.5e8	
Mean cost	4.5e8[c]	
Contingency analysis		
Sum of likely cost	4.2e8	
Probability of being < SLC	0.13%	
Confidence level	**Required contingency**	
	(value)	(% of SLC)
100%	68 181 493	16.17
99%	51 903 458	12.31
95%	43 820 069	10.39
90%	39 899 338	9.46
80%	34 917 705	8.28

(a) Flatter than normal curve. (b) Positively skewed. (c) At the 99% confidence level this mean is within 0.0603% of the true mean.

The result of this analysis indicates that about 16%, or 68.2 million should be added to the base cost as estimating uncertainty.[3] Based on the above, the project baseline estimate would then be 489.8 million.

Calculating the funded risk provision

The method used to develop the analysis for risks beyond the defined project scope, also uses a Monte Carlo probabilistic computer program employing a three-point distribution for each of the major risks considered.

In order to create the three-point distribution for the Monte Carlo analysis, the estimator selected the "lowest" and "highest" values for each risk category based on experience, while the "likely cost" is the original base cost for the work activity related to that risk.

The estimator would then apply an appropriate estimated probability of occurrence percentage for the lowest, highest and likely costs, and enter them in a input data table (see Table A.4).

3. The 100% confidence level is used because of the assumption that all of this money will be fully spent during project execution, in line with the ISDC.

Table A.4. Risk analysis input data

Description	Dist	Likely cost	% below	% above	Exp cost
Dry casks do not meet regulations	Tri	39 926 000	5.0	40.0	44 584 033
Additional ACM found post characterisation	Tri	2 158 000	5.0	20.0	2 265 900
Larege component transport needs supports	Tri	2 100 000	2.0	25.0	2 261 000
Reactor vessel segments cannot be "blended"	Tri	3 282 000	5.0	30.0	3 555 500
Containment concrete Stronger than estimated	Tri	2 098 000	10.0	20.0	2 167 933
Disposal site closes/store on-site	Tri	23 317 000	5.0	25.0	24 871 467
Soil contamination deeper than measured	Tri	742 000	10.0	25.0	779 100
Totals		**73 623 000**	**6.0**	**26.4**	**80 484 933**

The Monte Carlo analysis was then run, yielding the following outputs: a probability distribution for risk (Figure A.3); a cumulative probability curve for risk (Figure A.4); and accompanying statistical data (Table A.5).

In order to calculate the funded risk provision, the risk appetite needs to be taken into consideration. For the purposes of this case study, the risk appetite requires that the funding provision is sufficient to cover the costs associated with the 80% confidence level (or P80).

The result of this analysis for risk indicates that an additional funded risk provision of 14.4% or 10.6 million should be added above the project baseline estimate.

Figure A.3. Probability distribution for risk

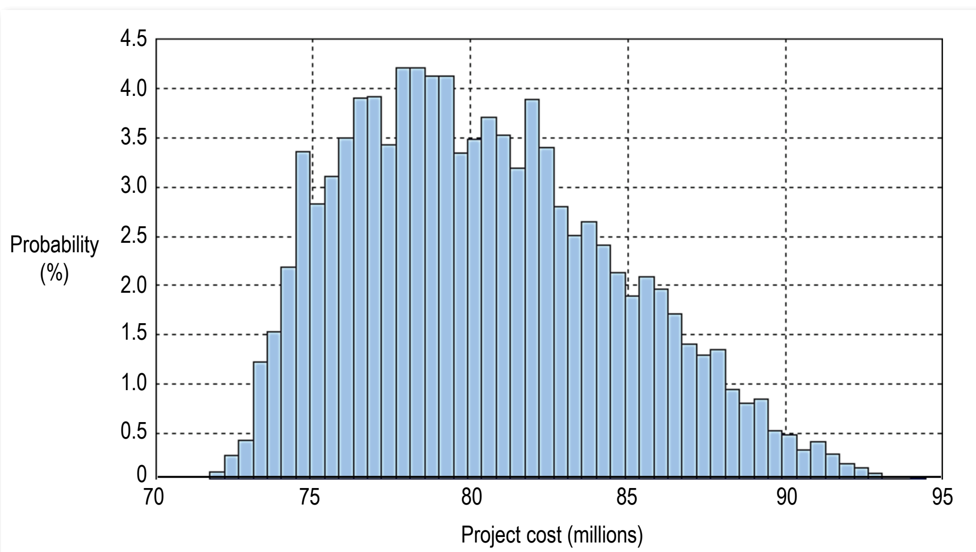


Figure A.4. Cumulative probability for risk

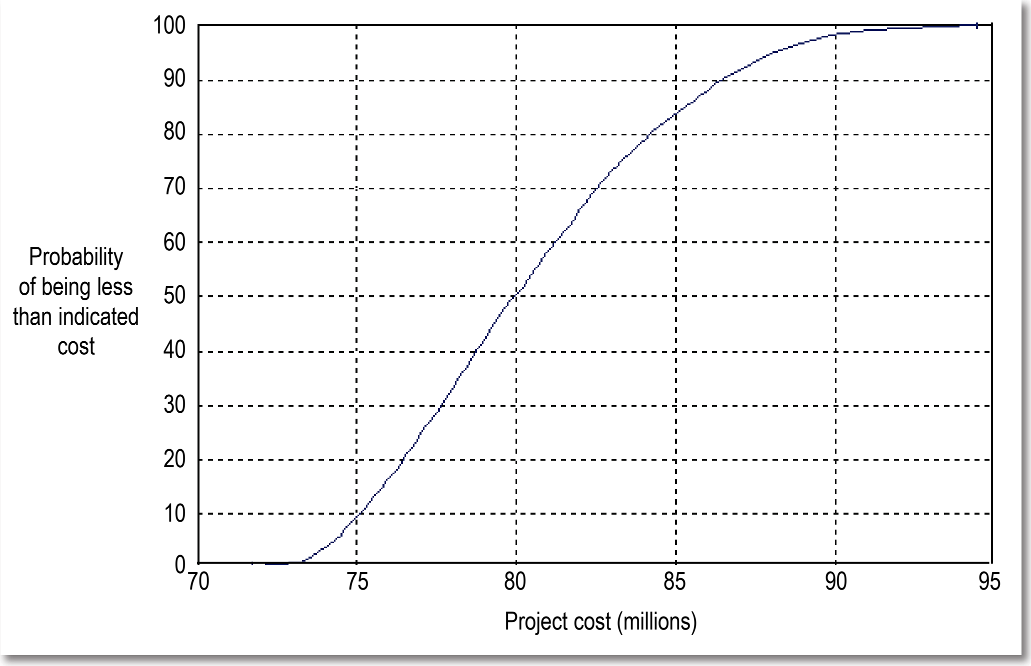


Table A.5. Basic statistics for the risk analysis

Basic statistics		
Lowest cost	71 711 518	
Highest cost	94 419 434	
Standard deviation	4 272 677	
Iterations run	5 000	
Kurtosis	2.540[a]	
Skewness	0.441[b]	
Averages		
Median cost	79 928 533	
Mean cost	80 390 992[c]	
Contingency analysis		
Sum of likely cost	73 623 000	
Probability of being < SLC	2.26%	
Confidence level	**Required contingency**	
	(value)	(% of SLC)
100%	20 796 434	28.25
99%	17 426 589	23.67
95%	14 438 986	19.61
90%	12 832 216	17.43
80%	10 565 504	14.35

(a) Flatter than normal curve. (b) Positively skewed. (c) At the 99% confidence level this mean is within 0.1936% of the true mean.

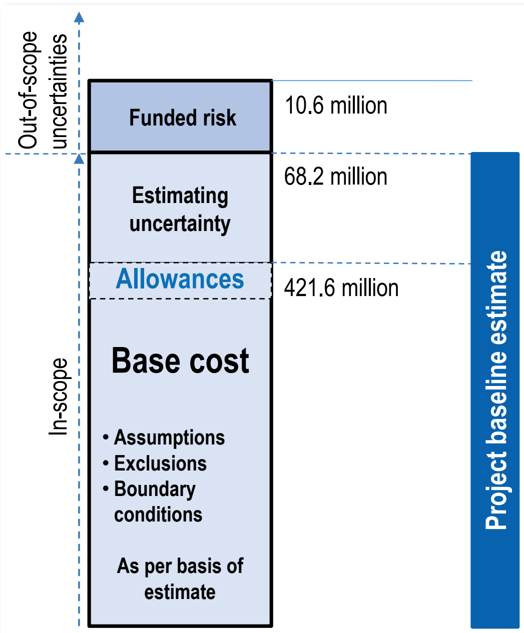
Conclusions

This case study illustrates a step-wise process for calculating estimating uncertainty and risk in line with the approach described in this report. The process is relatively straight-forward, and with the guidance provided in this report can be readily implemented.

The outcomes of this case study are summarised in Figure A.5. The base cost is 421.6 million, and includes allowances and risk mitigation scope, as set out in the BoE. The estimating uncertainty within the defined project scope is determined to be 68.2 million. The additional cost provision for funded risk is calculated to be 10.6 million.

Based on the above, the project baseline estimate would then be 489.8 million and the final funded cost for the project is 500.4 million.

Figure A.5. Summary of results from the case study calculations



Appendix B. Case study – Evolution over three decades of cost estimates for the decommissioning of a nuclear power plant

Introduction

This case study describes the evolution over a period of three decades of cost estimates for the decommissioning of an actual nuclear power plant. This nuclear power station has two light-water boiling water reactors (BWR), with a generation capacity of approximately 600 MWe from each unit.

The six cost estimates presented here were produced over a period of approximately 30 years beginning from the late 1970s. The period covered by the estimates considered here commences a few years after start of operation until after the closure of both units but a number of years before the planned start of decommissioning work. During this period, a total of four different models for producing the cost estimates were used. Accordingly, this case study needs to consider two interrelated issues: the development and evolution of the approaches used to produce the decommissioning cost estimates for this facility over the three decades; and the specific changes to the estimates themselves and the way they have addressed provisions for estimating uncertainty and risk.

Six cost estimates and four different models

This study presents six separate project baseline estimates produced at different points at time over the three decades considered. All the studies were produced by or on behalf of the nuclear licensees. In general, the main purpose of the cost estimates remained constant during the three decades, namely as part of the formal decision-making process for calculating contributions for future decommissioning as part of the national waste and decommissioning financing system. However, the very first estimate was prepared in order to inform the governmental deliberations on establishing national organisational and financial arrangements for waste and decommissioning.

The cost estimates presented from 1979 to 2004 were all based on extrapolations from reference facilities and inventories, using generic assumptions. The details of the methods used varied between the different types of generic estimates as shown in Table B.1. The final example, from 2008, is a detailed scenario-dependent site-specific decommissioning cost estimate.

The generic cost studies were done with the aim of being able to transfer the decommissioning calculations from the chosen reference BWR plant to the other BWRs in the country, and for this reason certain site-specific cost items are *not* included in the calculations.[1]

1. However, it was acknowledged at the outset that these site-specific costs would need to be incorporated when the project specific decommissioning cost calculations are done.

In contrast, the site-specific cost estimate is decommissioning scenario-dependant, concerns the decommissioning of the whole site including a number of common facilities, and is based on experience from how site-specific cost estimates are done in the United States. These methodological changes have implications for understanding and interpreting the estimates, as discussed later on in this case study.

The general changes in approach are summarised in the table below.

Table B.1. Dates, characteristics and purposes of the different studies

Type	Estimate	Characterisation/features	Primary purpose
Generic	1979	Very preliminary estimates of the cost and time required to dismantle a boiling water reactor, using a reference plant and data from other countries.	To inform governmental deliberations on establishing national organisational and financial arrangements for waste decommissioning.
	1986	Updated generic estimate with extrapolation using a particular reference plant for boiling water reactor decommissioning. The 1979 cost estimate was updated to reflect additional experience gained from maintenance and renovation work on nuclear power plants.	Prepared to meet the national requirements for licensees to prepare and update decommissioning cost estimates.
	1994 2000 2004	Updated generic estimate with extrapolation using a different reference plant for boiling water reactor decommissioning. The same reference plant was used for boiling water reactor decommissioning in all these three studies. In 1994, the earlier 1986 study was updated to incorporate new experience. The 2000 cost estimate concentrated on areas where knowledge was previously limited or where new information or legislation had been added since 1994. The 2004 updates the 2000 study with special emphasis on the area particularly studied since that report.	
Site-specific	2008	Scenario-dependant site-specific cost estimate for decommissioning of the whole site, including common facilities, based on experience from how cost estimates are done in the United States. Costs for the decommissioning of common facilities are allocated to unit 1.	

The evolution of decommissioning strategies, assumptions and boundary conditions

For the generic studies, it is assumed that initial planning for decommissioning starts during the last years of power operation and the project proceeds to hand-over of the cleared and decontaminated site for industrial purposes ("brown field"). Therefore, the decommissioning of each unit is divided into four phases: a transitional defueling operation; a shutdown operation; dismantling and demolition; and site restoration.

For the site-specific cost estimate, decommissioning follows an extended period of shutdown operation, and is divided into three phases. The initial decommissioning phase commences during the end of the shutdown operation period with the objective of preparing for active dismantling and demolition activities. The phases are as follows: preparations (including re-establishment of shutdown systems or organisational capacities where necessary); dismantling and demolition; and site restoration.

The overall assumptions and boundary conditions were generally consistent throughout the three decades, especially within the different generic approaches.[2] Common features for all the cost estimates, including the 2008 site-specific study, include:

- covers costs for decommissioning to the point where the plant is released from nuclear regulatory requirements;
- plant owner/operator oversees site operations and directly places contracts for dismantling activities;
- operational waste managed and transported off-site prior to dismantling (control rods, ion exchange resins, etc.);
- all waste and spent fuel removed from site without delay;
- reactor vessel internals (most active components) are dismantled first;
- industrialised process and proven techniques are used;
- removal of the structures to a depth of one metre below grade and the use of clean construction debris for fill;
- costs for insurance and regulatory costs are included;
- typical national salary and labour rates for different staff categories;
- inclusion of overhead cost and profit margins in contractors' hourly costs;
- estimating uncertainty provisions ("ISDC contingency") are included.

Exclusions

- costs of operational waste management;
- costs of waste and spent fuel transport, off-site management, and disposal;
- income from sale of free-released materials or equipment ("recycling");
- funded risk provisions.

There were some significant points of divergence between the generic studies and the site-specific study, which are summarised in Table B.2.

Development of the project baseline estimates over three decades

In all the cost studies considered here, the project baseline estimate is comprised of a base cost and some form of provision for estimating uncertainty.

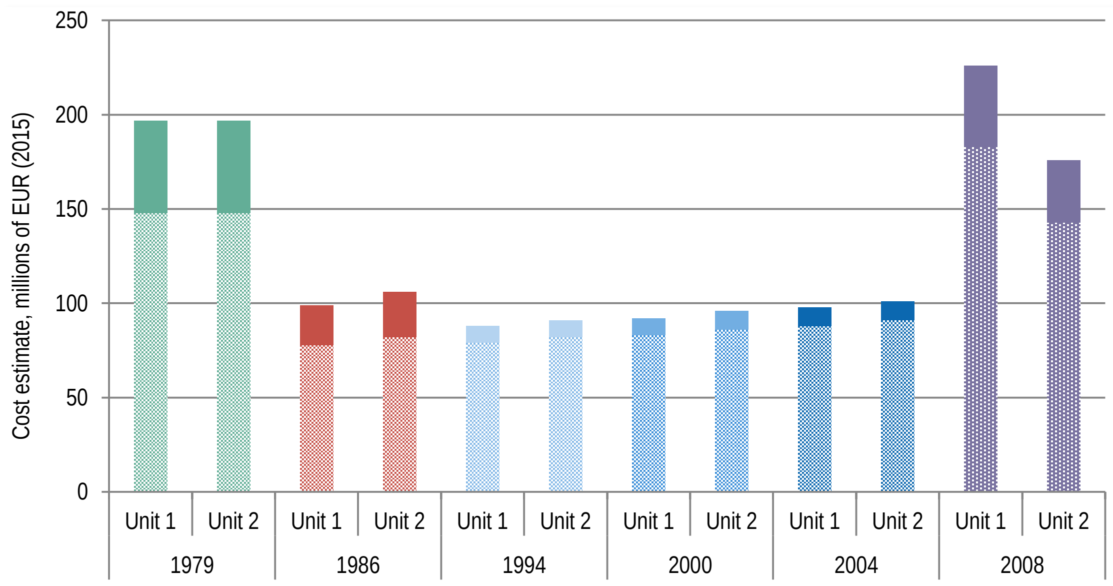
In Figure B.1, the project baseline estimates calculated for each unit are presented for each cost estimate study. Note that costs are given in EUR at 2015 values for all the estimates. In this figure, the different colour-coding relates to the four different underlying cost estimation methodologies applied. Note that for each column, the patterned part represents the estimated base costs, and the solid blocks of colour reflect the estimating uncertainty provisions. Funded risk provisions are *not* included in this figure.

2. There were some differences between the assumptions and boundary conditions used for the various generic cost estimates studies. Nonetheless, for the purposes of this case study, they can be treated as broadly equivalent.

Table B.2. Significant points of divergence between the generic studies and site-specific study

Generally applicable to generic studies	Applicable to site-specific study only
Direct dismantling, with pre-decommissioning planning during last years of operation and with no or only a short service operational period.	Deferred dismantling, with a long service operation period until 2018. No costs for service operation are included.
Other parallel activities on-site not considered.	No other activities on-site.
Dismantling done for individual units, certain site-specific cost items not included.	Common project for both units, in order to gain economic benefits by sharing costs.
Reference scenario. Only items that will be paid for by the national fund are included.	Several cost alternatives are offered besides the main scenario (i.e. one-piece reactor removal).
Specified plant equipment and building inside the unit fence are included. Some site-specific buildings are excluded.	All buildings and facilities included. Common buildings and systems assigned to unit 1. Other site-wide costs are generally allocated on an equal basis between the two units.
Defined starting point for decommissioning project: in final years of before shutdown. Decommissioning time schedule and organisation generically.	Defined starting point for decommissioning project: two years before start of dismantling. Duration of project calculated to be ca. nine years.
Decontamination of main systems during service operation is included. The cost of treating the resulting waste is not included.	No chemical decontamination of reactor circuits due to delayed dismantling.
Asbestos is excluded from studies from 1996 onwards as it was not allowed to be used at the time of construction of the reference plant.	Asbestos is included in the study as it was allowed to be used at the time of construction of the units at this station.
Contamination soil is not included in the study, as it is identified at the site of the reference facility.	Identified contaminated soil is included. Unit 1, as the first unit to enter dismantling, incurs most of the environmental impact, site characterisation and final status survey costs.

Figure B.1. Development of the cost estimates over time, including provisions for estimating uncertainty



Note: The patterned part represents the estimated base costs and the solid blocks of colour reflect the estimating uncertainty provisions.

Evolution of the estimating uncertainty provisions

There is quite some variation in the way in which the provisions for estimating uncertainty has been addressed in the cost estimates considered in this case study. The ways in which these provisions have changed over the period considered are summarised in Table B.3.

For the generic cost studies, a number of differing approaches were taken. It can be noted that these are broadly comparable to the approaches outlined in Section 3.3 of the main report.

For the 1979 and 1986 generic studies, a general provision for "unforeseen costs" was included. However, the scope of the provision may not precisely coincide with the "estimating uncertainty" provision used in this report, and indeed may overlap somewhat with the funded risk provision category.

For the 1994 to 2004 series of generic cost estimates, the distinction between estimating uncertainty and funded risk provisions is clearer. In this series of studies, the estimating uncertainty provisions were calculated in percentage values for individual cost items and then summed up to higher levels within the reference plant studies. For the purposes of this case study, these are taken as being a 10% global estimating uncertainty provision within the project baseline estimate.

For the 2008 site-specific cost estimate, provisions for estimating uncertainty ("ISDC contingencies") have been estimated in percentage values typically used in similar estimates developed in the United States. The estimating uncertainty provisions are applied on a line item basis, in line with the approaches outlined in Section 3.3 of the main report. This results in an overall estimating uncertainty provision of approximately 19% of the total project baseline estimate. The actual percentage values for particular activities are summarised in Table B.4.

Table B.3. Estimating uncertainty provisions in the cost estimates

Year of estimate	Estimate uncertainty provision	How the estimating uncertainty provision is applied
1979	25%[a]	Percentage addition to the total base estimate for "unforeseen costs".
1986	20-25%[a]	Additions to the base estimate of 25% for the costs of building demolition and 20% for other costs.
1994, 2000, 2004	10%[b]	Estimating uncertainty provision applied for the overall project.
2008	Ca 19%	Estimating uncertainty provision calculated and applied on a line item basis and range between 10% and 50% (see explanation below).

(a) The "unforeseen costs" used here may not precisely coincide with the "estimating uncertainty" provision used in this report, and indeed may overlap somewhat with the funded risk provision category.

(b) In 1994, the reference methodology changed from a global provision for "unforeseen costs" to distinguishing more formally between a deterministic provision within the cost estimate as an "allowance for unspecified items" corresponding to the "estimating uncertainty" provision used in this report, and for a funded risk provision, calculated separately as an allowance for unforeseen factors and risk. As the calculation of this "allowance for unspecified items" is not fully explained in the 1994, 2000 and 2004 estimates, a figure of 10% is used for the purpose of this case study. This can be compared with a global figure for the "estimating uncertainty" provision of 7% (and a range of between 3% and 11% for particular categories) from an updated version of the relevant boiling water reactor reference study in 2006.

Table B.4. Estimating uncertainty provisions in the 2008 site-specific study

Category in the cost estimate	Estimating uncertainty provision (%)
Decontamination	50
Contaminated component removal	25
Contaminated component packaging	10
Reactor segmentation	75
Reactor waste packaging	25
Non-radioactive component removal	15
Heavy equipment and tooling	15
Supplies	25
Engineering	15
Energy	15
Characterisation and termination surveys	30
Taxes and fees	10
Insurance	10
Staffing	15
Waste processing (metal melt)	15

How the funded risk provision has been addressed

There is no provision for risk beyond the defined scope of the project (funded risk provision) in the decommissioning cost estimates themselves. Instead, the funded risk provision is considered separately and is calculated in the context of the overall national waste and decommissioning programme funding system rather than at the project-specific level, with the exact approach to the calculations having evolved somewhat over time. A detailed description of this methodology is beyond the scope of this case study, but some general features and how this relates to decommissioning are described in this section.

As noted earlier, a general provision for "unforeseen costs" was included in the 1979 and 1986 generic cost estimates which may have partially overlapped with the funded risk provision category. From the 1994 decommissioning estimates onwards, a clearer distinction was made between provisions for the estimating uncertainty and for funded risks.

Provision for risk at the programme level addresses a range of considerations. Many of these are generally applicable across the entire programme (i.e. indexing of certain costs over time). Some are specific to particular types of projects not directly related to nuclear power plant decommissioning (e.g. construction of waste disposal facilities). Overall, these considerations are addressed through a risk analysis approach. This includes standard statistical methods and including Monte Carlo simulation techniques as described elsewhere in this report, in order to calculate the possible distributions and cost impacts of a range of variations and risks. Potential cost reductions ("opportunities") as well as potential cost increases ("threats") are considered. The outcomes are reflected as provisions at the programme level which would correspond to the funded risk provision as defined in this report.

Only a relatively small part of the risk provisions at the programme level specifically relate to nuclear power plant decommissioning. These can be described as risk categories that are used to calculate a decommissioning-specific provision within the overall programme funded risk provision. These are designed to capture specific assumptions or attributes of decommissioning costing, rather than be related to specific risks associated with particular decommissioning projects. When applied in the context of the 2008 site-specific decommissioning cost estimate, this process yielded a "low range" alternative with good method development and more efficient decontamination with a potential decommissioning cost saving of 15%. The "high range" alternative based on an assumed underestimation of the work involved and aggravating circumstances, for example the effects of fuel damage, gave a potential decommissioning cost increase of 45%. Implications of this approach to calculating a funded risk provision for decommissioning is considered further in the discussion section below.

Discussion

Discussion of the evolution of the estimates

The different approaches and models used in the various estimates considered here reflect developments in national expectations and experience in the field of decommissioning at the time they were produced.

The changes in cost estimation methodology and approaches have significant impacts on the decommissioning estimates, in particular the shift from a generic to a site-specific approach.[3] These differences also have significant implications for understanding the cost studies and the resulting variations in the costs.

In the generic cost estimates, a number of underlying issues can be identified. Clearly, the choice of which reference plant to use and how it was studied is significant. Direct comparison between the various estimates is more complicated because the choice of reference plant varied between the generic studies. Moreover, the extrapolation process itself may pose some issues, in particular where there is an assumed correlation between unit size and decommissioning cost, as there are more significant cost items than thermal power that influence the costs, and these additional cost considerations are more related to details of the individual plants than to generic features.

In addition, there are certain overall limitations associated with the use of generic cost estimates in informing project decisions. First, extrapolating from a general reference case to specific facilities can mask underlying factors that determine why these provisions may vary within a single yet heterogeneous group of projects. Second, these generic top-down approaches cannot be used to reliably forecast how costs might rise or fall as a result of changes in that way that a project might be delivered, and simplistic comparisons based on these estimates may lead to incorrect conclusions on alternative project strategies.

Bottom-up approaches as used in the 2008 site-specific cost estimate may address these limitations to a certain extent. Such an approach requires identifying all of the activities and resources that are used to execute a project and assigning a value to each of these. Estimating potential cost optimisation through a bottom-up approach can be considered a more robust and transparent method, and the detailed cost data allows

3. The 1979 preliminary estimate stands out in that it suggests a much higher cost than those of the other generic cost studies. Explanations for this may include not only the very preliminary nature of the 1979 estimate, but also the fact that it was based more on analysis in other countries, whereas the later generic studies were based on national reference scenarios and plants. It is also worth noting that the primary purpose of the 1979 analysis was to inform governmental deliberations on establishing new national organisational and financial arrangements for waste and decommissioning, rather than to provide input to the calculation of contributions for future decommissioning as part of the national waste and decommissioning financing system.

potential errors to be investigated and their impact tested, thereby facilitating the quality assurance process. Furthermore, this approach provides a basis for assessment which can be used to examine further the cost implication of alternative project designs in the process of project optimisation. However, it is recognised that a bottom-up approach is effort intensive, entailing not inconsiderable cost, time and expertise to apply the methods correctly.

The increases in the project baseline estimates over time may be due to a combination of factors. In addition to increases arising directly from an escalation in the anticipated costs, there may also be cost impacts due to the addition of scope or an increased maturity of the scope definition, or changes in the way the project is expected to be executed and even cost impacts arising because of minor modifications to the calculation model. From the information presented here, it is not possible to determine the relative importance of these or other potential contributory factors, and whether they changed over time.

Discussion of the treatment of the estimating uncertainty provision

In all the cost studies considered here, the project baseline estimate is comprised of a base cost and some form of provision for estimating uncertainty. It may be noted that the various approaches towards calculating the estimating uncertainty provision were in line with approaches described in Section 3.3 of the main report and the ISDC (NEA, 2012b).

Nonetheless, comparing such estimating uncertainty provisions between cost estimates is not straightforward and may lead to misleading conclusions. In particular, it should be noted that estimating uncertainty provisions for the same work in two different projects with comparable assumptions and boundary conditions may differ due to the specific calculation model used, because of the way in which the relationship between the project base cost and the estimating uncertainty provisions is treated within the particular calculation model used. Even where the same calculation model is used, the estimating uncertainty provisions may vary between cost estimates because of the differences in local conditions, as well as reliance on expert opinions and experiences.

Discussion of the treatment of the funded risk provision

There is no provision for risk beyond the defined scope of the project (funded risk provision) in the decommissioning cost estimates themselves.

Instead, provision for such risks is considered separately, in the context of the overall national waste and decommissioning programme funding system rather than at the project-specific level. Thus, while there is a documented and structured approach for developing and assigning financial provisions associated with risk during decommissioning in this context, there is effectively little direct linkage between the specific decommissioning cost estimates and the treatment of decommissioning-related risks at the programme level. As a consequence, it is not possible to evaluate the adequacy of the financial provision for risk derived at the programme level through consideration of the project baseline estimates. The separation of risk at the programme level from the decommissioning cost estimates themselves makes it difficult to test the robustness and underpinning of assumptions, exclusions, interdependencies and constraints around work scope objectives and deliverables at the project level, and their impact on cost.

Moreover, from the approach described here, it is difficult to extract the outputs for funded risk provision derived from the overall programme risk analysis and apply them to particular decommissioning projects. The analysis at the programme level seems to identify impacts rather than the cause and risk itself, while the probability of occurrence and how it might be influenced at the project level is not considered in a systematic manner. This hinders a systematic application of project risk management policies, procedures and practices which require a more explicit relationship with the input data (context, identifying, evaluating).

Appendix C. IAEA International Project on Decommissioning Risk Management (DRiMa) through the project lifecycle

The analysis of uncertainties and risk associated with development and implementation of a decommissioning project can be performed consistent with standard risk management methodology and processes. Based on IAEA safety standards on decommissioning and ISO Standards on risk management (ISO 31000:2009), the IAEA DRiMa Project on "Decommissioning and Risk Management" aims to provide recommendations on how to perform such analyses by considering the decommissioning plans, from initial to final version up to the implementation of the decommissioning and dismantling actions.

DRiMa specifies a hierarchy for the risk management framework based on delineating programme/project/phase/task/work package and specifying inter-dependencies across these.

Initial decommissioning plans are generally developed based on a set of high-level assumptions which need to be progressively confirmed during the lifecycle of the nuclear facility. These high-level assumptions are what define the overall project as they generate the need for decisions (so-called "strategic decisions") which then get endorsed in the final decommissioning plan and are used to subsequently define scope, schedule and cost. This process is critical as it is the framework that establishes how the decommissioning programme objective will be met and how boundary conditions are used. The process for making these strategic decisions is top-down and thus is the fundamental management step in delineating what is considered to be in the scope of the decommissioning program and what is considered to be out-of-scope.

One of the objectives of the DRiMa project is to analyse what could happen to the project if the high-level assumptions and assumed boundary conditions change when the project becomes mature. Uncertainties associated with these assumptions need to be analysed by addressing threats and opportunities (so-called "risk management at the strategic level"). An objective of decommissioning cost estimation is to ensure that these strategic decisions are clearly established in the basis of estimate (BoE) so that uncertainties which relate to a change in boundary conditions can be defined. The strategic risk management process can then consider alternative outcomes and probabilities and enable out-of-scope funding analysis.

Treatment response may take the form of alternative decisions and/or actions which are designed to manage threats and opportunities. Outcomes may be also the identification of some milestones which may compromise project/phase/task implementation if these milestones are not correctly addressed. The DRiMa approach does not address risks provisions but identifies what may happen if some of the high-level assumptions become invalid and impact safety, cost and/or schedule. From the point of view of cost estimates, the outcomes of the DRiMa approach may serve to allocate some financial provisions (funded risk) to the overall decommissioning cost.

Depending on the maturity of the project and assessment level (programme/project/phase/task/work package) two levels of assessment are proposed:

Level 1: Qualitative approach

- establishment of a number of high-level (key) assumptions based on the available decommissioning plan;
- screening of these assumptions with a list of risk families used as a prompter;
- assessment of the level of uncertainties for each assumption (expert judgement) – low/medium/high, etc.;
- monitoring and review process;
- treatment response and proposed actions (accept, mitigate, transfer, avoid, opportunities and exploit) to reduce the uncertainty level;
- assessment of the status of the key assumptions and implementation of level 2 evaluation if appropriate.

Level 2: Quantitative approach (further analysis as a result of the outcome of level 1)

- identification of possible threats or opportunities for each key assumption;
- screening of possible impact using the risk families;
- evaluations of probability and possible impact on safety, cost and schedule (detailed risk matrix);
- monitoring and review process;
- treatment response (accept, mitigate, transfer, avoid, opportunities and exploit) and proposed actions;
- assessment of the status of the key assumptions (open, rejected, modified, accepted, etc.).

Risk families:

The following risk families have been developed to support the DRiMa approach:

- initial conditions of facilities;
- final end state of decommissioning;
- waste and materials management;
- project management;
- organisation and human resources;
- finance;
- interfaces with contractors and suppliers (infrastructure and contractors);
- strategy and technology;
- legal and regulatory framework;
- safety (including radiation protection and conventional safety);
- external relation and communication.

Explanation of these families can be found in the DRiMa project report (IAEA, forthcoming).

Assumptions log/register:

It is recommended that the BoE captures all key assumptions, exclusions and boundary conditions to ensure traceability during the lifecycle of the project. The register helps to understand how these assumptions may evolve with scope maturity and how in-scope and out-of-scope delineation has been determined at that point in time. Anything excluded or not bound within the assumption list is therefore determined to be outside of the scope of the project and unfunded within the project baseline estimate.

DRiMa recommends development of a "project risk register" to assess risk of decommissioning actions to be performed at the level of the tasks and work packages, and aggregated through analysis to generate estimating uncertainty values at various levels up to and including the programme level for all activities that are in-scope. To enable separate analysis of out-of-scope uncertainties, consideration should be given to listing all strategic programme level risks, noting that treatment and analysis may be different as initiating events are often unknown and scenario analysis may be a better approach to interpret cost impact outcome ranges.

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Addressing Uncertainties in Cost Estimates for Decommissioning Nuclear Facilities

The cost estimation process of decommissioning nuclear facilities has continued to evolve in recent years, with a general trend towards demonstrating greater levels of detail in the estimate and more explicit consideration of uncertainties, the latter of which may have an impact on decommissioning project costs. The 2012 report on the *International Structure for Decommissioning Costing (ISDC) of Nuclear Installations*, a joint recommendation by the Nuclear Energy Agency (NEA), the International Atomic Energy Agency (IAEA) and the European Commission, proposes a standardised structure of cost items for decommissioning projects that can be used either directly for the production of cost estimates or for mapping of cost items for benchmarking purposes. The ISDC, however, provides only limited guidance on the treatment of uncertainty when preparing cost estimates. *Addressing Uncertainties in Cost Estimates for Decommissioning Nuclear Facilities*, prepared jointly by the NEA and IAEA, is intended to complement the ISDC, assisting cost estimators and reviewers in systematically addressing uncertainties in decommissioning cost estimates. Based on experiences gained in participating countries and projects, the report describes how uncertainty and risks can be analysed and incorporated in decommissioning cost estimates, while presenting the outcomes in a transparent manner.

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