Safety Reports Series

No. 97

Management of Project Risks in Decommissioning

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MANAGEMENT OF PROJECT RISKS IN DECOMMISSIONING

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FOREWORD

Decommissioning of facilities where radioactive material has been produced, used or managed is becoming an increasingly important task for many Member States. The decommissioning process is associated with numerous technical, safety and regulatory challenges. The IAEA has been working systematically for over three decades to assist Member States in addressing those challenges.

While the technical, safety and regulatory aspects of decommissioning, including management of safety risks, have been well covered in the IAEA programme of work, a need was recently identified for more information and practical guidance on management of project risks in decommissioning.

In response, the IAEA established the International Project on Decommissioning Risk Management (DRiMa) in 2012 to collect, analyse and document experiences and good practices in the application of project risk management during the planning and implementation of decommissioning activities.

The DRiMa project was carried out over a three year period (2012–2015) and was supported by approximately 70 experts from approximately 30 Member States. This publication: (i) summarizes the outcomes of the DRiMa project, (ii) provides practical guidance on and examples of the application of generally accepted risk management methodologies to the planning and implementation of decommissioning programmes, and (iii) demonstrates the role that risk management can play in supporting decommissioning project objectives, such as those in the areas of safety, costs and schedule.

The IAEA would like to express its gratitude to all the experts who contributed to the development and review of the report, in particular J. Kaulard (Germany), P. Francois (France), M. Pennington (United Kingdom), D. Skanata (Croatia) and K. Schruder (Canada). The IAEA officers responsible for this publication were V. Ljubenov of the Division of Radiation, Transport and Waste Safety and P. O'Sullivan of the Division of Nuclear Fuel Cycle and Waste Technology.

EDITORIAL NOTE

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1. INTRODUCTION

1.1. BACKGROUND

An increasing number of decommissioning activities are being undertaken on a worldwide basis at facilities where radioactive material has been produced, used or managed (e.g. stored, processed, disposed of). In most cases, this increase is the result of facilities reaching the end of their lifetime. In other cases, it is the consequence of decisions to shut down facilities before they reach the end of their expected lifetime for economic, political or social reasons, or as a result of accidents or unplanned events.

The decommissioning of a facility is usually conducted as a project. A decommissioning project usually starts when preparation of the final decommissioning plan (FDP) is initiated or, in some cases, when an authorization for decommissioning is granted. Implementation of a decommissioning project is always connected with different internal and external risks, which may have an impact on project objectives, such as those in the areas of safety, costs and schedule, and thus have to be managed by applying a systematic and proactive approach and methodology. In this publication such risks related to a decommissioning project are called project risks.

In 2007, the IAEA established the International Decommissioning Network to help Member States develop capabilities and plans for undertaking decommissioning activities. The importance of the management of project risks during decommissioning was discussed and recognized at the network's 2011 annual meeting [1, 2]. While it was felt that experience and good practices exist in this area, there was reason to believe that a comprehensive and systematic approach for the sharing of experience on the application of management of project risk during the decommissioning process warranted further attention. In order to address this issue, the International Project on Decommissioning Risk Management (DRiMa) was established to document and share methods and good practices in the application of risk management during the planning and implementation of decommissioning activities.

The rationale behind the creation of the DRiMa project included the following considerations:

— Decommissioning is often undertaken by institutions that lack experience in performing major projects and therefore may not be fully realizing the benefits of risk management.

— Feedback was received from missions and meetings that assistance was needed in managing project risks, and that project risk management was a priority issue.

Experience and good practices in the use of risk management in decommissioning exist in some Member States, but sharing of experiences was needed.

1.2. OBJECTIVE

The objective of this publication is to identify good practices from the collective experience of Member States in the application of risk management methodology to decommissioning, and to provide examples that focus on the application of risk management during the planning and implementation phases of decommissioning.

1.3. SCOPE

This publication focuses on the application of risk management methodologies during both the planning and implementation phases of decommissioning and provides practical guidance on the use of generally accepted risk management methodologies during these phases. In the context of decommissioning projects, two major categories of risk have been examined: strategic and operational. Under this approach, strategic risks are those more likely to be of concern during the planning phase of decommissioning, while operational risks are those more likely to be relevant to the actual implementation of decommissioning activities. This publication illustrates the dynamic nature of decommissioning risks that result in large measure from uncertainties inherent in the planning and execution of decommissioning projects, and the need for a periodic review and update (as appropriate) of the risks and assumptions to reflect any relevant changes in the configuration of the facility, the maturity of the project, and the hazards and complexities found with the decommissioning tasks. Guidance provided here, describing good practices, represents expert opinion but does not constitute recommendations made on the basis of a consensus of Member States.

The described methodology for the management of project risks in decommissioning is applicable to all types of facilities that are subject to decommissioning. However, it needs to be applied following a graded approach, so simpler tools and analyses could be applied in the case of small facilities or cases of simpler and shorter decommissioning projects.

1.4. STRUCTURE

Section 2 of this publication provides an overview of the general risk management process, as widely accepted and applied in different industries. The main steps of the process are described and basic risk treatment strategies are explained for both threats and opportunities. The use of risk registers is discussed.

Section 3 discusses specificities of the risk management methodology when applied to decommissioning projects. Interfaces of risk management with initial and final decommissioning planning and with safety assessment for decommissioning are discussed.

Section 4 focuses on aspects of risk management as applied at a strategic level, particularly as they relate to the management and control of key assumptions and strategic decisions, both of which represent important components of the planning phase of decommissioning. Also included in Section 4 is a summary of findings and good practices.

Section 5 addresses risk management at an operational level and illustrates the specific risk management steps to be followed during the implementation phase of decommissioning projects. As in Section 4, a summary of findings and good practices is also included in this section.

Section 6 provides insight into the relationship between risk management at the strategic level and risk management at the operational level.

Section 7 summarizes the important conclusions contained in the publication.

Some IAEA publications containing information, guidance and recommendations that relate to risk management and safety, and the unique aspects of decommissioning are to be found in the Bibliography.

Definitions of the terms employed in the report, including those terms that are or may be used interchangeably in the report or in the risk management literature, are provided in the Annex.

2. RISK MANAGEMENT

Risk management is the overall approach used in supporting and enabling an organization to control risk through processes involving the identification, assessment, treatment and monitoring of those risks. It is part of the responsibilities of management and an integral part of all organizational processes, including strategic planning and all project and change management processes [3]. While risk is often regarded as an uncertain outcome that usually has a negative impact on the achievement of an organization's objectives (i.e. risks that impose threats), uncertain outcomes may also positively affect the achievement of organizational objectives (i.e. risks that offer opportunities).

Therefore, risk management is intended to maximize opportunities and to minimize threats by providing a framework to control risk at all levels in the organization. While not removing the need for experience and judgement, risk management embodies a systematic approach that includes a series of well defined steps that support the decision making process by providing a good understanding of threats and opportunities as well as their likely impact and likelihood of occurrence. Risks have to be managed in an integrated fashion across all levels of the organization and across all phases of a facility's lifetime or a project.

The benefits derived from the adoption of a risk management framework include:

— Ensuring that all foreseeable risks in attaining the decommissioning project objectives are managed proactively and effectively;
— Identifying critical areas that require actions on the part of the project to ensure that appropriate resources are available;
— Supporting effective decision making under conditions of uncertainty;
— Improving organizational awareness of the risks inherent in the decommissioning process;
— Aiding in establishing an effective approach for communicating with external stakeholders and demonstrating project transparency [4].

In general, the application of risk management as part of the project management process has focused on operational considerations. The risk management process involves:

(i) Determining the context underlying a risk;
(ii) Qualitatively or quantitatively assessing a risk taking both the severity of impact and likelihood of occurrence into consideration;
(iii) Developing a treatment plan for controlling the risk (e.g. through actions to reduce probability and/or impact);
(iv) Developing a plan to ensure that the risks are systematically monitored, reviewed and revised as necessary.

In addition to the above, contingency plans can be prepared based on the eventuality that certain risks could be realized. Furthermore, it is advisable that attention be given to communications and consultations about the risks to ensure that stakeholders are fully aware of the circumstances surrounding project risk.

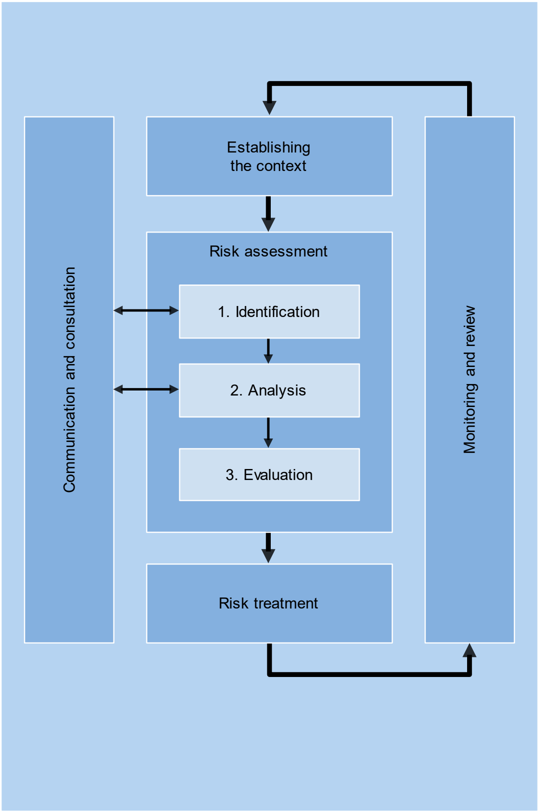

FIG. 1. Risk management process [3].

Implementation of this risk management process will increase the likelihood of meeting project and business objectives (see Fig. 1).

2.1. ESTABLISHING THE CONTEXT

Establishing the context serves to define the external and internal factors surrounding the project that need to be considered when managing risk. It is important to recognize that these factors need to be specific, highly relevant, and key to the individual project and its objectives to ensure that the relevant risks for the project are effectively identified and addressed. For the purposes of this report, external factors are those that primarily relate to the key drivers and trends that have an influence on the objectives of the organization. Internal factors are those that primarily relate to anything within the organization that has an influence on the objectives of the project, or on the delivery of those objectives. An examination of key assumptions and strategic decisions can be extremely useful in identifying both internal and external factors.

A key component in establishing context is the development of risk criteria, which involves the following considerations:

> "The organization should define criteria to be used to evaluate the significance of risk. The criteria should reflect the organization's values, objectives and resources. Some criteria can be imposed by, or derived from, legal and regulatory requirements and other requirements to which the organization subscribes. Risk criteria should be consistent with the organization's risk management policy, be defined at the beginning of any risk management process and be continually reviewed" [3].

> "When defining risk criteria, factors to be considered should include the following:

— the nature and types of causes and consequences that can occur and how they will be measured;
— how likelihood will be defined;
— the time frame(s) of the likelihood and/or consequence(s);
— how the level of risk is to be determined;
— the views of stakeholders;
— the level at which risk becomes acceptable or tolerable; and
— whether combinations of multiple risks should be taken into account and, if so, how and which combinations should be considered" [3].

The risk management process will drive key decisions concerning the prioritization of risks, and it is important that all parties, particularly stakeholders, understand the rationale behind the prioritization process, an understanding that can only be ensured if the criteria used in decision making are clear.

2.2. RISK ASSESSMENT

2.2.1. Identification

The first step of the risk assessment process is to identify potential risks to the decommissioning project, keeping in mind that risks can represent either threats or opportunities. The risk management process is designed to be iterative, and there may be merit in using the early iterations of the process to focus on identifying those risks of greatest concern to the project delivery. Risks that are less relevant, or risks generating less concern may be addressed in later iterations. However, if this approach is taken, caution is warranted to ensure that no relevant risks are unintentionally overlooked or forgotten.

The identification of threats and opportunities is supported by both formal and informal approaches. Workshops are typically used for gathering key personnel who can contribute to the identification of threats and opportunities. It can be beneficial to utilize the skills of personnel experienced in facilitating risk management workshops to help ensure a systematic and focused approach (e.g. through the use of techniques such as brainstorming). Risks identified through the safety assessment process [5] can also provide important input to the risk identification process.

2.2.2. Analysis

Risk analysis involves assessing both the likelihood (probability) of occurrence and the extent of the consequences (impact) for each identified risk. The analysis can be based on either a qualitative or quantitative approach depending on factors such as the complexity, size or maturity of the decommissioning project.

2.2.3. Evaluation

Risk evaluation comprises several components. The first involves scoring each of the risks based on an assessment of risk probability and risk impact. Figure 2 provides an example of a probability–impact diagram that could be used for risk evaluation. Numerical values could be associated with each level of risk probability and risk impact, to enable quantitative evaluation. It is important to note that in the case of risk impact, the risk criteria discussed above play a particularly pivotal role. For example, and further to an earlier discussion, if risk criteria reflect an organization's high level of concern about safety, then the risk impact score should be assigned accordingly.

Following the scoring process, a parameter referred to as a risk score can then be derived based on the product of a numerical value related to risk probability, and a numerical value related to the severity of the impact of the risk. Then the risk impact and probability scores and the total score are compared with the established risk criteria (see Section 2.1).

Visualizing the threats and opportunities in direct relationship to each other helps to focus on those risks that most require attention.

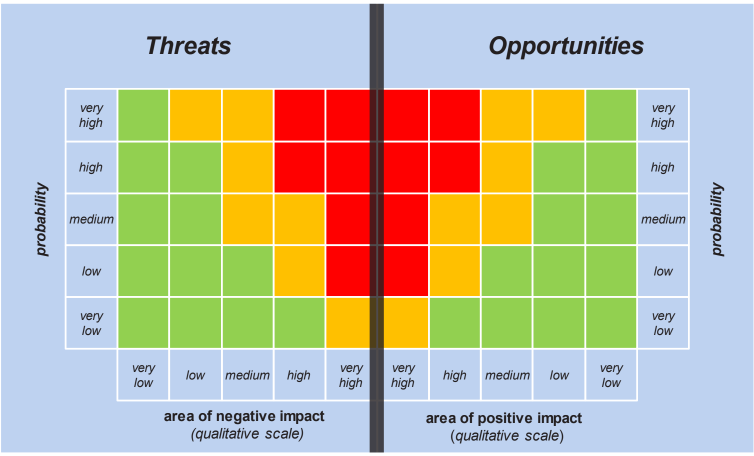

FIG. 2. Example of a double probability–impact diagram (risk matrix) for opportunities and threats.

2.3. RISK TREATMENT

The actions associated with risk treatment are somewhat more complex than the term 'treatment' might imply because in the context of risk management those actions may in fact not be active actions at all. The fundamental principle that needs to be established and understood with respect to risk treatment is that of residual risk. The principle of residual risk dictates that after implementing a risk treatment strategy, a project or organization needs to decide if the residual risk levels are or will be tolerable. If the residual risk levels are not tolerable, then a new risk treatment strategy will need to be developed and implemented.

Typical risk treatment strategies include those presented in Table 1. As might be expected, the risk criteria also play an important role in deciding risk treatment strategies, particularly as risk criteria relate to defining the tolerability of residual risk. For example, an organization with risk criteria that reflect highly risk adverse requirements will be less tolerant of residual risks.

In the case of threats, potential treatment strategies include the following:

— Avoid: take actions to ensure that the threat cannot occur or can have no impact on the project.
— Mitigate: identify and perform actions that will decrease the probability of the threat and/or its impact on the project.

— Transfer: transfer the threat to a third party that is better positioned to take appropriate actions. It is important that responsibility for the risk be clearly accepted by the third party.
— Accept: take no action to treat the risk; however, monitoring remains particularly important to determine if changes in the impact or probability warrant a change in treatment strategy.

In the case of opportunities, potential treatment strategies include the following [6]:

— Exploit: take actions to ensure that the opportunity can occur, and will have a beneficial impact on the project.
— Enhance: identify and perform actions that will increase the probability of the opportunity and/or its impact on the project.
— Share/transfer: share the opportunity with or transfer it to a third party that is better positioned to increase its probability or to maximize the benefits.
— Ignore: take no active measures to address the opportunity; however, adopt a reactive approach whereby monitoring remains active to determine if changes in benefits or probability warrant a change in treatment strategy.

It is good practice to prepare contingency, recovery or alternative plans for those risks that are viewed as being particularly problematic. These plans are usually prepared in advance and are designed for quick implementation when triggered by pre-established circumstances (e.g. when a threat is growing in likelihood and developing into an issue). In a similar fashion, advance plans can be prepared for use with developing opportunities.

TABLE 1. RISK TREATMENT STRATEGIES FOR THREATS AND OPPORTUNITIES

	Risk type	
	Threat	Opportunity
Risk treatment	Avoid	Exploit
	Mitigate	Enhance
	Transfer	Share/transfer
	Accept	Ignore

2.4. MONITORING AND REVIEW

Monitoring and review, in terms of the risk management process, is intended to be an ongoing activity that is performed on a periodic basis throughout both the planning phase and the implementation phase of a decommissioning project. Typical aspects of the monitoring and review process include:

- Identification of new risks as the facility or project status changes and as new information becomes available;
- Reassessment of the risk scores as the status of the decommissioning project changes or as new information becomes available;
- Monitoring the status of the actions being undertaken as part of the risk treatment process.

2.5. RISK REGISTER

As an output of the risk management process, it is general practice to develop a risk register where threats and opportunities are listed together with other related information such as treatment strategies and any associated actions.

To help ensure the effectiveness of the risk register, it needs to be regularly updated based on the output of the monitoring and review process. It is important that risks not be deleted from the risk register even if they no longer require explicit attention owing, for example, to the fact that they have expired or are no longer relevant. The preferred approach is to simply record a change in the status of the risks in the risk register. This approach will ensure that a complete record of the risks is maintained for possible future use (e.g. as input for other decommissioning projects undertaking risk management).

2.6. COMMUNICATION AND CONSULTATION

It is important that the risk management process include communication and consultation with internal and external stakeholders. This serves to:

- Keep stakeholders informed about the basis on which risk-driven decisions are made, and the reasons why particular actions are required;
- Ensure that the interests of stakeholders are adequately considered during the risk management process;
- Ensure that project transparency is being achieved and demonstrated.

3. RISK MANAGEMENT SPECIFIC TO DECOMMISSIONING

Management of project risks in the context of decommissioning plays an important role in the management and control of safety related risks (radiological and conventional) and hence supports project safety objectives in the same way as other project objectives such as cost or schedule.

3.1. DECOMMISSIONING PROCESS

Generally, the decommissioning process begins with the drafting of the initial decommissioning plan (IDP), proceeds through the preparation, approval and implementation of the FDP, and ends when dismantling, decontamination and cleanup actions are completed and the licence can be terminated [7].

Decommissioning planning has unique characteristics, such as:

— It has three stages during the life of a facility (initial, updated, final) [8].
— The planning process can span long periods of time (i.e. decades in those cases where the IDP is prepared during facility design and the FDP is prepared following facility shutdown).
— The initial plan contains key assumptions that may have relatively high levels of uncertainty resulting from the speculative nature of early key assumptions.

The planning process is discussed in more detail in Section 3.2, which includes a diagram depicting the planning process. Insights and conclusions about the differences between the operation of a facility and its decommissioning in terms of risks, safety, training and human resource management can be found in a number of IAEA publications [9–11].

The nature of decommissioning planning demands a somewhat unique approach to the management of project risks in that the application of such risk management is required at both a strategic and an operational level. The special approach necessitated by decommissioning planning was one of the drivers behind the DRiMa project. Of particular importance is the need to identify, assess, monitor and control (mitigate or exploit) the risks associated with the key assumptions that are included in the IDP, and which become strategic decisions in the FDP. Invalid, incorrect or outdated key assumptions, unless identified, can lead to incorrect strategic decisions, which in turn can adversely affect decommissioning implementation.

Risks associated with safety during the conduct of decommissioning actions can also be considered a kind of project risk, as they might have an impact on the overall project success. Many of these risks arise from the following circumstances surrounding the decommissioning process:

— Non-routine and first of a kind activities;
— Ongoing requirements to deal with unknown conditions;
— Lack of information concerning shutdown facilities;
— Presence of highly hazardous conditions and materials;
— Changes to containment barriers;
— Reduction in staffing levels — smaller stable resource pool;
— Potential for creating new hazards through, for example, system draining, cleaning and decontamination, spent fuel handling;
— An uncertain working environment;
— Access to high radiation and contamination levels on a more routine basis;
— Regular use of temporary structures;
— Reliance on supporting projects (e.g. waste disposal facilities).

3.2. DECOMMISSIONING PLANS

A particular challenge unique to decommissioning is the long time period often associated with the process, particularly in the decommissioning planning phase, where decades may separate planning from implementation. A consequence of this issue is that decommissioning plans may contain more information of a speculative nature, particularly in the form of key assumptions, than typically found in non-decommissioning project plans. The confidence in the correctness of the assumptions is expressed by their associated uncertainties. The relatively high levels of uncertainty, resulting from the speculative nature of early key assumptions, are generally manageable for an IDP, where refinements to key assumptions are a normal part of the planning process. However, in moving from an IDP to an FDP, the key assumptions become strategic decisions (see Fig. 3), and therefore processes need to be in place that will help to ensure that strategic decisions are based on the best information available, and that the uncertainties in those strategic decisions are as low as possible. This is particularly true in the case where any subsequent changes may be difficult to make after the FDP has been approved and decommissioning work is underway.

An important objective of the DRiMa project was to develop a means of managing and controlling the risks surrounding the uncertainties in key planning assumptions, and thereby control the uncertainties in any subsequent use of those key assumptions (e.g. in the development of strategic decisions).

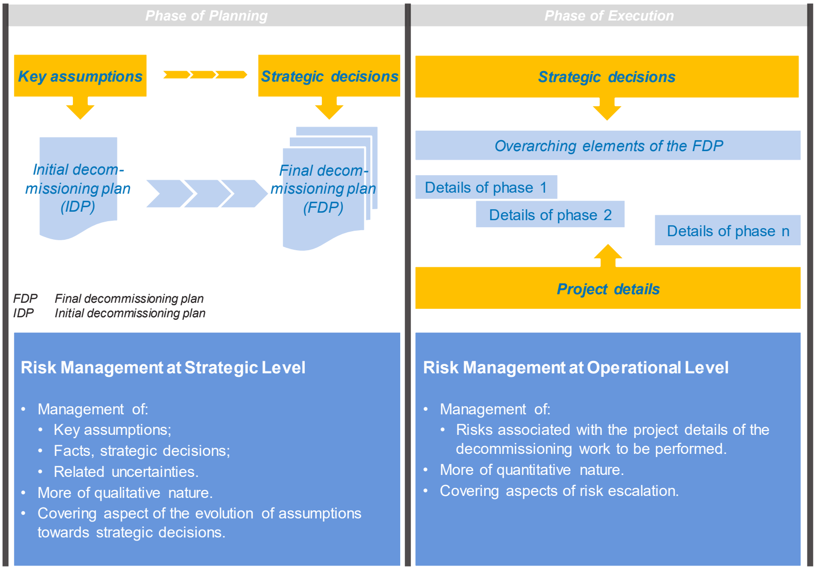

FIG. 3. Decommissioning process and related risk management aspects.

3.2.1. Initial decommissioning plan

IDPs are generally developed based on a limited number of key assumptions that may embody a high degree of uncertainty, and therefore these assumptions need to be regularly and systematically examined, confirmed and adjusted during the life cycle of the nuclear facility. An IDP typically covers the following topics:

— Identification of decommissioning options;
— Demonstration of the feasibility of the selected decommissioning option;
— Discussion of the mechanisms by which adequate financial resources will be secured for the decommissioning plan;
— Identification of waste categories, and an estimation of respective waste quantities together with their anticipated treatment, storage and disposal routes;
— Requirements for the preparation and retention of records and information relevant to the decommissioning project.

Accordingly, key assumptions for an IDP can be expected to address:

— The feasibility of decommissioning options;
— The waste management policy and related infrastructure;

— The availability of a funding mechanism;
— The regulatory and legal framework;
— The organizational structure and human resources;
— The related safety, security, environmental and health factors;
— The involvement of interested parties, social impact and public opinion.

At the time the IDP is first drafted, little or no detail may be available about important future circumstances related to topics such as dismantling and decontamination technologies, waste acceptance criteria, the availability of disposal and treatment facilities, the regulatory environment and the availability of funding. As a consequence, the IDP may be based on key assumptions that embody a high degree of uncertainty, a situation that in the case of decommissioning activities may be exacerbated by the fact that there could be a significant time period between the drafting of the IDP and the actual commencement of the decommissioning activities. The fact that an IDP may be based on uncertain and speculative future conditions underscores the importance of systematically undertaking risk management to manage (and reduce) these uncertainties.

3.2.2. Final decommissioning plan

The uncertainties inherent in early key assumptions are generally manageable for an IDP, where refinements to key assumptions are a normal part of the planning process. However, the FDP generally cannot tolerate uncertainty to the extent that an IDP can because, in many cases, the FDP (or equivalent) is formally approved, and is used to dictate the actual execution of the decommissioning work.

Over time, and as more information is obtained, the IDP and key assumptions can be updated and refined with a corresponding decrease in the uncertainties surrounding those key assumptions. Once the approval of the FDP has been secured, the key assumptions become strategic decisions, and a project phase is then initiated to implement the decommissioning actions as outlined in the FDP. Because the approved FDP generally represents formal permission to execute the decommissioning process, it can be difficult to change the contents of the FDP following the approval process. The importance of avoiding changes to an approved FDP further underscores the need for a systematic approach to ensure that the key assumptions, and correspondingly the strategic decisions, are based on sound decision making and the best information available.

Faced with a situation where an FDP needs to be prepared, but without the benefit of an IDP having been drafted first, the use of an assumptions register can still play a pivotal role in establishing the strategic decisions that underpin the FDP. In general, a primary objective in establishing an FDP needs to be the minimization of uncertainties surrounding the strategic decisions. To this end, the following process can be considered for the drafting of the FDP in the absence of an IDP:

— Prepare a list of key assumptions in a manner similar to that employed with an IDP. As might be expected, these assumptions may be different in nature than those typically found with an IDP for a new facility. For example, a key assumption such as ‘60 years of operation without accidents’ might be reasonably found in an IDP but would be largely irrelevant for a shutdown facility for which an FDP is being prepared. The participants in a workshop to identify the key assumptions for an FDP might be expected to have a significant level of decommissioning operational experience.
— Populate an assumptions register.
— Identify specific risks (threats and opportunities) that might arise if the key assumptions were to prove inaccurate.
— Analyse the risks generated in the above step by considering the probability and impact, and establish a risk score for each.
— Evaluate the key assumptions from the perspective of the corresponding risk scores. A key assumption associated with high risk scores may not be one that merits becoming a strategic decision in the FDP.

3.3. SAFETY ASSESSMENT

Although risk management and safety assessments may deal with the same decommissioning plan, they are two different processes. Risk management focuses on controlling risk in support of achieving the project objectives, while safety assessment focuses on demonstrating that the decommissioning actions can be conducted safely. However, the risks identified during the safety assessment process [5] can serve as important input to the risk identification process. Similarly, any conclusions reached during the process of safety assessment concerning impact and probability can provide important input into the risk analysis and assessment process.

It is very important that changes in the decommissioning plan designed to enhance opportunities or to mitigate threats be assessed with respect to possible impact on the safety assessment results. The same is true for safety related changes in the decommissioning plan, where the changes also need to be reviewed for possible impact on the project risks.

4. RISK MANAGEMENT AT THE STRATEGIC LEVEL

The fundamental objective of risk management at the strategic level (RMSL) is to support the development of decommissioning plans by ensuring that key assumptions and strategic decisions are based on the best available information. It comprises the identification, analysis, evaluation, treatment, monitoring and review of the key assumptions and strategic decisions underlying decommissioning planning, and also includes communication and consultation with interested parties concerning the status of project risks. Hence RMSL ensures that the 'key assumptions' contained in the IDP have been converted, to the greatest extent possible, to 'key facts' for use in the drafting of the FDP. Uncertainties in the IDP are to be expected, but every effort needs to be focused on minimizing the carryover of these uncertainties into the FDP. The benefits of RMSL are by no means limited to decommissioning, and typical uses can include:

— Management of uncertainty: when an organization requires a systematic process to help identify, manage and control the uncertainties in strategic planning assumptions.
— Improving decision making: when a process to improve the quality of information is required for the purposes of better decision making.
— Prioritization: when an organization has limited resources and must prioritize projects. An important input to the prioritization process could be the level of uncertainty associated with the planning assumptions surrounding each project. The organization could, for example, decide to proceed with the project that has the lowest uncertainty levels associated with the planning assumptions.
— 'Optioneering' (systematic examination of possible alternatives for performing the work): when circumstances require that an organization decide on a project strategy for which there are multiple options. For example, faced with several decommissioning options for a facility, the RMSL process could help provide direction as to which option comprises the lowest risk in terms of the underlying assumptions.
— Escalation: when a project or organizational unit needs a tool to help to recognize when there has been a loss in the ability to control or manage the threats and opportunities within the boundaries or scope of a project.

The benefits of RMSL are largely twofold. First, it results in a systematic process for identifying, assessing, treating and monitoring the uncertainties associated with key assumptions, thereby helping to ensure that the nature and validity of those assumptions are understood, and to the extent possible, controlled. Hence, RMSL requires that key assumptions be regularly confirmed during the life cycle of the nuclear facility destined for decommissioning. The second benefit manifests itself by providing assurance that if every effort has been made to address and mitigate the uncertainties surrounding the key assumptions, then logic would dictate that the strategic decisions underlying the FDP are as sound as reasonably achievable.

4.1. PROCESS

The main steps in the RMSL process are:

- Establish a set of key assumptions based on the best available information and aided by using a list of risk families as prompts during the identification process.
- Assess the level of uncertainty for each key assumption using expert judgement.
- Assess the consequences of a change in the accuracy or validity of the key assumptions. This step may only be required in special circumstances, for example, in the case described above where an FDP is being prepared in the absence of an IDP (see Section 3.2.2).
- Identify treatment actions to reduce the uncertainties found with the key assumptions.
- Develop an assumptions register.
- Monitor the key assumptions.

Ideally, RMSL is most effective when its application begins with the drafting of the IDP and is subsequently carried through into the preparation of the FDP. However, in a number of circumstances, the decommissioning planning process may begin with the preparation of the FDP (e.g. in those cases where facilities have been shut down and are in a state that requires immediate action). It is important to recognize that even under these circumstances, the process of identifying and assessing the key assumptions can be an invaluable tool in establishing the strategic decisions that are required for the FDP.

4.1.1. Establishing key assumptions

The initial step in the RMSL process is the identification of the key assumptions that support the IDP. It is of critical importance that the identification of assumptions be performed in a systematic fashion to ensure that the process is as complete as possible.

An assumption can reasonably be considered ‘key’ if a substantive change in that assumption triggers a major revision of the decommissioning plan. Key assumptions will have various levels of uncertainty, and therefore it is important that they be monitored, analysed and adjusted as the decommissioning plan matures. Key assumptions are likely to have a significant impact on the cost estimates and therefore the funding required for decommissioning and waste management projects. Therefore, results from the strategic risk management process need to be recognized and incorporated into decisions about the funding levels required for decommissioning and waste management projects. For example, strategic risk management can play an important role in establishing project contingencies and risk allowances (see also Section 5.6 on risk modelling).

Key assumptions might include, for example, the following:

— A facility will operate for its design life without major incidents of a type that would prevent an immediate dismantling strategy (prompt decommissioning).
— A facility will operate long enough to collect adequate financial resources for decommissioning.
— Disposal facilities will be in operation and have sufficient capacity for all of the types of radioactive waste produced during the decommissioning project.

It is particularly important to make the wording of the assumptions as explicit and precise as possible. For each key assumption, it is also important that background information and elements of context (e.g. the origin of the assumption) be captured. An advantage to recording background information is that it may be useful when the assumptions are subsequently monitored and reassessed. In some cases, the key assumptions presented in the IDP will be largely based on fact, and not on supposition (e.g. if a disposal facility for low and intermediate level waste is already available). Nonetheless, factual material of this nature should be included in the assumptions register, as it may form the basis of strategic decisions for inclusion in the FDP.

4.1.2. Assigning the level of uncertainty

The next step in the process is to assign a level of uncertainty to each key assumption. Usually, a qualitative approach is followed for the assignment of uncertainty where three levels of uncertainty are used (i.e. low, medium, high). When a level of uncertainty is assigned, the preparation of a documented explanation describing the reasoning behind the assignment can be valuable.

In many cases, the primary risk associated with key assumptions lies in the fact that they can undergo major changes, and that these changes can have far reaching impact on a decommissioning plan. For example, if a decommissioning plan is largely predicated on the assumption that a disposal facility will be available by a certain date, and that date is subsequently substantially changed, the decommissioning plan is likely to be significantly compromised. However, the application of RMSL at an early stage in the decommissioning planning process can serve to provide a warning about possible changes, and thereby enable a plan to be prepared well in advance (e.g. an alternative plan) for use in those cases where changes actually materialize. In this manner, it is possible to reduce the potential impact of changes in key assumptions on the decommissioning process. An important benefit of applying risk management to key assumptions is that it also helps with management of the risks associated with making strategic decisions by helping to ensure the dependability of any information used in the decision making process.

4.1.3. Identifying actions to reduce uncertainty levels

At the start of the process for developing action plans, attention is generally focused on those key assumptions that: (i) have a high level of uncertainty, and (ii) are likely to be of pivotal importance in both decommissioning planning and project execution (e.g. key assumptions related to preferred decommissioning options, cost estimates, required waste management infrastructure or stakeholder acceptance). In those cases where the key assumptions have high levels of uncertainty and are also of particular importance to the decommissioning strategy, actions may need to be identified and implemented to decrease the level of uncertainty. If the proposed actions cannot reduce uncertainties to acceptable levels (residual risk), the assumption may need to be revised or replaced.

4.1.4. Assumptions register

A tabular register (i.e. an assumptions register) can provide an effective means for tracking and monitoring key assumptions as well as their status and the status of any associated actions plans (see Fig. 4). An assumptions register facilitates understanding of how key assumptions evolve, and helps ensure actions are managed and completed in a defined time frame.

Assumptions register

Identification of assumptions					Uncertainty assessment		Actions		Assumptions Monitoring	
#	Assumptions descriptions	Risk family	Assumption origin (regulatory, technical other)	Comments	Level of uncertainty (low, medium, high)	Comments	Actions description	Actions status	Periodicity, comments, outcomes	Assumptions status
1										
2										

FIG. 4. Assumptions register template.

4.1.5. Assumptions monitoring

It is extremely important that the monitoring of key assumptions be performed periodically and at intervals appropriate to the state of the decommissioning planning process. In some cases, the monitoring intervals may be dictated by national requirements that might in themselves trigger a review of the key assumptions (e.g. facility relicensing). Notwithstanding the designated intervals, a re-examination may be undertaken if special circumstances so warrant, for example, as the result of any major modifications to the facility relative to that described in the IDP, or owing to any major changes in important strategic initiatives (e.g. national waste management strategies) that could affect the decommissioning option identified in the IDP. The monitoring process is typically performed during the periodic updates of the IDP. Some assumptions may need to be reviewed more frequently, and if this is the case, this requirement needs to be recorded in the assumptions register.

The licensee (operator), or organization responsible for the decommissioning plan, is generally considered to be responsible for putting in place the arrangements for the review of assumptions, a process that typically consists of the following activities:

- — Reviewing the status of the action plans identified in the assumptions register;
- — Reviewing the validity of the key assumptions together with any supporting information or documentation;
- — Reassessing the levels of uncertainty for the key assumptions;
- — Reassessing the action plans and their assignment;
- — Reviewing the processes that govern the periodic examination of the assumptions register;
- — Confirming that the reviews are being conducted appropriately.

The results of the review of the key assumptions could take the following forms:

- An assumption is confirmed as being factual with little or no uncertainty and therefore requires no further review. However, monitoring may still need to remain in effect to capture any refinement in data or information concerning the key assumption.
- The level of uncertainty for a key assumption has changed and the consequences of that change will need to be addressed. For example, it may be concluded that the uncertainties surrounding an assumption have increased, and that an action plan is now required.
- An assumption still has the same level of uncertainty:
  - The uncertainty is acceptable and no further actions are proposed;
  - The uncertainty is no longer acceptable and actions are needed.
- An assumption is no longer valid and needs to be replaced by a new or modified assumption. It is advisable to keep any replaced assumptions in the assumptions register to allow any subsequent tracking of changes.

The status of each assumption is best updated as part of the IDP revision process, and the updates recorded in the assumptions register.

4.1.6. Evaluating and analysing key assumptions

This section examines a situation where a more quantitative approach is taken in evaluating and analysing key assumptions. For some assumptions, it can be useful to perform a more quantitative risk assessment (Section 2.2) as a means of better understanding the consequences of an assumption undergoing a substantial change or becoming invalid. By applying the risk assessment methodology to certain key assumptions, particularly those that are of high importance and have a high level of uncertainty, it may be possible to make better informed decisions as to how those key assumptions can be best managed. For example, if the risk assessment process concludes that the consequences of using an invalid assumption are likely to be highly adverse in terms of parameters such as cost, schedule and even safety, consideration may need to be given to actually changing the decommissioning plan in such a fashion as to no longer rely on that assumption. This more quantitative risk assessment can be performed following the same general approach as that described in Section 5, with the assumptions register being updated as required to reflect any changes resulting from the assessment (see also Section 4.1.5). The assumptions register could also be modified to accommodate the use of the risk assessment process (e.g. by adding columns to record the risks associated with the assumptions).

4.2. GOOD PRACTICES

Good practices concerning RMSL include the following:

- In considering the long time frames involved, the extent of uncertainties in many planning assumptions, and other unique aspects surrounding decommissioning planning and implementation, the use of RMSL is particularly important and relevant.
- Given the importance of key assumptions on the development of decommissioning plans and on the ability to meet decommissioning objectives, a structured approach such as that embodied in RMSL is extremely important in effectively managing and controlling the uncertainties found with many key assumptions.
- It is important that the RMSL process and the associated assessment of assumptions be an ongoing process that includes regular monitoring, review and record keeping activities.
- The assumptions register is an important tool in the RMSL process. However, the register is best treated as an adaptable and flexible tool with a structure and content that can be changed according to the needs and nature of the information and data available.
- The assumptions register can be used in combination with standard risk management techniques such as risk assessment to support the decision making process and to develop action plans.
- Existing experience has shown that in most cases involving the analysis of assumptions, a qualitative assessment is sufficient.
- The conclusions and findings that result from the analysis of assumptions can be used in the periodic update of decommissioning plans.
- Ideally, the application of RMSL begins with the preparation of the IDP and continues into the FDP preparation phase. However, even in those cases where the planning process begins with the FDP, the use of RMSL can prove extremely important because it provides a useful tool in deciding which strategic decisions are most appropriate for inclusion in the FDP.

5. RISK MANAGEMENT AT THE OPERATIONAL LEVEL

The primary objective of risk management at the operational level (RMOL) is to control risks during the implementation and execution of a decommissioning project where that project is being conducted under an approved FDP (or equivalent document). At this stage of the project (i.e. an approved FDP or project plan is in place), the success of the project depends in large measure on the accuracy of the key assumptions upon which the strategic decisions in the FDP have been based.

The fundamental objective of RMOL is to support the implementation of the FDP. It comprises the identification, assessment, monitoring and treatment of those risks (threats and opportunities) primarily associated with the actual execution and implementation of the decommissioning plans (i.e. operational issues). RMOL follows the standard project risk management framework with the goal of increasing the probability of achieving the decommissioning objectives by controlling the risks and uncertainties surrounding the decommissioning project.

5.1. CONTEXT

A key step in initiating the risk management process at the operational level is to carefully define the context, scope and boundaries (exclusions and constraints) of the project. Given the importance of the context, scope and boundaries, it may be beneficial to confirm their accuracy and completeness with stakeholders before proceeding with the risk management process. Typical information that is used to define the context and the project boundaries can include:

- Project background and project rationale.
- Facility information and data (e.g. radiological conditions and the availability of historical information).
- Project starting point, end state criteria and success criteria.
- Project scope definition:
    - Strategic decisions, including the key assumptions register (Section 4.1.4);
    - Exclusions (i.e. scope not included in the project);
    - Constraints (i.e. limiting conditions the project is required to respect);
    - Interdependencies with other projects and organizations;
    - Uncertainties.
- Project schedule, including milestones and hold points.
- FDP.
- Decommissioning safety assessment and analysis reports.
- Communications status (e.g. with the public, stakeholders, the regulator).
- Regulatory environment.

The sharing of this information with all participants involved in the risk management process will contribute significantly to the effectiveness of that process.

5.2. RISK ASSESSMENT PROCESS

The steps in the risk assessment process include the following:

— Risk identification: a systematic identification and discussion of all relevant project risks (both threats and opportunities).
— Risk analysis: a characterization of the risks in terms of both probability of occurrence and severity of impact with an assignment of numerical values to both the probability (probability assessment value) and impact (impact assessment value) for each risk identified.
— Risk evaluation: a two part process comprising (i) the determination of risk level (i.e. the assignment of a risk score to each risk based on the product of the probability assessment value and the impact assessment value), and (ii) the prioritization of risks, based, for example, on a comparison of the results of risk analysis and the associated risk levels with risk criteria (see Section 2.2.3) to determine whether the risk and/or its magnitude is acceptable or tolerable. The two parts of the risk evaluation process are generally undertaken in concert, with risk criteria often being used to determine the impact assessment value.

At an operational level, the risk assessment process is typically undertaken in a workshop environment, and includes personnel with responsibilities, skills and knowledge appropriate to the project under consideration. The assessment process is often repeated for each major project step (e.g. as identified in the project work breakdown structure or based on hold points). The risk assessment process can be undertaken in one or more workshops depending on the stage of the project, scope and complexity. The risk workshop attendees would typically include personnel with the following roles, expertise and responsibilities:

— Project manager: overview of the project.
— Engineering representative: engineering and technical aspects.
— Decommissioning team supervisor: decommissioning knowledge and experience.
— Operational representative: operational knowledge of the facility.
— Safety specialist: safety and licensing perspective.

— Licensing and regulatory specialist: knowledge about the regulatory processes relevant to the project.
— Environmental protection specialist: status and requirements for any environmental assessments.
— Communications expert: communications plan for the project.
— Specialists: waste management, commercial operations, human resources, safety, radiological protection, analytical services and procurement, among others.
— Other project managers: insight into the manner in which other projects managed risk.
— Independent experts: experience from similar projects; knowledge and information about external supporting facilities and projects (e.g. waste storage/disposal facilities).

It may be beneficial to utilize a risk workshop facilitator who has experience in the organization's risk assessment processes and has the ability to guide the workshop participants through the process. The success of the workshop depends on the attendance and active participation of all the participants.

Depending on the size of the organization, other personnel who may usefully play a role in the risk assessment process can include:

— Risk manager: experience from other projects that have utilized the risk management process;
— Financial representative;
— Quality representative.

5.2.1. Risk identification

The purpose of risk identification is to ensure that all of the relevant risks and their potential impact on the project are identified, discussed and recorded. The identification of risks is often undertaken at a workshop with the entire project team in attendance as well as selected subject matter experts.

It is incumbent on the workshop participants to be fully engaged in the identification process, and to apply their specialized knowledge and expertise as broadly as possible to the process of identifying and describing risks. During the workshop, the risk families presented in the Appendix can be used as 'prompts' to help stimulate thinking about possible risks. The risks identified will, if appropriate, include both threats and opportunities. Two additional sources of prompts can include: (i) the work categories included in the work breakdown structure commonly used in project planning, and (ii) if available, a database of risks that have been identified in similar projects.

As risks are identified and entered into a risk register, it is beneficial to include sufficient details to ensure that the nature of the risks is clear and unambiguous. These additional details can be particularly important if subsequent analyses of the risks may be carried out by personnel who were not involved in their original identification. Further details on a risk register are described in Section 5.4.

Defining and wording risks as explicitly as possible with the exact nature of the threat or opportunity being made very clear is particularly useful and can avoid misunderstandings or misconceptions. For example, a risk statement such as “the amount of waste found in a facility is different from that expected” could, in fact, be either a threat or an opportunity depending upon whether the quantity is greater or smaller than expected. Therefore, the risk might be better worded as “the amount of waste found in the refuelling area is greater than assumed in the project plan, and this could result in exceeding the capacity of the disposal facility.” The better a risk is defined, the greater the likelihood it can be addressed and communicated.

5.2.2. Risk analysis

The risk analysis process takes the identified threats and opportunities and assesses both the probability (likelihood) and impact (consequences) of those threats and opportunities.

At an operational level, the assessment of probability typically uses a linear scale, such as the one shown in Table 2. Possible criteria or guidelines that might be used in assigning probability levels have been provided in Table 2 for illustrative purposes. The actual criteria employed by an organization are best developed taking risk criteria and project objectives into consideration.

At an operational level, the assessment of impact typically uses a linear scale, such as the one shown in Table 3. The impact assessment generally takes into consideration key factors such as cost and schedule. However, depending on the culture of the organization, other factors could be used such as safety or quality. In those situations where factors other than cost and schedule are used to assess impact, the risk criteria previously developed can be used to establish terms of reference against which the significance of a risk is evaluated.

When selecting the impact score, the general practice is to base it on the highest value for any of the identified factors (i.e. cost, schedule, safety, etc.). Possible criteria or guidelines for assessing the extent of cost and schedule impact have been provided for illustrative purposes in Table 3 to demonstrate the manner in which impact scores might be assigned. The actual criteria employed by an organization are best developed taking risk criteria and project objectives into consideration.

TABLE 2. EXAMPLE OF A SCALE OF PROBABILITY FOR USE IN RISK ANALYSIS

Probability score	Probability	Scale	Illustrative (sample) probability criteria
1	0–20%	VL	Very unlikely to occur; not known to have taken place with similar types of decommissioning projects
2	21–40%	L	Unlikely to occur; known to have occasionally taken place with similar types of decommissioning projects
3	41–60%	M	Known to have taken place with reasonable regularity on similar types of decommissioning projects
4	61–80%	H	Typically takes place with similar types of decommissioning projects
5	81–100%	VH	Almost certain to take place

Note: VL — very low; L — low; M — medium; H — high; VH — very high.

TABLE 3. EXAMPLE OF A SCALE OF IMPACT FOR USE IN RISK ANALYSIS

Impact score	Scale	Illustrative (sample) cost impact criteria	Illustrative (sample) schedule impact criteria
1	VL (insignificant)	<1% of the remaining budget	<1% of the remaining duration
2	L (minor)	1 to 5% of the remaining budget	1 to 5% of the remaining duration
3	M (moderate)	6 to 10% of the remaining budget	6 to 10% of the remaining duration
4	H (major)	11 to 20% of the remaining budget	11 to 20% of the remaining duration
5	VH (severe)	>20% of the remaining budget	>20% of the remaining duration

Note: VL — very low; L — low; M — medium; H — high; VH — very high.

5.2.3. Risk evaluation

Risk evaluation generally comprises three major components: (i) the development of risk criteria (see Section 2.1) to serve as terms of reference by which to assess levels of impact, (ii) the determination of risk levels (risk scores), and (iii) the prioritization of risks based in large measure on the risk criteria and the risk levels (scores).

5.2.3.1. Risk level

The determination of risk level involves scoring each of the risks based on the combined effects of probability (likelihood) and impact (consequences). The risk score is the product of the probability and impact scores. An example of a probability–impact diagram (risk matrix) is provided in Fig. 5. The exact nature of a probability–impact diagram may be dictated by the specific needs of an organization.

5.2.3.2. Prioritization

Prioritization is typically based on a score but could also take into account factors such as timing, costs, safety and reductions in the critical path schedule. The importance of scoring each risk is that it enables workshop participants to visualize the threats and opportunities in direct relation to each other and thereby to prioritize the risks. The risk matrix also serves as an effective means for communicating information about project risks to a wide range of audiences.

When calculating the potential impact of an opportunity, it is best to primarily focus on the cost or schedule savings that would result if the opportunity were to be realized. With the potential savings identified, the project can then decide if the effort (cost and schedule) to implement the opportunity merits pursuing.

Probability of Occurence			Risk Score = Probability Scale x Impact Scale (P X I)				
> 80%	Probability Scale Increasing Probability	5	5	10	15	20	25
60% - 80%		4	4	8	12	16	20
40% - 60%		3	3	6	9	12	15
20% - 40%		2	2	4	6	8	10
0% - 20%		1	1	2	3	4	5
			1	2	3	4	5
			Impact Scale Increasing Impact				
		Impact of Occurrence	Insignificant	Minor	Moderate	Major	Severe

FIG. 5. Example of a probability–impact diagram (risk matrix).

5.3. RISK TREATMENT

After assessing and prioritizing the risks, the next step is to determine the appropriate risk treatment strategy (see Table 4). The risk treatment strategy for threats principally involves proactively reducing the risks (i.e. by reducing probabilities and/or impact) to an acceptable level. In the case of opportunities, risk treatment usually involves proactively managing risks to exploit the expected benefits (see Section 2.3). The score corresponding to a given treatment strategy will depend on the organization's risk tolerance ('risk appetite') and on the nature of the organization's risk criteria.

The process for undertaking risk treatment strategies is generally as follows:

- Select treatment strategies based on risk scores and risk criteria.
- Develop action plans and identify the action owners required for the implementation of the treatment strategies.
- Develop the cost and schedule for the actions necessary for the risk treatment and incorporate them into the project plan. If the cost of the treatment strategy (i.e. in terms of both project cost and project schedule) is deemed to be too high in relation to the potential risk impact, the

TABLE 4. EXAMPLE OF A RISK TREATMENT SELECTION GUIDE

Strategy	Risk score	Definition
Avoid	20–25 (red)	Change the project plan/activity so that threat does not or cannot occur
Mitigate	6–16 (yellow)	Take action to reduce the probability and/or impact of the threat such that the risk is lowered to an acceptable level
Transfer	6–16 (yellow)	Transfer the risk to another party (e.g. a contractor) better positioned to address the threat and thereby lower the risk to acceptable levels
Accept	1–5 (green)	Accept the risk and take no further action; monitor the risk to ensure it remains acceptable
Exploit (opportunity)	6–25 (yellow, red)	Take action to increase the probability and/or impact of the opportunity

project (i.e. the project team) may need to reassess the actions or the risk treatment strategy.
— Record the relevant information, such as the actions, action owners and target completion dates, in the risk register.

For less complex projects, the above process may mark the end of the risk treatment phase, and the project can move to the next step of risk management (i.e. risk monitoring). For more complex projects, it is advisable to reanalyse and evaluate the residual risk associated with the threats by taking into account the effectiveness of the risk treatment actions. This review will involve reassessing the probability and impact of the threat based on the assumption that the risk treatment actions have been implemented.

Examples of possible risk treatment actions (for both threats and opportunities) are provided in Table 5.

5.4. RISK REGISTER

The project risk register serves as the record keeping tool for capturing all of the relevant details for each of the identified project risks. The risk register allows for day to day tracking of the risks and helps in prioritizing the risks and in developing the action plans for which the project team has responsibility.

An effective risk register will generally include information of the following types:

— A unique number to identify each risk.
— A description of the risk with particular attention being paid to the source of the risk and the potential impact. This description can play an important role in communicating the nature of the risk to stakeholders, and will help to ensure that readers with varying degrees of experience and knowledge about the project can understand and appreciate the risks.
— Type of risk (i.e. threat or opportunity).
— Status of the risk (e.g. open or closed).
— Risk owner.
— The project activities that the risk may potentially impact (e.g. cost, schedule, quality, safety).
— Risk analysis results prior to treatment actions:
    - The ratings for risk probability and impact before treatment;
    - Overall risk score;
    - The potential impact of the risk on the project explicitly in terms of quantitative measures for cost and schedule changes.

TABLE 5. EXAMPLES OF RISK TREATMENT ACTIONS

Risk (threat)	Risk family	Treatment	Action
Higher than expected levels of contamination are encountered during cutting operations	Radiological safety	Avoid	Change cutting technique to eliminate airborne contamination
Poor road conditions during the rainy season delay the transport of project materials and waste	Site characteristics	Avoid	Change the timing of transfers to the dry season
Technology proposed for handling fuel is rejected for safety reasons owing to the potential for additional fuel damage	Technology	Avoid	Change technology to a technique that would not place additional stress on the fuel
Volumes of waste are higher than expected	Waste estimation and characterization	Mitigate	Perform additional characterization to obtain improved information about the waste and thereby enhance waste segregation effectiveness
The use of new technology increases the frequency of delays, accidents, etc.	Technology	Mitigate	Use mock-ups to train staff in applying the new technology and improve safety and performance
Availability of qualified workers is lower than anticipated	Human resources	Mitigate	Initiate training courses prior to project startup to ensure that the required number of qualified workers is available
Unplanned delays occur owing to the unavailability of electrical power from the site infrastructure	Site characteristics	Mitigate	Procure and install dedicated project generators
Internal workers are found to have insufficient knowledge and training to accomplish the cutting of reactor internals in a timely fashion	Human resources	Transfer	Transfer responsibility for dismantling reactor internals to an experienced contractor

TABLE 5. EXAMPLES OF RISK TREATMENT ACTIONS (cont.)

Risk (threat)	Risk family	Treatment	Action
Unforeseen changes occur in regulatory requirements	Regulations and laws	Accept	No action taken; risk can be managed with existing resources
Unable to avoid small contamination events	Radiological safety	Accept	No action taken; the effort to totally avoid any contamination events is more costly than the cleanup of small contamination events
Unexpected workforce actions (e.g. strikes) occur	Human resources	Accept	No action taken; other resources are available
Risk (opportunity)			
Increase volume of material suitable for free release and reduce volume of waste in high level waste categories	Waste management infrastructure	Exploit	Invest additional efforts in waste decontamination
Enhance the knowledge and skills of internal workers to reduce reliance on external contractors and thereby reduce costs, and increase capabilities for future projects	Human resources	Exploit	Provide additional resources for training internal workers
Reduce the extent of labour intensive tasks	Technology	Exploit	Develop new tools using in-house resources to automate and mechanize labour intensive tasks
Remove the need for off-site waste disposal and waste processing	Technology	Exploit	Develop a waste treatment strategy that removes the requirement for off-site disposal and treatment

Identification			Assessment Prior to Treatment					Response / Treatment		Monitoring & Control	
Risk ID	Risk Description	Status	Calculate Risk Score (P x I)			Impact		Action	Cost of treatment strategy	Actual Outcome / Progress	Status
			Probability Scale (1 to 5)	Impact Scale (1 to 5)	Risk Score (P x I)	Cost	Schedule (days)				

FIG. 6. Example of a simplified risk register.

— Risk treatment strategy:
  - Type of strategy to be adopted (e.g. avoidance, risk transfer);
  - Treatment actions including action owners and target completion dates;
  - Cost of the treatment strategy.

— Residual risk remaining after completion of risk treatment (if applicable):
  - The rating for risk probability and impact following risk treatment;
  - Overall risk score following risk treatment.

— Notes that capture any discussions concerning the risks (e.g. considerations of risk criteria, rationales underlying changes in assessments, justifications for actions).

An example of a risk register is shown in Fig. 6.

5.5. RISK MONITORING

Once the risk treatment strategies have been defined and the risk register populated, the project can proceed to establishing the necessary processes for risk monitoring, which generally consists of the following activities:

— Monitoring the status of the actions developed for implementing the treatment strategy.

— Reviewing the risk register on a periodic basis. The review process can be completed as part of a project progress meeting, or as a specific risk review meeting.

As an aid in reviewing the risk register, the following questions can be considered:

- Is the risk still valid (i.e. has it expired, changed or become irrelevant)?
- Are the risk treatment actions progressing as planned?
- Does the risk still adequately describe the situation?
- Are the risk scores still appropriate?
- Are the treatment measures still considered effective?
- Are there any new risks (threats and opportunities)?

Revised risks or new risks are incorporated into the risk register, as well as any supporting information (e.g. the reasoning behind any additions or revisions). It is important that risks not be deleted from the risk register if they either have expired or are no longer relevant to the project, but the status of these risks can be changed. This approach will help to ensure that a complete record of the history behind the risks is maintained, and equally important, it preserves important risk management context, which can help in effectively monitoring the active and open risks that are still valid.

5.6. RISK MODELLING

The purpose of risk modelling is to assist in the development of suitable cost and schedule allowances (contingencies) by taking into account the impact of any post-treatment risks (residual risks) identified within the project risk register. The use of such a model is optional and depends on the organization's management system and the overall complexity of the project.

Risk models can be developed using commercially available software tools to calculate contingency values for inclusion in the project's total cost and schedule. The modelling process often relies on Monte Carlo simulations whereby costs and task durations are iteratively calculated using values selected at random from probability distribution functions for those parameters that can affect cost and schedule. The results can then be incorporated into the project's schedule and budget to provide a higher level of confidence that the project will be delivered as planned (i.e. on budget and on time).

5.7. GOOD PRACTICES

Good practices concerning RMOL include the following:

- Consider using a risk register, which has proven to be a valuable, flexible and easy way to identify, monitor and control project risks.
- Create and populate a risk database, which includes or uses other or past risk registers as a means for helping to generate risk registers for other projects. A database of this type can be particularly useful in the workshops dedicated to identifying risks.
- Ensure that the risk register is updated and used as a part of the decision making process at important points in the project, for example, at hold points.
- Consider having project managers from across the organization share and discuss their risk registers and having project managers from different projects participate in the risk identification workshops.
- Ask project leaders to report on risk and action status regularly, for example, as part of project meetings and reports.
- When working with contractors, consider generating a joint risk register to ensure that both parties understand the risks and the treatment actions. This approach can also help to ensure that the contractors have had a reasonable opportunity to provide meaningful input into the risk management process.
- Include, as part of end-of-project reports or annual reports, any recommendations, findings and lessons learned that are specific to the risk management process.
- As part of a general strategy for reducing the impact of risk, consider using a conservative approach in establishing the baseline for project delivery (i.e. an approach where the cost and schedule are based on the previous performance of comparable projects within the organization). This approach can also be followed in the identification and treatment of risks.
- Complete risk identification in a workshop environment, where it will generally be more effective than if it is conducted solely by, for example, the project manager. The broader the range of experience and expertise of the personnel participating in a risk identification workshop, the greater the likelihood that the risk register will be as comprehensive as possible.
- Ensure that reference material is available to workshop participants ahead of the actual workshop; this will aid the risk identification process.
- Consider using elements of both RMSL and RMOL. Whereas RMSL primarily applies to the planning process by managing the risks associated with the uncertainties surrounding key assumptions, RMOL primarily applies to managing the risks associated with the project implementation and execution process. However, aspects of both approaches can often be used in concert.

6. RELATIONSHIP BETWEEN RMSL AND RMOL

At a very basic level, it is the fact that key assumptions within an IDP become strategic decisions within the FDP that defines the relationship between RMSL and RMOL. RMSL serves to ensure that the strategic decisions and plans in the FDP are based on the best and most dependable information available, and RMOL serves to ensure that those decisions and plans are subsequently implemented with as little risk as possible to the project delivery. While RMOL makes use of the concept of risk level or risk score (defined as the magnitude of a risk as expressed in terms of the combination of consequences (impact) and their likelihood (probability)), RMSL generally only considers the level of uncertainty (or conversely the level of confidence) associated with a key assumption. The rationale behind this difference in approach is based on the fact that in the development of an IDP, where key assumptions are first identified, it may not be possible to fully understand the impact of changes in the key assumptions. However, in some circumstances, a more quantitative approach similar to that described in Section 5.2.3 can be undertaken to include considerations of consequences of changes in the key assumptions.

Key assumptions often carry a high degree of uncertainty and can be based on speculation about future conditions and circumstances. In contrast, the strategic decisions in the FDP need to be based on factual information to the greatest extent possible. The need for factual information arises because formal approval is often required to proceed with decommissioning as per the specific plans within the FDP, and subsequent changes to the FDP may be problematic in terms of issues such as approvals. It is RMSL in combination with RMOL that provide a systematic approach for use in ensuring that the transition from speculative assumptions to factually based strategic decisions is carried out effectively.

As a general rule, although the process may vary in some Member States, the FDP is that version of the decommissioning plan submitted to the regulatory body in preparation for initiating the implementation phase of the decommissioning plan (i.e. it marks a transition from planning to execution). Furthermore, approval of the FDP by the regulatory body may constitute approval to begin undertaking actual work. Therefore, what originally constituted an assumption or supposition in the IDP has become a strategic decision that will dictate how the actual work is carried out. For example, a key assumption may have been that the project would only use internal resources; however, in the FDP that same assumption will manifest itself as the strategic decision to use internal resources. Based on the FDP, a decommissioning project is initiated to implement the decommissioning actions. Operational risk management will identify and address the risks associated with the implementation of the strategic decisions (i.e. actions) as outlined in the FDP.

Regardless of the rigour with which the RMSL process has been applied, strategic decisions will need to be monitored and reviewed during the implementation of decommissioning. Changes to the strategic decisions, such as a change in the resource strategy from using internal resources to using external resources, would need to be verified against the FDP objectives and assessed by the project. This assessment would need to consider all the implications from a change in that decision, including the possibility that the FDP might require re-approval. At a minimum, any changes in strategic decisions would have to be examined in terms of safety assessments. The changes to strategic decisions may be initiated by the organization's management team or may be the result of issues identified by the project when performing decommissioning actions. Changes in strategic decisions can have far ranging consequences, a fact which underscores the importance of applying RMSL to the key assumptions to ensure, to the extent possible, that the strategic decisions will not require subsequent changes.

There are situations when it is necessary to escalate issues surrounding threats or opportunities to higher levels of management outside of the project team. As a general rule, the basis for such an action is the recognition that there has been a loss in the ability of the project to control or manage the threats or opportunities within the boundaries or scope of the project. The escalation serves to alert and request assistance from a level of management that may be better placed to deal with the threats or opportunities. Examples where escalation may be necessary include situations where:

— Decisions have been made that are outside of the control of the project, but which have the ability to compromise the project delivery. For example, where it has been decided that the starting point for the decommissioning project will be defined by the end point of another project.
— Risks are identified that can clearly be addressed more effectively by another organization (e.g. transferred from the decommissioning organization to the waste management organization).
— Common risks or opportunities from a number of projects can be consolidated to enable more efficient management, for example, common resource issues such as worker shortages that exist across a number of projects.

7. CONCLUDING REMARKS

This publication describes the application of risk management to both the planning and implementation phases of decommissioning projects and identifies good practices in the use of generally accepted risk management principles during these decommissioning phases.

In applying risk management to decommissioning, it was further recognized that in addition to the more customary use of risk management techniques during a project's execution phase, the unique aspects of decommissioning also called for an adaptation of the customary risk management process to address the planning process. As a consequence, this publication examines two topics (i.e. RMSL for planning purposes, and RMOL for project execution).

RMSL primarily focuses on the management of uncertainties surrounding key assumptions and strategic decisions during the planning phase of decommissioning (i.e. from the IDP to the FDP). RMOL primarily focuses on risks to the decommissioning project associated with the implementation and execution of the FDP.

This publication discusses the benefits of applying a standard risk management programme to a decommissioning project, and also introduces the concept of following a similar approach in the management of key assumptions and any strategic decisions that may result from those key assumptions. Taken together, these applications can both help to ensure realistic and defensible decommissioning plans (IDP and FDP) and support the achievement of decommissioning objectives in a timely and cost effective manner.

Appendix

RISK FAMILIES

In order to ensure that all relevant risks are identified during the application of RMSL and RMOL, a list of risk families specific to decommissioning can be used to enhance the systematic identification and evaluation of assumptions and risks. These families can serve as ‘prompts’ during the risk identification process to stimulate and facilitate thinking about possible risks in those areas relevant to decommissioning. The following list is provided as an example of risk families, and can be expanded as required:

— Initial condition of facility;
— End state of decommissioning project;
— Management of waste and materials;
— Organization and human resources;
— Finance;
— Interfaces with contractors and suppliers;
— Strategy and technology;
— Legal and regulatory framework;
— Safety;
— Interested parties.

While some of these risk families may not be applicable based on the nature of specific decommissioning projects, it is more likely that additional families will need to be added.

In Table 6, each risk family is broken down into subcategories and sub-subcategories as a means of providing more detail about specific subject areas that might reside within each risk family.

TABLE 6. RISK FAMILIES

Risk family		Prompts
1. Initial condition of facility	1.1. Physical status	1.1.1. Operational history and records
		1.1.2. List of SSCs[a] and their physical status
	1.2. Radiological status and characterization	1.2.1. Contamination of SSCs[a]
		1.2.2. Activation of SSCs[a]
		1.2.3. Contamination of soil and underground water
	1.3. Status of waste and materials	1.3.1. Spent fuel
		1.3.2. Operational waste
		1.3.3. Hazardous materials
	1.4. Site characteristics	1.4.1. Interdependencies with other facilities
		1.4.2. Site infrastructure
2. End state of decommissioning project	2.1. Definition of the end state of the project	2.1.1. Buildings
		2.1.2. Facility/site
	2.2. Difficulty in achieving the end state	2.2.1. Feasibility
3. Management of waste and materials	3.1. Waste management policy	3.1.1. Site release criteria
		3.1.2. Clearance levels
		3.1.3. Waste acceptance criteria
	3.2. Waste estimation and characterization	3.2.1. Operational waste
		3.2.2. Decommissioning waste (including secondary waste)
		3.2.3. Unknown waste
	3.3. Waste management infrastructure (on-site/off-site)	3.3.1. Treatment facilities
		3.3.2. Storage facilities
		3.3.3. Disposal facilities
		3.3.4. Transport

TABLE 6. RISK FAMILIES (cont.)

Risk family		Prompts
4. Organization and human resources	4.1. Organizational structure	4.1.1. Responsibilities
		4.1.2. Appropriate organization
		4.1.3. Organizational changes and transfer of responsibilities between organizations
	4.2. Human resources	4.2.1. Skills, knowledge and training
		4.2.2. Human factors and mentality change
		4.2.3. Interfaces with contractors and their integration into the project team
5. Finance	5.1. Cost	5.1.1. Cost estimation
	5.2. Funding	5.2.1. Funding sources
		5.2.2. Funding mechanism
		5.2.3. Financial governance
6. Interfaces with contractors and suppliers	6.1. Management of contractors and suppliers	6.1.1. Contractual strategy
		6.1.2. Procurement process and selection of contractors
	6.2. Contractor and supplier oversight	6.2.1. Safety culture and language aspects
		6.2.2. Skills and training
7. Strategy and technology	7.1. Decommissioning strategy	7.1.1. Immediate dismantling
		7.1.2. Deferred dismantling
		7.1.3. Combination
	7.2. Decommissioning scenarios	7.2.1. Technical feasibility
		7.2.2. Alternative scenarios
	7.3. Technology	7.3.1. Availability and maturity
		7.3.2. Research, development and demonstration

TABLE 6. RISK FAMILIES (cont.)

Risk family		Prompts
8. Legal and regulatory framework	8.1. Laws and regulations	8.1.1. Gaps in regulations 8.1.2. Inconsistencies in regulations 8.1.3. Potential legal and regulatory changes
	8.2. Licensing process	8.2.1. Complexity of the licensing processes 8.2.2. Uncertainty of regulatory review (outcomes, timing)
9. Safety	9.1. Radiological safety	9.1.1. Radiation protection of workers 9.1.2. Public radiation protection 9.1.3. Environmental releases
	9.2. Conventional safety	9.2.1. Conventional safety of workers 9.2.2. Impact of decommissioning activities (noise, dust, transport, etc.) 9.2.3. Impact of hazardous materials
	9.3. Security	9.3.1. Site security and access
10. Interested parties	10.1. Communication	10.1.1. Public acceptance 10.1.2. Transparency 10.1.3. Communication media
	10.2. Involvement of interested parties	10.2.1. Consultation
		10.2.2. Engagement

[a] SSCs: structures, systems and components.

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ABBREVIATIONS

DRiMa	International Project on Decommissioning Risk Management
FDP	final decommissioning plan
IDP	initial decommissioning plan
RMOL	risk management at the operational level
RMSL	risk management at the strategic level

Annex

DEFINITIONS

The terms 'risk' and 'safety' as used in the International Project on Decommissioning Risk Management (DRiMa) were not intended to be synonymous with the concepts of risk and safety as defined in the IAEA Safety Glossary [A–1]. Risk, in the context of this publication, is meant to reflect the concept embodied in the Project Management Institute [A–2] definition of risk: "an uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objectives such as scope, schedule, cost, and quality."

In this publication, the term 'safety' is used in a broader sense than that defined by the IAEA Safety Glossary [A–1]. As noted in IAEA Safety Standards Series No. GSR Part 6, Decommissioning of Facilities [A–3]:

"Non-radiological hazards, such as industrial hazards or hazards due to chemical waste, can be significant during decommissioning. Such hazards require due consideration in the planning and implementation process, in the safety assessments and environmental impact assessments, and in the estimation of costs and the provision of financial resources for the decommissioning project. However, these issues are outside the scope of this [GSR Part 6] publication and are not explicitly addressed here."

The term 'safety', as used in this report and unless indicated otherwise, is meant to apply to both radiological and non-radiological hazards, and includes the areas generally associated with conventional safety and health [A–4]. IAEA Safety Standards Series No. SSG-47, Decommissioning of Nuclear Power Plants, Research Reactors and Other Nuclear Fuel Cycle Facilities, also discusses the importance of addressing non-radiological hazards [A–5].

In an effort to provide as broad a perspective as possible, and in recognition of the fact that there can be important distinctions between definitions based on, for example, organizational mandates, this annex provides definitions for some terms from different organizations to illustrate differences in approach and purpose.

consequence, impact. "Outcome of an event affecting objectives" [A–6].

event. "In the context of the reporting and *analysis* of *events*, an *event* is any occurrence unintended by the *operator*, including operating error, equipment *failure* or other mishap, and deliberate action on the part of others, the consequences or potential consequences of which are not negligible from the point of view of *protection and safety*" [A–1].

However, there are alternative definitions:

"A risk with a probability of 1."

"Occurrence or change of a particular set of circumstances" [A–6].

level of risk, risk score. "Magnitude of a risk or combination of risks, expressed in terms of the combination of consequences and their likelihood" [A–6].

likelihood, probability. "Chance of something happening."

"Note: The English term 'likelihood' does not have a direct equivalent in some languages; instead, the equivalent of the term 'probability' is often used. However, in English, 'probability' is often narrowly interpreted as a mathematical term. Therefore, in risk management terminology, 'likelihood' is used with the intent that it should have the same broad interpretation as the term 'probability' has in many languages other than English" [A–7].

monitoring. "Continual checking, supervising, critically observing or determining the status in order to identify change from the performance level required or expected" [A–6].

project stakeholder. "an individual, group, or organization who may affect, be affected by, or perceive itself to be affected by a decision, activity, or outcome of a project" [A–2].

residual risk. "Risk remaining after risk treatment" [A–6].

"risks that are expected to remain after planned responses have been taken, as well as those that have been deliberately accepted" [A–2].

review. "Activity undertaken to determine the suitability, adequacy and effectiveness of the subject matter to achieve established objectives" [A–6].

risk. "A multiattribute quantity expressing *hazard*, danger or chance of harmful or injurious consequences associated with *exposures* or *potential exposures*. It relates to quantities such as the probability that specific deleterious consequences may arise and the magnitude and character of such consequences" [A–1].

“Depending on the context, the term *risk* may be used to represent a quantitative measure … or as a qualitative concept” [A–1].

However, other organizations define risk as:

“An uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objectives such as scope, schedule, cost, or quality” [A–2].

“Effect of uncertainty on objectives” [A–6].

risk analysis. “A qualitative characterization of the risks in terms of both likelihood of occurrence and severity of impact with an assignment of numerical values to both the probability and impact for each risk identified.”

“A process to comprehend the nature of risk and to determine the level of risk” [A–6].

risk assessment. “*Assessment* of the *radiation risks* and other risks associated with *normal operation* and possible *accidents* involving *facilities* and *activities*.

“This will normally include *consequence assessment*, together with some *assessment* of the probability of those consequences arising” [A–1].

However, the term can be used in a different context:

“Overall process of risk identification, risk analysis and risk evaluation” [A–6].

risk criteria. “Terms of reference against which the significance of a risk is evaluated” [A–6].

risk evaluation. “Process of comparing the results of risk analysis [level of risk, or risk score] with risk criteria to determine whether the risk and/or its magnitude is acceptable or tolerable” [A–6].

risk identification. “Process of finding, recognizing and describing risks” [A–6].

risk management. “Coordinated activities to direct and control an organization with regard to risk” [A–6].

“Project Risk Management includes the processes of conducting risk management planning, identification, analysis, response planning, and controlling risk on a project. The objectives of project risk management are to increase the likelihood and impact of positive events, and decrease the likelihood and impact of negative events in the project” [A–2].

risk management framework. “A set of components that provide the foundations and organizational arrangements for designing, implementing, monitoring, reviewing and continually improving risk management throughout the organization” [A–6].

risk management at the operational level. A process to control the risks associated with the implementation and execution of a decommissioning project where the project is being conducted under an approved final decommissioning plan (or equivalent document).

risk management plan. “A scheme within the risk management framework specifying the approach, the management components and resources to be applied to the management of risk” [A–6].

risk management at the strategic level, strategic risk management, assumptions management. A process to support the development of decommissioning plans by ensuring that key assumptions and strategic decisions are based on the best available information concerning those assumptions and decisions, and that mechanisms are in place to identify, understand, assess, treat and monitor the uncertainties inherent in the key assumptions and strategic decisions.

risk matrix, probability–impact diagram. “The risk matrix is a method for screening events that might result in an accident, with a view to prioritizing safety efforts in those areas where the risk is greatest. The method is based on evaluating these events, taking into consideration the safety measures in place to tackle them and the potential consequences of the events” [A–8].

risk treatment. “Actions taken to change risk probability or impact or both.”

“Process to modify risk” [A–6].

safety. “For the purposes of this [Safety Fundamentals] publication, ‘safety’ means the protection of people and the environment against radiation risks, and the safety of facilities and activities that give rise to radiation risks.

‘Safety’ as used here and in the IAEA safety standards includes the safety of nuclear installations, radiation safety, the safety of radioactive waste management and safety in the transport of radioactive material; it does not include non-radiation-related aspects of safety” [A–9].

Another definition is as follows:

“Conventional health and safety (CHS) on ONR’s [Office for Nuclear Regulation] sites refers to risks arising from operations not associated with nuclear material, ionising radiation (the Ionising Radiations Regulations 1999), or nuclear licensed activities (the Nuclear Installations Act 1965 as amended). Workplace risks include: work at height; asbestos; construction operations; work in confined spaces; electricity; machinery safety; workplace transport; lifting equipment; hazardous substances; exposure to noise and vibration; legionella” [A–4].

safety assessment. “*Safety analysis* is often used interchangeably with *safety assessment*. However, when the distinction is important, *safety analysis* should be used as a documented process for the study of *safety*, and *safety assessment* should be used as a documented process for the evaluation of *safety* — for example, evaluation of the magnitude of hazards, evaluation of the performance of *safety measures* and judgement of their adequacy, or quantification of the overall radiological impact or *safety* of a *facility* or *activity*” [A–1].

uncertainty. “A state of having limited knowledge about the subject of interest” [A–6].

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