# INTERNATIONAL ATOMIC ENERGY AGENCY

# Management of Project Risks in Decommissioning

(Working Material)


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# FOREWORD

There is an increasing number of decommissioning activities being undertaken on a worldwide basis at facilities where radioactive material has been or is currently being used, managed (e.g., stored, processed, disposed, etc.,), or produced. 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 undertake the decommissioning of facilities that have already been shut down as planned, or which were shutdown prior to reaching the end of their expected lifetime due to economic, political, or social reasons, or as a result of accidents or unplanned events.

In 2007, the IAEA established the International Decommissioning Network (IDN) to help Member States develop capabilities and plans for undertaking decommissioning activities. The importance of management of project risks during decommissioning was discussed and recognized at the 2011 Annual Meeting of the IDN. 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 risk management during the decommissioning process might warrant further attention. In order to address this issue, it was agreed to establish the Decommissioning Risk Management Project (DRiMa project) to document and share methods and good practices on the application of management of project risks during the planning and implementation of decommissioning activities.

The DRiMa project took into account existing international standards on risk management and sought to:

- Identify good practices from the collective experience of the Member States on the application of risk management methodology to decommissioning;

- Illustrate the role of risk management in key decision making processes during the lifecycle of nuclear facilities as it relates to both the planning and implementation of decommissioning;

- Illustrate the risk treatment strategies that can be employed to minimize threats and maximize opportunities during the decommissioning process;

- Improve the capabilities of Member States in this field, and enhance the exchange of information between Member States with respect to risk management as applied to decommissioning.

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. Project meetings took place in Vienna (Austria), Cologne (Germany), Zadar (Croatia) and Brussels (Belgium).

This publication (i) summarizes the outcomes of the DRiMa project, (ii) provides practical guidance and examples on the application of generally accepted risk management methodologies to the planning and implementation of decommissioning programs, and (iii) demonstrates the role that risk management can play in supporting decommissioning project safety objectives.

The IAEA would like to express its gratitude to all the experts who contributed to the development and review of the report, and in particular, to the coordinating working group of the DRiMa project – J. Kaulard (Germany), Chairman, P. Francois (France), M. Pennington (UK), D. Skanata (Croatia), K. Schruder (Canada). The Scientific Secretaries for the DRiMa project 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.

The development of this report has been coordinated by the Waste and Environmental Safety Section of the Division of Radiation, Transport and Waste Safety of the IAEA. The IAEA officer responsible for this publication was V. Ljubenov of the Division of Radiation, Transport and Waste Safety.

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# 1. INTRODUCTION

## 1.1. BACKGROUND

### 1.1.1. General

There is an increasing number of decommissioning activities being undertaken on a worldwide basis at facilities where radioactive material has been or is currently being used, managed (e.g., stored, processed, disposed, etc.,), or produced. In most cases, this increase is the result of facilities reaching the end of their lifetimes. In other cases, it is the consequence of decisions to undertake the decommissioning of facilities that have already been shut down as planned, or which were shutdown prior to reaching the end of their expected lifetimes due to economic, political, or social reasons, or as a result of accidents or unplanned events.

### 1.1.2. Decommissioning Risk Management (DRiMa) Project

In 2007, the IAEA established the International Decommissioning Network (IDN) to help Member States develop capabilities and plans for undertaking decommissioning activities. The importance of management of project risks during decommissioning was discussed and recognized at the 2011 Annual Meeting of the IDN. 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, it was agreed to establish the Decommissioning Risk Management Project (DRiMa project) to document and share methods and good practices on 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 which lack experience in performing engineering 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 a sharing of the experiences was needed.

### 1.1.3. Decommissioning risks and safety

The terms “risk” and “safety” as used in the DRiMa project was not intended to be synonymous with the concepts of risk and safety as defined in the IAEA Safety Glossary [1]. Risk, in the context of this DRiMa document, is meant to reflect the concept embodied in the Project Management Institute (PMI) [2] definition of risk,





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i.e., “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.”

Similarly, in this document, the term “safety” is used in a broader sense than that defined by the Agency [1]. As noted in IAEA GSR Part 6 [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 [4]. The Agency safety guide on the decommissioning of nuclear power plants and research reactors also discusses the importance of addressing non-radiological hazards [5].

Finally, risk management is not mandatory by Agency safety standards, but as evidenced by the discussions in this report and the results of the risk management workshops presented in the annex to this report, its incorporation into an integrated management system represents a sound practice in supporting a safety culture. It bears noting that the Project Management Institute [2] views risk management as one of the 10 areas in which a project manager must be competent.

### 1.1.4. **Unique characteristics of decommissioning projects**

Unique aspects of decommissioning projects relative to other types of projects are discussed below together with the role of risk management in addressing these unique characteristics.

#### 1.1.4.1. *Decommissioning planning*

The process of decommissioning planning has unique characteristics, i.e. (i) it has three stages during the life of a facility (initial, updated, final) [6], (ii) the planning process can span long periods of time, i.e., decades in those cases where the initial plan is prepared during facility design, and the final plan is prepared following facility shutdown, and (iii) 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 2.3 which includes a diagram depicting the planning process.

The nature of the decommissioning planning process demands a somewhat unique approach to risk management in that its application 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 initial decommissioning plan, and which become strategic decisions in the final decommissioning plan. Invalid, incorrect, or outdated key assumptions, unless identified, can lead to incorrect strategic decisions which in turn can adversely affect decommissioning implementation. It is for this reason that the DRiMa project considered risk management at both the strategic level (RMSL) and the operational level (RMOL).

1.1.4.2. *Decommissioning risk management and safety*

**Risk management, particularly in the context of decommissioning, can play an important role in the management and control of safety related risks (radiological and conventional) and as such supports project safety objectives.**

Decommissioning has distinctive characteristics relative to those found with new build nuclear projects, or with the types of activities found during the operation of a nuclear facility. Insights and conclusions about the differences between operational and decommissioning in terms of risks, safety, training, and human resource management can be found in a number of Agency reports [7-9].

While there will be differences from project to project, based on discussions in the above documents it is reasonable to conclude that risks associated with safety are likely to be more prevalent in decommissioning work than in new build projects or in operational activities. In examining the Agency references, many of these risks arise from the following circumstances surrounding the decommissioning process:

- Non-routine and first-of-a-kind activities;
- On-going 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 e.g., systems 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.

The fact that issues and risks surrounding safety pervade a decommissioning project is also evidenced by examining the risks identified in the risk management workshops, the results of which are presented in the Annexes.

The titles of some of the Agency safety standards and documents containing discussions, guidance, and recommendations that relate to risks, risk management, safety, the unique aspects of decommissioning, etc. are listed below. For each of the listed documents, those sections that are considered to be particularly relevant to the topics discussed in this (DRiMa) report are indicated in parentheses.

- **SF-1** *Fundamental Safety Principles* [10] (2.1.);

- **GSR Part 2** *Leadership and Management for Safety* [11] (4.15., 5.1., 1.3.);

- **GSR Part 4** *Safety Assessment for Facilities and Activities,* [12] (1.9., 3.3., 4.19., 4.51., 4.57.);



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- **GSR Part 6** *Decommissioning of Facilities, Part 6* [3] (1.21., 8.3.);
- **GS-G-3.1** *Application of the Management System for Facilities and Activities* [13] (2.42., 5.9., 5.18., 5.66., 6.49.);
- **GS-G-3.5** *The Management System for Nuclear Installations* [14] (5.43. to 5.78.);
- **WS-G-2.1** *Decommissioning of Nuclear Power Plants and Research Reactors,* [5] (1.8., 5.);
- **WS-G-2.5** *Safety Assessment for the Decommissioning of Facilities Using Radioactive Material* [15] (3.17., 3.35., 4.13.);
- **Safety Reports Series No. 36** *Safety Considerations in the Transition from Operation to Decommissioning of Nuclear Facilities* [8] (Section 4.);
- **Safety Reports Series No. 399** *Organization and Management for Decommissioning of Large Nuclear Facilities* [16] (4.3.);
- **NG-T-2.3** *Decommissioning of Nuclear Facilities: Training and Human Resource Considerations* [9] (Table 4, Appendix II, Appendix VII);
- **NP-T-3.21** *Procurement Engineering and Supply Chain Guidelines in Support of Operation and Maintenance of Nuclear Facilities* [17] (2.8., 3.6., 2.1.);
- **TECDOC-994** *Guidelines for Integrated Risk Assessment and Management in Large Industrial Areas* [18] (8.);
- **TECDOC-1209** *Risk Management: A Tool for Improving Nuclear Power Plant Performance* [19] (Figure 3, majority of document, see also page 80);
- **TECDOC-1685** *Application of the Risk Matrix Methodology to Radiotherapy* [20] (2.1.);

Risk is inherent in all organizations and in all activities, and risk management can play an integral role in managing decommissioning programs. Accordingly, it is considered good practice that a process for the management of risks be applied during the development of the decommissioning plans and the subsequent implementation of those plans.

In the context of this document, the application of risk management to the planning process as well as to the strategic decisions derived from those key assumptions is referred to as risk management at the strategic level (RMSL). By contrast, the application of risk management to the implementation and execution of the decommissioning project is referred to as risk management at the operational level (RMOL).

## 1.2. SCOPE

This publication focusses 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 to these phases.

Furthermore, this publication illustrates (i) the dynamic nature of decommissioning risks that result in large measure from uncertainties inherent in the planning and execution of decommissioning projects, and (ii) the need for the 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. All types of risk that can affect a project are considered whereby risk is viewed as a multi-dimensional entity which includes aspects such as safety, technology, security, legal frameworks, and commercial considerations, as well as the management of interested parties, for example, stakeholders.

For this report, and in the context of decommissioning projects, two major categories of risk have been examined, i.e., strategic and operational. Under this approach, strategic risks are considered as 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 discusses how a decommissioning project can successfully apply a standard risk management approach at the operational level (RMOL), and also introduces the benefits of following a related approach in the management of key assumptions as well as the resulting strategic decisions based on those assumptions by applying risk management at the strategic level (RMSL). Taken together, these applications can both help ensure realistic and defensible decommissioning plans as well as contribute to meeting decommissioning objectives in a timely and cost effective manner.

## 1.3. OBJECTIVES

The overall objective of this publication is to identify good practices from the collective experience of the Member States on 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.

The specific objectives are to:

- Explain the general principles of the risk management methodology;
- Illustrate the application of risk management as it specifically relates to the key assumptions and strategic decisions which underlie the decommissioning planning process;
- Enhance the likelihood of successfully meeting decommissioning project objectives by minimizing threats and maximizing opportunities;
- Discuss and explain the relationships between the two different categories of risk management addressed in this report, i.e., strategic and operational.

## 1.4. STRUCTURE OF THE REPORT

This publication is structured in the following manner:

- Section 1 provides introductory information on the background, scope and objectives of the DRiMa project and on the resulting report;



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- Section 2 provides an overview of risk management as applied to decommissioning. The section explains the general concept of the risk management process and in particular those aspects of risk management as they relate to decommissioning on both the strategic and operational levels. Also included in Section 2 are 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;
- Section 3 focusses on aspects of risk management as applied at a strategic level (RMSL), 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 3 are a summary of findings and good practices;
- Section 4 addresses risk management at an operational level (RMOL), and illustrates the specific risk management steps to be followed during the implementation phase of decommissioning projects. As was the case in Section 3, a summary of findings and good practices are also included in this section;
- Section 5 provides insight into the relationship between risk management at the strategic level (RMSL) and risk management at the operational level (RMOL);
- Chapter 6 summarizes important conclusions contained in the document;
- Chapter 7 provides the references used in the report.

In a set of annexes, further information and examples are provided on topics that include risk families and the use of both risk and assumption registers. In addition, examples showing how risk management can be applied during the planning and implementation phases of decommissioning are provided.

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# 2. OVERVIEW OF RISK MANAGEMENT FOR DECOMMISSIONING

One of the basic tenets of risk management is that 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 [21].

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. 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).

As such, 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 judgment, 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 impacts and probabilities. Risks have to be managed in an integrated fashion across all levels of the organization and across all phases of a facility lifetime or a project.

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.

An organization needs to consider a set of principles when setting up the framework for its management of risk. For further details on the risk management principles and the risk management framework, refer to [21, 22].

## 2.1. TERMS AND DEFINITIONS

To help ensure consistency and to avoid ambiguity, terms employed in this report are defined in Table 1. 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, definitions from different organization have been provided for some terms to illustrate differences in approach and purpose. For example, in IAEA usage, the term "safety" only applies to radiological risks, but in other jurisdictions the term can apply to both radiological and non-radiological risks. Terms listed in the same table cell in the left column are treated as being synonymous.

TABLE 1. TERMS AND DEFINITIONS

| Term | Definition |
|---|---|
| • risk management at the strategic level (RMSL)<br>• strategic risk management<br>• assumptions management | A process to support the development of decommissioning plans by ensuring that key assumptions and strategic decisions are based on 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. (this document) |
| risk management at the operational level (RMOL) | A process to control the risks associated with the implementation and execution of a decommissioning project where that project is being conducted under an approved FDP (or equivalent document). (this document) |
| 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, or quality." [2]<br><br>"A multi-attribute quantity expressing hazard, danger or chance of harmful or injurious consequences associated with actual 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." [1].<br><br>"Depending on the context, the term *risk* may be used to represent a quantitative measure […] or as a qualitative concept." […] [1].<br><br>"Effect of uncertainty on objectives" [23] |
| risk management | "Coordinated activities to direct and control an organization with regard to risk". [23]<br><br>"Risk management includes six main processes in PMBOK theory. These are risk management planning, risk identification, qualitative risk analysis, quantitative risk analysis, risk response planning, and risk monitoring and control." [2]<br><br>"Risk Management is the identification, assessment, and prioritization of risks followed by coordinated and economical application of resources to minimize, monitor, and control the probability and/or impact of unfortunate events or to maximize the realization of opportunities." [2] |
| risk management framework | "A set of components that provide the foundations and organizational arrangements for designing, |

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| | implementing, monitoring , reviewing and continually improving risk management throughout the organization.” [23] |
| 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” [23] |
| safety | “For the purposes of this [IAEA Safety Glossary] 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*.” [1]<br><br>“Project safety management includes all activities of the project sponsor/owner and the performing organization which determine safety policies, objectives and responsibilities so the project is planned and executed in a manner that prevents accidents which cause or have the potential to cause personal injury, fatalities or property damages. For convenience, the term safety management is used to include both, safety management and health management.” [2]<br><br>“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.” [4] |
| 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.” [2] |
| risk management process | “Risk management includes six main processes in PMBOK theory. These are risk management planning, risk identification, qualitative risk analysis, quantitative risk analysis, risk response planning, and risk monitoring and control.” [2]. |
| risk assessment | “Assessment of the radiological risks associated with normal operation and possible accidents involving a source or practice. This will normally include consequence assessment, together with |





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| | some assessment of the probability of those consequences arising.” [1]<br><br>“Overall process of risk identification , risk analysis and risk evaluation.” [23] |
| safety assessment | *“Safety analysis* is often used interchangeably with *safety assessment*. However, when the distinction is important, *safety analysis* should be used for the study of *safety*, and *safety assessment* 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.”* [1] |
| risk identification | “Process of finding, recognizing and describing risks.” [23] |
| 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.” [1]<br><br>“Occurrence or change of a particular set of circumstances” [23]<br><br>A risk with a probability of 1 (this document). |
| • likelihood<br><br>• probability | “Chance of something happening.<br>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.” [21] |
| • consequence<br><br>• impact | “Outcome of an event affecting objectives” [23] |
| risk analysis | “A process to comprehend the nature of risk and to determine the level of risk” [23].<br><br>A qualitative 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 and impact for each risk identified. (this document) |
| risk criteria | “Terms of reference against which the significance of a risk is evaluated.” [23] |

| | |
|---|---|
| • level of risk<br>• risk score | "Magnitude of a risk or combination of risks, expressed in terms of the combination of consequences and their likelihood." [23] |
| • probability impact diagram<br>• risk matrix | "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." [20] |
| 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." [23] |
| risk treatment | "Process to modify risk." [23] |
| residual risk | "Risk remaining after risk treatment." [23]<br>"[…] those risks that are expected to remain after the planned response of risk has been taken, as well as those that have been deliberately accepted." [2] |
| monitoring | "Continual checking, supervising, critically observing or determining the status in order to identify change from the performance level required or expected." [23] |
| review | "Activity undertaken to determine the suitability, adequacy and effectiveness of the subject matter to achieve established objectives." [23] |
| uncertainty | "A state of having limited knowledge about the subject of interest." [23] |

## 2.2 RISK MANAGEMENT PROCESS

### 2.2.1 Risk management at the operational level (RMOL)

The primary objective of 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.

In general, the application of risk management as part of the project management process has focussed on operational considerations. As such, the risk management process involves (i) determining the context underlying a risk, (ii) qualitatively or quantitatively assessing a risk taking both the severity of impacts and probability of occurrence into consideration, (iii) developing a treatment plan for controlling the risk, e.g., through actions to reduce probability and/or impact, and (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. Implementation of this risk management process will increase the likelihood of meeting project and business objectives (see Figure 1).

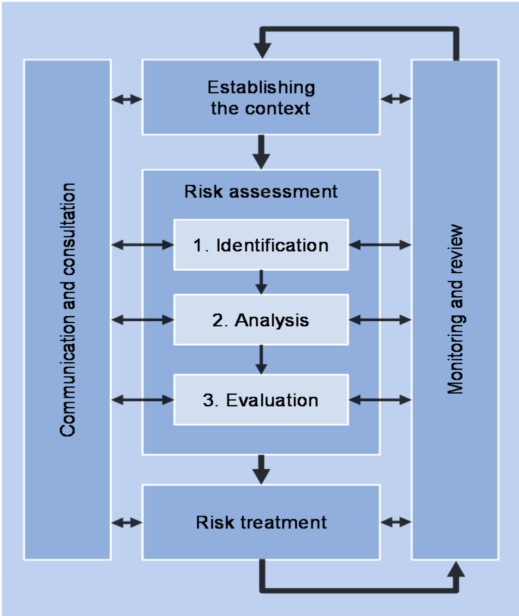


*FIG. 1. Risk management process [21].*

Further details about the components of the risk management process as presented in Figure 1 are provided below.

#### *2.2.1.1. Establishing the context*

Establishing the context serves to define those external and internal factors surrounding the project which 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. The key assumptions and any strategic decisions derived in the planning process, and as discussed in Section 3, will play a formative role in the process of establishing context for RMOL.

For the purposes of this report, external factors are considered as those that primarily relate to the key drivers and trends that have an influence on the objectives of the organization. Internal factors are treated as 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 As noted above, an examination of key assumptions and strategic decisions can be extremely useful in identifying both internal and external factors.

#### *2.2.1.2. Determining Risk Criteria*


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A key component in establishing context involves the development of risk criteria which is 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.
>
> 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 timeframe(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." [21]

Particular emphasis is being placed on the topic of risk criteria in this report because of its importance in establishing and communicating the rationale and reasoning behind the risk assessment process, i.e., identification, analysis, and evaluation. 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. As an example, it may be decided that any risks involving safety will automatically be given a high rating on the numerical impact scale.

#### *2.2.1.3. Risk assessment*

Risk assessment (see Figure 1) includes the identification, analysis, and evaluation of risk, as discussed below.

*Identification of risks*

The first step of the risk assessment process is to identify potential risks to the decommissioning project, and as noted earlier, risks can represent either threats or opportunities. The risk management process is designed to be iterative, and as such there may be merit in using the early iterations of the process to focus on identifying those risks of greatest concern to project delivery. Risks that are less relevant, or risks generating less concern may be addressed in later iterations. However, if this



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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 focussed approach e.g., through the use of such techniques as brainstorming. Risks identified through the safety assessment process [15] can also provide important input to the risk identification process.

*Analysis of the risks*

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.

*Evaluation of risks*

Risk evaluation comprises several components. The first involves scoring each of the risks based on an assessment of risk probability and risk impact. It is important to note that in the case of the latter, 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 the product of a numerical value related to risk probability, and a numerical value related to the severity of the impact of the risk.

Once the risk scores have been determined, the results can be presented diagrammatically to aid in better understanding the outcomes of the risk evaluation process. An example of one such diagram that considers the combined effects of both risk probability and risk impact is provided in Figure 2. Each project may have its own probability impact diagram, which may also be referred to as a risk matrix.

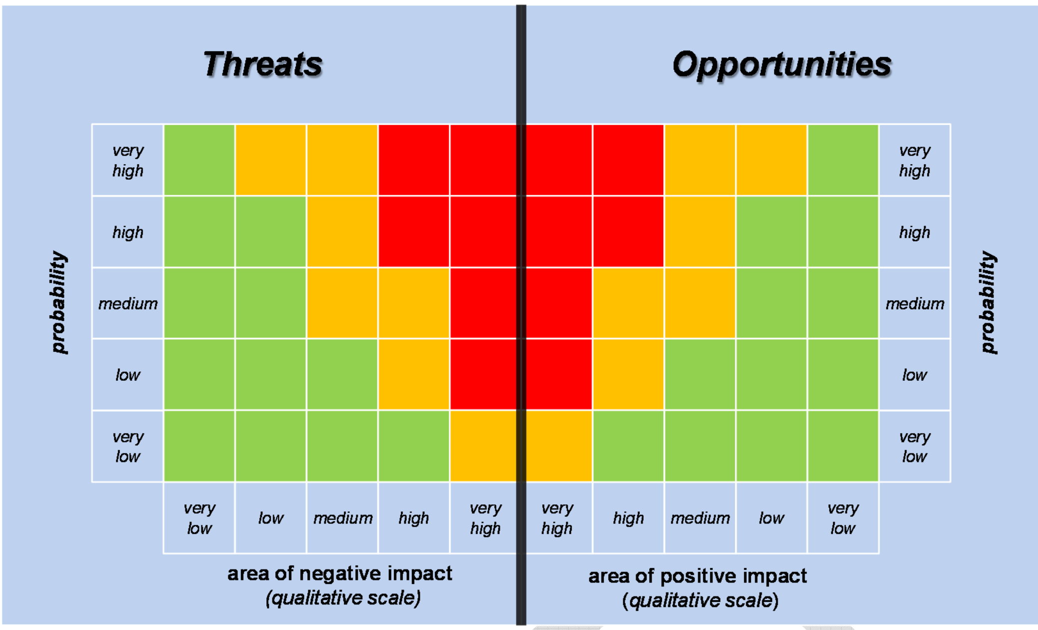


*FIG. 2 . Example of a double probability impact diagram (risk matrix) for opportunities and threats (based on [24]).*

The importance of scoring the risks and placing the results on a risk matrix is that it helps visualize the threats and opportunities in direct relationship to each other. This in turn helps in the prioritization process and allows resources to be focused on those risks which most require treatment.

#### *2.2.1.4. 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 taking no active actions at all. The fundamental principle that needs to be established and understood with respect to risk treatment is the concept 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 2. As might be expected, the risk criteria also play an important role in deciding on 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.

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TABLE 2. RISK TREATMENT STRATEGIES FOR THREATS AND OPPORTUNITIES

| Risk Type | Threat | Opportunity |
|---|---|---|
| | Avoid | Exploit |
| | Mitigate | Share |
| | Transfer | Enhance |
| | Accept | Ignore |

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 actions that will decrease the probability and/or the impact of the threat on the project;
- Transfer: transfer 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 impacts or probability warrant a change in treatment strategy.

In the case of opportunities, potential treatment strategies include the following [24]:

- Exploit: take actions to ensure that the opportunity can occur, and will have a beneficial impact on the project;
- Enhance: identify actions that will increase the probability and/or impact of the opportunity on the project;
- Transfer: transfer to a third party that is better positioned to increase the probability of the opportunity 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.

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.

It is often 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 if and 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.

#### *2.2.1.5. 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.

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 due, for example, to the fact that they have expired, are no longer relevant, etc. 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.

#### *2.2.1.6. 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 that 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.

### 2.2.2. Risk management at the strategic level (RMSL)

The application of risk management to strategic issues and strategic planning, i.e., strategic risk management, is increasingly being employed by a variety of organizations. A recognition of the fact that the key assumptions utilized in decommissioning planning can be reasonably equated to the strategic assumptions important in strategic risk management formed an important input to the deliberations and objectives of the DRiMa project. A variety of the components associated with RMOL and discussed in Section 2.2.1 can also be applied, as appropriate, to the RMSL process.

## 2.3. RISK MANAGEMENT SPECIFIC TO DECOMMISSIONING

### 2.3.1. Overview

Generally, the decommissioning process begins with the drafting of the initial decommissioning plan [3], proceeds through the preparation, approval, and implementation of the final decommissioning plan [3], and ends when dismantling, decontamination, and clean-up actions are completed and the license can be terminated.



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Organizations charged with responsibility for delivering projects are continually faced with challenges arising from the need to prioritize projects and to make strategic decisions concerning the best courses of action. This also applies to decommissioning organizations, but the latter is faced with additional and unique circumstances that can often make the challenges even more complicated. One such complication can result from the long time periods often associated with the decommissioning process, particularly in the decommissioning planning phase where decades may separate planning from implementation. A consequence of this timeframe 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 Figure 3), and therefore processes needs to be in place that will help ensure that the 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.

In view of the above, 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.

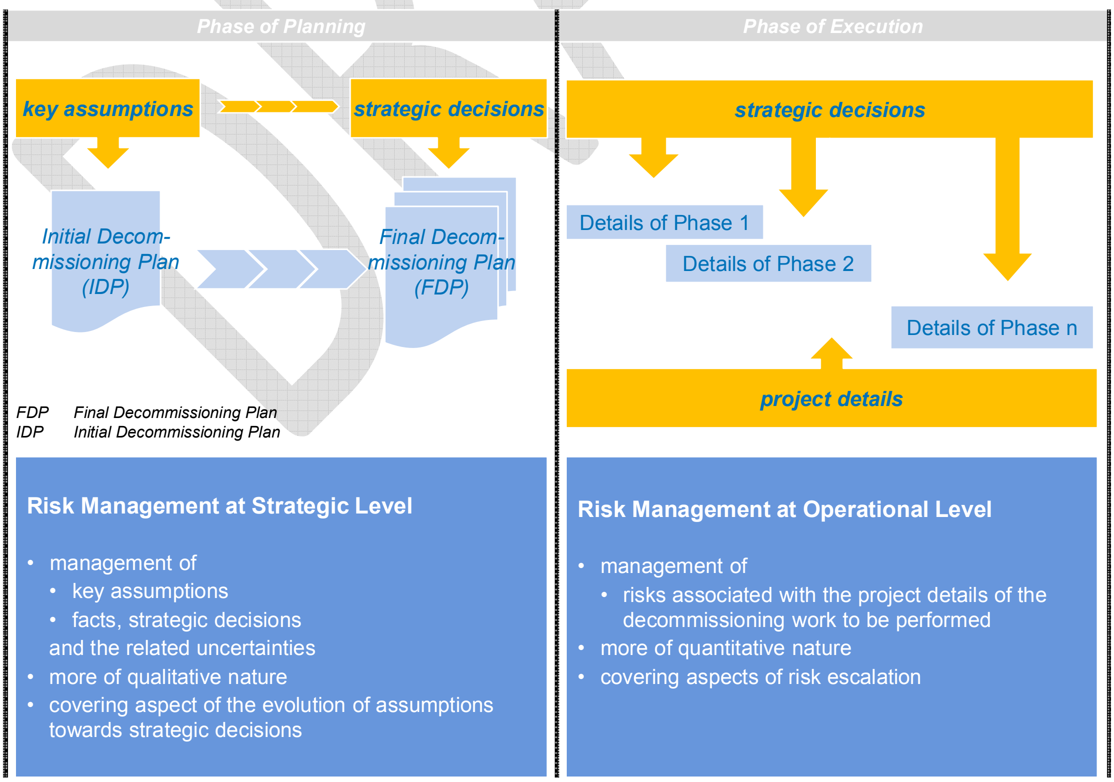


*FIG. 3. Risk management at the strategic and operational levels.*





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At the time the IDP is first drafted, little or no details may be available about important future circumstances related to such topics as dismantling and decontamination technologies, waste acceptance criteria, the availability of disposal and treatment facilities, the regulatory environment, the availability of funding, etc. 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.

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 decommissioning work. It is considered useful to reiterate that RMSL is important for use in reducing the uncertainties surrounding key assumptions so that the resulting FDP will not be jeopardized by strategic decisions and decommissioning strategies that have been based on uncertain information.

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 ensuring that the key assumptions, and correspondingly the strategic assumptions, are based on sound decision making and the best information available.

The benefits of RMSL are largely two-fold. 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. As such, RMSL requires that key assumptions be regularly confirmed during the lifecycle 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.

In many cases, the primary risk associated with key assumptions lies in the fact that these assumptions can undergo major changes, and that these changes can have far reaching impacts 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 warning about possible changes, and thereby enable a plan to be prepared well in advance (e.g., an alternative IDP) for use in those cases where those changes actually materialize. In this manner, it is possible to reduce the potential impacts of changes in key assumptions on the decommissioning process. An important benefit of applying risk management to key assumptions is that it also helps manage the risks associated with making strategic decisions by helping to ensure the dependability of any information used in the decision making process.

By contrast, RMOL is the process of identifying, assessing, monitoring, and treating 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.

One difference that will become apparent in this report is that 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 (impacts) 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 impacts of changes in the key assumptions. However, in some circumstances, a more quantitative approach which includes considering the consequences of changes in the key assumptions can be undertaken (see Section 3.4)

### 2.3.2. 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 "prompters" 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 facilities;
- End state of the decommissioning project;
- Waste and materials management;
- Organization & human resources;
- Finance;
- Interfaces with contractors & suppliers;
- Strategy & 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.

Further details on risk families can be found in Annex I.

## 2.4. RELATIONSHIP BETWEEN RISK MANAGEMENT, SAFETY ASSESSMENT, AND DECOMMISSIONING PLANS

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 focusses on demonstrating that the decommissioning actions can be conducted safely. However, the risks identified during the safety assessment process [15] can serve as important input to the risk identification process. Similarly, any conclusions reached during the process of safety assessment concerning impacts 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 impacts 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 impacts on the project risks.

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# 3. RISK MANAGEMENT AT THE STRATEGIC LEVEL (RMSL)

## 3.1. SCOPE AND OBJECTIVES

In this document, the scope of RMSL 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.

The fundamental objective of RMSL is to support the development of decommissioning plans by ensuring that key assumptions and strategic decisions are based on best available information, and that mechanisms are in place to identify, understand, assess, treat, and monitor the uncertainties inherent in the key assumptions and strategic decisions.

From a very pragmatic and fundamental perspective, it may be helpful to consider the primary objective of RMSL as being one of undertaking those activities that will ensure 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 focussed on minimizing the carryover of these uncertainties into the FDP.

## 3.2. STRATEGIC RISK MANAGEMENT

Risk management at the strategic level is a technique that can be used both in managing the risks associated with the uncertainties in planning assumptions as well as providing important input into decision making processes by helping to ensure that decisions are based on the most reliable information. These benefits are by no means limited to decommissioning, and typical uses of RMSL can include:

- **Management of uncertainty:** an organization requires a systematic process to help identify, manage, and control the uncertainties in strategic planning assumptions;
- **Improving decision making:** a process to improve the quality of information is required for the purposes of better decision making;
- **Prioritization:** 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:** 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;

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- **Escalation:** a project or organizational unit needs a tool to help in recognizing when there has been a loss in the ability to control or manage the threats and/or opportunities within the boundaries or scope of a project.

Risk management on the operational level (RMOL) relates to all aspects associated with the actual implementation and execution of the FDP. The distinction between RMSL and RMOL is important as it may influence the manner in which the risk management process is carried out, for example, in the nature of the personnel involved in the risk identification process. Figure 3 illustrates the relationship between RMSL and RMOL.

For the purpose of this publication, risk management on the strategic level (RMSL) is defined as those risk management initiatives which relate primarily to the decommissioning planning phase, i.e., the development of the IDP and the process used in reaching key strategic decisions for the FDP. From this perspective, RMSL primarily applies to those risks and uncertainties associated with the key assumptions and their subsequent role in establishing strategic decisions upon which FDP is based.

Initial decommissioning plans (IDPs) are generally developed based on a limited number of key assumptions that may embody a high degree uncertainty, and as such these assumptions need to be regularly and systematically examined, confirmed, and adjusted during the lifecycle of the nuclear facility.

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 the 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 4.3 on risk modelling).

RMSL can be implemented at any time during the preparation of the IDP or FDP. The RMSL process is primarily qualitative in nature, but can include a quantitative assessment using an approach similar to that used with RMOL (see Section 3.4).

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 require immediate action as soon as possible. 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.

Faced with a situation where an FDP needs to be prepared, but without the benefit of an IDP having been first drafted, 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, a process which incorporates components of both RMSL and RMOL:

- 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 as shown in Annex II.
- Identify specific risks (threats and opportunities) that might arise if the key assumptions were to prove inaccurate (see Anex II, Table II-4).
- Analyze the risks generated in the above step (i.e., consider probability and impact) in a manner similar to that employed with RMOL, and establish a risk score for each. These scores may be more qualitative in nature than those generated in the RMOL process.
- 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. RMSL PROCESS (ASSUMPTIONS MANAGEMENT)

As discussed above, RMSL is the process of identifying, assessing, treating, and monitoring key assumptions and strategic decisions and their associated uncertainties. RMSL can also be used as part of the process for making the strategic decisions that underlie the FDP. The main steps in this process are:

- Establish a set of key assumptions based on the best available information and aided by using a list of risk families as prompters during the identification process;
- Assess the level of uncertainty for each key assumption using expert judgment;
- 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 3.4);
- Identify treatment actions to reduce the uncertainties found with the key assumptions;
- Develop an assumptions register;
- Monitor the key assumptions.

Each of these steps is further explained below.

### 3.3.1. Establishment of key assumptions

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 impacts, and public opinion.

The initial step in the RMSL process is the identification of the key assumptions that support the IDP. It is of critical importance that identification of assumptions be performed in a systematic fashion to ensure that the process is as complete as possible. One such systematic approach involves the use of risk families as prompters in the manner described in Section 2.

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.



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Additional examples of key assumptions can be found in Annex II, Table II-4.

### 3.3.2. Assignment of the level of uncertainty

The next step in the process of strategic risk management (assumptions management) is to assign a level of uncertainty to each key assumption.

It is usual that a qualitative approach be 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.

### 3.3.3. Identification of actions to reduce uncertainty levels

At the start of the process for developing action plans, attention is generally focussed 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 are of particular importance to the decommissioning strategy, and also have high levels of uncertainty, 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.

### 3.3.4. Assumptions register

A specific 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 Table 3). An assumptions register helps in understanding how key assumptions evolve, and ensures actions are managed and completed in a defined timeframe. Examples of the use of an assumptions register for an initial and updated decommissioning plan are provided in Annex II.

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TABLE 3. ASSUMPTIONS REGISTER TEMPLATE

| Assumptions register | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Identification of assumptions | | | | Uncertainty assessment | | Actions | | Assumptions Monitoring | |
| N° | Assumptions description | 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 | | | | | | | | | | |

### 3.3.5. 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 re-licensing. 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 due 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 responsible for putting in place arrangements for the review of the assumptions, a process which 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 a level of uncertainty;
    - o The uncertainty is acceptable and no further actions are proposed;
    - o 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.

## 3.4. APPLICATION OF THE RISK ASSESSMENT PROCESS TO 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 risk assessment (Section 2.2.1) as a means of better understanding the consequences of an assumption undergoing a substantial change or becoming invalid. In the context of this report, risk assessment is more generally applied to the RMOL process. However, by applying the risk assessment methodology to certain key assumptions, particularly those characterized by being of high importance and also having 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 such parameters 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 risk assessment can be performed following the same general approach as that described in Section 4 with the assumptions register being updated as required to reflect any changes resulting from the assessment (see also Section 3.4). 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.

## 3.5. FINDINGS AND GOOD PRACTICES

The following findings and good practices concerning RMSL were derived and identified during the development of this publication:

- 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 whereby the structure and content 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;


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- 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.

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# 4. RISK MANAGEMENT AT THE OPERATIONAL LEVEL (RMOL)

## 4.1. SCOPE AND OBJECTIVES

The purpose and scope of this section is to describe the manner in which RMOL can be applied to the implementation phase of a decommissioning project. However, as noted above, some aspects of RMOL can also be effectively applied as part of the RMSL process.

The fundamental objective of RMOL is to support the implementation of the FDP, and to ensure that mechanisms are in place to identify, understand, assess, treat, and monitor the risks (both threats and opportunities) inherent in that implementation process.

## 4.2. OPERATIONAL RISK MANAGEMENT

The overall process of risk management at the operational level follows the risk management process illustrated in Figure 1. The process is iterative in nature with further explanations about the steps in the process being provided below.

### 4.2.1. Establishing the context for operational risk management

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 these topics (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, but is not limited to:

- 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 3.3.4);
    - Exclusions, i.e., scope not included in the project;
    - Constraints, i.e., limiting conditions the project is required to respect;
    - Inter-dependencies with other projects and organizations;
    - Uncertainties;
- Project schedule, including milestones and hold points;
- The final decommissioning plan;
- Decommissioning safety assessment and analysis reports;
- Communications status, e.g., with the public, stakeholders, the regulator, etc.;
- The 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.

### 4.2.2. Risk assessment process

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 (WBS), 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, procurement, etc.;
- 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. A successful workshop depends on the attendance and active participation of all the participants.

Depending on the size of the organization, other personnel that 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.

The steps in the risk assessment process are described below, but for introductory purposes can be summarized as follows:

- **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 2.2.1.2) 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 in determining the impact assessment value.

#### *4.2.2.1. Risk identification.*

The purpose of risk identification is to ensure that all of the relevant risks and their potential impacts 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 Section 2 and Annex I 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 (WBS) 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 4.2.4.

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 more or less than expected. Therefore, the risk might be better worded as "the amount of waste found in the refueling 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.



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#### *4.2.2.2. Risk analysis.*

The risk analysis process takes the identified threats and opportunities and assesses both the probability (likelihood) and impact (consequence) 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 4. Possible criteria or guidelines which might be used in assigning probability levels have been provided in the table for illustrative purposes. The actual criteria employed by an organization are best developed taking risk criteria and project objectives into consideration.

TABLE 4. EXAMPLE OF A SCALE OF PROBABILITY FOR USE IN RISK ANALYSIS.

| Probability score | Probability | Scale[1)] | Illustrative (sample) Probability Criteria |
|---|---|---|---|
| 1 | 0-20% | VL | Very unlikely to occur. Risk is not known to have taken place with similar types of decommissioning projects. |
| 2 | 21-40% | L | Unlikely to occur. Risk is known to have occasionally taken place with similar types decommissioning projects. |
| 3 | 41-60% | M | Risk is known to have taken place with reasonable regularity on similar types of decommissioning projects. |
| 4 | 61-80% | H | Risk typically takes place with similar types of decommissioning projects. |
| 5 | 81-100% | VH | Risk is almost certain to take place. |

1) VL: Very Low; L: Low; M: Medium; H: High; VH: Very High

At an operational level, the **assessment of impact** typically uses a linear scale such as the one shown in Table 5. 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, it is general practice 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 impacts have been provided for illustrative purposes in Table 5 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 5. EXAMPLE OF A SCALE OF IMPACT FOR USE IN RISK ANALYSIS.

| Impact score | Scale[1)] | 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 |

[1)] VL: Very Low; L: Low; M: Medium; H: High; VH: Very High

#### *4.2.2.3. Risk evaluation*

Risk evaluation generally comprises three major components (i) the development of risk criteria (see Section 2.2.1.2) 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).

*Risk level (risk scores)*

The determination of risk level involves scoring each of the risks based on the combined effects of probability (likelihood) and impact (consequence). The risk score is the product of the probability and impact scores. An example of a probability impact diagram (risk matrix) is provided in Table 6. The exact nature of a probability impact diagram may be dictated by the specific needs of an organization.

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TABLE 6. EXAMPLE OF A PROBABILITY IMPACT DIAGRAM (RISK MATRIX).

| Probability of Occurance | Probability Scale / Increasing Probability | | Risk Score = Probability Scale x Impact Scale (P X I) | | | | |
|---|---|---|---|---|---|---|---|
| > 80% | | 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 |

*Prioritization*

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 allow the risks to be prioritized. The risk matrix also serves as an effective means for communicating information about project risks to a wide range of audiences.

The prioritization is typically based on score, but could also take into account factors such as timing, costs, safety, and reductions in the critical path schedule.

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.

#### 4.2.3. Risk treatment

After assessing and prioritizing the risks, the next step is to determine the appropriate risk treatment strategy. The risk treatment strategy for threats principally involves proactively reducing the risks (i.e., by reducing probabilities and/or impacts) to an acceptable level. In the case of opportunities, risk treatment usually involves proactively managing the risks to exploit the expected benefits.

As discussed in Section 2.2.1, there are four different strategies that are generally used in the treatment of threats:

- Avoidance;
- Mitigation;
- Transfer;
- Acceptance.

For opportunities, the main treatment strategies include the following:

- Exploit
- Share
- Enhance
- Ignore

More information on the treatment of opportunities is provided in Section 2.2.1.

Table 7 provides specific guidance in the selection of a risk treatment strategy based on the risk score (refer also to Table 6). The score upon which a treatment strategy is selected will depend in part on the organization's risk tolerance ("risk appetite"), and will also depend on the nature of an organization's risk criteria.

TABLE 7. 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 actions. 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 |

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

- Select treatment strategies based on risk scores and risk criteria;
- Develop the 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 impacts, the project (i.e., the project team) may need to reassess the actions or the risk treatment strategy;
- Record the actions, action owners, target completion dates, etc., 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 would be well advised to periodically re-analyze 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.



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Examples of possible risk treatment actions (for both threats and opportunities) are provided in Table 8.

TABLE 8. EXAMPLES OF RISK TREATMENT ACTIONS

| Risk (Threat) | Risk Family | Treatment | Action |
|---|---|---|---|
| Higher than expected levels of contamination are encountered during cutting operations | Radiological Safety | Avoidance | Change cutting technique to eliminate airborne contamination. |
| Poor road conditions during the rainy season delay the transport of project materials and waste. | Site Characteristics | Avoidance | Change the timing of transfers to the dry season. |
| Technology proposed for handling fuel is rejected for safety reasons due to the potential for additional fuel damage. | Technology | Avoidance | Technology changed to a technique that would not place additional stress on the fuel. |
| | | | |
| Volumes of waste are higher than expected. | Waste Estimation and Characterization | Mitigation | Perform additional characterization to obtain improved information about the wastes and thereby enhance waste segregation effectiveness. |
| The use of new technology increases the frequency of delays, accidents, etc | Technology | Mitigation | Perform mock-ups to train staff and improve safety and performance. |
| Availability of qualified workers is less than anticipated. | Human Resources | Mitigation | Initiate training courses prior to project start up to ensure that the required number of qualified workers is available |
| Unplanned delays occur due to the unavailability of electrical power from the site infrastructure. | Site Characteristics | Mitigation | Procure and install dedicated project generators. |
| | | | |
| Internal resources are found to have insufficient knowledge and training to accomplish the cutting of reactor internals in a timely fashion | Human Resources | Risk transfer | Transfer responsibility for dismantling reactor internals to an experienced contractor. |
| | | | |
| Unforeseen changes occur in regulatory requirements | Regulations and Laws | Acceptance | No actions taken. Risk can be managed with existing resources. |
| Unable to avoid small contamination events. | Radiological Safety | Acceptance | No actions taken. The effort to totally avoid any contamination events is more costly than the clean up of small events |

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| | | | |
|---|---|---|---|
| | | | |
| Unexpected workforce actions (e.g., strikes) occur. | Human Resources | Acceptance | No actions 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 labor intensive tasks | Technology | Exploit | Develop new tools using in-house resources to automate and mechanize labor 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. |

#### 4.2.4. 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 type:

- 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 impacts. This description can play an important role in communicating the nature of the risk to stakeholders, and will help 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, etc.;
- Risk analysis results prior to treatment actions, i.e.;
    - 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.
- Risk treatment strategy;

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- Type of strategy to be adopted, e.g., avoidance, risk transfer, etc.;
  - 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, etc.

An example of a risk register is shown in Table 9 and in Annex III.

TABLE 9. EXAMPLE OF A SIMPLIFIED RISK REGISTER

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

### 4.2.5. 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 have either expired or

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are no longer relevant to the project, but to simply change the status of the risk. This approach will help 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.

## 4.3. 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 total project 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 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.

## 4.4. FINDINGS AND GOOD PRACTICES

The following findings and good practices concerning RMOL were derived and identified during the development of this publication:

- Include, as part of project close-out reports or annual reports, any recommendations, findings, and lessons learned specific to the risk management process;
- 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 would be particularly useful in the workshops dedicated to identifying risks;
- Consider having project managers from across the organization share and discuss their risk registers and have project managers from different projects participate in the risk identification workshops;
- When working with contractors, the project might consider generating a joint risk register to ensure that both parties understand the risks and the treatment actions. This approach would also help ensure that the contractors have had a reasonable opportunity to provide meaningful input into the risk management process;
- Ask project leaders to report on risk and action status regularly, for example, as part of project meetings and reports;
- 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;
- Include project risks and their status in project reports, e.g., the annual project report;
- As part of a general strategy for reducing the impacts of risk, there may be merit in using a conservative approach in establishing the baseline for project


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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;

- Risk identification will generally be more effective if completed in a workshop environment rather than having it 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;
- Ensuring that reference material is available to workshop participants ahead of the actual workshop will help in the risk identification process;
- The use of a risk register has proven to be a valuable, flexible, and easy to use tool for identifying, monitoring, and controlling project risks;
- 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.

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# 5. RELATIONSHIP BETWEEN RMSL AND RMOL

The relationship between RMSL and RMOL is represented diagrammatically in Figure 3.

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 project delivery.

Key assumptions often carry a high degree of uncertainty and can be based on speculations 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 in large measure from the point that the FDP often constitutes formal approval to proceed with decommissioning as per the specific plans within the FDP, and subsequent changes to the FDP may be problematic in terms of approvals, etc. It is RMSL in combination with RMOL that provides 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 final decommissioning plan (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 initial decommissioning plan (IDP) has become a strategic decision that will dictate how 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 risks associated with the implementation of the strategic decisions (i.e., actions) as outlined in the FDP.

Regardless of the rigor 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 the use of internal resources to 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. As 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 and/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 and/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 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 which 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 affect more efficient management, for example, common resource issues such as worker shortages that exist across a number of projects.

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# 6. SUMMARY

This publication describes the application of risk management to both the planning and implementation phases of decommissioning projects, and identifies good practices on the use of generally accepted risk management principles to these decommissioning phases. The process of decommissioning generally starts with the drafting of the initial decommissioning plan (IDP), proceeds through the preparation, approval, and implementation of the final decommissioning plan (FDP), and ends when dismantling, decontamination and clean-up actions are completed and the facility is released from regulatory control or released with restrictions on its future use.

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

Risk management on the strategic level (RMSL) primarily focuses on the management of the uncertainties surrounding key assumptions and strategic decisions during the planning phase of decommissioning, i.e., from the initial decommissioning plan to the final decommissioning plan. Risk management on the operational level (RMOL) primarily focuses on risks to the decommissioning project associated with the implementation and execution of the final decommissioning plan.

This publication discusses the benefits of applying a standard risk management program 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. In the context of this document, the former application is referred to as risk management at the operational level (RMOL), and the latter as risk management at the strategic level (RMSL). Taken together, these applications can both help ensure realistic and defensible decommissioning plans (IDP and FDP) and support the achievement of decommissioning objectives in a timely and cost effective manner.

The application of risk management to decommissioning, and particularly to the decommissioning planning process, provides further examples of the versatility of a risk management program. Other examples of risk management being used in diverse fields include applications to regulatory frameworks [25], as well as radiotherapy [20].



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# ANNEX I. RISK FAMILIES

Further to discussions in Section 2.3.2, the Table I-1 provides examples of risk families. In order to utilize this table as part of the process of identifying risks, each risk family has been broken down into sub and sub-sub categories as a means of providing more detail about specific subject areas that might reside within each risk family. These subjects can then be used as “prompts” to stimulate thinking and idea generation during the risk identification process.

TABLE I-1. RISK FAMILIES

| Risk family | Prompts | | | |
|---|---|---|---|---|
| 1. Initial condition of facilities | 1.1 | Physical status | 1.1.1 | Operational history and records |
| | | | 1.1.2 | List and state of system structures and components (SSCs ) |
| | 1.2 | Radiological status and characterisation | 1.2.1 | Contamination of SSCs |
| | | | 1.2.2 | Activation of SSCs |
| | | | 1.2.3 | Soil & underground water contamination |
| | 1.3 | Waste and materials status | 1.3.1 | Spent fuel |
| | | | 1.3.2 | Operational waste |
| | | | 1.3.3 | Hazardous materials |
| | 1.4. | Site characteristics | 1.4.1 | Interdependencies with 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 to achieve the end state | 2.2.1 | Feasibility |
| 3. Waste and materials management | 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 characterisation | 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 / out site) | 3.3.1. | Treatment facilities |
| | | | 3.3.2 | Storage facilities |
| | | | 3.3.3 | Disposal facilities |
| | | | 3.3.4 | Transport |
| 4. Organisation & Human resources | 4.1 | Organisational structure | 4.1.1 | Responsibilities |
| | | | 4.1.2 | Appropriate organisation |
| | | | 4.1.3 | Organisation Changes and transfer |
| | 4.2 | Human resources | 4.2.1 | Skills, knowledge & Training |

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| Risk family | Prompts | |
|---|---|---|
| | | 4.2.2 Human factors and mentality change |
| | | 4.2.3 Contractors interfaces and integration |
| 5. Finance | 5.1 Cost | 5.1.1 Cost estimation |
| | 5.2 Funding | 5.2.1 Funding origin |
| | | 5.2.2 Funding mechanism |
| | | 5.2.3 Financial governance |
| 6. Interfaces with contractors & suppliers | 6.1 Contractors & suppliers management | 6.1.1 Contract strategy |
| | | 6.1.2 Tender procedures & selection |
| | 6.2 Contractors and suppliers oversight | 6.2.1 Safety culture and Language |
| | | 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 |
| 8. Legal and Regulatory framework | 8.1 Laws and Regulations | 8.1.1 Gap 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 Workers radiation protection |
| | | 9.1.2 Public radiation protection |
| | | 9.1.3 Environmental releases |
| | 9.2 Conventional safety | 9.2.1 Workers conventional safety |
| | | 9.2.2 Impact of decommissioning activities (noise, disturbance, transports…) |
| | | 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. Understanding and knowledge |
| | | 10.1.2 Transparency on the project |
| | | 10.1.3 Communication media |
| | 10.2 Involvement | 10.2.1 Consultation |
| | | 10.2.2 Engagement |

# ANNEX II. APPLICATION OF RISK MANAGEMENT AT THE STRATEGIC LEVEL (RMSL) - EXAMPLES

Annex II includes the following information:

- Table II-1: a template for an assumptions register;
- Table II-2: an example of an entry in an assumptions register for an initial decommissioning plan (IDP);
- Table II-3: an example of changes made to an entry in an assumptions register as part of the revision process for an initial decommissioning plan;
- Table II-4: examples of key assumptions and associated risks.

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TABLE II-1. TEMPLATE FOR AN ASSUMPTIONS REGISTER

| Assumptions register | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Identification of assumptions | | | | | Uncertainty assessment | | Actions | | Assumptions Monitoring | |
| N° | Assumptions description | 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 | | | | | | | | | | |

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TABLE II-2. ENTRY IN AN ASSUMPTIONS REGISTER FOR AN INITIAL DECOMMISSIONING PLAN (IDP)

| Assumptions register | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Identification of assumptions | | | | | Uncertainty assessment | | Actions | | Assumptions Monitoring | |
| N° | Assumptions description | Risk family | Assumption origin (regulatory, technical, other) | Comments | Level of uncertainty (low, medium, high) | Comments | Actions description | Actions status | Periodicity, comments, outcomes | Assumptions status |
| 7 | RW and AC from decommissioning will be placed into the metal containers and shipped to the National RW disposal facility that is supposed to be available at the time of permanent shutdown of the facility | 3 - Waste and materials management | National RW management programme | National RW management programme is in an early drafting phase | Low | It is supposed that National RW management programme will be adopted and implemented in the meantime | Monitor adoption and implementation of the National RW management programme | Open | Every 5 years | Valid |

TABLE II-3. CHANGES TO AN ENTRY IN AN ASSUMPTIONS REGISTER AS PART OF THE REVISION PROCESS FOR AN INITIAL DECOMMISSIONING PLAN (IDP)

| Assumptions register | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Identification of assumptions | | | | | Uncertainty assessment | | Actions | | Assumptions Monitoring | |
| N° | Assumptions description | Risk family | Assumption origin (regulatory, technical, other) | Comments | Level of uncertainty (low, medium, high) | Comments | Actions description | Actions status | Periodicity, comments, outcomes | Assumptions status |
| 7 | RW and AC from decommissioning will be placed into the metal containers and shipped to the National RW disposal facility that is supposed to be available at the time of permanent shutdown of the facility | 3 - Waste and materials management | National RW management programme | National RW management programme is adopted in the meantime and currently is in implementation | High | Implementation of the National RW management programme is not proceeding satisfactory due to strong opposition from local community | FDP must be changed. A storage facility for RW and AC should be designed and constructed. Financial resources for storage facility should be taken from cost item dedicated for RW and AC transportation | Open. Status of the previously undertaken action is closed | No need for further monitoring. Assumption is changed | Not valid. New assumption is: RW and AC from decommissioning will be placed into the metal containers that will be stored on site |





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TABLE II-4. EXAMPLES OF KEY ASSUMPTIONS (AND ASSOCIATED RISKS)

| Key Assumption | Possible Risks to the Key Assumptions |
|---|---|
| Facility operates for 60 years without major accidents or upsets. | • An accident forces a premature shutdown of the facility. |
| The decommission strategy will be prompt decommissioning. | • Incidents and unplanned events affect planned decommissioning strategy (e.g., prompt decommissioning becomes impractical);<br>• Supporting infrastructure not available;<br>• Funding not available. |
| The infrastructure required to support the decommissioning project (e.g., storage, processing, and disposal facilities) will meet the project requirements in terms of timing and capacity. | • Delay in infrastructure availability;<br>• Levels of waste exceed facility capacities;<br>• Unexpected types of waste cannot be accepted by the facilities. |
| Funding will be available and meet project requirements in terms of level and timing. | • Delays in securing funding;<br>• Insufficient funds;<br>• Project costs exceed available funds. |
| All technologies required for decommissioning will be available and function as required. | • Development of required technologies delayed (e.g., R&D delayed);<br>• Technologies do not function as planned;<br>• Unexpected facility conditions cannot be managed with available technologies. |
| Decommissioning will be performed by external contractors | • Qualified contractors not available;<br>• Tendering process not effective in procuring the required human resources. |



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|---|---|
| Current waste classification specifications and clearance levels will still be in effect at decommissioning project start, and remain in effect throughout the project. | • Clearance levels become more restrictive;<br>• Changes in waste classifications invalidate waste volumes used in project planning. |
| Well defined regulatory framework with clear requirements surrounding approval processes are in place at project start, and remain unchanged throughout the project. | • New regulations are implemented that do not match project planning assumptions;<br>• Regulatory body undergoes organizational changes that affect the approval processes. |
| Organizational unit responsible for facility operation will operate the facility (including appropriate record keeping) in a manner that will optimize subsequent decommissioning activities. | • Facility operated with little or no regard for subsequent decommissioning requirements;<br>• Turnover procedures for transfer from operations to decommissioning not followed;<br>• Operational and decommissioning requirements are found to be significantly misaligned due to a lack of mutual planning and communication;<br>• Poor record keeping for accidents, unplanned events, and upset conditions;<br>• Decommissioning organization not included in event reporting system during operational phase;<br>• Long operating period leads to loss of key staff with knowledge important to subsequent decommissioning activities. |
| Provisions for spent fuel removal will meet project requirements | • Delays in fuel removal have significant impacts on project in terms of cost and schedule. |
| Inflation rate will correspond with project planning projections. | • Greater than expected inflation rate. |
| Information required by decommissioning will be available at turnover | • Quality, quantity, and usefulness of information less than |

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| | |
|---|---|
| from operations. | expected;<br>• Required information and records accidently lost or destroyed. |
| Decommissioning considerations and requirements properly taken into account during facility design and construction. | • Facility designed and constructed with little or no regard for decommissioning considerations;<br>• Significant departure from design during the construction process, and drawings not adequately updated to capture the "as built" features in the facility;<br>• Decommissioning organization not included in the facility design review. |
| No major modifications to the facility during operations. | • Significant modifications;<br>• Modifications poorly documented;<br>• Implications of modifications on decommissioning not considered during design and construction;<br>• Decommissioning organization not included in design reviews of proposed modifications;<br>• Configuration management poorly executed. |
| Decommissioning will be completed x years after facility shutdown | • Decommissioning takes longer than expected for a variety of unexpected reasons.<br>• Decommissioning initiated sooner than planned affecting expectations with respect to delay and decay effects (source term calculations). |
| The phased approach identified in the decommissioning project plan will be followed. | • Additional phases required;<br>• Identified phases prove to be inappropriate in practice. |


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| | |
|---|---|
| Project end state will remain as industrial re-use, current clean up criteria remain unchanged. | • Clean up criteria become more restrictive;<br>• Intended future use of site is changed. |
| Surrounding facilities will have no impact on the decommissioning strategy. | • Events and developments at surrounding facilities invalidate planned decommissioning strategies;<br>• Environmental assessment process elevates importance of the impacts from surrounding facilities. |
| Public interest continues to support the end use, end state, and cleanup criteria as identified in the project plan | • Major shift in public opinion at variance with project plans. |

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# ANNEX III. APPLICATION OF RISK MANAGEMENT AT THE OPERATIONAL LEVEL (RMOL) - EXAMPLES

## III-1 CONTENTS OF ANNEX III

- Table III-1: a template for a risk register;
- Section III-2: results from a risk management workshop for the Sofia Reactor;
- Section III-3: results from a risk management workshop for the decommissioning of historical waste in UJV REZ, A.S (Czech Republic);
- Section III-4: results from a risk management workshop for the Lithuania NPP Project “Dismantling of INPP Reactor Building A1 Equipment”.

The examples presented in Annex III are the results of three risk management workshops that were held during the DRiMa project on aspects of operational risk management. All of the workshops were based on information from actual decommissioning projects. The information was discussed by the risk management workshop attendees, and the risks were identified and analysed by applying the DRiMa methodologies discussed in the body of this report. The extent to which specific information was shared with workshop participants was only to the level required to support the workshop activities.

It is important to note that the risk management workshops were intended to be an exercise, and as such the time available was limited. As a consequence, the risk identification process is by definition incomplete. However, these examples provide a good illustration of how to identify risks and populate risk registers.

The examples from the three workshops include the following information:

- Background information about the decommissioning project, including context, excluded scope and project constraints (limitations);
- A description of the risks identified;
- An excerpt from the resulting risk register.

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TABLE III-1. RISK REGISTER TEMPLATE

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

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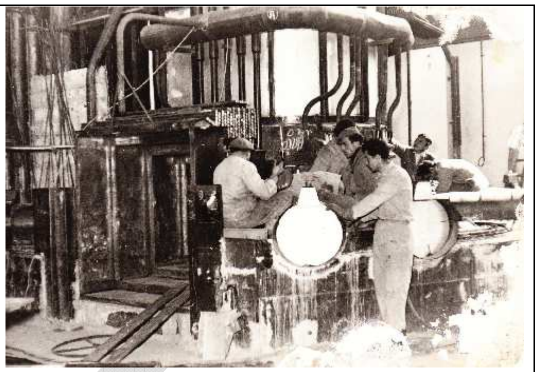
## III-2 RISK MANAGEMENT WORKSHOP - SOFIA REACTOR

### III-2.1 Project description

*Research reactor biological shield*



*Historical photograph taken during the construction of the biological shield*

*View of the reactor pool prior to the dismantlement of internal components*

*View of the reactor pool following dismantlement of internal components*

*Removal of reactor internal components*

*Removal of graphite blocks*

*FIG III-1. Photographs taken during decommissioning operations at the Sofia reactor*

Project background:

- A government decision was taken to shut down the reactor in 1989;
- The reactor facility was to be re-used for a new reactor;
- This project was intended to support the completion of a subsequent project i.e., it was a prerequisite for a new reactor.

Facility Information:

- Reactor drawings are available;
- Workers are available with knowledge of the facility;
- There is no loose contamination on the outside of reactor;
- Field data and calculations for radioactive waste volumes and doses are available;
- There is some operational history and data available, but it is not complete;
- The reactor is a pool type, with 11 horizontal and 12 vertical experimental chambers;
- Records for the plant configuration include:
  - Drawings;
  - Construction materials.

Project Starting Point:

- Spent nuclear fuel has been removed from the site, and approval to begin decommissioning has been granted by the regulatory agency;
- There is insufficient space for on-site storage of radioactive waste.

Project End State:

- The required end state is as follows: (i) reactor dismantled, (ii) radiological conditions below the levels required to permit the construction of a new reactor, and (iii) waste sent to a repository.

Success Criteria:

- Facility ready for refurbishment with the decommissioning having been carried out in such a manner that existing systems required for the new reactor are not damaged (i.e., ventilation and sewage);
- Old equipment terminated in such a fashion as to allow it to be connected to new equipment;
- Delivery of the project achieved on budget and on schedule.

Project Scope Definition – Key Assumptions:

- Generated wastes are accepted by the repository;
- Funding is secured for the project;
- There are no changes in decommissioning strategy;

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- There are no changes in applicable regulations and legislation which could adversely impact the decommissioning project;
- Levels of contamination are consistent with preliminary characterization results;
- Drawings and documentation for the facility are available and accurate;
- Resources are available from a sub-contractor for the execution of the work; Existing equipment such as ventilation systems and cranes can be used for the dismantling work.

Exclusions:

- Certain building systems are not subject to decommissioning and dismantlement (i.e., ventilation system and cranes);
- Building remediation;
- Underground storage;
- Local waste storage.

Constraints:

- Existing base building systems need to be maintained for future project use and any contamination of these systems needs to be minimized;
- Old equipment has to be terminated in such a fashion as to allow it to be connected to new equipment;
- Dose limit cannot exceed 200 μSv per person per day.

Inter-dependencies:

- Waste management organizations;
- Contractors;
- Designers of the new reactors.

Uncertainties:

- Condition of the graphite blocks, i.e., readiness for shipment.

Project schedule and milestones:

- Project completion in 5 months;
- The completion date is not flexible and is constrained by the schedule for the new reactor project.

Hold Points:

- No hold points have been established.

### III-2.2 Risks identified during the workshop

Waste Management:

- Waste is not accepted by the waste repository;
- Graphite blocks require treatment prior to shipment off-site;
- Lack of accepted or approved free-release criteria;
- Characterization data for the waste is found to be inaccurate;
- Volume of waste generated is greater than planned;
- Expected distribution of waste volumes between VLLW, LLW, and HLW categories does not match planning levels, with more in the higher waste categories than expected;
- Inability to meet transportation and shipping requirements for waste;
- Operational waste is not removed and needs to be dealt with by the decommissioning project;
- Unplanned treatment of waste is required prior to shipment off-site;
- Volumes of secondary waste exceed planning expectations;
- Waste containers are not available when required.

Technical and Technology:

- Conventional cutting techniques are not adequate, e.g., too slow;
- Failure of existing in-place equipment e.g., the ventilation system ;
- Planned technique for the handling of graphite blocks proves inadequate, and a new technique is required;
- Updated requirements (e.g., electrical or building codes) come into effect for the existing equipment scheduled for re-use in the new reactor;
- Additional training required;
- Crane capacity is not sufficient for the removal of waste;
- Capacity of the ventilation system is not sufficient for planned work;
- Laydown areas for container storage or new equipment proves insufficient.

Contractors:

- Skills and capabilities of contract workers prove inadequate;
- Availability of contractors less than that used in project planning;
- Contractors do not have sufficient nuclear safety experience;
- Contractor responsibilities are not clear;
- Contractor does not follow the work plan;
- Design contractor for new reactor facility changes requirements for equipment installations relative to that used in project planning;


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- The number of workers available for completing the work scope proves inadequate due to radiation dose constraints;
- As a consequence of competing priorities, the number of workers proves to be insufficient.

Knowledge/Human Resources:

- Plant information is found to be more inaccurate or incomplete than expected;
- Risks arise that were not identified in the risk management process;
- Efforts to determine the manner in which the past building systems have been isolated are unsuccessful;
- Key staff leave during the project;
- Unexpected difficulties arise as a result of inexperienced project staff – first decommissioning project;
- The end state requirements are changed relative to those used in project planning;
- Unexpected loss of operational knowledge through the retirement or loss of operations staff;
- Difficulty in transferring knowledge to the contractor;
- Shortage of resources as a result of unexpected bioassay monitoring requirements or dose constraints.

Asset Condition/Site Arrangements:

- Site infrastructure (e.g., roads) proves insufficient or inadequate for work;
- Unplanned maintenance of existing equipment adversely impacts project schedule;
- Unexpected shortage of adequate HEPA filters;
- Availability of radiation protection (RP) monitoring equipment to support decommissioning work is less than that identified in the project plan;
- Unexpected lack of adequate RP personal protective equipment (PPE).

Stakeholders (Internal/External):

- Change in government policy invalidates key assumptions used in project planning;
- New legislation for waste disposal acceptance criteria, safety, etc., invalidates key assumptions used in project planning;
- Changes in regulatory framework makes securing regulatory approvals a longer process than identified in the project plans;
- The extent to which defined requirements are provided by the regulator for decommissioning approvals is less than expected;


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- Lengthy delays relative to the project plan in obtaining approvals arise as a result of greater than expected involvement by interested parties;
- An unexpected change in priorities by the client;
- Time required in getting the safety case accepted by the regulator exceeds project plan schedule durations;
- Time required in getting environmental assessment accepted by the regulator exceeds project plan schedule durations.

Safety:

- An accident stops the project;
- Emergency preparedness arrangements and procedures are found to be inadequate;
- Availability of calibrated equipment is less than expected due, for example, to a lack of maintenance;
- Fire from cutting operations;
- Dropped loads from poor rigging and lifting practices result in a contamination event or personal injury;
- Unexpected levels of personnel contamination due to poor handling practices, cutting operations, etc.;
- Unexpected spread of contamination due to cutting operations due to poor RP practices, ventilation, or tent failure;
- Inhalation of fumes from plasma cutting operations in spite of extensive precautions;
- Dose rates higher than expected due to poor radiological characterization data (e.g., of the graphite);
- Unplanned loss of power to safety critical systems;

Finance and Budget:

- Shortfall in funding;
- Budget and/or cash flow reductions;
- Project cost and schedule contingencies prove inadequate;
- Cost overruns by the contractor.

Opportunities:

- Secure an approval for free release criteria as a means of salvaging and recycling material;
- Use internal staff rather than contract (external) staff;
- Consider using remote tooling and equipment for cutting operations to reduce dose and schedule;



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- Improve radiological planning (e.g., through dose reduction plans) to improve dose management.

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## III-2.3 Risk register with examples

TABLE III-2. RISK REGISTER WITH EXAMPLES OF RISKS DEVELOPED DURING THE RISK MANAGEMENT WORKSHOP – SOFIA REACTOR

| Identification | | | | | | Assessment Prior to Treatment | | | | | Response/Treatment | | | | Assessment After Treatment | | | Monitoring & Control |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Calculate Risk Score (P x I) | | | Impact | | | | | | Calculate Risk Score | | | |
| Risk ID | Risk Description | Type of Risk | Status | Risk Owner | Activities risk can impact | Probability Scale (1 to 5) | Impact Scale (1 to 5) | Risk Score (P x I) | Cost ($) | Schedule (days) | Action | Action Owner | Due Date | Cost of treatment strategy | Probability Scale (1 to 5) | Impact Scale (1 to 5) | Risk Score (P x I) | Actual Outcome / Progress |
| 1 | Waste not accepted in repository which results in the requirement for interim storage on-site which impact future projects | threat | Open | Elka | Work package on waste disposal | 3 | 4 | 12 | 400k | 90 | Mitigate - obtain formal agreement from waste repository to take waste | Elka | 2009 sep | 10k | 1 | 4 | 4 | |
| 2 | Spread of contamination from graphite removal results in contamination of building and personnel which impacts the schedule | threat | Open | hussein | Work package on graphite removal | 3 | 3 | 9 | 50k | 15 | mitigate - install protective barriers with local ventilation during work and utilize additional rp PPE | Narmine | 2009 Oct | 5k | 1 | 2 | 2 | |
| 3 | Define and gain agreement on cricteria for free releasing waste which will result in the ability to salvage some of the waste and reduce the amount of RAW | opportunity | Open | Mika | Work package on waste disposal | 1 | 4 | 4 | (40k) | 10 | No action - score not high enough | | | | | | | |



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## III-3. RISK MANAGEMENT WORKSHOP - DECOMMISSIONING OF HISTORICAL WASTE IN UJV REZ, A.S (CZECH REPUBLIC)

### III-3.1 Project description

*FIG. III-2. Original condition of the storage facility (left), and following the installation of an overbuilding and other systems (right)*

Project Background:

- The facility was originally established in 1958 for the storage of contaminated equipment and spent fuel assemblies from the research reactor;
- The facility, which is partially underground, comprises 8 storage cells with a total volume 1,400 $m^3$;
- The facility operated as a storage facility until 1993;
- Following its shutdown in 1993, the facility was designated as an ecological and environmental liability under the responsibility of the government;
- The facility was included as part of a large project, i.e., "Decommissioning of Old Nuclear Facilities at the Nuclear Research Institute Rez";
- The project is characterized by high levels of ecological and environmental risks;
- There is a requirement for re-use of the facility for other purposes.

Facility Information:

- Drawings are available;
- Inventory and characterization information is largely missing;
- Workers with knowledge of the facility are available;
- No external contamination.

Project starting point:

- The installation of the overbuilding, ventilation system, and crane is complete;

- Spent fuel has been removed;
- External monitoring points have been established (e.g., water monitoring wells, dose measurement stations, etc.).

*FIG. III-3. Original condition of storage cells and waste*

Project End State:

- All waste removed from the facility;
- Entire facility decontaminated to a “reasonable level”;
- The equipment installed as part of the project (i.e., overbuilding, ventilation system, and crane) to remain in place at the conclusion of the project.

Success Criteria:

- All waste removed;
- Facility ready for re-use;
- Stakeholder acceptance, based on the results presented in the final report.

Project Scope Definition – Key Assumptions:

- Waste, which includes graphite, is accepted by repository;
- The volume of waste (expected to be high) can be managed by the repository;
- Waste conditioning is as effective as planned;
- Decontamination technology is as effective as planned;
- Waste acceptance approvals are received on time;
- The percentage of waste that qualifies for free release is as planned;
- The characteristics of the unknown waste are similar to those of the known waste;
- Sufficient human resources are available;
  - internal staff;
  - contract staff.

- The ventilation system and crane are available when required;
- The project budget remains available and secure;
- The project budget is sufficient;
- The completion deadline remains unchanged, and is dictated by budgetary considerations;
- Sealed sources are found to be in the condition assumed in project planning;
- The use of existing "licensed" containers is acceptable.

Exclusions:

- Demolition of the building;
- Removal of the crane and ventilation system installed as part of the project;
- Site and land remediation.

Constraints:

- Waste processing capacity;
- Waste repository capacity;
- Crane capacity;
- Ventilation capacity in terms of ability to support cutting operations;
- Availability and quality of site infrastructure, e.g., roads.

Inter-dependencies:

- Site infrastructure organizations, e.g., those organizations responsible for roads, power, etc.;
- Analytical services organizations, e.g., those organizations providing waste characterization, environmental analyses, internal dosimetry, etc.;
- Waste repository organization;
- Other concurrently running projects within the organization;
- Contractors.

Uncertainties:

- Waste characteristics:
    - Radiological
    - Physical form
    - Condition
    - Chemical properties
    - Organic materials
    - Hazardous substances
- Waste acceptance criteria for:
    - Sealed sources
    - Radioactive waste



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- Mixed waste

- Values for free release criteria;
- Exact requirements for the level of decontamination required, particularly in terms of the facility end state criteria;
- Project schedule and milestones (there is little or no flexibility in the required completion date for the removal, decontamination, processing, and disposal of waste by the end of 2016);
- Consequences arising from a lack of project hold points.

### III-3.2 Risks identified during the workshop

Waste Management:

- Repository does not accept certain types of waste, e.g., graphite, sealed sources, super-compacted wastes, etc.;
- Repository has insufficient capacity for the volume of waste generated during the project;
- Free release criteria are not approved or available in time for use by the project;
- Insufficient waste processing capacity;
- Waste characteristics are different from those predicted by initial characterization studies;
- Unexpected difficulties arise as a result of the current inability to predict the volumes of secondary waste;
- Characterization team (e.g., analytical services) not available as required.

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Technical and Technology:


*FIG. III-4. Examples of techniques planned for use in decommissioning operations, i.e., plasma cutting, circular saw cutting, hydraulic power sheers for segmentation, evaporation system for secondary liquid waste processing*

- Conventional cutting techniques are less effective than assumed in project planning;
- Evaporator for secondary liquid waste is not available;
- Technology for decontamination is not available.

Contractors:

- Availability of contractors is not to the level assumed in project planning;
- Daily communications and instructions are not effective.

Knowledge and Human Resources:

- Loss of key knowledge, e.g., through the loss of key staff, accidental destruction of records, etc.;
- Reliable information about the end state requirements, e.g., acceptable levels of decontamination, handover point, clearance criteria, etc., is lacking;

- Waste records and documentation is less complete or useful than expected;
- Inability to handle sealed sources utilizing internal resources as originally planned.

Asset Condition and Site Arrangements:

- The structural integrity of the storage cells is poorer than expected;
- Site infrastructure support not available as planned;
- Roads prove to be inadequate for intended use;
- Waste transport is unavailable or does not meet project requirements;
- Scheduling clashes arise with other projects or operational activities involving;
    - Waste management;
    - Maintenance and repair;
    - Road access.

Stakeholders (Internal/External):

- External: there is a change in the government that adversely affects the project plan;
- Internal: there is a change in project priorities and in decisions concerning project objectives, (in actual fact, the project deadline has already been changed).

Safety:

- Unexpected health and safety issues arise during:
    - Access and egress procedures;
    - Lifting operations.
- Cutting operations present unexpected safety and health risks with respect to fire hazards, spread of contamination, mechanical difficulties, etc.;
- Electrical shock hazards are different in nature or greater in extent than anticipated;
- Radiological hazards are different in nature or greater in extent than anticipated;
- The integrity of waste packages is poorer than expected;
- Dose rates are greater than expected;
- A collision occurs during a transport operation with either another vehicle or with a structure.

Finance and Budget:

- The fixed budget established for the project proves to be insufficient;
- Inflation rates are greater than those used in the project planning process;
- Project contingencies are insufficient.

Opportunities:

- Increase the effectiveness of steel decontamination procedures using available technologies;



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- Release and sell quantities of scrap steel in quantities greater than planned;
- Use an emptied storage cell for waste segregation operations;
- Increase the efficiency of work processes by, e.g., batching the work for contractors;
- Develop future re-use opportunities for the real estate associated with the facility;
- Establish clarity and certainty about end state requirements for use in future projects;
- Enhance workforce skills and capabilities for future work (e.g., in areas of decommissioning techniques, historical waste processing, etc.);
- Provide a positive outcome for the Ministry in terms of public relations.

*FIG. III-5. Examples of equipment that could help in realizing the opportunities discussed above, i.e., ultrasonic decontamination bath, abrasive decontamination chamber, low background measurement chamber for free release measurements*

## III-3.3 Risk Register with examples

TABLE III-3. RISK REGISTER WITH EXAMPLES OF RISKS DEVELOPED DURING THE RISK MANAGEMENT WORKSHOP – DECOMMISSIONING OF HISTORICAL WASTE IN UJV REZ

| Identification | | | | | Assessment Prior to Treatment | | | | | Response/Treatment | | Assessment After Treatment | | | Monitoring & Control |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Calculate Risk Score (P x I) | | | Impact | | | | Calculate Risk Score | | | |
| Risk ID | Risk Description | Status | Risk Owner | Activities risk can impact | Probability Scale (1 to 5) | Impact Scale (1 to 5) | Risk Score (P x I) | Cost ($) | Schedule (days) | Action | Cost of treatment strategy | Probability Scale (1 to 5) | Impact Scale (1 to 5) | Risk Score (P x I) | Actual Outcome / Progress |
| 1 | Waste content is unknown and during recovery material is discovered that does not meet waste acceptance criteria which causes delays and additional costs | Open | Milan | waste disposal | 3 | 3 | 9 | $250k | 90 | Identify packages that can be used for non-conforming wastes | $50k | 3 | 2 | 6 | |
| 2 | Contractors are not available as planned to support the work which results in delays to the project | Open | Steven | waste recovery | 4 | 2 | 8 | $100k | 60 | Ensure execution schedule is agreed with contractor | $2k | 2 | 2 | 4 | |
| 3 | During the cutting of material contamination is rele | Open | Sophie | waste recovery | 4 | 2 | 8 | $30k | 30 | Ensure adequate containment is established for all cutting activities | $30k | 2 | 2 | 4 | |

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## III-4. RISK MANAGEMENT WORKSHOP – IGNALINA NP, LITHUANIA: PROJECT “DISMANTLING OF INPP REACTOR BUILDING A1 EQUIPMENT”

### III-4.1 Project description

Project Background:

- Ignalina NPP (INPP) Unit 1 was shut down in 2004, Unit 2 in 2009;
- INPP decommissioning strategy: immediate dismantlement;
- Final decommissioning plan, Version 7, was updated in 2014;
- Schedule for the megaproject for INPP decommissioning shows activities continuing until 2038;
- The decommissioning process is financed through the EU, the European Bank for Reconstruction and Development (EBRD), and the Ignalina decommissioning fund;
- INPP Employees: 2103.

Reactor Building A1 Information:

- Building A1 contains an RBMK-1500 reactor along with the main circulation circuit, the main auxiliary systems for the reactor, the emergency core cooling system, the accident localisation system, and the control and protection system. The hall above the reactor is a large open workspace housing the refuelling machine. The spent nuclear fuel (SNF) storage pool is situated in an adjacent hall, but separated from the reactor hall;
- The reactor compartment is a rectilinear structure with a horizontal cross-section of 90 m x 90 m and a height of around 53 m;
- Building and equipment drawings are available;
- Operational and maintenance records are available;
- Preliminary engineering and inventory data is available.

Project Start Point:

- Spent nuclear fuel has been removed from Unit 1, but there are spent fuel assemblies in the Unit 1 fuel storage pool;
- Storage facilities for radioactive waste are under construction;
- The determination of radioactive nuclide inventory for Building A1 is under development;
- There is some experience in the management of dismantling and decontamination (D&D) projects in INPP.

Project End State:

- Reactor Building A1 equipment dismantled, with radioactive waste treated and transported to storage facilities;

- Specified building systems remain in place for subsequent projects;
- Building A1 ready for the next stage of decommissioning, i.e. preparation for demolition.

Success Criteria:

- Project accomplished on time and within the defined budget;
- Radioactive wastes treated and stored in accordance with project plans;
- No negative impact on interrelated projects;
- No accidents;
- No release of contamination above planned and approved levels;
- No doses above planned levels.

Project Scope Definition – Assumptions:

- Project funding remains secure;
- No changes in the dismantling strategy during the course of the project;
- Any changes in regulations and legislation will not negatively impact the project;
- Levels of contamination are consistent with preliminary characterization data;
- Drawings and documentation for the facility are accurate;
- Existing facility equipment such as the ventilation system and cranes can be used for the D&D activities;
- No changes in the interconnected projects, e.g. waste management projects, that will negatively impact the D&D work. The interrelated projects include the following:
    - The ***solid radioactive waste management and storage facilities*** (projects B2/3/4) are planned to be in operation by 2018. Currently, solid radioactive waste produced by INPP (post- operation) is stored in temporary concrete storage facilities on the INPP site. The objective of projects B2/3/4 is the construction of new solid radioactive waste management and storage facilities, which are to include B2 (solid radioactive waste retrieval facility) and B3/4 (solid waste treatment and storage facility);
    - The ***interim spent nuclear fuel storage facility*** (project B1) is planned to be in operation by the end of 2017. The objective of project B1 is to build an interim storage facility for spent RBMK-1500 nuclear fuel from Ignalina NPP Units 1 and 2;
    - The ***near surface repository for low and intermediate level short-lived radioactive waste*** (Project B25) is scheduled to be in operation by 2020. INPP's low- and intermediate-level short-lived radioactive waste from both operational and decommissioning work will be disposed of



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in a near surface repository (the repository has been designed to have a capacity of 100,000 $m^3$);
    - The ***landfill facility for short-lived very low level waste*** (project B19) is planned to be in operation by 2018 (the landfill has been designed to have 3 modules with a capacity of 20,000 $m^3$ each).
- No changes in the reactor dismantling project scope that adversely affects the project deliverables;
- Spent nuclear fuel will be unloaded from the SNF pool 1 in 2021;
- Existing facilities for decontamination work at INPP will be available and in operation in accordance with project plan requirements;
- Existing facilities for size reduction at INPP will be available and in operation in accordance with project plan requirements;
- D&D activities will be performed by INPP personnel (project requires approximately 180 employees).

Exclusions:
- The main systems of Building A1 are to remain in place (i.e. ventilation and cranes);
- Dismantling of the reactor itself is not included in the project scope.

Constraints:
- Existing utility and service systems in Building A1 are to remain in place and operational for subsequent projects;
- There is insufficient space in Building A1 for decontamination and waste storage activities to be performed in close proximity to the D&D activities;
- Containers for the transportation of radioactive waste can only be placed in the Building A1 transportation corridor;
- There are limitations in the capacity of the ***Free Release Measurement Facility (Project B10),*** a centralized INPP facility to determine if materials meet free release criteria;
- The capacity of existing facilities for decontamination activities is limited;
- Time limitations exist for working on contaminated equipment due to dose rates;
- Limitations in the availability of INPP staff due to an aging workforce.

Inter-dependencies:
- Concurrent with the D&D projects being carried out at INPP, other projects involving a variety of objectives are being implemented at INPP in buildings D1, V1, B1, G2, D2, V2, B2, A2, Reactor 1, and Reactor 2;

- There are interdependencies and possible conflicts with the projects listed above as well as with operational activities that require the same waste management routes, services, transportation, equipment, etc.

Uncertainties:

- No specific technology has yet been developed for reactor dismantling, and this could have a possible impact on the Project A1 scope;
- No specific solutions have proven acceptable for the treatment of radioactive graphite, and this could have possible impacts on the reactor dismantling project as well as on the project for Building A1equipment dismantlement;
- It is not clear what the source of funding for the project will be after 2021;
- The extent of any impacts resulting from shortcomings in the radioactive waste treatment programs is not known.

Project schedule and milestones:

- Engineering and licensing of D&D to be completed by February 2018;
- Dismantlement of Building A1 equipment to be completed by November 2025;
- Waste treatment to be completed by April 2026.

### III-4.2 Risks identified during the workshop:

Initial condition of facilities:

- Unexpected areas of radioactive contamination are found;
- Unexpected asbestos contamination is found in the facility;
- There are delays in the completion of the spent fuel management storage facility;
- Unexpectedly adverse conditions are found in the fuel bays;
- Historical data is not of the accuracy assumed in the project planning process;
- Loads are heavier than expected and exceed the building crane capacities;
- Unexpected gaps in the knowledge about the facility are identified;
- Unexpected information is found concerning events that occurred during the operational phase of INPP;
- The integrity of the building structure is poorer than anticipated;
- Delays in decommissioning activities arise from the discovery of unknown design features in the reactor;
- Radiological characterization information is less thorough than expected;
- Unanticipated limitations arise in the ability to access design information;
- Issues and difficulties with defueling procedures;
- Radioactive inventory and source term information not available in time;
- Greater than expected complexities in Building A1equipment configurations;
- Insufficient site support facilities (e.g., power, heating);
- Radiation zoning is found to be inappropriate for decommissioning purposes.



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Decommissioning End State:

- Completion date for Building A1 equipment dismantlement is missed;
- End state acceptance criteria are changed to more demanding requirements;
- Waste storage facility not ready for the required project (end-state) completion date;
- Inability to meet approved clean-up criteria for contamination in Building A1;
- Capacity of facilities for the management of waste is insufficient;
- Damage to the equipment that is required for subsequent projects;
- Interferences develop between multiple projects that are concurrently underway;
- Radioactive waste treatment process is not ready when required by the project;
- Opportunity: investigate the possibility of moving waste treatment activities to another project;
- A change in public opinion concerning the nature of the D&D end state negatively impacts the project;
- The Building A1 equipment cannot be adequately removed to meet the required end-state;
- Regulatory issues arise concerning high level waste storage which negatively impact the project;
- Decontamination techniques are not successful in meeting required end state criteria;
- Dismantling techniques are not successful in meeting performance requirements, e.g., in terms of completion time requirements.

Waste and Materials Management:

- Shortage of interim waste storage capacity;
- Clearance criteria become more restrictive;
- The waste storage facility is not ready when required by the project;
- A change in waste acceptance criteria, or the lack of these criteria negatively impacts the project (selected as an example for the risk register);
- Delays in the transportation of the waste relative to project plans;
- Waste volumes change or are incorrect relative to the quantities used in project planning in such a manner as to adversely affect project completion (selected as an example for the risk register);
- Incident occurs during waste transport that adversely affects project completion;
- Unexpected waste category (e.g., a mixed waste type) is discovered that requires time and resources to manage;
- High-level waste (other than fuel) discovered during the project;
- Handling of large and heavy equipment is slower than expected;
- More secondary waste is generated than planned for;
- Strategy for radioactive waste storage changes which adversely impacts on project delivery;
- Opportunity: an effective means for storing bulky wastes is developed (selected as an example for the risk register);
- Waste substantially different from that assumed in project planning is found in the pool (e.g., damaged fuel);
- Waste treatment facilities are not as effective as anticipated;



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- Waste transport routes prove to be insufficient and/or inadequate;
- Disposal facility are either not built, or not built in time to meet project requirements;
- Interim fuel storage facility is not ready in time to meet project requirements;
- Unexpected inability to find an acceptable method for managing mixed conventional waste;
- Opportunity: criteria are developed and approved for non-standard waste which allows for the disposal of larger components;
- Requirement to treat greater volumes of secondary waste than planned for in the project plans.

Project:

- A re-location of the waste disposal site increases the time required to transport waste;
- Workflow interfaces between multiple groups causes inefficiencies and delays;
- Opportunity: sell the waste metal rather sending it for disposal;
- Difficulty in retaining experienced workers;
- Opportunity: government establishes an agreement for fuel repatriation;
- No source of funding after 2021;
- Rejection of Environmental Assessment;
- Unanticipated delays in obtaining approvals;
- Unexpected shortage of trained D&D staff;
- Unanticipated lack of qualified contractors;
- Technical procedures are found to be inadequate;
- Inefficient supply chain management (procurement) processes;
- Compounding of delays in milestone delivery;
- Coordination between multiple projects proves more difficult than expected;
- Various changes require updates and additional approvals for project plans which slows the progress of the project;
- Appropriate suppliers difficult to locate;
- Priorities change in the sequencing of projects;
- Inability to find contractors in a timely manner;
- Requirement to replace the contractor;
- Opportunity: work can be accomplished ahead of schedule, or performed in parallel to reduce timelines;
- Previously unidentified constraints on the contracting process;
- Incidents on other projects cause a change in strategy which negatively impacts the project. For example, accidents on other projects lead to heightened regulatory oversight on all projects;
- Design changes on a supporting project adversely affect the ability to meet project objectives;
- Opportunity: develop new waste treatment techniques.

Organization and Human Resources:

- Number of technicians identified in project resource plan proves insufficient;

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- Number of decommissioning managers identified in project resource plan proves insufficient;
- Unexpected difficulty in implementing organizational procedures;
- Number of trade workers identified in project resource plan proves insufficient;
- Unable to secure the required number of technicians, decommissioning managers, and trade workers;
- Inability to obtain sufficient training resources for supporting new types of work;
- Unclear roles and responsibilities between staff and contractors lead to project inefficiencies;
- Waste records prove to be poorly organized;
- Interfaces between the project (company) and external contractors are found to be more difficult to coordinate than expected (selected as an example for the risk register);
- The age profile of the workforce causes problems; for example, through the loss of skilled workers as a result of retirement;
- Unexpected internal conflicts cause schedule issues.

Finance:

- Cost control mechanisms are not effective or are not in place;
- Unplanned escalation of costs leading to overruns;
- Problems encountered with project oversight and supervision in terms of the release of funding;
- Cost estimates are found to be inaccurate due to unplanned scope of work;
- Lack of funding for future work;
- Cost and schedule contingencies prove to be inadequate;
- Loss of funding from internal or external sources;
- Funds allocated in the project for fuel disposal prove insufficient;
- Unexpected and adverse effects due to external factors (e.g., market conditions, inflation);
- Mismanagement of funds.

Interface with Contractors and Suppliers:

- Delays in securing contractors;
- Contracting mechanisms and procedures are found to be unclear, and this leads to delays;
- The program and procedures for contractor management prove to be ineffective (e.g., procedures for dispute resolution);
- Habitual and unplanned delays in contractor work;
- Process for securing regulatory approvals is found to be less defined than anticipated;
- Poor nuclear safety culture exhibited by contractors;
- Tendering and procurement processes are more complicated than expected and lead to delays;



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- Language differences lead to work inefficiencies;
- There is a failure of the contract with the contractor (e.g., through contractor bankruptcy).

Strategy and Technology:

- The planned use of a first of a kind technique or technology by the project proves unsuccessful or is the source of unanticipated costs and delays;
- The uncertainty and lack of clarity about the roles and responsibilities for approving new techniques and technologies leads to higher than expected approval costs;
- Opportunity: An improvement in technology and knowledge brought about by the use of the first of a kind technology enables improvements in work efficiency and/or a reduction in costs;
- The decision to proceed with immediate dismantlement rather than take advantage of delay and decay leads to higher than expected doses and more serious contamination events;
- A lack of experience in the use of new technologies leads to unplanned delays and costs;
- The unavailability of proven technologies for use on this project contributes to risk impacts that are higher than those predicted during the risk analysis process.

Legal and Regulatory Framework:

- Regulations change in a manner that adversely affects the project objectives;
- Regulatory approvals take longer than the durations identified in the project schedule;
- The license for the facility is not extended to accommodate the project timeline;
- Unplanned difficulties are encountered in efforts to meet environmental assessment requirements;
- Regulatory scrutiny exceeds that anticipated during project planning;
- Process for securing regulatory approvals is found to be less defined than expected, for example, there is an ongoing uncertainty in the level of regulatory review required;
- New and unanticipated regulatory bodies become involved in the project;
- Unclear roles and responsibilities in obtaining regulatory approvals delay the approval processes relative to the project schedule.

Safety:

- Conventional safety procedures prove inadequate;
- Workers reach maximum dose more quickly than expected;
- Discrepancies arise between radiological and industrial safety requirements (selected as an example for the risk register);
- The number of workers qualified to work in a radiological environment is found to be inadequate;



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- Inadequate or missing procedures for emergencies (i.e., emergency preparedness procedures) leads to an unexpected escalation in the severity and frequency of unplanned events;
- Difficulties are encountered in securing an adequate supply of safety equipment, and this limits the size of the workforce that can execute specific types of work;
- An incident occurs during fuel material recovery that adversely affects project schedule and costs;
- Ongoing and constant changes in working conditions decrease work efficiency to a greater extent than anticipated in the work plans.

External Relationships and Communication:

- A higher than expected public demand for access to internal documents decreases the time available for personnel to work on the project;
- Public opinion changes in a manner that negatively impacts the project;
- During the course of the project, stakeholders and interested parties change their position on the key assumptions and strategic decisions upon which the project has been based (e.g., different clean up requirements);
- Difficulties arise in securing approvals and sign-offs that confirm that the project has been completed, i.e., that project end state requirements have been met;
- A higher than expected level of media requests and interactions increase demands on project staff;
- An increase in the communication requirements of stakeholders, the public, regulatory bodies, the media, etc., place a major and unplanned additional burden on project staff;
- Legal issues develop between parties, e.g., the project and contractors;
- The public input process for the environmental assessment initiative takes longer and requires more resources than identified in the project plan;
- Decreased interest by the stakeholders and interested parties during the course of the project adversely affects priorities for resources, funding, etc.;
- Opportunity: Proactively increase the support for the project by increasing communications with interested parties and employing various media to show the benefits arising from similar work in other countries.

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### III-4.3 Risk register with examples

TABLE III-4. RISK REGISTER WITH EXAMPLES OF RISKS DEVELOPED DURING THE RISK MANAGEMENT WORKSHOP – DECOMMISSIONING OF HISTORICAL WASTE IN UJV REZ

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| Identification | | | | | Assessment Prior to Treatment | | | | | Response/Treatment | | Assessment After Treatment | | | Monitoring & Control |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Calculate Risk Score (P x I) | | | Impact | | | | Calculate Risk Score | | | |
| Risk ID | Risk Description | Status | Risk Owner | Activities risk can impact | Probability Scale (1 to 5) | Impact Scale (1 to 5) | Risk Score (P x I) | Cost ($) | Schedule (days) | Action | Cost of treatment strategy | Probability Scale (1 to 5) | Impact Scale (1 to 5) | Risk Score (P x I) | Actual Outcome / Progress |
| 1 | As a result of the Waste Acceptance Criteria changing, we have more LLW waste than planned, which would lead to higher costs | Open | Milan | waste disposal | 1 | 4 | 4 | $2M | 0 | Accept | | | | | |
| 2 | As a result of a change in waste volumes, we have insufficient disposal capacity which would lead to increased storage costs and delays | Open | Hans | waste disposal, | 3 | 4 | 12 | $20M | 1000 | Mitigate - invest in other technology to reduce the volume (Sophie), introduce conditional clearance criteria (Michael), ensure the design of the disposal facility can accommodate some additional waste volumes (Stephen), | 1. $800k 2. $300k 3. $10k | 1 | 2 | 2 | 2015 Nov 2 - Stephen has spoken with the waste management group and they will respond to us in January |
| 3 | As a result of inadequate processes, we have a poor interface mechanisms between the company and the external contractors which would lead to delays and increased costs | Open | Hussein | procurement of equipment, materials | 4 | 2 | 8 | $500k | 100 | Transfer - have the contractor propose an interface process as part of their bid (Dejan) | $20k | 2 | 2 | 4 | |
| 4 | As a result of discrepancies between radiological and industrial safety, we could have inappropriate work control which would lead to higher doses to workers and radiological events | Open | Dimitro | dismantling, transportation, packaging, decontamination | 2 | 2 | 4 | $100k | 30 | accept | | | | | |
| 5 | As a result of rescoping the project end-state for waste treatment, we could lower the amount of waste to be treated by the project by transferring to a future project which would lead to reduced costs and schedule. | Open | Ivanka | waste treatment, disposal | 4 | 3 | 12 | $2M | 300 | Exploit - Negotiate with Project Sponsor to move some waste treatment to the another program (Christian) | $5k | | | | |
| 6 | As a result of a change in packaging requirements, we are able to store bulky waste without cuttings which would save time and costs (and doses) | Open | Asif | dismantling, transportation, packaging, decontamination | 4 | 3 | 12 | $1M | 300 | Exploit - Negotiate with Waste Management Group to change the packaging concept used in the disposal facility | $100k | | | | |

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# LIST OF MEETINGS

## Consultants Meetings

13-17 February 2012, Vienna Austria
28 May – 1 June 2012, Madrid, Spain
13-17 May 2013, Cologne, Germany
2-6 June 2014, Zadar, Croatia
8-12 June 2015, Brussels, Belgium
22-26 February 2016, Vienna Austria
17-21 October 2016, Vienna Austria

## Technical Meetings

17-21 December 2012, Vienna Austria
7-11 October 2013, Vienna Austria
17-21 November 2014, Cologne, Germany
2-6 November 2015, Vienna Austria

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