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Project Management and Planning

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Contents

1. Introduction

This report has been prepared under the Work Package 2 (WP2) of the Co-ordination Network on Decommissioning of Nuclear Installations (CND) under the contract no. 0508855 (FI60) from the European Commission's Research and Technological Development (RTD) Division to a consortium of European nuclear organisations. This work was carried out by DECOM a. s. (Slovak Republic) acting as the work package manager supported by AF-Colenco AG of Switzerland.

The paramount focus of the nuclear industry's management and management system must remain on nuclear safety, environment, reliability and quality. There is general recognition that it must address also other critical processes and operations that are essential for its performance and success as a business.

The management system approach to quality management requires that all key aspects for successful operations of the nuclear business, including decommissioning must be considered and managed to achieve its established mandate and objectives. The current global environment and competitive leverage for survival requires that the management system must achieve the required business performance and results to meet the expectations of all its key stakeholders.

The International Atomic Energy Agency (IAEA) is taking a leading role in the direction of integrating all elements of managing nuclear facilities and activities. The IAEA wants to ensure that all inter-related aspects such as economics, health and safety, security, quality assurance and environment are not considered separately to nuclear safety but rather as a single integrated management system that covers them all.

The IAEA has developed within its Safety Standards the safety requirements on management systems for facilities and activities [1] and an appropriate guide [2] that cover aspects of safety, economics, quality, health, and environment. The IAEA developed the most comprehensive system of standards and guidelines for main activities and tasks related to decommissioning of nuclear facilities [3, 4, 5, 6], accompanying this standard, comparing to other international organisations.

The objective of this document is to propose baseline guidance/a (generic) model for an integrated management/planning system for decommissioning. It should be a state-of-the-art in this area in a form appropriate for the Co-ordination Network on Decommissioning of Nuclear Installations (CND). Recognising the leading role of the IAEA in this area, the proposed baseline guidance is based mostly on the IAEA documents complemented by other available resources, especially ISO standards and guidelines.

At the beginning of the document, the basic words and terms that are used in the document and that might cause confusion, are clarified and defined in order to avoid ambiguity. A general introduction, a management and integrated management system with a process approach and examples for identification of processes of organisations are described in the next section. Afterwards, decommissioning activities and their characteristics are introduced with requirements for planning these activities. The integrated management system requirements and a baseline scheme of an integrated management system are given in the further section. In the last part of the document different approaches to decommissioning project management are considered.

2. Basic definitions and terms

System

A system is the interconnection of components to achieve a given objective, or as defined in ISO 9000: 2000 a set of interrelated or interacting elements. The term ‘system’ has a variety of meanings in different contexts.

Process

1. A course of action or proceeding, especially a series of progressive stages in the manufacture of a product or some other *operation*.
2. A set of interrelated or interacting *activities* that transforms inputs into outputs.

The process has defined objective(s), input(s), output(s), activities, and resources.

Process approach

The systematic identification and management of the processes employed within an organisation, and particularly the interactions between such processes, is referred to as the ‘process approach’ in ISO 9000: 2000.

Management

Management is defined (in ISO 9000) as coordinated activities to *direct* and *control* an organisation [7].

Management system

Management system is a set of interrelated or interacting elements for establishing policies and objectives and enabling the objectives to be achieved in an efficient and effective manner [7]. As an element of a management system is understood a group of integrated activities the aim of which is to fulfil a certain/particular goal of the system.

The component parts of a *management system* include the organisational structure, resources and processes.

Integration

Integrated means combined; putting all the internal management practices into one system but not as separate components. For these systems to be an integral part of the company’s management system there have to be linkages so that the boundaries between processes are seamless [8].

Integrated management

Integrated management is a concept whereby functional management is dispersed throughout an organisation, so that managers manage a range of functions, e.g., a manufacturing manager would manage planning, manufacturing, safety, personnel, quality, environment, finance, etc.

Integrated management is a holistic ‘joined up thinking’ approach to management and embraces concepts such as sustainability and ethics. It covers all types of management and every aspect that an organisation is required to manage including corporate leadership, management system, organisation culture, competence base, systems, processes, and stakeholder interactions.

Integrated Management Systems

An integrated management system (IMS) is a management system, which integrates all relevant components of a business into one coherent system so as to enable the optimal achievement of its business objectives [8].

3. Integrated management and planning of decommissioning

3.1 General characteristics and description of a management system

A management system is defined as a set of interrelated or interacting elements or components that establishes policies and objectives and that enables those objectives to be achieved in a safe, efficient and effective way in a company or an organisation. These components include the organisation, resources and processes. Therefore, people, equipment, and culture are part of the system as well as documented policies and practices [9]. Generally speaking, actually anything which has an effect on business results should be part of the management system. Management system refers to what the organisation does to manage its processes, or activities, so that its products or services meet the objectives it has set itself, such as, e.g.,:

- satisfying the customer's quality requirements,
- complying with regulations, or
- meeting environmental objectives.

The purpose and the benefit of a management system reside in it being a means:

- to achieve business objectives;
- to increase understanding of current operations and the likely impact of change;
- to communicate knowledge;
- to demonstrate compliance (with the requirements);
- to establish 'best practice';
- to ensure consistency;
- to set priorities;
- to change behaviour.

Traditionally, separate management systems were developed to address issues such as quality, environment, health and safety, finance, human resources, information technology and data protection. Other aspects of running an organisation which need to be managed include corporate social responsibility (CSR), data security, risk management and business continuity, etc. The traditional approach has been to address individual aspects separately. The term management system reflects and includes the evolution in the quality management approach from the initial concept of 'quality control' (controlling the quality of products) through 'quality assurance' (the system to ensure the quality of products, services and processes) and 'quality management' (the system to manage quality). This evolution is depicted in Figure 3.1 [10].

The term 'management system' is also used instead of 'quality assurance' in the recent IAEA documents concerning management.

Standards for some of the management systems (e.g., quality, environment) were developed by the International Standards Organisation (ISO) so that they have a uniform format with shared language and methodology and they also comprise continual improvement of management systems in the organisation. Standards are written guidelines which help to do things, or to make things more efficiently or more safely. They are written through a formal prescribed process which involves consultation with relevant bodies and reaching consensus across all interested parties so that the final document meets the needs of business and society. Management system standards provide a model to follow in setting up and operating a management system. This model incorporates the features on which experts in the field have reached a consensus as being the international state-of-the-art. All standards take the form of either: specifications, methods, vocabularies, codes of practice or guides. Using the international standards enables to transfer wide potential hidden in them into common praxis even with workers, which are experts in these areas. But attention – in view of the application of even the best standards, it is necessary to develop an approach in a creative way and not in a mechanistic way, and it is necessary to customise them to particular conditions in which they are to be applied. Standards have world-wide validity, but specifics of particular countries and cultures must be reflected by local experts.

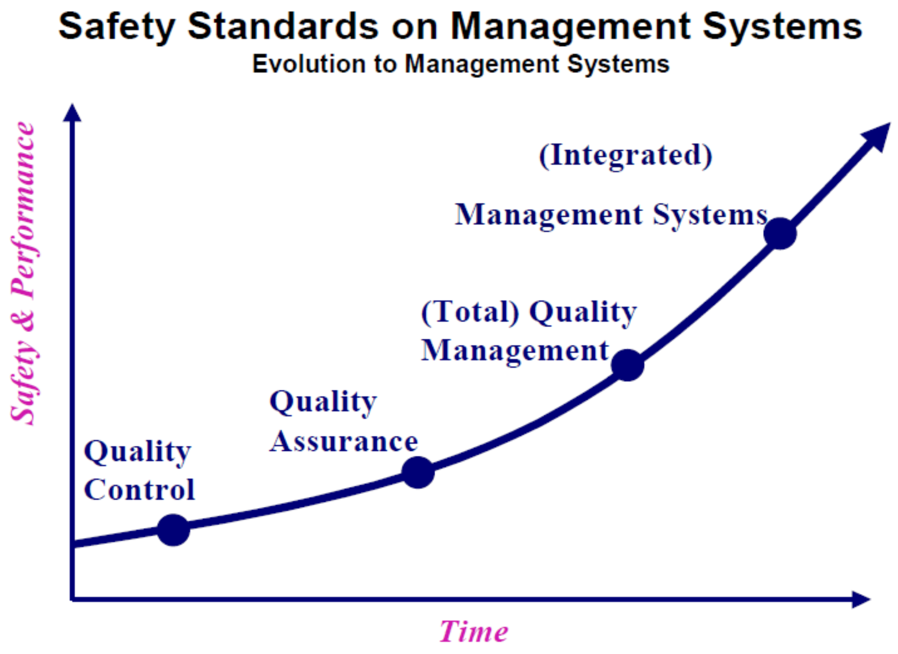

Figure 3.1 Evolution to management systems

Although the management system standards have been developed at different times, they have matured over the last years and common features in the requirements can be seen now even though they are not structured identically as yet [11]. The requirements in general address:

- Policy:

  Defining, documenting, maintaining and communicating overall intentions relative to an aspect of organisational performance, e.g., quality, environment, profit and safety.

- Planning:

  Establishing objectives, measures and targets for fulfilling the policies, assessing risks and developing plans and processes for achieving the objectives that take due account of these risks.

- Implementation:

  Resourcing, operating and controlling the processes as planned, including the handling of conforming and non-conforming outputs.

- Measurement:

  Monitoring, measuring and auditing processes, the fulfilment of objectives and policies and the satisfaction of stakeholders.

- Review:

  Analysis and evaluation of the results of measurement, determination of performance against objectives and determination of changes needed to policies, objectives, measures, targets and processes for the continuing suitability, adequacy and effectiveness of the system.

Management system standards have been produced to address a variety of company needs. The structure and content of these new standards are now very similar, often incorporating common elements such as control of documents and records, internal audit, corrective and preventive action, management review and continual improvement. The Plan, Do, Check, Act (PDCA) cycle, popularised by Deming has become the foundation for many of these new standards. Given the diversity of organisational type and size, in both the private and public sectors, it is no surprise that there is no standard for a management system structure.

PAS 99:2006 is a Publicly Available Specification of common requirements for management systems [12] that can be used as a framework for an integrated management system. It is a specification of common management system requirements as a framework for integration. It has been developed to help organisations who are looking to implement the requirements of two or more standards in an integrated way. It takes account of the six common requirements for management systems:

1. Policy;
2. Planning;
3. Implementation and Operation;
4. Performance Assessment;
5. Improvement;
6. Management Review.

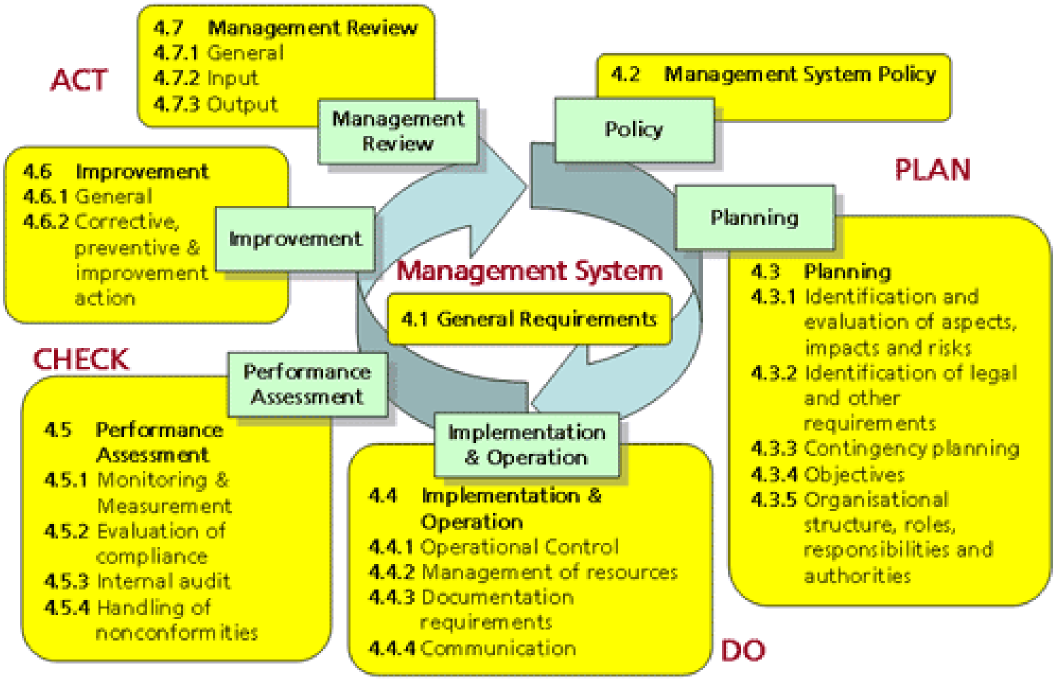

Figure 3.2 Structure of a management system according to PAS 99 and PDCA

While each management system standard has its own specific requirements, these 6 subjects will be present in all of them and could be adopted as a basis for integration.

Figure 3.2, adapted from PAS 99, shows the basic structure of a management system based around the 6 categories listed above and the PDCA cycle.

3.1.1 How should the management standards be used?

An organisation has many stakeholders and delivers outputs that are mainly intended to satisfy these stakeholders. The management system standards serve the achievement, control, assurance and improvement of stakeholder requirements and their applicability. There are three ways of using these standards:

- as a source of information on best practice that can be consulted to identify opportunities for improvement in business performance;
- as a set of requirements that are implemented by the organisation;
- as criteria for assessing the capability of a management system or any of its component parts.

The way some standards have been promoted has not helped their cause because they have been perceived as addressing issues separate from the business of managing the organisation. Invariably, organisations are being told to implement the ISO 9000 or some other standard but implementation is often not the best approach to take. Hence, in response, some organisations have set up new systems of documentation that run in parallel to the operating systems in place.

Regrettably, certification has followed implementation and it is certification that has driven the rate of adoption rather than a quest for economic performance.

Many organisations have implemented these standards because they have put it into effect and fulfilled an obligation to do as required and recommended by the standard. Implementation implies we pick up the standard and do what it requires. As the standards do not tell us to stop doing those things that adversely affect performance, these things continue. If the culture is not right, these things will not only continue but make any implementation of standards ineffective. This approach is like taking medicine but continuing the lifestyle that prompted the medication.

Doing as the standards require will not necessarily result in improved performance. A far better way is to consult the standards, establish a management system that enables the organisation to fulfil its goals and then assess the system by applying them. In applying these standards one should not create a separate system but look at the organisation as a system of processes and look for alignment with the requirements and recommendations of the various standards. Where there is no alignment:

- verify that the requirement is really applicable in your circumstances;
- change the organisation’s processes only if it will yield a business benefit.

Changing a process simply to meet the requirements of a standard is absurd. There has to be a real benefit to the organisation. Only change the organisation’s processes to bring about an improvement in its performance, utilisation of resources or alignment with stakeholder needs and expectations.

3.1.2 Description of a management system

A common starting point for an organisation when it defines its management system has often been to do it in relation to how it complies with the requirements of an external standard. So it would define, for example, a ‘quality management system’, or an ‘environmental management system’, based on the structure of the relevant standard, rather than on a logical definition of how the organisation operates.

The resultant multiplicity of systems is now recognised as wasteful and confusing, and there is a welcome recognition that such standards should have a common format. ISO 9001:2000 is now being used as the model for a number of other standards, but there is still an unfortunate tendency to use the layout of a standard itself as the starting point for describing and structuring a management system.

It should always be remembered that these standards specify the requirements for a system to enable compliance to be assessed – they do not mandate a particular format for the description of the system.

A more constructive and pragmatic approach is to focus on the organisation's mission, its stakeholders and their needs, to define how the organisation will satisfy these needs (i.e., its processes) and to be clear about what it needs to do to ensure that these processes are effective.

It is also worth stressing that the 'system' exists whether or not it has been defined (in the same way) as a process exists even if it has not been described in narrative or flowchart.

In order to understand relations within the management system that are based on the process approach one should remember that:

- a system is a collection of sub-systems;
- a sub-system is a collection of processes;
- a process is a collection of activities;
- a task is the smallest parcel of work to be carried out by a person or group of people;
- a procedure is just a way of doing things.

These elements/components of the system include the organisation, resources and processes and therefore understanding of relations among them is important when a system or process should be developed and implemented. A short guidance (as an example) on the concept and use of the process approach for management systems with examples of identification and planning of processes of the organisation is described in the following section.

3.1.3 Description of a process approach

A major advantage of the process approach, when compared to other approaches, is in the management and control of the interactions between these processes and the interfaces between the functional hierarchies of the organisation.

Inputs and intended outputs may be tangible (such as equipment, materials or components) or intangible (such as energy or information). Outputs can also be unintended; such as waste or pollution.

Each process has customers and other interested parties (who may be either internal or external to the organisation) that are affected by the process and who define the required outputs according to their needs and expectations. One should be aware that a process has defined objective(s), input(s), output(s), activities, and resources.

A system should be used to gather data, which can be analysed to provide information about process performance and to determine the need for corrective action or improvement.

All processes should be aligned with the objectives of the organisation and be designed to add value, relative to the scope and complexity of the organisation.

Process effectiveness and efficiency can be assessed through internal or external review processes.

There are identified many types of processes. The following types can be taken as an example [13]:

- *Processes for the management of an organisation*. These include processes relating to strategic planning, establishing policies, setting objectives, providing communication, ensuring availability of resources needed and management reviews.
- *Processes for managing resources*. These include all those processes for the provision of the resources that are needed for the processes for managing an organisation, for realisation, and for measurement.
- *Realisation processes*. These include all processes that provide the intended output of the organisation.

- *Measurement, analysis and improvement processes*. These include those processes needed to measure and gather data for performance analysis and improvement of effectiveness and efficiency. They include measuring, monitoring and auditing processes, corrective and preventive actions and are an integral part of the management, resource management and realisation processes.

A process approach is a powerful way of organising and managing how work activities are performed. Organisations are often structured into a hierarchy of functional units and are usually managed vertically, with responsibility for the intended outputs being divided among functional units. Consequently, problems that occur at the interface boundaries are often given less priority than the short-term goals of the units. This leads to little or no improvement to the interested party, as actions are usually focused on the functions, rather than overall benefit to the organisation. The process approach introduces horizontal management, crossing the barriers between different functional units and unifying their focus to the main goals of the organisation. It also improves management of process interfaces. Applying the principle of process approach typically leads to:

- systematically defining the activities necessary to obtain a desired result.
- establishing clear responsibility and accountability for managing key activities.
- analysing and measuring of the capability of key activities.
- identifying the interfaces of key activities within and between the functions of the organisation.
- focusing on the factors such as resources, methods, and materials that will improve key activities of the organisation.
- evaluating risks, consequences and impacts of activities on customers, suppliers and other interested parties.

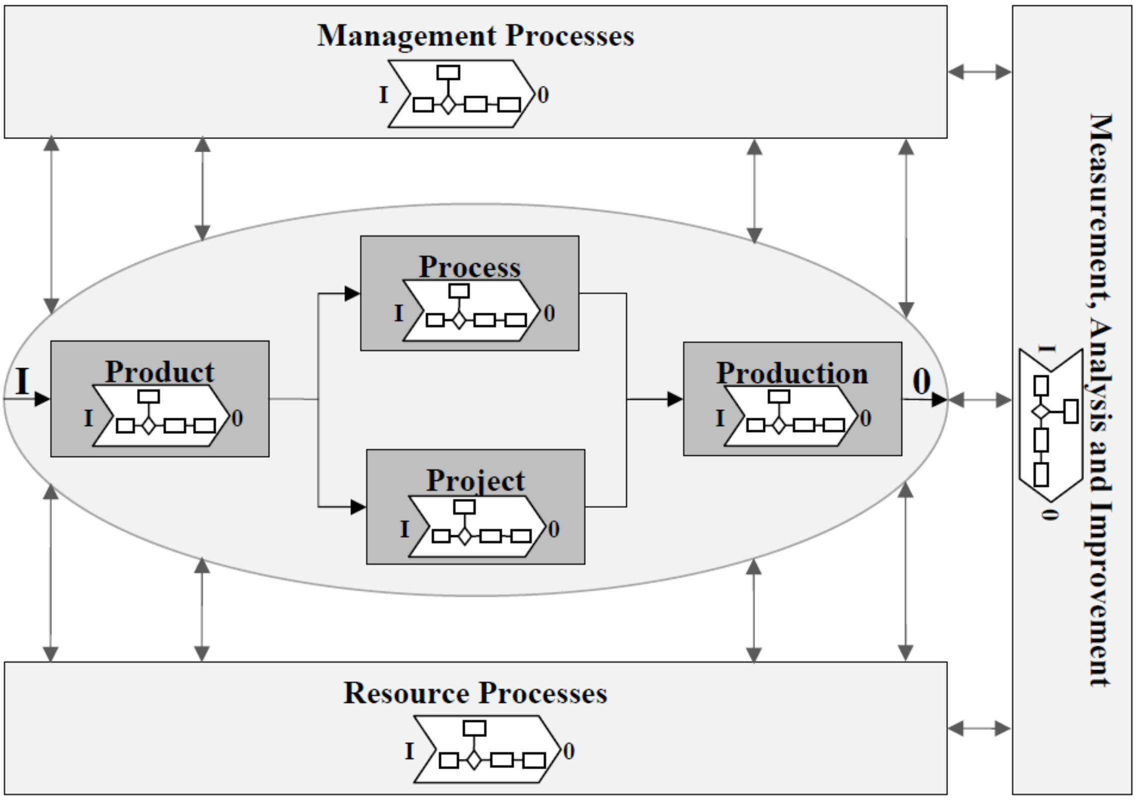

Figure 3.3 Example of a processes sequence and their interaction

The outputs from one process may be inputs to other processes and interlinked into the overall network or system. For generic examples, see Figure 3.3 [13].

The following implementation methodology can be applied to any type of process [13]. The step sequence (from a) to f)) is only one method and is not intended to be prescriptive. Some steps may be carried out simultaneously.

a) Identification of the processes of the organisation

Steps in the process approach	What to do?	Guidance
1. Define the purpose of the organisation.	The organisation should identify its customers and other interested parties as well as their requirements, needs and expectations to define the organisation's intended outputs.	Gather, analyse and determine customer and other interested parties requirements, and other needs and expectations. Communicate frequently with customers and other interested parties to ensure continual understanding of their requirements, needs and expectations. Determine the requirements for quality management, environmental management, occupational health and safety, management, business risk, social responsibilities and other management system disciplines that will be applied within the organisation.
2. Define the policies and the objectives of the organisation.	Based on analyses of the requirements, needs and expectations, establish the organisation's policies and objectives.	The top management should decide which markets the organisation should address and develop relevant policies. Based on these policies, the management should then establish objectives for the intended outputs (e.g., products, environmental performance, occupational health and safety performance).
3. Determine the processes needed in the organisation.	Identify all the processes that are needed to produce the intended outputs.	Determine the processes needed for achieving the intended outputs. These processes include management, resources, realisation and measurement and improvement. Identify all process inputs and outputs, along with the suppliers, customers and other interested parties (who may be internal or external).
4. Determine the sequence and the interaction of processes.	Determine how the processes flow in sequence and interaction.	Define and develop a description of the network of processes and their interaction. Consider the following: - the customer of each process; - the inputs and outputs of each process; - which processes are interacting; - interfaces and what are their characteristics; - timing and sequence of the interacting processes; - effectiveness and efficiency of the sequence. Methods and tools such as block diagrams, matrix and flowcharts can be used to support the development of process sequences and their interactions. Note: As an example, a realisation process that results in an output, such as product delivered to a customer, will interact with other processes (such as management, measurement and monitoring, and resource provision processes).
5. Define process ownership.	Assign responsibility and authority for each process.	The management should define individual roles and responsibilities for ensuring the implementation, maintenance and improvement of each process and its interactions. Such an individual is usually referred to as the 'process owner'. To manage process interactions, it may be useful to establish a 'process management team', that has an overview across all the processes, and which includes representatives from each of the interacting processes.

Steps in the process approach	What to do?	Guidance
6. Define process documentation.	Determine those processes that are to be documented and how.	Processes exist within the organisation and the initial approach should be limited to identifying and managing them in the most appropriate way. There is no 'catalogue', or list of processes, that have to be documented. The main purpose of documentation is to enable the consistent and stable operation of the processes. The organisation should determine which processes are to be documented, on the basis of: - the size of the organisation and its type of activities; - the complexity of its processes and their interactions; - the criticality of the processes; and - the availability of competent personnel. When it is necessary to document processes, a number of different methods can be used such as graphical representations, written instructions, checklists, flow charts, visual media, or electronic methods. Note: For more guidance, see the ISO 9000 Introduction and Support Package module 'Guidance on the Documentation Requirements of ISO 9001:2000'.

b) Planning of a process

Steps in the process approach	What to do?	Guidance
1. Define the activities within the process.	Determine the activities needed to achieve the intended outputs of the process.	Define the required inputs and outputs of the process. Determine the activities required to transform the inputs into the required outputs. Determine and define the sequence and interaction of the activities within the process. Determine how each activity will be performed. Note: In some cases, the customer may specify the way the process is to be performed.
2. Define the monitoring and measurement requirements.	Determine where and how measuring and monitoring should be applied. This should be both for control and improvement of the processes, as well as for the intended process outputs. Determine the need for recording results.	Identify the measures and monitoring criteria for process control and process performance, to determine the effectiveness and efficiency of the process, taking into account factors such as: - Conformity with requirements; - Customer satisfaction; - Supplier performance; - On time delivery; - Lead times; - Failure rates; - Waste; - Process costs; - Incident frequency.
3. Define the resources needed.	Determine the resources needed for the effective operation of each process.	Examples of resources include: - Human resources; - Infrastructure; - Work environment; - Information; - Natural resources; - Materials; - Financial resources.

Steps in the process approach	What to do?	Guidance
4. Verify the process and its activities against its planned objectives.	Confirm that the characteristics of the process and its activities are consistent with the purpose of the organisation.	Verify that all the requirements identified are satisfied. If not, consider what additional process activities are required and return to improve the process.

The first step of process definition is to identify the boundaries. This is where the process begins and ends. The beginning of a process starts with a trigger that causes a specific action to be taken by a person, another process, or work group. The ending occurs when the results get passed on to another person, process, or work group.

The beginning trigger starts when someone performs an action on an input that they receive from a supplier (another work group, vendor, or person). The input can be physical, such as raw material, parts, a person to be interviewed, etc., or information, such as a computer printout, request form, etc. The ending trigger is when the results of the process are passed on to the customer (another work group, person, or outside customer). The output can be physical, such as a television set, new hire, etc., or information, such as a typed letter, grant, etc.

Notice that every person at every level has two roles:

- The role of customer where they receive a trigger from a supplier (either external or internal).
- The role of supplier where they pass the result on to a customer (either external or internal).

Summarising can be said that the process definition lists what happens between the start and end points. It includes all the activities performed by each department, group, or person who are involved in the process. Activities are the major ‘works’ that transform an input into an output.

c) Implementation and measurement of the process

Implement the processes and their activities as planned. The organisation may develop a project for implementation that includes, but is not limited to:

- Communication;
- Awareness;
- Training;
- Change management;
- Management involvement;
- Applicable review activities.

Perform the measurements, monitoring and controls as planned.

d) Analysis of the process

Evaluate process data obtained from monitoring and measuring, in order to quantify process performance. Where appropriate, use statistical methods.

Compare the results of process performance measurements with the defined requirements of the process to confirm process effectiveness, efficiency and any need for corrective action.

Identify process improvement opportunities based on process performance data and report to the top management on the performance of the process, as appropriate.

e) Corrective action and improvement of the process

The method for implementing corrective actions should be defined, to eliminate the root causes of problems (examples of problems include errors, defects, lack of adequate process controls). Implement the corrective action and verify its effectiveness.

Once the planned process requirements are achieved, the organisation should focus its efforts on actions to improve process performance to higher levels, on a continual basis.

The method for improvement should be defined and implemented (examples of improvements include: process simplification, enhancement of efficiency, improvement of effectiveness, reduction of process cycle time). Verify the effectiveness of the improvement.

Risk analysis tools may be employed to identify potential problems. The root cause(s) of these potential problems should also be identified and corrected, preventing occurrence in all processes with similarly identified risks.

The PDCA methodology (Plan-Do-Check-Act) could be a useful tool to define, implement and control corrective actions, and improvements. The methodology applies equally to high-level strategic processes and to simple operational activities.

f) Documentation of the process and the system

A very important part of the management system is documentation of the system, needed for its running, effective planning, operation and control of its processes and the implementation and continual improvement of the effectiveness of the system. Documentation requirements for quality management system are described further and should be understood as an example and illustration of the system documentation extent for other systems.

General requirements in the ISO 9001:2000 require an organization to "establish, document, implement, and maintain a quality management system and continually improve its effectiveness in accordance with the requirements of this International Standard". The quality management system documentation *shall* include:

- documented statements of a quality policy and quality objectives;
- a quality manual;
- documented procedures required by this International Standard;
- documents needed by the organization to ensure the effective planning, operation and control of its processes;
- records required by this International Standard.

It is stressed that ISO 9001 requires a *"Documented quality management system"*, and not a "*system of documents"*.

3.2 Integrated management system

Together with growing complexity of relationships in society, management is no longer a single problem of individual managers and is becoming more and more multidisciplinary and interdisciplinary. In this context, it is necessary to take into account both partial aspects of the management process and the process as a whole. The approach resulting from the above mentioned bases is named as 'Integrated Management System' (IMS). The integrated management system introduces complex and sectional views of managing the firm. As being usual nowadays, it is based on process views both on core activities of the organisation (core processes) and on supporting processes including managerial processes.

Integrated management systems are designed to manage all management objectives, adopted standards and stakeholder requirements (including regulatory) via a single management system and should be synonymous with good management.

The integrated approach requires combining all the internal business management practices into one system. For the different systems to be properly integrated, rather than simply being separate systems joined together, there have to be effective linkages so that the boundaries between processes are seamless. An integrated management system embraces personnel, quality, health, safety, environment, security, financial, public relations, ethics, etc. Therefore, people, equipment and business (organisational) culture are part of the system as well as the documented policies and practices [14, 15].

An integrated management system is a management system which integrates several or all components of a business into one coherent system so as to enable all of the organisation's objectives to be achieved. Therefore, an integrated management system should integrate all currently formalised systems focusing on quality, health and safety, environment, personnel, finance, security, etc. What this means is that all the processes and the documents that describe them would be integrated.

The word 'integrated' suggests that you take discrete systems and somehow combine them. A number of differences and ambiguities have been identified in literature in the interpretation of what integration means and how it should be accomplished. In principle, there are at least two ways how the word 'integration' is understood:

1. in the area of system's certification;
2. in the area of managing the firm/company.

In the first area, "Integrated Management System" is called such managing system in organisation, regardless of size or sector, where two (e.g., quality and environmental management) or three (quality, environmental, occupational health and safety management) of their management systems are integrated into one holistic set of documentation, policies, procedures and processes. The list is not finite and the range of standards incorporated into the integrated management system may vary. There is a move towards 'integrating' management systems, especially when a company is seeking combined certification against more than one external standard, based on an external assessment of a single system description.

In the second area, an "Integrated Management System" embraces personnel, quality, health, safety, and environment, security, finance, public relations, ethics, etc., and any system, which is required by the effective running of a business, can be integrated either totally or partially under a unified management structure.

For something to be integrated it does not just sit next to the other components – it has to be fixed to the others so as to make a whole. Therefore, putting the financial system, the quality system and the environmental and safety system into one book of policies and procedures is not enough. It does not constitute an integrated management system. Creating one national standard for management systems is not integration either. Buying a software package which handles quality, safety and environmental documentation is not integration, nor is merging disciplines such as putting the quality manager, safety manager and environmental manager in one department. Integrated management is a concept whereby functional management is dispersed throughout an organisation so that managers manage a range of functions together. As an example, it may be a manufacturing manager who manages planning, manufacturing, safety, personnel, quality, environment, finance, etc., as one package [9].

Integration is designed:

- to ensure focus on business goals and objectives;
- to harmonise and optimise practices;
- to reduce risks to the business and increase profitability;
- to balance conflicting objectives;
- to eliminate conflicting responsibilities and relationships;
- to create consistency;
- to reduce duplication and therefore costs;
- to improve communications;
- to facilitate training and development.

There are several good reasons for integration:

- to reduce duplication and therefore costs;
- to diffuse the power system;
- to turn the focus onto business goals;
- to formalise informal systems;
- to harmonise and optimise practices.

Integrated management systems use less resource and if properly designed are more effective than fragmented management systems. The following have been identified as key advantages of integrated management and integrated management systems:

- More concise minimalist management system with all aspects adding value without redundancy.
- Enhanced communication through simplicity and uniformity.
- Easier compliance, less violations, greater employee participation and ownership leading to reduced stress and better utilisation of creativity.
- Better quality/risk issues conflict resolution and management.
- Enhanced stakeholder understanding and satisfaction.
- Accelerated training and reduction in training needs.
- Reduced monitoring (audits/inspections) including certification surveillance.
- Improved management and process transparency leading to more efficient and effective management review and action planning.
- Faster change dynamics supporting optimal organisational evolution.
- Better implementation and return from initiatives such as the business excellence model or Total Quality Management.

3.3 Decommissioning activities/tasks and their characteristics

"Decommissioning", when applied in its broadest sense to nuclear facilities, covers all of the administrative and technical actions associated with cessation of operation and withdrawal from service and it is the final phase in their lifecycle after siting, design, construction, commissioning and operation. The purpose of these actions (activities and tasks) is to allow removal of some or all of the regulatory controls that apply to the nuclear facility while securing the long-term safety of the public and the environment, and continuing to protect the health and safety of decommissioning workers in the process. Decommissioning is a complex process involving operations and activities connected with detailed surveys, decontamination and dismantling of plant, equipment and facilities, demolition of buildings and structures, site remediation, management of resulting waste and other materials. All activities take place under a regulatory framework that takes into account the importance of the health and safety of the operating staff, the general public and protection of the environment.

The reported experience demonstrates that careful planning and management is essential in ensuring that decommissioning of nuclear facilities is accomplished in a safe and cost-effective manner. On the other side it has been noted on several occasions that the major weakness in decommissioning projects is poor or inadequate planning and management, including unclear identification of roles and responsibilities.

In order to be aware of actions complexity and diversity, activities and tasks to be performed and managed for decommissioning are shortly (not exhaustive) described further. The main issues are:

- *Safety*: It comprises radiation safety, (measurement and inventory of personnel doses, radiological surveys, monitoring of personnel, systems and materials), industrial safety, protection of personnel, environment and population, safety assessment (development of a safety case), ensuring security and physical protection.
- *Procedures, processes and operations directly related to decommissioning (comprising planning and implementation of plans)*: detailed radiological and physical characterisation, decontamination, dismantling, material and radioactive and non-radioactive waste management including the clearance process and logistics (transport of materials within and outside of the facility), demolition and site clean-up.
- *Technical support*: repair, maintenance, engineering.
- *Licensing and regulatory aspects*: including licence termination.
- *Administrative support and services*: organisation and management, provision of resources (finance, equipment, people), contracts and procurement, human resources management, control and management of documents, records and information, managing of change (organisation, configuration), knowledge management, quality assurance, accounting and finance, interfaces, work permits, emergency planning, fire protection, information technology.
- *Project management (by owner and contractors)*: management of scope, time, cost, quality, human and other resources, communication, risk, procurement, information system.

Processes that have to be applied to perform the above mentioned actions safely and cost effectively will be described in Section 4.

4. Generic model for an integrated management/planning system

4.1 Requirements for the planning of decommissioning activities

Decommissioning activities should be performed with an optimised approach to achieving a progressive and systematic reduction in radiological hazards, and are undertaken on the basis of planning and assessment to ensure the safety of workers and the public and protection of the environment, both during and after the decommissioning operations. Decommissioning can be facilitated by planning and preparatory work undertaken during the entire lifetime of the nuclear installation. These actions are intended to minimise the eventual occupational and environmental impacts which can occur during the active and passive processes undertaken during decommissioning.

General experience has shown that there are a number of planning, management and operational issues facing management which ideally require attention some years before a plant is finally shut down. Several of these, as listed below, were selected based on this experience:

- Stakeholder issues including staff and public relations;
- Regulatory and licensing issues including Environmental Impact Assessment;
- Organisational restructuring;
- Decommissioning plans and technology;
- Training and retraining;
- Defueling and fuel management;
- Waste management and disposal;
- Funding and finance;
- Project strategy, planning and contracting;
- Records and documentation.

It is extremely important to appoint a decommissioning manager and preferably to do this before the plant is shut down. This manager would have the responsibility for undertaking the development of an adequate decommissioning plan. The manager need not necessarily have direct experience in the operation and maintenance of the plant. Sometimes formulating this plan can be the responsibility of a central company headquarters department, if this exists, or undertaken by engaging specialist consultants or contractors.

An appropriate organisational structure is needed for the decommissioning task force in order to identify lines of responsibility and to allow individual responsibilities to be defined. At an appropriate time, the decommissioning organisation must be merged or replace the existing operational structure which will eventually cease to exist. At a site where there is a plant that is to be shutdown while some others remain in operation, it is vital to clarify the demarcation between operational and decommissioning responsibilities.

In changing an organisation from an operating regime to decommissioning, there is a need for cultural change. This can be achieved by retraining in-house staff, extensive use of experienced contractors or, even more drastically, by changing the ownership/licensee of the facility to one specifically created for decommissioning.

Decommissioning can be divided into preparatory and implementation phases:

- Preparations for decommissioning include the development of a decommissioning strategy, initial and ongoing decommissioning planning (with periodical updating during operation of a facility) and radiological characterisation of the facility, preparation of a final decommissioning plan and its submission to the regulatory body for authorisation or approval.

- Implementation of decommissioning includes management of the project and execution of the decommissioning plan, management of the waste and demonstration that the site meets the end state criteria defined in the plan.

The basic safety requirements that must be satisfied during the planning and implementation of decommissioning for the termination of practices and for the release of facilities from regulatory control are given here from publications [6, 16]. These publications address the radiological hazards resulting from decommissioning activities, general requirements and guidelines.

Non-radiological hazards, such as industrial hazards or hazards due to chemical waste, can also be significant during decommissioning. These issues shall be given due consideration during the planning and implementation process, in the safety assessments and environmental assessments, and in the estimation of costs and the provision of finance for the decommissioning project.

Each country where organisations use, possess, store or handle radioactive material shall include provisions in its national legal framework for decommissioning where the requirements are specified for the whole process as for the submission time, contents and scope of documents for applications and approvals, etc. All phases of decommissioning, from the initial plan to the final release of the facility from regulatory control, shall be regulated.

The responsible organisation shall implement planning for decommissioning and shall carry out the decommissioning activities in compliance with the national safety standards and requirements and shall also be responsible for all aspects of safety and environmental protection during the decommissioning activities.

The responsible organisation shall provide financial assurances and resources to cover the costs associated with safe decommissioning, including management of the resulting radioactive waste.

The responsible organisation shall define a decommissioning strategy on which the planning for decommissioning will be based. The strategy shall be consistent with the national decommissioning and waste management policy. The decommissioning strategy shall include provisions to ensure that, if final shutdown occurs before a final decommissioning plan is prepared, adequate arrangements are provided to ensure the safety of the facility until a satisfactory decommissioning plan can be prepared and implemented. An evaluation of the various decommissioning options should be performed by considering a wide range of issues, with special emphasis on the balance between the safety requirements and the resources available at the time of implementing decommissioning. Cost-benefit or multi-attribute type analyses provide systematic means for such an evaluation. These analyses should utilise realistic estimates of both costs and radiation doses. Herewith it should be ensured that the selected option meets all the applicable safety requirements.

The responsible organisation shall prepare and maintain a decommissioning plan throughout the lifetime of the facility, unless otherwise approved by the regulatory body, in order to show that the decommissioning can be accomplished safely to meet the defined end state.

The decommissioning plan shall be supported by an appropriate safety assessment covering the planned decommissioning activities and abnormal events that may occur during decommissioning. The assessment shall address occupational exposures and potential releases of radioactive substances with resulting exposure of the public.

A graded approach shall be applied to the development of the decommissioning plan. The type of information and the level of detail in the plan shall be commensurate with the type and status of the facility and the hazards associated with the decommissioning of the facility.

For new facilities, consideration of decommissioning shall begin early in the design stage and shall continue through to the termination of the practice or the final release of the facility from regulatory control. The regulatory body shall ensure that operators take into account eventual decommissioning activities in the design, construction and operation of the facility, including features to facilitate decommissioning, the maintenance of records of the facility, and consideration of physical and procedural methods to prevent the spread of contamination.

Four stages of planning are envisaged: initial, ongoing, for licensing and for project implementation. For a given reactor, the degree of detail will increase from the initial to the final decommissioning plan. This planning process will result in the production of a decommissioning plan.

Planning is envisaged for the:

1. Construction of a facility – initial planning.
2. Operations of the facility – conceptual – ongoing.
3. Licensing purposes – to obtain licensing for decommissioning.
4. Projects for implementation, including de-licensing of the site.

4.1.1 Planning for decommissioning before construction

A first/initial plan for decommissioning should be prepared and submitted by the responsible organisation in support of the licence application for the construction of a new reactor. Although the level of detail in the first plan will necessarily be lower than that in the final decommissioning plan, many of the aspects listed in the final plan should be considered in a conceptual fashion. A generic study showing the feasibility of decommissioning may suffice for this plan, particularly in standardised installations. Depending on applicable regulations, the plan should address the costs and the means of financing the decommissioning work.

4.1.2 Planning for decommissioning during operations

The responsible organisation shall prepare and submit to the regulatory body a conceptual decommissioning plan together with the application for authorisation to operate the facility. This decommissioning plan is necessary to ensure that sufficient funds will be available for decommissioning, to facilitate early planning for minimisation of the need for decontamination, and to provide for early acquisition and maintenance of records important for decommissioning.

This conceptual plan shall be reviewed, updated periodically, at least every five years or as prescribed by the regulatory body, or when specific circumstances warrant, such as if changes in an operational process, lead to significant changes to the plan. It should be made more comprehensive with respect to technological developments in decommissioning, incidents that may have occurred, including abnormal events, amendments in regulations and government policy, and, where applicable, cost estimates and financial provisions. The decommissioning plan should evolve with respect to safety considerations, based on operational experience and on information reflecting improved technology. All significant systems and structural changes during plant operation should be reflected in the process of ongoing planning for decommissioning. Revisions or amendments shall also be made as necessary in the light of operational experience gained, new or revised safety requirements or technological developments. If an incident or accident occurs, the decommissioning plan shall be reviewed as soon as possible and modified as necessary.

4.1.3 Planning for licensing of decommissioning

When the timing of the final shutdown of a nuclear reactor is known, the responsible organisation should initiate detailed studies and finalise proposals for decommissioning. Following this, the responsible organisation should submit an application containing the final decommissioning plan for review and approval by the regulatory body. The decommissioning plan may require amendments or further refinements as decommissioning proceeds, and may require further regulatory approval.

If the selected decommissioning option results in phased decommissioning with significant periods of time between phases, a higher level of detail for items identified in the following section may be required for the next phase being executed. As a result of executing an individual phase of the decommissioning, some modification to the planning for subsequent phases may be needed. In such cases, subsequent sections of the decommissioning plan may require updating and reviewing.

This plan shall define how the project will be managed, including: the site management plan, the roles and responsibilities of the organisations involved, safety and radiation protection measures, quality assurance, a waste management plan, documentation and record keeping requirements, a safety assessment and an environmental assessment and their criteria, surveillance measures during the implementation phase, physical protection measures as required, and any other requirements established by the regulatory body of the country.

The following list of items (detailed requirements are subject of legislative) have to be considered for the final decommissioning plan:

- a description of the nuclear facility, the site and the surrounding area that could affect, and be affected by, decommissioning;
- the life history of the nuclear facility, reasons for taking it out of service, and the planned use of the nuclear installation and the site during and after decommissioning;
- a description of the legal and regulatory framework within which decommissioning will be carried out;
- explicit requirements for appropriate radiological criteria for guiding decommissioning;
- a description of the proposed decommissioning activities, including a time schedule;
- the rationale for the preferred decommissioning option, if selected;
- safety assessments and environmental impact assessments, including the radiological and non-radiological hazards to workers, the public and the environment; this will include a description of the proposed radiation protection procedures to be used during decommissioning;
- a description of the proposed environmental monitoring programme to be implemented during decommissioning;
- a description of the experience, resources, responsibilities and structure of the decommissioning organisation, including the technical qualification/skills of the staff;
- an assessment of the availability of special services, engineering and decommissioning techniques required, including any decontamination, dismantling and cutting technologies as well as remotely operated equipment needed to complete decommissioning safely;
- a description of the quality assurance programme;
- an assessment of the amount, type and location of residual radioactive and hazardous non-radioactive materials in the nuclear reactor installation, including calculation methods and measurements used to determine the inventory of each;
- a description of the waste management practices, including items such as:
    1. identification and characterisation of sources, types and volumes of waste;
    2. criteria for segregating materials;
    3. proposed treatment, conditioning, transport, storage and disposal methods;

4. the potential to reuse and recycle materials, and related criteria; and

5. anticipated discharges of radioactive and hazardous non-radioactive materials to the environment;

- a description of other applicable important technical and administrative considerations such as safeguards, physical security arrangements and details of emergency preparedness;
- a description of the monitoring programme, equipment and methods to be used to verify that the site will comply with the release criteria;
- details of the estimated cost of decommissioning, including waste management, and the source of funds required to carry out the work; and
- a provision for performing a final confirmatory radiological survey at the end of decommissioning.

During the preparation of the final decommissioning plan, the extent and type of radioactive material (irradiated and contaminated structures and components) at the facility shall be determined by means of a detailed characterisation survey and on the basis of records collected during the operational period. If nuclear material or operational waste remains at the facility, this radioactive material shall be included in the characterisation survey.

The methodology and criteria that the operating organisation will use to demonstrate that the proposed end state has been achieved shall be stated in the decommissioning plan.

Interested parties shall be provided with an opportunity to review the final decommissioning plan and to provide comments on the plan to the regulatory body prior to its approval.

4.1.4 Planning for the implementation of decommissioning

While the decommissioning plan and safety and environmental assessment are being reviewed by regulatory bodies, detailed planning and engineering can begin. As soon as detailed data are made available from the radioactive inventory of the nuclear facility and the site characterisation programme, decisions on the handling of components, structures and soil can be made [17].

Multiple levels of planning documents are usually prepared. A hierarchical work breakdown structure is developed which divides the work into manageable packages, which identify what is to be done and how, and addresses the basic safety considerations of the activity. Another level of documents are the detailed work procedures.

The work packages identify the purpose and the description of the task, applicable criteria and the activity sequence of events. The criteria include engineering and technical requirements; health, safety and environmental protection requirements; and reference to applicable standards. Work packages refer to other documents such as radiological health and safety manual, waste management manual, security plan, quality assurance programme, fire protection programme, etc.

The detailed work procedures identify the step-by-step instructions to perform each task, the required equipment and associated operating parameters (cutting speeds, gas pressures, power requirements, etc.), safety precautions and disposal methods, as applicable. Detailed work procedures are general or specific work procedures. General work procedures are used for repetitive activities such as the construction of contamination control tents, rigging and lifting, pipe cutting methods and maintenance of filtered equipment (HEPA vacuum cleaners, ventilation units, liquid filtration systems, etc.). Specific work procedures apply only to unique tasks such as core dismantling activities or asbestos removal, where general work procedures cannot be fully applied.

As the work packages and detailed work procedures are developed, the baseline cost estimate, schedule and personnel radiological exposure estimates are refined. These can then become the guidelines against which the project performance is measured.

The decommissioning plan will identify and justify the decommissioning work activities. However, before work commences, work packages are developed for these activities and analysed in sufficient detail to allow the decommissioning team to execute the work with a clear understanding and without the need for further significant explanation. The packages are arranged into interrelated groups, and a schedule of activities usually represented by a bar or Gantt chart would be prepared.

Formal project management techniques are applied to the creation and management of work packages. A critical path network, i.e., a diagram indicating the sequences and the interdependences of the various work packages may be used. The work packages are planned as soon as possible because such planning greatly assists in the development of detailed cost estimates and the identification of specialist support and equipment that may be needed. Without this level of planning it is difficult to schedule the decommissioning of a large nuclear facility with any degree of certainty.

Procedures for allocating work packages to the decommissioning team are developed. Work monitoring arrangements are set up so that the project management schedule can be re-evaluated when unexpected circumstances arise. The decommissioning project manager holds periodic formal review meetings with all supervisors and safety staff to assess work done, current status of the facility and future tasks. Each member of the team would then be aware of what is to be done next in other parts of the programme and in other related activities.

From the formal project meetings, progress reports including revised cost estimates are prepared periodically and are presented to the regulatory body, licensee and other authorities, as required, including the organisation providing the funds.

Contractors are used for a wide variety of tasks. These contractors need careful management by the licensee to ensure that the licensee retains control of intellectual property and assets remain available to the licensee. If the contractor is replaced, a proper hand-over is arranged so that the new contractor’s staff is trained to be suitably qualified and experienced when they take over.

The licensee has the responsibility for ensuring that contractors achieve the required quality, although contractors are responsible for the quality of their own work. Once their detailed work plan is approved by the licensee, this assurance is achieved by a programme of surveillance and inspections.

4.2 Integrated management system requirements

The IAEA Safety Requirements publication [1] defines the requirements for establishing, implementing, assessing and continually improving a management system. The management system is understood as a set of interrelated or interacting elements that establishes policies and objectives and which enables those objectives to be achieved in a safe, efficient and effective manner. A management system designed to fulfil these requirements integrates safety, health, environmental, security, quality and economic elements; however, safety is the fundamental principle upon which the management system is based. These requirements must be met to ensure the protection of people and the environment. The main objective of the requirements for the management system is to ensure, by considering the implications of all actions not within separate management systems but with regard to safety as a whole, that safety is not compromised. These requirements are applicable throughout the lifetime of facilities, including decommissioning as the last phase of the lifetime of a nuclear facility, and for the entire duration of activities in normal, transient and emergency situations. This includes any subsequent period of institutional control that may be necessary.

The integrated management system requirements defined in the following sections cover topics that either directly relate to safety or are part of the managerial framework without which safety cannot be ensured and maintained. Thus, topics such as management commitment, communications and other aspects are included from the perspective of seeking to enhance safety as well as performance.

4.2.1 Background

The standards of the International Organisation for Standardisation on environmental management systems and on quality management systems were considered in developing the requirements [1] as well as the experience of the IAEA Member States in developing, implementing and improving management systems. An IAEA Safety Guide in support of these requirements provides generic guidance on the application of the management system for all facilities and activities and for their regulation [2]. In addition to the generic guidance, there are several specific IAEA Safety Guides that provide additional guidance on implementing these requirements in specific areas of decommissioning. The term management system reflects and includes the initial concept of 'quality control' (controlling the quality of products) and its evolution through quality assurance (the system to ensure the quality of products) and 'quality management' (the system to manage quality).

The requirements are based on two key concepts:

1. work may be structured and interpreted as a set of interacting processes;
2. all individuals involved contribute to achieving safety and quality objectives.

The objective of the requirements for establishing, documenting, implementing, assessing and continually improving a management system that integrates safety, health, environmental, security, quality and economic elements is to ensure that safety is properly taken into account in all the activities of an organisation and to ensure that safety is not compromised, by considering the implications of all actions not within separate management systems but with regard to safety as a whole.

These safety requirements comprise requirements:

1. for the management system, including those relating to safety culture, grading and documentation;
2. for the responsibilities of the senior management for the development and implementation of the management system;
3. for the resource management;
4. for the processes of the organisation including their specification, development and management and for the generic processes of the management system; and
5. for the measurement, assessment and improvement of the management system.

4.2.2 Management system

4.2.2.1 General requirements

A management system shall be established, implemented, assessed and continually improved. It shall be aligned with the goals of the organisation and shall contribute to their achievement. The main aim of the management system shall be to achieve and enhance safety by:

1. bringing together in a coherent manner all the requirements for managing the organisation;
2. describing the planned and systematic actions necessary to provide adequate confidence that all these requirements are satisfied;

3. ensuring that health, environmental, security, quality and economic requirements are not considered separately from safety requirements, to help preclude their possible negative impact on safety.

The management system shall identify and integrate with the requirements contained within further documents such as are:

- the statutory and regulatory requirements of the given country;
- any requirements formally agreed with interested parties (also known as ‘stakeholders’);
- all other relevant IAEA and EU Safety Requirements publications, such as those on emergency preparedness and response and safety assessment;
- requirements from other relevant codes and standards adopted for use by the organisation.

The organisation shall be able to demonstrate the effective fulfilment of its management system requirements.

4.2.2.2 Safety culture

The management system shall be used to promote and support a strong safety culture by:

- ensuring a common understanding of the key aspects of safety culture within the organisation;
- providing the means by which the organisation supports individuals and teams in carrying out their tasks safely and successfully, taking into account the interaction between individuals, technology and the organisation;
- reinforcing a learning and questioning attitude at all levels of the organisation;
- providing the means by which the organisation continually seeks to develop and improve its safety culture.

4.2.2.3 Grading the application of management system requirements

The application of management system requirements shall be graded so as to deploy appropriate resources for the decommissioning of a nuclear facility, on the basis of the consideration of:

- the significance and complexity of each product or activity in the frame of decommissioning;
- the hazards and the magnitude of the potential impact (risks) associated with the safety, health, environmental, security, quality and economic elements of each product or activity during decommissioning;
- the possible consequences if a product fails or an activity is carried out incorrectly.

Grading of the application of management system requirements shall be applied to the products and activities of each process related to decommissioning.

4.2.2.4 Documentation of the management system

The documentation of the management system shall include at least the following:

- the policy statements of the organisation;
- a description of the management system (manual);
- a description of the structure of the organisation;

- a description of the functional responsibilities, accountabilities, levels of authority and interactions of those managing, performing and assessing work;
- a description of the processes and supporting information that explain how work is to be prepared, reviewed, carried out, recorded, assessed and improved.

The documentation of the management system shall be developed to be understandable to those who use it and documents shall be readable, readily identifiable and available at the point of use.

4.2.3 Management responsibility

4.2.3.1 Management commitment

The management at all levels shall demonstrate its commitment to the establishment, implementation, assessment and continual improvement of the management system and shall allocate adequate resources to carry out these activities.

The senior management shall develop individual values, institutional values and behavioural expectations for the organisation to support the implementation of the management system and shall act as role models in the promulgation of these values and expectations.

The management at all levels shall communicate to individuals the need to adopt these individual values, institutional values and behavioural expectations as well as to comply with the requirements of the management system.

The management at all levels shall foster the involvement of all individuals in the implementation and continual improvement of the management system.

The senior management shall ensure that it is clear when, how and by whom decisions are to be made within the management system.

4.2.3.2 Satisfaction of interested parties

The expectations of interested parties shall be considered by the senior management in the activities and interactions in the processes of the management system, with the aim of enhancing the satisfaction of interested parties while at the same time ensuring that safety is not compromised.

4.2.3.3 Organisational policies

The senior management shall develop the policies of the organisation. The policies shall be appropriate to the activities and facilities of the organisation.

4.2.3.4 Planning

The senior management shall establish goals, strategies, plans and objectives that are consistent with the policies of the organisation.

The senior management shall develop the goals, strategies, plans and objectives of the organisation in an integrated manner so that their collective impact on safety is understood and managed.

The senior management shall ensure that measurable objectives for implementing the goals, strategies and plans are established through appropriate processes at various levels in the organisation.

The senior management shall ensure that the implementation of the plans is regularly reviewed against these objectives and that actions are taken to address deviations from the plans where necessary.

4.2.3.5 Responsibility and authority for the management system

The senior management shall be ultimately responsible for the management system and shall ensure that it is established, implemented, assessed and continually improved.

An individual reporting directly to the senior management shall have specific responsibility and authority for:

- coordinating the development and the implementation of the management system, and its assessment and continual improvement;
- reporting on the performance of the management system, including its influence on safety and safety culture, and any need for improvement;
- resolving any potential conflicts between requirements and within the processes of the management system.

The organisation shall retain overall responsibility for the management system when an external organisation is involved in the work of developing all or part of the management system.

4.2.4 Resource management

4.2.4.1 Provision of resources

The senior management shall determine the amount of resources necessary and shall provide the resources to carry out the activities of the organisation and to establish, implement, assess and continually improve the management system. Under resources are understood individuals, infrastructure, the working environment, information and knowledge, and suppliers, as well as material and financial resources.

The information and knowledge of the organisation shall be managed as a resource.

4.2.4.2 Human resources

The senior management shall determine the competence requirements for individuals at all levels and shall provide training or take other actions to achieve the required level of competence. An evaluation of the effectiveness of the actions taken shall be conducted. Suitable proficiency shall be achieved and maintained.

The senior management shall ensure that individuals are competent to perform their assigned work and that they understand the consequences for safety of their activities. Individuals shall have received appropriate education and training, and shall have acquired suitable skills, knowledge and experience to ensure their competence. Training shall ensure that individuals are aware of the relevance and importance of their activities and of how their activities contribute to safety in the achievement of the organisation's objectives.

4.2.4.3 Infrastructure and the working environment

The senior management shall determine, provide, maintain and re-evaluate the infrastructure and the working environment necessary for work to be carried out in a safe manner and for requirements to be met.

4.2.5 Process implementation

4.2.5.1 Developing processes

The processes of the management system that are needed to achieve the goals, provide the means to meet all requirements and deliver the products of the organisation, shall be identified and their development shall be planned, implemented, assessed and continually improved.

The sequence and interactions of the processes shall be determined and the methods necessary to ensure the effectiveness of both the implementation and the control of the processes shall be determined and implemented.

The development of each process shall ensure that the following are achieved:

- Process requirements, such as applicable regulatory, statutory, legal, safety, health, environmental, security, quality and economic requirements, are specified and addressed.
- Hazards and risks are identified, together with any necessary mitigation actions.
- Interactions with interfacing processes are identified.
- Process inputs are identified.
- The process flow is described.
- Process outputs (products) are identified.
- Process measurement criteria are established.

The activities of and interfaces between different individuals or groups involved in a single process shall be planned, controlled and managed in a manner that ensures effective communication and the clear assignment of responsibilities.

4.2.5.2 Process management

For each process a designated individual shall be given the authority and responsibility for:

- developing and documenting the process and maintaining the necessary supporting documentation;
- ensuring that there is effective interaction between interfacing processes;
- ensuring that process documentation is consistent with any existing documents;
- ensuring that the records required to demonstrate that the process results have been achieved are specified in the process documentation;
- monitoring and reporting on the performance of the process;
- promoting improvement in the process;
- ensuring that the process, including any subsequent changes to it, is aligned with the goals, strategies, plans and objectives of the organisation.

For each process, any activities for inspection, testing, verification and validation, their acceptance criteria and the responsibilities for carrying out these activities shall be specified. For each process, it shall be specified if and when these activities are to be performed by designated individuals or groups other than those who originally performed the work.

Each process shall be evaluated to ensure that it remains effective.

The work performed in each process shall be carried out under controlled conditions, by using approved current procedures, instructions, drawings or other appropriate means that are periodically reviewed to ensure their adequacy and effectiveness. Results shall be compared with expected values.

The control of processes contracted to external organisations shall be identified within the management system. The organisation shall retain overall responsibility when contracting any processes.

4.2.5.3 Generic management system processes

The following generic processes shall be developed in the management system:

- *Control of documents:*

  Documents, which may include policies; procedures when documented; instructions; specifications; drawings; training materials; and any other texts that describe processes, specify requirements or establish product specifications shall be controlled. All individuals involved in preparing, revising, reviewing or approving documents shall be specifically assigned this work, shall be competent to carry it out and shall be given access to appropriate information on which to base their input or decisions. It shall be ensured that document users are aware of and use appropriate and correct documents.

  Changes to documents shall be reviewed and recorded and shall be subject to the same level of approval as the documents themselves.

- *Control of products:*

  Specifications and requirements for products, including any subsequent changes, shall be in accordance with established standards and shall incorporate applicable requirements. Products that interface or interact with each other shall be identified and controlled.

  Activities for inspection, testing, verification and validation shall be completed before the acceptance, implementation or operational use of products. The tools and equipment used for these activities shall be of the proper range, type, accuracy and precision.

  The organisation shall confirm that products meet the specified requirements and shall ensure that products perform satisfactorily in service.

  Products shall be provided in such a form that it can be verified that they satisfy the requirements.

  Controls shall be used to ensure that products do not bypass the required verification activities.

  Products shall be identified to ensure their proper use. Where traceability is a requirement, the organisation shall control and record the unique identification of the product.

  Products shall be handled, transported, stored, maintained and operated as specified, to prevent their damage, loss, deterioration or inadvertent use.

- *Control of records:*

  Records shall be specified in the process documentation and shall be controlled. All records shall be readable, complete, identifiable and easily retrievable.

  Retention times of records and associated test materials and specimens shall be established to be consistent with the statutory requirements and knowledge management obligations of the organisation. The media used for records shall be such as to ensure that the records are readable for the duration of the retention times specified for each record.

- *Purchasing:*

  Suppliers of products shall be selected on the basis of specified criteria and their performance shall be evaluated.

  Purchasing requirements shall be developed and specified in procurement documents. Evidence that products meet these requirements shall be available to the organisation before the product is used.

Requirements for the reporting and resolution of non-conformances shall be specified in procurement documents.

- *Communication:*

  Information relevant to safety, health, environmental, security, quality and economic goals shall be communicated to individuals in the organisation and, where necessary, to other interested parties.

  Internal communication concerning the implementation and effectiveness of the management system shall take place between the various levels and functions of the organisation.

- *Managing organisational change:*

  Organisational changes shall be evaluated and classified according to their importance to safety and each change shall be justified.

  The implementation of such changes shall be planned, controlled, communicated, monitored, tracked and recorded to ensure that safety is not compromised.

4.2.5.4 Processes common to all stages including those specific to decommissioning

The following processes are common to all stages of a nuclear facility. These processes are not explicitly mentioned in the requirements [1] but they are given in a draft of a new guidance [18]. The applicability of the guidance should be utilised by the facility taking into account the decommissioning stage of the nuclear facility, the organisation size and structure and the nature of the activities to be carried out:

- *Project management:*

  Project management is the conduct of delivering a project in accordance with its agreed scope, schedule, cost and quality requirements, dealing with all the challenges and risks encountered from its pre-planning phase to completion. This is achieved by performing a variety of tasks in a planned sequence and deploying resources effectively and efficiently.

- *Work planning and control:*

  The work planning and control process is utilised during design, construction, commissioning, operation and decommissioning and therefore it should ensure that work at the nuclear facility is properly planned and completed in a safe and efficient manner. The work planning and control process should list and be able to sort all work requests on the basis of work description, priority assigned, date initiated and configuration requirements to perform the work. The system should be able to track the status of all work requests, in particular those on hold for planning, spare parts, materials or other constraints. The system should be capable of tracking completion of testing prior to return to service.

- *Workplace risk assessment:*

  In addition to the risk assessments carried out during the planning and control process, workplace risk assessments (sometimes referred to as ‘point of work’ risk assessments) should be required for all activities carried out by the facility’s individuals and by contractors’ individuals that may pose a particular risk of injury, harm or damage.

- *Personnel safety:*

  * *Industrial safety:*

    A process reflecting the country’s industrial safety regulations should be established for all individuals, suppliers and visitors, and should refer to the industrial safety rules and practices that are to be adopted. The process should include arrangements for the effective planning, organisation, monitoring and review of the preventive and protective measures.

The operating organisation should provide support, guidance and assistance for facility individuals in the area of industrial safety.

  * *Radiological safety:*

    A process should be established and implemented for radiological safety for each working group, area and activity to ensure that radiation exposure is as low as is reasonably achievable.

- *Control and supervision of contractors:*

  A process should be developed to control and supervise contractors carrying out work at a nuclear facility. Contractors should perform work under the same controls as, and to the same working standards as, nuclear facility individuals.

- *Design:*

  The design process requires the use of sound engineering/scientific principles and appropriate design standards. The design process should take into account the guidance provided in the series of IAEA safety guides on design of nuclear power plants.

- *Configuration management:*

  Configuration management is a process of identifying and documenting the characteristics of a facility's structures, systems and components (including computer systems and software), and of ensuring that consistency is maintained between the design requirements, physical configuration and facility configuration documentation. The configuration management process should ensure this consistency and is fundamental to safe operation. For example, after maintenance is carried out, the plant, systems and components should be returned strictly to their design configuration.

  Configuration management recognises that there are three elements, which should be in equilibrium: design requirements, facility configuration documentation, and physical configuration.

- *Plant modification:*

  A process should be established and implemented to control modifications to the systems, structures and components. Additional guidance is given in references [19] and [20].

- *Maintenance:*

  A process should be established and implemented for the maintenance of the systems, structures and components of the facility. Additional guidance is given in reference [20].

- *Housekeeping and cleanliness:*

  Maintaining housekeeping and cleanliness should be considered an essential process to provide a clean workplace and to encourage a high standard of workmanship. The process should establish, maintain and enforce standards for housekeeping and cleanliness.

- *Handling and storage:*

  The process of handling and storage should ensure that only correct items are used in the nuclear facility. For this purpose, items should be identified. Physical identification should be used to the extent possible and the identification should be transferred to each part of an item before it is subdivided.

Provisions should be made to prevent the damage, deterioration or loss of items. For this purpose, items should be stored in a manner that provides for ready retrieval and protection. Storage should be controlled to prevent deterioration of degradable material.

- *Inventory management:*

  The process for inventory management should be designed so that spares and other consumable items are available when required to ensure that safety is not compromised. The facility should first establish an inventory register and ensure that the procurement process is aligned to maintain stocks at an acceptable level.

- *Identification and labelling of systems, structures and components:*

  A process should be established and implemented to ensure systems, structures and components are uniquely and permanently labelled to provide individuals with sufficient information to positively identify them.

- *Waste management:*

  The generation of radioactive waste during operation and decommissioning should be minimised and provisions made for the safe handling, storage, transport and disposal of radioactive waste liquids, solids and gases. Additional requirements are indicated in reference [21].

- *Environmental management:*

  The facility should develop a process for the management of the environmental aspects of its activities, products or services that should be controlled in order to avoid a significant negative impact on the environment.

- *Regulatory interface:*

  The facility's management system should establish a process by which regulatory and statutory requirements are clearly described and met. The facility should also ensure that interface arrangements are established with all relevant regulatory bodies. For example, this would include meetings (types, frequency, terms of reference), reporting and communication routes, etc. The interface arrangements should also identify the information needs of the regulatory bodies.

- *Information technology:*

  Management system controls should be considered throughout all phases of the information technology lifetime: the acquisition and supply of a new system, development, operation and maintenance.

- *Fire protection:*

  The organisation should establish and implement a fire prevention and protection process to protect individuals and items that is appropriate to the stage in the lifetime of the facility.

- *Security:*

  The organisation should establish and implement a security process to prevent individuals from deliberately carrying out unauthorised actions that could jeopardise safety. The process should be appropriate to the stage in the lifetime of the facility [20].

- *Decommissioning:*

  The facility should establish and implement a decommissioning process involving tasks, operations and activities connected and directly related to decommissioning. They comprise the development of the physical and radiological inventory of the facility, planning and implementation of plans, decontamination, dismantling, material and radioactive and non-radioactive waste management including the clearance process and logistics (transport of materials within and outside of the facility), demolition and site clean-up. Appropriate procedures should be developed for all these tasks, operations and activities.

In addition to the procedures mentioned above, generic management system processes and processes common to all stages of the lifetime cycle should be applied as appropriate for:

- technical support: repair, maintenance and engineering;
- licensing and regulatory aspects including licence termination;
- administrative support and services.

4.2.6 Measurement, assessment and improvement

4.2.6.1 Monitoring and measurement

The effectiveness of the management system shall be monitored and measured to confirm the ability of the processes to achieve the intended results and to identify opportunities for improvement.

4.2.6.2 Self-assessment

The senior management and the management at all other levels in the organisation shall carry out self-assessment to evaluate the performance of work and the improvement of the safety culture.

4.2.6.3 Independent assessment

Independent assessments shall be conducted regularly on behalf of the senior management:

- to evaluate the effectiveness of processes in meeting and fulfilling goals, strategies, plans and objectives;
- to determine the adequacy of work performance and leadership;
- to evaluate the organisation’s safety culture;
- to monitor product quality;
- to identify opportunities for improvement.

An organisational unit shall be established with the responsibility for conducting independent assessments. This unit shall have sufficient authority to discharge its responsibilities.

Individuals conducting independent assessments shall not assess their own work.

The senior management shall evaluate the results of the independent assessments, shall take any necessary actions, and shall record and communicate their decisions and the reasons for these.

4.2.6.4 Management system review

A management system review shall be conducted at planned intervals to ensure the continuing suitability and effectiveness of the management system and its ability to enable the objectives set for the organisation to be accomplished.

The review shall cover but shall not be limited to:

- Outputs from all forms of assessment;
- Results delivered and objectives achieved by the organisation and its processes;
- Non-conformances and corrective and preventive actions;
- Lessons learned from other organisations;
- Opportunities for improvement.

Weaknesses and obstacles shall be identified, evaluated and remedied in a timely manner.

The review shall identify whether there is a need to make changes to or improvements in policies, goals, strategies, plans, objectives and processes.

4.2.6.5 Non-conformances and corrective and preventive actions

The causes of non-conformances shall be determined and remedial actions shall be taken to prevent their recurrence.

Products and processes that do not conform to the specified requirements shall be identified, segregated, controlled, recorded and reported to an appropriate level of management within the organisation. The impact of non-conformances shall be evaluated and non-conforming products or processes shall be either:

- accepted;
- reworked or corrected within a specified time period; or
- rejected and discarded or destroyed to prevent their inadvertent use.

Concessions granted to allow acceptance of a non-conforming product or process shall be subject to authorisation. When non-conforming products or processes are reworked or corrected, they shall be subject to inspection to demonstrate their conformity with requirements or expected results.

Corrective actions for eliminating non-conformances shall be determined and implemented. Preventive actions to eliminate the causes of potential non-conformances shall be determined and taken.

The status and effectiveness of all corrective and preventive actions shall be monitored and reported to the management at an appropriate level in the organisation.

Potential non-conformances that could detract from the organisation's performance shall be identified. This shall be done: by using feedback from other organisations, both internal and external; through the use of technical advances and research; through the sharing of knowledge and experience; and through the use of techniques that identify best practices.

4.2.6.6 Improvement

Opportunities for the improvement of the management system shall be identified and actions to improve the processes shall be selected, planned and recorded.

Improvement plans shall include plans for the provision of adequate resources. Actions for improvement shall be monitored through to their completion and the effectiveness of the improvement shall be checked.

4.3 Advantages of the integrated management system

There are several good reasons for the integration of management, especially occupational health and safety together with environmental management. The most important reason for an integrated management system (IMS) is that this will reduce costs, since many routines can be coordinated more effectively. For example when reporting deviations, this has to be done for all areas, as it affects all areas. Coordinated reporting is much simpler. There is a large potential for saving money with an integrated management system as compared to separate systems.

Another important driving force is legislation. Legislation concerning management systems is predominant in the area of occupational health and safety.

A third reason for integration is customers' requests. It is becoming more frequent that public authorities as buyers of products and services require that, in order to get a contract, the company must have a management system.

In general, examples of integrated management system advantages are:

- Reduced duplication of activities and therefore costs.
- Balance of conflicting objectives, e.g., between occupational health and environment.
- Eliminating of conflicting responsibilities and relationships.
- Harmonising and optimising practices.
- Creating consistency.
- Improved communication.
- Facilitating training and development.

Integrating the management systems also facilitates the focus on the most important aspects in a company. Separate systems tend to put focus on each area instead of the common area.

Experiences from using integrated management systems indicate that some problems have been identified with an integrated management system that are common for all management systems like:

- Demand for resources, especially if the management system shall be certified.
- Long term efforts.
- Substantial documentation.
- A risk that the standard is guiding, rather than the demand of the company.
- Large efforts in education of all personnel are required.
- Not neutral regarding competitiveness; within the EU, authorities in different countries interpret rules in different ways.
- The management system can encourage a conservative control culture instead of a creative work for continuous improvements.
- An attitude 'the system takes care of everything' can develop.

Problems specific for integrated management systems may be:

- Competing standards.
- Areas with vague indicators like safety can be neglected.
- Different cultures in the organisation regarding quality, environment and occupational health and safety.
- In downsizing an organisation, economic factors can be the main driving force for an integrated management system which can lead to resistance from the personnel.

Some experience is available from companies working with an integrated management system. The main experience is that the integrated management system must be dimensioned according to the needs and conditions in the company.

Other experiences indicate that:

- the integrated management system must be ‘owned’ by the users.
- the integrated management system must give simple and easily accessible information regarding what-when-who.
- information technology systems should not control the development of the integrated management system.
- one step needs to be taken at a time.
- visions need to be created and communicated to employees.
- the engagement of the top management is crucial starting from a communicated policy.

5. A baseline scheme of the integrated management system

An integrated management system should be used to ensure that adequate measures are in place to address technical issues relating to safety, protection of health, protection of the environment, security, quality and economics. Solutions to technical problems are provided by means of such processes as design and research and development, which are controlled by the management system. The main philosophy behind integrated management systems is to take the common aspects and elements of different management systems and combine them in a single system.

An organisation considering integration should consider the following approach:

- Identify all stakeholder needs and expectations and describe these in terms the organisation understands and can measure.
- Identify where in the organisations processes these needs are fulfilled and the management systems that manage the delivery of these needs.
- Identify the potential efficiency gains and opportunities for taking waste out of the system through integrated approach to delivering stakeholder needs.
- Monitor effect, audit and review performance after change.

Whilst different management systems have several unique elements, they also have many common ones such as policy development, documentation and reporting, auditing, emergency and awareness, operational procedures and process control and training.

The integration of management systems allows the common elements of the systems to be identified and merged as one, whilst still recognizing individual requirements that each system will have.

To ensure effective integrated management systems, the following functions must be performed:

- *Risk Assessment*: This should address customer perceptions, health and safety risks, environmental concerns and impacts and process failure modes. By having a common approach it will be easier to compare risks occurring in different parts of the business.
- *Norms and Regulations Management*: To capture norms and regulations with respect to product specifications, environment and health and safety and their impacts on the business.
- *Continual Improvement Management*: This should focus on specific improvement programmes related to quality, health and safety and environment.
- *Stakeholders Awareness*: This should address needs of customers, staff and the general public with respect to quality, health and safety and environment.

The business process approach is the best to be adopted for the development of an integrated management system whether an organisation has or has not an existing formal system. The benefits are that one coherent system can be built which serves business needs and does not tie the organisation to a particular standard. The standards are used to assist identifying tasks and processes. This approach starts by looking at the business as a whole and establishing its objectives, mission and core processes which deliver the objectives and achieve this mission.

The management, in the management system:

- should recognize the need to specify when activities in such processes are required to be conducted,
- should require the scope of the activities to be carefully defined,
- should require the activities to be carried out carefully,
- should require the results to be evaluated and taken into account appropriately.

Technical issues may also have to be addressed so that managerial functions, such as independent verification and checking, may be carried out.

For the decommissioning stage, the facility should develop and implement a management system that:

- Follows the requirements given in Section 4.2. Some of these (e.g., integrated information management system) will be discussed in more detail further.
- Takes into account the generic guidance contained in Section 4.2 [18], as well as the guidance contained within the main body of this document.
- Addresses the requirements of reference [21] concerning radioactive waste management.
- Takes into account the relevant activities described in the series of IAEA safety guide [16] and the requirements in publication [19] when developing the processes and organizational structure during the decommissioning stage. These publications extensively describe the activities that need to be described in the management system processes during the decommissioning stage.

When developing the structured approach to the grading of the management system requirements, the following should be considered:

- The need for and detail of decommissioning documents.
- The management of decommissioning waste.
- The review and approval of decommissioning documents.
- The type and detail of training of individuals carrying out decommissioning activities.
- The controls applied to dismantling the plant, removing equipment and demolition.

The first step to integrating management is to identify the common elements between each of the systems. A gap analysis of the individual systems is required to determine which elements can be combined. Table 5.1 illustrates the common system elements, and indicates how they can be accessed horizontally within the integrated management system structure or vertically down through an independently certifiable management system [22].

Once common elements are identified, a series of integrated procedures, work instructions, registers and other components of the management system are required to be written. It is important that the management systems are no longer viewed as individual systems. An integrated management system requires all internal management practices to be combined into one system. For it to become an integral part of the company’s management system there have to be linkages so that the boundaries between the processes are as seamless as possible.

The integrated management systems can be viewed as a transverse connection between the different standards, where the standards have a number of similarities and common activities [23]. This approach has been selected with aligned non-standardized systems and processes for a graphical model/scheme of the generic integrated management system (the original systems and some processes became sub-systems) which is depicted in the Figure 5.1.

Table 5.1 Common elements of management systems

Systems elements	Environmental	Operational health and safety	Possible common elements
Policy and objectives	Environmental policy	Operational health and safety policy	Corporate policy
Responsibilities and leadership	Environmental responsibilities	Operational health and safety responsibilities	General responsibilities
Procedures	Corporate environmental procedures	Corporate operational health and safety procedures	Integrated procedures
Needs analysis	Legal requirements	Job safety analysis, legal requirements	Interested parties, stakeholders, government, community, contract review procedures
System planning and implementation	System specific environmental procedures	System specific operational health and safety procedures	Document control, incidents, corrective actions, emergency response
Hazards and risks	Significant environmental aspects	Hazard assessment and risk analysis	Integrated risk assessment protocol
Process and activity management	Environmental management programs	Hazardous materials management, plant safety management	General management procedures, plant and asset management
Monitoring and measurement	Licenses and approvals monitoring	Operational health and safety inspections	General monitoring procedures
Resource allocation	Environmental training	Operational health and safety training and competencies	Site induction, needs analysis procedures
Communications	Complaints	Operational health and safety committee, disputes	Communication lines and procedures
Review and improvement	Environmental system audit	Operational health and safety system audit	Integrated management system audit plan

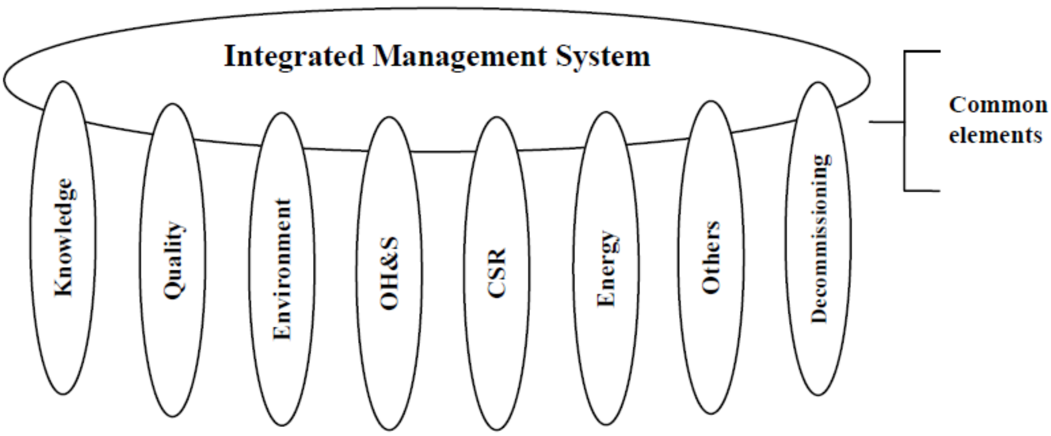

Figure 5.1 Integrated management system as a transverse connection between standardised and non standardised systems and processes

A synergy between the different areas of an integrated management system can be created even with different levels of integration. In the discussions of integrated management systems, distinctions between two approaches/levels of integration are often mentioned within literature:

1. Alignment: A parallelisation of the systems using the similarities of the standards to structure the system. The purpose of the alignment is to reduce administration and audit costs. Still separate procedures for each area but placed in only one manual.

2. Integration: Full integration in all relevant procedures and instructions.

Summing up, an integrated management system consists of the unique and common elements in the standards and systems as well as a common handbook with the documentation of processes, procedures, etc. However, this is just the system – in order to make it work in the organisation there is also a common challenge regarding management commitment, employee motivation and participation, stakeholder involvement, and a focus on continuous improvements of the performance in the different areas. In other words changing organisational culture and tradition might be the real challenge compared to building up an integrated system.

When the elements and the components of the integrated system are identified a framework is required in which the integrated management system is to be housed. By using a web-based interface the integrated system can be operated through a single interface. This single interface provides an enormous advantage over the conventional paper based system, both as an operational system and at the implementation phase.

When implementing an integrated management system, it can often be difficult to integrate at the operational level. After they have been written, many manuals are shelved and if not used on a daily operational level, fail in what they are designed to do. When the system is easy to use and information is quick to access, operational staff is more likely to use the system elements. This leads to familiarity of the system requirements, and reduces risk of operators failing to follow instructions.

Through careful design considerations and a thorough understanding of the users needs, the advantages of the web-based interfaces are vast, and include:

- The ability to access information using a common web browser internally through the business units or externally through the World Wide Web. For example this could allow customers to access all the necessary data.
- User friendly graphical interfaces that incorporate photos, plans and drawings make data easier to access and easier to understand.
- Non-linear access to information to allow users to access material in several ways as appropriate to the users needs.
- The incorporation of real time information or directly accessible databases to provide the latest information to the user. This can also include automated collection and manipulation of data such as monitoring and graphing water quality data.
- Facilitating decentralization, which allows broader access to central databases to regional offices and vice versa.
- Referenced information to be directly accessed by hyperlinks in web documents, e.g., regulatory requirements, reports, supplier information.
- Enhanced quality control, as all data will be in the read only format, and updates or revisions are only feasible through a central location.
- Enabling storage of large amounts of data.
- The feasibility to expand to other business systems to incorporate operations, human resources, asset management, etc.

Design considerations for the system should be very carefully assessed. The system would need to be reliable, easy to administer, not require large ongoing maintenance costs or commitments to extensive information technology resources, and allow for expansion or integration with other business information systems if required, in the future. The foreseen demands on the decommissioning system must be capable to accommodate all the information regarding various types of activities, which are to be performed during the decommissioning process. Additionally, the system must be capable to manage all the data defined for full process management. The architecture of the application software following worldwide practice should be network distribution architecture. The best model for such a system is an intranet architecture, i.e., clients use web browsers as front and back applications, and middle applications are hosted on servers.

The network infrastructure must be available at any time. Availability and reliability comprise:

- data protection and back up;
- avoidance of system failure, i.e., guarantee of data and hardware availability.

The system is required for both management and operational purposes. Being an integrated system, much of the information generated through the management system is required to be used in every day operational activities. It is recognised that the same information would be required to be accessed differently by different users.

The decommissioning of a nuclear power plant is primarily a technical, an organisational and a logistic problem. Thus, very complex tasks have to be solved taking into account the continuously increasing amount of project data with real time data access at any time, specific demands on project planning, cost calculation and project supervision as well as complex documentation and last but not least the necessity to inform the authorities and the public in a comprehensive manner. One of the biggest challenges facing any organisation today is how to manage and integrate an ever-increasing amount of information, especially when this information is in a variety of data types and formats. “Information Systems” (IS), “Management Information Systems” (MIS) and “Integrated Management Information Systems” (IMIS) are used for this purpose.

The terms “Management Information System” and “Information Systems” are often confused. “Information Systems” are usually systems that are not intended for decision making and refer to information technology used by people to accomplish a specified organisational or individual objective. The technology may be used in gathering, processing, storing and disseminating of information and the users are trained in the use of that technology, as well as in the procedures to be followed in doing so. Computers provide most of the storage and processing capabilities, while data communications – specifically networks – provide the means for dissemination and remote access of information.

A “Management Information System” is a computer system designed to help managers plan and direct business and organisational operations. They are those systems that allow managers to make decisions for the successful operation of businesses. Management information systems consist of computer resources, people, and procedures used in modern business enterprises.

All information recorded, analysed and processed through the computer system, should be available to the different levels of the organisation. The term “Management Information System” is used broadly in a number of contexts and includes (but is not limited to): decision support systems, resource and people management applications, project management, and database retrieval application. A “Management Information System” is a planned system of collecting, processing, storing and disseminating data in the form of information needed to carry out the management functions, especially decision making.

Figure 5.2 illustrates some of the typical elements of a computer based integrated facility management information system. A computer system can enable access to all categories of records. If records are in a hardcopy form, their storage location is important for their retrieval and is given in the system, whereas if records are in an electronic format they can be accessed directly and displayed. It is important to audit an information system regularly to determine throughout the lifetime of a facility if the system contains adequate data for its decommissioning.

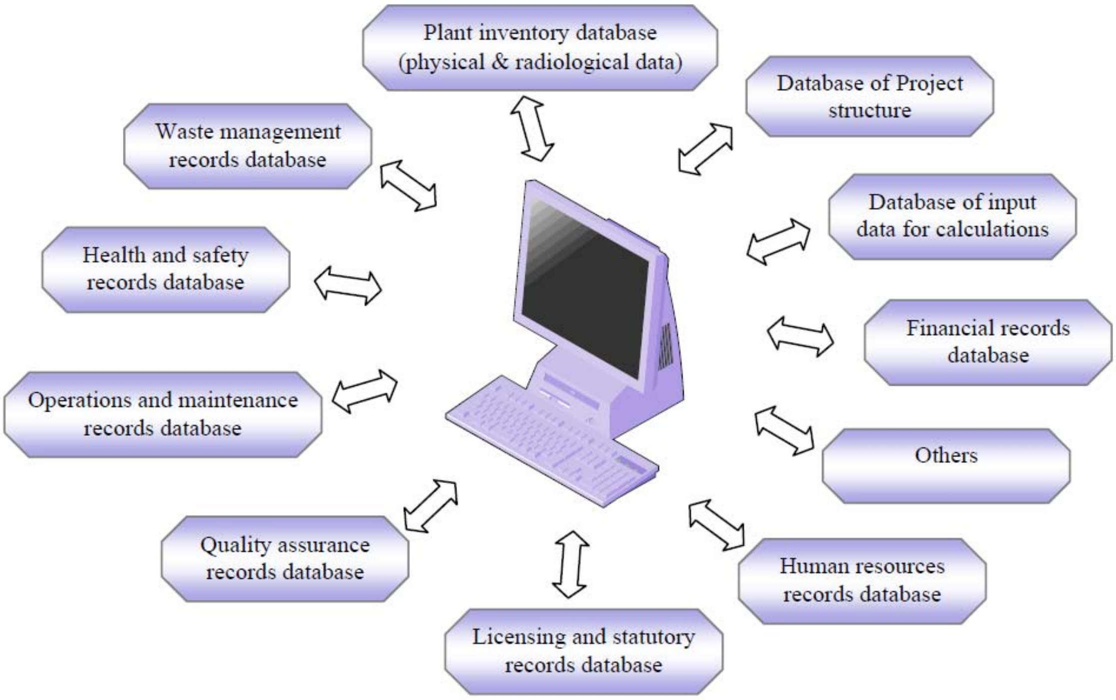

Figure 5.2 Integrated management information system

The planning and management of a nuclear power plant decommissioning project, and especially the handling of the large amounts of material, requires a computerized planning and management tool based on a suitable data base. Usually, this tool consists of an interrelated data base and the necessary user modules working above the database and supporting all the tasks necessary for:

- Documentation;
- Registration of the plant status, and the physical and radiological inventory;
- Planning and calculations;
- Project management with supervision and tracking;
- Safe enclosure (if appropriate);
- Environmental information.

The management system for decommissioning should be open and adaptable to the needs of the requirements.

The basic layout of a decommissioning management system is indicated in Figure 5.3 [24].

As output of the management system, depending on the applied modules usually the following results can be obtained:

- Time schedules, eventually with critical path;
- Personnel capacity plan;
- Information about personnel dose;
- Necessary resources;
- Costs and money flow;
- Mass flow with radioactive waste flow including characteristics and disposal information;
- Comparison of actual/planned performance (results) of the project;

- Documentation and records information.

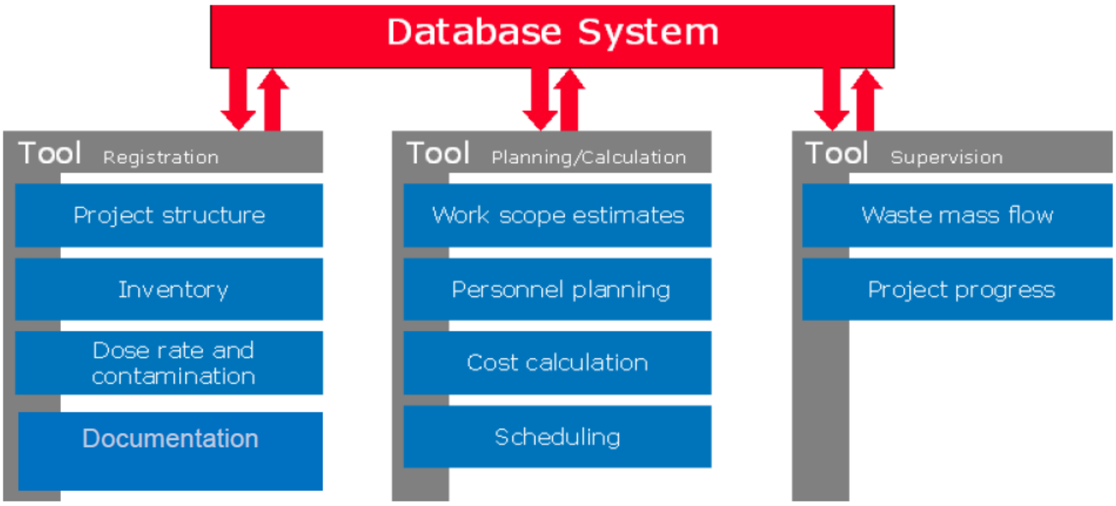

Figure 5.3 Basic layout of the decommissioning management system

It is necessary to be aware that each decommissioning project has its own technical, legal, economical boundary conditions with permanent changes. Thus the software modules must be specific, flexible and adaptable to take these conditions into account. The user modules for the main project tasks - planning, cost and working resource definition as well as mass flow, project management and tracking - should be developed and be described as well as the interaction between the data base and the processing system and the practical needs of the decommissioning project.

6. Project management approaches

In this section, an overview is given of a selected number of reference projects relating to decommissioning alternatives and strategy selection, development of a decommissioning plan, application documents, content and needed data elaboration, project management approach, including the identification of a number of differences.

6.1 Aspects of decommissioning alternatives and strategy selection

The choice of a strategy for the decommissioning of a nuclear power plant or any other large nuclear facility is of great importance. The selection and development of decommissioning options will affect the costs, the duration of the decommissioning period, the amount of radioactive wastes that will be produced, the radiological impact on workers, the public and the environment, etc. Adequate management and organisation of a decommissioning project are important factors for a successful implementation of the decommissioning activities.

6.1.1 Decommissioning strategies

The International Atomic Energy Agency (IAEA) has defined three decommissioning strategies: *immediate dismantling*, *deferred dismantling* and *entombment* [23]. 'No action' has not been regarded as an acceptable decommissioning strategy.

Immediate dismantling commences shortly after shut down, if necessary following a short transition period to prepare for implementation of the decommissioning strategy.

Decommissioning is expected to commence after the transition period and continues in phases or as a single project until an approved end state including the release of the facility or site from regulatory control has been reached.

As an alternative strategy, dismantling may be deferred for a period of up to several decades. *Deferred dismantling* is a strategy in which a facility or site is placed in a safe condition for a period of time, followed by decontamination and dismantling. During the deferred dismantling period, a surveillance and maintenance programme is implemented to ensure that the required level of safety is maintained. During the shutdown and transition phases, facility specific actions are necessary to reduce and isolate the source term (removal of spent fuel, conditioning of remaining operational or legacy wastes, etc.) in order to prepare the facility/site for the deferred dismantling period.

Entombment is a strategy in which the remaining radioactive material is permanently encapsulated on site. A low and intermediate level waste repository is effectively established and the requirements and controls for the establishment, operation and closure of waste repositories are applicable.

Although evaluation of the prevailing factors could clearly indicate one of the above mentioned strategies, constraints and overruling factors may occur in practice and necessitate the selection of a combination of strategies or exclude one or more strategies from consideration.

The process for the decommissioning of a nuclear power plant comprises a set of technical and time consuming activities. Proposing several options for the decommissioning of the nuclear power plant (at least two), evaluating and comparing these options and recommending (selecting) the most suitable option from the legislative, safety, economic, technical, time, and social point of view is one of the inevitable conditions that have to be fulfilled before the very start of the decommissioning process.

6.1.2 Selection of a decommissioning strategy

The selection of a strategy for the decommissioning of a nuclear power plant out of different options by comparing only one criterion (e.g., total decommissioning costs or total collective effective dose) leads to a one-sided assessment of the most suitable option. This method does not consider other criteria that can have an impact on the selection process and does not evaluate the rate of their influence on the final decision. For this reason, it has been proposed to use a multi-criterion analysis (MCA) for the comparison of decommissioning options and the selection of the most suitable option based on the results of this comparison and detailed assessment. A multi-criterion analysis is a powerful tool, which is able to compare particular options by considering a large scale of criteria and also take into account the rate of their importance.

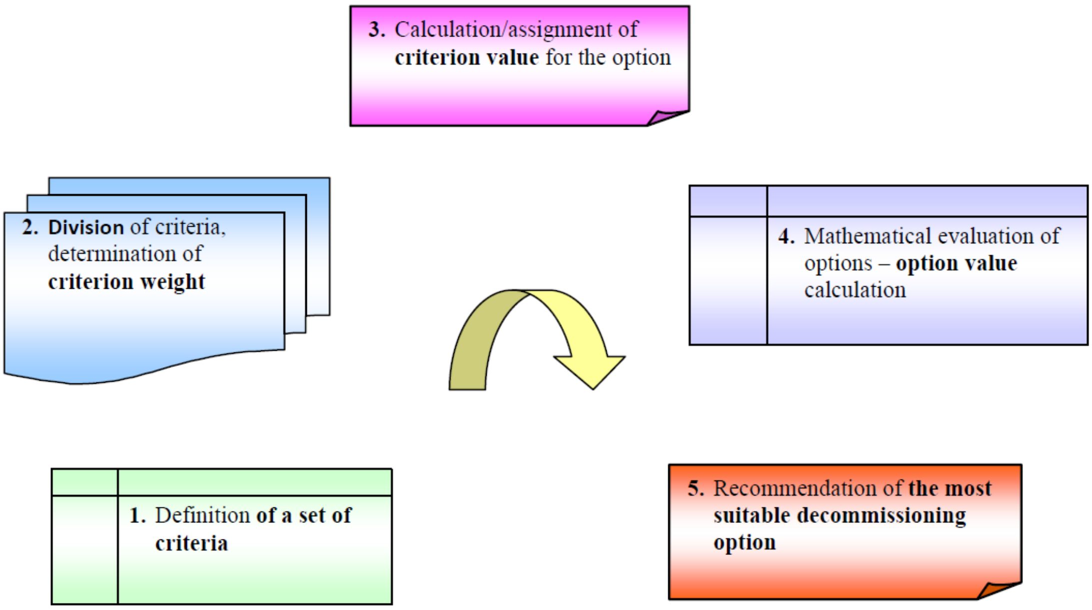

Figure 6.1 Scheme of a multi-criterion analysis

The multi-criterion analysis of options for the decommissioning of nuclear power plants and the selection of the most suitable option is a general world-wide used method. The final quality of a multi-criterion analysis depends on the two following conditions:

- The first condition is a correct definition of a particular set of criteria to be taken into account during the assessment. Consequently, it is necessary to describe adequately all important properties, which have to be taken into account during the assessment process.
- The second condition is reasonable scaling of particular criteria importance from the most suitable option selection point of view. The importance of each criterion has to be defined by assignment of a criterion weight. Due to this, the influence of more significant criteria on the final results of mathematical processing will be emphasized. On the contrary, the impact of less important criteria will be appropriately reduced.

The basic steps during the implementation of a multi-criterion analysis can be summarised as follows:

1. Definition of a particular set of criteria.
2. Division of criteria into objective and subjective classes and determination of the criterion weight.
3. Calculation/assignment of the criterion value for the option.
4. Mathematical evaluation of the options according to the methodology - calculation of the option values.

5. Recommendation of the most suitable option for the decommissioning of the nuclear power plant on the basis of the results obtained from the comparison of the analysed options.

Table 6.1 List of main characteristic parameters for evaluating the analysed options for the management of the decommissioning of a nuclear power plant

No.	Characteristic parameter of decommissioning	Unit
1	Total costs	€
2	Collective effective dose	man.Sv
3	Duration of the decommissioning process under the authorisation for decommissioning	year
4	Labour hours needed	hours
5	Amount of liquid radioactive wastes (before processing at salinity 200 g/dm^3)	m^3
6	Radioactivity of gaseous effluents	Bq
7	Radioactivity of liquid effluents	Bq
8	Amount of released metals	Mg
9	Amount of recyclable building waste	Mg
10	Amount of conventional waste	Mg
11	Amount of radioactive waste for near surface repository	Mg
12	Amount of radioactive waste for deep geological repository	Mg
13	Time load of site by radioactivity	year

6.2 Decommissioning plan

The documents that are required to be prepared to support the decommissioning effort are specified by the regulatory body. One document that is specifically referred to in IAEA publications is the decommissioning plan: “A decommissioning plan shall be developed for each nuclear facility, unless otherwise required by the regulatory body, to show that decommissioning can be accomplished safely” [24]. Other IAEA publications provide guidance on the planning process for decommissioning. Initial versions of these documents are by necessity less detailed than the final documents. The amount of detail increases as the plans for the decommissioning of a facility progress from an initial plan to the final one and uncertainties are reduced.

The responsibilities of the regulatory body have been described as follows: “The regulatory body shall establish safety criteria for the decommissioning of nuclear facilities, including conditions on the end points of decommissioning” [24]. This means that the regulatory body will define the types of documents to be submitted by the responsible organisation in order to show that decommissioning will be performed safely. The regulatory body provides guidance on the type of information that is required for it to review the proposed activities and evaluate the overall safety of the concept.

Furthermore, it is required that: “The operator shall establish and maintain decommissioning plans which are commensurate with the type and status of the facility’ [24]. This allocates to the operator the overall responsibility for the planning of decommissioning. The operator is responsible for the overall safety during the entire decommissioning process.

6.2.1 Pre-decommissioning aspects of decommissioning planning

The pre-decommissioning phase covers all activities related to the preparation for actual decommissioning work at the facility [25]. It includes strategic and conceptual studies in view of developing decommissioning strategies; detailed planning including preparation of the decommissioning plan; accumulation of preliminary characterisation data; a baseline cost estimate for the work; preparing workers in view of the transition from operations to decommissioning; and safety and environmental studies.

Activities normally associated with operation such as spent fuel transfer, processing of operational waste and some decontamination may also be included in this phase and may extend into the following post-shutdown phase. It is important for decommissioning planners and cost estimators to address the costs related to these activities as either an operating or a decommissioning cost.

The pre-decommissioning phase also includes the activities relating to all license applications and approvals from regulatory bodies, revisions of technical specifications to reduce unnecessary requirements and costs after shutdown, adjustment of insurance premiums, reconfiguration of security provisions to facilitate increased vehicular traffic and workforce, and operation and maintenance procedures.

During this phase, also the criteria for the release of materials and equipment from regulatory control are determined and agreed upon by the regulatory bodies and stakeholders. These criteria will affect the decontamination methods and the costs for decommissioning, and to some extent determine the permissible end points for the buildings and structures of the facility. In the facility, the radiological and hazardous material surveys and analyses are conducted, starting with an historical site assessment of operational experience. This historical site assessment can provide insight as to where to expect contamination as well as the concentration levels and thereby establishing a work scope for related activities. The disposition of radioactive and hazardous materials may require special planning and arrangements for packaging, transportation and disposal and needs to be taken into account during the preparation of the decommissioning plan.

During the pre-decommissioning phase it is necessary to evaluate the availability, the readiness, and the performance of storage and disposal facilities for radioactive wastes of various categories. Any requirements or terms of the waste storage and disposal facilities have to be taken into account during the development of the decommissioning programmes and plans. An evaluation has to be made of the availability and sufficiency of financial assets accumulated in the decommissioning fund for the normal financing of planned activities.

The organisation that will perform the actual decommissioning activities is also selected during this phase. This may typically be either the owner/licensee (self-performing the work) or a qualified contractor (sometimes referred to as a “Decommissioning Operations Contractor”). If a contractor will perform the project, specifications have to be prepared and to be distributed to potential bidders. Their financial and technical qualifications have to be evaluated and a contract to be awarded.

6.2.2 Decommissioning plan

The decommissioning plan is a key document in the entire decommissioning process. It contains the information on which the regulatory body will base its decision regarding the relative safety of the decommissioning concept as proposed by the operator. There is a range of support documentation that will probably be referenced and summarised briefly in the decommissioning plan. This is particularly likely for large, complex decommissioning projects. In some countries, and for smaller facilities, these support documents may be integrated into the decommissioning plan itself.

Table 6.2 provides a list of the major topics that have to be addressed in a decommissioning plan. The detail presented for each of these topics may vary largely depending on the type of facility, the quantity, type and chemical form of the radio-nuclides involved, and the stage in the life cycle of the facility. Much of the information required in a decommissioning plan may result from specific individual documents, including a decommissioning environmental report, a decommissioning safety assessment, a radiation protection programme, a health and safety programme, a cost estimate, a waste management programme, a quality assurance programme, an emergency response plan, a project surveillance and maintenance programme, a project final radiological survey plan and a (partial) final decommissioning report. In the decommissioning plan, these documents may be incorporated by giving references, with a brief summary provided in the plan.

Table 6.2 Typical table of contents for a decommissioning plan

1. Introduction
2. Facility Description
3. Decommissioning Strategy
4. Project Management
5. Decommissioning Activities
6. Surveillance and Maintenance
7. Waste Management
8. Cost Estimate and Funding Mechanisms
9. Safety Assessment
10. Environmental Assessment
11. Health and Safety
12. Quality Assurance
13. Emergency Planning
14. Physical Security and Safeguards
15. Final Radiation Survey

6.2.3 Types of decommissioning plans

Decommissioning plans are developed in three stages during the lifetime of a facility: an initial decommissioning plan, updated decommissioning plans and a final decommissioning plan.

An initial decommissioning plan is prepared during the design stage of the facility. This plan is normally required before the regulatory body will provide an operating licence. A minimal level of detail has to be provided and many of the conclusions can be based on realistic assumptions. Some of the information identified in Table 6.2 may not be available at that time and should be added later during the periodic review and revision of the initial plan.

The initial decommissioning plan should focus on the major pieces of equipment, the structure of the facility, the types and expected quantities of radio-nuclides to be used or handled, major processes, design drawings and process flow diagrams. The primary purpose of this version of the plan is:

1. to provide basic information on the complexity of the decommissioning process;
2. to establish the decommissioning funding programme and collection mechanism;
3. to document the assumptions for the decommissioning process;
4. to establish procedures for the collection of relevant information during operation and maintenance.

The information is critical in developing the initial decommissioning cost estimate. This cost estimate is necessary to identify the funding mechanism for decommissioning. In addition to the cost estimate, the initial decommissioning plan should include the following information, some of which will have to be based on logical assumptions:

1. Site location and description;
2. Building and system description;
3. Identification of potentially activated and contaminated areas and equipment;
4. Tentative decommissioning strategy;
5. Assumed decommissioning activities;
6. Initial estimate of waste by category;
7. Record keeping requirements during operations;
8. Experience from decommissioning projects of similar facilities.

The initial decommissioning plan has to be updated periodically during the lifetime of the facility. Each update should include information on changes of equipment or processes, unplanned events, changes in support capabilities including waste management and radiological monitoring, update of radiological conditions, changes in legislative requirements, changes in financial assumptions and improvements in decommissioning technology. This updated plan becomes more detailed as the end of the operating period approaches and additional information is included. The assumptions of the initial plan should be validated, and conclusions have to be drawn concerning the proposed decommissioning strategy. The proposed decommissioning strategy will result in a revised value of the decommissioning cost which can be used to confirm the funding mechanism.

The final decommissioning plan is normally prepared before the facility permanently ceases operation, except when the facility is to go into a deferred dismantling mode. If this is the case, the plan is finalised approximately three to five years before the end of the safe enclosure phase. This final plan is detailed and will include the topics identified in Table 6.2. Approval by the regulatory body is normally needed before the final decommissioning strategy can be implemented, i.e., decontamination and dismantling. This plan is the basis for the development of the detailed work instructions and procedures.

6.3 Application documents

The decommissioning management system should be described by a set of documents establishing the overall controls and measures to be developed and applied by an organisation to achieve its goals [2]. The controls and measures should be applied to every unit and to every individual within the organisation. The documenting of the management system should be appropriate to the implementing organisation and to the work and should be readily understandable to users.

The documentation should also be flexible enough to accommodate changes in policy; in strategic aims; in safety, health, environmental, security, quality and economic considerations; and in regulatory requirements and other statutes. It should also accommodate the feedback of experience from implementation and from internal and external lessons learned. The management system should adopt a vocabulary that is coherent, makes sense, and is clear, unambiguous and readily understandable. To this end, each document should be written in a manner appropriate to the level of expertise of its users and in a manner that reflects the correct ways of working (i.e., ‘user friendly’).

The management system should include measures to ensure that documentation is available in a language appropriate to the user. The management should define the languages to be used for the work instructions and procedures and should specify measures to ensure that individuals understand what they are asked to do. Documents that have been translated should be reviewed to ensure that the text reflects the intent of the original document and is not just a literal translation. Vocabulary that is internal to an organisation should be made available to contractors and subcontractors who are engaged by the organisation to carry out work or to provide services. The content of documents should be determined with the participation of the individuals who will use these to implement the work and of other individuals the work of whom will be affected by the documents. These individuals should also be consulted during subsequent revisions of the documents. For detailed working documents, there should be a period of trial use, and validation should be carried out and recorded to determine the accuracy of the documents. Changes should be made, as necessary, to ensure the effective communication of expectations [2].

An organisation may operate facilities at several sites, or it may operate a facility or implement an activity using nuclear or radiation technology that is part of a large organisation. In such cases, the management system for the whole organisation should be established to integrate the objectives common to both the facility and the whole organisation, and the mission and the operation of the facility. To complement such management systems, specific local processes may be necessary and should be used to address activities that are unique to one or more of the organisation's facilities, sites or organisational units.

6.3.1 Information structure

A three level structure of information may promote clarity and avoid repetition by establishing the amount of information and the level of detail appropriate to each type of document, and by using cross-references between specific documents at the different levels. A typical three level structure may consist of:

- "Level 1": An overview of how the organisation and its management system are designed to meet the policies and the objectives.
- "Level 2": A description of the processes to be implemented to achieve the policies and the objectives, and the specification of which organisational unit will carry out these processes.
- "Level 3": Detailed instructions and guidance that enable the processes to be carried out and specification of the individual or the unit that has to perform the work.

6.3.1.1 "Level 1" information

"Level 1" information should provide an overview of the policies and the objectives of the organisation and should describe the management system that addresses the requirements that apply to the activities of the organisation. The information at this level of the management system should be the primary means of the senior management for communicating to individuals the expectations of the management, their strategies for success and the methods for achieving the objectives of the organisation. The senior management in the organisation should ensure that "Level 1" information is distributed to individuals for the purpose of implementation, and that the content is effectively understood and implemented.

6.3.1.2 "Level 2" information

"Level 2" information should describe the processes of the organisation and provide specific detail on which activities should be performed and which organisational unit should implement these. This information should:

- define the process map of the management system, including the interactions between the processes.
- define the responsibilities and lines of communication, internal and external to the organisation in each area of activity, for example in processes and interface arrangements.

- define measurable objectives and specify which activities are to be carried out and controlled and who is responsible and accountable, and, where appropriate, should refer to supporting information.
- identify and plan activities to ensure that work is dealt with in a safe, systematic and expeditious manner.

Information at this level should provide administrative guidance to managers in all positions. It should outline the actions that managers should take to implement the management system of the organisation. It should not be used to provide the details of how technical tasks are to be performed. Technical tasks should be detailed in information at “Level 3”.

The content of sections typically contained in documents at “Level 2” should comprise: purpose, scope, responsibilities, definitions and abbreviations, references, records, details. In detail, the sections of a document should describe what is to be done, typically by providing the following information:

- Planning and scheduling considerations, to ensure that work is dealt with safely, systematically and expeditiously;
- Administrative and technical information;
- Work steps and actions to be carried out;
- Responsibilities and authorities;
- Interfaces;
- Lines of communication both within and outside the organisation;
- Any cross-references between the document and other documents, including working documents at “Level 3”.

To avoid unnecessary detail, cross-reference should be made to “Level 3” information, such as supporting guidance or detailed working documents.

6.3.1.3 “Level 3” information

“Level 3” information should include:

- Detailed working documents:

  “Level 3” information should consist of a wide range of documents to prescribe the specific details for the performance of tasks by individuals or by small functional groups or teams. The type and format of documents at this level can vary considerably, depending on the application involved. The primary consideration should be to ensure that the documents are suitable for use by the appropriate individuals and that the content is clear, concise and unambiguous, whatever the format.
- Job descriptions:

  Job descriptions should be developed for the different competences or types of work to define the total scope of each individual’s job. Job descriptions should be used to establish baselines for identifying training and competence needs. While job descriptions are usually mandatory only at supervisory levels and above, they are an excellent way for the senior management to communicate responsibilities, authority and interfaces to all individuals.

6.3.2 Work packages and procedures/instructions

As already referred to in Section 4.1.4, while the decommissioning plan and the safety and environmental assessment are being reviewed by the regulatory bodies, detailed planning and engineering can be started in order to prepare the decommissioning activities. As soon as detailed data are made available from the radioactive inventory of the nuclear facility and the site characterisation programme, decisions on the handling of components, structures and soil can be made.

Usually, multiple levels of planning documents are prepared; one example will be described below. A hierarchical work breakdown structure will also be developed, dividing the work into manageable packages, which identify what is to be done and how, and addresses the basic safety considerations of the activity. Another level of documents deals with the detailed work procedures [16].

Work packages identify the purpose and provide a description of the tasks, applicable criteria and the activity sequence of events. The criteria include engineering and technical requirements; health, safety and environmental protection requirements; and reference to applicable standards. Work packages may refer to other documents such as a radiological health and safety manual, a waste management manual, a security plan, a quality assurance programme, a fire protection programme, etc.

Detailed work procedures describe the step-by-step instructions to perform each task; the required equipment and associated operating parameters (cutting speeds, gas pressures, power requirements, etc.); safety precautions; and disposal methods, as applicable. Detailed work procedures may be general or specific work procedures. General work procedures are used for repetitive activities such as the construction of contamination control tents; rigging and lifting; pipe cutting methods; and maintenance of filtered equipment (HEPA vacuum cleaners, ventilation units, liquid filtration systems, etc.). Specific work procedures apply to unique tasks such as core dismantling activities or asbestos removal, where general work procedures cannot be fully applied. As the work packages and the detailed work procedures are developed, the baseline cost estimate, schedule and personnel radiological exposure estimates are refined. These can then become the guidelines against which the project performance is measured.

The decommissioning plan will identify and justify the decommissioning work activities. However, before activities are started, work packages are developed for these activities and analysed in sufficient detail to allow the decommissioning team to execute the work with a clear understanding and without the need for further significant explanation. The packages are arranged into interrelated groups, and a schedule of activities would be prepared, usually represented by a bar or Gantt chart. Formal project management techniques are applied to the creation and management of the work packages. A critical path network, i.e., a diagram indicating the sequences and interdependences of the various work packages may be used. The work packages are planned as soon as possible because such planning greatly assists in the development of a detailed cost estimate and the identification of specialist support and equipment that may be needed. Without this level of planning it is difficult to schedule the decommissioning of a large nuclear facility with any degree of certainty.

Procedures for allocating work packages to the decommissioning team should be developed. Work monitoring arrangements are set up so that the project management schedule can be re-evaluated when unexpected circumstances arise. The decommissioning project manager will hold periodic formal review meetings with all supervisors and the safety staff to assess the work that has been implemented, the current status of the facility and the future tasks. Each member of the team should then be aware of what is to be done next in other parts of the programme and in other related activities.

From the formal project meetings, progress reports including revised cost estimates are prepared periodically and are presented to the regulatory body, the licensee and other authorities, as required, including the organisation providing the funds.

6.4 Organisation of the project management

The organisational structure and the structure of the tasks, working packages and individual issues of the decommissioning project should include all of the organisations or institutions that, even partially, will take part in the implementation of the activities. In their organisation orders, these organisations will have an organisational structure with clearly defined functional responsibilities, authority levels and defined internal and external communication. Connections and contact areas among the participants in the decommissioning shall be defined in their quality assurance programme and internal rules. It is important to define the tasks and the responsibilities of the implementation and design organisations.

Independency of organisational parts responsible for inspection of the performed activities must be defined within the organisational structure of the individual participants in the decommissioning activities. Independency and sufficient competence of the organisational parts responsible for safeguard and inspection to make a follow-up of the project schedule and the quality shall be set by organisational incorporation of these parts, usually directly under the head of the organisation; and by defining their competencies and responsibilities.

The organisational structure of the decommissioning project shall use, partially or fully, some parts of the operating organisational structure even during the decommissioning activities. These are mainly the design parts, such as management, occupational health and safety, fire protection, production, quality assurance and administration. The organisational order must define the responsibilities, duties and competencies of these organisational parts.

The project management should be largely applied during the decommissioning activities, with clear definitions of the responsibilities and the competences for the individual projects. A description of the project hierarchy shall be developed to be compared with the functional management organisation used during operation.

In order to safeguard communication and coordination of all the project participants if there is more than one supplier, it is suitable to form a project management council (PMC) that shall have decisive competences and shall be superior to the project manager (see Figure 6.2).

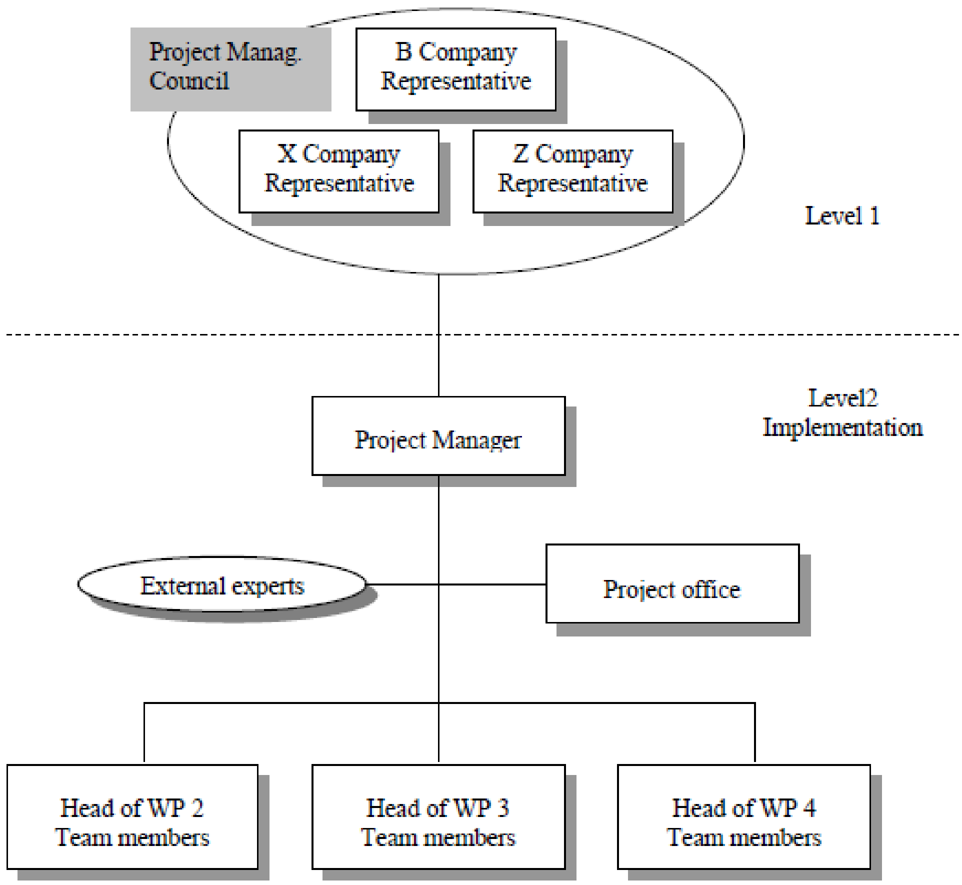

Figure 6.2 Project organisation

The project management council should:

- authorise the project or a phase.
- define and specify goals and select the best option.
- coordinate persons and other resources.
- monitor, measure and adopt remedial activities.
- finish the project.

The project management should provide a possibility to allocate workers in the project processes in a flexible way and to use expert employees effectively as per their background.

The documentation of the decommissioning project shall include programmes that contain specific requirements for quality assurance during the decommissioning of nuclear equipment. The quality assurance programmes should contain a summary of regulatory requirements and procedures of activities; methods of control of documentation and records including verification, update and marking; and methods for organisational and technical safeguard of the activities and processes, including specification of competences, responsibilities and requirements for eligibility of employees that are performing these activities.

In order to safeguard radiation and industrial safety during the decommissioning project, it is important that high-quality work is achieved also in the previous stages of the lifetime of the nuclear equipment. The radiation protection programme should ensure that radiation protection is optimised and that doses are kept within appropriate limits. Although the principles and aims of radiation protection during operations and during decommissioning are fundamentally the same, the methods and procedures of implementation of the radiation protection may be different. During decommissioning, special situations may need to be considered, which may require the use of specialised equipment and the implementation of certain non-routine procedures [15]. This goal can be achieved by a quality assurance system based on the recommendations of the International Atomic Energy Agency or on the standards of the International Standards Organisation, 9000: 2000.

Procedures on how to achieve the selection and the training of employees for the quality-related activities shall be defined in the individual quality assurance programmes of the general contractors. These categories of workers have to meet requirements for qualifications and practical experience. The organisations have to take and to keep records on employees' qualifications and have to develop procedures on staff preparation and training.

The suppliers' employees, who perform dismantling activities, controls and demolition of selected equipment, selected civil structures and reserved technical equipment in nuclear energy, shall have sufficient knowledge in their respective fields and about the particular equipment. These employees shall hold a valid certificate of their qualification as per the respective performed activity. Furthermore, these employees shall have knowledge about the valid provisions, regulations, standards, respective quality assurance programmes and technological procedures.

Verification of qualification of the supplier organisations' employees and the organisations' certificates shall be performed by employees of the implementer of the decommissioning activities. On their request, the suppliers' employees are obliged to show their qualification in the respective field pursuant to the valid contract. These documents and certificates shall be collected and archived by the implementer of the decommissioning activities during the related decommissioning period.

Special processes should be specifically safeguarded during the management of the decommissioning project. Special processes are such activities, where successful implementation depends on a precise execution of the individual implementation steps in a certain sequence, as well as on observance of prescribed conditions, and their output cannot be fully verified by a final inspection.

Such type of processes is performed in accordance with documented procedures and exclusively by qualified staff. Process implementation and meeting of the prescribed parameters is subject to a continuous control. Records of the controls are processed in such a manner that the entire course of activities and the final condition of the object or the result of the activity is clear.

In order to have the particular controls carried out during the decommissioning activities, the controls have to be processed into a practical form, as prescribed for the implementer or the supplier. Control operations are either prescribed directly in the drawing documentation as technical specifications, or are stated in the technological procedures on the performed activities.

In the course of the decommissioning activities, the owner should carry out an independent random control of the equipment, of the activities performed on the important equipment, of the activities as per the control plan or control sheets, and should be present at the suppliers' control in their full extent. Documenting the execution of the controls should contain a catalogue (list) of controls including their placement in the process, the methodology of control execution, requirements for environment and testing devices and criteria for the evaluation of the control results.

The controls shall be performed only by employees who have the respective qualification for the control activities and were appointed by the organisation for these activities. Qualification and certification of the control employees is required in a demonstrable form (all of the certificates relating to results of special courses and trainings must be in a written form). The employees performing the controls cannot depend on the performed activities or persons whose activity is being controlled.

The project management should define the principles of change management, i.e., the change of technical standards, technical conditions and quality assurance programmes.

There should be an obligation to develop quality assurance programmes for every lifetime stage of the nuclear equipment, including the decommissioning stage, and quality assurance for the selected equipment. Such development was made by manufacturers or suppliers of the selected equipment.

In the decommissioning process, independent implementer's and suppliers' employees shall perform internal audits in the extent as determined in the respective quality assurance programmes.

External audits shall be performed by independent client's and owner's employees at the supplier, in the extent as determined in the respective quality assurance programmes or by means of random controls during the dismantling activities.

Except for the stated internal and external audits, the activities affecting the quality of the selected equipment are subject to independent supervision and special supervision of the authorities; the results thereof are opinions and decisions binding for all participants in the decommissioning of the nuclear equipment.

For the process of proposal, discussion and authorisation of amendments to an activity package during the decommissioning of nuclear equipment, procedures should be defined on how to solve each amendment, including small amendments to the documentation issued by the designer, the implementer of the decommissioning activities and the suppliers, pursuant to the concluded contracts. Each participant in the decommissioning project shall be obliged to follow his provisions. The implementer should develop a procedure on how to incorporate changes into the as-built documentation.

The records must be legible, complete and identifiable. The records shall be distributed and treated pursuant to the procedures. It should be feasible to assign the record to an activity or to the equipment it relates to.

The next subsections comprise information on typical models of decommissioning management that have been used in different countries of the European Union.

6.4.1 Decommissioning by own personnel

Figure 6.3 shows the organisational structure of the team management for a decommissioning project led and executed by the operator. In this case, the operator performs most of the decommissioning tasks using the own operational and maintenance staff [16].

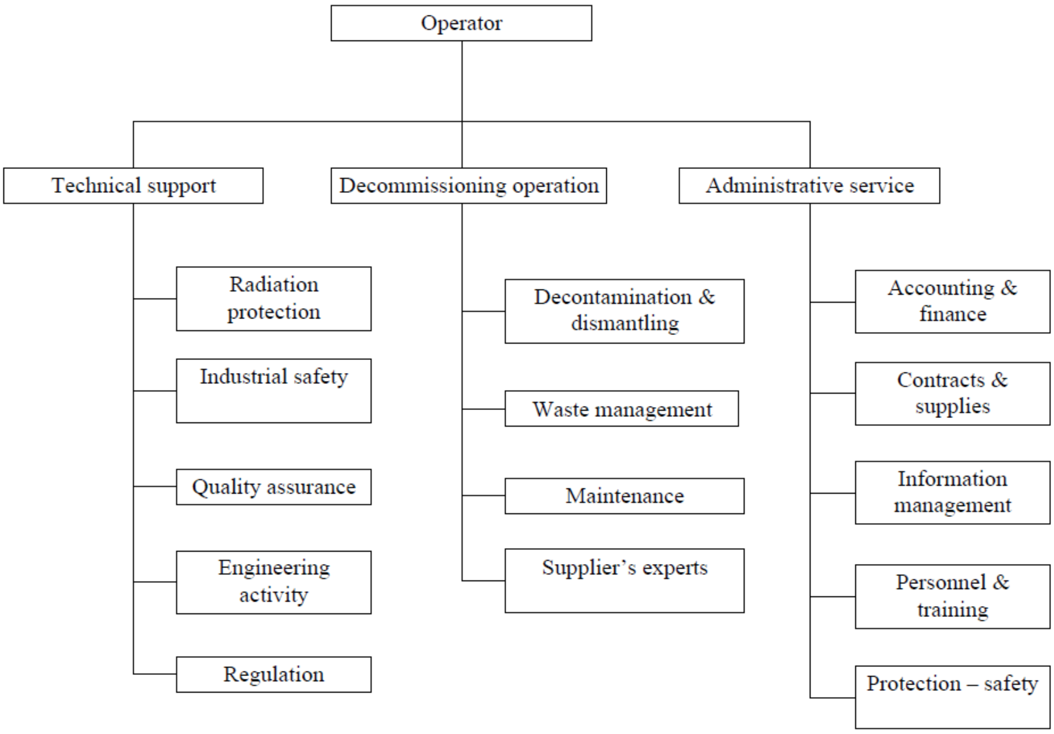

Figure 6.3 Organisational structure of decommissioning performed by the operator

The three main teams are responsible for:

- technical support;
- decommissioning operations;
- administrative services.

Many sites have an operating team style of organisation to start with and it is recognised that their expertise and knowledge is vital. However, experience has shown that it is sometimes not effective to use an operating style organisation as a new and different organisation may be needed which is specifically oriented to the new tasks. This is particularly so, as decommissioning is more an operation similar to the construction than to the operation of a plant. It is important, however, to incorporate some of the experienced site personnel within the new team so that their expertise can be fully utilised.

Such an organisation implies a smooth transition from an operating reactor to a reactor in a decommissioning phase.

6.4.2 Decommissioning by a general contractor

Figure 6.4 shows the organisational structure of a decommissioning team management where the operator hired an external supplier to perform the decommissioning activities [16].

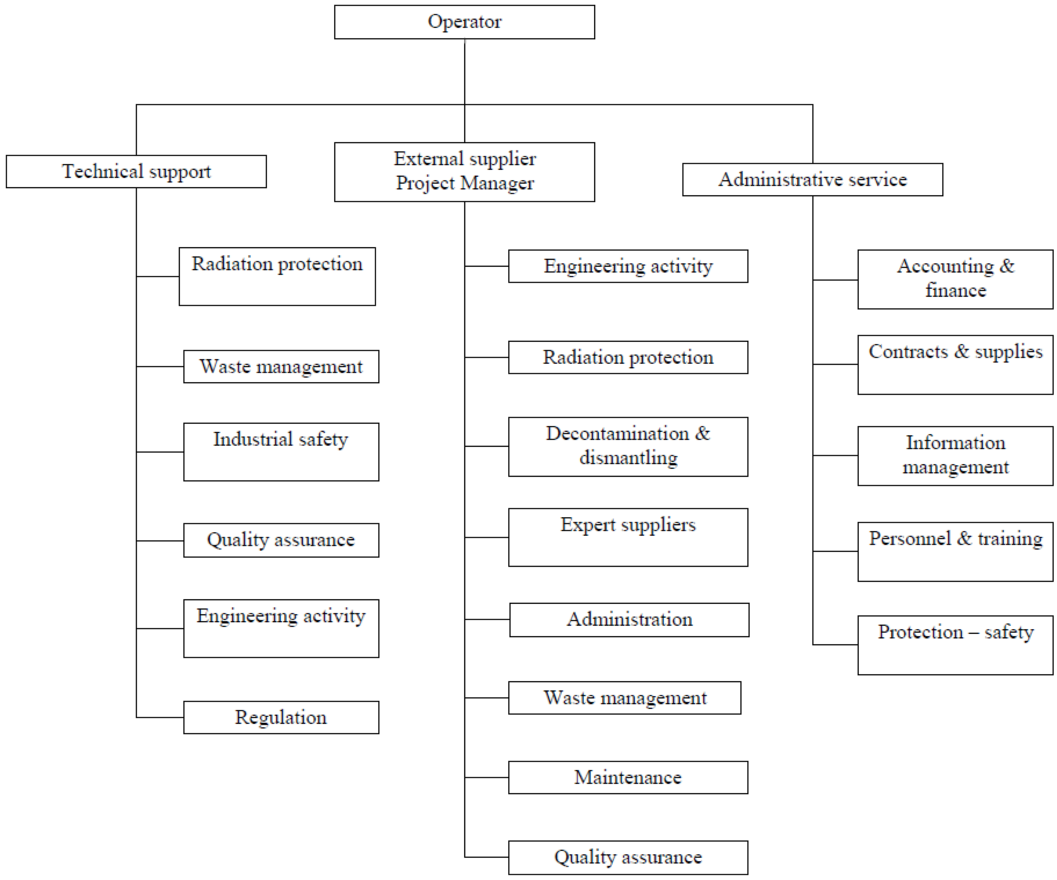

Figure 6.4 Organisational structure of decommissioning performed by an external supplier

The figure shows a management team where the licensee hires an outside organisation to perform the majority of the work and the licensee provides supervision and verification of the activities. In either case, the licensee retains overall responsibility for the project and ensures that all regulatory authority requirements are fulfilled.

The operator supervises and authorises the activities. The operator (the owner or the decommissioning licensee) remains always responsible for the decommissioning activities towards the regulatory authorities.

6.4.3 Multi-contractors

Figure 6.5 shows the organisational structure of a decommissioning team management where the decommissioning activities are carried out by several contractors.

The organisation consists of a number of project dedicated groups reporting to the facility and project control coordinator manager. The facility and project control coordinator manager, in turn, reports functionally and administratively to the suppliers manager of projects. To retain operational independence from all projects relating to the decommissioning activities, the quality assurance engineer and the licensing supervisor report administratively to the manager of the projects, but functionally to the respective functional groups outside the project groups within the operator. The project dedicated groups, except the health and safety group, report administratively and functionally to the facility and project control coordinator manager. Again, to retain some operational independence, the health and safety group reports administratively to the facility and project control coordinator manager but functionally to a group outside of the project.

6.4.4 Support for the supplier

The assessment of the general suppliers of the decommissioning process should consist of two parts. A first stage, assessment of the quality assurance programmes, should be concluded by authorisation of these quality documents. The second stage should include a verification of the implementation and efficiency of the declared quality programmes in practice.

The obligation to have a documented and effective quality system that meets the requirements for the particular implemented decommissioning stage should also apply for external suppliers.

The selection of suppliers and sub-suppliers to the general suppliers shall be carried out and documented in a way that provides a proof that the selection was carried out in accordance with the criteria defined in advance. The selection must be carried out before the order is placed or the contractual relationship established.

In order to show compliance of their procedures, the suppliers shall show the condition of their measuring, controlling and testing device that will be used during the decommissioning and dismantling activities. As a result, it is necessary for the suppliers of services and equipment to observe the related provisions when fulfilling the contractual requirements of the implementer of the decommissioning project. These provisions shall be binding for all suppliers.

In general, gauges, controlling and testing devices shall be maintained and used in such a manner that it secures that the measurement uncertainty is known and the given requirements are met.

Conform to the design conditions, the supplier shall:

- determine the required types of measurements, set accuracy thereof and select appropriate controlling and testing devices.
- safeguard calibration of the controlling and testing devices and verification of test software in the appointed intervals that follow the valid national reference standard. If there are no applicable reference standards, the calibration method must be reliably documented.
- mark all of the gauges, measuring and testing devices and test software with a suitable identification mark and keep records on calibration so that the calibration condition of the gauges is known at any time.
- have developed own internal regulation, for the purpose of assurance of metrological regulation.

In order to verify fulfilment of the suppliers' duties, the implementer of a decommissioning project shall perform regular inspections so that he knows the real conditions of the work, makes assessment thereof and, if any discrepancies are found, requests corrective and preventive measures in the affected field.

The general suppliers shall have developed and implemented rules of handling, storage and transport of material, parts, components, equipment, systems and structures they are responsible for. The regulation shall secure treatment of material during handling, transport and storage, preventing damage.

Where special handling is required, detailed instructions shall be developed and implemented, including the use of special handling equipment. Storage instructions shall regulate requirements for methods of placing, cleaning, conservation and packaging of material during storage in order to prevent corrosion, contamination, degradation, damage or loss of marking.

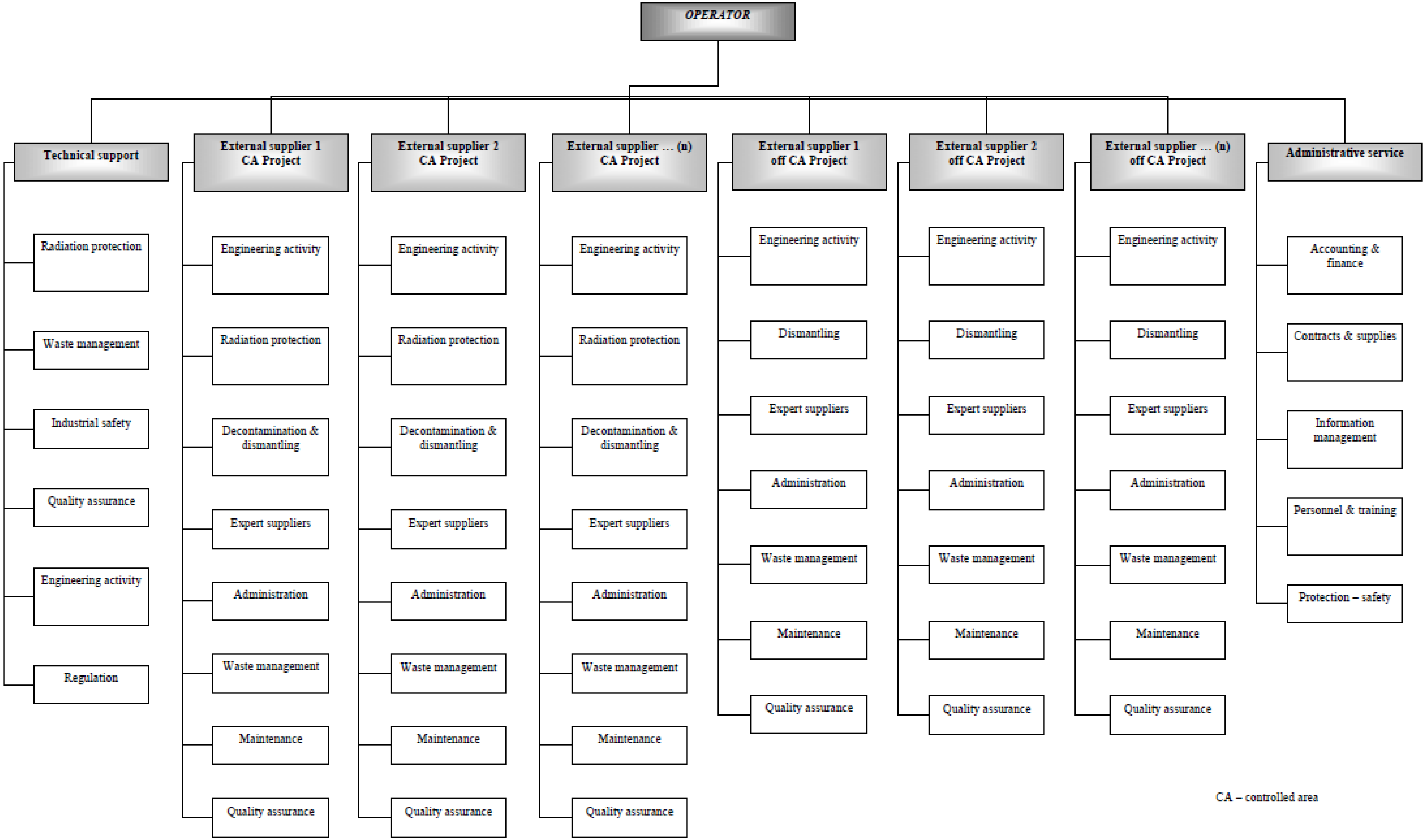

Figure 6.5 Multi contractors - organisational structure

Instructions on storage, handling and transport shall allow for fulfilment of safe work requirements.

During storage (and handling and transport), the responsible supplier's employees shall perform prescribed controls. The supplier develops a record from the controls and has it verified by the implementer of the decommissioning project. This record shall form a part of the back-up documentation. Through his own employees, the implementer of the decommissioning project shall perform independent and unplanned controls in the stated field. If discrepancies are found, a removal mechanism shall be contractually adopted.

For the decommissioning stage of the facility, the following deviations shall be regarded as discrepancies:

- for the project, a discrepancy between the preliminary design and the design requirements, a discrepancy between the preliminary design and the executive design, or among various executive designs;
- for the individual stages of decommissioning and dismantling, deviations from the executive design, valid standards, rules, technical specifications, regulations, technological procedures on dismantling, prescribed test parameters during the decommissioning, or other deviations that could cause reduction in quality of procedures or pose a threat to safe operation.

The responsibilities of the individual suppliers shall be defined to inform the implementer of the decommissioning project on discrepancies, removal deadlines, processing of technical solutions how to remove discrepancies, and development of a list of discrepancies, including an update thereof.

6.4.5 Specific models

6.4.5.1 Multiple units projects – single site

The decommissioning of multiple units project should be supported by processes of control, estimation and administration services. Based on an analysis of the development of the company and the personnel strategy, a technical concept should be developed and the project should be broken down up to the working package level. The basic handling structure should be the primary structure, which is directly related to progressive execution of the decommissioning activities. It comprises the following levels:

- *General project* is the sum of all projects aimed at decommissioning the facility until the site has reached a state which allows further use.
- *Projects* are clearly defined parts of the general project, with a main objective.
- *Part projects* are parts of the project to reach the objective of the project, which has a definite objective and clearly defined corresponding measures.
- *Programmes* are clearly defined parts of the project, with a definite part objective, for which additional criteria (as, e.g., points of execution or organisation) may be used.
- *Working packages* are units of planning and execution work with complete content definition, measures, costs, capacities, interfaces, etc., which are treated as a unified whole in the frame of the time schedule, the budget schedule and the personnel plan. Further broken down levels for the execution of the working packages are defined under the same aspects and treated accordingly:
    * *Activities* are clearly defined parts of the working packages, if the working package does not fulfil the criteria of the in-depth structuring of that project.
    * *Actions* are defined sub-units of an activity that are not considered in the central cost calculation.

* *Tasks* are defined sub-units of an action, as, e.g., to-do lists.

Individual tasks are the smallest planning units while the working packages level is the main control level. Each working package has a complete specification (e.g., definition, task details, target dates, costs, capacities interfaces etc.) together with a 'Project Permit' signed by the managing director. On the basis of the working package, the network plan, time schedule, budget plan and personnel plan will be prepared and the project execution supervised [26].

The working packages are at the centre of all planning and controlling work, in the framework of the basic handling structure of the project work. At this level, top and bottom control as well as estimation and calculation converge, as is depicted in Figure 6.6.

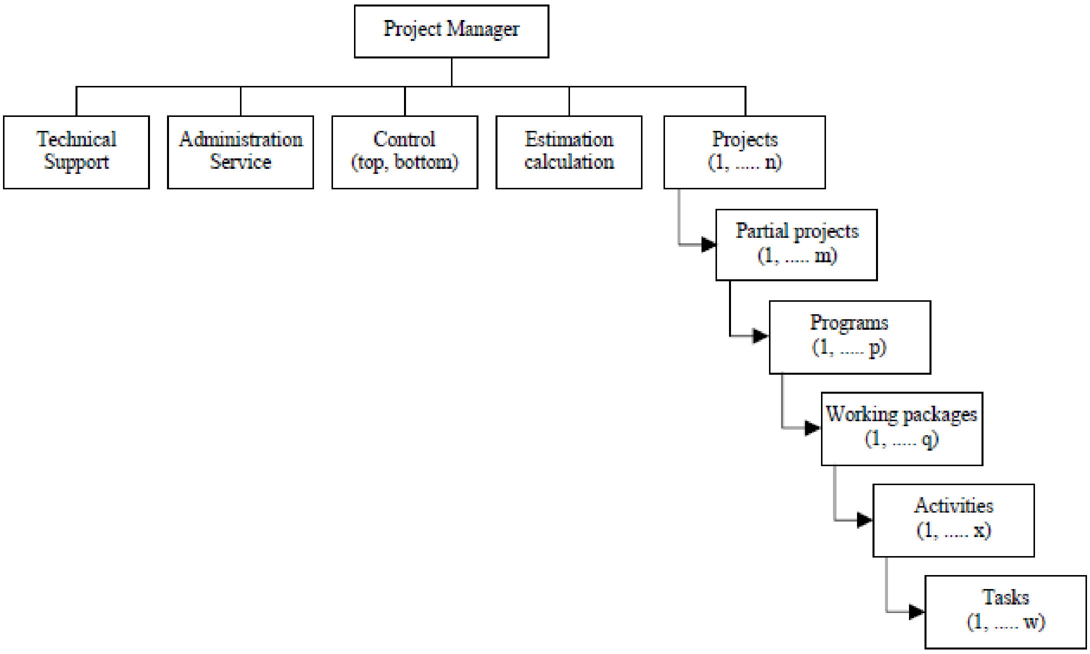

Figure 6.6 Multiple units project – single site organisational structure

6.4.5.2 Multiple projects – multiple sites

The organisational structure of multiple decommissioning projects on multiple sites is divided into main central departments and a lot of territorial units; in addition, there will be a staff position of business development.

The territorial units have to be strictly connected to the central departments that should control and give guidance to ensure an organic development of the activities.

The business development should work together with the above mentioned departments as they share the same market strategy and the same resources.

As indicated in Figure 6.7, the central departments should consist of:

- administration and budget;
- human resources and services;
- engineering and technologies;
- legal department;
- health physics and safety;
- decommissioning and fuel operations.

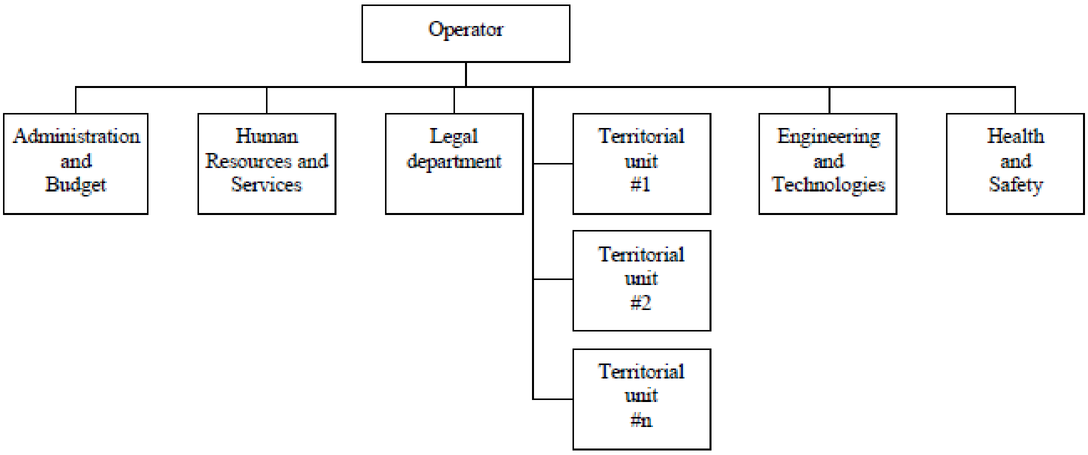

Figure 6.7 Multiple projects - multiple sites organisational structure

The territorial units are in charge of:

- facility management under the different configurations, according to unitary schemes;
- participation in engineering activities, in the definition of detailed working programmes and in identifying the needed resources;
- implementation of the operational activities with internal and/or external resources;
- final assessment of the components, systems and structures in a passive safe storage condition.

During a passive safe storage preparation, the activities are mainly devoted to:

- facility operational management;
- activities for decommissioning.

6.4.5.3 Decommissioning after an accident

The decommissioning of nuclear power plants after a standard shutdown is currently a well known process. Another situation is the decommissioning of a nuclear power plant after an accident, each case of accident being authentic. In such cases, it is always needed to concentrate a lot of energy on the following specific aspects:

- Analysing the radiological situation;
- Putting the accent on safety;
- Management of the situation after the accident;
- Management of non-standard wastes;
- Special techniques and procedures requiring research and development;
- Preparing the status for standard-like decommissioning.

In more detail, these aspects comprise:

- *Radiological characterisation:*

  After an accident, the radiological characteristics are specific, as well for the nuclide composition as for the level of contamination. The nuclide composition of the contamination of systems has two main components. The first components are the activated corrosion products due to the material of the primary systems which is mostly mild steel. The second components are the fission products and the trans-uranic elements released through damaged fuel cladding.

The non-standard radiological situation in nuclear power plants after an accident requires extensive radiological characterisation in several campaigns. The data are needed for developing the documents for decommissioning planning and licensing, for safety assessment of processes and equipment to be developed, for environmental impact assessment and for developing the waste management systems.

- *Safety aspects:*

  Safety has an absolute priority in the implementation of new procedures and equipment. In general, a two phased process for safety assessment is to be applied for critical operations or equipment. A first phase comprises a safety assessment of procedures and equipment as they are designed. The requirements of the safety assessments are then implemented into the final design before manufacturing of the equipment. In the second phase of the safety assessment, the achieved properties after manufacturing are analysed in order to evaluate whether the requirements of the safety assessment are met. The equipment and procedure then undergo cold and hot testing to confirm the required properties, and only after this phase the equipment and procedure will be approved by the regulatory authority. The process will be facilitated if the regulatory authority will be involved into the process from the beginning.

- *Management of the situation after the accident:*

  Early after shutdown, also other activities with consequences for the decommissioning operations may be performed like decontamination activities and storing of wastes. There may be significant volumes of liquid wastes with high specific radioactivity stored at the nuclear power plant. Experience shows that remediation of leakages of these liquid wastes require sophisticated technical solutions which are very expensive and time consuming.

  High dose rates in premises may require the application of remotely controlled techniques for operations like decontamination and dismantling of highly contaminated tanks and other equipment, retrieval of wastes from liquid waste collecting tanks and other applications.

  Systematic approaches have been applied for the remediation of leakages from storage tanks and shafts, including a detailed analysis of the situation in affected groundwater by water sampling, computer modelling of the evolution of the situation in the groundwater under various boundary conditions for supporting the decision for remediation activities. The primary sources of contamination have to be removed and measures have to be applied for preventing further leakages on site.

- *Waste management:*

  Developing the infrastructure for the management of radioactive wastes has to be organised in a systematic manner in order to develop systems capable of processing all historical wastes from the nuclear power plant. Modification of known processes may be needed in order to meet the requirements resulting from the specific physical-chemical properties.

- *Specific approaches, research and development:*

  Due to the specific situation in the nuclear power plant after an accident, it may not be easy to apply available decommissioning and waste management procedures and techniques directly. In most cases, techniques will have to be adapted to the local conditions, or it will be needed to develop tailored procedures and relevant equipment. The phases of design, manufacturing, testing, licensing and putting into operation of specific procedures and equipment will take time and will extend the total duration of the process. Specific approaches and aspects of the complex nuclear situation will be reflected in the final state.

In comparison with other decommissioning projects, the part of research and development activities within the whole volume of decommissioning activities may be significantly higher. This will concern especially the waste management technologies, remote controlled systems, systems for spent fuel handling, radio-chemical characterisation and sampling, visualisation and other issues like unique codes for evaluation and optimisation of decommissioning parameters.

According to these aspects, a special useful organisational structure has to be developed. The main differences, when comparing with standard decommissioning cases, will be:

- the duration;
- the application of specific procedures and techniques;
- the costs.

6.5 Differences in typical project management approaches

In existing decommissioning projects, the transition from operations to deconstruction has highlighted many key elements:

- new baseline of time frame and costs to suit employees and stakeholders;
- restructuring of the site economic model;
- focus on improved safety and safety infrastructure;
- select early example projects to demonstrate achievement;
- convert to a construction-like project attitude;
- work with stakeholders towards a rapid demolition schedule;
- competitive subcontracted production work;
- renegotiate labour agreements;
- renegotiate regulatory agreements.

In several cases, the site safety record has been significantly improved over the first year and the pace of activity increased rapidly to meet the production targets.

It has been seen that balancing ongoing operation costs with deconstruction costs has a high impact on the total project. Cutting the cost of operations by rapid closure, re-engineering and refined licensing has shown to be most beneficial.

Some important differences between deconstruction and operations have been identified:

- temporary versus permanent design life;
- activity versus facility based safety management;
- as-verified versus as-built configuration;
- off-normal versus routine safety risk;
- environmental and nuclear regulatory closure versus continuing operations;
- management of change versus steady-state;
- reduced administrative support;
- new employee training expectation;
- employee tenure reduced and goals re-focused.

Some of the challenges that have been faced were:

- inadequate nuclear safety mindset;
- nuclear and environmental regulation focused on operation;
- inadequate and inappropriate safety infrastructure;
- stakeholder expectations;
- workforce culture.

In general, it has been seen that the transition of culture from operations to decommissioning took time, but could be accomplished.

After a nuclear facility has been shutdown, the holder of the operational licence is required to secure the decommissioning activities. The holder of the decommissioning licence is responsible for the decommissioning activities. As indicated, theoretically several approaches are possible of how to decommission the nuclear equipment of a nuclear facility:

- decommissioning performed by own personnel of the operator;
- decommissioning performed by a general supplier organisation;
- decommissioning performed by multi suppliers organisations;
- decommissioning performed in specific cases (multiple unit - one site; multiple sites - one owner; decommissioning after an accident).

All approaches comprise performance of the decommissioning procedures until take-over of radioactive wastes at the storage facility, or the release of materials or conventional wastes from the decommissioning operations.

The organisation and the management during the decommissioning operations have a different inner structure than during the operation of a nuclear power plant. The main differences between the “decommissioning” and the “operational” conditions are shown in Table 6.3.

Table 6.3 Differences between “decommissioning” and “operational” conditions

Decommissioning	Operations
- Temporary proposal of organisational structures supporting the dismantling. - Safety management system based on the decommissioning issues. - Development-based management. - Safety risk mitigation; however, continuously changing situation. - Change management during decommissioning. - Reduction of administration. - Employee retraining on new activities. - Immediate employment – focused on work goals. - New or development requirements / supervision requirements.	- Permanent organisational structures of production. - Safety management systems based on operational nuclear safety. - Plan-based management. - Important safety risks; however stabile and routine. - Steady state management during operation. - Steady state in administrative. - Routine training and retraining. - Stabile employment with normal goals. - Permanent and developed requirements for operation.

In the course of preparation for decommissioning, the scope of activities is large and focuses on hiring of experts on decommissioning, waste treatment, and analyses of preparation and licensing costs. The workers may mainly not be full-time employees.

During the transition period, project management is applied alongside the operational management structure. The operational structure allows for circumstances and requirements of both operation and decommissioning.

At the beginning of the planning process, the management structure must be inevitably defined and implemented. It must be performed by workers who are technically and professionally qualified and have practical experience. The workers experienced in coordination, management and engineering will be involved in the project in its initial phase in order to perform efficient planning and successful start of the decommissioning operations. In the initial phases, it is preferred to have workers who were involved in the power plant operation and have knowledge of the power plant and the history of changes.

7. Project management issues

7.1 Management organisation and responsibilities

As mentioned in Section 4.1, general experience has shown that there are a number of central issues facing management which ideally require attention some years before a plant is finally shut down. Several of these, as listed below, were selected based on this experience:

- Stakeholder issues including staff and public relations;
- Regulatory and licensing issues including environmental impact assessment;
- Organisational restructuring;
- Decommissioning plans and technology;
- Training and retraining;
- Defueling and fuel management;
- Waste management and disposal;
- Funding and finance;
- Project strategy, planning and contracting;
- Records and documentation.

In the following paragraphs, various aspects and key issues are discussed but not rigorously following the above list, as many issues overlap and are discussed in relation to each other. Several lessons learned relating to key issues can be found in [26].

It is extremely important to appoint a decommissioning manager and preferably to do this before the plant is shut down. This manager would have the responsibility for undertaking the development of an adequate decommissioning plan. The manager need not necessarily have direct experience in the operation and maintenance of the plant. Sometimes formulating this plan can be the responsibility of a central company headquarters department, if this exists, or can be undertaken by engaging specialist consultants or contractors.

An appropriate organisational structure is needed for the decommissioning task force in order to identify lines of responsibility and to allow individual responsibilities to be defined. At an appropriate time, the decommissioning organisation must be merged with or replace the existing operational structure which will eventually cease to exist. At a site where there is a plant that is to be shutdown while some other facilities remain in operation, it is vital to clarify the demarcation between operational and decommissioning responsibilities.

Restructuring the organisation for decommissioning is often very problematic. The change from an operating regime with clear production goals to one aimed at demolition, dismantling and disposal, is difficult in a project and regulatory environment. A number of examples of initiatives to achieve this are given in [26]. A fundamental change in the organisation is beset by problems associated with staff morale, a persistent hope that the plant will restart and the lack of suitable training for both management and workers. Lack of equipment and financial resources to undertake even simple tasks often occurs. More seriously, confusion can arise if there is no decommissioning plan or any clear strategy or objectives. This condition can be exacerbated if, for example, key issues such as spent fuel management are not being resolved in a timely manner. Specific aspects of decommissioning planning are given in [26].

In changing an organisation from an operating regime to decommissioning, there is a need for cultural change. This can be achieved by retraining in-house staff, extensive use of experienced contractors or, even more drastically, by changing the ownership/licensee of the facility to one specifically created for decommissioning.

From reported experience, the main conclusions are identified below [26]:

- National decommissioning policies are evolving due to an accumulation of the experience at national and international levels.
- Experience has shown that to ignore public relations aspects of decommissioning can lead to many adverse situations and delays. Lack of information is often treated as lack in transparency by the public.
- Planning is an essential part of all decommissioning activities and there are numerous reports on the benefits of good planning. Planning at least a few years in advance while the facilities are still in operation is best, preferably with appointment of a dedicated project team. There are also reports of where lack of planning has lead to unnecessary and avoidable problems.
- Reviews of ongoing decommissioning processes are essential for two main reasons:
    * Firstly, the assumptions made at the initial planning stage will inevitably need review. This especially concerns funding and planning of longer decommissioning projects.
    * The second is that improvements in the decommissioning activities during the project need to be included.
- Roles and responsibilities of the stakeholders are best determined at an early stage in the decommissioning planning. Waste and spent fuel management issues are particularly relevant in this regard.
- Human resources need to be focused on. Ideally, skilled operating staff would be integrated into the decommissioning team.
- The uncertainties felt by personnel when a plant is finally shut down is common in all situations and should be anticipated.
- Feedback has been received from contractors on decommissioning experience. Based on this experience, it is recognised that advantages can be obtained by training of personnel in respect to radiological protection, use of new equipment and work safety. The benefits are risk minimisation and timely delivery of the plan, resulting in safe and cost effective work.
- The identification of radioactive waste streams and routes is a key issue in decommissioning planning. The absence of routes for waste disposal can result in delays in the decommissioning process.
- The importance of secure record keeping throughout the design, operation and decommissioning of a facility is widely recognised.

The senior management is responsible and accountable for the planning and implementation of a management system that is appropriate to the organisation. It is the role of the senior management to establish and cultivate principles that integrate all requirements into daily work. Senior managers should provide the individuals performing the work with the necessary information, tools, support and encouragement to perform their assigned work properly.

Visible and active support, strong leadership and the commitment of the senior management are fundamental to the success of the management system. Senior managers should communicate the beliefs that underlie the organisation’s policies through their own behaviour and management practices. The whole organisation should share the management’s perception and beliefs about the importance of the management system and the need to achieve the policies and objectives of the organisation.

Managers should be held responsible for ensuring that individuals working under their supervision have been provided with the necessary training, resources and direction. These elements should be provided before any work begins.

In assigning responsibilities and accountabilities, managers should ensure that the individuals concerned have the capabilities and the appropriate resources to discharge these responsibilities effectively. They should also ensure that individuals are aware of and accept their responsibilities, and that they know how their responsibilities relate to those of others in the organisation.

Managers should examine samples of work practices and related information on a regular basis to identify areas needing improvement. They should also encourage each individual under their supervision to look for more efficient and effective ways of accomplishing assigned tasks.

The senior management should be fully committed to the management system and should regard it as a tool for use in managing the organisation. The commitment of the senior management should foster long term commitment and engagement on the part of the management and of all individuals of the organisation, through a process of participation and consultation.

The individual who has responsibility for the management system should have the authority to raise issues relating to the management system at senior management meetings and to report on the status of corrective actions and improvements. If necessary, the individual should become involved in resolving any conflicts.

In some cases, the organisation may appoint external organisations or individuals to develop all or part of the management system. However, the disadvantage of doing this is that there is no “ownership” of the management system within the organisation.

If the management system is developed by an external organisation, care should be taken to ensure that the management system is relevant to the objectives of the organisation and that it addresses the actual processes of the organisation, and is not only a “model” management system as used in other industries [2].

7.2 Work breakdown structures and schedules

7.2.1 Work breakdown structure

A work breakdown structure (WBS) is a deliverable-oriented hierarchical decomposition of the work to be executed by the project team, to accomplish the project objectives and create the required deliverables. A deliverable is any unique and verifiable product, result or capability to perform a service that is identified in the project management planning documentation, and must be produced and provided to complete the project.

A work breakdown structure organises and defines the total scope of the project. It sub-divides the project work into smaller, more manageable pieces of work, with each descending level of the work breakdown structure representing an increasingly detailed definition of the project work. The planned work contained within the lowest-level work breakdown structure components, which are called work packages, can be scheduled, cost estimated, monitored, and controlled.

Although each project is unique, a work breakdown structure from a previous project can often be used as a template for a new project, since some projects will resemble another prior project to some extent.

7.2.2 Decomposition

Decomposition is the sub-division of project deliverables into smaller, more manageable components until the work and deliverables are defined to the work package level. The work package level is the lowest level in the work breakdown structure, and is the point at which the cost and schedule for the work can be reliably estimated. The level of detail for work packages will vary with the size and complexity of the project. Decomposition may not be possible for a deliverable or sub-project that will be accomplished far into the future. The project management team usually waits until the deliverable or sub-project is clarified so the details of the work breakdown structure can be developed. This technique is sometimes referred to as rolling wave planning.

Different deliverables can have different levels of decomposition. To arrive at a manageable work effort (i.e., a work package), the work for some deliverables needs to be decomposed only to the next level, while others need more levels of decomposition. As the work is decomposed to lower levels of detail, the ability to plan, manage, and control the work is enhanced. However, excessive decomposition can lead to non-productive management effort, inefficient use of resources, and decreased efficiency in performing the work. The project team needs to seek a balance between too little and too much in the level of work breakdown structure planning detail.

Decomposition of the total project work generally involves the following activities:

- Identifying the deliverables and related work;
- Structuring and organising the work breakdown structure;
- Decomposing the upper work breakdown structure levels into lower level detailed components;
- Developing and assigning identification codes to the work breakdown structure components;
- Verifying that the degree of decomposition of the work is necessary and sufficient.

Identifying the major deliverables of the project and the work needed to produce those deliverables requires analysing the detailed project scope statement. This analysis requires a degree of expert judgment to identify all the work including project management deliverables and those deliverables required by contract.

Structuring and organising the deliverables and associated project work into a work breakdown structure that can meet the control and management requirements of the project management team is an analytical technique that may be done with the use of a work breakdown structure template. The resulting structure can take a number of forms, such as:

- using the major deliverables and sub-projects as the first level of decomposition.
- using sub-projects, where the sub-projects may be developed by organisations outside the project team. For example, in some application areas, the project work breakdown structure can be defined and developed in multiple parts, such as a project summary work breakdown structure with multiple sub-projects within the work breakdown structure that can be contracted out. The seller then develops the supporting contract work breakdown structure as part of the contracted work.
- using the phases of the project life cycle as the first level of decomposition, with the project deliverables inserted at the second level.
- using different approaches within each branch of the work breakdown structure.

Decomposition of the upper level work breakdown structure components requires sub-dividing the work for each of the deliverables or sub-projects into its fundamental components, where the work breakdown structure components represent verifiable products, services, or results. Each component should be clearly and completely defined and assigned to a specific performing organisational unit that accepts responsibility for the work breakdown structure component's completion. The components are defined in terms of how the work of the project will actually be executed and controlled. Verifying the correctness of the decomposition requires determining that the lower-level work breakdown structure components are those that are necessary and sufficient for completion of the corresponding higher-level deliverables.

Each work breakdown structure component, including work package and control accounts within a work breakdown structure, is generally assigned a unique identifier from a code of accounts. These identifiers provide a structure for hierarchical summation of costs, schedule, and resource information.

The work breakdown structure should not be confused with other kinds of breakdown structures used to present project information. Other structures used in some application areas or other knowledge areas include [27]:

- Organisational breakdown structure (OBS): provides a hierarchically organised depiction of the project organisation arranged so that the work packages can be related to the performing organisational units.
- Risk breakdown structure (RBS): a hierarchically organised depiction of the identified project risks arranged by risk category.
- Resource breakdown structure (ReBS): a hierarchically organised depiction of the resources by type to be used on the project.

A companion document to the work breakdown structure is the work breakdown structure dictionary, which is a component of the detailed project scope definition and is used to verify that the deliverables being produced and accepted are included in the approved project scope. The detailed content of the components contained in a work breakdown structure, including work packages and control accounts, can be described in the work breakdown structure dictionary. For each work breakdown structure component, the work breakdown structure dictionary should include a code of account identifier, a statement of work, the responsible organisation, and a list of schedule milestones.

7.2.3 Schedules

Projects are generally complex endeavours and a plan is essential to guide the execution of the project. As progress is recorded on a project, the remaining work requires re-assessment in light of the new information. Rarely does the execution of a project proceed as initially planned. In a typical project climate, a defined and refined scheduling process is required to predict, recognise, and address the factors and issues potentially affecting project performance.

The purpose of scheduling is to provide a "roadmap" that represents how and when the project will deliver the products defined in the project scope and by the project team. Scheduling is one of the basic requirements of project management planning and strategic analysis. Its main objective is to establish the time required for a project.

Project time management includes the processes required to accomplish timely completion of the project. The project time management processes include the following:

1. *Activity definition*: identifying the specific schedule activities that need to be performed to produce the various project deliverables.
2. *Activity sequencing*: identifying and documenting dependencies among schedule activities.
3. *Activity resource estimating*: estimating the type and the quantities of resources required to perform each schedule activity.

4. *Activity duration estimating*: estimating the number of work periods that will be needed to complete individual schedule activities.
5. *Schedule development*: analysing activity sequences, durations, resource requirements, and schedule constraints to create the project schedule.
6. *Schedule control*: controlling changes to the project schedule.

These processes interact with each other and with other processes of the project management as well.

Defining the schedule activities involves identifying and documenting the work that is planned to be performed. The *activity definition* process will identify the deliverables at the lowest level in the work breakdown structure, which is called the work package. Project work packages are planned (decomposed) into smaller components called schedule activities to provide a basis for estimating, scheduling, executing, and monitoring and controlling the project work. Implicit in this process is defining and planning the schedule activities such that the project objectives will be met.

Activity sequencing involves identifying and documenting the logical relationships among schedule activities. Schedule activities can be logically sequenced with proper precedence relationships, as well as leads and lags to support later development of a realistic and achievable project schedule. Sequencing can be performed by using project management software.

A method called “Precedence Diagramming Method” (PDM) is a method of constructing a project schedule network diagram that uses boxes or rectangles, referred to as nodes, to represent activities and connects them with arrows that show the dependencies. The “Precedence Diagramming Method” includes four types of dependencies or precedence relationships:

- *Finish-to-Start*: the initiation of the successor activity depends upon the completion of the predecessor activity.
- *Finish-to-Finish*: the completion of the successor activity depends upon the completion of the predecessor activity.
- *Start-to-Start*: the initiation of the successor activity depends upon the initiation of the predecessor activity.
- *Start-to-Finish*: the completion of the successor activity depends upon the initiation of the predecessor activity.

In the “Precedence Diagramming Method”, *finish-to-start* is the most commonly used type of precedence relationship.

Estimating *schedule activity resources* involves determining what resources (persons, equipment or materials) and what quantities of each resource will be used, and when each resource will be available to perform project activities. The activity resource estimating process is closely coordinated with the cost estimating process.

The process of estimating *schedule activity durations* uses information on schedule activity scope of work, required resource types, estimated resource quantities, and resource calendars with resource availabilities. The duration estimate is progressively elaborated, and the process considers the quality and availability of the input data.

Project schedule development is an iterative process, which determines planned start and finish dates for project activities. Schedule development can require that duration estimates and resource estimates are reviewed and revised to create an approved project schedule that can serve as a baseline against which progress can be tracked. Schedule development continues throughout the project as work progresses, the project management plan changes, and anticipated risk events occur or disappear as new risks are identified.

The project scope statement contains assumptions and constraints that can impact the development of the project schedule. Assumptions are those documented schedule-related factors that, for schedule development purposes, are considered to be true, real, or certain. Constraints are factors that will limit the project management team's options when performing schedule network analysis.

There are two major categories of time constraints considered during schedule development:

- Imposed dates on activity starts or finishes can be used to restrict the start or finish to occur either no earlier than a specified date or no later than a specified date. While several constraints are typically available in project management software, the "Start No Earlier Than" and the "Finish No Later Than" constraints are the most commonly used. Date constraints include such situations as agreed-upon contract dates, a market window on a technology project, weather restrictions on outdoor activities, government-mandated compliance with environmental remediation, and delivery of material from parties not represented in the project schedule.
- The project sponsor, project customer, or other stakeholders often dictate key events or major milestones affecting the completion of certain deliverables by a specified date. Once scheduled, these dates become expected and can be moved only through approved changes. Milestones can also be used to indicate interfaces with work outside of the project. Such work is typically not in the project database and milestones with constraint dates can provide the appropriate schedule interface.

The project schedule includes at least a planned start date and a planned finish date, for each schedule activity. If resource planning is done at an early stage, then the project schedule would remain preliminary until resource assignments have been confirmed, and scheduled start dates and finish dates are established. This process usually happens no later than at completion of the project management plan. A project target schedule may also be developed with defined target start dates and target finish dates for each schedule activity. The project schedule can be presented in summary form, sometimes referred to as the master schedule or milestone schedule, or presented in detail. Although a project schedule can be presented in tabular form, it is more often presented graphically, using one or more of the following formats:

- *Project schedule network diagrams*: These diagrams, with activity date information, usually show both the project network logic and the project's critical path schedule activities. These diagrams can be presented in the activity-on-node diagram format, or presented in a time-scaled schedule network diagram format that is sometimes called a logic bar chart.
- *Bar charts*: These charts, with bars representing activities, show activity start and end dates, as well as expected durations. Bar charts are relatively easy to read, and are frequently used in management presentations.
- *Milestone charts*: These charts are similar to bar charts, but only identify the scheduled start or completion of major deliverables and key external interfaces.

Milestones will have zero duration, will be used as bench marks to measure progress against, and can also reflect the start and finish points for various project events or conditions. Generally, a milestone will represent the start or completion of a part of the project and/or may be associated with external constraints, such as the completion of a deliverable or the receipt of an external input. As a minimum, each project must have a start milestone and finish milestone.

Once agreed upon, the first version of the schedule that is developmentally complete to be approved for capture or copied for future reference is called the project baseline schedule. This baseline becomes the benchmark against which project performance may be measured. It is a generally accepted practice that every project should have a baseline schedule in place before the execution of the project work commences.

Once the baseline has been approved, reports are distributed in accordance with the project's communication plan and changes are monitored and controlled through the integrated change control process.

7.3 Cost and manpower estimates

Estimating decommissioning costs and collecting funds are the prerequisites for safe, timely and cost effective decommissioning [27]. One of the main messages for planned activities in decommissioning costing is that it is increasingly important to ensure that higher cost effectiveness should be achieved in the management of nuclear liabilities. Possible ways to achieve this is to identify effective solutions for individual decommissioning activities and in this way to optimise the costs. The trend is to achieve a better understanding of cost estimates and, based on those, to fine tune the funding mechanisms [28].

Costing means estimation of costs and also other decommissioning parameters like manpower, duration, exposure, amount of waste and others. Manpower is a typical "neutral" decommissioning parameter which reflects the amount of work performed within the decommissioning project fairly independent of national conditions. Manpower is the main indicator of the size of the project. Costs for the same amount of work can vary markedly due to various national conditions, but the extent of manpower may be similar. Manpower is normally the basis for the calculation of costs and other decommissioning parameters. Manpower items represent the real amount of work performed under given conditions at the facility. Therefore, costs and manpower are decommissioning parameters which should be presented together.

The cost estimating process is a kind of modelling of the decommissioning process. Better understanding of the costing process, clear definition and mutual links of individual costing elements that should reflect all relevant aspects of the decommissioning process, could enhance modelling of the decommissioning process in order to be closer to the real process. In this way, decommissioning costing will also be able to optimise the decommissioning processes in order to define the optimal cost and time structure and to ensure the safety of the process.

Management of cost estimates should ensure that cost estimates implemented during the life cycle of the facility consider all relevant factors which have impact on the decommissioning costs and at the same time, that all national, site and facility specific issues were taken into account. The costing can be done by an own group or can be contracted to a specialised company.

7.3.1 Management of cost estimates during the life cycle of a facility

Decommissioning costing implemented during the life cycle of a facility has a graded character. Management of costs during the various phases means to ensure the conditions for decommissioning costing (establishing the costing group or contracting the costing) starting from the preliminary conceptual level at the commissioning stage, through periodical updating of the decommissioning costs up to the final decommissioning plan. Typical features of main phases of costing, relevant to the level of the decommissioning plan, are the following:

- *Preliminary conceptual decommissioning plan.* Robust cost estimates are typical for this stage with low level of details and relatively high contingency. Several decommissioning options are considered.
- *Conceptual decommissioning plan.* An intermediate level of details with grading of details in the course of time is identified. Several revisions are developed during the life cycle of the facility. Several strategies are considered and as the shutdown is nearing, one strategy is selected, which is further elaborated in the final decommissioning plan.

- *Final decommissioning plan.* One selected option is considered. The costing is detailed with relatively low overall contingency. The detailed facility inventory with data on structures and systems and detailed radiological data (after shutdown, removal of spent fuel and all operational media, and decontamination of the primary system) are available for costing purposes. The costing methodology is detailed; the costing items correspond with the detailed work packages.
- *Decommissioning phases.* Detailed working packages including costs are elaborated. The data are introduced into the integrated management and planning system for decommissioning and are compared with the real data from the process in order to develop feedback for improving the cost estimates for the next phases or work packages of decommissioning.

The procedure is presented in the principal scheme of cycles of decommissioning costing of Figure 7.1.

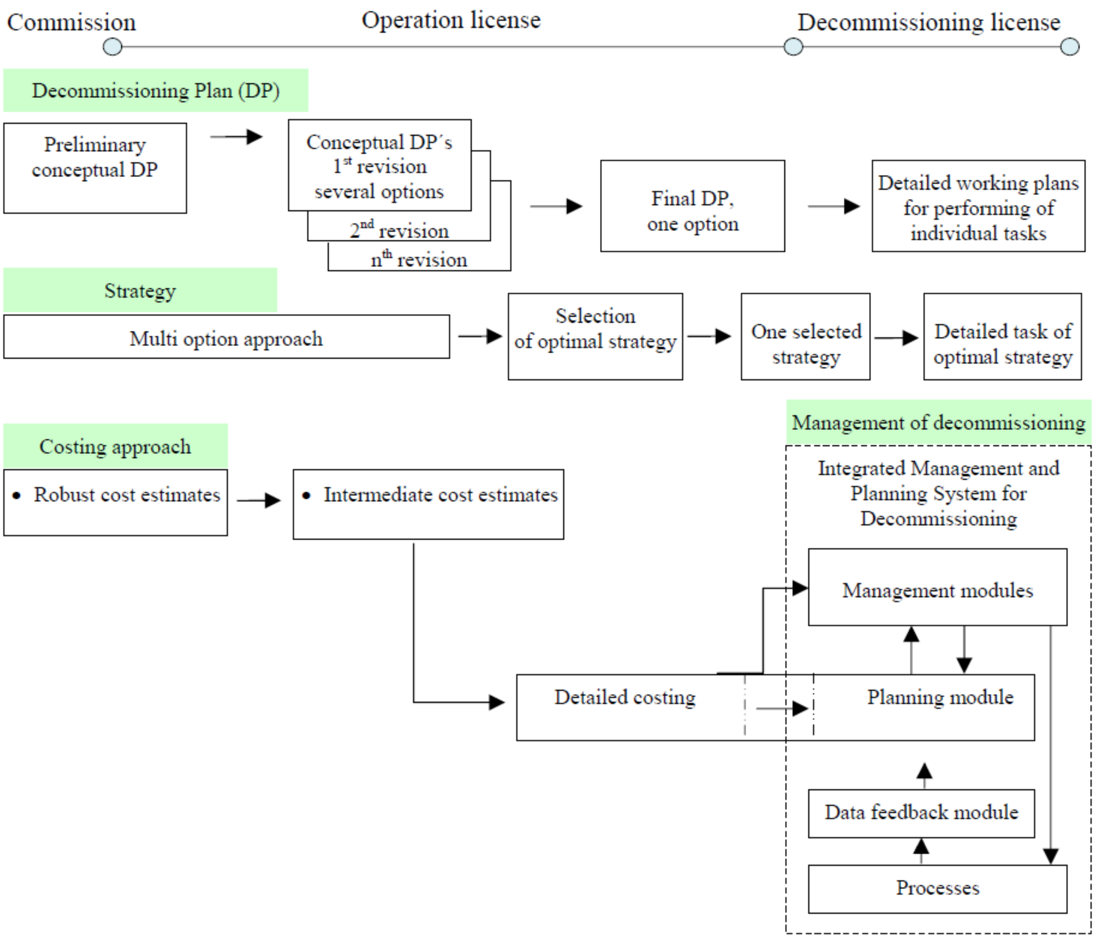

Figure 7.1 Principal scheme of cycles of decommissioning costing

7.3.2 Periodical reviews and updates of cost estimates

Periodical review and update of cost estimates is an effective tool to keep the cost estimates as close as possible to the most probable real decommissioning costs, which may vary due to changes in the conditions that were considered to be the boundary conditions for estimating the costs. The management of the life cycle phases of the facility and the management of decommissioning should take care of these periodical reviews of decommissioning costs.

There are several reasons for performing an update of the decommissioning costs:

- *Project specific reasons.* Examples are changes in documented conditions; changing of overhead costs; additional licensing conditions; planned tools or equipment; incidents or accidents in the facility; etc.
- *External reasons.* These could be changing interest and inflation rates; new regulations, acts, licensing policy; waste shipment problems; changed repository acceptance criteria and fees; newly employed technologies; gained experience at running decommissioning projects.
- *Reasons related to cost estimation methodologies.* These may include insufficient basic data (masses, radiological inventory, contamination level of components and buildings); the approach to the technical processes (idealised processes for cost estimations vs. real processes); the duration of the licensing process (duration and costs; delay in licensing); staff qualification and labour costs (major part of the total project; exact estimation of the number of workers; different sources of employee salaries and hourly rates); distribution factors and waste disposal (theoretical mass distribution vs. real mass flow; simplified approach; forecast of quantities of radioactive wastes).
- *External effects on cost estimation.* Such effects may comprise change and growth of the scope of the project (changing strategies due to operator decisions; revised processes and technical approaches); change of regulatory standards and laws (changing boundary conditions may enforce a strategy change; safety related changes often require increasing safety efforts, e.g., radiation protection); the availability of a final repository (no final repository for radioactive waste and thus unknown repository fees; acceptance criteria for containers important for waste conditioning and packaging).

The approaches for periodical reviews can be different for state owned facilities or for private facilities. A periodical update for state owned facilities has typically longer review periods and the update is also performed at external changes like compensation with annual budget or stretching of the project according to the available annual budget. Shorter review periods (3 - 5 years, in some cases annually) are typical for private owned facilities; counter measures aiming at minimising total project costs (i.e., project time), additional capacities, shifts and/or parallel execution of tasks are other examples of reasons for reviewing and updating decommissioning costs.

The reasons for periodical reviews and updates may also differ as for the phase of decommissioning. In the phases before the start of the decommissioning activities, the reasons may be regulatory changes (international, federal, local regulatory aspects); change of plant conditions; cost increases (interest/inflation rates, labour, energy, overhead costs); changes in waste disposal criteria or costs; change in management; political changes; local stakeholder involvement; etc.

In the phases during the decommissioning activities, the reasons for periodical reviews and updates may be changes in the plant conditions; new technology becoming available; increase of experience/lessons learned that affect project approaches/costs; changes related to project implementation; tool/equipment breakdown; incidents (spills, injuries, releases); labour strike; etc.

The management of the decommissioning activities should take care, that a dedicated cost estimation group would be available at least in phases close to shutdown of the plant and also during the first critical phases of decommissioning. An alternative option is periodical contracting of cost reviews and updates.

In general, periodical reviews and updates of decommissioning costs are needed as decommissioning costs usually will not decrease. Regulations related to decommissioning get more stringent, waste disposal costs continue to increase, other costs such as labour, energy and taxes also increase. Project changes and uncertainties are also mostly cost increasing.

Updating of decommissioning costs is performed routinely, normally every 3 - 5 years, depending on national legislation. As getting closer to decommissioning, the period for updating can become shorter. The management should take care, that decommissioning costing will consider the specific issues of the national decommissioning background, the site or the facility when reviewing the decommissioning costs. A parametric cost estimation approach has proven to be effective in periodical reviews.

7.3.3 Standardised cost estimation

One of the objectives of the European Commission (EC), the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (OECD/NEA) and the International Atomic Energy Agency (IAEA) in decommissioning costing is the promotion of harmonisation in presenting the decommissioning costs [25, 29]. It is recommended that the costs should be presented in a standardised cost structure [30]. The costs, as calculated in many current cost methodologies, have in principle a different project specific or national specific structure. Harmonisation in decommissioning costing means that a standardised cost structure is implemented in the calculation methodologies in order to calculate the costs directly in this standardised structure [30]. An alternative option would include reorganising the calculated data into the standardised cost structure.

The reasons for issuing the document with the standardised cost structure [30], were the inconsistencies in presented costs of various decommissioning projects caused by different extents of activities; technical, local and financial factors; waste management systems, etc. In order to achieve harmonisation in costing, a universal structure of decommissioning costs was developed as a result of an analysis of the spectrum of activities defined in many decommissioning projects of various nuclear facilities. In this way, the standardised cost structure covers activities which in principle can be identified for any decommissioning project. The standardised structure is defied as a system of cost items classified in 11 sections [30].

The standardised cost structure (also called “Proposed Standardised List of Items for Costing Purposes in the Decommissioning of Nuclear Installations, “PSL”) was developed as a hierarchical structure and one of the advantages of this structure is the numbering of the hierarchical levels up to the third level. From this level down, typical items are listed. For any user, it is possible to add additional levels of details.

The structure, as defined, is a unique platform for the harmonisation of decommissioning costing, at least for presenting the costs for decommissioning. The objective of implementing items of the “PSL” structure is the obligatory use of the numbered levels and the openness of the standardised structure for additional project specific definitions of decommissioning activities down from the last (third) numbered level. This approach “fixed on top, open downwards” offers the possibilities for the implementation of the “PSL” structure in principle for any nuclear facility. It means that nuclear facilities of various types could have their own specific spectrum of decommissioning activities within a harmonised structure.

One of the main objectives of the management of cost estimations should be implementation of the standardised cost structure in all cycles of costing [30].

7.3.4 Parametric cost estimation approach

Normally, the recommended procedure for selection the optimal decommissioning option is performed based on a multi-attribute analysis [25]. This means that a relevant set of decommissioning options, which cover the considered decommissioning strategy, should be evaluated. Each option is evaluated and optimised individually and from this set of options, one optimal option is selected based on pre-defined criteria for multi-attribute analysis.

Parametric cost estimation means that a costing methodology and a tool are available that enable easy recalculation of costs and other decommissioning parameters, and re-development of the decommissioning schedule, by changing a critical set of input data. Parametric cost estimation presumes that there is a set of input data common for all decommissioning options to be evaluated and a set of data specific for each decommissioning option. A parametric costing system can be developed by proper linking of the inventory data and a unit factors database with the calculation structure.

A parametric costing system is effective for the evaluation of various decommissioning options and for the selection of the optimal decommissioning strategy. The principal scheme of a parametric cost estimation system which implements the standardised cost structure [29, 30] is presented in Figure 7.2.

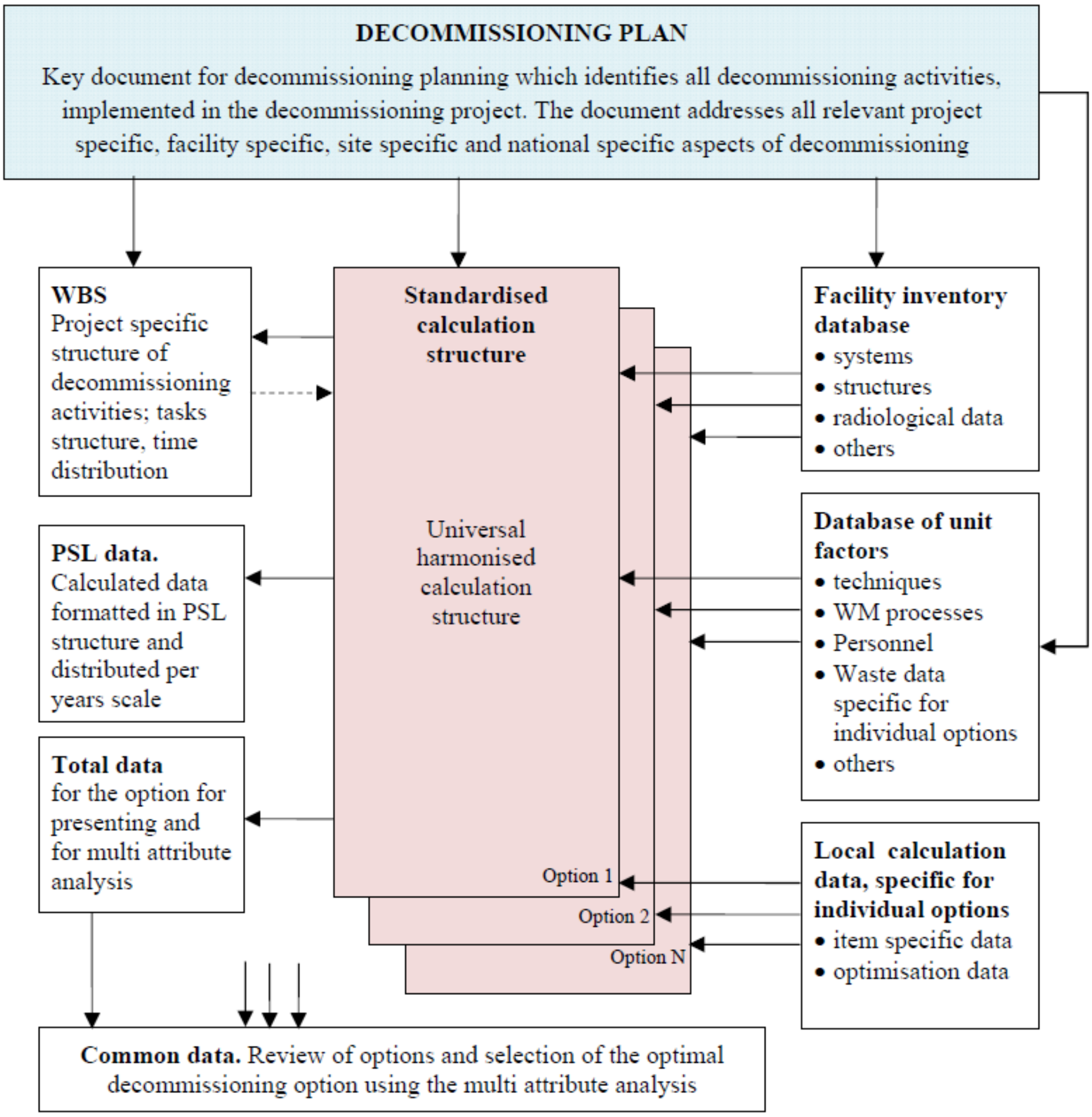

Figure 7.2 Principal scheme of a parametric cost estimation system that implements the standardised cost structure

7.4 Contracting models

The type of contract negotiated between the owner/licensee and a contractor (or a contractor and sub-contractors) is a powerful mechanism to control costs and maintain a project within budget and schedule [25]. The driving force of competition among contractors will lead them into committing to perform the work and to absorb a certain amount of risk in return for a potentially attractive return (fee). The more risk they absorb, the higher the potential fee to the contractor, and conversely, the potential for greater losses if they cannot perform the work scope within the agreed upon contract price and face major financial losses.

The owner/licensee balances the benefits of putting a contractor at risk, versus sharing the risk to ensure the project is completed successfully. When the facility site conditions (i.e., characterisation) are not well known, the owner/licensee accepts some of the risk and structures the contract to protect both the owner and the contractor for a win-win situation.

7.4.1 Fixed price (lump sum) contracts

Fixed-price contracts (also called lump sum) involve contractor bids on a fixed scope of work within a fixed period of time and for a single price. All of the contractor’s costs for labour, material, equipment (direct costs), and overhead, general and administrative expenses (indirect costs), contingency and profit are included in the lump sum. Milestones are established for the purposes of progress payments, but the owner/licensee does not have access to the contractor’s cost basis or fee. The fixed price is unchangeable unless the work scope changes and the owner/licensee agree to the terms and conditions of the extra cost.

This type of contract favours the owner/licensee in that the contract value is known and not readily subject to change. However, it does require a comprehensive and accurate site characterisation that is agreed upon between the owner/licensee and the contractor before the contract is signed. In one such arrangement, the owner/licensee required the prospective bidders to direct the characterisation team retained by the owner to sample and survey any area of the plant where the bidders believed there might be contamination. The resulting sample information was made available to all bidders to assist them in preparing their fixed price cost estimates. Upon award of the contract, the successful bidder was not permitted to claim out-of-scope change orders for reasons of new or undiscovered contamination. Five major contractors bid on the project and the successful bidder agreed to these terms. The owner/licensee was assured of a fixed cost, even though one or more sub-contractors had to complete the work at as much a twice their original bid price. The risk to the owner/licensee in this type of contracting is that the contractor backs out of the contract and either faces severe financial difficulties, allows the bonding company (if used) to hire a contractor to finish the work, or pays the liquidated damages. These interruptions could significantly delay progress on the project at additional cost to the owner/licensee.

7.4.2 Time and material contract

This type of contract is used where the owner/licensee has not performed an adequate characterisation of the facility, or such detailed characterisation is not possible because of poor documentation of prior history or because of extremely high radiation/contamination areas prohibiting manual access for sampling and surveying. Other reasons may include an indeterminate work scope, wherein the working conditions are likely to change as the contractor progresses in the planned project. The contractor is expected to provide its best estimate of the cost for owner/licensee budgeting purposes, but is allowed to charge his normal direct and indirect costs, and profit on an hourly basis for the crew and management team assigned to the project for the duration on the job. There is no contingency for the contractor included in this type of contract. This type of contract is usually written for relatively small, unique projects where the total budget is within the capabilities of the owner/licensee. Sometimes, time and material contracts may be imbedded within a larger fixed price contract for the special conditions mentioned earlier.

7.4.3 Cost-plus-fixed fee contracts

This type of contract is a compromise between the former two types. It provides reimbursement of direct and indirect costs to the contractor, and a negotiated fixed fee for the overall project. Direct and indirect costs and an earned percentage of the fixed fee are paid on a milestone completion basis. There is no contingency for the contractor included in this type of contract. For projects where the scope is subject to change, the contractor is protected from uncertainties and the owner/licensee's costs are under greater control than under a time and materials contract. The only risk to the contractor is if the project takes considerably longer to complete than anticipated, and the overall fee percentage begins to dwindle. The contractor continues to commit experienced labour resources at a diminishing profit.

7.4.4 Target cost-plus-incentive-fee

Both owner/licensee and contractors favour this type of contract since it provides a high degree of control by the owner/licensee, and a reward for good performance to the contractor. The contractor bids the target cost (including direct and indirect costs, and usually contingency) for the project and negotiates a percentage incentive fee for completing the job sooner at lower cost. It encourages creativity and high productivity of the workforce to improve on the target cost, while also boosting morale of the workforce to feel pride in their accomplishment.

Often, the contractor shares the incentive fee with its key personnel for successfully achieving cost and schedule improvements. However, the owner/licensee usually provides for a penalty if the contractor fails to meet the target cost or schedule, deducting a proportionate amount from the incentive fee for cost and schedule overruns. Other penalties may be imposed if the contractor work practices result in safety violations or injury to workers or the public. The competitive bidding process ensures the bidder will not inflate the target cost unreasonably, as the next bidder is likely to attempt to under-bid the work.

7.4.5 Target cost-plus-incentive-fee with shared savings

This type of contract is identical to the previous arrangement, except the owner/licensee and contractor share in the savings achieved in performing the work below the targets. Under this arrangement, the owner/licensee has a vested interest to assist the contractor to meet its targets, rather than to be in an adversarial role. Working as a team generally improves productivity, morale, and efficiency, thereby improving target performance.

7.4.6 Other arrangements

Other contractual arrangements are possible following these examples of standard contract terms and conditions. In the end, the owner/licensee has a better chance of succeeding to meet its objectives of cost control and schedule if it participates in a cooperative manner with the contractor. Owners/licensees, who seek to drive the contractor to the brink of bankruptcy, usually end up paying for poor performance, incurring safety risks, schedule delays, and cost overruns.

7.4.7 Written agreement of project original scope and schedule

While the contract between the owner/licensee and the decommissioning contractor may identify the scope and schedule in broad categories, a more detailed scope and schedule document may be prepared to ensure there is total agreement between the parties before the work begins. Failure to implement such agreements has resulted in adversarial relationships between the parties and usually is settled in litigation at significant additional cost. This agreement is a living document as scope changes are implemented and periodically updated to record change orders. The level of detail in this agreement is greater than what is recorded in the contract modifications.

7.5 Project reporting and documentation, record keeping

For the purposes of decommissioning, it is necessary for all relevant information about the installation in decommissioning to be available. This requirement is the same for small nuclear installations (research reactors, medical or nuclear facilities) and for energy producing nuclear installations. Generally, it is valid that the amount of available information about the nuclear facility after final shut down is decreasing. Operators working on the facility may be moved to other positions and their knowledge about individual parts of the nuclear facility will be lost. Another problem is that after shut down of the reactor, the operational personnel may forget all operational habits as the time goes. Also printed information and design documentation, operational regulations and protocols, records from working conferences, manuals and so on may be lost if there is no effort to store these.

For the reasons mentioned, it is necessary to develop systems for collecting and sorting relevant information and systems to store this information for future use. Such systems are known as record management systems (RCMS) [34].

The main data necessary for decommissioning activities after termination of operations of a nuclear installation can be divided into 2 basic areas:

- Data about construction and renovation of the nuclear facility.
- Data about operations, shut down of the nuclear facility and data about the conditions of the facility after shut down.

7.5.1 Data about construction and renovation of the nuclear facility

In general, these data are generated during the design, the construction and the operation of the nuclear facility. Mainly they comprise the following information:

- Data about the characteristics of the location where the nuclear facility was built, the geological and radiological characterisation of the environment.
- The design documentation of the nuclear installation, the buildings and the technological objects, including the material and building calculations.
- A detailed photo documentation of individual parts of the nuclear installation.
- Records about the amount and the type of used structural materials.
- The characterisation of the technological devices from the used structural materials point of view.
- Quality certificates.
- Safety analyses of emergency situations in the nuclear installation.
- The characterisation of the influence of the nuclear installation on the environment.
- Documentation about the tests of the nuclear installation before starting operations.
- Documents relating to the process of obtaining the operation licence.
- The preliminary decommissioning plan for the installation.

If the related information should not be available before the start of the decommissioning process, the necessary information will have to be collected by means of interventions on the construction part of the buildings or the technological parts of the nuclear installation.

7.5.2 Data about operations, shut down of the nuclear facility and data about the conditions of the facility after shut down

Data about operations of the nuclear installation are generated during the operational lifetime of the installation and mainly comprise the following information:

- Requirements for obtaining the licence for operations and for keeping the licence.
- Safety analyses.
- Operational regulations and manuals.
- Data about the radiological situation in the nuclear installation and in its surroundings.
- Operational and service records.
- Records about non-standard conditions of the nuclear installation and individual technological units.
- Plans for potential decontamination and protocols about its performance.
- Technical specifications and limits.
- Documentation about performed changes and interferences between the buildings and the technological parts of the nuclear installation.
- Inventory of dangerous materials located within the nuclear installation.
- Connection and influence on surrounding nuclear or non-nuclear installations.
- Records about performed inspections and controls and the evaluations.
- Records about radioactive waste management.
- Records about termination of operation of the nuclear installation or individual technological equipment during the operations and after shut down of the nuclear installation.
- Records about the quality system.
- Information about neutron flux and its distribution during operations.
- Information about sources of radioactive irradiation and their location in the surrounding of the nuclear installation.
- Records about irradiation and embrittlement of structural materials.
- Results of laboratory tests influencing the decommissioning process.

If information about the condition of the nuclear installation is lost or unavailable, it mostly considers data about the buildings and the technological modifications of parts of the nuclear installation that have been implemented.

7.5.3 Selection of the collected information about the nuclear installation

From the previous sub-sections it can be concluded that, in view of the decommissioning process, a large amount of data of different quality and categories about the nuclear installation has to be collected. It will be suitable to classify this information into the necessary categories and at the same time connect these to the integrated information system described in Section 7.6, Information technology systems.

7.5.4 Storage system for the records about the nuclear installation

The collection, categorisation, maintenance and distribution of records with data about nuclear installations can be implemented by means of a record management system (RCMS).

Such a record management system should be installed according to the designated procedure of the quality system in order to be able to pass independent audits at all levels.

From the decommissioning point of view, the primary goal of a record management system is to provide the choice of relevant records necessary to support the decommissioning process and to verify the suitability of the data source. This also includes storing the necessary information during institutional inspections and, if necessary, also after ending this stage.

During the implementation of any of the above mentioned activities, the system should be able to provide the following:

- Identification of records together with verification of the data source.
- Transfer, delivery and acceptance of records.
- Index of stored records.
- Storage of categorised records.
- Inspection of approach to individual records.
- Inspection of change of individual records.
- Regular data transfer to different storage media.
- National and international archive requirements.

Records may be stored as follows:

- *Printed, paper form*: Advantages of this form are that it is usually the original record; it is easy to create copies; and changes are easily identified. Disadvantages are mainly the large space necessary for storing the papers; possible damage; and the fact that the papers can be easily lost.
- *Microfilms*: Advantages of this form are that microfilms can be easily stored; it is easy to create copies; and changes are easily identified. Disadvantages are mainly the large volume of the media necessary for storing large amounts of information; possible damage; the fact that they can be easily lost; and clumsiness at the creation of solid paper copies.
- *Magnetic tapes and discs*: Advantages of this form are that it is a simple and compact storage medium; copying does not result in depreciation of recorded data; and there is a possibility for updating of data. Disadvantages of these media are depreciation in case of physical or magnetic damage; information in paper form must be scanned to enable that it can be stored in this form; and the necessity of regular update of hardware and software as a result of technical developments.
- *Optical and compact disks and digital video disks*: Advantages of this form are that it is a simple and compact storage medium; copying does not result in depreciation of recorded data; and simple and prompt access to data. Disadvantages of these media are that information in paper form must be scanned to enable that it can be stored in this form; and the necessity of regular update of hardware and software as a result of technical developments.

The system for the collection, classification, storage and management of information necessary in the decommissioning process presents high requirements for the operator of a nuclear installation. From the decommissioning process point of view, a record management system (RCMS) is an absolute necessity, however.

7.6 Information technology systems

Currently, the requirements for decommissioning are reviewed and incorporated into the design and operational procedures for a new facility. Accordingly, it is important that managing the records generated receives serious and proper consideration at this stage.

During the operation of a facility the information on the original design and modifications to it, is normally maintained as a recoverable record. In addition, careful attention is given to the operational records of the facility, for example dose rate surveys, dose commitments, contamination maps, unplanned events and waste management records. It should be noted that these records will form the basis for the records needed for the post-operational phase, including the decommissioning phase.

For existing operating or shutdown facilities without a decommissioning plan, the establishment of a decommissioning plan and strategy is a high priority. This includes the consideration and identification of the records important for decommissioning.

The main sources of data from which a records management system for decommissioning can be selected and assembled at the end of the lifetime of a facility are:

- design, construction and modification data;
- operating, shutdown and post-shutdown data.

Opportunities exist to build data collection and record keeping systems to operate as part of an integrated facility information system for a nuclear facility at its design and construction stage. Information should be available from different sources (operation of the facility, maintenance, radiological protection activities and waste management) and in several forms (as figures, images, samples and reports). An integrated facility information system can be designed to provide retrieval and manipulation of the data in a transparent way for its users. Records should be indexed by elements such as the classification of the records system, their type and their location. Further, it may be particularly helpful in any such database to flag data that may be of particular importance to decommissioning.

Scanning the hardcopy records required for decommissioning into an electronic records management system may provide enhanced search and retrieval capabilities, as well as providing a back-up for the hardcopy records.

Figure 5.2 in Section 5 illustrates the typical elements of a computer based integrated facility management information system. A computer system can enable access to all categories of records. If records are in a hardcopy form, their storage location is important for their retrieval, whereas if records are in an electronic format they can be accessed directly and displayed. It is important to audit an information system regularly to determine throughout the lifetime of a facility if the system contains adequate data for its decommissioning.

An integrated management information system is essential for the collection, cataloguing, maintenance and dissemination of records for the required timeframe, which could be several decades. The records management system needs to be established with written instructions, procedures or plans with quality assurance procedures, and regular independent auditing is necessary at all stages.

The primary focus of a decommissioning records management system is to ensure that the relevant records are selected to support decommissioning and that the data sources are validated, as appropriate. This may include the preservation of the necessary information for the duration of the active institutional control period and, where necessary, beyond this period. The information may exist in many media forms. Issues that need to be addressed through a system of documented instructions, procedures and plans, to ensure that the integrity of the information is preserved, may include:

- The requirements and responsibilities of all parties;
- The identification of records, including the validation of data sources;
- The transmittal, receipt and acceptability of the records;
- Record indexing and retrievability;
- Record retention classification;
- The record medium (e.g., paper, microfilm or electronic) and the primary and secondary storage locations;
- The protection of the records from adverse environments;
- Access control;
- The control of modifications to the records;
- The periodic reproduction or transfer between record forms;
- The national and international archives requirements.

A few examples of recent experience in the management of records are presented in [31, 32].

7.7 Project risk management

Project risk is an uncertain event or condition that, if it occurs, has a positive or a negative effect on at least one project objective, such as time, cost, scope, or quality (i.e., where the project time objective is to deliver in accordance with the agreed-upon schedule; where the project cost objective is to deliver within the agreed-upon cost; etc.). A risk may have one or more causes and, if it occurs, one or more impacts. If either of these uncertain events occurs, there may be an impact on the project cost, schedule, or performance. Risk conditions could include aspects of the project's or organisation's environment that may contribute to project risk, such as poor project management practices, lack of integrated management systems, concurrent multiple projects, or dependency on external participants who cannot be controlled.

Project risk has its origins in the uncertainty that is present in all projects. Known risks are those that have been identified and analysed, and it may be possible to plan for those risks using the processes described in this section. Unknown risks cannot be managed pro-actively, and a prudent response by the project team can be to allocate a general contingency against such risks, as well as against any known risks for which it may not be cost-effective or possible to develop a pro-active response.

Organisations perceive risk as it relates to threats to project success, or to opportunities to enhance chances of project success. Risks that are threats to the project may be accepted if the risk is in balance with the reward that may be gained by taking the risk. Risks that are opportunities, such as work acceleration that may be gained by assigning additional staff, may be pursued to benefit the project's objectives.

A consistent approach to risk that meets the organisation's requirements should be developed for each project, and communication about risk and its handling should be open and honest. Risk responses reflect an organisation's perceived balance between risk-taking and risk-avoidance.

Project risk management is a basic part of the project management as such [27, 30] and includes the processes concerned with conducting risk management planning, identification, analysis, responses, and monitoring and control on a project; most of these processes are updated throughout the project. The objectives of project risk management are to increase the probability and impact of positive events, and decrease the probability and impact of events adverse to the project.

The project risk management processes include the following:

1. *Risk management planning*: deciding how to approach, plan, and execute the risk management activities for a project.
2. *Risk identification*: determining which risks might affect the project and documenting their characteristics.
3. *Qualitative risk analysis*: prioritising risks for subsequent further analysis or action by assessing and combining their probability of occurrence and impact.
4. *Quantitative risk analysis*: numerically analysing the effect on overall project objectives of identified risks.
5. *Risk response planning*: developing options and actions to enhance opportunities, and to reduce threats to project objectives.
6. *Risk monitoring and control*: tracking identified risks, monitoring residual risks, and identifying new risks, executing risk response plans, and evaluating their effectiveness throughout the project life cycle.

These processes interact with each other and with the processes in the other knowledge areas [27, 30] as well.

- *Risk Management Planning*: is the process of deciding how to approach and conduct the risk management activities for a project. This process should be completed early during project planning.

  Project teams hold planning meetings to develop the risk management plan. Attendees at these meetings may include the project manager, selected project team members and stakeholders, anyone in the organisation with responsibility to manage the risk planning and execution activities, and others, as needed.

  Basic plans for conducting the risk management activities are defined at the planning meetings of the project teams. Risk cost elements and schedule activities will be developed for inclusion in the project budget and schedule, respectively. Risk responsibilities will be assigned. General organisational templates for risk categories and definitions of terms such as levels of risk, probability by type of risk, impact by type of objectives, and the probability and impact matrix will be tailored to the specific project. The outputs of these activities will be summarised in the risk management plan which describes how risk management will be structured and performed on the project. It becomes a subset of the project management plan.

  The risk management plan includes the following:

  * *Methodology*: defines the approaches, tools, and data sources that may be used to perform risk management on the project.
  * *Roles and responsibilities*: defines the lead, support, and risk management team membership for each type of activity in the risk management plan, assigns people to these roles, and clarifies their responsibilities.
  * *Budgeting*: assigns resources and estimated costs needed for risk management for inclusion in the project cost baseline.
  * *Timing*: defines when and how often the risk management process will be performed throughout the project life cycle, and establishes risk management activities to be included in the project schedule.
  * *Risk categories*: provides a structure that ensures a comprehensive process of systematically identifying risk to a consistent level of detail and contributes to the effectiveness and quality of risk identification. The risk categories may be revisited during the risk identification process. A good practice is to review the risk categories during the risk management planning process prior to their use in the risk identification process.

* *Definitions of risk probability and impact*: the quality and credibility of the qualitative risk analysis process requires that different levels of the risks' probabilities and impacts be defined. General definitions of probability levels and impact levels are tailored to the individual project during the risk management planning process for use in the qualitative risk analysis process. A relative scale representing probability values from "very unlikely" to "almost certainty" could be used.

- *Risk identification*: determines which risks might affect the project and documents their characteristics. Risk identification is an iterative process because new risks may become known as the project progresses through its life cycle. The frequency of iteration and who participates in each cycle will vary from case to case. The project team should be involved in the process so that they can develop and maintain a sense of ownership of, and responsibility for, the risks and associated risk response actions. Stakeholders outside the project team may provide additional objective information. The risk identification process usually leads to the qualitative risk analysis process; alternatively, it can lead directly to the quantitative risk analysis process. The outputs from risk identification are typically contained in a document that is called a risk register.

  The risk register ultimately contains the outcomes of the other risk management processes as they are conducted. It contains:

  * *List of identified risks*: the identified risks, including their root causes and uncertain project assumptions, are described. Risks can cover nearly any topic.
  * *List of potential responses*: potential responses to a risk may be identified during the risk identification process. These responses, if identified, may be useful as inputs to the risk response planning process.
  * *Root causes of risk*: these are the fundamental conditions or events that may give rise to the identified risk.
  * *Updated risk categories*: the process of identifying risks can lead to new risk categories being added to the list of risk categories. The risk breakdown structure (RBS) developed in the risk management planning process may have to be enhanced or amended, based on the outcomes of the risk identification process.

- *Qualitative risk analysis*: includes methods for prioritising the identified risks for further action, such as quantitative risk analysis or risk response planning. Organisations can improve the project's performance effectively by focusing on high-priority risks. Qualitative risk analysis assesses the priority of identified risks using their probability of occurring, the corresponding impact on project objectives if the risks do occur, as well as other factors such as the time frame and risk tolerance of the project constraints of cost, schedule, scope, and quality. Qualitative risk analysis is usually a rapid and cost-effective means of establishing priorities for risk response planning, and lays the foundation for quantitative risk analysis, if this is required. Qualitative risk analysis should be revisited during the project's life cycle to stay current with changes in the project risks.

  Risk probability assessment investigates the likelihood that each specific risk will occur. Risk impact assessment investigates the potential effect on a project objective such as time, cost, scope, or quality, including both negative effects for threats and positive effects for opportunities. Probability and impact are assessed for each identified risk. Expert judgment is required, since there may be little information on risks from the organisation's database of past projects. The organisation should determine which combinations of probability and impact result in a classification of high risk, moderate risk and low risk.

The output from qualitative analysis is the risk register updated with information from qualitative risk analysis and the updated risk register is included in the project management plan. The risk register updates from qualitative risk analysis include:

* *Relative ranking or priority list of project risks*: the probability and impact matrix can be used to classify risks according to their individual significance. Risks may be listed by priority separately for cost, time, scope, and quality, since organisations may value one objective over another. A description of the basis for the assessed probability and impact should be included for risks assessed as important to the project.
* *Risks grouped by categories*: risk categorisation can reveal common root causes of risk or project areas requiring particular attention. Discovering concentrations of risk may improve the effectiveness of risk responses.
* *List of risks requiring response in the near-term*: those risks that require an urgent response and those that can be handled at a later date may be put into different groups.
* *List of risks for additional analysis and response*: some risks might warrant more analysis, including quantitative risk analysis, as well as response action.
* *Watch lists of low priority risks*: risks that are not assessed as important in the qualitative risk analysis process can be placed on a watch list for continued monitoring.
* *Trends in qualitative risk analysis results*: as the analysis is repeated, a trend for particular risks may become apparent, and can make risk response or further analysis more or less urgent/important.

- *Quantitative risk analysis*: is performed on risks that have been prioritised by the qualitative risk analysis process as potentially and substantially impacting the project's competing demands. The quantitative risk analysis process analyses the effect of those risk events and assigns a numerical rating to those risks. It also presents a quantitative approach to making decisions in the presence of uncertainty. This process uses techniques such as "Monte Carlo" simulation and decision tree analysis:

* to quantify the possible outcomes for the project and their probabilities.
* to assess the probability of achieving specific project objectives.
* to identify risks requiring the most attention by quantifying their relative contribution to overall project risk.
* to identify realistic and achievable cost, schedule, or scope targets, given the project risks.
* to determine the best project management decision when some conditions or outcomes are uncertain.

Quantitative risk analysis should be repeated after risk response planning, as well as part of risk monitoring and control, to determine if the overall project risk has been satisfactorily decreased. Trends can indicate the need for more or less risk management action. It is an input to the risk response planning process.

Output of the qualitative risk analysis is in the quantitative risk analysis updated risk register. Updates include the following main components:

* *Probabilistic analysis of the project*: estimates are made of potential project schedule and cost outcomes, listing the possible completion dates and costs with their associated confidence levels. This output, typically expressed as a cumulative distribution, is used with stakeholder risk tolerances to permit quantification of the cost and time contingency reserves. Such contingency reserves are needed to

bring the risk of overrunning stated project objectives to a level acceptable to the organisation.

* *Probability of achieving cost and time objectives*: with the risks facing the project, the probability of achieving project objectives under the current plan can be estimated using quantitative risk analysis results.
* *Prioritised list of quantified risks*: this list of risks includes those that pose the greatest threat or present the greatest opportunity to the project. These include the risks that require the greatest cost contingency and those that are most likely to influence the critical path.
* *Trends in quantitative risk analysis results*: as the analysis is repeated, a trend may become apparent that leads to conclusions affecting risk responses.

- *Risk response planning*: is the process of developing options, and determining actions to enhance opportunities and reduce threats to the project's objectives. It follows the qualitative risk analysis and quantitative risk analysis processes. It includes the identification and assignment of one or more persons (the 'risk response owner') to take responsibility for each agreed-to and funded risk response. Risk response planning addresses the risks by their priority, inserting resources and activities into the budget, schedule, and project management plan, as needed.

  Planned risk responses must be appropriate to the significance of the risk, cost effective in meeting the challenge, timely, realistic within the project context, agreed upon by all parties involved, and owned by a responsible person. Selecting the best risk response from several options is often required. The risk response planning section presents commonly used approaches to planning responses to the risks. Risks include threats and opportunities that can affect project success, and responses are discussed for each.

  The risk register is first developed in the risk identification process, and is updated during the qualitative and quantitative risk analysis processes. The risk response planning process may have to refer back to identified risks, root causes of risks, lists of potential responses, risk owners, symptoms, and warning signs in developing risk responses.

  Several risk response strategies are available. The strategy or mix of strategies most likely to be effective should be selected for each risk. Risk analysis tools, such as decision tree analysis, can be used to choose the most appropriate responses. Then, specific actions are developed to implement that strategy. Primary and back-up strategies may be selected. A fall-back plan can be developed for implementation if the selected strategy turns out not to be fully effective, or if an accepted risk occurs. Often, a contingency reserve is allocated for time or cost. Finally, contingency plans can be developed, along with identification of the conditions that trigger their execution.

  Strategies for negative risks or threats: three strategies typically deal with threats or risks that may have negative impacts on project objectives if they occur. These strategies are to avoid, transfer, or mitigate:

  * *Avoid*: risk avoidance involves changing the project management plan to eliminate the threat posed by an adverse risk, to isolate the project objectives from the risk's impact, or to relax the objective that is in jeopardy, such as extending the schedule or reducing the scope. Some risks that arise early in the project can be avoided by clarifying requirements, obtaining information, improving communication, or acquiring expertise.
  * *Transfer*: risk transference requires shifting the negative impact of a threat, along with ownership of the response, to a third party. Transferring the risk simply

gives another party responsibility for its management; it does not eliminate it. Transferring liability for risk is most effective in dealing with financial risk exposure. Risk transference nearly always involves payment of a risk premium to the party taking on the risk. Contracts may be used to transfer liability for specified risks to another party. In many cases, use of a cost-type contract may transfer the cost risk to the buyer, while a fixed-price contract may transfer risk to the seller, if the project's design is stable.

* *Mitigate*: risk mitigation implies a reduction in the probability and/or impact of an adverse risk event to an acceptable threshold. Taking early action to reduce the probability and/or impact of a risk occurring on the project is often more effective than trying to repair the damage after the risk has occurred. Adopting less complex processes, conducting more tests, or choosing a more stable supplier are examples of mitigation actions. Mitigation may require prototype development to reduce the risk of scaling up from a bench-scale model of a process or product. Where it is not possible to reduce probability, a mitigation response might address the risk impact by targeting linkages that determine the severity. For example, designing redundancy into a sub-system may reduce the impact from a failure of the original component.

Output of the risk response planning is:

1. Updated risk register;
2. Project management plan (updates);
3. Risk related contractual agreements.

In the risk response planning process, appropriate responses are chosen, agreed-upon, and included in the risk register. The risk register should be written to a level of detail that corresponds with the priority ranking and the planned response. Often, the high and moderate risks are addressed in detail. Risks judged to be of low priority are included in a 'watch list' for periodic monitoring. Components of the risk register at this point can include:

* Identified risks, their descriptions, area(s) of the project affected (e.g., work breakdown structure element), their causes (e.g., risk breakdown structure element), and how they may affect project objectives.
* Risk owners and assigned responsibilities.
* Outputs from the qualitative and quantitative risk analysis processes, including prioritised lists of project risks and probabilistic analysis of the project.
* Agreed-upon response strategies.
* Specific actions to implement the chosen response strategy.
* Symptoms and warning signs of risks' occurrence.
* Budget and schedule activities required to implement the chosen responses.
* Contingency reserves of time and cost designed to provide for stakeholders' risk tolerances.
* Contingency plans and triggers that call for their executions.
* Residual risks that are expected to remain after planned responses have been taken, as well as those that have been deliberately accepted.
* Secondary risks that arise as a direct outcome of implementing a risk response.
* Contingency reserves that are calculated based on the quantitative analysis of the project and the organisation's response.

Project management plan (updates): the project management plan is updated as response activities are added after review and disposition through the integrated change control process. Risk response strategies, once agreed to, must be fed back into the appropriate processes in other knowledge areas, including the project's budget and schedule.

Risk-related contractual agreements: contractual agreements, such as agreements for insurance, services, and other items as appropriate, can be prepared to specify each party's responsibility for specific risks, should they occur.

- *Risk monitoring and control*: is the process of identifying, analysing, and planning for newly arising risks, keeping track of the identified risks and those on the watch list, reanalysing existing risks, monitoring trigger conditions for contingency plans, monitoring residual risks, and reviewing the execution of risk responses while evaluating their effectiveness. The risk monitoring and control process applies techniques, such as variance and trend analysis, which require the use of performance data generated during project execution. Risk monitoring and control, as well as the other risk management processes, is an ongoing process for the life of the project. Other purposes of risk monitoring and control are to determine if:

  * project assumptions are still valid;
  * risk, as assessed, has changed from its prior state, with analysis of trends;
  * proper risk management policies and procedures are being followed;
  * contingency reserves of cost or schedule should be modified in line with the risks of the project.

Risk monitoring and control can involve choosing alternative strategies, executing a contingency or fallback plan, taking corrective action, and modifying the project management plan. The risk response owner reports periodically to the project manager on the effectiveness of the plan, any unanticipated effects, and any mid-course correction needed to handle the risk appropriately. Risk monitoring and control also includes updating the organisational process assets including project lessons-learned databases and risk management templates for the benefit of future projects.

Outputs of the risk monitoring and control are following documents:

1. Risk register (updates);
2. Requested changes;
3. Recommended corrective actions;
4. Recommended preventive actions;
5. Organisational process assets (updates);
6. Project management plan (updates).

These output documents may comprise:

1. *Risk register (updates):*

   An updated risk register contains:

   - Outcomes of risk reassessments, risk audits, and periodic risk reviews. These outcomes may include updates to probability, impact, priority, response plans, ownership, and other elements of the risk register. Outcomes can also include closing risks that are no longer applicable.
   - The actual outcomes of the project's risks and of risk responses that can help project managers plan for risk throughout the organisation, as well as on future projects. This completes the record of risk management on

the project, is an input to the close project process, and becomes part of the project closure documents.

2. *Requested changes:*

   Implementing contingency plans or workarounds frequently results in a requirement to change the project management plan to respond to risks. Requested changes are prepared and submitted to the integrated change control process as an output of the risk monitoring and control process. Approved change requests are issued and become inputs to the direct and manage project execution process and to the risk monitoring and control process.

3. *Recommended corrective actions*

   Recommended corrective actions include contingency plans and workaround plans. The latter are responses that were not initially planned, but are required to deal with emerging risks that were previously unidentified or accepted passively. Workarounds should be properly documented and included in both the direct and manage project execution and monitor and control project work processes. Recommended corrective actions are inputs to the integrated change control process.

4. *Recommended preventive actions*

   Recommended preventive actions are used to bring the project into compliance with the project management plan.

5. *Organisational process assets (updates)*

   The six project risk management processes produce information that can be used for future projects, and should be captured in the organisational process assets. The templates for the risk management plan, including the probability and impact matrix, and risk register, can be updated at project closure. Risks can be documented and the risk breakdown structure updated. Lessons learned from the project risk management activities can contribute to the lessons learned knowledge database of the organisation. Data on the actual costs and durations of project activities can be added to the organisation’s databases. The final versions of the risk register and the risk management plan templates, checklists, and risk breakdown structures are included.

6. *Project management plan (updates)*

   If the approved change requests have an effect on the risk management processes, then the corresponding component documents of the project management plan are revised and reissued to reflect the approved changes.

8. Concluding remarks and recommendations

On the basis of the decommissioning experience and lessons learned the following recommendations can be made:

- It is very important to appoint a decommissioning manager and preferably to do this before the facility is shut down. This manager would have the responsibility for undertaking the development of an adequate decommissioning plan in time.
- Collection of the overall plant inventory has to be started as soon as possible. Mass inventory, setting-up of a dose rate/contamination atlas and extensive sampling to determine the nuclide vectors have to be carried out carefully. This is mandatory for preplanning the mass and activity flows as well as the necessary treatment facilities and devices. All logistics, including buffer storage, have to be prepared very carefully.
- As an essential tool for the decommissioning of a nuclear power plant, a well running management system comprised of a centralised database system with consistent data and modular structure of user’s modules working above the database is recommended.
- The basis for the development of this tool is a thorough analysis of the current plant status, the decommissioning objectives, the technical possibilities and all the boundary conditions.
- A clear project structure is a main basis of a well running management system.
- A modular structure of each user’s module is recommended.
- The implementation of the modules should be performed successively.
- The tool for decommissioning should be open and adaptable to the requirements.
- A lot of variants of project management approaches are possible for being used for the decommissioning of a nuclear power plant. The approaches depend on several aspects, which might be different for each country.
- Options for the organisation of the project management for the decommissioning of a nuclear power plant, evaluating and comparing these options and selecting the most suitable option from the legislative, safety, economic, technical, time, and social point of view is one of the inevitable conditions that have to be fulfilled before the very start of the decommissioning process.
- The availability of a decommissioning plan in the pre-decommissioning phase is very important and it should cover all activities related to the preparation of the actual decommissioning work at the facility. It should include strategic and conceptual studies in view of developing decommissioning strategies; detailed planning including preparation of the final decommissioning plan; accumulation of preliminary characterisation data; a baseline cost estimate for the work; preparing workers in view of the transition from operations to decommissioning; and safety and environmental studies.
- The documentation of the decommissioning project should include programmes that contain specific requirements for quality assurance during the decommissioning of nuclear equipment. The quality assurance programmes should contain a summary of regulatory requirements and procedures of activities; methods of control of documentation and records including verification, update and marking; and methods for organisational and technical safeguard of the activities and processes, including specification of competences, responsibilities and requirements for eligibility of employees that are performing these activities.
- The decommissioning management system should be described by a set of documents establishing the overall controls and measures to be developed and applied by an

organisation to achieve its goals. As soon as detailed data are made available from the radioactive inventory of the nuclear facility and the site characterisation programme, decisions on the handling of components, structures and soil can be made.

- After a nuclear facility has been shutdown, the holder of the operational licence is required to secure the decommissioning activities. The holder of the decommissioning license is responsible for the decommissioning activities. Several approaches on how decommissioning of nuclear equipment should be performed may be adopted (decommissioning performed by own personnel of the operator; by a general supplier organisation; by multi supplier organisations; in specific cases).
- All approaches comprise performance of the decommissioning procedures until take-over of radioactive wastes at the storage facility, or the release of materials or conventional wastes from the decommissioning operations.

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Annex 1

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Draft Report

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