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No. NG-T-1.6

Management of Nuclear Power Plant Projects

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MANAGEMENT OF NUCLEAR POWER PLANT PROJECTS

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The Agency's Statute was approved on 23 October 1956 by the Conference on the Statute of the IAEA held at United Nations Headquarters, New York; it entered into force on 29 July 1957. The Headquarters of the Agency are situated in Vienna. Its principal objective is "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world''.

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FOREWORD

The IAEA's statutory role is to "seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world". Among other functions, the Agency is authorized to "foster the exchange of scientific and technical information on peaceful uses of atomic energy". One way this is achieved is through a range of technical publications including the IAEA Nuclear Energy Series.

The IAEA Nuclear Energy Series comprises publications designed to further the use of nuclear technologies in support of sustainable development, to advance nuclear science and technology, catalyse innovation and build capacity to support the existing and expanded use of nuclear power and nuclear science applications. The publications include information covering all policy, technological and management aspects of the definition and implementation of activities involving the peaceful use of nuclear technology.

The IAEA safety standards establish fundamental principles, requirements and recommendations to ensure nuclear safety and serve as a global reference for protecting people and the environment from harmful effects of ionizing radiation.

When IAEA Nuclear Energy Series publications address safety, it is ensured that the IAEA safety standards are referred to as the current boundary conditions for the application of nuclear technology.

Member States that want to introduce a nuclear power programme in their country will need to pass through several phases during the implementation of this process.

This publication provides information on the implementation of a project management framework as a part of the management system, and the necessary systems to manage the activities to be carried out within the nuclear project itself.

The work was funded by the IAEA Peaceful Uses Initiative, which is directed to increase the capability of Member States to plan and implement nuclear power programmes and to establish and enhance national nuclear infrastructure. It should be used in conjunction with the IAEA Safety Standards Series and other appropriate safety, security and safeguards related publications.

The IAEA wishes to acknowledge the assistance provided by the contributors listed at the end of this report, in particular J.P. Boogaard (the Netherlands), J.H., Moore (Canada) and R. Speedy (South Africa) for their roles in putting together the final version.

The Scientific Secretary responsible for the preparation of this publication was P.T. Pyy of the Division of Nuclear Power.

CONTENTS

1. INTRODUCTION

1.1. BACKGROUND

Successes and failures within recent nuclear facility development and construction projects have highlighted the importance of implementing a structured and controlled project management approach to projects within the global nuclear industry. The management of a nuclear project throughout its life cycle, from development to decommissioning, has proved to be a challenging task, especially for a Member State new to the industry. Given the specifics of nuclear technology, nuclear project management is not just about delivering a facility and its associated physical infrastructure. It is also about confidently delivering a sustainable solution that can be safely, securely and reliably managed throughout its life cycle, involving many different stakeholders' interests in the process.

1.2. OBJECTIVE

Several organizations internationally offer mature project management knowledge bases. While helpful in numerous areas of project management, these more generic guides usually do not completely cater to the specifics of nuclear projects. This report has been developed from shared management practices and consolidated experiences provided by a number of invited nuclear project management specialists through a series of workshops and working groups organized by the IAEA. Its objective is to provide readers with a structured and methodical framework for the management of nuclear projects from their initiation to their closeout, so as to enable a best practice approach.

The publication captures the essence of international best practices and makes them available in a structured and organized way to assist management teams in planning and managing nuclear projects. Newcomer countries and their projects receive special emphasis. As there are many different solutions for achieving a successful project, the intention is not to be too prescriptive or to only give one approach.

The key objectives are:

- To provide an insight into the various available approaches for the implementation of the role of the owner/operator that should be considered by the Member State when structuring and managing the national programme consistent with other IAEA guidance;
- To provide a basic project management structure and a platform for continuous improvement on which an owner/operator can initiate a nuclear project;
- To highlight focus areas where nuclear projects require special attention;
- To highlight good practices about specific aspects of nuclear project management based on international experience.

Guidance provided here, describing good practices, represents expert opinion but does not constitute recommendations made on the basis of a consensus of Member States.

1.3. SCOPE

Practical information is given about various project management methodologies and management system approaches necessary to manage nuclear projects. This includes new build nuclear projects and other projects that may be performed by nuclear organizations, such as system upgrades or refurbishments within the context of the national infrastructure programme [1]. A coordinated management system approach is presented, facilitating compliance with national and major international legislative and regulatory requirements and standards. IAEA publications are referred to, where appropriate, for more detailed information and guidance on specific aspects.

This report endeavours to present a harmonized approach that may be used to structure the owner/operator management system and establish and manage nuclear projects and their development activities irrespective of the adopted approach. It gives information on the planning and execution of the project life cycle.

This publication does not focus on nuclear facility manufacturing, construction, operations or decommissioning management in as much detail, since they are sufficiently covered by other IAEA publications. For example, IAEA Nuclear Energy Series No. NP-T-2.7 [2] covers project management during the construction phase of a nuclear power plant (NPP), and IAEA Nuclear Energy Series No. NP-T-3.21 [3] covers management of procurement related to nuclear facilities. Various aspects of decommissioning are discussed in IAEA Safety Standards Series No. GSR Part 6, Decommissioning of Facilities [4] and IAEA Nuclear Energy Series Nos NW-T-2.5 and NW-G-2.1 [5, 6].

1.4. USERS

This publication is primarily intended to be used by management and staff of potential owner/operator organizations who are planning for or involved in the execution of a nuclear project. It may also be useful in informing the staff within the nuclear energy programme implementing organization (NEPIO), key vendors, contractors and other organizations involved in a project. It provides insight into the complexities of project management and delineates the various interfaces and structures necessary to manage the national programme.

While some countries may already have a well established nuclear operating and maintenance capability, recent international experience has shown that a different area of expertise and skill set is required for the management of new NPP development and construction projects. This unique capability can be quickly lost once a previous new build project has been concluded. For this reason, it is recommended that countries re-embarking on new build projects pay careful attention to recent international experience, and they may therefore also find value in this publication. Emphasis is placed on regaining the specific expertise and infrastructure required to support a new construction project, as opposed to that which has been maintained to manage an existing operating station.

1.5. STRUCTURE

In an attempt to enhance readability this publication is structured and sequenced into seven sections. Section 2 gives an overview of projects in general and of what organizational, national programme or company related factors influence such projects. Section 3 provides an overview of IAEA and available international project management guidance, as well as guidance related to both small projects and large megaprojects. Section 4 provides a comprehensive list of important areas to be managed within a nuclear project and approaches to managing them. Section 5 describes specific steps to implement a project management system and to incorporate documented international best practices into such a system. Section 6 describes specific project management steps to be taken during each of Milestone Phases 1, 2 and 3 of an NPP project, as well as topics that deserve early attention for commissioning, operations and decommissioning. Section 7 provides a short overview on the key messages from this publication. Various appendices provide more detail on specific topics in these sections where warranted.

2. NUCLEAR PROJECTS AND FACTORS THAT INFLUENCE THEM

2.1. WHAT IS A PROJECT?

The term ‘project’ can be defined in many ways; however, the Project Management Institute (PMI) defines a project as simply “a temporary endeavour undertaken to create a unique product, service or result” [7]. Projects are typically critical to the realization of the performing organization’s business strategy because they are a means by which the strategy of a company is implemented.

Projects are different from other ongoing operations within an organization because unlike operations, projects have a definite beginning and an end — they have a limited duration. Similarly, the individual processes that are used to manage specific project activities have a definite beginning and end. This is discussed in more detail in Appendix II in the context of an adapted Deming cycle.

Projects usually involve one or more elements that have not been addressed in the past and are therefore unique. A product or service may also be unique even if the category to which it belongs is not unique. For example, although several NPPs of generally the same design may have been built in the past, the creation of a new NPP will be a new and different project because each facility can include elements such as a unique location (sometimes with different norms, values, legislation and regulations), customized or adapted designs, regionally available components, different owners, different stakeholders, different construction forces or other differentiating factors.

A nuclear project is one that involves a nuclear facility or activity. A nuclear facility and activity is defined in the IAEA Safety Glossary [8] as a "general term encompassing *nuclear facilities,* uses of all *sources* of *ionizing radiation,* all *radioactive waste management activities, transport of radioactive material* and any other *practice* or circumstances in which people may be subject to *exposure* to *radiation* from naturally occurring or artificial *sources*." In a nuclear context, a project can thus include any of the following:

- Development of a new nuclear facility such as an NPP, research reactor, mine, fuel fabrication facility or irradiation facility as part of a national programme of projects;
- Major refurbishments, additions or life extension projects for a facility, often requiring extended outages;
- Decommissioning, waste storage and site remediation or restoration projects;
- Modifications to an existing nuclear facility that may be done on-line or during shorter duration outages;
- Management of nuclear facility maintenance activities (outages, component specific projects, etc.);
- Management of nuclear engineering or research related activities (e.g. studies, risk assessments, R&D projects);
- Managing nuclear transportation related projects;
- Improvement initiatives related to nuclear facilities or activities.

Although this publication focuses primarily on the management of NPP related projects, many of the principles described can be applied to most nuclear projects.

Conventional project management texts often convey the concept of a project management 'triangle' that illustrates the potential trade-offs between the key dimensions of a project. Any adjustment in one dimension affects the others. Different publications can define the dimensions slightly differently; however, common examples use the three dimensions of scope (project features and quality), time (or schedule) and cost (budget, resources, etc.). An increase in scope typically means a longer schedule and higher costs, a tight schedule can lead to increased costs and scope reductions, while a tight budget can mean a longer schedule and reduced scope. Often quality is separated out as impacting on all three dimensions (Fig. 1), since a desire to increase product quality can impact on cost, time to completion or the affordability of features/scope of the item or project.

Another expression of the same basic concept is being told to 'pick any two' options for the completion of a project: fast, good or cheap. This 'choice' is admittedly simplistic in nature, since it does not emphasize a balancing of the three elements; nor does it address the need, in a nuclear context, to always address nuclear safety and security at a foundational level.

2.2. PROJECT PHASES AND LIFE CYCLE

Projects can be seen as divided into a number of phases within which different activities predominate. Formal approvals are typically sought to proceed from one phase to the next, as progression to a later phase often entails financial and other resource commitments. There are usually five phases involved, as described below (see also Fig. 2):

(i) Project identification: During this phase the initial business need for the project is defined. This typically includes an assessment of the business need, gap or opportunity to be addressed. This work is normally funded externally from the project, since the project itself has not yet been approved.
At operating facilities, potential projects are often identified by engineering staff through system health reviews, component condition assessments, the life cycle plans that are prepared for major systems,

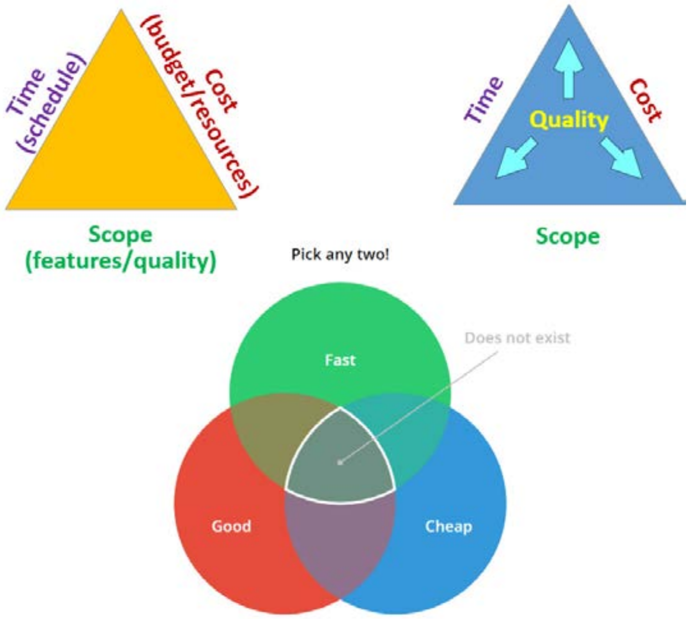

FIG. 1. Examples of project management concepts.

periodic safety reviews or due to changes in regulatory requirements. Other drivers may include the need to address spare parts issues, obsolescence, an opportunity to improve reliability based on forced loss rate analysis or security needs. Projects with an anticipated benefit for multiple sites may be identified and sponsored by support divisions. Station screening committees typically review potential projects and forward their recommendations for approval based on the net benefit documented in business cases.

For new build projects, project identification is typically done via a process of energy planning, pre-feasibility study and alternative selection for the country or region in question.

(ii) Project initiation: During this phase viable alternatives are evaluated and the initial project scope, schedule, conceptual funding and applicable stakeholders for the preferred alternative are identified. If the review concludes that undertaking a project is the recommended solution, the next step for most projects is the preparation of a financial business case for the next project phase. Potential projects are screened and success at this phase will lead to an allocation of the future funding.

(iii) Project development and definition: During the development and definition phase the project is fully defined and is demonstrated as being ready for execution. This would include the completion of sufficient engineering to determine bulk material requirements, development of the project cost estimate and execution plan, assessment of risk and development of mitigation plans, identification of and application for any requirements for regulatory approvals, and procurement of long lead engineered equipment. A financial release for the next project phase is sought at this time.

(iv) Project execution: During this phase detailed engineering, procurement (if not completed in the definition phase) and detailed construction/installation planning and/or physical execution of the project and commissioning work are completed.

(v) Project closeout and lessons learned: The closeout phase is the last phase in the project life cycle, and includes financial and contract closeout, preparation of a project closeout report and analysis of lessons learned.

Note that the project phases in Fig. 2 should not be confused with the nuclear power programme phases (1–3) as defined in IAEA Nuclear Energy Series No. NG-G-3.1 (Rev. 1), Milestones in the Development of a National Infrastructure for Nuclear Power [1]. In this, project development and execution take place during Phase 2 and Phase 3 of the Milestones Approach, subject to positive knowledgeable commitment in Milestone Phase 1.

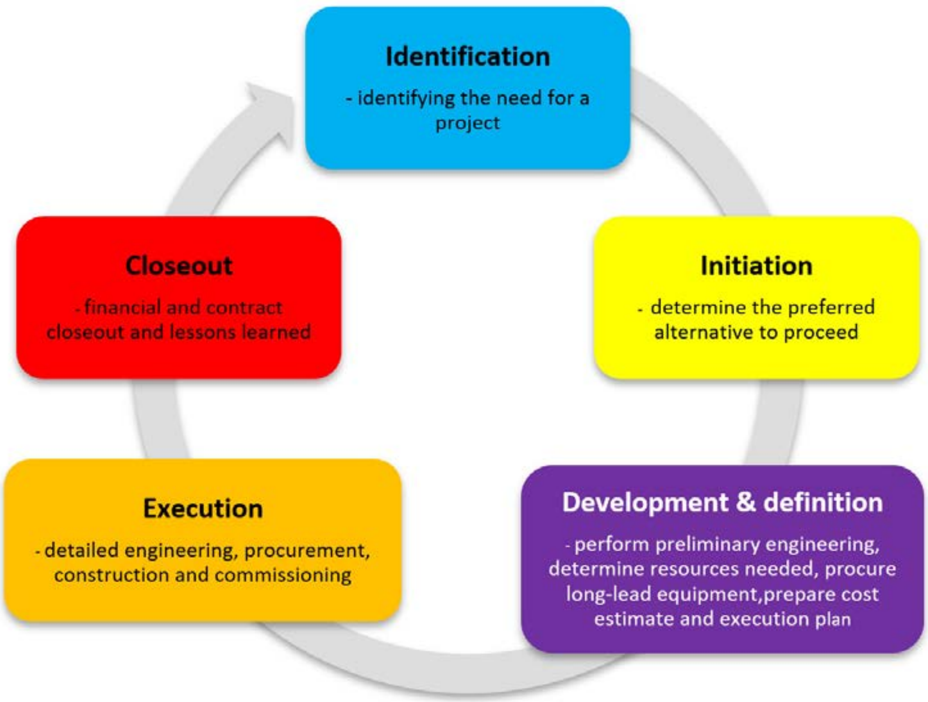

FIG. 2. Typical project life cycle.

2.3. EXTERNAL ENVIRONMENT AND ORGANIZATIONAL FACTORS THAT INFLUENCE PROJECTS

Nuclear projects exist in the context of their external environments and those of the companies that are executing them. An external environment that a project exists in but does not specifically control can greatly affect any projects that are undertaken. A project, no matter how well it is managed, cannot always overcome a negative external environment where this exists.

As shown in Fig. 3, some factors impacting on nuclear projects include:

- Project stakeholders and other interested parties;
- Governmental policy, political climate and energy planning mechanisms;
- Industrial involvement capability and goals (of the government or the company);
- National nuclear power programme;
- Regulatory environment;
- Company ownership structure;
- Mandate/business strategy, financing and electricity market models of the company (including its geographic scope);
- Company's project portfolio;
- Access to qualified and competent personnel, including those with project management experience;
- Access to organizational assets;
- Organizational culture and leadership style;
- Communications methods;
- Organizational structure and composition.

The following subsections discuss some of the key considerations involved.

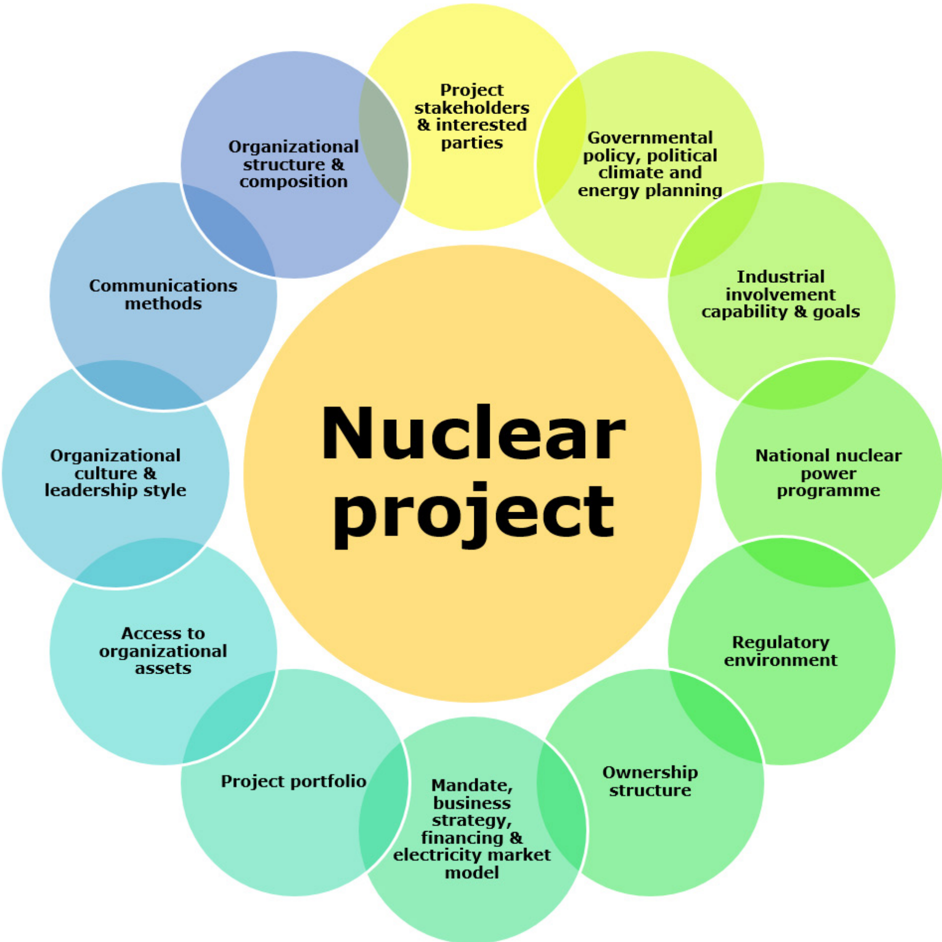

FIG. 3. Enterprise and external environment factors that influence nuclear projects.

2.3.1. External environment factors

External environment factors impact any project to some degree. Large or politically sensitive nuclear projects such as nuclear new builds or waste repositories attract significant public interest and so are particularly sensitive to these factors. The main external factors are described in the following subsections.

2.3.1.1. Project stakeholders and interested parties

Stakeholder management is a key part of project management. A large nuclear project can impact on many groups both within and external to a company. They can include government leaders, suppliers, the news media, medical and health professionals, special and public interest groups, consumer groups, other non-governmental organizations, individual citizens and informal opinion makers who may significantly affect the opinion of the community [9]. Stakeholders and other interested parties can even be from outside of the country in which the project is being executed.

Key internal stakeholders (individuals not assigned to the project organization) can include the project sponsor, the end user of the project (e.g. operations or maintenance personnel) or senior leadership who are responsible for choosing which projects to proceed with.

External events can impact the opinions of key stakeholders and the political environment in which they operate, so stakeholder engagement and management is an ongoing process.

2.3.1.2. Governmental policy, political climate and energy planning

To be successful, a nuclear power project requires an extended national commitment to nuclear power that will span several generations. As such, its justification is best assessed by whether or not it can be expected to yield a sustained overall benefit to the Member State throughout its life cycle. The need to establish a justification for the overall benefit is articulated in Principle 4 of the IAEA Safety Standards Series No. SF-1, Fundamental Safety Principles [10] and Principle 1 of the IAEA Nuclear Energy Series No. NE-BP, Nuclear Energy Basic Principles [11]. For a new NPP project, a preliminary decision on its overall benefit should have already been made by the Member State at the end of Milestone 1. This decision would normally be backed up by long term energy planning as well as socioeconomic benefit studies on the national effect of the project as part of the pre-feasibility study conducted (see Section 2.3.1.4). The development of such a project normally requires the existence of an enabling environment offering the necessary socioeconomic stability and sustained political and institutional support necessary for such a project.

Energy planning will conservatively specify the required plant capacities and commissioning dates, taking into account factors such as cost, promotion of a diverse energy mix and security of supply. These considerations are necessary to maximize the long term socioeconomic benefit to the Member State. As is the case with other technologies, energy planners should also take into account the sustainable supply of fuel and associated services. Energy planning is discussed further in numerous IAEA publications, including IAEA Nuclear Energy Series No. NG-T-3.3, Preparation of a Feasibility Study for New Nuclear Power Projects [12], Enhanced Electricity System Analysis For Decision Making — A Reference Book [13], Technical Reports Series No. 245, Energy and Nuclear Power Planning in Developing Countries [14] and IAEA-TECDOC-1259, Nuclear Power Programme Planning: An Integrated Approach [15].

As the market implementation approach can have a significant effect on the relative success of the national programme, it needs to be considered as an integral part of the decision to invest in nuclear power.

2.3.1.3. Industrial involvement capability and goals

Large nuclear projects bring potential for local industrial involvement. Governments typically wish to encourage such involvement and need to determine, in conjunction with the project developers, to what degree the country's technical and industrial resources (e.g. local universities and research institutes, local engineering, manufacturing, construction and service provider companies) can and should take part in the project. Participation needs to be both economically sound and able to meet certain strategic national needs. Any project requirements in this area need to be determined early on so that they can be incorporated into detailed project planning.

IAEA Nuclear Energy Series No. NG-T-3.4 discusses industrial involvement issues in the context of a national nuclear power programme [16]. The ISO 10845 series of standards Parts 5 to 8 [17–20] discuss how national goals can be incorporated into construction procurement contracts.

2.3.1.4. National nuclear power programme

A country's national nuclear power programme invariably impacts on any nuclear project planned within that jurisdiction. A large programme with many projects is more attractive for companies to invest in and for potential workers to develop the skills necessary to work in the industry. The distinction between a nuclear power programme and a new NPP project is made in NG-G-3.1 (Rev.1) [1]. Specifically, a nuclear power programme includes:

> "one or more nuclear power plants, possible related projects, such as uranium exploration and fuel fabrication, and the supporting infrastructure. As the programme develops, many specific activities will be undertaken to implement the first nuclear power plant *project,* and it is important that the distinction be clear. Projects are temporary undertakings to develop and construct nuclear power plants. The infrastructure provides the processes and capabilities to enable the project activities and the subsequent operation of the nuclear power plant to be implemented safely, securely and sustainably."

Note that in the context of this publication a nuclear project can be a project related to any nuclear facility or activity, not just nuclear new builds. The main considerations are national infrastructure considerations, NEPIO to owner/operator interface considerations, and programme life cycle considerations and their descriptions follow:

(a) National infrastructure considerations

Nuclear facilities exist within the context of a larger national environment and its supporting infrastructure. Depending on the country and on the size and scope of the project involved, substantial efforts may be necessary to develop the broader national infrastructure in order for the project to proceed successfully. The infrastructure addresses not only the specific needs of the project itself (e.g. human resources, suppliers, transportation networks) but also the required legal and regulatory framework within which the project can be defined and managed.

The IAEA offers guidance in the area of a recommended approach in NG-G-3.1 (Rev. 1) [1]. The publication defines and suggests monitoring of the progress of 19 key national infrastructural issues as part of the achievement of three defined milestones. Figure 4 depicts this approach and highlights a first NPP project within the national infrastructure programme. A national strategy for the introduction of nuclear power is needed, as described in IAEA Nuclear Energy Series No. NG-T-3.14, Building a National Position for a New Nuclear Power Programme [21].

A nuclear power construction programme necessitates the division of national responsibilities among multiple discrete key organizations. The role of the owner/operator, which manages and operates the NPP as well as forming the organization where the asset resides, is just one of these organizations. In some cases, the owner/operator's project may be only one of several NPP projects executed within a broader national programme.

Other key roles are those of the NEPIO[1], which manages the broader infrastructure programme; the nuclear regulator responsible for the licensing and oversight of the nuclear facility; various governmental ministries and

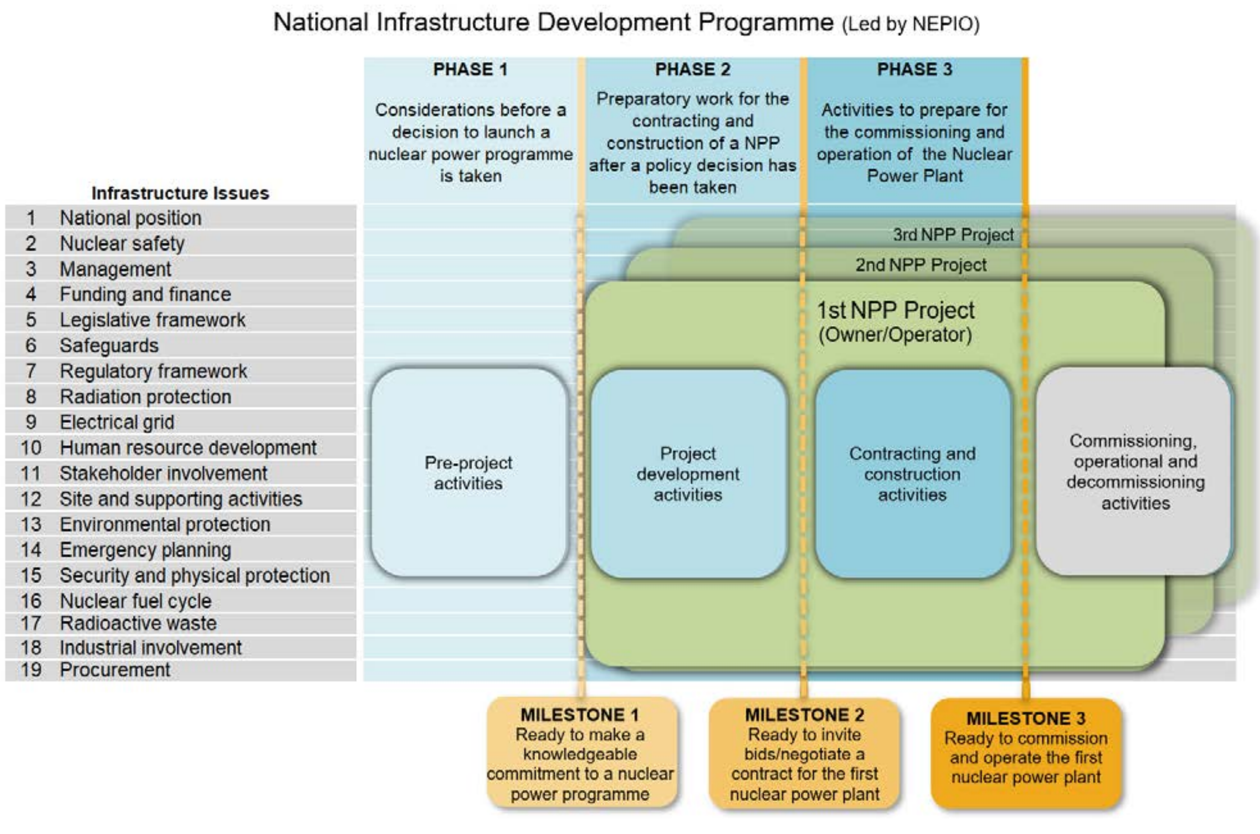

FIG. 4. National nuclear power infrastructure programme and three specific projects based on the IAEA's Milestones Approach.

[1] A NEPIO may or may not be a single entity. In some cases, it is a conglomeration of several entities working together towards the implementation of a nuclear power programme. Reference [22] describes NEPIO responsibilities.

regulatory authorities; and the national educational system. In countries with established nuclear programmes, the owner/operator would normally take over most or all of the functions of the NEPIO.

The initial buildout of a nuclear plant or fleet of plants typically establishes the basic national infrastructure necessary for long term operation of such facilities. As fleets age, however, maintaining such an infrastructure can become more challenging as some organizations (e.g. key suppliers) may choose to reduce support to or exit the industry.

(b) NEPIO to owner/operator interface considerations

Depending on the maturity of the national infrastructure, and the identified market implementation approach, various roles, responsibilities and interfaces may need to be clarified between the NEPIO and the owner/operator when moving into Phase 2 in the Milestones Approach. This could include, for example, roles and responsibilities related to the following:

- Site selection (note: any preliminary site feasibility studies of candidate sites that have been initiated by the NEPIO during Phase 1 should be made available to the owner/operator in Phase 2 to identify candidate sites for detailed evaluation and characterization);
- Market implementation approaches (studies of various economic and funding models should be provided to the owner/operator);
- Local infrastructure planning and industrial development initiatives;
- Establishment of industrial participation policies, strategies, planning and requirements;
- Nuclear fuel and radioactive waste management policies and planning;
- Approval authorities for the NEPIO and other external stakeholders (e.g. ministry responsible for energy matters), if necessary, within the project management system of the owner/operator;
- Communication channels and integration with the nuclear power programme management system established by the NEPIO (e.g. reporting, risk identification and mitigation).

The owner/operator should remain sensitive to the level of definition and robustness of the various key determining issues, monitor them for any potential developments and appropriately manage any change that may be needed in the project organization. The owner/operator needs to take responsibility for all the project activities from Milestone Phase 2 on.

Failure to adequately assign key roles and responsibilities early on in the national programme can lead to significant inefficiencies, as well as the potential for later rework within the project.

(c) Programme life cycle considerations

Nuclear projects have a distinct beginning, proceed through a series of planning and execution stages, and eventually are closed out. Nuclear power programmes are similar in that they have a beginning and then proceed through a number of related projects, each with its own beginning, planning, execution and closeout stages.

The particular stage that a nuclear programme is at and the overall plan for nuclear power introduction greatly influences the particular projects under consideration. Risk and uncertainty are greatest earlier on, balanced by the increased potential to be able to impact on final outcomes (i.e. cost of change is lower). Some factors to be considered include:

- Deployment of a single technology allows the streamlining of processes associated with facility development, licensing, construction, industrial involvement and operations.
- Allowing two or more competing technologies can provide possible benefits relating to market competition.
- Use of mature proven technologies with capable vendors can reduce risk.
- Decisions on the level of local industrial involvement need to be made (that is, at what point and to what degree to invest in the longer term development and use of local industries or the development of ‘first of a kind’ engineering). See IAEA Nuclear Energy Series No. NG-T-3.4 for further information on industrial involvement [16], as well as NG-T-3.14 on building a national position for a new nuclear power programme [21].

- The timing of the nuclear programme with respect to schedule contingencies and the gaining of experience on initial NPP units, and the minimization of demobilization and loss of established resources on subsequent units.

Much of this information would be considered as part of a project specific pre-feasibility or feasibility study. Refer to NG-T-3.3 [12] for more information on feasibility studies.

2.3.1.5. Regulatory environment

The owner/operator assumes a high level of accountability and responsibility in ensuring that a nuclear facility can be safely managed throughout its life cycle. The responsibility placed on the licensee is best articulated in SF-1 [10], which under its first principle states that the prime responsibility for safety must rest with the licensee throughout the lifetime of facilities and activities. It further states that this responsibility cannot be delegated.

The owner/operator of a nuclear project thus needs to understand the regulations that apply to the project and how they are enacted through national legislation, regulations, codes and standards. Foreign codes and standards that vendors may wish to utilize will need to be assessed as to their consistency with national safety requirements. This need includes both applicable nuclear regulations and non-nuclear regulations that apply in the jurisdiction. These can include equipment standards (product safety standards, pressure boundary regulations, etc.), installation codes (e.g. electrical codes, building codes and plumbing codes), labour standards, industrial health and safety standards, environmental protection standards, regulations related to waterways and coastal areas, and others. These regulations may impact on how the owner/operator organizes itself and the project team.

Nuclear regulations and licensing processes are especially important. The project organization has to perform many important tasks in order to prepare for the major responsibility undertaken by the owner/operator once fuel is loaded into the reactor. Some of these tasks, which contribute to the design and licensing basis of an NPP, begin early in Phase 2 of the national programme. The management of the site evaluation studies is one of these key activities. This requires the owner/operator to develop the necessary functions to fulfil its role as licensee early on in this phase.

The key licensing tasks, required to fulfil the owner/operator's responsibility for nuclear safety, need to be embedded into a regulatory licensing process that is included within the project plan. This licensing process acts to ensure that the licensee establishes and maintains safety throughout the life cycle of the facility. It is good practice for activities to be overseen by an independent regulator with appropriate mandate and jurisdiction. While defined national regulations can adopt different approaches to the nuclear licensing process, several licensing steps can be expected. These licensing steps are discussed in more detail in Section 4.14 of this publication and section 2.5 of NP-T-2.7 [2].

Further information on the requirements that have to be fulfilled is given in Section 4.14. Some applicable IAEA Safety Standards may be found in the following references: GSR Part 1 (Rev. 1) [23], GSR Part 2 [24], GSR Part 3 (Interim) [25], GSR Part 4 [26], GSR Part 5 [27], GSR Part 6 [4], GSR Part 7 [28], NS-R-3 (Rev. 1) [29], SSR-2/1 (Rev. 1) [30], SSR-2/2 (Rev. 1) [31], and SSG-16 [32].

2.3.2. Organizational factors

Organizational factors are those related to the company or broader organization responsible for a project but outside of the project itself. They are, in a sense, pre-existing conditions that the project team has limited ability to influence.

2.3.2.1. Ownership structure

Ownership structure can impact in many ways on nuclear projects. Different owners may have different strategies or objectives with respect to the long term operation of the facility, and where government participates in ownership, energy politics can impact on investment decisions. Having multiple owners can make decisions or agreements that can impact a project more difficult. Large owners that are experienced in project work can bring substantial resources to bear on any new project.

Member states have adopted various ownership and industrial involvement approaches specific to their circumstances and national priorities to guide the development of a national nuclear power industry. Ownership models for NPPs range from those employing independent power producers to those engaging nationally affiliated owner/operators. Large successes have also been realized by facilitating the establishment and support of the local nuclear manufacturing and construction sectors through the establishment of key considerations in the adopted national industrial involvement strategy and approach.

Several NPP ownership models and industrial involvement approaches have been used in the past and should be considered when developing a suitable strategy for a newcomer country. Some examples are as follows (see Appendix I for more detail):

- Nationally or regionally affiliated owner/operator and NPP vendor (common in mature countries with a nationally based NPP vendor);
- Nationally or regionally affiliated owner/operator and appointed NPP vendor (in countries without a nationally based vendor where the government or the NEPIO has decided to proceed with a single foreign NPP vendor);
- Appointed owner/operator or build–own–operate/transfer (BOO/BOOT) model;
- Public–private partnerships (similar to BOO/BOOT);
- Regional market/multinational model (useful in smaller countries where a large NPP would be too big for the national grid).

Not all models may be appropriate for the Member State, and most have long term consequences in characterizing the future electricity market. The ownership model best suited to the Member State depends on several factors including:

- Desired market structure in terms of privatization versus State owned utilities;
- Type and extent of government support;
- Availability and ownership of suitable NPP sites;
- Availability of human resources with project management and nuclear construction knowledge;
- Establishment of a precedent and need for flexibility to facilitate future projects;
- Need to complete key development activities, such as siting studies and approvals, before a project can be defined enough to establish the necessary key NPP project contracts in Phase 3;
- Ability to establish and justify the necessary legal basis for the establishment of key contracts;
- Sustainability of the implementation approach (by maintaining long term competitiveness and cost effectiveness leading to long term key partner relationships);
- Possible mitigations/options if required.

2.3.2.2. Mandate, business strategy, financing and electricity market models

An organization's business strategy and mandate from its owners will impact whether a project is approved or not. Many nuclear projects are executed within government owned company structures and are thus implicitly constrained to be executed within that government's area of jurisdiction. Additionally, for new build projects, the particular technologies to be used, number of units, their timing and the extent to which local resources will be used may be already determined by the government.

Existing market mechanisms to determine and manage generation planning, grid integration, authorizations, tariffs and operational management, as well as other power market regulatory requirements, may already be in place. In this case, they will need to be extended to incorporate the unique characteristics of a nuclear facility. For a nuclear programme, an established energy market regulator may undertake this work with the assistance of the NEPIO and the future owner/operator. Where these structures are not in place the NEPIO will need to make the necessary arrangements to ensure that the benefits of the facility can be successfully and sustainably translated into realisable benefits.

Several models exist that can be considered for a newcomer country. For established countries, the model to be used would likely be pre-established. The models include the following:

- **Free or merchant market model**: In this model, the establishment of a balance between supply and demand sets the pricing. Given the nature of and the long term investment required for nuclear power, the success of this model normally relies on the establishment of additional minimum price guarantees.
- **Regulated model**: In this model, an independent market regulator is responsible for establishing and periodically reviewing tariffs, often on a cost-plus basis. Ease of establishing investment will depend on the robustness of the market and trust in the market regulator.
- **Fixed tariff with management clauses**: A tariff is established that remains more or less fixed to allow the investors to recover their investment over a fixed period of time.
- **'Mankala' model (Finland)**: In this model, a group of intensive power users club together to establish an owner/operator, effectively financing and committing to purchase production quotas from the NPP at cost.

The suitability and readiness of the market approach has a considerable effect on the owner/operator. While an owner/operator is normally engaged early in Phase 2 of a national programme, it is really only in Phase 3 during the establishment of the power supply agreements that the owner/operator position within the national programme is secured. Market implementation planning will normally need to be in an advanced state once financing for the NPP is sought early in Phase 3, so as to satisfy the various financial stakeholders of the long term ability to fund and operate the NPP. To ease investment the mechanism should be as robust and trusted as possible, reducing the need for any additional guarantees.

The market implementation approach will also be needed to inform various strategies and plans in Phase 2, such as responsibilities for project development, contracting and procurement strategies as well as the scope of the nuclear project in relation to the national programme and other national or future projects.

Any mid-project changes to the market implementation approach will likely cause delays and need revision of the role and responsibilities assigned to the owner/operator. It may also necessitate the review of various project activities to ensure their continued viability. This could significantly affect the project structuring and schedule, as well as hamper the ability to optimize the project commercially.

2.3.2.3. Project portfolio

The owner/operator may have other nuclear, or even conventional, projects and operational facility upgrades within its investment portfolio. These projects may be at different phases of their life cycles. Owner/operators typically select, coordinate and control these projects within a framework of portfolios and/or programmes in which common elements of the various projects can best be managed together. Potential projects and other asset investments are prioritized and selected to proceed based on the overall goals of the organization. The Construction Industry Institute (CII) has produced an implementation resource for construction project portfolio management [33], and other resources are also available [34, 35].

In the power sector, mature utilities often divide power generation projects into separate portfolios:

- Assets undergoing development;
- Assets under construction;
- Assets in operation;
- Assets undergoing decommissioning activities.

Nuclear operators often divide their specific projects into categories such as regulatory projects, projects that impact equipment reliability, projects that optimize generation, address obsolescence issues or improve industrial safety, or other categories.

The nature of the owner/operator's portfolio can have a pronounced effect on the structuring of a project. The owner/operator will need to ensure the establishment and incorporation of any portfolio and programme level requirements into the particular project being considered. Portfolio and programme level requirements may initiate from aspects such as the need to:

- Make provision for or share a site or other facilities that the owner/operator has or intends to build;
- Manage commonalities in design between different facilities in the owner/operator's fleet;
- Share and prioritize the use of specialized resources within the organization;
- Select only a limited number of projects to proceed based on resource limitations (funding, personnel or other resources).

Although the owner/operator needs to take portfolio and programme structuring into account, they are not key topics within this guide.

2.3.2.4. Access to organizational assets

Projects are assigned a portion of an organization's resources as part of their set-up. These can include personnel, facilities and equipment. The quality, capacity and usefulness of each can influence the project. Large nuclear projects typically have substantial personnel requirements and experienced personnel can be difficult to free from other duties or projects. The best personnel are rarely available exactly when they are needed, and the skills necessary to manage large capital projects may not be readily available in new organizations. Similar difficulties may be encountered in utilizing an organization's facilities or equipment (e.g. transport and work equipment, office space).

Additionally, organizations have a set of processes, procedures and obtained experience, knowledge and lessons learned that they use to apply to their projects. These can include vendor information, cost, schedule and other performance data from previous projects, standard organizational processes (e.g. human resources procedures, engineering and design processes, industrial safety processes), project management tools and templates for various activities and access to commercial databases containing cost or risk information. Each of these can be used as inputs to the planning for any new project, can help to understand or reduce risks or can reduce the time and effort necessary to get a new project started.

Planning for the new project will need to start from the basis of what resources are initially available from the parent organization.

2.3.2.5. Organizational culture and leadership style

Organizational culture, style and norms of behaviour affect how projects are conducted. For nuclear projects, a culture that emphasizes safety in all its aspects (e.g. nuclear, radiation, industrial and environmental) above all is an important feature. This, however, can take time to develop and new participants from outside the nuclear industry may not possess this at the outset. Shared experiences and a common vision are necessary to achieve this.

Senior management has a critical role in establishing a proper culture for safety for nuclear projects. IAEA Safety Standards Series No. GSR Part 2 [24], Requirement 1 indicates that "**The registrant or licensee — starting with the senior management — shall ensure that the fundamental safety objective of protecting people and the environment from harmful effects of ionizing radiation is achieved**", while Requirement 2 states that "**Managers shall demonstrate leadership for safety and commitment to safety**".

2.3.2.6. Communication methods

Different organizations communicate in different ways based on organizational culture, language, geographic distribution, hierarchy and other factors. The degree to which open communication is encouraged and fostered can vary from region to region and thus can impact on international projects. The ability of stakeholders and project team members to use electronic methods of communication (including email, texting, instant messaging, social media, video and web conferencing, and other forms of electronic media) to communicate with the project manager formally or informally can also assist international projects to be successful.

External communication to interested parties, stakeholders and the general public can be important for nuclear projects that typically are accompanied by high levels of external interest. Refer to Section 2.3.1.1 of this publication on stakeholder and interested party involvement for more detail, and see also Section 4.7 on internal project communication. An on-line IAEA Nuclear Communicator's Toolbox[2] is available.

2.3.2.7. Organizational structure and composition

The specific characteristics of the owner/operator will influence the structuring and planning of a nuclear project within its organization. A large, experienced projects organization may already exist within the organization or one may need to be newly created. The owner/operator may itself be new if it has been created specifically for the new nuclear project.

In planning for a new project, some general aspects should be considered:

- The functioning and integration of the project with other existing projects and programmes and any other business dealings that the owner/operator may have. The project may share resources, specialized functions or even common sites with other projects within the owner/operator's project portfolio.
- How the role of the owner/operator can be expected to evolve as it progresses through development into construction and later into operations and maintenance.
- How the owner/operator will establish and maintain all the functions and processes required to be a competent licensee and knowledgeable customer.

When these considerations are taken into account the owner/operator will need to make decisions on how the various projects and roles are structured within the owner/operator's organization, as well as which functions will be contracted out. The changing nature of the owner/operator roles for a new NPP project is illustrated in Fig. 5. Specific organization models for the nuclear project are discussed further in Section 4.6 related to human resources.

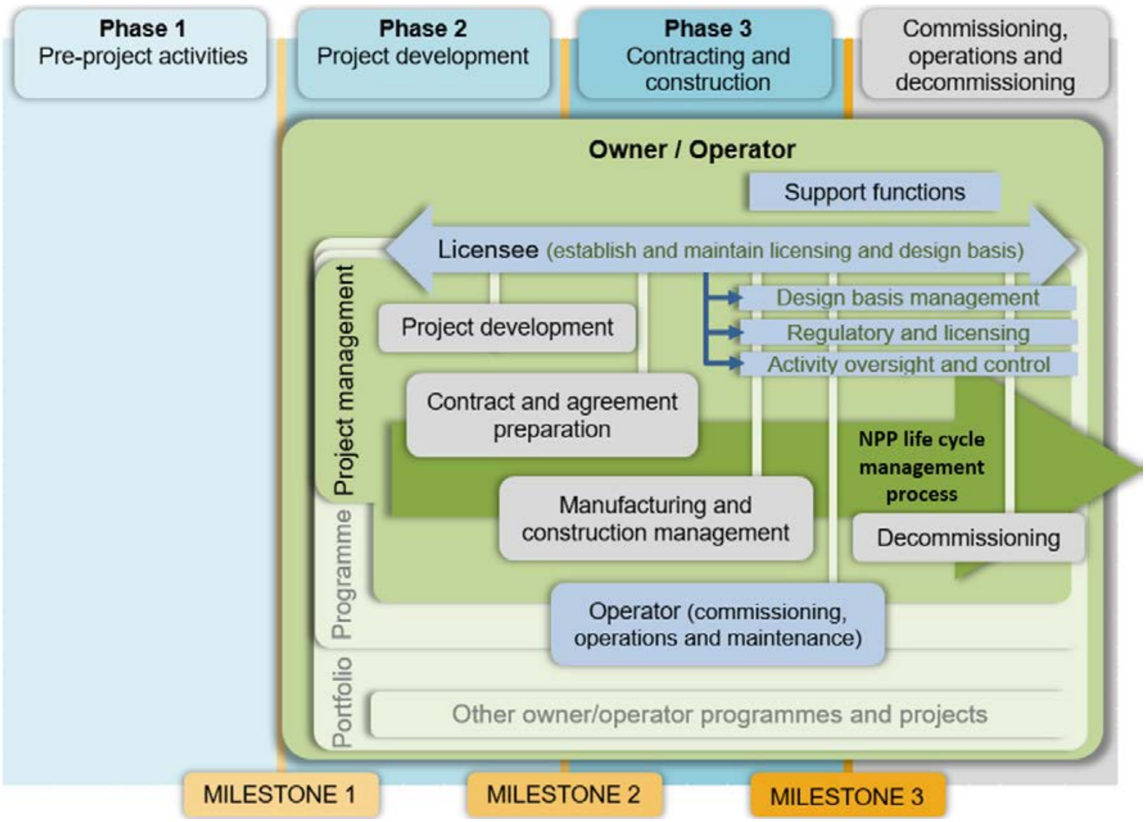

FIG. 5. Structuring of a typical NPP project within an owner/operator's portfolio for a newcomer country.

[2] See https://www.iaea.org/resources/nuclear-communicators-toolbox

3. PROJECT MANAGEMENT GUIDANCE

Project management guidance is available worldwide from a large number of sources. This section describes applicable IAEA publications as well as others related to best practices of project management.

It is important that nuclear project managers adopt a consistent methodology for projects within their jurisdiction. This allows practitioners to gain experience with the chosen methodology, become efficient in its use and make improvements to their internal processes on an ongoing basis.

This publication will use an adaptation of a number of international tools to describe a high quality project management process for a nuclear project. Many of the international frameworks use as their base a series of 'plan, do, check, act' (PDCA) cycles. More information on this topic is available in Appendix II.

3.1. IAEA STANDARDS AND PUBLICATIONS

3.1.1. Safety standards

IAEA Safety Standards indirectly discuss project management in the context of management systems standards related to nuclear facilities and activities. GSR Part 2 [24], in particular, discusses a number of management system requirements that are applicable to nuclear projects. These requirements apply to the design, construction and operation of nuclear facilities and thus to nuclear projects in general. Selected requirements from GSR Part 2 [24] and their applicability to nuclear project management are summarized in Table 1.

TABLE 1. SELECTED GSR PART 2 REQUIREMENTS RELATED TO NUCLEAR PROJECT MANAGEMENT

GSR Part 2 Requirement	Applicability to project management
Requirement 1: Achieving the fundamental safety objective	Requires licensees, starting with senior management, to ensure the fundamental safety objective of protecting the people and the environment from harmful effects of ionizing radiation is achieved. This includes all activities related to nuclear projects, including those activities performed during construction and commissioning that have safety implications for the operations phase.
Requirement 2: Demonstration of leadership for safety by managers	Requires managers, including project managers, to demonstrate leadership and commitment to safety.
Requirement 3: Responsibility of senior management for the management system	Requires senior management to establish, sustain and continually improve a management system to ensure safety. This applies to management systems for nuclear projects.
Requirement 4: Goals, strategies, plans and objectives	Requires senior management to establish goals, strategies, plans and objectives for the organization in accordance with the organization's safety policy. Requires nuclear project goals (e.g. cost or schedule) to not compromise safety.
Requirement 5: Interaction with interested parties	Requires that communication with interested parties takes place related to radiation risks associated with the operation of facilities and the conduct of activities. For major nuclear projects, this can require a significant effort and to take place early in the project.
Requirement 6: Integration of the management system	Requires management systems be integrated and address safety, health, security, quality, human and organizational factors, and societal and economic elements so that safety is not compromised.

TABLE 1. SELECTED GSR PART 2 REQUIREMENTS RELATED TO NUCLEAR PROJECT MANAGEMENT (cont.)

GSR Part 2 Requirement	Applicability to project management
Requirement 7: Application of the graded approach to the management system	Graded approaches are to be documented that take into account safety significance and complexity.
Requirement 8: Documentation of the management system	Requires the management system for a nuclear project be documented.
Requirement 9: Provision of resources	Requires resources (individuals, work environment, knowledge, information, suppliers, material and financial resources) to manage nuclear projects. Senior management is accountable to determine the competencies and resources required and obtain them internally or externally. Requires training to maintain the competence of individuals so that they can work safely and understand performance standards. Knowledge and the information of the organization to be managed as a resource, thus projects are required to ensure that project knowledge is transferred to the operating organization.
Requirement 10: Management of processes and activities	Requires project processes and activities to be developed, documented and managed to achieve the project goals without compromising safety. Activities for inspection, testing, verification and validation, acceptance criteria and the responsibilities for carrying out such activities are required to be specified. Requirements for independent inspection, testing, and verification and validation are required to be specified.
Requirement 11: Management of the supply chain	Requires arrangements to be in place with vendors, contractors and suppliers for specifying, monitoring and managing the supply of items, products and services that may influence safety. Project procurement processes are extremely important and procurement related data is required to be transferred to the operating organization as part of project turnover. See section 4.10 for more detail.
Requirement 12: Fostering a culture for safety	Requires individuals in organizations, from senior managers downwards, to foster a strong safety culture. Requires the management system and leadership for safety to foster and sustain a strong safety culture.
Requirement 13: Measurement, assessment and improvement of the management system	Requires management systems to be measured, assessed and improved to enhance safety performance, including minimizing the occurrence of problems relating to safety.
Requirement 14: Measurement, assessment and improvement of leadership for safety and of safety culture	Requires senior management to regularly commission assessments of leadership and culture for safety within the project organization.

Other Safety Guides related to management systems include IAEA Safety Standards Series Nos GS-G-3.1 to GS-G-3.5 and TS-G-1.4 [36–41] .

Safety Standards Series No. GS-G-3.5 [40], for example, has a section on project management. It defines project management as

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

3.1.2. Nuclear energy series

Various publications in the IAEA Nuclear Energy Series discuss nuclear projects and project management in some detail. IAEA Nuclear Energy Series No. NP-T-2.7 [2] provides guidelines and experience related to project management during the construction phase of NPP projects. This includes guidance for preparing for the construction phase and for managing work during the construction and commissioning phases. Lessons learned related to construction management and from projects in specific countries are also provided. IAEA Nuclear Energy Series No. NP-T-2.5 discusses construction technologies [42] for NPP projects and NP-T-3.3 [43] covers industrial safety aspects, including the holding of constructability, operability, maintainability and safety (COMS) reviews for projects to minimize risk.

IAEA Nuclear Energy Series No. NG-T-1.3 [44] provides details on the development and implementation of a process based management system. As will be described later in this publication, such a system should be used for the project management system employed on a nuclear project. A related publication, IAEA-TECDOC-1740 [45], discusses the graded application of management system requirements, and annex VI to that publication describes an example of the grading of supply chain activities for a major project.

IAEA Nuclear Energy Series No. NP-T-3.21 [3] discusses procurement issues in the context of the operation and maintenance of nuclear facilities, including procurement related needs and processes for major projects. Procurement is one of the key elements to be managed on any project and will be discussed later in Section 4.10 of this publication. A related online Nuclear Contracting Toolkit[3] provides guidance for procurement activities related to a major nuclear development project.

Financing of nuclear projects is discussed in IAEA Nuclear Energy Series Nos NG-T-4.1 [46] and NG-T-4.2 [47]. Bidding and bid evaluation is discussed in Nuclear Energy Series No. NG-T-3.9 [48]. Feasibility studies for nuclear projects are discussed in Nuclear Energy Series No. NG-T-3.3 [12].

3.1.3. Other IAEA references

IAEA-TECDOC-1390 [49] discusses construction and commissioning experience related to some specific evolutionary water cooled NPP projects that were constructed between 1991 and 2005. It includes information on some of the project management approaches employed.

IAEA Technical Report Series No. 279 [50] was published in 1988 and provides detail on traditional approaches to NPP project management that were in use up to that date. It was largely superseded by IAEA Nuclear Energy Series No. NP-T-2.7 [2] described above.

Publications in the IAEA Services Series detail review services related to NPP projects and programmes that may be of use to Member States. These can include the Construction Readiness Review service [51], Integrated Nuclear Infrastructure Review (INIR) missions [52], Operational Safety Review Team (OSART) missions [53], Safety Culture Reviews [54] and others.

Various aspects of decommissioning are discussed in IAEA Safety Standards Series No. GSR Part 6 [4] and Nuclear Energy Series Nos NW-T-2.5 and NW-G-2.1 [5, 6].

3.2. INTERNATIONAL PROJECT AND CONSTRUCTION MANAGEMENT GUIDANCE

Various organizations around the world have produced valuable frameworks and guidance related to project and construction management. Organizations involved in managing nuclear projects are recommended to join project and construction management organizations that are active in their jurisdiction and to incorporate their guidance and best practices into the organization's management system framework.

It is important that nuclear project managers adopt a consistent methodology for projects within their jurisdiction. This allows practitioners to gain experience with the chosen processes, become efficient in their use and make improvements on an ongoing basis.

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[3] See https://www-legacy.iaea.org/NuclearPower/Infrastructure/NuclearContractingToolkit/manage-contract/index.html

Multiple methodologies may need to be incorporated into the management system, since each individual methodology can be targeted at specific types or sizes of projects. The methodologies can be adapted and combined as necessary for a given organization based on individual circumstances.

Note that in most cases, project management definitions adopted by the various frameworks are generally consistent. They can, however, be different in their emphasis or applicability, or concentrate on a particular stage of the project life cycle. One has to be careful when implementing a project management methodology to ensure that consistent definitions are established within an organization. Some terms can have important different meanings within the different published methodologies.

Appendix III describes these project and construction management frameworks at a high level and discusses their particular focus and regional applicability.

It should be noted that the conventional project management approaches that are included in Appendix III can be difficult to apply in all aspects for large nuclear projects. Nuclear facilities are complex and multiorganizational, and many project management approaches have an implicit assumption that they will take place within the same or a very limited number of organizations. Conventional project management systems talk about ‘appointing a project manager’ or ‘selecting the core team’. On a large NPP project there will invariably be multiple core teams that will need to effectively work together. Additionally, owner/operators of nuclear facilities cannot delegate their licensed authority. These licensing arrangements are even more stringent than in an aerospace environment. Conventional project management guidance does not tend to discuss the type of control that owner/operators in nuclear projects need to maintain.

Competency frameworks for project management are discussed in Section 4.6.8.1 and further details and comparisons can be found in Refs [55, 56]. Implementing best practices from these organizational frameworks is discussed in Section 5.2.

3.3. SMALL PROJECT GUIDANCE

Large projects often get the respect and attention they need because of their size, and offer large returns on the time and effort invested. They are thus almost always accompanied by the use of standard project management practices as described in this publication.

Small projects, on the other hand, are often overlooked as candidates for project management control. Moreover, due to their smaller budgets, a full suite of project management tools and oversight is typically not cost-effective. However, when added together a portfolio of small projects can be as important to an organization’s success as a single or a small number of large projects. The CII estimates that 40–50% of all construction industry capital budgets are spent on small projects [57]. Nuclear decommissioning programmes, for example, are often run as a series of small projects.

Successful organizations commonly attempt to keep a team of individuals assigned to manage their portfolio of small projects. This facilitates learning, continual improvement and the streamlining of processes to reflect the shorter duration of small projects. The shorter cycle times allow this team to learn from project to project and to go through the PDCA cycle a number of times. This can extend to support organizations such as engineering or construction service providers, which can be hired using a strategic alliance concept.

A common mistake with running a small project is to skip important project management principles entirely and just ‘get on with the work’. Understanding a project’s scope and objectives, for example, is as important for a small project as for a large one. The CII’s research [58], for example, has shown that small project performance can be improved if the applicable programme incorporates the following project management practices:

- Front end planning that incorporates project checklists;
- Core project teams that can improve schedule and decrease the funding approval cycle;
- Standard written processes specifically geared to small projects;
- Maintenance projects that are combined with a small capital projects programme;
- Alliances and preferred supplier agreements.

The definition of what ‘small’ or ‘big’ means can vary widely from organization to organization. The PMI defines small projects as taking fewer than 30 days to complete, while the CII defines them as projects costing in the range of US $ 100 000 to US $ 2 000 000 [57]. In a nuclear context, the high end of the CII range or even greater is more appropriate.

Several project management organizations and authors have concentrated on the challenges of small project management. The CII, for example, has issued a small project toolkit [57] that provides resources tailored for smaller projects and a project definition rating index specific to small industrial [59] and small infrastructure [60] projects. Other resources are available in Refs [58, 61–66].

3.4. MEGAPROJECT GUIDANCE

Similar to small projects, there has been increased interest in recent years in the particular characteristics of megaprojects. Megaprojects are large scale, complex ventures that typically cost US $ 0.5 billion or more, take many years to develop and build, involve multiple public and private stakeholders, are transformational and impact on millions of people. They include the construction of new nuclear or conventional power plants, large oil and gas facilities, major infrastructure and transportation projects such as highways, tunnels, bridges, railways, seaports and even cultural events such as the Olympic Games.

Due to a history of relatively poor deliveries of megaprojects, studies have been undertaken about the particular difficulties involved in managing them. In some cases incentives exist to overstate the income that will be received from such projects, underestimate costs, and exaggerate future social and economic benefits due to lack of accountability and risk-sharing mechanisms [67]. It has been argued that "the weaknesses of the conventional approach [to megaproject project management] can be overcome by emphasizing risk, institutional issues and accountability" [67].

The Independent Project Analysis (IPA) Institute has looked at the differences between megaprojects and other projects on a worldwide basis. It reported a failure rate for megaprojects of about 65%, while that for smaller projects was 35% [68]. Failure in this study was defined as having real cost growth of greater than 25%, schedule slippage of greater than 25%, cost competitiveness issues based on an absolute measure of greater than 25% or severe and continuing operational problems for two years or more following startup. The best performing megaprojects had the best index rating for front end planning, and every single megaproject that attempted a 'cost-reduction exercise' just prior to or just after authorization failed. Project management deficiencies (by the project vendor) were found culpable in less than 10% of the projects studied.

The IPA thus identifies the following as 'key virtues' for success in industrial megaprojects [68]:

- "I want to allocate the value fairly and stabilize the project";
- "I want it on a schedule that will permit success, no faster";
- "The deal will precede and shape the scope";
- "We will follow best practice in front-end definition";
- "The only way it can cost less is if I want less";
- "It is our project. We carry the risk";
- "Accountability and responsibility start at home".

3.5. FRONT END PLANNING

Front end planning (FEP), front end loading (FEL)[4] or pre-project planning are the activities undertaken at the beginning of a project to ensure that the project is properly defined, planned and estimated so that an informed decision can be made as to its viability and readiness to proceed. It involves gathering an understanding of residual risks remaining with the project and reviewing what plans are in place to address the risks. It occurs early on in a project's life cycle since that is the time when the project is most easily and economically impacted. Projects with adequate FEP do not always succeed, but those with inadequate FEP most often fail [69].

[4] Note that in a scheduling context 'front end loading' can have a different meaning, referring to the scheduling of resources towards the beginning (front) of any planned activity. This would be as opposed to 'back end loading', whereby resources would be applied more towards the end of an activity.

The CII has done extensive research on FEP, and has published an FEP toolkit [70] that helps define the functions involved in FEP and provides a process that can be used in the planning of capital projects. A key part of the toolkit is a number of methods for rating the adequacy of project definition, called 'Project Definition Rating Indices' (PDRIs)'. PDRIs are available for industrial projects [71], building projects [72], infrastructure projects [73], small industrial [59] and small infrastructure [60] projects. The European Construction Institute (ECI) has published a manual on project development and definition [74].

Various organizations and project management consultants can provide independent assessments of project readiness. Some, such as the benchmarking programmes of the IPA or the CII, can provide comparisons between similar projects worldwide.

3.6. VALUE ENGINEERING

Value engineering (VE) generally refers to systematic approaches to ensure reasonable delivery of products and services by using an examination of the delivery function. Value is defined as the ratio of function to cost. Consequently, either improving the function or reducing the cost may increase it.

Originally developed by Lawrence D. Miles of the General Electric Company in 1947, VE principles have been adapted for a worldwide audience. The main publication describing the technique is Ref. [75], and AXELOS has published a detailed best practice guide related to management of value [76]. The European Community's Strategic Programme for Innovation and Technology adopted 'value management' as its official term for the approach. It described the same philosophical concept, but in terms that were more in keeping with European management styles.

VE can be applied to a project during its early planning (project initiation) stage, when the benefits can be greatest. It involves:

- Identifying the main elements of a product, service or project;
- Analysing the functions of those elements;
- Developing alternative solutions for delivering those functions;
- Assessing the alternative solutions;
- Allocating costs to the alternative solutions;
- Developing in more detail the alternatives with the highest likelihood of success.

The process is performed in a workshop setting in which creative methods for delivering the project's function(s) are structurally evaluated. Figure 6 illustrates the process.

An example of where VE may be used would be during the construction phase of a project. The VE process might identify innovative construction methods that could be used, such as using pre-assembled formwork, modular scaffolding or modular construction. Any of these approaches might be able to save time, reduce costs and/or increase quality levels for the project.

3.7. DESIGN TO COST

Design to cost (DTC) is a cost management technique that can be used in early project development. It establishes cost goals at specified levels of a work breakdown structure and then requires the project team to creatively make trades-offs that ensure that the project will meet those cost goals. In DTC, the cost goals are essentially a separate project requirement added that could be specified in the project charter. In a project environment, DTC operates very similarly to VE in that it attempts to remove unnecessary features from a proposed system or project where project cost goals are important. Section 3.1.2 of IAEA Nuclear Energy Series No. NP-T-3.21 [3] provides an example of DTC used at Slovenské elektrárne.

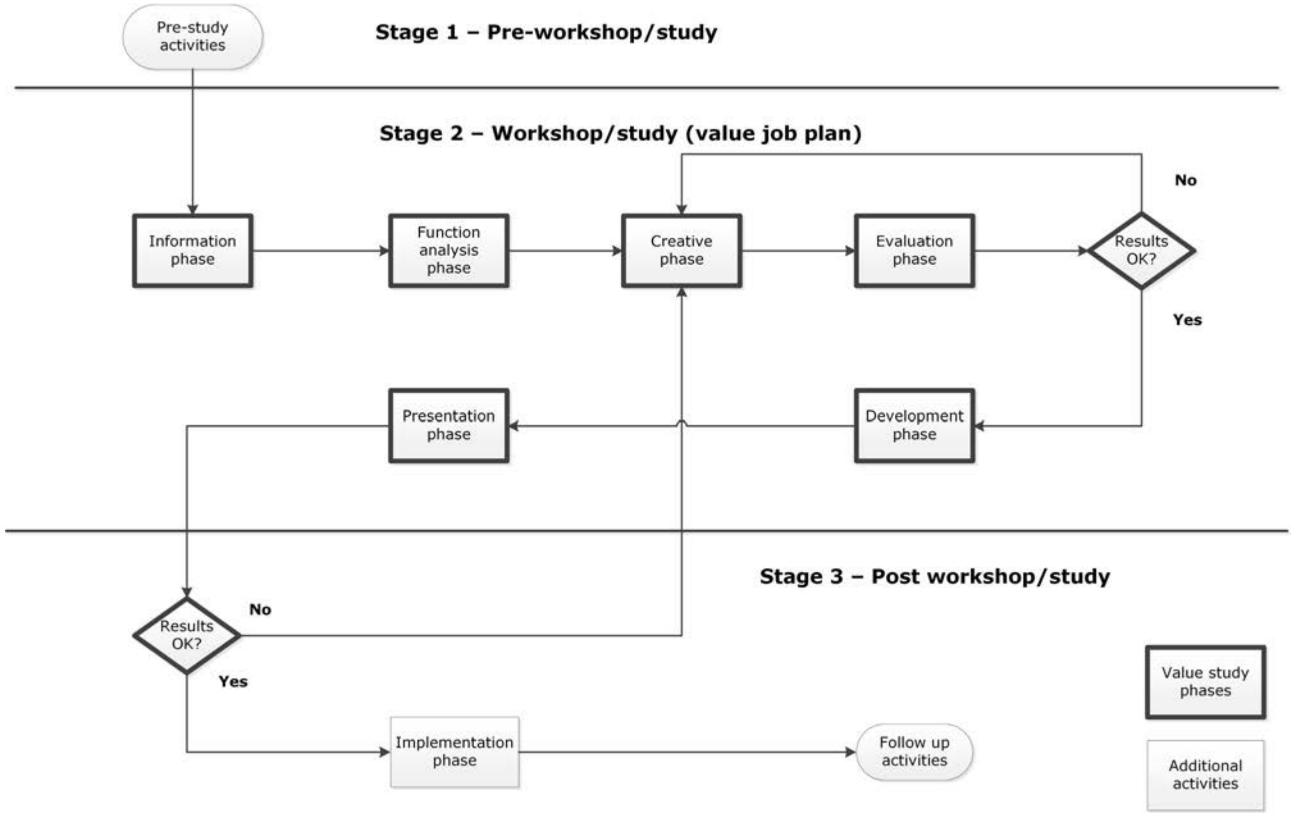

FIG. 6. VE process (reproduced courtesy of SAVE International [77]).

4. AREAS TO BE MANAGED IN NUCLEAR PROJECTS

People working on projects need to manage a number of diverse areas and report to many different individuals and organizations. This section describes the major items to be managed and provides descriptions of some of the available tools used to manage them.

Figure 7 shows the areas that need to be managed and the subsections of this publication in which they are described. The first ten subsections in Section 4 (left hand side of the figure) mostly cover the elements/items identified in the PMI's Project Management Body of Knowledge (PMBOK Guide), with examples tailored for nuclear projects. The subsequent subsections (right hand side of the figure) mostly cover elements/items that are specific to, or of special importance for, nuclear projects.

4.1. INTEGRATION

Project management is sometimes referred to as the process of 'making sure everyone else is doing his or her job in a concerted manner'. This oversight and coordination role is referred to as project 'integration management', which means ensuring that processes and systems are in place within the project to ensure the project team is aligned and working as planned on its major objectives and deliverables.

IAEA Safety Standards Series No. GSR Part 2 [24] speaks to the importance of integration on safety, stating that the management system **"shall integrate its elements, including safety, health, environmental, security, quality, human-and-organizational-factor, societal and economic elements, so that safety is not compromised."** This especially true for large nuclear projects.

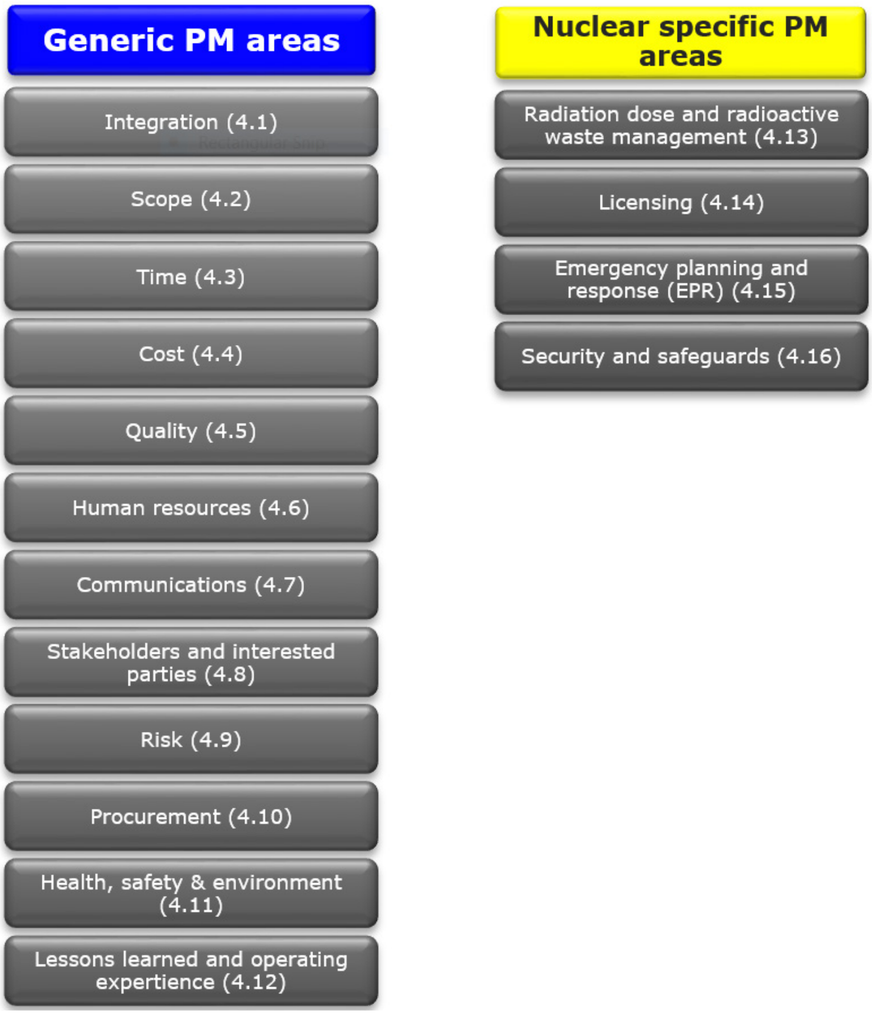

FIG. 7. Areas to be managed for nuclear projects.

This section covers some of the tools typically used to encourage project integration. Project integration during construction is also discussed in Section 2.2.4 of IAEA Nuclear Energy Series No. NP-T-2.7 [2].

4.1.1. Project charters

A project charter (or project mandate and brief) is a key tool used to define and control a project at a high level. It provides clear direction and authority to the project team with respect to project objectives, scope, requirements, measures of success and other items. It facilitates making key decisions as to whether a project should proceed in the context of other investment opportunities. The project charter should not be confused with a project plan, which is an internal project document used to define the management of each project phase. The role of the project plan is discussed in Section 4.1.3.

Project charters are created at project initiation and are normally not revised unless there is a major change to project scope or deliverables. It is an agreement between the owner of a project (the project sponsor) and the project manager as to what ultimately the project is designed to deliver. Its highest level of approval is thus typically the project sponsor. Experience has shown that a well written project charter can be important if disputes surrounding what the project team was expected to deliver occur.

A project charter should address parameters such as:

- **Business needs/problem definition**: Statement of business needs and objective(s), or statement of the problem to be solved or opportunity to be addressed by the project. This would have been already negotiated and agreed to by the project board and the project execution function.

- **Project scope and deliverables**: A high level statement of the scope covered by the project in line with the established market implementation approach should be included. Specific inclusions and exclusions should be noted, and performance metrics and criteria as well as priorities for the deliverables should be identified. Requirements in addition to local legislation and regulations may also be stipulated. These may include, among others, requirements pertaining to the:
  - Establishment and use of local expertise and resources;
  - Securing of project funding, financing and even the seeking of additional equity contributions;
  - Price of the produced electricity (sometimes with capital and operating cost separated);
  - Provisions to be made for future items such as maintenance, refurbishments or decommissioning;
  - High level technical objectives, for example, expected operating lifetime.
- **Assumptions, constraints and known risks**: Assumptions related to the project and any desired constraints (e.g. time, dates, cost, regulatory or licensing expectations, corporate constraints, language of communication).
- **Relationship to other projects**: Consideration should also be given to any shared scope and interfaces or provisions for other current or future projects within the company's or the supplier's project portfolio, or even to large unrelated projects that may vie for similar resources or be prerequisites to the start of the project in question.
- **Accountabilities and responsibilities**: High level project responsibilities and authorities of the project manager and project team should be established, including:
  - Financial (authority limits, gated or staged approval approaches for project phases, etc.);
  - Reporting and coordination requirements;
  - Project stakeholder and public communication;
  - Nuclear safety, security and safeguards, etc.
- **Project team members and key stakeholders**: A preliminary list of key project team members and stakeholders.

Note that in some project management methodologies, such as PRINCE2, the project's business case takes the role of the project charter. In PRINCE2, the business case is continuously updated, and is considered a draft until the project has been planned. It is then used during project execution to check that the project will continue to deliver its identified benefits [78].

A sample project charter template is included in the IAEA's Nuclear Contracting Toolkit[5]. The project charter often covers items specific to the project environment (see Section 2.3.1) such as ownership and industrial involvement schemes.

4.1.2. Life cycle management strategies

Due to their long service life, nuclear facilities and their related projects can benefit from a documented life cycle management strategy. These are high level strategic plans that help to ensure that the facility can be managed in conformance with its licensing requirements over its entire life cycle. During the early phase of a facility's planning, it is not expected that the strategy would be very detailed. It should, however, be mature and well informed by the time the project is ready to proceed with the bid invitation/contract negotiation process (i.e. at the end of Phase 2), since the information contained is a valuable input to the project's detailed planning and specifications.

This strategy is used to inform detailed project planning (see Section 4.1.3) and should address aspects such as:

- **Siting:** A preliminary strategy that directs site selection, characterization, environmental permitting and evaluation on aspects such as the number and timing of sites to go through the process, in parallel or series, as well as any contingencies and mitigations, etc.
- **Stakeholder involvement:** A detailed strategy for the analysis of regional stakeholders and the involvement of interested parties in the project development phase.
- **Licensing management:** A preliminary strategy on how the various nuclear and non-nuclear licences will be applied for and managed.

[5] See https://www-legacy.iaea.org/NuclearPower/Infrastructure/NuclearContractingToolkit/manage-contract/index.html

- **Industrial involvement:** A preliminary strategy on technology transfer, supplier development and required local content. The use of local resources should also be considered. If appropriate the owner/operator may have to work with functions within the government to assist in developing a national strategy. This national strategy may need to be supplemented by strategic requirements from within the project organization to effectively inform planning for current and future projects. The national industrialization strategy may be supported through the establishment of appropriate legislation, regulation and import controls.
- **Contract strategy — generation supply agreements:** A preliminary strategy for electricity supply and other supply agreements such as district heating and desalination if applicable.
- **Contract strategy — key NPP supply agreements:** A preliminary strategy for key facility component supply agreements should be developed.
- **Funding and financing:** A detailed strategy for the funding of the project development phase and a preliminary strategy for the remaining life cycle should be in place.
- **Nuclear fuel cycle front and back end:** A preliminary strategy which takes into account any applicable legislation and policies, including funding mechanisms for long term liabilities. At this phase the strategy should be comprehensive enough to inform stakeholders and the public of available options.
- **Nuclear waste management:** A preliminary strategy conforming to applicable local legislation and policy to inform stakeholders and the public of available options. Any requirements for the siting of waste treatment, interim and final storage facilities should be established and embedded in the requirements for site selection.
- **Decommissioning:** A preliminary strategy or preliminary decommissioning plan should be in place conforming to applicable local legislation to inform stakeholders and the public of available options.

For each of these aspects the following criteria should be considered:

- National policy, strategy, legislation and regulation;
- International best practice;
- Alternatives, and their advantages and disadvantages.

4.1.3. Project management or execution plans

Project planning, control and oversight are functions that belong to the adapted PDCA cycle shown in Appendix II, Fig. 37. The most important tool to communicate a project's objectives, roles, responsibilities, baseline schedules and approach to activities is the project plan. Without a plan there can be no control of a project.

The project plan illustrated in Fig. 8 (for a new build project) is a dynamic set of planning information that is regularly updated to provide progress information and periodically baselined for performance reporting. This planning information specifies when project activities are expected to occur and with which resources. It becomes more detailed as the project proceeds through its various phases.

A project plan helps to ensure that:

- Key issues important to the success of the project are identified, defined and understood at the earliest possible stage;
- Project team members, end users and line authority are provided with a common understanding of the project and the planned method of execution;
- Orientation is provided to new project team members.

A new baseline of each component of the plan is established and approved at each project gate as specified by the project governance framework, which is described in Section 5.1. Each baselined plan would include a high level overall plan for the entire life cycle of the nuclear facility as well as a detailed plan for the upcoming project phase for which approval is being sought.

Typical project plan content is shown in Table 2. Depending on the particulars of a given project not all of the elements may be necessary.

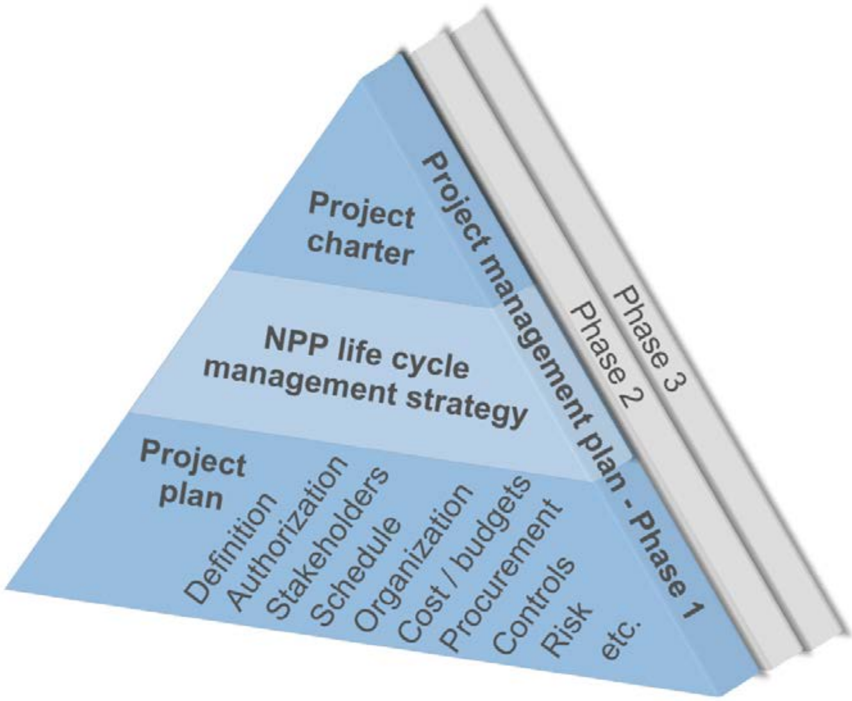

FIG. 8. The project plan is regularly updated and baselined as the project passes through the various approval gates defined in the project governance framework (see Fig. 33).

TABLE 2. TYPICAL PROJECT MANAGEMENT/EXECUTION PLAN CONTENT

Topic	Description
Project definition	Referring to the project charter, this section would describe the project mission, objectives, high level scope (including its work breakdown structure), project requirements, responsibilities and authorities as well as outlining project phases, required approval gates and critical success factors.
Project authorization	Summarizes budgetary authorizations received to proceed with the project up to the current project phase.
Stakeholder analysis	Documents the applicable external and internal stakeholders, their areas of interest and plans for contact.
Approvals and third party requirements	Documents any permits, approvals or third party requirements impacting on the project.
Execution and delivery strategy	Defines project phases, resources, contracting approaches, insurance approaches, bonding and security and risk allocation.
Organization, roles and responsibilities	Identifies the organizational approach envisaged for overall management of the project and the roles and responsibilities for key members of the project team.
Health and safety management	Describes the plan for management of occupational safety and health on the project.
Project staffing	Describes staffing and resource acquisition and resource development plans.

TABLE 2. TYPICAL PROJECT MANAGEMENT/EXECUTION PLAN CONTENT (cont.)

Topic	Description
Authority levels	Identifies organizational authority levels for approval of project in-scope expenditures, the spending of contingency amounts, commitments of the organization in discussions/negotiations with regulatory agencies and project designs.
Schedule and milestones	Provides a target schedule and major milestones for the project.
Project costs	Provides detail on the project's cost breakdown structure, the current cost estimate and the basis of the estimate. Describes project cash flows, project financial and funding plans and release of funds strategy (i.e. project phases).
Project controls	Describes the procedures to be used for project control of cost and schedule, change management, progress monitoring and claims.
Performance measurement	Describes the processes and metrics to be used for performance measurement and status reporting.
Risk management	Documents how risk management will be performed for the project. Documents the roles and responsibilities for project team members, the methodology and tools to be used, and the schedule for risk management. Describes any lessons learned incorporated into the project plan and lessons learned processes.
Requirements management	Describes how requirements impact the project (e.g. licensing, regulations (nuclear, grid, other)), governmental requirements, internal organizational requirements, and international requirements) will be recorded and managed.
Licensing and regulatory approvals	Describes how licences and regulatory approvals will be managed for the project, including siting, reactor or facility design approval and others.
Engineering management plan	Describes how engineering work on the project will be managed and resourced, its general scope items and processes for submittals and reviews.
Procurement plan	Describes the procurement process being utilized, contract models being sought and the plan for procurement of major equipment, including roles and responsibilities.
Construction oversight, installation and commissioning management plan	Describes how construction and commissioning work on the project will be managed and resourced, key suppliers and subcontractors' arrangements for factory and on-site testing, etc.
Environmental oversight plan	Describes how the project will ensure that all environmental approvals are in place such that the overall project schedule is not affected and that construction activities are carried out in an environmentally acceptable manner to meet all environmental requirements. Includes any requirements for management of conventional or radioactive waste.
Communications plan	Describes how the project intends to manage public communications, internal project and company communications, communications with contractors and confidentiality issues.
Records management	Describes project records management processes, storage locations and storage media, electronic document management systems and records identification/coding methodologies.
Project closeout	Describes the processes to be used for project turnover and closeout.
Administration	Describes on what basis the project execution plan will be updated, i.e. inputs, frequency, etc.

4.1.4. Managing and monitoring ongoing work

Project control, monitoring and oversight involve analysing information to understand, influence and predict important project objectives such as resources, cost and time schedule. This makes effective project management, planning and decision making possible. Organizations such as the IPA Institute have reported a positive correlation between better project control practices and reduced schedule slippage and cost growth in project execution. Cost improvements from project control best practices can range from 6 to 20% [79].

Using techniques such as project milestones and earned value management (EVM) can often more effectively control project activities.

4.1.4.1. Project milestone management

A project milestone is a "significant point or event in a project" [7], and lists of such milestones are often used as a useful communication and control tool. They are used as signal posts for a project's major events such as start or end date, need for external review or input, need for budget checks, submission of a major deliverable and for other purposes. They have a fixed date but no duration.

Project milestones are frequently used to monitor project progress, but there are limitations to their usefulness. They usually show progress only on the critical path, and may ignore non-critical activities.

Note that the IAEA's Milestones Approach [1] for new nuclear programmes uses a similar concept for describing the progress of a national nuclear programme. However, it only defines three milestones, while a typical NPP project taking place during Phase 2 and Phase 3 would define many more.

4.1.4.2. EVM techniques

The PMI defines EVM as a "methodology that combines scope, schedule, and resource measurements to assess project performance and progress" [7]. It integrates the project's scope, cost and schedule baselines and compares them to the project's actual performance. EVM develops and monitors three key dimensions for each work package and control account: the planned value of the work to be done at a given time (e.g. the estimated cost of work that has been done), the amount of work done at that given time and the actual cost of the work done at that given time. For the technique to be effective, individual items need to be costed and scheduled appropriately and measures of completeness for longer duration items (e.g. percentage complete to be credited, weighted milestones) need to be formalized.

As far as possible, progress should be tracked by measuring the completion of concrete, physical, useful deliverables or events. This is as opposed to secondary measures like hours worked or costs incurred that may not indicate the true progress of the project. Concrete deliverables can include items such as the number of design packages delivered to the constructor, number of work packages fully assessed, percentage of materials delivered to the site, metres of cable tray or pipe installed, cubic metres of concrete poured, major components being delivered, etc.

Figure 9 shows a typical EVM tracking chart which can be used to review whether a project (or part of a project) is behind or ahead of schedule, or above or below its planned budget, based on the work done to date. The PMI, the American Association of Cost Engineering (AACE) and TechAmerica have published detailed guides to EVM [80–82].

4.1.4.3. Requirements management

Large or even small projects can include hundreds or thousands of specific commitments or requirements. These can originate from diverse sources such as the project scope document, regulatory bodies, the NEPIO, the government, other stakeholders and interested parties, international commitments, etc. Specific requirements for a facility such as an NPP can be extensive, often numbering in the tens of thousands of detailed requirements. Requirements management is the process of documenting, analysing, tracing, prioritizing and agreeing on requirements and then controlling change and communicating to relevant stakeholders. It represents a continuous quality assurance and quality control process throughout a project (see Section 4.5).

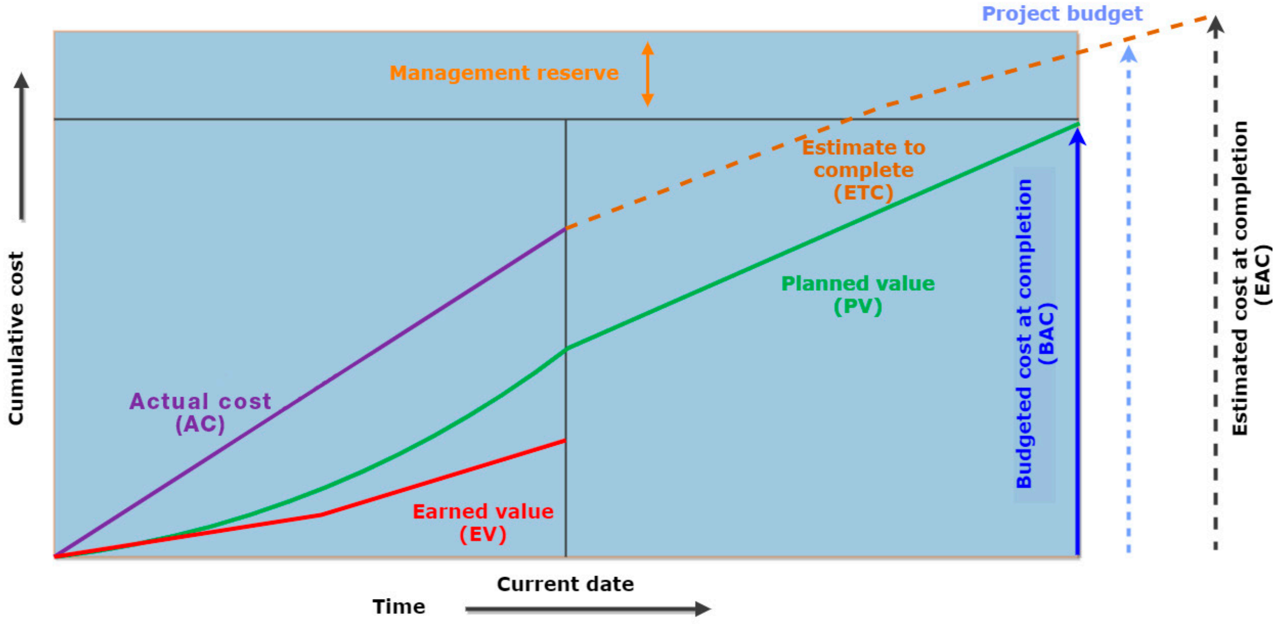

FIG. 9. Typical EVM tracking chart – the figure depicts a situation where the actual costs are high when compared to the earned value.

Many organizations manage project requirements in a discrete manner. That is, commitments to, say, a regulatory body might be tracked in a regulatory commitment database, project scope requirements would be included in the project scope document, financial commitments would be managed by the finance department, specific end user requirements might be found in a constructability review document, etc.

Some organizations, however, attempt to manage project requirements in an integrated manner using a centralized method. This can be a daunting but useful exercise, since ensuring all necessary project requirements have been met is normally a requirement at closeout.

Categories of requirements can be established ranging from absolute requirements that have to be met to more discretionary criteria that can be used to optimize the project. This range of requirements makes requirements management a complicated and dynamic exercise. Not all requirements can or should be accepted by a project team. This leads to the necessity to make decisions about the feasibility of meeting certain requirements and the necessity to negotiate the requirement base with the various stakeholders. Once accepted, a requirement should be monitored to ensure that it is met. This is often done via software tools or a simple requirement traceability matrix, whereby requirements are mapped in accordance with their origin and specification within the design and contracting documentation right through to the verification of their achievement.

Countries introducing nuclear power for the first time may underestimate the level of detail needed to adequately specify an NPP. Experienced individuals involved in operating NPPs are, however, well suited to assisting in such efforts. Owners' requirements can include specific technical features, process requirements, commercial conditions (e.g. intellectual property rights, training support, project management reporting), items related to the project's scope (e.g. vendor scope versus owner scope), regulations, codes and standards to be addressed (including the need to address nuclear safety regulations that can affect the supply of equipment), items stemming from development phase activities such as environmental approval conditions, development of safety and security culture programmes or items related to the licensing of a design (e.g. design maturity, vendor involvement needed for the licensing process, pre-licensing reviews by a regulator, requirements for having a reference plant in operation). Features that may be beyond a 'base design' but that can afford production, reliability or maintainability benefits can be explored. The IAEA's Nuclear Contracting Toolkit[6] contains a list of some typical areas of interest in owners' requirements.

To assist in developing a complete list of technical requirements, the owner/operator can engage with other owner/operators, potential NPP suppliers and external consultants. Some common sets of user requirements are available, such as those in Refs [83, 84]. Proposed NPP designs will need to be assessed by the owner/operator

[6] See https://www-legacy.iaea.org/NuclearPower/Infrastructure/NuclearContractingToolkit/manage-contract/index.html

to ensure that such designs meet all requirements. Where possible a design margin can be introduced to allow for uncertainties or changes to requirements or for issues arising during manufacturing, construction and operation. These design margins will assist in ensuring that the NPP continues to meet regulatory requirements throughout its life cycle. IAEA Nuclear Energy Series Nos. NP-T-1.10 [85] and NP-T-2.1 [86] can be referred to for more detail.

4.1.4.4. Project management technology

Increasingly, software platforms that support information sharing among all project team members are becoming available. In the past, less technologically advanced owners and contractors would rely on a mixture of off-the-shelf solutions that often did not communicate well with each other. Project managers or support staff would need to manually move the data between them, using email or even paper.

Newer platforms attempt provide a ‘single source of truth’ for project participants and support project integration. Often a mix of different software from different vendors is needed to provide the necessary functionality. Even when different software vendors are involved, integration between vendor products to eliminate duplicate data entry can yield improvements and is increasingly employed. Nuclear facilities have huge amounts of data and documents associated with them and integrated software and data repositories are necessary to adequately manage them.

Substantial savings can often be achieved on construction projects using advanced software. McKinsey & Company reports, for example, that on an American tunnel project that involved almost 600 vendors, the contractor developed a single platform solution for bidding, tendering and contract management. This saved the team more than 20 hours of staff time per week, cut down the time to generate reports by 75% and sped up document transmittals by 90%. In another case, a $ 5 billion rail project saved more than $ 110 million and boosted productivity by using automated work flows for reviews and approvals [87].

Digital solutions can help manage some or all of the following items:

- Contract management;
- Requests for information and change orders;
- Transmittals and submittals;
- Design shop drawings and document reviews (often via standard electronic document management systems (EDMS));
- Inspections, quality and safety;
- Bidding and tendering;
- Building information management (BIM);
- Daily site reports;
- Plan management;
- Project cost management;
- Project scheduling;
- Handover to operations and maintenance department;
- Project reporting;
- Requirements management;
- Estimating;
- Accounting;
- Materials tracking;
- Crew tracking.

Data obtained via analysis of the above has the potential to reveal cost, productivity and safety gains that were not anticipated by the project team.

4.1.4.5. Work package assessment

Work packages are a complete set of documentation, in paper or electronic form, that is needed by field trades to perform a specific work activity (e.g. a specific installation, construction or commissioning activity). Typically, they are of a limited size so as to not be unwieldy or hard to follow, perhaps containing one week of field activities.

All elements necessary to complete the scope of the work package (e.g. materials, consumables, procedures, design information) should be organized and delivered in the package to the workforce trades before the work is started.

Traditionally, field trades can face large amounts of rework due to both poor field planning and poor coordination between design and construction. The loss of productivity caused by rework can be reduced substantially if the work packaging and assessment process is implemented properly.

Work package assessment is the process of reviewing approved design and material related data associated with the necessary activity and translating it into a format by which the work can be efficiently scheduled, estimated and safely and predictably executed. Assessors need to have knowledge and experience related to construction methods, design configuration, resource requirements, available standard procedures drawings, purchasing and more.

The CII includes advanced work packaging (AWP) as one of its key project best practices. It takes a more strategic approach than the typical work packaging that is used for almost all projects. It defines AWP as

> "a planned, executable process that encompasses the work on a … project, beginning with initial planning and continuing through detailed design and construction execution. AWP provides the framework for productive and progressive construction, and presumes the existence of a construction execution plan." [88].

It thus extends the practices of work package assessment into the earlier design phases of a project and focuses on the specific boundaries and dependencies between various construction and engineering work packages (CWPs and EWPs). It requires an effective flow of information, which

> "in turn, depends upon having a disciplined set of procedures. Integrated work packages in the field must be supported by an effective project controls system that is based on a clear WBS. Integrated work packages also require established document control and materials management systems" [88].

Figure 10 shows the overall flow of information in this framework from preliminary planning and design through to construction.

Documented benefits of AWP are reported to include productivity improvements of the order of 25% in the field, with corresponding reductions of 10% of total installed cost [89].

Information on CII research and lessons learned related to AWP are documented in Refs [88–94].

4.1.5. Project change control

Changes are inevitable during any large project. This applies even for those with fixed price contracts where all scope elements may not have been completely defined prior to the start. Changes should not necessarily be seen as a cause for concern, but if effectively managed, as opportunities to improve the project.

Changes may be due to changing business needs, economic trends, technology changes, government intervention, changes in project requirements, work scope changes, force majeure or other factors. Project teams

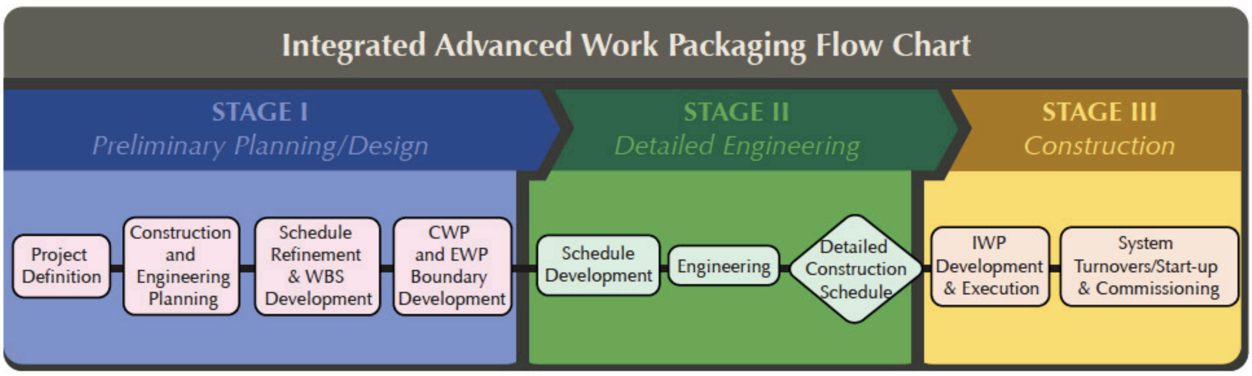

FIG. 10. CII integrated AWP flowchart (CWP: construction work package; EWP: engineering work package; IWP: installation work package) (reproduced courtesy of the CII [88]).

will need to be satisfied that any changes requested are in fact justified. Any advantage gained in terms of additional benefit received or reduced costs, time or risk will need to be assessed against the cost, schedule or risk impact of its attempted implementation.

A process is thus needed for addressing contract changes in a timely manner. The project manager or an approved delegate can typically approve some changes, while other significant changes may need to be approved by the project sponsor or project board. Change control and claims processes are discussed further in Section 4.4.5.2.

4.1.6. Project closure

At project closure all the project activities have been completed, or a decision has been made to discontinue. This is the time point where evaluating and recording the achievements and the experience gained from the project is crucial. Some thought should be given at the start of a project as to how it will be evaluated at the end, preferably in the project charter document (see Section 4.1.1).

Refer to Section 4.12 for details on project evaluation and operating experience.

4.1.7. Alignment and team building

Poorly aligned teams can engender mistrust, poor communication, poor cooperation and an adversarial relationship between the project owner, designer and constructor. Alignment is "the condition where appropriate project participants are working within acceptable tolerances to develop and meet a uniformly defined and understood set of project objectives" [95]. CII research has shown a positive correlation between increased efforts to gain alignment during early stages of a project and project success. An implementation resource is available [95] that explains the process of achieving alignment and provides a diagnostic tool to measure team alignment and indicate areas of needed focus.

The CII's research identifies ten critical alignment issues that, if focused on during pre-project planning, will increase the likelihood of project success. These are [95]:

- Stakeholders are appropriately represented on the project team;
- Project leadership is defined, effective and accountable;
- Priority between cost, schedule and required quality features is clear;
- Communication within the team and with stakeholders is open and effective;
- Team meetings are timely and productive;
- The team culture fosters trust, honesty and shared values;
- The pre-project planning process includes sufficient funding, schedule and scope to meet objectives;
- The reward and recognition system promotes meeting project objectives;
- Teamwork and team building programmes are effective;
- Planning tools (checklists, simulations and work flow diagrams) are effectively used.

The CII's diagnostic tool, called an 'alignment thermometer', plots the results of a survey of project team members. Its output indicates whether the project is aligned on the above critical alignment issues.

Alignment is critical on nuclear projects around the concept of culture for safety. All participants associated with the project need to share a common vision whereby safety is of the utmost importance. Efforts are needed to extend this through the supplier and vendor communities.

IAEA Safety Standards Series No. GS-G-3.5 [40] on management systems for nuclear installations promotes team building as one way of helping to change an organization's culture for safety. In a project context, team building exercises can assist where issues are present within a team's culture or where a team is newly formed and has not yet worked together. Team building enhances social relations and define roles within teams, often using facilitated, fun, collaborative tasks. Teams with personal knowledge of one another and with fewer interpersonal conflicts generally function more effectively than others. Numerous resources related to team building and managing people are available, including Refs [96, 97].

4.1.8. Knowledge management

Owner/operators, as nuclear facility licensees, require that their organizations have a high level of competence in ensuring that the right knowledge and information is validated, recorded, preserved, maintained and readily available when needed. IAEA Safety Standards No. GSR Part 2 (para. 4.27) indicates that "The knowledge and the information of the organization shall be managed as a resource" [24]. To achieve this it is important to have a full understanding of the requirements for knowledge management (KM) throughout the life cycle of their facilities. This knowledge extends to the development, design, construction, operations and maintenance, refurbishment and decommissioning phases (Fig. 11).

For projects, there are several aspects of KM that are of particular importance. These are based on the transitory nature of some project teams and the long term needs for knowledge retention that nuclear facilities have. These include:

- The need for project organizations to gather and utilize lessons learned from previous projects and to pass lessons from the current projects to future ones (e.g. knowledge about client/owner organization, project management knowledge, knowledge of who knows what on the project team, costing/estimating knowledge, technical and regulatory knowledge);
- The need for knowledge related to the currently active project to be quickly and widely disseminated to project team members (e.g. status, progress, short term and long term plans, issues and lessons, etc.);

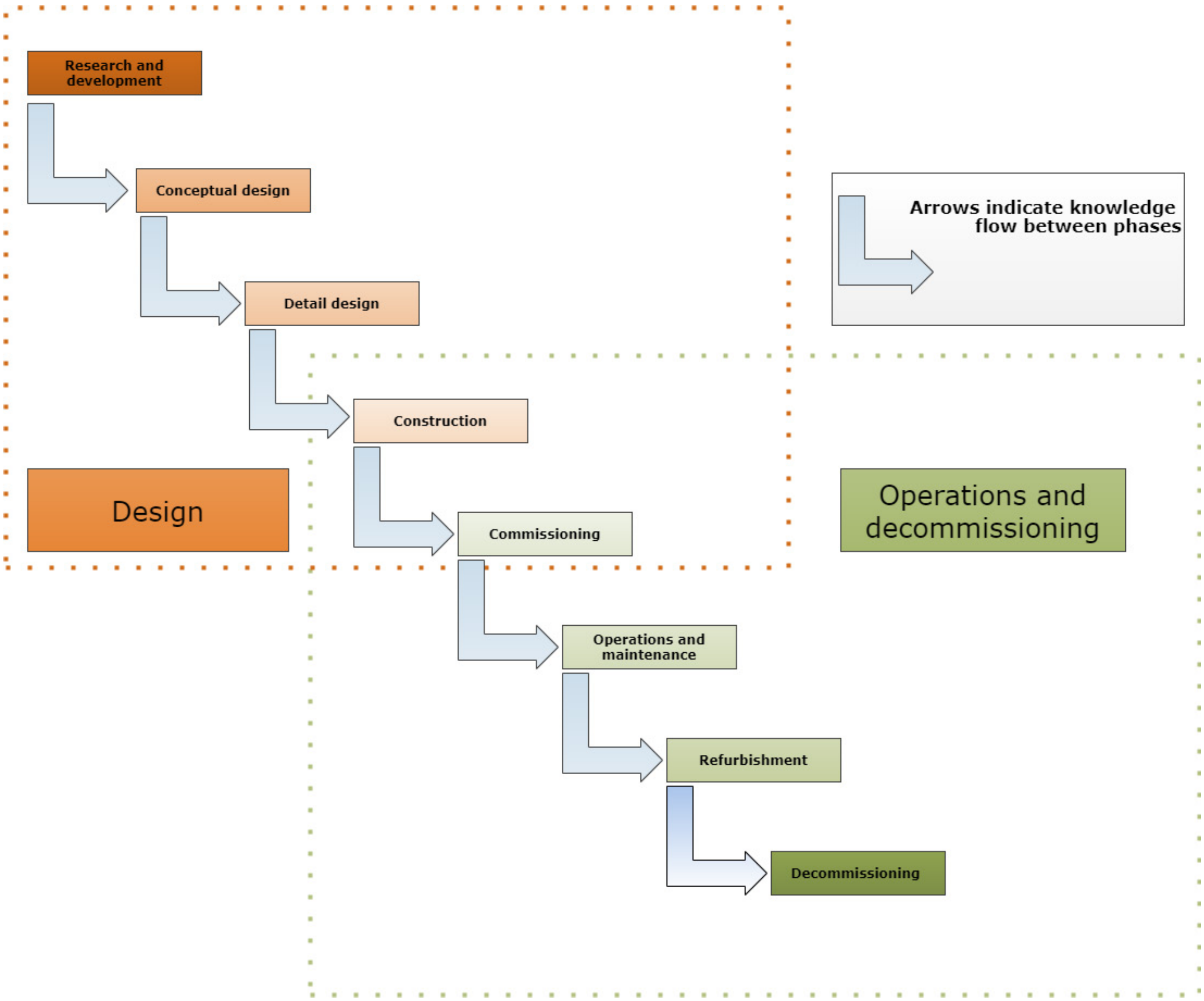

FIG. 11. Knowledge transfer through the phases of an NPP life cycle [98].

- The need for knowledge related to the current project to be captured and passed on to the eventual operating organization in an accurate and timely manner (e.g. design, procurement, installation, commissioning and operational data).

A strategy and plan to address all of these areas is necessary for each project. Tools for conducting a KM self-assessment are contained in IAEA Nuclear Energy Series No. NG-T-6.10 [99] and in IAEA-TECDOC-1586 [100]. These tools, which can be used as part of preparations for an IAEA KM assist visit (KMAV), can help project organizations in assessing their current status versus the desired state and current or future barriers, and will drive the proper KM strategy development. An interactive training course on Nuclear Knowledge Management is also available from the IAEA.

4.2. SCOPE

4.2.1. Initiation and project charter

Control of a project's scope is critical to ensure that project objectives are met and that costs are kept under control. A project's high level scope is normally defined in a project charter or similar document (see Section 4.1.1). Key stakeholders are recommended to be involved in the development of this document to ensure that the wants or needs of their organizations are understood and dispositioned.

4.2.2. Detailed scoping

During project definition, the detailed scope of a project is defined. Inputs to this process include the project charter and any project requirements documents.

Operating facilities often develop standard design or modification scoping checklists that can help organizations to ensure that all issues important to the facility are addressed for new projects. Issues of concern are noted and are tracked as part of the project until they are confirmed as formally addressed. The project scope may need expansion to include work that might not be strictly related to the original problem statement. For example, a new chemical delivery system may necessitate additional equipment to be purchased for spill response, new emergency showers and personal protective equipment for worker protection, new spare parts to be stocked in the warehouse, additional training, new procedures, etc.

These checklists can thus identify any impacts on items that may not have been considered. Some of these items can include regulatory approvals, codes and standards to be applied, occupational health and safety requirements, fire protection equipment and programmes, equipment qualification, emergency response procedures, environmental protection, seismic and other natural hazards, maintenance programmes, operations and maintenance procedures, design configuration documents, plant databases, security systems, safeguards, spare parts, training programmes and others.

4.2.3. PBS/WBS preparation

The precise activities and deliverables to be provided by the project are typically documented and controlled through the use of a plant breakdown structure (PBS) and a work breakdown structure (WBS). The following subsections describe each in turn.

4.2.3.1. Plant breakdown structure

A PBS is a hierarchical hardware breakdown structure of physical components of a project. A complete PBS helps ensure that all physical components of a project are accounted for within the project scope. The PBS should cover 100% of the project scope as defined in the project charter. For an NPP this normally includes items such as the site, on- and off-site infrastructure, nuclear and conventional island, balance of plant and other facilities required to manage the NPP life cycle. The particulars of any owner's scope (work to be executed by the owner) and any detailed owner's requirements for the project should be included.

The IAEA's Code of Accounts in Technical Report Series No. 396 [101], a newer online version in its Nuclear Contracting Toolkit[7] and a version prepared by the Gen IV International Forum (Appendix F of Ref. [102]) are example tools for preparing a PBS and for thus ensuring that all parts of an NPP project are addressed. A generic code of accounts for process industry projects is also available from the AACE [103]. Figure 12 displays a sample portion of the IAEA's online code of accounts.

Functionality should be included in the PBS to extend it to lower levels of breakdown as the project becomes defined in more detail. The PBS provides an indexing system to ensure all of the project hardware is systematically accounted for, as well as providing a framework for summarizing information.

4.2.3.2. WBS

A WBS is a hierarchical tree structure that divides a project into phases, deliverables and work activities. It is developed by starting with the end objective and successively subdividing it into manageable components in terms of size, duration and responsibility (e.g. systems, subsystems, components, tasks, subtasks and work activities) which include all steps necessary to achieve the objective. It specifies *what* will be done, not *when* or *how*.

A high level WBS is established from the PBS, which is extended to cover all necessary project deliverables that are required in the process of delivering the physical plant. This WBS will thus also include all necessary strategies, study reports, plans, licensing and permits needed as part of the project. As is the case with the PBS, the WBS should include the functionality to be extended to lower levels as the project is defined in more detail. The WBS provides an indexing system to ensure all activities on the project are systematically accounted for, as well as providing a framework for summary information such as budgets and resource plans. Figure 13 provides a sample simplified WBS for a project. Note that not all levels of detail are shown in this example.

The activities required to deliver each element of the WBS need to be defined in terms of their requirements, acceptance criteria, required controls and oversight, sequencing, duration, required resources, level of expertise, cost, procurement requirements and associated risks. These are normally defined as 'activity specifications' or a 'WBS dictionary'. The project schedule, budget and resource plans can become more refined as these

IAEA | NUCLEAR CONTRACTING TOOLKIT

IAEA Code of Accounts

Project Name:

Project Ref. No.

Show All CoA Items | Wrap Long Text in Table | Show Applicable CoA Items | Un-wrap Text in Table

IAEA CoA No.	Type of Cost	Level 1	Level 2	Level 3	Level 4	Is IAEA CoA Applicable?
22.221.1.11	BASE COSTS	Reactor plant equipment	Reactor equipment	Reactor vessel	Reactor vessel and accessories	
22.221.1.12	BASE COSTS	Reactor plant equipment	Reactor equipment	Reactor vessel	Closure head and attachments	
22.221.1.13	BASE COSTS	Reactor plant equipment	Reactor equipment	Reactor vessel	Studs, fasteners, seals and gaskets	
22.221.1.14	BASE COSTS	Reactor plant equipment	Reactor equipment	Reactor vessel	Calandria tubes and fittings	
22.221.1.15	BASE COSTS	Reactor plant equipment	Reactor equipment	Reactor vessel	Pressure tubes and fittings	
22.221.1.16	BASE COSTS	Reactor plant equipment	Reactor equipment	Reactor vessel	Insulation	
22.221.1.17	BASE COSTS	Reactor plant equipment	Reactor equipment	Reactor vessel	Tools and miscellaneous	
22.221.2.21	BASE COSTS	Reactor plant equipment	Reactor equipment	Reactor vessel internals	Tanks	
22.221.2.22	BASE COSTS	Reactor plant equipment	Reactor equipment	Reactor vessel internals	Baffles and related equip.	
22.221.2.23	BASE COSTS	Reactor plant equipment	Reactor equipment	Reactor vessel internals	Upper core structure	

FIG. 12. Sample portion of IAEA code of accounts.

[7] See https://www-legacy.iaea.org/NuclearPower/Infrastructure/NuclearContractingToolkit/manage-contract/index.html

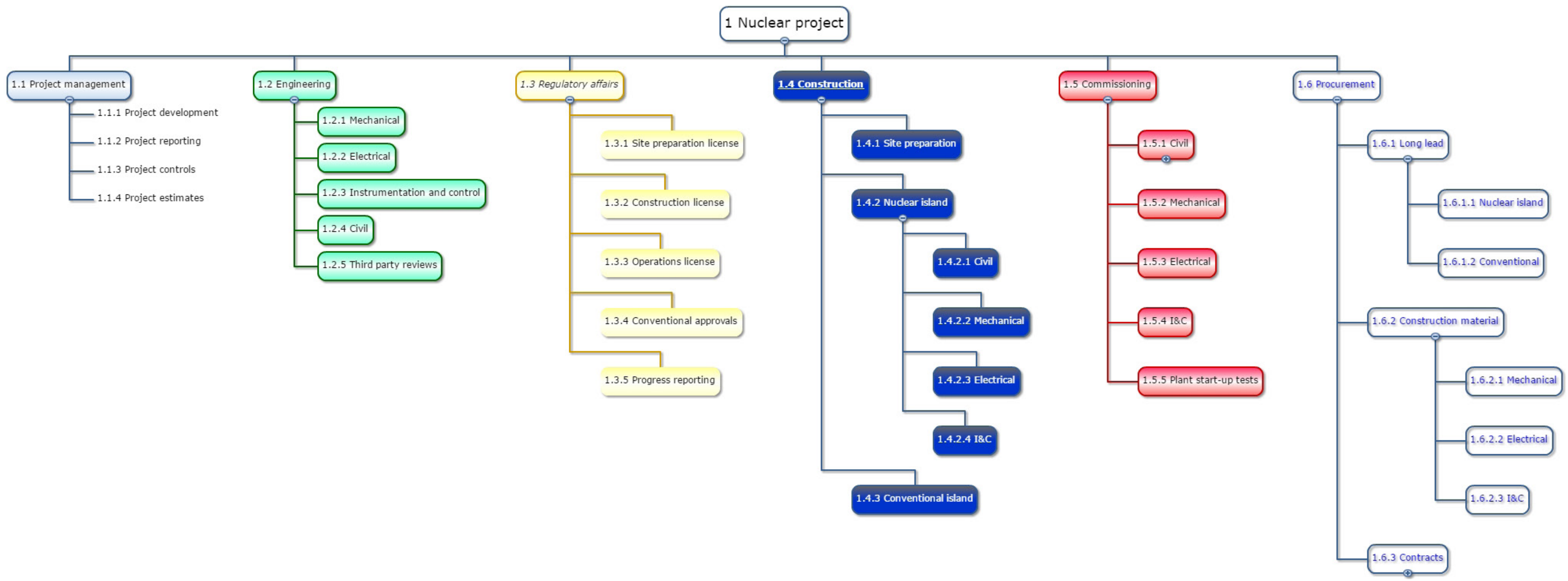

FIG. 13. Sample WBS for a project.

specifications become known for all of the WBS elements. Figure 14 illustrates how the WBS and these individual activities are linked.

For control purposes the resources required to complete each WBS item are typically derived from the organizational breakdown structure (OBS) described in Sections 4.4.1 and 4.6.4.

Organizations that regularly execute projects will typically produce a model WBS that is designed to capture the typical work required for a generic project. This reduces the work needed to produce a WBS and also helps in the comparison of different project spending on similar activities.

The PMI and AACE provide guidance on preparation of a WBS [104, 105].

4.2.4. Owner's scope

The identification of the owner's scope on a project is an important step to help minimize the potential for future project disputes. Any contract for a project assumes that the vendor/contractor will provide a 'complete' project; however, this can be open to different interpretations at a detailed level. For example, in the context of an NPP project, choices are necessary as to what organization will be responsible for such activities as site preparation, providing site services (including temporary services), providing office facilities, providing information packages for regulators, applying for permits and licences (see Section 4.14), etc. Similar choices are necessary for smaller projects.

Good practice is to explicitly define what the owner organization will provide and then use contract language to ensure that the undefined areas are within the contractor's accountability. Newcomer countries typically place more scope onto the vendor/contractor, especially for their first NPP, and a full turnkey seems to be the preferred option for them. Some responsibilities, for example those related to licensing and project oversight, cannot be fully delegated. See Section 2.3.2 for more discussion on organizational factors.

4.2.5. Scope verification

Scope verification is the process of formal confirmation that a project's scope has been correctly documented and incorporated into project planning. It confirms that each item identified in the project's scope statement is included within the activities that are planned to be delivered by the project and, conversely, that all items within the project plan are as intended by the desired/documented project scope. Project items are those identified by a specific WBS element (see Section 4.2.3.2).

The process of scope verification thus requires a formal review of the project's WBS, following its finalization, against accepted key scope documents such as the project charter (see Section 4.1.1) or any requirements document (see Section 4.1.4.3) that may have more detailed scope information.

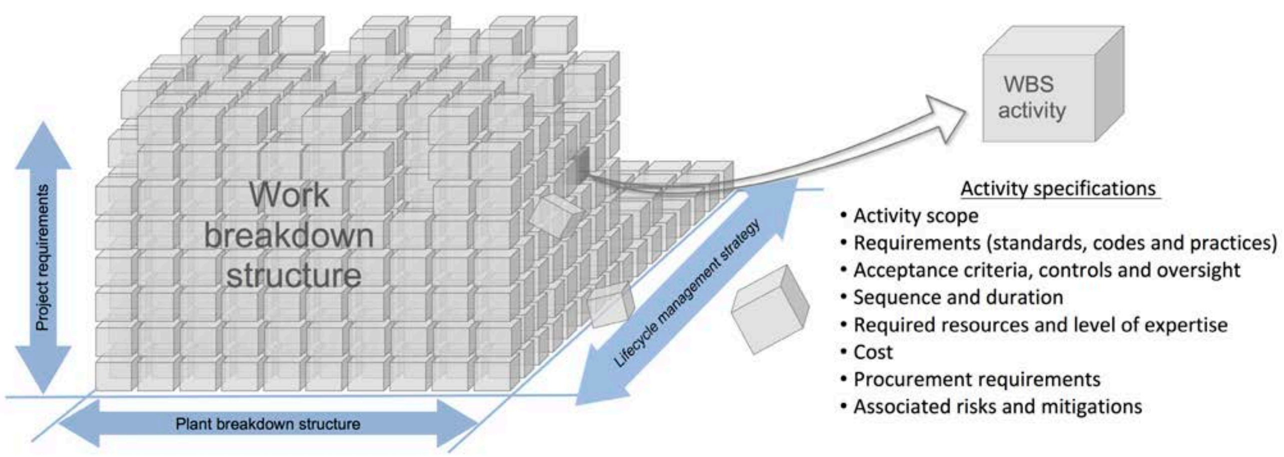

FIG. 14. Activity specifications should be developed for each element of the WBS before consolidated project plans can be compiled.

Note that some project management documentation refers to ‘scope verification’ as a different process that is performed during system or facility turnover. In this context, scope verification confirms that the requested deliverables to be provided by a project have in fact been completed. The turnover process for large nuclear projects is discussed in some depth in section 4.2 of IAEA Nuclear Energy Series No. NP-T-2.7 [2].

4.2.6. Scope change control

Despite best efforts, the detailed scope of a project may need to be changed (added to or partially deleted) during project execution. A scope change control system is needed to ensure that all of the stakeholders concerned with the change are made aware that it is being submitted, agreed upon, processed, disapproved or approved and implemented. Budgets, schedules, performance metrics or other documentation may need to be updated to reflect the scope change.

Despite having approved scope changes to a project, it is important that organizations keep track of the original schedule and cost baseline for a project and use that as a reference to assess overall project performance. Excessive scope changes/additions during a project’s life cycle often indicate poor FEP processes.

4.3. TIME

4.3.1. Baseline schedule

Time management for projects revolves around the project schedule. Activities identified at the lowest level of the WBS are loaded into scheduling software and sequenced in their logical order. Constraints or dependencies related to each activity (if necessary) are identified, the resources necessary to complete them (personnel, material, consumables, equipment or contracts) are assigned (using the project’s cost breakdown structure, see Section 4.4.1), a work schedule (e.g. hours or days per week) is set up for each resource, and a resultant schedule produced. Key milestones that identify the start or end of specific activities are identified. The project schedule needs to reflect all of the work associated with delivering the project on time, including elements not being funded directly by the project.

Schedules are typically represented via Gantt or Programme Evaluation and Review Technique charts, which are graphic representations of the project’s activities, the time it takes to complete them and the sequence in which they should be done. Project management software is typically used to create these analyses. A sample Gantt chart is provided in Fig. 15.

Summary schedules showing lower levels of detail can be derived from the integrated project schedule (the most detailed level of the schedule). Figure 16 illustrates the concept. Any vendors and contractors working on the project may have their own particular schedules; however, these need to be strongly linked to the project’s master schedule. Ideally all work groups would work off the same schedule and use the same software tools.

Scheduling and scheduling levels for NPP projects are further discussed in section 3.5 of IAEA Nuclear Energy Series No. NP-T-2.7 [2] and the PMI has issued a schedule practice standard [106]. The National Aeronautics and Space Administration (NASA) has produced a detailed schedule management handbook [107] that contains numerous examples and lessons learned.

Once the initial schedule has been prepared, it needs careful analysis to ensure that it is realistic and optimized. Some typical activities in this area include reviewing the project’s critical path, resource levelling and running ‘what if?’ scenarios.

Critical path method (CPM) analysis is the process of looking at all of the activities that are to be completed, and calculating the ‘best line’ — or critical path — to take so that the project is completed in the minimum amount of time. This path would have no intrinsic ‘float’ (i.e. time that any task in a path could be delayed without causing a delay in the overall project). The method calculates the earliest and latest possible start and finish times for project activities and estimates the dependencies among them to create a schedule of critical activities and dates. Analysis of the schedule and resequencing of some activities can often reduce critical path dependencies. Higher risk activities can often be moved earlier in a schedule to allow greater time for mitigation without impacting on the critical path.

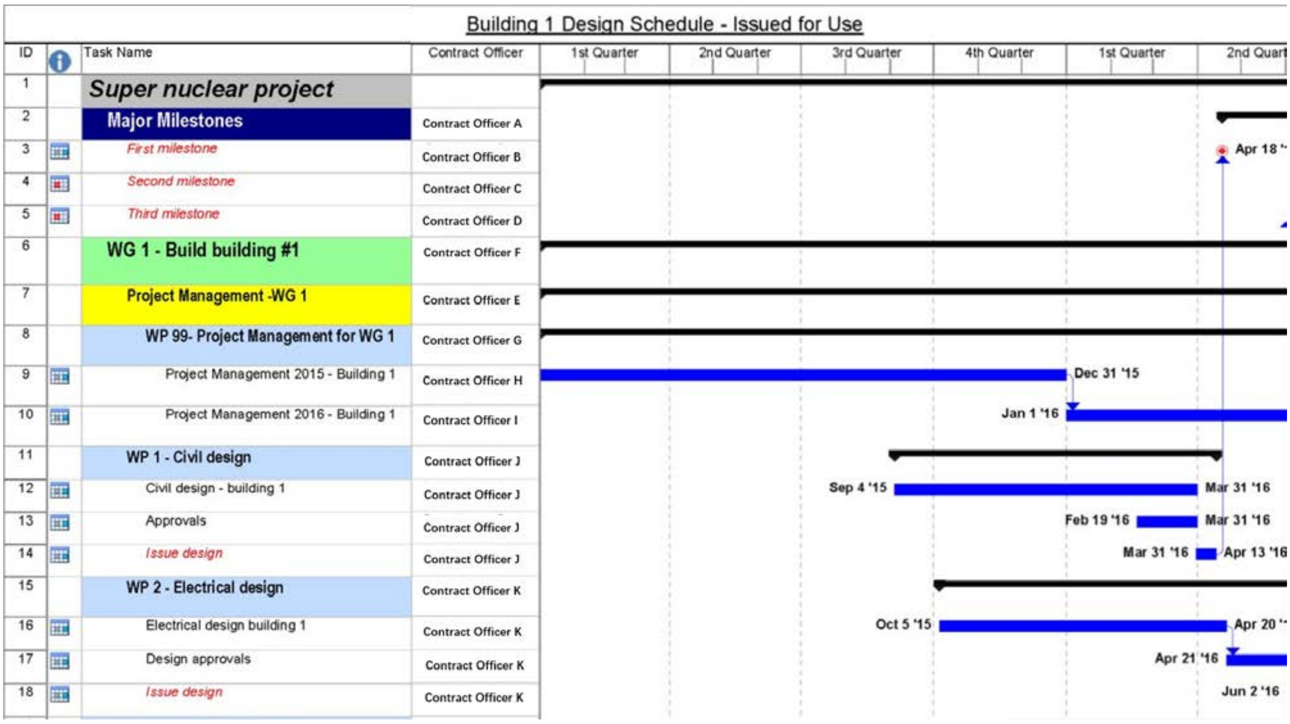

FIG. 15. Simple example Gantt chart for the design phase of a project.

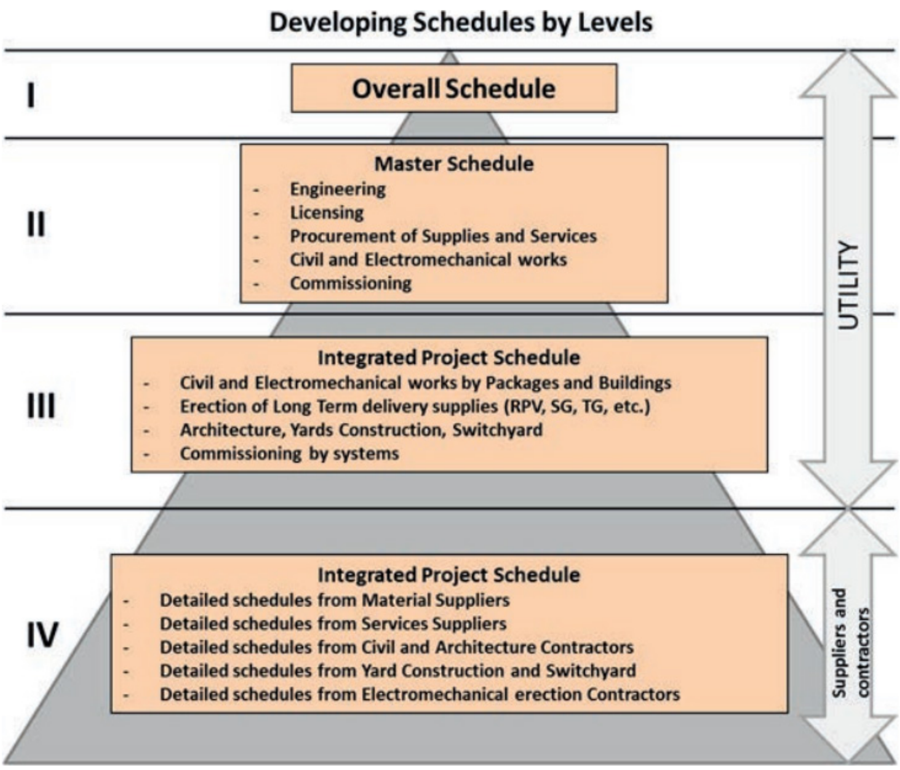

FIG. 16. Scheduling levels (reproduced from Ref. [2]).

Any resource has capacity limits; that is, a project cannot apply an infinite number of personnel or other resources to complete a task in zero time. Resource levelling is the process of reviewing the sequence of activities to ensure that excessive demand is not put on resources at any point in time. If resources are available only in limited quantities, then the timing of activities can be changed so that the most critical activities have the first priority for the resources.

A process known as the critical chain method also addresses resource availability. Activities are planned to use their latest possible start and finish dates. This adds extra time between activities, which can be used to help manage work disruptions. Critical resources need not be just personnel; key construction equipment such as heavy transport and lift equipment can also be critical and require careful scheduling and planning.

'What if' scenario analysis examines the effects of different scenarios on a project. Simulations are run, often using Monte Carlo methods, to determine the effects of various adverse, or harmful, assumptions on the project. Projects can then measure and plan for the risks posed in these scenarios.

4.3.2. Project milestone and schedule management

Project milestones as derived from a project schedule are a typical project communication and control tool. Project managers often publish lists of key milestones and use metrics such as percentage of milestones completed on time as a project performance indicator. Such milestone completion rates are often regularly reviewed by senior management and may even be tied to bonus schemes for project team members.

Once the initial project schedule has been prepared and finalized it becomes the baseline schedule for the project. Project progress (e.g. activity completion, project costs) is then measured against this baseline. The baseline is not updated unless a specific change to it is approved, often in the context of a new project phase or superseding release of funds.

Project progress requires regular (often daily or twice daily during construction and commissioning) updating to ensure that the status of the work is known, resources utilized are recorded, future resource needs are reforecast if needed, and work groups understand and can plan for upcoming activities. Data for these updates can come from formal and informal sources. These can include work groups inputting progress directly into computer systems, cost and schedule analysts inputting data received during team meetings or direct contact with work group representatives. Figure 13 of IAEA Nuclear Energy Series No. NP-T-2.7 [2] illustrates a typical flow of information in gathering data for schedule updating.

Once updated, schedules need analysis to identify potential issues. These can include missed or delayed activities or deliverables, over or under allocation of resources, or the potential for missing future milestones or cost increases. The reasons for any of these occurrences need to be investigated and schedule adjustments made as required. These can include adjustments to assessed resources, changing duration estimates, tasks and dependencies or updating workforce development plans. Any new risks should be identified via project risk management processes (see Section 4.9).

4.3.3. Impact of late deliverables

Late deliverables can have a negative impact on a project that goes well beyond their simple effect on schedule and cost. Secondary effects such as errors, rework, activity resequencing, overtime, delay time, expediting or design changes caused by one or more late deliverables can exacerbate their initial effects and lead to further schedule delays. Such changes can place undue pressure on the project safety, quality, cost and schedule. Furthermore, with the additional strain placed on meeting these goals, extra pressure is also placed on the individuals, teams and organizations involved in a project [108].

Late deliverables can include such items as:

- Engineering documents, approvals or responses to requests for information;
- Engineered equipment;
- Bulk materials;
- Fabricated materials;
- Prefabricated assemblies;
- Permits (including regulatory authorizations or licences);

- Project plans;
- Human resources;
- Utilities and infrastructure (e.g. roads, utility tie-ins);
- Construction equipment.

Some of the above can be due to or produced by other separately managed projects.

The CII has produced a number of publications related to the impact of late deliverables on construction projects, including a guide that can help to identify and weight potential risks associated with late deliverables [108] and a number of case studies [109]. Identified risks can be incorporated into a project's risk register.

Of the ten late deliverable categories studied by the CII, the following were found to be the most prevalent groupings, in terms of both severity and commonality [108]:

- Engineering documents, reviews and approvals;
- Speciality equipment and materials (i.e. engineered equipment, prefabricated materials and fabricated assemblies).

This would indicate that special attention to the impacts of engineered and speciality items on projects is of particular importance. Of particular note is the need to not overestimate the level of experience and capacity of a typical engineering organization to meet an aggressive project schedule, and the need to only use cost and schedule predictions for speciality items that have been confirmed by individuals in the supply chain who have consulted with suppliers and contractors.

4.3.4. Schedule metrics and schedule risk analysis (SRA)

A common metric to monitor schedules is the schedule performance index (SPI). SPI is a ratio of the earned value of a project to its planned value (PV). If the SPI is less than one, it indicates that the project is potentially behind schedule to date, whereas an SPI greater than one indicates that the project is running ahead of schedule. Refer to Section 4.1.4.2 for more details on EVM.

Schedule risk analysis (SRA) is similar to a traditional CPM analysis (see Section 4.3.1) except that rather than each activity having a single duration value, it has a range of durations that including a minimum duration, maximum duration and most likely duration. Monte Carlo risk analysis is then done on the schedule by running it thousands of times, sampling values from the defined ranges of each activity with each run.

These results from such analysis will provide confidence ranges for the end date of the project. These can offer dates ranging from 0% confidence (P0) to 100% confidence (P100). In many projects P75 or P80 dates are regarded as acceptable forecasts with any residual risks identified. A useful output from such an exercise is the quantitative identification of the riskiest areas of a project's schedule, allowing for the possibility of risk mitigation. Additionally, the risk analysis tool can often be linked to a project's cost model so that the impact of any schedule delays can be reflected on a project's cost estimate.

4.4. COST

Cost management includes controlling all costs related to a project. Activities include project planning, estimating, budgeting monitoring and controlling costs. This section covers how costs are tracked under a typical cost breakdown structure for a project, and some of the issues surrounding estimating, budgeting, monitoring and controlling costs.

4.4.1. Cost breakdown structure

A cost breakdown structure (CBS) is a hierarchical definition of the key cost elements of a project. These include labour, materials and other direct and indirect costs. For a complex project there can be many sublevels of these major elements below the high level divisions. Scheduled activities within the WBS would be tied to these individual cost accounts. Figure 17 shows a sample high level CBS.

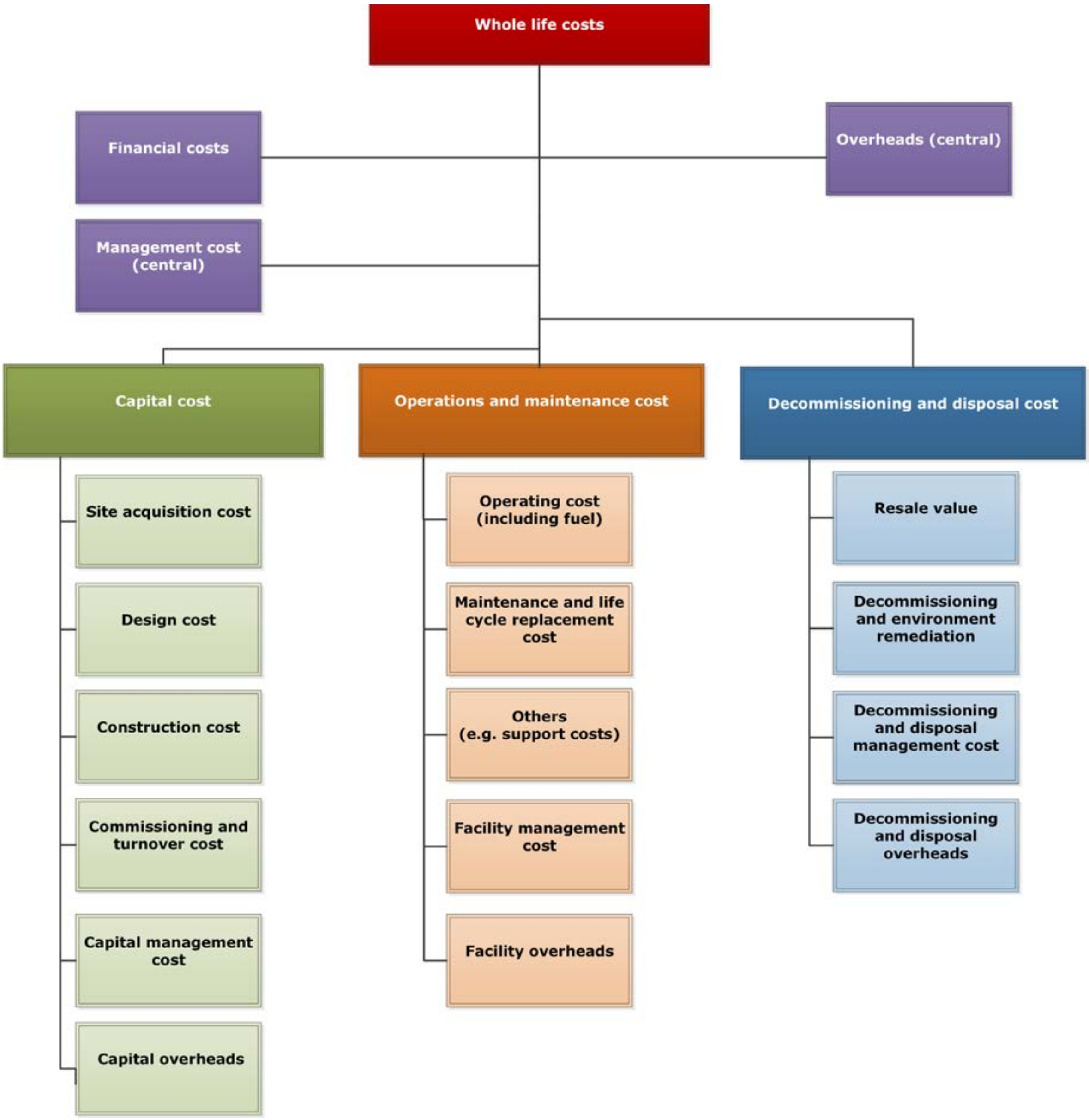

FIG. 17. Sample CBS.

The CBS allows for the tracking of project costs and helps to evaluate the effectiveness of the estimate versus the work in place, remaining work and overall costs.

Figure 18 shows the relationship between a WBS, OBS and CBS. Each work item (from the WBS) that is worked on by a separate resource (from the OBS) is captured in a separate cost account (a CBS item).

4.4.2. Cost estimating

Estimating is the process of developing an approximation of the financial resources needed to complete a project. It takes inputs from the project's preliminary scope, schedule, cost structure, risks and external factors, and from previous and similar projects. Through various tools and techniques it produces a cost estimate for the various project activities and the project as a whole.

Estimators use a number of practices to get to a reasonable estimate. The PMI's PMBOK Guide [7] and Managing Successful Projects with PRINCE2 [110] from AXELOS include useful information for this, and it has been used as the basis for creating the following list:

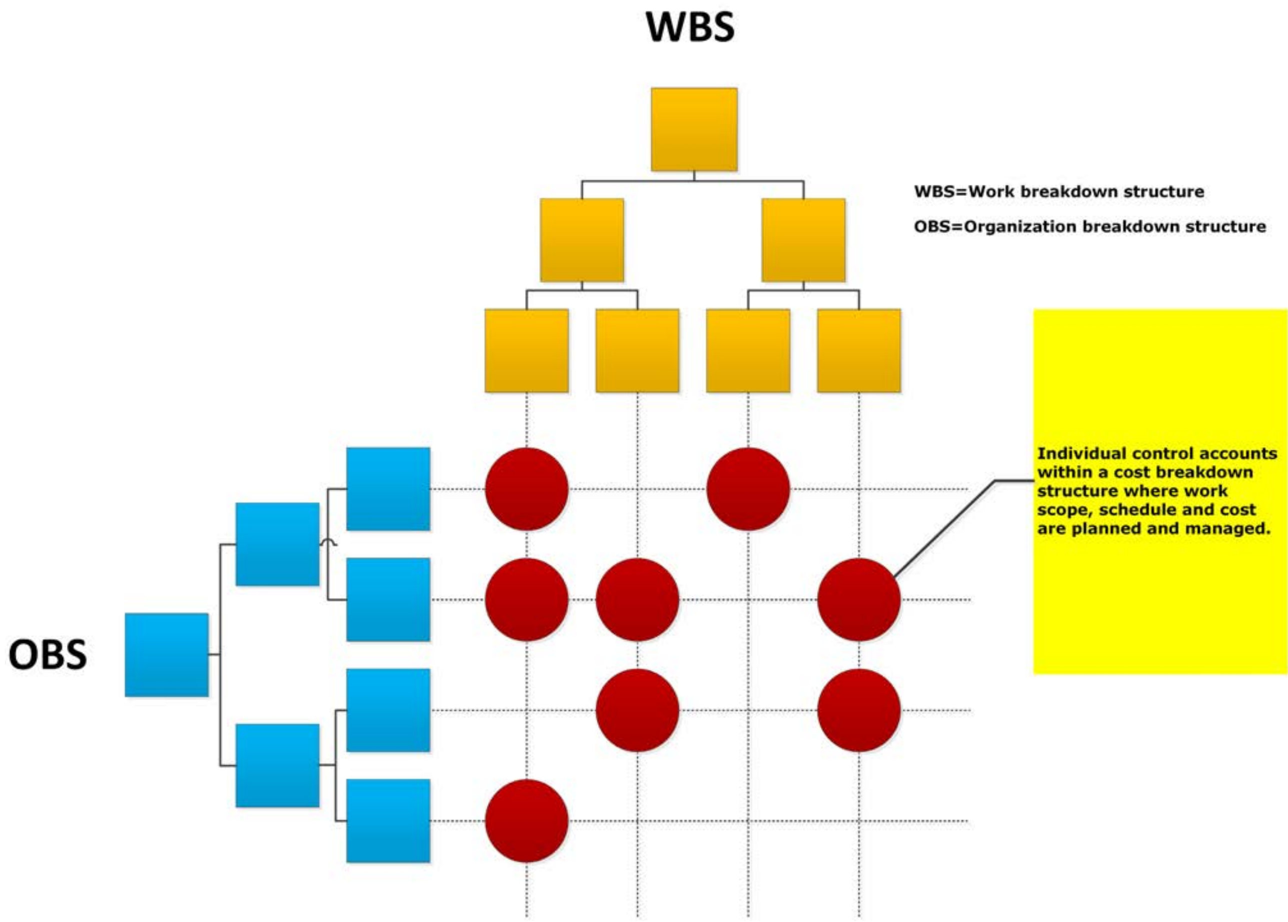

FIG. 18. Relationship between WBS, OBS and CBS.

- Expert judgement (use of individual people intimately familiar with the work);
- Analogous or comparative estimating (using similar activities from previous projects as the basis of the estimate);
- Parametric estimating (using a formula based on durations, quantities of items, etc., to derive an estimate);
- Top down estimating (produce a good overall estimate for the project (by whatever means) and then subdivide the estimate based on historical data or other methods; for example, design is typically X% of a project's cost);
- Bottom-up estimating (each item is estimated separately and the individual estimates are then summed together to find the total project estimate);
- Single-point estimating (use of sample data to calculate a single value which is to serve as a most likely value for the duration of an activity);
- Three-point estimating (using a best-case scenario, a pessimistic one and an expected scenario, with the final estimate being the weighted average of the three);
- Reserve analysis (adding extra time to the schedule (called a *contingency reserve* or a *buffer*) to account for extra risk);
- Cost of quality (using assumptions about costs of quality (incorporating costs required to prevent or address non-conformances or failures) to help prepare activity cost estimates);
- Project management software (use of project management software, such as a scheduling software tool, to help plan, organize and manage resource pools and develop estimates);
- Vendor bid analysis (analysis of what the project should cost based on bids from qualified vendors);
- Group decision making techniques (e.g. brainstorming or Delphi techniques (obtaining group input for ideas and problem solving without requiring face to face participation using a series of questionnaires interspersed with information summaries and feedback from preceding responses to achieve an estimate) or nominal group techniques).

Maintaining the independence of those individuals performing cost estimating is important. Underestimates of costs can occur due to pressure from the project team or senior executives, and overestimates can occur where organizations maintain a punitive environment related to even minor cost overruns.

Standard metrics can be used to help validate various aspects of a prepared estimate. Ratios of costs to costs (e.g. total cost/equipment cost, construction labour/cost of bulk material), resources to cost (e.g. field hours/total project cost), cost to resource (e.g. labour/person hours) or resource to resource (trade hours/material quantities, engineering hours/drawings) can be useful tools for comparison, especially when compared to those based on large numbers of benchmarked capital projects.

The AACE has published a number of recommended practices related to cost estimating. Some selected examples are available in Refs [111–117]. Figure 19 shows how the AACE describes estimate classes and their expected accuracy range at various project phases. This translates into reduced project contingency being allocated as the project progresses towards greater definition (see Section 4.4.3).

The PMI has also issued a project estimating practice standard [118]. The IAEA has issued publications in the Nuclear Energy Series related to cost estimating of spent fuel storage [119], the nuclear research reactor fuel cycle [120] and research reactor decommissioning projects [121].

4.4.3. Budgeting and contingency

Budgeting is the process of allocating project costs over time, and as such links the project estimate to the project schedule. Organizations typically need to plan financially on a monthly, a quarterly and an annual bases. Among other things, they need to ensure that they have enough cash on hand to pay monthly invoices. Financing arrangements may need to be made to cover large expenditures, projects, equipment purchases and operating and maintenance costs. Large projects or a portfolio of projects will impact on these requirements significantly.

Contingency is a risk management process that helps to ensure that there is sufficient project budget available to fund reasonably expected project events that are not part of the baseline plan. Project budgets for a given phase typically include a contingency reserve. This reserve is used by the project manager to fund known or predictable risks that have been identified before the start of a project phase (i.e. risks documented in the risk register). Also included in the project overall budget is a management reserve that is not under the control of the project manager, but rather the project sponsor. Management reserves fund risks that are unknown or not predicted in advance of the particular project phase.

	Primary Characteristic	*Secondary Characteristic*		
ESTIMATE CLASS	**MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES** Expressed as % of complete definition	**END USAGE** Typical purpose of estimate	**METHODOLOGY** Typical estimating method	**EXPECTED ACCURACY RANGE** Typical variation in low and high ranges [a]
Class 5	0% to 2%	Concept screening	Capacity factored, parametric models, judgment, or analogy	L: -20% to -50% H: +30% to +100%
Class 4	1% to 15%	Study or feasibility	Equipment factored or parametric models	L: -15% to -30% H: +20% to +50%
Class 3	10% to 40%	Budget authorization or control	Semi-detailed unit costs with assembly level line items	L: -10% to -20% H: +10% to +30%
Class 2	30% to 75%	Control or bid/tender	Detailed unit cost with forced detailed take-off	L: -5% to -15% H: +5% to +20%
Class 1	65% to 100%	Check estimate or bid/tender	Detailed unit cost with detailed take-off	L: -3% to -10% H: +3% to +15%

FIG. 19. AACE estimate classes and accuracy ranges (reproduced courtesy of the AACE [111]).

The AACE has published numerous guides related to establishing appropriate financial contingency for a project, available in Refs [122–126]. Further details on risk management are discussed in Section 4.9. Contingency for NPP projects is further discussed in section 3.5.2 of IAEA Nuclear Energy Series No. NP-T-2.7 [2].

Generally, as a project becomes more defined its number of unknowns is reduced and its inherent riskiness is decreased. This allows the amount of contingency reserved by the project to be reduced over time. The logical extension of this is at project closure, when there is no remaining risk and the final project cost is known.

4.4.4. Financing

Based on the cost estimate, a project financial plan needs to be established that gives an indication of the expected range of costs of ownership of the facility and the anticipated funding and financing mechanisms. Project financing is discussed in some detail in IAEA Nuclear Energy Series Nos NG-T-4.1, NG-T-4.2 and NG-T-4.6 [46, 47, 127]. A detailed project budget is then established for the project development phase. This budget is based on the WBS, the project schedule and the activity specifications.

During the development phase, funding is necessary for non-facility activities, including planning related to and delivery of education, training, research, regulation, spent fuel, emergency preparedness and response, waste and decommissioning [1]. The project charter and scope documents need to confirm what portion of these (if any) will be covered by the project budget. Even when these are not funded by the project budget, the project still needs mechanisms in place that ensure that the areas do not pose a risk to the project proceeding on schedule.

4.4.5. Controlling costs

4.4.5.1. EVM and forecasting

Costs on a project need continual review so that they do not rise out of control. Carefully monitoring project costs using EVM techniques, as described in Section 4.1.4.2, is an acknowledged part of this. Regularly updating the project's forecasted cost at completion and taking corrective actions as required is key.

4.4.5.2. Claims and change management

Change is part of every large project (see Section 4.1.5). Left unmanaged, claims and changes requested by vendors and suppliers on some projects can easily increase project costs so that any project contingency is used up. Projects can quickly go over budget.

Perhaps the best defence against claims is a combination of detailed FEP (see Section 3.5), an appropriate contract model for the project in question, appropriate risk allocation and careful contract administration practices. Figure 20, from section 3.2.3.1 of IAEA Nuclear Energy Series No. NP-T-3.21 [3], describes which contract types are most appropriate based on project scope definition.

Despite all best efforts, some contract changes may be requested or a claim for increased costs may be filed by a vendor. Typically the validity and final outcome of such claim processes depend strongly on the documentation maintained by each of the parties. Organizations with strong contract administration processes and methods, a clear change order process and good record keeping are most likely to be successful. Large claims can result in the need to release contingency or management reserve funds (see Section 4.4.3).

An important part of managing such changes is an agreed dispute resolution process. Such processes often allow for the referral of a contract issue within a specified time period to an impartial dispute resolution board. Whatever process is used it is necessary to have it agreed to as part of the original project contract negotiations, so that it is ready to be used when contract execution begins.

A sample change management process typical of a large nuclear project is shown in Fig. 21. It is designed to address changes such as project costs, scope, schedules or annual cash flows in a systematic way. A graded approach to change approvals is taken, with the most impactful changes requiring a new business case to be approved at a high level, and the smallest of changes being approved at a low level through the applicable project management office.

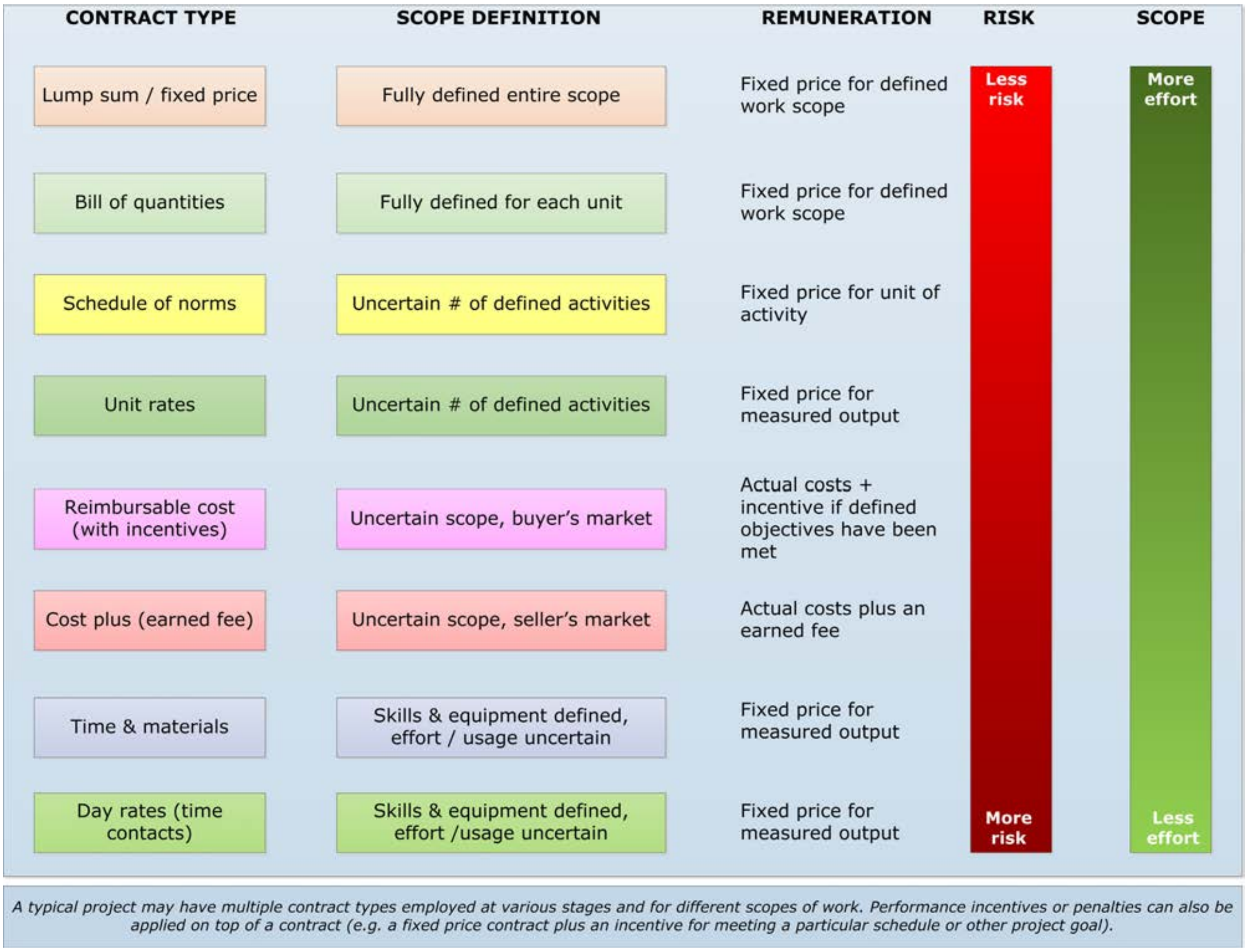

FIG. 20. Contract types versus appropriateness based on scope definition, risk profile and scoping effort required (reproduced from Ref. [3]).

4.4.6. Cost metrics

A common metric to monitor cost is the cost performance index (CPI). The CPI is a ratio of the earned value of a project to its actual cost. If the CPI is less than one, it indicates that the project is running over budget. This represents a risk in that the project may run out of money before it is completed. A CPI of greater than one indicates that the project is running under budget. The reason for this should be investigated to determine whether the project is actually achieving cost savings or whether the original estimates were unrealistically high. Refer to Section 4.1.4.2 for more details on EVM.

Another number that is regularly tracked is the overall project estimate at completion. Whether calculated simply using the costs to date plus the budget for remaining work, or more analytically using SRA methods (see Section 4.3.4), the final estimate at completion is an important calculation to help forecast whether the project will remain within its allocated budget.

On a project portfolio basis, a good metric is the project cost growth index (PCGI). Project growth is defined as the final cost of a project at closeout divided by the amount of the first project release (i.e. the 'final' project cost/budget released to the project manager to spend before any project superseding releases were approved). PCGIs greater than 1 can indicate that project planning did not adequately anticipate potential risks when the original release of funds was approved. An improving project organization would see its PCGI scores for projects increasingly get closer to 1 over time, indicating a trend towards greater project predictability.

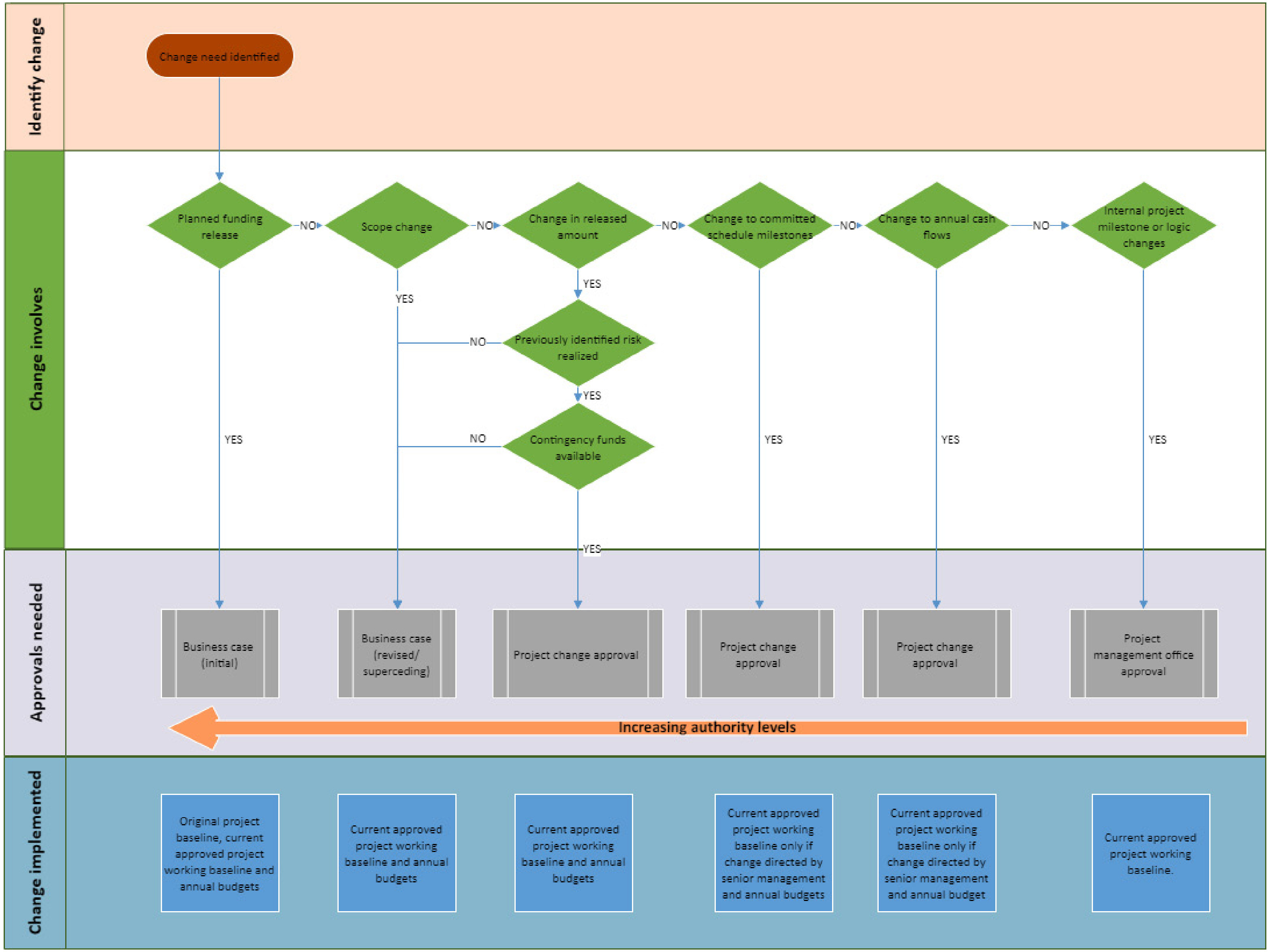

FIG. 21. Typical change management process for a large project.

4.5. QUALITY

Quality, simply defined, is a product's ability to meet its requirements. Quality is important for nuclear projects, particularly in the areas of engineering and design, procurement/supply, construction/installation, commissioning and decommissioning. Efforts to ensure quality in these areas need to take high priority.

During the execution of activities, the monitoring of quality control acceptance rates, as well as oversight intervention frequencies, can give a good indication of the overall quality of workmanship. Low acceptance rates or high frequencies of oversight interventions are a clear sign that an organization is over reliant on these functions, which when stressed may result in undetected or delayed realization of project risks. This may result in regulatory intervention, large rework and/or project delays. The management of quality can help to reduce the numbers of human performance events, engineering errors, material defects and field rework.

The robustness of the oversight function is key in providing the nuclear regulator with a degree of confidence in the competence of the owner/operator to manage a nuclear project. Measures should, therefore, be put in place to ensure that a high level of quality is prevalent and that control and oversight functions are periodically reviewed for effectiveness, are dynamic and are focused on prevention rather than being encumbered with corrective activities. This applies not only to the construction and operation of the facility itself, but also to project development activities.

Quality is generally addressed through a combination of ensuring that processes and procedures present are adequate (via checking of quality assurance or management systems functions) and by doing specific inspections of products (quality control activities). Futher details on quality assurance and quality control as a part of management system for nuclear facilities and activities are discussed in IAEA-TECDOC-1910 [128]. Quality planning and management for NPP projects are further discussed in section 3.6 of IAEA Nuclear Energy Series No. NP-T-2.7 [2]. The publication provides examples of quality oversight activities for engineering, procurement and site works. Construction quality surveillance is discussed in section 3.7 of the same publication. Requirements management as a quality tool is discussed in Section 4.1.4.3 of this publication.

4.5.1. Quality assurance

Article 13 of the Convention on Nuclear Safety [129] concerns quality assurance and requires each contracting party to "take the appropriate steps to ensure that quality assurance programmes are established and implemented with a view to providing confidence that specified requirements for all activities important to nuclear safety are satisfied throughout the life of a nuclear installation."

Basic objectives, concepts and principles to ensure the safety of nuclear facilities are presented in SF-1 [10]. This publication forms a top level publication in the hierarchy of the IAEA Safety Standards Series. In this context quality and safety are assured through an organization's management system. According to para. 3.12 of Ref. [10]:

> "Leadership in safety matters has to be demonstrated at the highest levels in an organization. Safety has to be achieved and maintained by means of an effective management system. This system has to integrate all elements of management so that requirements for safety are established and applied coherently with other requirements, including those for human performance, quality and security, and so that safety is not compromised by other requirements or demands. The management system also has to ensure the promotion of a safety culture, the regular assessment of safety performance and the application of lessons learned from experience" [10].

The above implies that quality needs to be carefully considered and planned into any project policies or procedure. This includes, for example, considering the quality standards to be applied and acceptance criteria, and ensuring that sufficient subject matter expert and interdisciplinary reviews are incorporated into design processes, scope and specification documents are clearly written, steps are taken to improve the effectiveness of construction activities, the potential for human performance errors is considered, individuals are sufficiently trained and capable of doing their assigned work, and quality records are maintained, as well as many other factors.

Further details on the application of management systems are available in IAEA Safety Standards GSR Part 2 [24], GS-G-3.1 to 3.5 and TS-G-1.4 [36–41]. Grading of management system requirements is addressed in IAEA-TECDOC-1740 [45]. Auditing, vendor oversight and inspections, which are an important part of any nuclear management system, are discussed in sections 3.4 and 3.5 of IAEA Nuclear Energy Series No. NP-T-3.21 [3]. Also refer to section 4.1.4.3 of this publication.

4.5.2. Quality control

Quality control is that part of quality management focused on fulfilling quality requirements. While quality assurance relates to how a process is performed or how a product is made, quality control is more about the inspection aspect of quality management. Inspections are completed based on predefined acceptance criteria.

Inspection is the process of measuring, examining and testing to gauge one or more characteristics of a product or service, and the comparison of these with specified requirements to determine conformity. Products, processes and various other results can be inspected to make sure that the object coming off a production line, or the service being provided, is correct and meets specifications. Trained and experienced inspectors are needed to be able to detect non-conformities.

In a nuclear context, inspection activities can be graded based on safety significance or other requirements. They can include such items as reviews and acceptance of designs, drawings, reports or other documents, witnessing of construction field activities or inspections or testing of materials, components or complete systems, either at the factory, upon receipt, following installation or during commissioning. Requirements for management systems, quality control, audits and oversight should be documented and established. During project development, for example, this could entail the establishment of specifications for the various development studies that identify the necessary codes and standards to be met.

Section 3.5 of IAEA Nuclear Energy Series No. NP-T-3.21 [3] discusses inspection activities related to equipment procurement and section 3.7 and appendix X of that same publication discuss source surveillance and oversight activities related to contractors.

4.5.3. Quality metrics

Numerous quality related metrics are useful to be developed and tracked for a project. Some of these can include:

- Rework metrics (engineering, construction or commissioning errors requiring rework; ‘unplanned’ field changes to a design (those that could reasonably have been averted), etc.);
- Failed inspections or tests (including statistical data such as percentage passed versus failed, percentage passed at the first test, etc.);
- Timeliness (e.g. time between identification of a non-conformance and actual raising of a non-conformance report (NCR) on the corrective action system; time between opening and resolving NCRs, work package closeout progress);
- Human performance related events;
- Procedural non-compliances;
- Occupational safety and health related metrics (see NP-T-3.3 [43]).

Classification of the cause of the issue (e.g. workmanship, coordination, design, inadequate training, manufacturing defect, plan/shop drawings review, shop fabrication, unknown field condition) will help in the analysis of such events and the development of corrective actions.

4.6. HUMAN RESOURCES

4.6.1. Human resource planning

IAEA Safety Standards No. GSR Part 2 (Requirement 9) emphasizes the importance that resources have in the context of nuclear activities, stating that **“Senior management shall determine the competencies and resources necessary to carry out the activities of the organization safely and shall provide them”** [24]. This applies equally to nuclear projects.

Nuclear projects require a variety of skills. Individuals at all levels need to be competent in these skills, be able to work safely and understand the standards that they are expected to apply [24]. Human resource planning is needed to identify all of the skills needed, the required timeframes when they need to be available and any constraints on their acquisition or availability such as regulations surrounding government, union contracting or hours of work. Staff who will be required to support any modifications that are installed by a project team may also require training in the modification specifics. A plan should be developed to recruit, induct, train, develop and qualify all necessary resources and identify and mitigate associated risks.

A part of such a plan would be the development of written roles and responsibilities for each position, establishing target organization charts for the project and the facility and preparing a staffing plan for acquiring the needed resources. Of particular importance is the coordination of the project organization's human resources needs with those of the eventual owner/operator, since a good number of project personnel would be expected to eventually move to the owner/operator organization. IAEA Nuclear Energy Series No. NG-G-2.1 [130] provides details on human resource planning in the field of nuclear energy, NG-T-3.10 [131] covers workforce planning for new nuclear power programmes and IAEA-TECDOC-1364 [132] provides some lessons learned. For new build projects, the IAEA Competency Framework[8] can be referred to for the various competencies needed at each phase of a new NPP programme.

The IAEA offers expert missions and review services to help Member States develop and enhance their national and organizational human resources plans, to review their training arrangements and provide guidance for long term operation.

4.6.2. The owner's role

The 'owner' of a project can be thought of as the entity that has the ultimate decision authority related to the project. As such it may not be the individual project investors, but rather the company or part of the company tasked with signing the project contract on behalf of the investors and with otherwise managing the project. The CII indicates that an owner:

> "is responsible for establishing the basic objective of the project that will serve as the justification for securing funding for the project and will, upon completion of the project, own and operate the facility. Such an owner may rely upon another entity within or outside the organization to translate the basic objective into a scope, and then manage the cost, schedule, and execution of the project. In many projects, the entity that bears the title and responsibility of 'owner' will change throughout the life of the project." [133]

The owner's role on a project evolves as it moves through its phases. As such, the duties of the owner/operator and its roles and responsibilities need to be adapted over time. Different specialist functions, contractors and vendors will be brought onto the project.

For a large nuclear project, the owner's roles can be broadly defined as follows:

(1) **Project development management**: Responsible for the management of site investigations and approvals as well as initial project planning;
(2) **Procurement management**: Responsible for specification of requirements, procurement of supply contracts and securing of financing;
(3) **Construction management**: Responsible for the overall management of the manufacturing, construction and installation;
(4) **Operations and maintenance management**: Responsible for the management of commissioning (in conjunction with the construction management function), operations and maintenance of the facility;
(5) **Decommissioning management**: Responsible for the transfer of the facility to a decommissioning entity or for management of the decommissioning itself.

[8] See https://nucleus.iaea.org/competency-framework/

In all these roles, the proactive leadership demonstrated by the owner is key to achieving excellent project performance. The owner, for example, sets expectations for industrial safety on its job site, which has been shown to be greatly improved when the owner/operator shows leadership in this area [43].

IAEA Nuclear Energy Series No. NG-T-3.1 (Rev. 1) [134] discusses the changing role of the owner/operator during the different phases of an NPP project. It should be noted that the owner and operator roles may exist in different organizations. The operator is ultimately responsible for the safety of the NPP and is the NPP licence holder (refer to Section 4.14), while the owner is the organization recognized by the law as having the ultimate right to use the NPP and receive the profits from its operation. Usually the owner is responsible for financing and most other activities would be delegated to the operator (by contract).

4.6.3. Organizational structure

(a) Functional structures

Functional organization structures are hierarchical in nature, where each person has only one supervisor. Individuals are organized by speciality, such as engineering, maintenance, construction, finance, legal, etc. Each organization functions essentially independently from the others. They have the benefit of being strong technically within the various functional areas but, if not managed well, can have poor communications and not be suitable for inter-departmental cooperation or large projects. Where necessary, part time project teams can be established within functional organizations.

(b) Project structures

As opposed to a functional structure, an organization strictly designed around a project structure is one in which all individuals are assigned full time to the project in question and where the project manager has full control over project resources. Projects have all the resources they need, but the individual development of personnel in their functional or technical areas can be neglected in favour of short term project goals.

(c) Matrix structures

Most nuclear projects are organized around a matrix structure that integrates the benefits of the specialized workforce functional structure into cross-functional project teams. IAEA Nuclear Energy Series No. NG-T-2.7, Managing Human Performance to Improve Nuclear Facility Operation [135], can be referred to for more information.

Each member of the workforce reports to a specialized workforce function such as the planning, finance or plant engineering department. These workforce functions have the appropriate authority and responsibility to act throughout the project within their field of expertise. They are responsible for the establishment of necessary policies, procedures, instructions, in-house codes and standards, as well as the management of skills and resource development within their field of expertise. In addition to this they have the responsibility to oversee the quality of work performed on activities, again from the perspective of their field of functional expertise.

Individuals are assigned to a project along with team members from other workforce functions on a full time or part time basis. For the duration of the project, they report to the project manager in terms of task orientated performance (including what has to be done and by when). From a functional performance or quality perspective, they still report to their functional managers. This assures that the management of quality has a degree of independence from the operational pressures placed on the task or project manager.

The degree of control of the functional organizations versus the project organizations can vary, with those where the functional organizations tend to dominate being called ‘weak matrix’ organizations and those where the project organizations tend to dominate being called ‘strong matrix’ organizations.

It is the task or project manager’s responsibility to ensure the mapping and establishment of interdisciplinary processes or workflows that enable the delivery of the various phased objectives.

This matrix structure approach illustrated in Fig. 22 can be used at various levels within the organization.

Sound project management applicable to complex nuclear projects is characterized by strong matrix structures that allow for the integration of high levels of specialized expertise to focus on interdisciplinary deliverables.

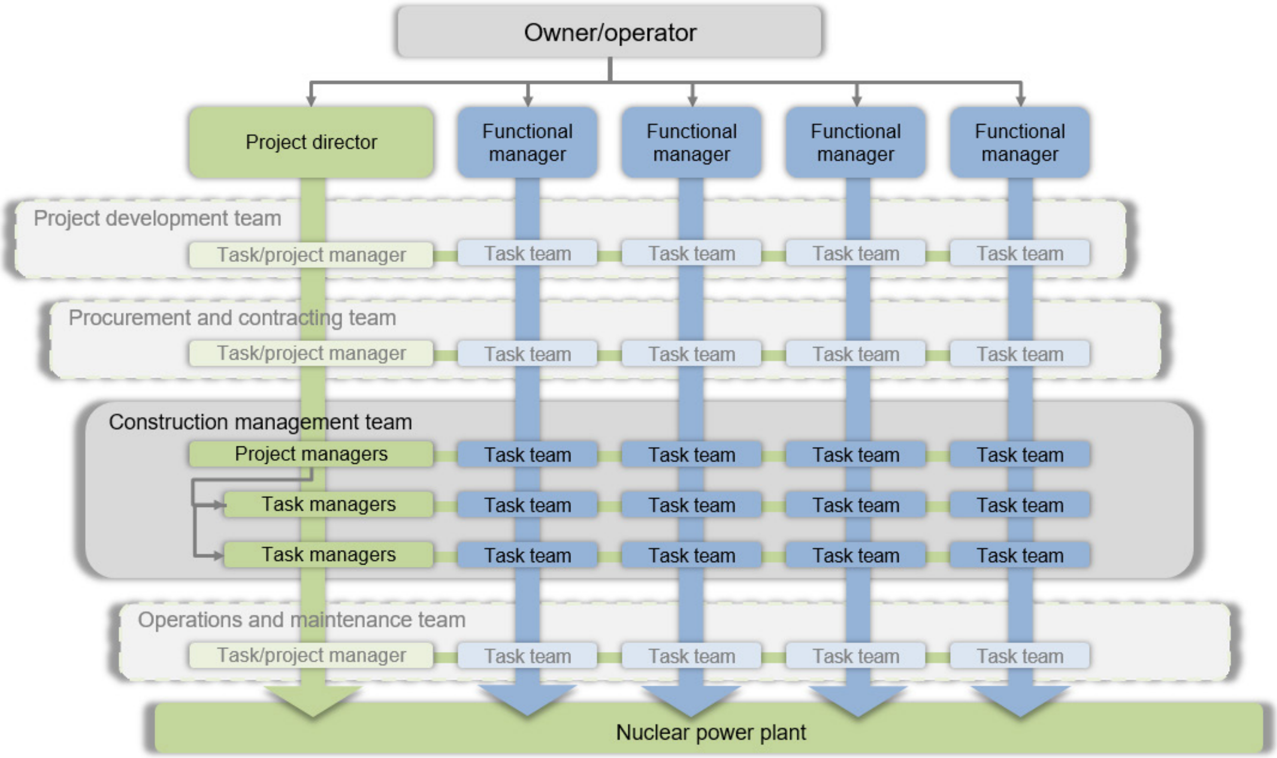

FIG. 22. Matrix structure approach to nuclear project management.

The management of a nuclear project requires a high level of expertise in numerous areas. It takes a considerable length of time to recruit, train and qualify personnel to the level necessary for them to perform their functions. The owner/operator needs to develop a good understanding of which resources are required by when, as well as how long the lead times are to develop this expertise. Methods to transfer knowledge from the project/construction organization to the line organization that is responsible for operating the facility need to be considered.

Resource planning needs to be addressed by the owner/operator right from the beginning of Phase 2 as defined in the IAEA's Milestones in the Development of a National Infrastructure for Nuclear Power, Nuclear Energy Series No. NG-G-3.1 (Rev. 1) [1]. Identification, selection, recruitment and training of personnel is a lengthy process. The IAEA Nuclear Energy Series No. NG-T-3.10 [131] on workforce planning should be referred to for more detail. Appendix I of Ref. [131] contains a list of required workforce functions and staffing levels for operational NPPs. Additional functions and staff may be required during the development and construction phases, depending on the type of contracting approach adopted.

(d) Partnership structures

Different companies can work together on a single project under a contracted partnership, joint venture, consortium or alliance. In this structure, one organization takes the lead and assigns a project manager to coordinate the overall project. These arrangements are common in the nuclear industry for large projects. The various companies involved share expertise (e.g. nuclear or conventional design, other engineering, construction or project management expertise) and financial risk. They are a flexible structure that can change from project to project; however, the project team assembled often takes some time to become fully efficient and work out all of the necessary interfaces between the parties.

Organizations that have experience with working together previously in a long term partnership or strategic alliance typically have a greater potential for success. Research has shown improvements in project cost, schedule, quality, claims and overall job satisfaction [136].

The CII has produced some guidance on partnering for construction projects [137] as an aid in evaluating partnering, preparing for partnering, selecting a partner, and implementing and maintaining a partnering relationship.

(e) Committees and work groups

During the structuring of project processes and workforce functions, it may be beneficial to establish various control and oversight bodies either within the project company or with the parent owner/operator organization. These are called committees and work groups, and they may be more permanent or temporary depending on the need. Even the project core management team may be considered as a work group.

Committees and work groups can, if implemented correctly, assist in increasing the efficiency and effectiveness of managing the project by improving communication. They should be structured and arranged in such a way that they support the effective and efficient functioning of the project processes with a specific focus on the interdisciplinary core processes.

Committees and work groups often give support in financial planning or aid the engineering director or manager. However, some functions, especially within the project's core processes, are multidisciplinary in nature. In these cases, it is best practice to establish a cross-functional committee or working group that is comprised of the relevant personnel or authorities required to ensure that decisions are well represented, robustly considered and debated if necessary and that a consolidated position is established on behalf of the project organization.

Potential committees and working groups are discussed more in Appendix IV.

4.6.4. Organizational breakdown structure (OBS)

Project organizations typically define an OBS (see Fig. 23) to indicate how a specific project will be organized and controlled. An OBS is a framework for the identification of accountability, responsibility, management and approvals of all authorized work scope. The OBS helps management focus on establishing the most efficient organization by taking into consideration the availability and capability of management and technical staff, including subcontractors, to achieve the project objectives.

The OBS identifies the lowest level organizations responsible for each segment of work, including subcontracted and intra-organizational efforts. Each work segment (as defined by a WBS; see Section 4.2.3) is assigned to an OBS work group for project control (performance monitoring and supervision) purposes. Each OBS element will have its accountabilities and responsibilities defined within the project's management system, for example in the form of detailed job descriptions.

4.6.5. Establishing the project board

Project investors and key project stakeholders often have diverse project objectives and interests. Consolidation of ideas, negotiation and even compromise are often required to effectively direct, monitor and oversee the project. This interaction is often facilitated by the establishment of a high level integrated decision making forum. Such a function may already exist under a portfolio or programme management structure within a larger organization (see Section 2.3.2.3), or it may necessitate the establishment of a dedicated project board or other suitable structure to fulfil the following functions:

- Allow investors or investor groups and key stakeholders to participate in directing the project. Given the extended duration of a typical nuclear project, international experience has highlighted the importance of establishing good working relationships with all key stakeholders. The representation and sustainability of key project contractors and suppliers should also be considered.
- Establish key project objectives and decisions (see Section 4.1.1).
- Establish an effective governance framework to manage project approvals.
- Oversee the project at the highest level by ensuring that the necessary controls, monitoring and oversight are in place and effective to manage risk and compliance.

This high level entity is referred to in this guide as the project board. To be effective, the project board will require an established and agreed set of operating rules or terms of reference. Other legally binding agreements such as shareholding and/or partnership agreements may also be required. The project board may hold accountability as prescribed by any applicable national legislation and regulations, and may have specific responsibilities for nuclear safety. The review of these terms of reference or agreements may be necessary as negotiations with

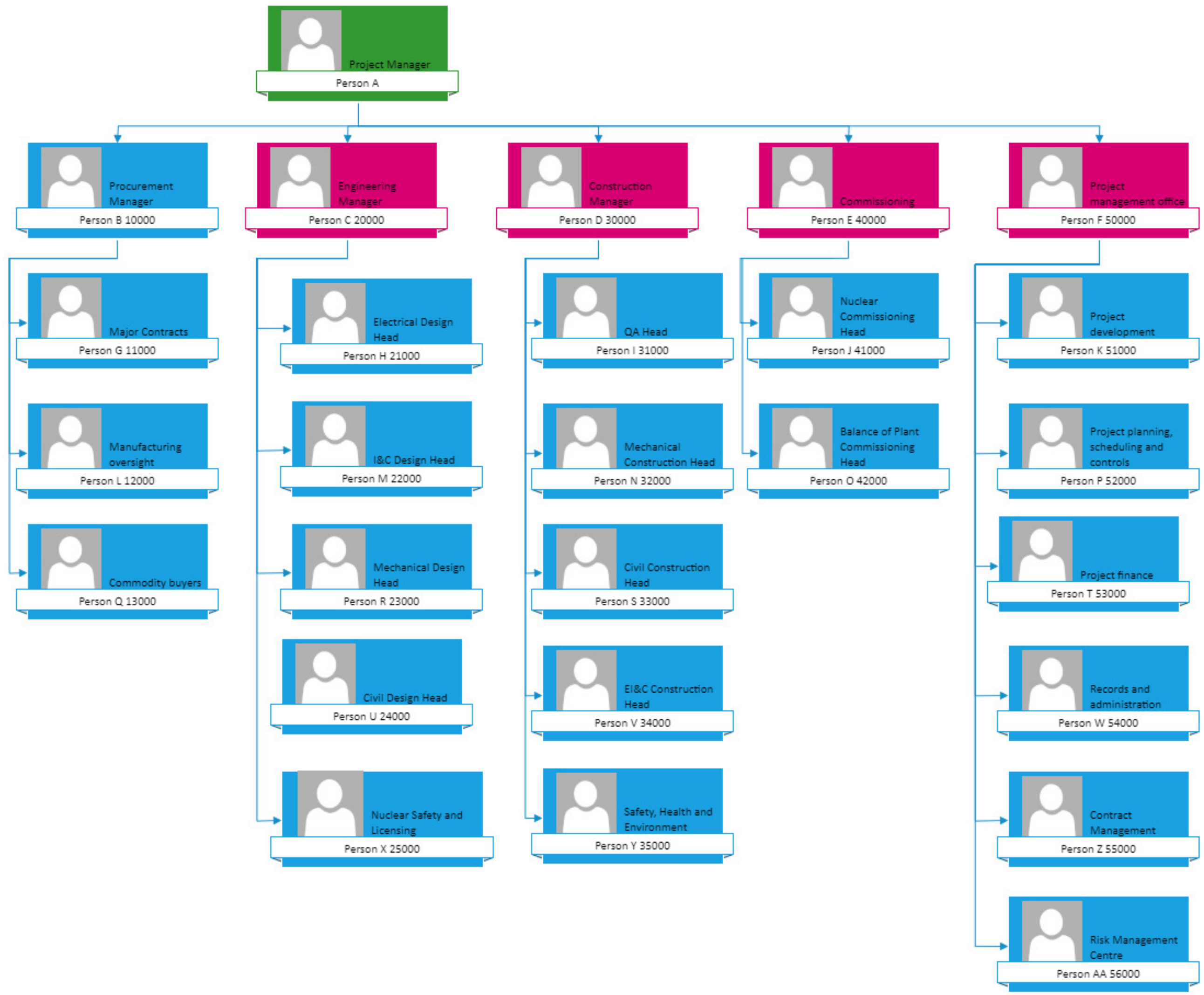

FIG. 23. Sample OBS.

key stakeholders' progress and the various investors are brought onto the project in line with the overall market implementation approach.

The project board may need to delegate some of its authorities, or at the very least establish advisory committees, to assist it in dispensing its various duties on the project. This will be discussed further in Appendix IV.

The failure to include key project stakeholders early on in the project life cycle can result in the project becoming misaligned from achieving objectives which are later proved to be necessary. This topic is further discussed in Stakeholder Involvement Throughout the Life Cycle of Nuclear Facilities, IAEA Nuclear Energy Series No. NG-T-1.4 [9].

Once the project board has been established it can begin to make decisions on the adoption and/or development of the various governance elements required for effective project management.

4.6.6. Appointing the project manager

A project manager or director is normally appointed by the project board as an executive authority and is responsible for directing and controlling the project on a day to day basis in line with the approved project plan, prescribed project controls and directives as issued by the board. The project manager (or director) remains accountable to the project board, which needs to implement appropriate monitoring and oversight measures. In some jurisdictions the project manager for critical nuclear projects such as a new build needs confirmatory approval from the regulatory body.

IAEA Safety Standards Series No. GS-G-3.5, para. 5.44 [40] states that the characteristics of a good project manager should include:

"(a) Understanding the requirements of the project and the results to be achieved;
(b) Understanding the technologies and resources necessary to manage the project;
(c) Ability to plan, organize, lead and control the project;
(d) Being a good and effective communicator who can ensure that the project team remains well informed of the expectations on it and the status of the project;
(e) Ability to deal with uncertainties and risks and to take good decisions in a timely manner;
(f) Ability to communicate and negotiate effectively with interested parties;
(g) Energy, enthusiasm, resolve and intellectual acuteness to deal with emerging issues."

Furthermore, to perform effectively, para. 5.45 states,

"the project manager and the team should have authority over all elements of the project, including:

(a) Making all necessary organizational, commercial and technical decisions;
(b) Specifying the organizational structure, functions, responsibilities and accountabilities of the team so as to achieve the goals of the project in accordance with the specified requirements;
(c) Selecting and managing all contractors in accordance with any limitations of the organization, such as financial authorizations;
(d) Controlling the funding, scheduling and quality of the project;
(e) Meeting statutory and other mandatory requirements;
(f) Meeting and possibly exceeding the requirements of those authorizing the project (sometimes referred to as the customer or project sponsor)."

4.6.7. Appointing the project core team

The project core team (sometimes referred to as the leadership team or senior management team) is faced with the challenge of sustaining good management practices over extended periods of time to achieve consistently high levels of quality within the project's economic constraints. Whether contracted by the owner or a within a larger owner's organization, this requires the team to be visible in establishing and maintaining an organizational culture that ultimately becomes embedded into daily work processes, practices and behaviours.

It is crucial to nominate a good core project team that then delivers the message of the organizational objectives and the relevant actions that are necessary to achieve them. One of the first actions for a project manager or director is thus to find a reliable core team. There is not a single right or wrong core team composition, but often positions are created for directors or senior managers responsible for legal matters; procurement and contracting; safety, security, safeguards and licensing; engineering; project planning and control; human resources and management oversight and quality. There also may be responsible persons for finance, public communication, special project areas (e.g. siting studies, grid studies, owner's scope in construction) and a deputy project director.

These core team members then work in close cooperation with the project manager to plan their areas of responsibility in a detailed manner. By this approach, all the parts of the management system will be delegated.

4.6.8. Acquire and develop staff

Beyond the project core team, individuals need to be recruited and trained in their specific project roles. Recruitment is guided by the overall national nuclear human resources plan, in case of a national programme for example, for the first NPP in the country or by the company programme as was discussed in Section 4.6.1. Specific workforce functions and competencies will need to be developed and evolved as a particular project progresses. For new build projects, the IAEA Competency Framework[9] can be referred to for the various competencies needed at each phase of a new NPP programme.

Once staff have been acquired, orientation and job-specific training is important. A systematic approach to training (SAT) for such activities is recommended. SAT is one of the most important tools that enable nuclear facilities to ensure the competence of their personnel. It provides a structured approach to ensure that any training provided is based on their actual needs and is properly evaluated to ensure its effectiveness. IAEA Nuclear Energy Series No. NG-G-2.1 [130] describes the SAT process. Training can be provided on the SAT approach, and a new SAT e-learning module[10] is available.

Note that plant modifications may also require a review of staff training needs and training delivery. This would ensure that operations, maintenance or engineering staff became fully familiar with any new technology being installed.

4.6.8.1. Project management competencies

Various organizations have investigated the specific competencies needed by project personnel in order to successfully manage projects. These are summarized in Table 3.

TABLE 3. SELECTED PROJECT MANAGEMENT COMPETENCY APPROACHES

Organization	PM competency approach	Reference
Project Management Institute (PMI)	Classifies competencies into three different competency dimensions: knowledge, personal and performance. Both the knowledge and performance competencies are organized around the nine project management knowledge areas. Personal competencies are broken up into six areas: achievement and action, helping and human service, impact and influence, managerial, cognitive and personal effectiveness. Certification is available for project, programme, portfolio management, risk or scheduling management professionals and others.	[7]
International Project Management Association (IPMA)	The IPMA competency baseline identifies 29 competence elements divided into categories of perspective, people and practice competences that are used by a project manager.	[138]

[9] See https://nucleus.iaea.org/competency-framework/

[10] See https://www.iaea.org/topics/infrastructure-development/e-learning-for-nuclear-newcomers

TABLE 3. SELECTED PROJECT MANAGEMENT COMPETENCY APPROACHES (cont.)

Organization	PM competency approach	Reference
Australian Institute of Project Management (AIPM)	National competency standards for project management (NCSPM) developed in consultation with the industry and under the auspices of the Australian National Training Authority. The PMBOK Guide is adopted as the knowledge base for the NCSPM and depicts the competencies around the PMI's nine knowledge areas. Certification available for practising project practitioners, project managers, senior project managers, project directors, portfolio executives and project management organizations.	[139]
The Engineering Advancement Association (ENAA) and the Project Management Association of Japan (PMAJ)	Three levels of certification are available in ascending order: project management specialist, project management registered and project management architect.	[140]
Association eCH (HERMES 5)	Two levels of certification are available — a foundation level and an advanced level with requalification every three years.	[141]

Behavioural competences are one area that is often overlooked. This includes aspects such as "situational leadership, tolerance of external events, tolerance of people's personalities, conflict resolution, commitment to the project and to the project team, staffing of project team, etc." [142]. Efforts to enhance these skills within an organization should be part of recruitment and training efforts.

4.6.8.2. Contracting and supplemental personnel

It is normally not feasible to maintain all of the necessary capability needed for a nuclear project within the owner/operator organization since certain expertise may only be necessary for short durations. For example, the important role of the nuclear licensee may necessitate the sharing of certain resources and expertise between the project and the owner/operator's organization (licensing is further discussed in Section 4.14).

Where expertise is only needed for short time, management of some duties by other specialist organizations is often considered. While such an arrangement has numerous benefits, the owner/operator will need to consider the management and long term sustainability of such relationships, as the owner/operator normally retains the associated accountability and risks over the facility's lifetime, including into decommissioning. The owner/operator thus needs to make an informed decision based on their unique circumstances as to which expertise is going to be maintained within its own organization versus those that will be contracted out. Of concern is how this expertise will be developed, maintained and evolve within the organization, understanding that there is a need for, as a minimum, an 'informed customer' role over the long term. IAEA Nuclear Energy Series No. NP-T-3.21 [3], Section 2.3, discusses the informed customer concept.

4.7. COMMUNICATIONS

Communications planning is the process of determining the information and communication needs of the project's stakeholders and interested parties: who will need what information, when they will need it, how they will need it, how it will be given to them and by whom.

4.7.1. Communications audience

Communications are needed both internally to the project and externally to project stakeholders and interested parties. The internal audience will be most interested in project status, progress and their specific activities. The external audience will be interested in overall project status and how the project might impact on them personally. Refer to Section 4.8 of this publication for more information on stakeholder and interested party management.

IAEA Safety Standards No. GSR Part 2, Requirement 5, para. 4.6, emphasizes the need to communicate with interested parties about radiation risks and unexpected events at nuclear facilities and have “an appropriate strategy for interaction with them” [24]. Moreover, nuclear projects have uniquely high levels of political and public interest and so have communications needs that typically go far beyond projects in the non-nuclear sector. In these challenging circumstances, one should also remember the vital role of communication to the project team.

4.7.2. Communication methods

Communication speed and clarity within a project can have a big influence on its success. Numerous stakeholders, both internal to and external to the project, need to be communicated with on a regular basis to ensure that they remain in alignment and are working efficiently. Communications can be both formal and informal, written or verbal, and be in the vertical (i.e. up or down the organizational structure) or horizontal (i.e. with peers) direction.

Communication can occur in many ways, with tactics or methods often employed including:

- Face to face communications;
- Email;
- Telephones or mobile devices;
- Internal or external publications (e.g. newsletters, direct mail, press releases, schedules);
- Intranet (internal) or internet (external) websites;
- Social media;
- Electronic document management systems;
- Video (via internet or broadcast television);
- Meetings (e.g. planning meetings, monthly progress meetings, lessons learned meetings, project execution update meetings, other team meetings as required);
- Displays;
- Tours, ‘open house’ days or other community events for the general public.

Communication speed and clarity can have a big influence on the success of a project. Regular contact between team members is necessary, and the use of electronic communications (including email, texting, instant messaging, social media, video and web conferencing, and other forms of electronic media) to communicate either formally or informally can assist. In some cases project team members may reside in different countries. For new nuclear builds, this is almost always the case. Such ‘virtual teams’ may need to accommodate differences in culture, working hours, time zones, local conditions and language. Communication barriers can additionally include those listed below [143]:

- Technology and connectivity issues;
- Difficulty reading visual cues;
- Leadership requirements;
- Team and individual accountability;
- Lack of engagement and trust;
- Lack of procedures for virtual teaming.

The CII has produced an implementation resource [144] that is designed to assist in understanding virtual teaming for dispersed project teams.

International projects may also have a need to communicate in multiple languages. Suppliers, project team members, construction staff and others may have varying degrees of fluency in the project’s primary working language. They therefore may benefit from targeted communication in their native language.

An online Nuclear Communicator’s Toolbox[11] is available to assist in communications efforts.

[11] See https://www.iaea.org/resources/nuclear-communicators-toolbox

4.7.3. Communications planning

A communications plan is thus seen as an essential part of project planning and is normally part of any project management/execution plan (Section 4.1.3).

Communication plans can be developed using a process similar to the following:

- Identify key programme stakeholders and interested parties;
- Assess the communications requirements of each;
- Review communications experience from previous similar projects;
- Review the project charter and risk register for risks and issues associated with communication management;
- Prepare communications plan(s) based on these requirements;
- Align differing needs to enhance the communications programme efficiency;
- Design, prepare and issue communications for specific stakeholders or groups of stakeholders, as required;
- Manage the communications programme and update the plan as needed and document lessons learned.

Developed plans would identify:

- The targets of communication;
- The frequency of communication;
- Tactics or formats to be used;
- How communications issues will be escalated and when;
- Where project communications related information will be stored and who can access it.

A formal communications matrix is a tool that can help document some of the above items. It helps document the project team's agreed method for communicating various aspects of the project, such as routine status, problem resolution, decisions, etc. Table 4 shows an example portion of a typical matrix that deals with project reporting.

Some external stakeholders, such as the regulatory body, often have their own communications stakeholders (e.g. members of the general public) and thus need to have their own communications plans. IAEA Safety Standards No. GSR Part 1 (Requirement 36) [23] and GSG-6 [145], for example, discuss communications and consultation with interested parties by regulatory bodies.

4.8. STAKEHOLDERS AND INTERESTED PARTIES

As was discussed in Section 2.3.1.1, all individuals and groups can impact on projects in positive or negative ways. Moreover, IAEA Safety Standards No. GSR Part 2, Requirement 5, indicates that stakeholder communication is important, stating that **"Senior management shall ensure that appropriate interaction with interested parties takes place"** [24].

Stakeholder groups and key individuals need to be identified and a strategy developed and implemented to engage them at the appropriate time. Specific communications activities should be planned (see Section 4.7) based on their specific needs. If not engaged early, such stakeholders may believe that their input was superficial or not valued and become opponents to the particular project. Interested parties can be internal to the project, internal to the owner/operator organization, external governmental, regulatory or non-regulatory bodies or others.

The PMI indicates that

> "stakeholder management is more than improving communications and requires more than managing a team. Stakeholder management is about creation and maintenance of relationships between the project team and stakeholders, with the aim to satisfy their respective needs and requirements within project boundaries" [7].

A project oversight board (as was described in Section 4.6.5) is one approach that can be used to encourage key stakeholder involvement and ensure stakeholders are regularly informed of the project and its associated risks.

IAEA Nuclear Energy Series No. NG-T-1.4 provides guidance on managing stakeholder involvement [9] and Nos NW-T-3.5 [146] and NW-T-2.5 [5], respectively, provide guidance on stakeholder involvement specifically for

TABLE 4. PORTION OF A COMMUNICATIONS MATRIX DEALING WITH PROJECT REPORTING

Stakeholders	Company management							Project management		Project team members		
Reports	Government	Board of directors	Executive management team	Nuclear oversight committee	President (CEO)	Chief financial officer (CFO)	Senior vice president	Project executive team	Project manager	Project function vice presidents	Project team directors	Project team function managers
Board update		X				X	X	X				
Consolidated programme status report							X	X				
Detailed programme reports							X	X		X		
Project reports							X	X	X	X		
Functional reports							X	X			X	X
Nuclear oversight report		X		X								
Major project status report (large projects)			X	X								
Corporate scorecard			X		X	X	X	X				
Funding analysis and cost variance reports									X	X	X	X
Major contract reports							X	X	X	X		
Financial reports						X	X	X				

environmental remediation and decommissioning projects. INSAG-20 [147] discusses stakeholder involvement in nuclear issues and some appropriate procedures for engagement.

4.9. RISK

Project risk management requires constant communication, education and effort to build awareness and provide value by mitigating risks before they can negatively impact on a project. It is a continuous and iterative process that includes updating project related risk documents and associated risk management plans.

Project personnel may not naturally think and communicate in terms of risk, and so training in risk concepts may require project resources to ensure that perceptions and expectations are clear.

4.9.1. Risk management framework

A typical risk management framework is described in IAEA-TECDOC-1209 [148]. Shown in Fig. 24, it consists of steps to identify risks, identify techniques or strategies to manage those risks, implement those techniques and then monitor their effectiveness.

ISO 31000:2018 [149], Risk Management – Principles and guidance, provides principles, a framework and a process for managing risk. The associated IEC 31010:2009 [150] is a supporting standard for ISO 31000:2018 [149] and provides guidance on selection and application of systematic techniques for risk assessment. Major projects should have defined risk management structures that specify the chain of authority, communication structure and management framework with which risk management and decision processes will occur. For risk management to be effective, it should be an integral part of a project's management system (e.g. standards, procedures, directives, policies and other management documentation).

Risks can be identified using a number of techniques. PRINCE2 [110] identifies the following as possible methods:

- Review lessons (review of previous projects or project stages to identify threats and opportunities);
- Risk checklists (in-house lists of risks that are used to simulate thinking);
- Risk prompt lists (publicly available lists of risks that are relevant to a wide range of projects);
- Brainstorming (workshops of knowledgeable individuals used to identify risks or understand stakeholder views of particular risks);
- Risk breakdown structure (similar to a project's CBS or WBS, this is a hierarchical decomposition of a project used to illustrate potential sources of risk in different categories, such as by project phase or by types of risk (e.g. political, economic, technological, sociological, legal)).

Detailed risk management frameworks and recommendations include those published by the PMI [151], AXELOS [34, 110, 152], the CII [153–155], the ECI [156] and HM Treasury (United Kingdom) [157].

FIG. 24. Risk management framework from IAEA-TECDOC-1209 [148].

4.9.2. Evaluating and documenting risks

Risks can be evaluated using expert judgement against their probability of occurrence and their consequences, either on a qualitative or semi-quantitative basis. Quantitative analysis of risks (typically to evaluate expected cost impacts or a range of impacts) is discussed in Refs [112, 123–125, 154, 158]. Expert assessments can be assisted by the use of independent assessments or structured tools such as the CII's PDRI, which were discussed in Section 3.5.

Figure 25 shows a typical qualitative risk ranking chart that provides a colour rating (red, amber, yellow or green) for each identified risk. In the chart for probabilities/likelihoods, 'almost certain' means the risk is expected to occur in most circumstances, 'likely' means it would probably occur in most circumstances, 'possible' means it could occur at some time, 'unlikely' means it is not expected to occur and 'rare' means it may occur only in exceptional circumstances. For consequences, 'extreme' means it has significant impact on the achievement of goals/objectives, 'high' or 'moderate' imply high or moderate impacts, 'low' implies impact only on a limited aspect of an activity and 'negligible' implies that the consequences are dealt with by routine operations.

A typical deliverable of risk management processes is a regularly updated risk management plan and 'risk register' (or 'risk log'). A sample risk register is available in the IAEA's online Nuclear Contracting Toolkit[12]. Commercial or customized software products are available that specialize in recording and analysing risks at a project or corporate level. Such products are designed to inform all stakeholders about how and by whom the identified risks will be managed (accepted, avoided, mitigated/enhanced or transferred), what residual risk remains following mitigation actions and what monitoring will be done. Such plans can be made mandatory as part of project funding steps and can also be done routinely as part of regular project or organizational risk reviews. Some organizations also assess opportunities (positive events) as part of their risk management framework, which represents good practice.

Schedule risk assessment using Monte Carlo techniques was discussed in Section 4.3.4.

IAEA Nuclear Energy Series No. NP-T-2.7 [2], Section 2.6, discusses issues surrounding the risks related to construction contracts and NP-T-3.21 [3] discusses risk management in the context of procurement and contracting.

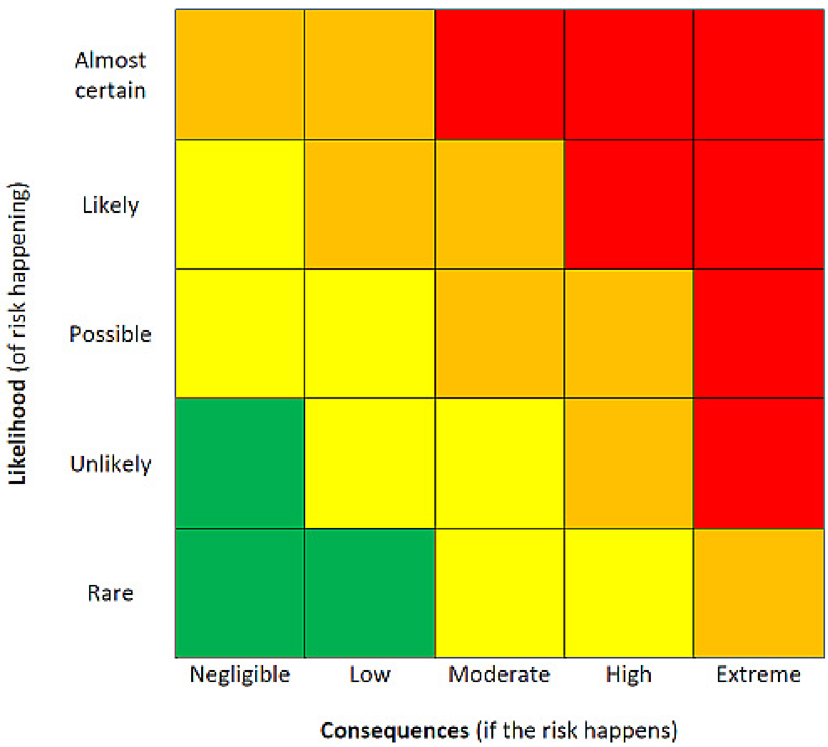

FIG. 25. Typical risk ranking chart [3].

[12] See https://www-legacy.iaea.org/NuclearPower/Infrastructure/NuclearContractingToolkit/manage-contract/index.html

NG-T-4.6 [127] discusses financial risk management for new nuclear projects. An IAEA project entitled 'DRiMa' [159] addresses strategic and operational risk management in decommissioning. The World Nuclear Association has produced a report [160] that discusses typical risks and risk allocation for nuclear projects during their various stages and how to control and monitor those risks.

4.9.3. Design maturity risk

International experience has shown that having high degree of design maturity can be useful in minimizing project risk, even for small projects. While owner/operator needs and risk tolerances may differ in this regard, design maturity remains a key topic. Design maturity for a new NPP can be assessed through aspects such as the existence of reference plants or system under construction to the same design; the existence of a reference plant or system already in operation; the extent of design modifications recommended to the identified reference plant; the licensing of the design in other countries; relicensing reviews performed by a nuclear regulator; etc. Consideration should also be given to the experience of the designer, manufacturers and constructors in managing a nuclear project together. Potential owners should be wary of and validate any unsubstantiated vendor claims in this area.

The level of design maturity of a first of a kind NPP is difficult to establish and as such the owner/operator needs to build significant control and contingencies into the project planning to address possible risks. It is important to bear in mind that although an NPP unit may have been built and commissioned elsewhere, exporting it to a new country with a different supply chain, different construction trades and potentially different codes and standards always represents certain first of a kind risks.

For smaller projects, design maturity of the proposed solution also needs to be assessed. Innovative 'first of a kind' solutions may need additional factory testing or phased site implementation to minimize safety or production risks to the nuclear facility.

4.9.4. Risk allocation

Risk allocation should be done in a compromising and educated manner, recognizing the unique circumstances of each specific project. Some owners mistakenly believe that they can through the contracting process transfer all project risk to the vendor community. The primary vendor might then in turn push risk to its lower tier sub-suppliers. As a consequence, parties with the least amount of control and influence over many of the risk producing factors and decisions can often carry the majority of the risk burden. This usually ends up costing the owner financially, since vendors will add exorbitant risk premiums to their bids for the work in question or even refuse to bid on the work entirely.

Ultimately the project risk rests with the owner, and so the owner needs to actively manage the various risks present with the project, and make conscious decisions regarding the advisability and practicality of which risks to attempt to transfer to other project participants.

The CII has developed a 'Two-Party Risk Assessment and Allocation Model' [161] that is designed to identify, assess and allocate risk before project execution so that risk management efforts during project performance are minimized.

4.9.5. Portfolio and programme risk

Project portfolios and programmes (discussed in Section 2.3.2.3) also need risk management processes applied. Owners need to maintain a portfolio or programme-level risk analysis of all ongoing significant projects in order to monitor their status, risks and vulnerabilities with respect to schedule, cost, scope and performance and to control the total organizational risk. This implies that a current risk assessment of all ongoing projects in the portfolio is available that includes information related to individual project vulnerabilities. Processes to roll up individual project reports for senior management review are a typical part of such activities.

A method to manage and compare individual projects within a portfolio can be useful to focus attention on those projects that are in the most difficulty and would benefit from special attention. Figure 26 illustrates a project health index metric that was in use at a nuclear operating organization for this purpose.

Project Health Criteria	+1	+2
Milestone Adherence	Missed last milestone	Missed last 2 milestones
CPI Projected Cost Impact	> $1M	> $2M
SPI Projected Schedule Growth	> 3 Months	> 6 months
Current Year Cash Flow Variance	>+15%/-10%	>+30%/-15%
Project Manager Forecast	Forecast to use contingency	Forecast to use more than contingency
Scope Growth	> $1M	> $2M

Index	0-1	2-3	4-5	6-12
Project Health				

FIG. 26. Project health index calculation in use at a nuclear operating organization.

4.9.6. Internal controls

An effective system of internal controls throughout a project can help to bring a risk to management's attention in time for management to take corrective action and to minimize the potential for risk events. Internal controls include processes for review, approval and control of financial transactions and contracts (including separation of duties), financial audits, self-assessments, procedures for disaster recovery, security procedures, a code of business conduct, processes for recording and reporting of risks to senior management, and others.

4.9.7. Other risk references

Section 4.3.3 of this publication discusses the impact of late deliverables on a project, which is a key project risk.

The CII's Integrated Project Risk Assessment (IPRA) tool [153] can be used to assess the degree of risk on any project, but it is especially useful for developers of complex projects in unfamiliar venues or localities, which can be typical of international nuclear projects.

Securing project insurance is a risk mitigation tool that is discussed in IAEA Nuclear Energy Series No. NG-T-4.1 [46]. Other references related to risk management for projects include Refs [112, 151, 152, 154, 156, 162–166].

4.10. PROCUREMENT

Procurement and management of the supply chain are key activities for nuclear projects. If not properly managed they can by themselves lead to project failure. They also contribute strongly to nuclear safety, with IAEA Safety Standards No. GSR Part 2, Requirement 11, indicating that organizations **"shall put in place arrangements with vendors, contractors and suppliers for specifying, monitoring and managing the supply to it of items, products and services that may influence safety"** [24].

Nuclear procurement processes are extensively covered in the IAEA's Nuclear Energy Series No. NP-T-3.21 [3] and an online Nuclear Contracting Toolkit[13] is available for nuclear projects. Management of supply chain participants, including service providers, is of particular importance. This includes vendor selection and oversight, management systems, inspections and testing, having an informed customer role, fairness and ethics issues, contract administration and other functions.

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[13] See https://www-legacy.iaea.org/NuclearPower/Infrastructure/NuclearContractingToolkit/manage-contract/index.html

Audit rights for the owner to validate cost reporting, schedule updates and physical progress are of particular importance and need to be well documented in requests for proposals and bid invitation specifications (BISs).

IAEA Nuclear Energy Series No. NP-T-2.7 [2], Section 2.4, discusses issues surrounding the management of construction contracts. Some lessons learned include the need to pay attention to supplier quality programme compliance and records, materials certification and traceability, equipment qualification for nuclear applications, proper certification of inspections and final tests, and schedule adherence.

4.11. HEALTH, SAFETY AND ENVIRONMENT

4.11.1. Industrial safety and health

Research has shown that construction projects with good industrial safety and health records are more successful in terms of cost and schedule [167, 168] and specific reviews of industrial safety practices at NPPs have been a part of IAEA Operational Safety Reviews (OSARTs) [53, 169] for decades. It is crucial for a nuclear project to convince the interested parties that striving for excellence in the area of industrial safety and health helps to demonstrate a culture for safety in all areas. A concept of ‘AHARA’ or ‘as high as reasonably achievable’ in the area of industrial safety and health is a good starting point.

IAEA Nuclear Energy Series No. NP-T-3.3 [43] provides examples of good practices related to industrial safety and health for nuclear facilities including construction projects. The International Labour Organization’s (ILO) guidelines on occupational safety and health (OSH) management [170] are incorporated into that publication. Good practices that are mentioned include:

- Ensuring project owners place a strong emphasis on OSH, show leadership in this area and incorporate excellent OSH practices into the management system;
- Ensuring contractors and subcontractors are evaluated on safety performance, are indoctrinated and trained in site safety practices and hazards and are incorporated into other project OSH activities;
- Ensure worker participation in OSH programmes is sought and encouraged;
- Ensure constructability reviews are performed on preliminary designs that include reviews of OSH concerns;
- Ensure periods of high activity and/or risk receive special planning and attention.

4.11.2. Environmental protection

Construction projects in the nuclear sector require additional measures to protect the natural environment. A sound environmental management plan coupled with strict field adherence to good environmental practices can go a long way in maintaining stakeholder support for a project. Many projects require the development of a specific environmental protection plan.

Specific requirements for environmental protection can come from international, national, regional and local standards and regulations or from the project owner itself. Establishing organization commitments, mitigations and control measures should take place as part of project planning. Some aspects to be considered can include:

- Recycling and waste management;
- Hazardous substance and waste handling;
- Emissions during construction;
- Environmental clean-up efforts;
- Protection of historical/archaeological sites;
- Protection of site soil, vegetation and wildlife;
- Noise monitoring and control;
- Site drainage and storm water management;
- Dust control;
- Light pollution/trespass affecting nearby communities;
- Traffic management;

- Vector control (organisms that transmit diseases such as mosquitoes, flies, rodents, cockroaches and fleas) during construction activities;
- Permits needed;
- Training and communication efforts needed.

4.12. LESSONS LEARNED AND OPERATING EXPERIENCE

Section 6 of IAEA Safety Standards Nos GSR Part 2 [24], GS-G-3.1 [36] and GS-G-3.5 [40] all speak to the importance of lessons learned in improving the management system related to nuclear activities such as projects. Project performance is enhanced by the use of lessons learned and experience from previous projects and from the current project as it proceeds. Lessons can include information about management system processes, equipment, techniques, tools or procedures that either made a contribution to the project's achievements or were a source of problems. Previous projects from both nuclear and non-nuclear industries can provide lessons, as can both successful and unsuccessful projects. Similar projects can be benchmarked to determine what went well, what went poorly and what lessons can be applied to the new project.

Where a similar project to the one being planned is in progress elsewhere in the world, a good practice for the new project organization is to station an individual at the similar project site. This individual, through regular interaction with the project team members, can more readily capture and document lessons learned for transmission to the new project organization.

Industry events and project OPEX can be captured from various sources such as the IAEA IRS database [171], WANO/INPO databases, OECD-NEA reports (e.g. Ref. [172]), World Nuclear Association reports (e.g. Ref. [160]) CANDU Owners Group OPEX sharing mechanisms and others. Vendor specific OPEX can be obtained from shared auditing groups such as NUPIC and CANPAC. Project specific or phase specific closeout reports, oversight reports and audits can also provide insights and lessons learned. The CII provides guidance on developing lessons learned programmes for construction projects [173] and the AACE [35] emphasizes the importance of capturing project historical information in an accessible database for future strategic planning. Section 5 of IAEA Nuclear Energy Series No. NP-T-2.7 [2] provides some lessons learned related to NPP construction projects, IAEA-TECDOC-1653 [174] provides guidance on setting up an OPEX programme, IAEA-TECDOC-1390 [49] provides some previous NPP construction experience and the Nuclear Contracting Toolkit[14] provides a lessons learned sources guide and a template for a post-project review.

Project organizations typically establish specific individuals and methods to obtain, screen, review and disseminate OPEX lessons throughout the project organization, including to applicable vendors and subcontractors during the conduct of the project. Project team members are also expected to maintain regular contact with their counterparts in similar projects to share common issues and experience. Formal peer teams can be a way to facilitate this interaction. Any lessons learned should be shared with the broader nuclear industry to help improve its future performance.

At project closure, GS-G-3.5 [40] para. 5.61 recommends that projects should be reviewed against their original intent:

"For example:

(a) Did the project achieve its objectives?
(b) Did it realize the expected benefits claimed for it in the original proposal?
(c) Did it operate within its scope?
(d) Did the products or results of the project meet the relevant criteria?
(e) Was the project completed within the schedule outlined in the project plan?
(f) Was the project completed within the budget?
(g) Has the project been adequately documented and have the necessary records been generated, maintained and handed over, as necessary?"

[14] See https://www-legacy.iaea.org/NuclearPower/Infrastructure/NuclearContractingToolkit/manage-contract/index.html

4.13. RADIATION DOSE AND RADIOACTIVE WASTE MANAGEMENT

It is a fundamental safety principle (Principle 6 in the IAEA's Fundamental Safety Principles) that risks to individuals are to be limited, that is, that **"measures for controlling radiation risks must ensure that no individual bears an unacceptable risk of harm"** [10]. Dose management or 'ALARA' (as low as reasonably achievable) management is the managing of the radiation risk that is inherent in nuclear facilities, to eliminate unplanned radiation exposures and to keep any radiation dose to workers ALARA.

Dose management typically involves reviewing the facility design and taking appropriate engineering control measures to reduce radiation doses and radioactive waste. A radiation protection organization is set up prior to the project encountering radiation risks. An ALARA plan is produced, which includes estimating doses to be received by workers based on the facility design and work activities needed. Once radioactive work commences, radiation levels are measured and monitored as appropriate and work planning mechanisms are implemented to ensure doses to workers are kept ALARA. ALARA tools and equipment can include shielding, personal protective clothing and equipment, robotics, decontamination, training and mock up facilities (to minimize time in a radiation area), and others.

Radioactive waste generated during the course of the project also needs to be managed, as do national plans for the eventual storage and disposal of low, medium and high level radioactive waste.

Numerous IAEA publications cover the radiation protection of workers and control of radiation sources. These include IAEA Safety Standards Series Nos GSR Part 3 [25], GS-G-1.5 [175], NS-G-1.13 [176], NS-G-2.7 [177], NS-G-4.6 [178], RS-G-1.1 [179], RS-G-1.2 [180], RS-G-1.3 [181], RS-G-1.4 [182], RS-G-1.7 [183], RS-G-1.8 [184], SSG-11 [185], Safety Reports Series No. 84 [186] and others.

IAEA Safety Standards Series Nos GSR Part 5 [27], SSR-5 [187], SSG-40 [188], GS-G-3.3 [38], GS-G-3.4 [39], NS-G-2.7 [177] and NS-G-4.6 [178] cover various aspects of radioactive waste management.

4.14. LICENSING (NUCLEAR, ENVIRONMENTAL AND OTHER)

Nuclear facilities have licensing and regulatory requirements that vary by country. The licensing of such facilities is essentially a 'project within a project', since different organizations are typically involved and the owner/operator, as the facility licensee, is limited in the extent to which it can delegate licensing activities to the facility vendor or other third parties.

It is important for the owner/operator to thoroughly understand and embed all licensing requirements within the project framework. This allows them to be applied correctly and transmitted as necessary to the facility designers and to suppliers.

Licensing efforts are necessarywith the nuclear facility site, the specific design to be built (including its safety assessment), its environmental impact and other non-nuclear codes and standards that might apply. The duties of the licensee change significantly as the project enters different phases. Careful planning is needed to ensure that the required level of competency is available to manage the role of licensee throughout the facility's life cycle.

It is good practice for the owner/operator to develop a thorough understanding of the necessary licensing steps and associated regulations and ensure that they are well addressed within the management framework of the project. Given the dominant role that the licensing process takes within the management of the project, it is important that the owner/operator secures as much certainty on the licensing process as possible. This certainty can often be enhanced by:

- Supporting the various regulators (nuclear and non-nuclear) with training and technical information where possible to help ensure that the national regulations are mature, with little or no ambiguity, before they are implemented within the project.
- Ensuring that the national regulations and applicable international treaty obligations are well understood.
- Ensuring that formal arrangements with the regulators are in place to effectively manage all licensing activities and that these are supported by adequate planning and resources.
- Considering regulatory knowledge from current global manufacturing and construction projects when establishing requirements and specifications to reduce the risk of mid-project changes to the national regulations.

- Ensuring that the need to comply with the necessary legislated and regulatory requirements is specified within the various project supply agreements.
- Ensuring that all licensed activities are robustly considered, planned and executed within the bounds of the regulations at all times.
- Facilitating the regulatory process where possible via the use of specialized independent review and 'third party' oversight organizations during the planning and execution of licensed activities. Such functions can act to increase nuclear safety awareness as well as reduce the oversight burden placed on the regulator.

As licensing is a central concern for new build projects, Sections 6.3.6 and 6.4.1.4 of this publication discuss it in various phases of a new NPP project. The following subsections discuss some specific aspects of nuclear and non-nuclear licensing.

4.14.1. Nuclear licensing

IAEA Safety Guide No. SSG-12 [189] covers the licensing process for nuclear installations and INSAG-26 [190] discusses the licensing of a country's first NPP. Licensing management for NPP projects is further discussed in Section 2.5 of IAEA Nuclear Energy Series No. NP-T-2.7 [2].

The detailed nuclear regulatory requirements applicable to a project are country specific; however, some typical licensing activities are illustrated in Fig. 27. This figure is based on SSG-16 [32] and depicts the long time scale of an NPP project in a two-step nuclear licensing model (i.e. with separate construction and operating licence steps). Other models with one combined licence step exist, for example in the United States of America [191], and separate site licence or design certification processes may also exist.

Licensing is the responsibility of the owner/operator, who will be supported by the applicable facility vendor. Typically, the owner/operator will need to demonstrate the fulfilment of the following key requirements in different nuclear facility life cycle phases:

- Establish that the selected site will be suitable to support the safe, secure and reliable operation of the facility without presenting any unnecessary challenges (activities shaded in green in Fig. 27). This activity is mainly conducted through the execution of site evaluation studies. In the event that national regulation permits such

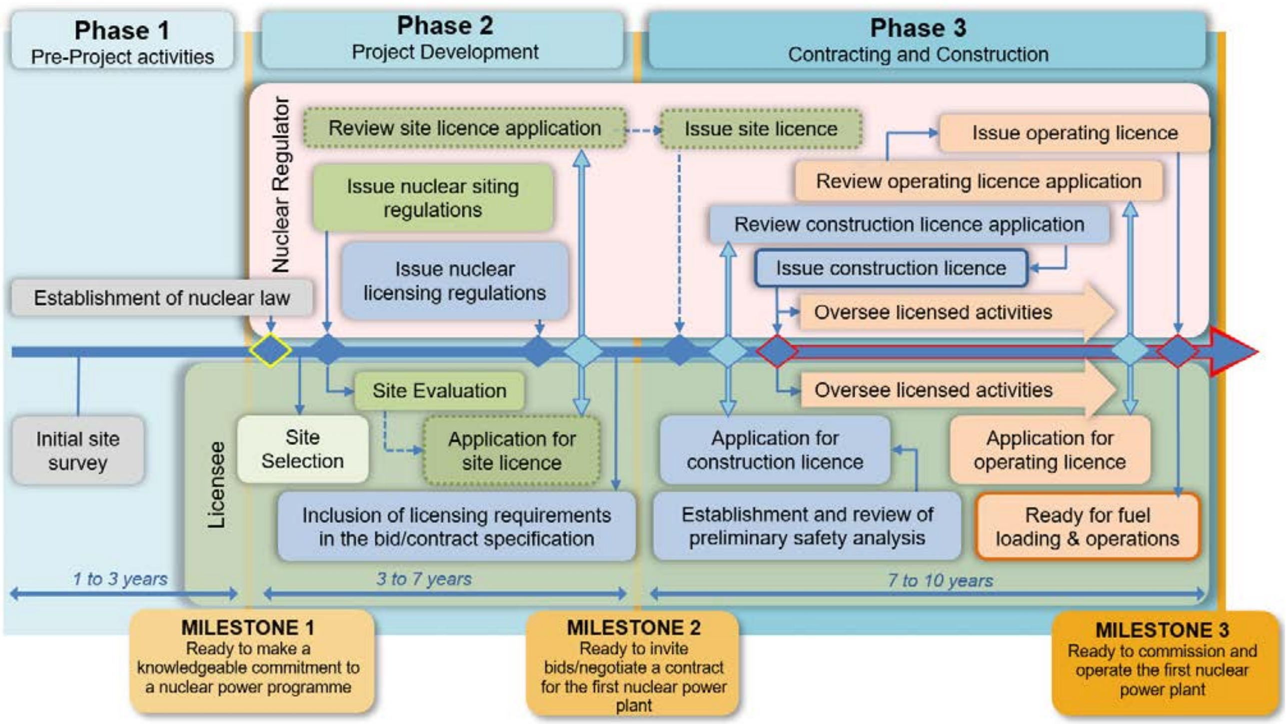

FIG. 27. A typical national nuclear licensing process and responsibilities with two licensing steps.

an approach, a site licence may be applied for through the regulator. Failing this, the licensee will need to apply for a combined siting and design approval once a particular design has been selected, reviewed and found to be acceptable by the licensee.

- Establish that once built the selected design and specifications for the manufacturing, construction, installation and commissioning activities will produce a facility that can be operated, maintained and decommissioned in a safe, secure and reliable manner (activities shaded in blue in Fig. 27). In some countries the nuclear regulator facilitates a separate process for the technology vendor to obtain a design approval or certificate prior to being selected by any particular licensee. As this often requires the dedication of large regulatory resources prior to the certainty of construction it is not common practice for a country new to nuclear technology.
- Ensure, via the establishment of an appropriate oversight, surveillance and assessment regime, that all tasks during manufacturing, construction, installation and commissioning that could have an effect on nuclear safety are conducted in strict accordance with the agreed design and relevant specifications (activities shaded in orange in Fig. 27). This will ensure that the as-built conditions do not deviate from those specified in the agreed design.
- Ensure that all operating, maintenance and modification activities occur in accordance with the requirements of the operating licence and that the facility remains within the licensed design parameters after any changes.
- Ensure that adequate provisions are made for the safe and secure disposal of low and intermediate level nuclear waste and spent nuclear fuel, as well as for the decommissioning of the plant, and that these activities are conducted in accordance with the licensing requirements when implemented.

Each step of the licensing process may be divided into several stages that may be merged or combined as appropriate to facilitate the regulatory process. Combining authorizations or licences (e.g. for construction and operation), as done in some countries, may also decrease licensing risk, but at the same time the requirements for design completeness may be greater. Time schedules for NPP licensing processes are difficult to establish and to compare.

An independent nuclear regulatory body is necessary for the nuclear licensing process. In a newcomer country, the regulatory body may need to be newly established in conjunction with the nuclear project. In such a case, regulatory body staff recruitment, training and development and the establishment of a national system of nuclear regulation will also be necessary. Since there can be no nuclear licence provided in the absence of a regulatory body, progress in its establishment needs to be tracked and managed as part of the project activities. Even established countries will have needs in this area, since a large new nuclear project may put staffing pressures on an existing regulator.

4.14.2. Environmental and other non-nuclear licences or regulations

Non-nuclear related national legislation and regulations will normally lead to the need to address non-nuclear legal and regulatory requirements. An environmental impact assessment and a municipal building permit are typical examples.

For such legislation and regulations, a good practice early on is to identify the potential regulatory organizations that may impact on the facility. This can include the agencies responsible for waterways, environmental emissions, wildlife protection, building, electrical or plumbing codes, occupational health and safety, national standards organizations, pressure boundary practices, trades qualifications, labour laws, security, emergency response and others. The project would then prepare a list of potential laws and regulations that might be impactful and develop a strategy to work with the applicable regulators to address any concerns or contradictions. In some cases existing regulations may need to be modified or new laws or regulations passed.

IAEA Nuclear Energy Series No. NG-T-3.11 [192] covers the environmental assessment process specific to new nuclear power programmes.

4.15. EMERGENCY PLANNING AND RESPONSE (EPR)

Nuclear facilities need to be integrated into a country’s system of local, regional, national and international EPR mechanisms. Both radiological and conventional (non-nuclear) emergency planning need to be addressed as well as on-site and off-site (e.g. transportation related) incidents. Many of the activities in this area (such as specifying the particular response organizations, establishing regulations and communications mechanisms, etc.) are governmental responsibilities; however, lack of progress in this area can impact on a nuclear project. As such, the project organization needs to support and track progress in this area, and take necessary steps to integrate the new project into established EPR mechanisms.

IAEA Safety Standards related to emergency response include GSR Part 7 [28], GS-G-2.1 [193] and GSG-2 [194]. Publications in the IAEA's Emergency Preparedness and Response Series such as Refs [195–204] can be useful for Member States in setting up their radiological incident response protocols.

4.16. SECURITY AND SAFEGUARDS

Nuclear facilities are unique in terms of security and safeguards requirements. These requirements will impact on and will need to be reflected in the design of the facility.

Strict adherence to security and safeguards measures is necessary once nuclear material is brought on-site, usually part way through the construction phase. Planning for such a time is necessary in the early project stages. Systems, equipment and personnel are all required to be in place to allow for the nuclear material delivery, and methods to account for all nuclear material need to be in place. The IAEA Nuclear Security Series of publications, notably No. 13 [205], covers physical protection aspects. Security for NPP construction projects is further discussed in section 2.8 of IAEA Nuclear Energy Series No. NP-T-2.7 [2]. Incorporating safeguards by design for new nuclear facilities is covered by IAEA Nuclear Energy Series Nos NP-T-2.8 and NP-T-2.9 [206, 207] as well as NF-T-4.7 [208].

On a national level, a nuclear security regulator may need to be established if one does not exist already. Similar to the nuclear regulator that was discussed in Section 4.14, a nuclear security regulator will have staffing, training and development needs and a system of national regulation may need to be established that requires project attention and tracking. The nuclear security regulator will need to define the plant's design basis threat and its nuclear security requirements, have programmes to manage sensitive information and to promote a security culture, and develop competencies necessary to approve nuclear site security plans and inspect facilities. Activities in this area will need to be complete prior to a contract being signed for the facility.

In the safeguards area, national agreements for cooperation with the IAEA will need to be established well in advance of nuclear material delivery. Models for such agreements and protocols are available [209, 210] and various safeguards implementation practices guides are available to address topics such as the provision of information to the IAEA (SVS-33 [211]) and the documentation of lessons learned (SVS-31 [212]). A 'State or Regional Authority with responsibility for safeguards' may need to be established at the national (or regional) level to ensure and facilitate the implementation of safeguards in the State or States of a region. In addition to its safeguards functions, the relevant authority (if established within a broader nuclear authority) may have additional responsibilities "associated with nuclear safety, security, radiation protection and export/import controls" [213].

5. DEVELOPING AND IMPLEMENTING A MANAGEMENT SYSTEM FOR A PROJECT AND IMPLEMENTING BEST PRACTICES

5.1. ESTABLISHING A PROCESS BASED PROJECT MANAGEMENT SYSTEM

5.1.1. Background

Managing a large project presents a real challenge, as project complexity quickly escalates once vendors and support organizations are contracted. These organizations will each tend to advocate for their own ways of managing things, yet they all need to be aligned and coordinated. Global, multi-tier supply chains can make managing manufacturing and construction difficult.

The owner/operator, as the project client, ensures that a project management system is planned and in place at an early stage. The project management system needs to be fully integrated with the management system of the company. In other words, the project management system is one of the components of the overall organization's management system and can utilize, benefit from and adapt as necessary the organization's pre-established corporate processes, whenever those processes are available.

IAEA Safety Standards No. GSR Part 2 [24] speaks to the importance of developing a management system, stating in its Requirement 10 that **"Processes and activities shall be developed and shall be effectively managed to achieve the organization's goals without compromising safety."** Moreover, it indicates in para. 4.28 that processes "shall be documented and the necessary supporting documentation shall be maintained".

The following approaches need to be considered when establishing the framework for an effective management system:

- **Establishing a process based approach to management**: When structuring an overall approach to the management system, it is useful to identify the various processes and their relative levels of importance to the project organization.
- **Establishing the project organization and its interfaces**: This management system needs to encompass interfaces with all organizations involved (e.g. through contracts) in the project and define the responsibilities for all project activities. The exact interfaces, the exchanged information and the methods of exchange all need to be defined, either in the contracts or in lower level project procedures.
- **Employing a graded approach to the management system**: The rigour applied to different project activities needs to be graded, i.e. oversight is commensurate with the activity's importance to safety, reliability, economy, etc. It is not possible to strictly control everything.

Similarly, the project information, records and KM have to be ensured, as discussed in Section 4.1.8.

A management system for a project is a structured, integrated and hierarchical living framework for all project policies, processes, procedures and instructions. The management system normally specifies the processes required to implement project activities, as well as conveying the necessary responsibilities and authorities. It needs to be regularly updated based on decisions made at project decision gates.

A generic example of an integrated management system for projects is illustrated in Fig. 28. This consists of the following components (potentially as part of an overall system for managing corporate organization structures, portfolios and programmes):

- An integrated project management system;
- A project management plan specific to the given project (see Section 4.1.3);
- Project manuals that describe standards for performing specific activities (e.g. a project management manual, licensing management manual and special manuals, such as for preparing a business case for approval to proceed);
- Systems for managing project knowledge, information and records (see Section 4.1.8).

Note that for newcomer country NPP development projects, during Phase 1 the management system would be that employed by the NEPIO for planning and managing its activities related to setting up the national nuclear programme, while in Milestone phases 2 and 3 separate (but integrated) management systems would run in parallel for the various programme and project participants (NEPIO, owner/operator, NPP vendor, suppliers, regulator, etc.).

All these components may include processes, procedures and instructions. Use of processes to depict and break repeated activities into manageable sequential parts is a central concept in modern management systems such as those described in GSR Part 2 [24], NG-T-1.3 [44] or ISO 9001:2015 [214].

A process focus is needed to ensure that the various project functions are efficiently integrated in the manner necessary to manage a nuclear project. Extensive guidance is offered by the IAEA with respect to the establishment of such management systems. IAEA Nuclear Energy Series No. NG-T-1.3 [44] in particular should be referred to for more detail on the establishment of a process based approach.

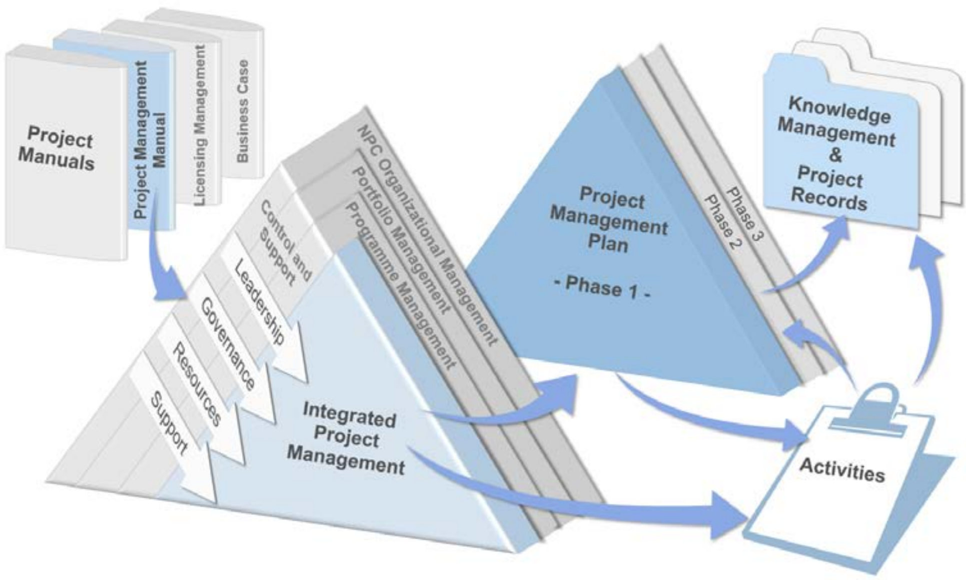

FIG. 28. Sample project management system elements.

Process based management offers a documented, traceable approach that can be used to demonstrate consistency in meeting requirements and delivering the intended results in an environment conducive to continuous improvement.

All processes related to a project need to be developed and documented. Appendix I of IAEA Nuclear Energy Series No. NG-T-1.3 [44] indicates the elements that need to be included within such a management system structure (utilizing the PDCA model; see Appendix II):

Organizations that are new to the nuclear sector will need to pay special attention to the incorporation of safety and security culture programmes into their management system. An awareness of the importance of these topics will need to be put in place throughout the project organization, including key contractors and suppliers.

5.1.2. Establishing a process hierarchy

A process hierarchy needs to be established within which the individual management system processes will reside. Figure 29 shows a sample governance hierarchy as identified in NG-T-1.3 [44]. Figure 30 illustrates an actual implementation of an management system that is used by a large nuclear operating organization.

Organizations building nuclear projects will often inherit a pre-established governance framework and a set of high level policies from the parent organization. In other cases, such as a country's first nuclear project with its owner/operator organization, these may need to be originated from within the project organization or the NEPIO. A dedicated team with senior management support would normally be required to develop such a new management system.

5.1.3. Developing project processes

Once the management system's hierarchy has been established, individual processes can be identified and developed. Ensuring that any processes established by the owner/operator are aligned with those of the project vendor, main contractor and subcontractors is of special importance. Ideally, the entire project team will be working to a single set of procedures.

Dividing processes into management, core and support process categories (Fig. 31) may assist to guide the structure and focus of the project management system. Appendix III of NG-T-1.3 [44] provides a methodology as to how to distinguish between the three types. Decision making related processes for an organization are called management processes, processes that establish an end product or service for an external customer or that have the greatest impact on performance are usually referred to as core processes, while processes delivering to an internal customer are often called support processes. These are described in more detail in the subsections that follow.

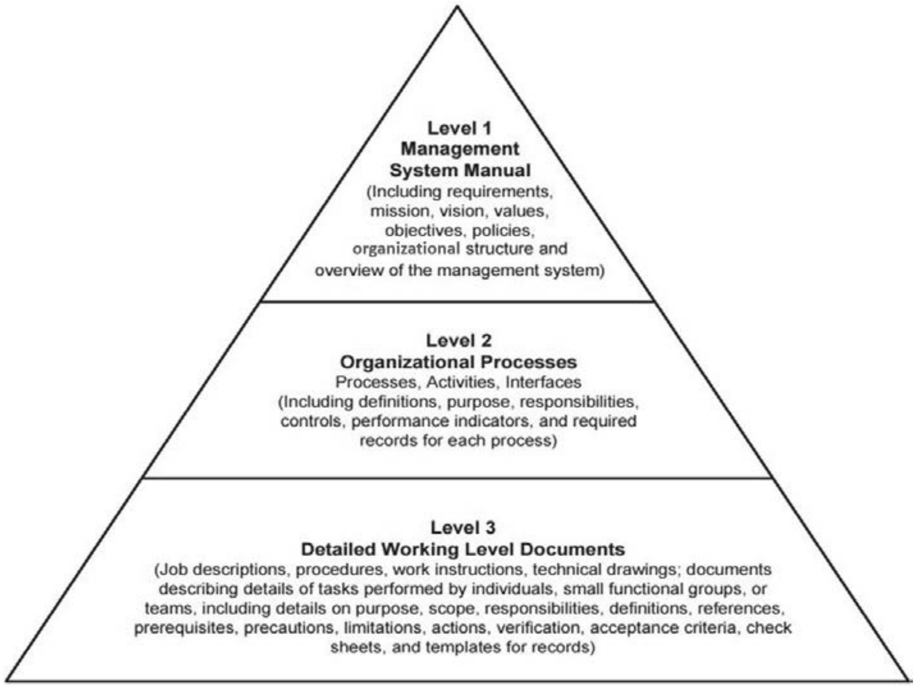

FIG. 29. A generic hierarchy of documents in a process based management system [44].

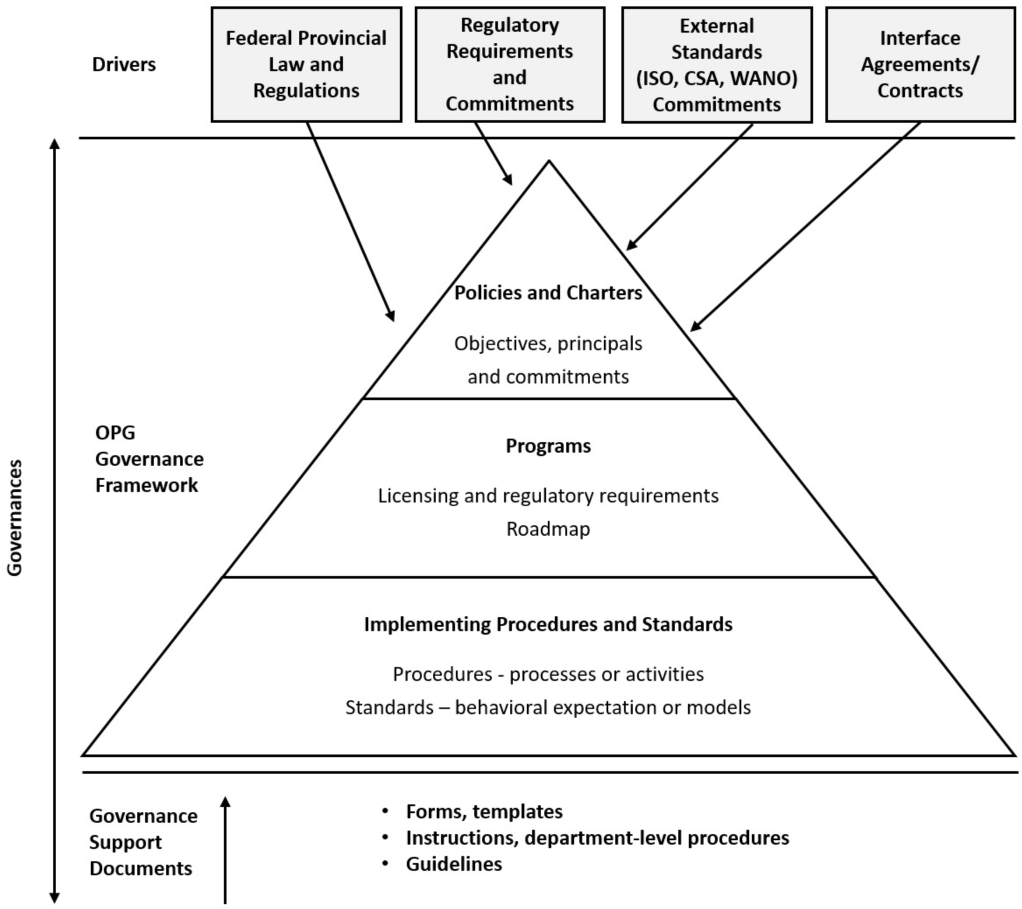

FIG. 30. Ontario Power Generation governance framework (reproduced courtesy of Ontario Power Generation).

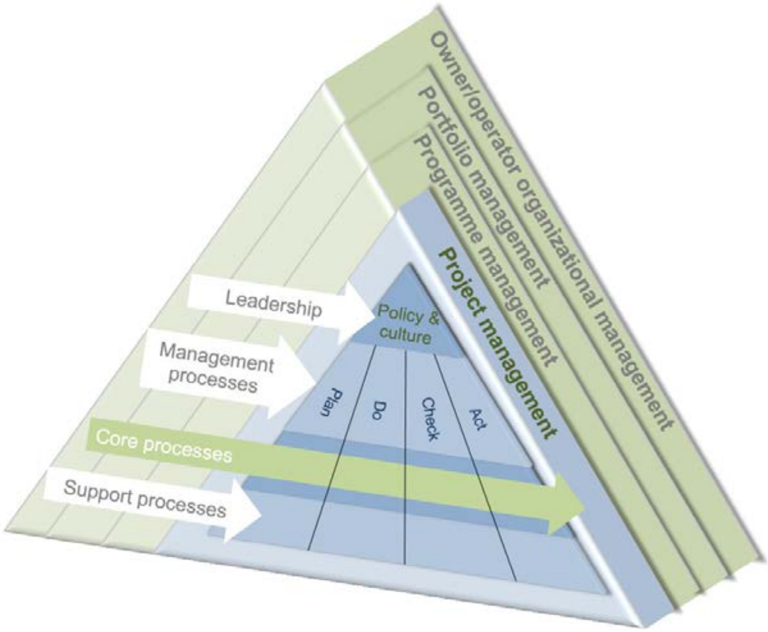

FIG. 31. Project management, core and support process categories for an owner/operator.

The following aspects should be considered for each identified process:

- Identification of the scope and objectives of the process;
- Identification of requirements from key interested parties (stakeholders, main contractor, regulator, etc.) and customers either internal or external to the project organization;
- Conformance to applicable legislation, regulation and industry codes and standards;
- Learning from experience and international best practice;
- Planning of sequenced activities;
- Establishment and assignment of suitable resources and skilled workforce;
- Establishment of process controls, identification of acceptance criteria and implementation of necessary monitoring and measurements;
- Establishment of a function to identify and manage process risks;
- Where necessary, the establishment of an independent oversight function.

5.1.3.1. Management processes

Management or executive processes "ensure the operation of the entire management system" [44]. They deal with the directing, planning, decision making, risk management, executing and monitoring, controlling and reporting activities of the organization. Table 5 identifies some typical processes in this area related to nuclear projects.

5.1.3.2. Core processes

Core processes integrate and coordinate the necessary activities to achieve the main organizational objectives in each phase. They are those processes "whose output is critical to the success of the facility or activity" [44]. In some cases the distinction between core processes and management processes can be difficult to identify and, in fact, may be situation dependent or dependent on the stage that a project is at. Table 6 lists some typical core processes related to a nuclear facility project.

5.1.3.3. Support processes

Support processes "provide the infrastructure necessary for all other processes" [44]. They act to support management and core processes in terms of supplying necessary skills, resources and controls. They normally reside

TABLE 5. EXAMPLE MANAGEMENT PROCESSES RELATED TO NUCLEAR FACILITY PROJECTS

Example responsible organization unit	Topic	Description
Corporate board/project board	Vision, mission, values, goals, objectives, policy statements, structure	High level statements or processes that establish organizational priorities, objectives and structure
Corporate board/project board	High level organizational planning	Performing situational analysis, forecasting, strategy development and corporate risk management
Project board/project management team	Detailed project planning	Development of the project charter and NPP life cycle strategy as well as the operational planning for the project
Corporate board/project board	Portfolio management	Processes that manage the selection of projects to proceed (e.g. for evaluating maturity, priority and feasibility of projects)
Corporate human resources/project human resource management	Resource planning	Processes to ensure that adequate resources, processes and capabilities are in place to effectively implement the project (recrutement and the related works may also be a support process, see 5.1.3.3)
Programme and project planning/ management, procurement and control offices	Project controls/procedures	Processes to coordinate and manage activities in accordance with the established regulatory requirements and the project plan, and establish and manage the various key project contracts. Includes detailed processes for assessing, scheduling and executing work, procurement, performing training, etc.
Project management/quality offices	Grading of application of requirements and related controls	Methods for grading the level of control or oversight applied to project activities (IAEA-TECDOC-1740 [45])
Project security management offices	Security management	Processes for managing site security
Project management offices (with aid of the project management team and risk management team)	Risk management	Processes related to risk management at a project or programme level and with detailed risk management and mitigation occurring at the project or sub-project activity level
Nuclear safety office (with aid of specialists for non-nuclear licences)	Safety, design basis and licensing management	Processes and plans for managing safety, design basis and licensing with regulators
An independent oversight unit with project control office	Project management control and oversight	Processes for managing oversight of the project. Includes those related to performance review, earned value progress tracking, quality surveillance, monitoring the effectiveness of controls, etc.
Project management team and all the project offices	Self-evaluation and corrective action	Processes for project self-evaluation, corrective action, incorporating lessons learned and continual improvement (refer to GSR Part 2 [24], Requirement 13)

TABLE 6. EXAMPLE CORE PROCESSES RELATED TO NUCLEAR FACILITY PROJECTS

Example responsible organization unit	Topic	Description
Engineering and other organizations within the owner/operator	Ensuring and sustaining new facility viability	Processes that evaluate a facility's economic feasibility, including those related to energy forecasting, planning, performing feasibility studies, grid integration planning and business case development Once the facility is operational, processes for production planning and management, operational and maintenance management, nuclear fuel management, etc. need to be in place
Strategic planning organization/senior executives	Local and national infrastructure and facility establishment and management	Processes to perform local and national infrastructure assessments and planning and to establish, and where necessary manage, this infrastructure and facilities
Design engineering and nuclear safety organizations (with aid from the main facility contractor/designer, in practice in most cases by partnering)	Establishing and maintaining the design and licensing basis	Processes to ensure that nuclear and non-nuclear regulatory requirements are met and that the facility is designed, manufactured, constructed, commissioned, operated and maintained in a way that is in accordance with its approved design basis. Process are thus needed, for example, for: • Management of project requirements in a systematic way; • Performance of site evaluation studies so as to determine all possible challenges and conditions that the selected site can impose on the NPP; • Incorporation of project requirements and site evaluation results into a set of design specifications against which the facilty's design can either be established or evaluated; • Managing design activities, including performance of design reviews, verification and validation activities; • Managing procurement activities, including vendor oversight; • Managing construction and commissioning actitivites, including contractor oversight; • Establishing effective project controls and oversight over activities in accordance with a graded approach; • Establishing an effective configuration management process to control design changes through design, manufacturing, construction and operations.

within the organization (that is, are not usually provided by external organizations) and they do not change from one project phase to another. They may include functions such as administrative support, accounting, document control, human resources, computer support, transportation and others. Using existing corporate governance, where possible, is normally good practice.

Efficient management of these support processes will allow a greater level management focus on the more complex core and management processes.

5.1.4. Project manuals

Project manuals are often used as guides to select project topics. These are useful in offering an insight into how various components of the project are being managed. They normally make reference to more detailed project processes, procedures and instructions within the project management system that should be referenced and used during the execution of project activities.

While the specific set of manuals will likely differ from one project to another, Table 7 provides some examples.

TABLE 7. SAMPLE SELECTED PROJECT MANUALS FOR A NUCLEAR PROJECT

Manual subject area	Description
Project management manual and plan	Acts as an introduction to the management of the project, highlighting aspects such a high level project description, project leadership, goals, key policies and management structure. Provides an orientation and integration tool, and as such needs to be well communicated, readily accessible, easy to read and effective in introducing the project and providing an index referring readers to more detailed information where necessary. It is normally used for induction purposes for employees and contractors starting on the project, and should be used as a first point of reference.
Licensing management manual and plan	A specific manual and plan focusing on how the safety of the facility is expected to be controlled and managed throughout its life cycle, initially in licensing the site and the design. This manual should also provide a key mechanism in guiding the interface with the nuclear regulator. A licensing plan provides a common understanding of the regulatory requirements and necessary licensing steps to be followed. This includes all necessary documentation required for the licensing process and submission requirements, as well as the time window considered necessary for the review and assessment process. Design specific information may need to be obtained from the contracted vendor. Experience has shown that it is easier to get commitment to the licensing process and the required licensing information from all stakeholders if the related requirements are provided to the potential vendor/s before the technology is selected. Provisions governing the transfer of required documentation should be included in the contract. These requirements and licensing plan need to be agreed with the nuclear safety regulatory body before contracting. Non-nuclear licences and/or permits need to be taken into account in a licensing plan.
Business case manual	A guide to preparing a financial justification for a project based on an organization's corporate standards. Business cases are a specific presentation of the project directed at potential investors, project approvers and other key stakeholders. It gives insight into the funding needs, viability and risks associated with the project. It is typically kept confidential for commercial reasons.

5.2. DEVELOPING AND ENCOURAGING BEST PRACTICES

Project teams are typically pressured to meet individual project objectives on time and on budget. This can often take time away from organizational performance improvement in the delivery of such projects. Project organizations are encouraged to systematically research and implement best practices in all areas of their projects. Once implemented across a portfolio of projects, such practices can provide the greatest overall benefit and eventually help organizations achieve more consistent success.

Several organizations have done work on best practices within the project area. Some of these are detailed in the following sections.

5.2.1. PMI best practices

The PMI provides a framework, Organizational Project Management Maturity Model (OPM3®) [215], that offers an organization-wide view of portfolio management, programme management and project management to support achieving best practices within each of these domains. In the OPM3 context a best practice

> "is achieved when an organization demonstrates consistent organizational project management processes evidenced by its aggregated capabilities and successful outcomes. For organizational project management, this includes the ability to deliver projects predictably, consistently, and successfully to implement organizational strategies" [215].

The list of specific best practices in OPM3 is very extensive (approximately 600 best practices are identified). Best practices are categorized by the domain that they apply to (project, programme or portfolio) and whether they are considered as an organizational enabler (that facilitates the implementation of best practices) or a standardize, measure, control and improve (SMCI) action for a specific process). Each best practice is made up of capabilities, and should have a demonstrable set of outcomes and key performance indicators.

Organizations are encouraged by the PMI to evaluate their current management processes against OPM3 best practices, assess their project management maturity, and identify areas that are in need of improvement. Some sample best practices associated with the process of developing a project management plan are listed in Table 8.

An OPM3 assessment will provide separate and overall ratings (expressed as a percentage) related to an organization's maturity with respect to organizational enablers and in the project, programme and portfolio domains.

5.2.2. CII best practices

For construction related projects, the CII has identified the items in Table 9 as proven best practices [216] and has produced various implementation guides and research publications related to them individually. It has also produced a guide for deploying such practices in unfamiliar countries [217], which can be a characteristic of nuclear projects.

The CII concluded that

> "best practices may improve performance not only in terms of cost, schedule, and safety, but they might also increase the consistency and predictability of project performance. By improving the consistency of project delivery, a company will have a better chance of improving project performance over the long term. This combined benefit of best practice use will likely give companies a distinct competitive advantage" [218].

The CII has indicated that organizational barriers to implementing best practices can include:

- Low familiarity with best practices;
- Lack of commitment to best practices;
- Limited emphasis on training and education concerning best practices;
- Failure to integrate new ideas and recommendations into the organization's procedures;
- Limited benchmarking of costs and benefits;
- Lack of innovation within the industry due to risk aversion.

TABLE 8. SAMPLE OPM3 BEST PRACTICES ASSOCIATED WITH PROCESS 'DEVELOP PROJECT MANAGEMENT PLAN'

SMCI area	Area for assessment
Standardize	• Process has an active process governing body • Process is documented • Process is communicated • Process is standardized (consistently implemented and repeatable)
Measure	• Customer requirements are incorporated into measurements • Critical characteristics are identified • Critical characteristics are measured • Inputs are related to results • Critical inputs are measured
Control	• Control plan is developed • Control plan is implemented • Stability is achieved
Improve	• Problems are identified • Improvements are implemented (indicated by widespread participation) • Improvements are sustainable

TABLE 9. CII BEST PRACTICES FOR CONSTRUCTION PROJECTS

Best practice name	Description (from Ref. [216])	IAEA related reference (Section in this publication unless otherwise stated)
AWP	The overall process flow of all the detailed work packages (construction, engineering and installation work packages). AWP is a planned, executable process that encompasses the work on an EPC project, beginning with initial planning and continuing through detailed design and construction execution. It provides the framework for productive and progressive construction and presumes the existence of a construction execution plan.	4.1.4.5
Alignment	The condition whereby appropriate project participants are working within acceptable tolerances to develop and meet a uniformly defined and understood set of project objectives.	4.1.7
Benchmarking and metrics	The systematic process of measuring an organization's performance against recognized leaders for the purpose of determining best practices that lead to superior performance when adapted and utilized.	II.4
Change management	The process of incorporating a balanced change culture of recognition, planning and evaluation of project changes in an organization to effectively manage project changes.	4.1.5
Constructability	Optimizing the design in consideration of effective performance of construction related activities.	NP-T-3.3 [43]
Dispute prevention and resolution	Techniques that include the use of a dispute resolution board as an alternate dispute resolution process for addressing disputes in their early stages before they can affect the progress of the work, create adversarial positions and lead to litigation.	4.4.5.2, Nuclear Contracting Toolkit[a]
FEP	The essential process of developing sufficient strategic information with which owners can address risk and make decisions to commit resources in order to maximize the potential for a successful project.	3.5
Implementation of CII research	The comprehensive and effective use of proven CII products by member organizations as outlined in the CII Implementation Model.	5.2.2
Lessons learned	A critical element in the management of institutional knowledge, an effective lessons learned programme will facilitate the continuous improvement of processes and procedures and provide a direct advantage in an increasingly competitive industry.	4.12
Materials management	An integrated process for planning and controlling all necessary efforts to make certain that the quality and quantity of materials and equipment are appropriately specified in a timely manner, are obtained at a reasonable cost and are available when needed.	4.10 NP-T-3.21 [3]
Partnering	A long term commitment between two or more organizations, as in an alliance, or it may be applied to a shorter period of time such as the duration of a project. The purpose of partnering is to achieve specific business objectives by maximizing the effectiveness of each participant's resources.	4.6.3.d

TABLE 9. CII BEST PRACTICES FOR CONSTRUCTION PROJECTS (cont.)

Best practice name	Description (from Ref. [216])	IAEA related reference (Section in this publication unless otherwise stated)
Planning for startup	Startup is defined as the transitional phase between plant construction completion and commercial operations that encompasses all activities that bridge these two phases, including systems turnover, check-out of systems, commissioning of systems, introduction of feedstocks and performance testing.	NP-T-2.10 [219]
Project risk assessment	The process to identify, assess and manage risk. The project team evaluates risk exposure for potential project impact to provide focus for mitigation strategies.	4.9
Quality management	Quality management incorporates all activities conducted to improve the efficiency, contract compliance and cost effectiveness of design, engineering, procurement, QA/QC, construction and startup elements of construction projects.	4.5
Team building	A project focused process that builds and develops shared goals, interdependence, trust and commitment, and accountability among team members, and that seeks to improve team members' problem solving skills.	4.1.7
Zero accidents techniques	Includes site specific safety programmes and implementation, auditing, and incentive efforts to create a project environment and a level of training that embraces the mindset that all accidents are preventable and that zero accidents is an obtainable goal.	4.11 NP-T-3.3 [43]
Planning for modularization	The evaluation and determination of off-site construction in the FEP phase to achieve specific strategic objectives and improved project outcomes. Includes developing a business case and execution strategy for large scale transfer of stick-built construction efforts from the jobsite to fabrication shops or yards.	NP-T-2.5 [42]

[a] See https://www-legacy.iaea.org/NuclearPower/Infrastructure/NuclearContractingToolkit/manage-contract/index.html.

5.2.3. AACE value management or value improving practices

The AACE has identified a number of focused and effective value improving practices in its Total Cost Management framework [35]. The most significant of these is the value analysis/VE process that was described separately in Section 3.6. This practice, and others that are deemed important to enhancing value, are listed in Table 10.

5.2.4. UK best management practice portfolio

Since 2000, the UK's Office of Government Commerce (OGC) and, more recently, since 2010, the UK's Cabinet Office have documented a set of best management practices for their major projects. These practices "present flexible, practical and effective guidance, drawn from a range of the most successful global business experiences. Distilled to its essential elements, the guidance can then be applied to every sort of business and organisation" [220].

Table 11 lists the identified best practices. Many of these best practices have been discussed in other sections of this publication. Further information can be found by visiting the product specific websites found below.

TABLE 10. AACE VALUE IMPROVING PRACTICES (ADAPTED FROM REF. [35])

Value improving practice name	Description	IAEA related reference (section in this publication unless otherwise stated)
Requirements elicitation and analysis	Understanding of customer/stakeholder requirements for the project	4.1.4.3
Target costing and cost deployment	Making cost a requirement in the design	3.7
Decision analysis	Selecting alternatives based upon analysis that translates values into monetary measures (e.g. putting schedule or quality values into cost terms)	
Life cycle costing	Looking at entire life cycle cost for decisions instead of just original investment or project cost. This would include costs to acquire, produce, construct, operate, retire and dispose of an asset	[221, 222]
Risk management	Similar to value analysis/VE except that it focuses on risk factors and external factors that influences	4.9
Optimization	Processes that achieve best or optimal schedules, cost estimates and budgets for a project, often using simulations	4.3, 4.4
Benchmarking	Measuring and analysing other projects, processes or practices with the goal of identifying gaps in one's own practices and improving performance	II.4
Review and validation	Steps to ensure that a process and its outcome meet established performance requirements (often cost and schedule related)	4.2.5 (for example)
Manufacturing analysis	Optimizing product and production system design in consideration of effective performance of manufacturing and related activities	Similar to constructability analysis below
Constructability analysis	Optimizing design in consideration of effective performance of construction related activities	NP-T-3.3 [43]
Reliability, availability and maintainability analysis	Optimizing the performance or operability of process systems or their components in consideration of predicted future asset performance	NP-T-3.3 [43]

TABLE 11. UK OFFICE OF GOVERNMENT COMMERCE/CABINET OFFICE/AXELOS GLOBAL BEST PRACTICES

Best practice name	Application	Reference
PRojects IN Controlled Environments (PRINCE2®)	Project management	[110] and Appendix I Section III.4
Managing Successful Programmes (MSP®)	Programme management	[34] and Appendix I Section III.5
Management of Risk (M_o_R®)	Risk management	[152] and Section 4.9
IT Service Management (ITIL®)	IT service management	[223–227]

TABLE 11. UK OFFICE OF GOVERNMENT COMMERCE/CABINET OFFICE/AXELOS GLOBAL BEST PRACTICES (cont.)

Best practice name	Application	Reference
Management of Portfolios (MoP™)	Portfolio management	[228] and Section 2.3.2.3
Management of Value (MoV™)	Value management	[76] and Section 3.6
Portfolio, Programme and Project Offices (P3O®)	Establishing dedicated organizations for critical project areas	[229] and Section 5.2.5
Portfolio, programme and project management maturity model (P3M3®)	Assessment methodology for organizational maturity	[230]

5.2.5. Project management offices or centres of excellence

Many nuclear operating organizations have established project management offices (PMOs) or centres of excellence to provide support and guidance to personnel working on projects. PMOs help the organization deliver its projects in the most strategic and efficient way by standardizing policies and developing standard project management methodologies for use within the organization.

PMOs can establish dedicated subsections with expertise in critical specialized areas. Individuals within these subsections will typically have advanced training and knowledge in their assigned areas. Ontario Power Generation, for example, established centres of excellence in 2008 to address issues it was experiencing with in-house managed projects. The issues included high cost and schedule deviances, frequent scope changes, inefficient processes to track contractor performance and inconsistent processes to manage risks. The centres of excellence were established under a manager of FEP in the following areas [231]:

- Value engineering;
- Cost engineering;
- Risk management;
- Scheduling;
- Estimating;
- Cost management.

Figure 32 shows the project FEP process established at that time.

6. PROJECT MANAGEMENT ACTIVITIES FOR A NEW NPP IN EACH PROJECT PHASE

6.1. INTRODUCTION

As discussed in Section 2.2, projects and processes can be described in terms of phases. The IAEA's Milestones Approach [1], for example, divides a country's NPP development programme into a number of phases that are separated by three major milestones. Individual projects can also be divided into phases, with one sample division (as detailed by the CII [232]) being feasibility, concept, detailed scope, detailed design, procurement, construction, commissioning and startup and handover and closeout.

As a large project develops over time, it is neither possible nor desirable at the project's beginning to plan in detail all of the steps that would be necessary to deliver the entire project. Detailed design is not complete,

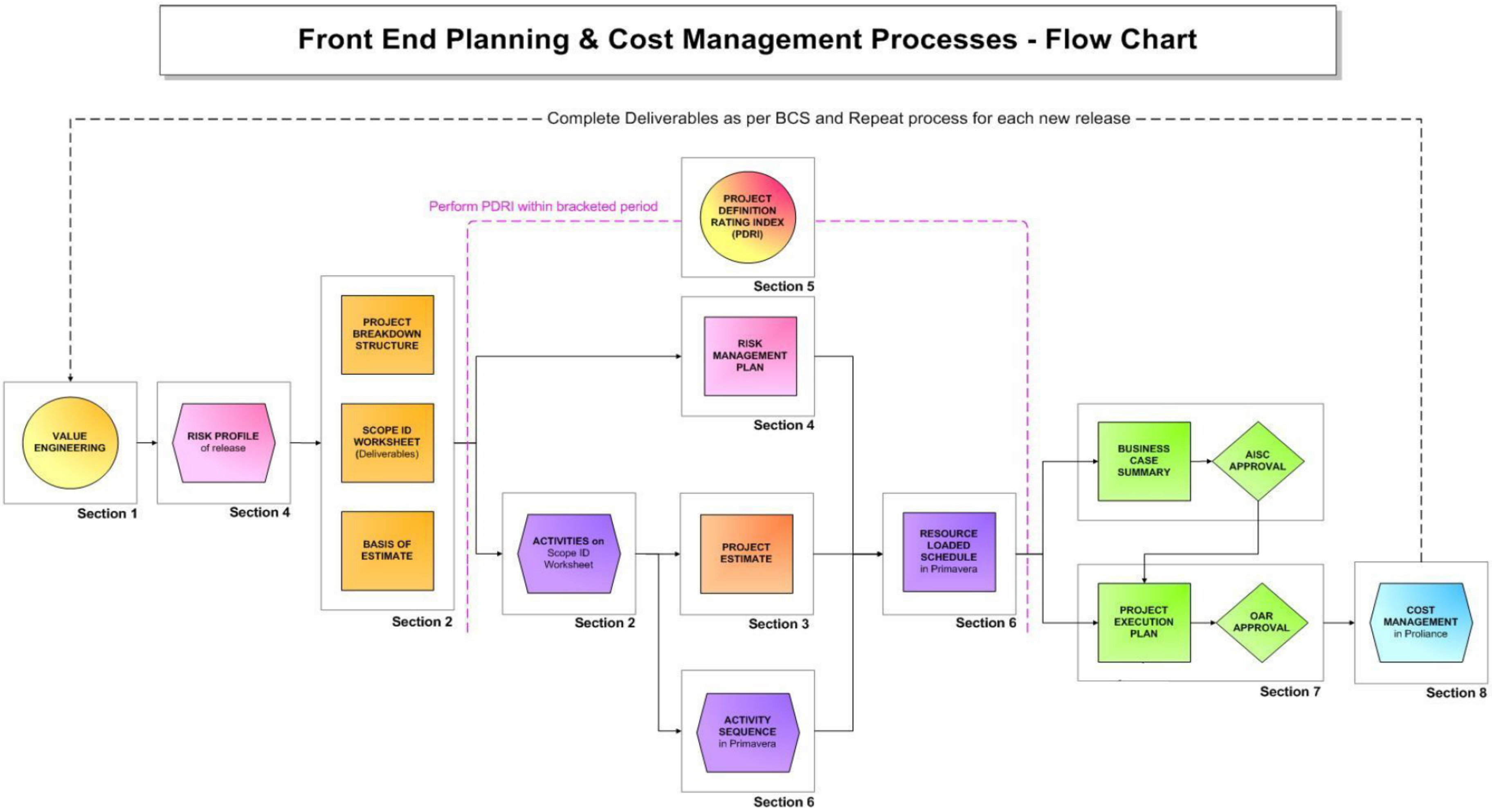

FIG. 32. OPG FEP process (reproduced courtesy of Ontario Power Generation [231]).

sub-supplier contracts are not negotiated and many other items that could impact on the project require further definition.

Thus, for financial purposes, projects are often divided into phases that are separated by approval gates. High level planning is done for the entire project and detailed planning is done for the next project phase. This allows the project to be divided into more manageable sections for which good definition is known and a detailed plan and budget can be produced with high confidence.

Figure 33 and Table 12 describe an example of project approval gates for a sample NPP project overlaid on the IAEA's Milestones Approach framework. It shows approval gates for project development, contract and agreement, early preparation, and final investment decision. Non-financial hold point approval gates related to Milestone 3 (construction completion) and the commissioning and handover process are also shown. It should be noted that construction completion milestones, commissioning and turnovers are typically progressed on a system-by-system basis, as described in IAEA Nuclear Energy Series Nos NP-T-2.7 [2] and NP-T-2.10 [219].

This system of establishing project phases/stages and approval gates is commonly used in project management practice, and as such many guides and approval gate checklists and good practices are available. Typically, some sort of assessment is made prior to the approval gate that the given project is ready to proceed to its next stage.

The CII's suite of PDRI tools [71–73] is one such method that is in use in many organizations, including numerous nuclear plant owner/operators, the US Department of Energy, NASA and other large constructors and owners. The IAEA's construction readiness review (CORR) guidelines [51] is an example of an external review that might be done prior to starting a project's construction phase.

At each of these approval gates, before initiating the defined phases, the project board or designated authority will review progress and the planning done for the next phase. The following elements are typically considered at each approval gate:

- Progress of the project during the last stage;
- Project status, development gaps and risks (should it proceed to the following phase);
- Continued feasibility of the project;
- Detailed plan for the next phase;
- Required budget and resources for the next phase;
- In the case of newcomer countries, the status of the (national/local) nuclear power infrastructure development [1] required to support the owner/operator's project.

It is ultimately up to the project board to define and establish requirements for the approval gates. The implementation of periodic reviews such as annual reviews is also common. Activity planning and responsibilities

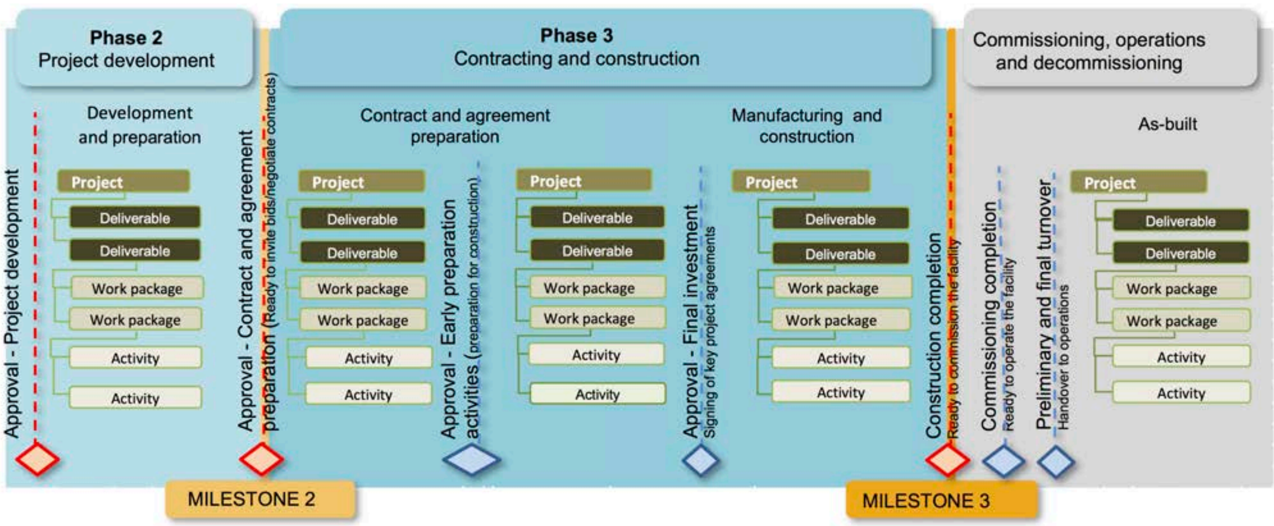

FIG. 33. Defining phases and approval gates for a nuclear power project.

TABLE 12. SAMPLE FINANCIAL APPROVAL GATES FOR AN NPP PROJECT

Gate	Description
Project development	At this gate it is verified that the national nuclear power infrastructure programme has achieved Milestone 1; a review of the project risk management plan has been completed; preliminary project feasibility is assessed; plans are approved for activities to establish the project development baseline; and necessary budgets and resources required for project development activities are approved.
Contract and agreement (ready to invite bids or negotiate contract)	At this gate a review is conducted on the activities performed in Phase 2; the site environmental approval has been obtained; the site nuclear licence or permit has been obtained; the site has been acquired; the site characterization studies are complete; a review of the project risk management plan has been completed; it has been verified that the national nuclear power infrastructure programme has achieved Milestone 2; the project feasibility is reaffirmed by the owner/operator; all necessary deliverables in preparation for the contracting and agreement process have been completed; the project investors are satisfied that when implemented the approved plans have a reasonable chance of concluding all necessary agreements; and approval of the necessary budgets and resources required for the contracting and agreement process is obtained. While some development activities may not be complete, a holistic decision may be taken to proceed to the next phase to finalize the main contract(s). In this case the incomplete activities need to be carefully planned for early completion in the next phase, flagged and managed in terms of risk management and brought to the attention of the project board when seeking approval. The required national nuclear infrastructure generally needs to be in place (i.e. legislation, regulation and security and safeguard requirements) to keep risks at a manageable level.
Early preparation (preparation for construction)	Sometimes involving a limited notice/authorization to proceed, this approval initiates the execution of limited preparatory work on the project. Execution of the contracting and agreement process and the establishment of the necessary contracts is often a time consuming process. Several activities can and should be conducted in parallel, often at some risk to both the owner/operator and possibly the preferred vendor. This can assist in bringing the schedule forward by a significant amount, especially since activities such as site integration engineering, local infrastructure establishment and safety case and documentation review often have high associated schedule risks. These activities could include site integration design and safety case review, as well as the reservation of manufacturing slots and initiation of limited manufacturing and construction activities which have long lead times. Several design changes may also be required for the project where it differs from the design of the reference plant (known as pre-engineering). These design changes, as well as the related engineering activities, may need to begin early to secure the project schedule. This limited work will likely require the establishment of a contractual agreement and may need to be terminated if final investment approval is not forthcoming.
Final investment decision (signing of key project agreements and contracts)	At this point, the funding, equity and financing plans are approved that allow the project to proceed through commissioning. Vendor supply agreements or main contracts have been drafted, negotiated and are ready for signatures; the engineering design either complies with the project specific requirements or robust plans are in place to ensure its compliance by a set date; the safety analysis report has either been drafted, reviewed and deemed to be licensable by the owner/operator or robust plans are in place to ensure it is completed in a timely manner; and all necessary construction permits have either been approved or carefully scrutinized to ensure that any associated risks have been identified and well managed. Since the final investment approval normally signifies the initiation of major manufacturing and construction work, it is a very important approval gate. The project budget and cost of standing time quickly escalate from the previous phase. Aspects such as the design and construction licence, as well as all the other important contributors, have to be suitably confirmed and managed in terms of their ability to affect the project's critical path. Given the extent of the commitment at the final investment approval, the project will in most cases be forced to proceed to commissioning almost irrespective of any and all challenges faced during construction.

are generally established for the next phase of the project before it is released through the approval gate, resulting in the project plan being baselined at each of these gates (see Section 4.3.1).

It should be noted that various other hold points or gates may be established as part of the project for technical, completion assurance and regulatory reasons. These can include witnessing of key long lead item manufacturing steps, reviews to confirm installation completion of particular systems (readiness to hand over to commissioning),

commissioning completeness (ready for system handover for operation) and final completion (complete final plant handover to operations). Regulatory hold points may exist, for example, for the start of fuel loading or the start of approach to criticality. Details of such technical or regulatory hold points fall outside the scope of this guide but are discussed in IAEA Nuclear Energy Series Nos NP-T-2.7 [2] and NP-T-2.10 [219].

The following sections provide more detail surrounding the specific activities and considerations for project management within each project phase of an NPP development project using the phases defined in the IAEA's Milestones Approach [1]. Figure 34 provides an overview of these sections.

6.2. PHASE 1 (PRE-PROJECT ACTIVITIES)

During Phase 1, a country analyses all of the issues that would be involved in introducing nuclear power, so that at the end of Phase 1, it is in a position to make a knowledgeable decision on whether or not to introduce nuclear power [1]. Establishing a national position for a new nuclear power programme is discussed in IAEA

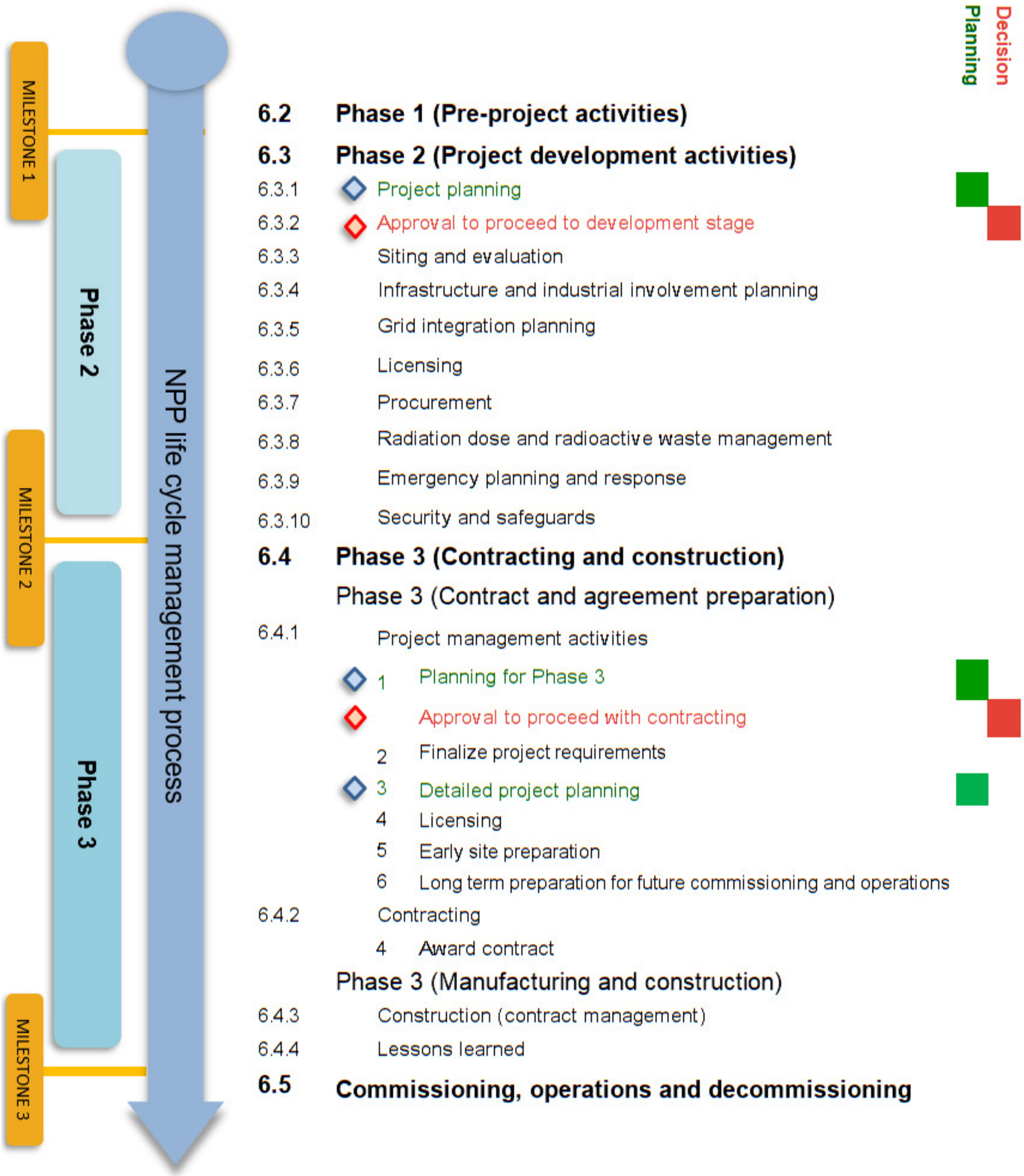

FIG. 34. Project phases and activities for an NPP project in the context of the IAEA's Milestones Approach. Milestone Phase 3 has been divided into two main sub-phases in the figure.

Nuclear Energy Series No. NG-T-3.14 [21]. No specific power plant project has been defined, nor has a project team for a specific project been assembled; however, many of the outputs of the phase are used as inputs to Phase 2. This work is normally coordinated through a temporary organization known as a NEPIO. As work progresses other organizations such as a national nuclear regulator and emergency response organizations may be set up and any support legislation may be implemented via government ministries.

A major deliverable by the NEPIO at this stage is a pre-feasibility study and comprehensive report into the viability of a potential NPP project. Pre-feasibility and feasibility studies are discussed in detail in IAEA Nuclear Energy Series Nos NG-T-3.3 [12] and NG-T-3.14 [21]. Such studies would normally address all 19 infrastructure issues. The pre-feasibility and feasibility studies normally consist of:

"— An analysis of energy demand and energy alternatives;
— An evaluation of the impacts of nuclear power on the national economy, for example gross domestic product and employment;
— A preliminary technology assessment to identify technologies that are consistent with national requirements;
— Consideration of siting possibilities and grid capacity;
— Consideration of financing options, ownership options and operator responsibilities;
— Consideration of long term costs and obligations relating to spent fuel, radioactive waste and decommissioning;
— Consideration of possible human resource needs and external support needs of the regulatory body and owner/operator;
— Recognition that there remains a non-zero possibility of a severe accident, and the country will need to be able to deal with the consequences of such an accident;
— Consideration of the needs of each of the infrastructure issues and a plan for how they will be met in Phase 2." [1]

If the NPP is to be constructed in a country new to nuclear power then the NEPIO is recommended to consider working with the potential owner/operator to host an INIR [52] in line with the IAEA's Milestones Approach. This will assess the readiness of the national nuclear power infrastructure to support the NPP project. Any recommendations raised during the INIR review should be closed or appropriately mitigated. INIR missions can be held at the end of Phase 1 (initial and follow-up missions as required) as well at the end of Phase 2 (see Section 6.3.2 for Phase 2 INIR information). Additional information on evaluation of a country's national infrastructure is available in IAEA Nuclear Energy Series No. NG-T-3.2 (Rev. 1) [233].

Work during this phase by the NEPIO would itself be managed as a project or programme, with the objective being to provide the supporting documents described above and put the country in a place to make a knowledgeable decision regarding nuclear power. The principles described in this publication (e.g. proper scope definition, planning, scheduling) would be followed for this 'pre-project project'. Of special importance is work towards ensuring the alignment of key stakeholders inside and outside of the government regarding the national position on nuclear power (see Section 4.1.7 on alignment), since this is key to proceeding to the next phase.

6.3. PHASE 2 (PROJECT DEVELOPMENT ACTIVITIES)

Phase 2 consists of all preparatory work to prepare for the contracting and construction of a specific NPP after a national policy decision has been taken by the government. Its broad objective is to bring the project to a position whereby it is ready to start the bidding/negotiation process for the facility. This includes establishing the owner/operator of the NPP, establishing the NPP project company (if separate from the owner/operator), performing a site specific feasibility study, doing preferred site assessments, establishing the independent nuclear regulatory body, establishing the security regulator and beginning establishing EPR mechanisms. The owner/operator also has to ensure that, by the end of Phase 2, it has developed the competence and knowledge to negotiate a contract for the NPP, manage it to meet regulatory requirements and be a knowledgeable customer in Phase 3.

Table 15 in Appendix V details the high level activities for this phase as identified in the IAEA's Nuclear Energy Series No. NG-G-3.1 (Rev. 1) [1]. The reference, however, does not identify a typical sequence of these activities, nor provide further guidance on how to perform such activities. The following sections are designed to provide assistance in these areas.

All necessary studies, planning and approvals need to be completed. This includes such items as preparing detailed project plans, performing site selection and evaluation, performing local and national infrastructure and industrial involvement planning and completing grid integration planning.

The following parts of this section detail the typical activities needed to achieve these objectives.

6.3.1. Project planning

Phase 2 is the phase in which the actual nuclear project begins. The NEPIO organization that was established in Phase 1 will hand over the major accountability for project development to a defined owner/operator. The owner/operator will be the lead on the project for this phase, although other organizations (e.g. governments, the regulator, the grid operator) will continue to have vital roles. The owner/operator may be an existing company (e.g. an electricity generating utility) or a newly formed project company. The NEPIO may continue to play a role during this phase to ensure that national or regional initiatives outside of the owner/operator's responsibility but within the 19 infrastructure issues continue to be progressed.

Figure 35 outlines a simple process for project development that can be used to direct the major activities of the owner/operator during this phase. Each step will be described in more detail in the following Sections 6.3.1.1 to 6.3.2. The bulk of the effort lies in developing the detailed project plan. Of particular importance in this phase is establishing a high level life cycle management strategy for the facility (Section 4.1.2) and detailed planning for the procurement and contracting to be done in Phase 3 (Sections 4.1.3 and 4.10).

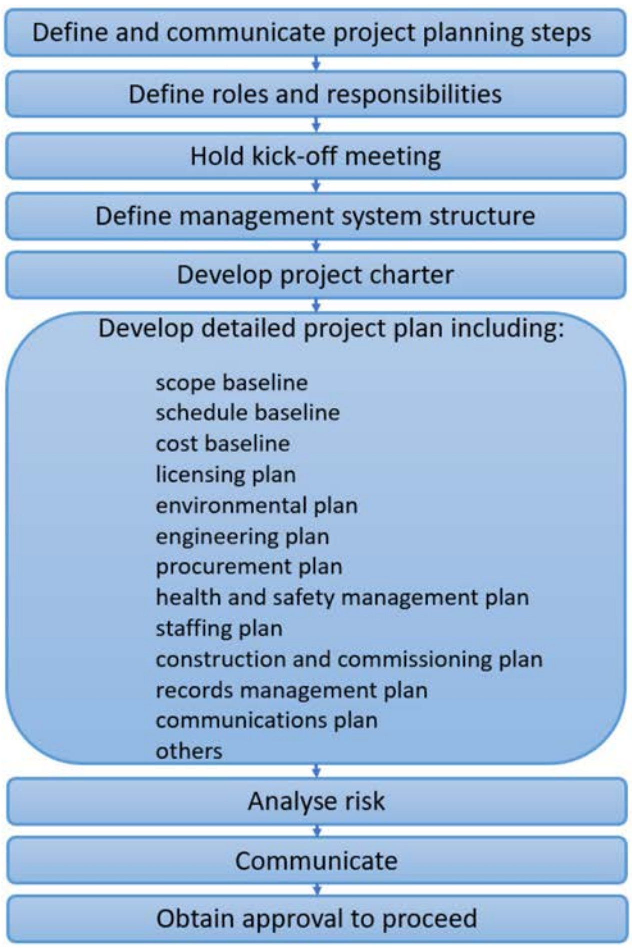

FIG. 35. Project development steps by owner/operator.

6.3.1.1. Define and communicate project planning steps

Once the NEPIO has designated the owner/operator for the new facility, a small core team of individuals from that organization is normally assigned to begin project development. This team, which will grow larger over time, is tasked primarily with developing a realistic project plan that can be approved by senior executives in order to proceed to the bidding and contract negotiation phase (Phase 3).

Many of the project's key stakeholders may not fully understand accepted best practices for project planning as described in this publication or elsewhere. They may not have been involved with large nuclear or other large capital projects before. A key initial step, therefore, is to educate the key stakeholders about the planning process and the outline of the eventual project plan. It is essential for them to understand the importance of this set of processes and documents and to be familiar with its content, since they will be asked to review and approve the final documents that pertain to them once they are ready.

The content of a typical project plan was described in Section 4.1.3 of this publication.

6.3.1.2. Define roles and responsibilities

Roles and responsibilities of key individuals need to be defined at an early stage. Key individuals on the core project team needed at the very start include:

- Project sponsor: the senior executive within the ownership structure who 'owns', secures funds for, provides senior direction to and champions the entire project. Sponsors need to review and approve all aspects of the project plan.
- Project owner: the entire investing agency or company(ies) involved in the project's ownership structure (i.e. the corporate entity, not a specific individual sponsor).
- Project manager/director: the individual who creates, executes and controls the project plan and manages the project on a day to day basis.
- Designated subject matter business experts (e.g. engineering, legal, finance, estimating, procurement, insurance, regulatory support, communications, risk management, auditors, operations, maintenance, government representatives): they will define certain requirements for the project within their areas of expertise and help to develop the project scope and project plan.
- Project development team members: reporting to the project manager, these individuals will develop the detailed deliverables (plans, reports, schedules, budgets, etc.) needed to plan and progress the project to the next phase.

Staff will be recruited, trained and developed over time for the project team in accordance with a defined workforce development and organizational plan. This plan will become part of the detailed project plan. Similar plans need to be in place for the regulatory body and the NEPIO may retain a role to coordinate national human resources development efforts.

6.3.1.3. Hold a kick-off meeting

A kick-off meeting is an effective way to bring stakeholders together to discuss the project at its beginning and to initiate the planning process. It can assist in team building and alignment activities that were discussed in Section 4.1.7, and demonstrate the active involvement and interest of the project sponsor.

Some potential topics that might be included in a kick-off meeting include:

- Organization's business vision and strategy (from sponsor);
- Project vision, goals and objectives (from sponsor);
- Roles and responsibilities;
- Initial project plan (30/90 day planning);
- How success will be measured;
- Potential risks and bottlenecks;
- Logistics and team communication;

- Project management methods and best practices to be followed;
- Project management tools to be used.

6.3.1.4. Define management system structure

At an early stage, the project team will need to start issuing policies, processes and procedures to govern project activities as part of a management system. A structure for such governance needs to be established and work on establishing specific processes needs to be started. Depending on the jurisdiction such systems may need to be independently certified. Systems for knowledge capture and preservation will need to be established (see Section 4.1.8).

Section 5.1 of this publication discusses the establishment of a process based management system for a nuclear project in more detail based on Ref. [44].

Organizations new to the nuclear sector will need to pay special attention to the incorporation of safety and security culture programmes into their management system. An awareness of the importance of these topics will need to be established throughout the project organization, including key contractors and suppliers.

6.3.1.5. Develop a project charter

Assuming a project charter has not formally been developed by the NEPIO, the project sponsor or another organization, the first deliverable to be prepared by the project is the project charter. Typical content for a charter document is described in Section 4.1.1.

The project charter is arguably the most important document for a project. It describes what the outcome of the project will be, is used to get common agreement among the stakeholders about its scope and decreases the chances of miscommunication. This document may need to be revised during the course of the project if the project direction (as documented in the charter) needs to be changed.

6.3.1.6. Develop a detailed project plan

Detailed project planning consists of developing the knowledge, skills, experience and supporting evidence to produce a detailed project plan for the execution phase of the project. The contents of a typical project plan are described in Section 4.1.3. At an early stage of Phase 2, some of the project plan contents need to be more fully developed than others. Activities later in the facility's life such as manufacturing, construction, commissioning, operations and maintenance and decommissioning may only have high level plans at the outset. Greater levels of definition will be provided as the project develops since in practice, planning is a continuous activity that takes place throughout the life cycle of a project and a facility.

Information gathering to support project planning is critical at this stage. For countries undertaking their first nuclear power project, this is even more important. Preparatory work that was completed by the NEPIO and others and the status of the national nuclear power infrastructure development required to support the project should be carefully reviewed by the owner/operator. The owner/operator needs to establish an 'informed customer' role (see Section 4.6.8.2) that includes the methods and processes to develop its staff to be able to independently validate and assess any claims made by the proposed facility vendors. This includes the ability to evaluate various technologies, produce independent cost and schedule estimates for the project, the ability to produce detailed owner's requirements for the facility and the general ability to manage a large capital project. Owner/operators with previous experience of managing large conventional projects (e.g. hydroelectric or thermal generation facilities) can apply some of the lessons learned from those projects in the nuclear field.

Some approaches to gather such information include:

- Direct training by prospective NPP vendors; international nuclear organizations (IAEA, INPO, WANO, etc.);
- Benchmarking similar projects (ideally including direct interviews with former and current project team members);
- Hiring experienced international consultants with nuclear construction, nuclear operations and project management experience (into staff positions, advisory roles, auditing roles or through establishing an owner's engineer role);
- Literature reviews for OPEX related to large nuclear and large non-nuclear projects.

6.3.1.7. Analyse risk

In this phase, a risk management plan should be in place that identifies and mitigates key risks in Phase 2 and looks ahead to Phase 3. The respective mitigations will need to be planned and funded along with the remainder of the project activities. Periodic reviews should be scheduled (see Section 4.9).

Activities not under the direct control of the owner/operator are of particular interest. These include activities being performed related to the independent nuclear and security regulators, the grid operator, EPR organizations, national and site infrastructure support and others.

6.3.1.8. Communicate

As was described in Section 4.7, communications and stakeholder management is an essential aspect of project planning and a part of any significant project plan. The project plan itself needs formal and informal communication to project stakeholders at this stage to help secure support for the next phase gate investment decision. Also of importance is the need to communicate the process for changing the contents of the plan as necessary and the key stakeholder roles/responsibilities for the upcoming phases.

It is important at this stage that formal and informal communications channels be established with the nuclear regulatory body and for the regulatory body to initiate its own stakeholder involvement programme.

6.3.2. Approval to proceed to development stage

6.3.2.1. Project readiness assessment and report

A feasibility review of the preliminary business case should be conducted and a formal release of funds to cover the project development phase needs to be approved. While there may have been a national decision to invest in nuclear power, the owner/operator will likely need to make its own preliminary decision on the viability of the project. The motivations and preliminary feasibility of the project should be well understood to ensure that it is in line with the owner/operator's objectives. Although the development phase budget is a few per cent of the overall capital cost, it still constitutes a significant investment and as such the owner/operator should have a strong degree of confidence in the overall feasibility of the project. Government stakeholders may also have a role in approving the project to go ahead.

The process of the feasibility review can be enhanced by the performance of formal external assessments and self-assessments. A Phase 2 INIR review (see Section 6.3.4), external oversight board reviews, third party reviews by audit organizations and the CII's PDRI (see Section 3.5) are sample methods that can be considered at this stage.

6.3.2.2. Preliminary business case

In this phase, a preliminary business case is typically established that demonstrates the relative feasibility of the project given the range of costs and supply agreements that should be achievable through engagement and negotiations. This preliminary business case needs to be sufficiently detailed to give potential investors and financiers the required confidence in the project during the next phase. It will be updated as negotiations and contract drafting progress so as to form a complete business case to inform the final investment approval, before the signing of the various key NPP contracts and agreements.

6.3.3. Siting and evaluation

Siting and evaluation (Fig. 36) are key activities involved in laying the ground work for a nuclear project. IAEA Nuclear Energy Series No. NG-T-3.7 [234] covers these activities in detail, with section 3 of that publication describing how to project manage the process.

The first part of siting (site surveys and selection) provides the project with a list of candidate sites for the facility. The second part (site evaluation) provides detailed confirmation of the site's acceptability from a nuclear safety design parameter envelope perspective and initiates regular site monitoring from the start of plant construction and throughout plant operation.

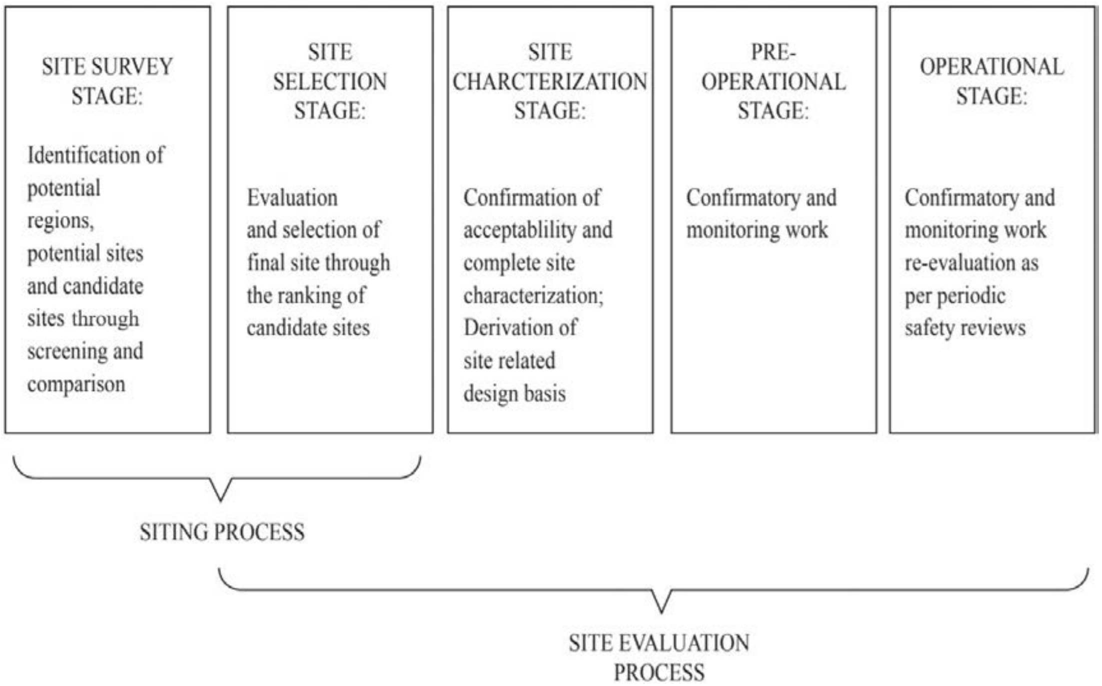

FIG. 36. Stages in the siting process and site evaluation process [235].

Due to their long life and the tendency of requirements to increase over time, selected nuclear facility sites need to have comfortable margins for all siting requirements applicable to nuclear safety.

6.3.3.1. Site surveys and selection

The IAEA offers guidance on site survey and selection activities in IAEA Specific Safety Guide SSG-35 [235] and Nuclear Energy Series No. NG-T-3.7 [234]. Site selection identifies the best acceptable sites for the particular required nuclear installation(s), taking into account nuclear safety and other considerations, which can include economic and social factors. The appropriateness of a site is measured by a set of exclusionary, avoidance and suitability criteria.

Exclusionary criteria can include a host of factors, regulatory or otherwise, whereby it is deemed unfeasible to engineer a solution for the particular characteristic of the site. An example would be excluding sites with unacceptable rates or severity of natural disasters such as large earthquakes. In some jurisdictions, a lack of evidence of public support for the facility can be an exclusion criteria.

Viable sites that pass exclusion criteria are then ranked based on avoidance and suitability criteria (which can also be referred to as ‘discretionary’ criteria). These can include criteria that measure the site’s attractiveness from the perspective of the owner/operator, NEPIO or government. The ease or cost of providing a transmission grid connection or of providing site services (air, sewage connections, worker accommodation, etc.), or the potential for regional economic development, are examples of discretionary criteria. Avoidance criteria “are not strictly go/no go criteria but are utilized to identify broad areas with more favourable than unfavourable conditions. For example, a higher water table increases construction costs and flooding risks, while ease of access to cooling water reduces operating costs” [234].

Table 13 shows a sample process for site selection. Refer to Table 2 of Ref. [234] for a more detailed process.

As the site selection process tends to attract attention, especially once environmental evaluations are under way, strong expert and key stakeholder endorsement of the process should be sought before initiating any activities. Appropriate public participation and communication needs to be part of the siting process.

TABLE 13. SITE SELECTION ACTIVITIES

Key activity	Description and comment
Establish site selection scope	Document scope of site selection based on requirements of the owner/operator, NEPIO and government. These can include the number of units to be accommodated and their power output, any associated facilities such as nuclear waste treatment, disposal and interim used nuclear fuel storage facilities, any synergies and provisions for parallel or future projects, identification of contingency sites, regional economic development considerations and others. Expectations regarding future expansion should also be documented. In some cases site selection studies can commence in a generic manner that allows for the use of a site for any similarly sized generation technology (i.e. nuclear or conventional).
Define plant parameter envelope	Define a bounding set of requirements that characterize the type of facility designs that need to be accommodated. These can include the required land footprint, acceptable heat sinks (e.g. cooling towers versus once-through cooling), emergency planning zones, heavy component transport facilities needed, etc.
Establish exclusionary and discretionary criteria	Establish exclusionary and discretionary criteria along with weighting factors for use during site ranking.
Perform site surveys	Consider establishing or acquiring geographical information system capability to assist in collating and analysing geographical data. Perform site surveys to obtain sufficient regional and site specific information.
Rank sites	Rank viable sites that pass exclusion criteria filter. Incorporate detailed cost and risk estimations.
Approve rankings	Record the results of the site selection and have them approved by the necessary stakeholders/authorities.

6.3.3.2. Site evaluation

Site evaluation for a nuclear installation is a process to fully characterize the site specific conditions pertinent to the safety of the nuclear installation. It is to be confirmed that the applicable site does not place any undue requirements on any of the expected designs included in the enveloping criteria for the plant. This work needs to be completed prior to the start of Phase 3 to allow for confirmation of the site the proposed facility will be built on and to allow any site specific information and concerns to be transmitted to prospective vendors.

IAEA Safety Standards Series No. NS-R-3 (Rev. 1) [29] on site evaluation specifies the requirements to be met when evaluating site appropriateness. Acceptability is based upon:

(a) Establishment of an adequate graded quality assurance programme for the conduct of site evaluation activities;
(b) Establishment of suitable records;
(c) Provision for independent peer reviews;
(d) Need to take into account appropriate operational experience;
(e) Determining the probability and level of impact of external natural and human induced events that are likely to affect the nuclear installation;
(f) Determination of characteristics that define how the nuclear installation is likely to affect the site and surrounding region (nuclear safety impacts);
(g) Establishment of facilities required to monitor relevant natural and human induced events over the life cycle of the nuclear installation from the start of construction until the end of decommissioning.

The above requirements are typically incorporated into appropriate national legislation and regulations that stipulate requirements for nuclear site evaluations. Thus the legislation or regulations need to be in place prior to starting this process. Additionally, the licensee (typically the owner/operator) needs to have sufficient oversight in place surrounding the site evaluation activities (qualified individuals to review and accept evaluation reports, informed customer personnel, etc.) to adequately fulfil its nuclear safety responsibilities.

At the end of the process, IAEA Safety Guide SSG-12, para. 3.4 indicates that “the regulatory body should be involved in the decision as to the acceptability of the selected site and should have the authority to establish conditions for the site or to reject a proposed site on the basis of safety concerns” [189].

6.3.3.3. Land acquisition

This activity involves the acquisition of the land necessary to accommodate the NPP, its construction or laydown areas as well as any land requirements that may be necessary for the supply of services in and around the site. Planning for land acquisition will need constructability input to ensure that items such as temporary equipment storage, heavy load access (via land or water) and craning and lifting can be accomplished on the chosen site.

Like siting and evaluation, the process of purchasing or expropriating land for a nuclear facility is of high public interest. Current landowners and nearby residents need to be communicated with and treated fairly during the process. Early land acquisition is an important risk mitigation tool for any nuclear project. In some countries such a process can be performed even before site evaluation is completed. If a particular site fails the site evaluation process for a nuclear facility, the government or owner/operator can often repurpose the site for a non-nuclear facility.

6.3.4. Infrastructure and industrial involvement planning

As an NPP project is a large and complex project it invariably has a significant impact on the local community and national industry. This impact can significantly benefit the country and the local community. The project will also rely on the efficient involvement of local and national resources to participate effectively in the project. Various studies are required to understand what is required and plan any necessary interventions.

Guidance to the owner/operator may be given in the form of a national policy, legislation or regulations that may have to be complied with. The NEPIO and the owner/operator may have a joint role in establishing the industrial involvement plan. The plan needs to be finalized before procurement of the NPP is initiated so that any initiatives can be incorporated into the project’s BIS. The following steps should be considered:

- **Nuclear power industrial requirement study (ideally this should have already been completed for Milestone 1)**: Provides an understanding of what services and products are required for each phase of the facility life cycle, as well as the type of codes and standards required during project development, construction, operations and maintenance.
- **Industrial capability assessment (ideally this should have already been completed for Milestone 1)**: Assesses what local and national capability exists within the country to provide the above services and products, which companies wish to participate in the project and any required development enablers/imperatives.
- **Industrial involvement strategy and plan**: Establishes a strategy and identifies capability gaps. Develops a plan that identifies which products and services are to be contracted locally and which companies are to be targeted, and provides a plan to address any development gaps. Appropriate requirements need to be established and embedded in the project’s BIS and the overall project plan (refer to Nuclear Energy Series Nos NG-T-3.4 [16] and NP-T-3.21 [3] Section 3.6.2.1(e) for details).

As was discussed in Section 6.2 on Phase 1 activities, INIR missions [52] can help assess the national nuclear power infrastructure in terms of its readiness to support the owner/operator in performing the various project development activities. INIR missions can be held at the end of Phase 1 (initial and follow-up missions as required) as well as at the end of Phase 2 (see Section 6.3.2 for Phase 2 INIR information and IAEA Nuclear Energy Series No. NG-T-3.2 (Rev. 1) [233]).

6.3.5. Grid integration planning

For most countries introducing nuclear power for the first time, an NPP will normally constitute a large portion of the local generation capacity of a national grid. This, coupled with the effects that an unreliable or unstable grid could have on the safety of an NPP, means that significant modification and upgrading of the strength of the grid may be necessary for the successful operation of the NPP. Planned or unexpected shutdowns of a large NPP can also give rise to sizable frequency and voltage disturbances on the grid, challenging its stability. IAEA Nuclear Energy Series No. NG-T-3.8 [236] should be referred to for more information.

Grid planning studies are required to be performed in Phase 2 on a regional basis, potentially involving neighbouring countries. Since the final NPP design/technology is not confirmed until Phase 3, these studies need to be conducted using generic or bounding NPP design parameters. The studies will typically include:

- Long term load growth and planned generation studies;
- Site transmission integration studies;
- Outage planning of generation and transmission equipment;
- Grid stability studies under all operating conditions;
- National interconnection studies.

The project's engineering design authority needs to work with the grid planner/operator/regulator to develop a set of requirements that the NPP will need to fulfil in order to be successfully operated on the national grid. The requirements need to be ready for and incorporated into the eventual BIS for the NPP. These requirements should include:

- General grid specifications: frequencies, etc.;
- Grid management interface specifications: load following, frequency support, etc.;
- Requirements for the restoration of supply following outages, including any black start requirements.

Based on the results of these studies, a grid enhancement/improvement plan will need to be developed to accommodate the NPP. These plans will include details of the physical connection to the grid as well as any required physical enhancements or operational changes needed in order to achieve the necessary grid connection reliability so as to ensure the safe and reliable operation of the NPP. Financing and funding of these grid enhancements will likely need to be supplied by the grid operator, so these will need to be planned for well in advance.

6.3.6. Licensing

Obtaining nuclear, environmental and other licences or permits is a key part of any nuclear project. The steps to be followed are normally of great public interest and so stakeholder communication and public participation need to be carefully managed.

6.3.6.1. Establish independent regulatory body

Where one has not been established previously, an independent nuclear regulatory body needs to be established to guide and regulate the licensing process. In support of this, the government needs to establish an appropriate legal framework for nuclear safety, security, safeguards and civil liability for nuclear damage.

6.3.6.2. Nuclear installation site licensing

The objective of applying for a site licence by the owner/operator is to achieve a regulatory approval of the site for a particular design or envelope of bounding designs. If this is done in Phase 2 of the project it will reduce the project schedule risk and speed up the licensing process in Phase 3.

The regulatory body needs to establish the facility licensing system, define requirements related to facility design, construction and radiation protection, define processes for approvals of designs, and define any other regulations that will govern the facility.

Often separate licences are sought and granted for site preparation, NPP design and NPP construction. This can allow for some limited site activities to occur (e.g. site grading, road construction) prior to a choice of specific NPP technology having being made.

In the event that national regulations do not provide for a site licence application then a combined licence may have to be applied for later in Phase 3 of the project.

Site licensing activities can begin following the successful completion of site evaluation studies (Section 6.3.3) that confirm that the proposed site meets with all necessary nuclear safety and other established requirements. A regulatory framework for site licensing needs to be in place, as does a governance framework within the owner/operator's organization. Often this is documented in a licensing management manual that has work flows and a licensing plan accepted by the nuclear regulator.

This manual, much like the project management manual, gives personnel involved in the licensing process, as well as the regulator, an insight into the licensing process and into how the licensing basis for the project will be established and maintained. If the licensing process leads to applying for a site licence, this will typically occur towards the end of Phase 2. In this case the licensee will need to develop a working relationship with the regulator during this phase. The processes and procedures agreed to at this time will be documented in the licensing management manual and extended into Phase 3.

IAEA Safety Guide No. SSG-12 [189] covers the licensing process for nuclear installations and INSAG-26 [190] covers the licensing of a country's first NPP.

6.3.6.3. Environmental permits and licensing

Environmental assessments, permits and licensing processes can vary considerably among jurisdictions. For nuclear facilities, they can be regulated either by the nuclear regulatory body or via a country's environment ministry or environmental regulatory authority. For a country's first NPP new or changed processes for environmental permits and licensing may need to be developed and new laws may need to be passed by the government. These processes need to be in place to allow for the required assessments, permits and licensing to take place during Phase 2. This provides confidence to potential vendors as to any additional requirements to be applied in Phase 3.

A typical process involves establishing a baseline of the environmental condition of the site and its surrounding areas to enable future analysis of the effect of the NPP on the site, understanding and analysing all potentially significant impacts that the NPP could have on the site and its surrounding area, developing management and mitigation plans to minimize the potential impact of the NPP on the site, holding a series of public hearings on the subject and obtaining all necessary approvals. Future expansion on the site should be considered so that any environmental studies and approvals obtained at this time are binding (i.e. future uses are incorporated).

IAEA Nuclear Energy Series No. NG-T-3.11 [192] covers the environmental assessment process for new nuclear power programmes.

6.3.6.4. Other permits and licences

Other non-nuclear government agencies may have specific permits or licensing requirements related to a nuclear facility. These can include agencies like those responsible for waterways, building, electrical or plumbing codes, occupational health and safety, national standards organizations, pressure boundary practices, trades qualifications, transportation, chemicals, labour laws (including those applicable to the use of foreign labour), etc.

A process needs to be followed to identify the applicable codes and standards that apply to the facility, interface with the responsible organizations to confirm what their impacts will be on the project and document these impacts for inclusion in the project's BIS. In some cases, memorandums of understanding between different agencies may be needed or a lengthy process to make changes to long standing regulations or to develop new regulations may be needed to facilitate construction of the facility. Conflicting requirements between different agencies may need to be resolved.

6.3.7. Procurement

6.3.7.1. Procurement of services and planning in Phase 2

The project organization will need to subcontract certain activities or services during Phase 2 and prepare itself to negotiate a contract for the facility in Phase 3. All necessary planning for this subcontracting should be established (see Section 4.10), with special attention and oversight given to safety related procurement activities.

The IAEA's Nuclear Energy Series No. NG-G-3.1 (Rev. 1) [1] on the Milestones Approach indicates that during Phase 2 it is important to

> "develop the capability to procure required services for pre-project activities (e.g. environmental impact assessment, siting and consulting), in particular:
>
> — To ensure suppliers have appropriate expertise and experience;
> — To prepare formal specifications for the services required;
> — To include quality standards in the service specifications."

IAEA Nuclear Energy Series No. NP-T-3.21 [3] on procurement covers many details on good practices to follow in the establishment of contracts, including the oversight of safety related purchases, supplier assessment and qualification, producing specifications and addressing various quality standards.

6.3.7.2. Procurement strategy development

In preparation for the bidding process and contract negotiations in Phase 3, the owner/operator needs to carefully plan its approach during Phase 2. The first step of this is defining a procurement strategy for the purchase and applicable processes and procedures to manage the procurement.

Development of a procurement strategy requires that the owner/operator:

- Identify any constraints related to the procurement (e.g. legal, regulatory or other constraints, including any international trade agreements and treaties or local labour agreements as applicable).
- Define and document an overall procurement policy (e.g. commitment to fair, equitable, transparent, competitive and cost-effective procurement and the promotion of any secondary procurement policies; consider ISO 10845-1 [237] as a basis for sustainable procurement).
- Define implementing processes for the procurement (bid invitation and evaluation). IAEA Nuclear Energy Series No. NP-T-3.21 [3] provides some useful models for procurement and major contract approaches.
- Define risk management processes (update of risk management planning; performing international benchmarking and lessons learned for major projects).
- Perform market analysis (e.g. analysis of the supply market for the facility/product to be purchased; market survey for potential technology to be applied; and track record and order book of proposed vendors).

  Note that for large projects, this knowledge acquisition phase can be one of the most important steps in the overall process. Most people have not run a major/mega project/programme from start to finish, and potential NPP owner/operators may not have experience in running major projects. Thus, visiting other major/mega projects in both the nuclear and non-nuclear sectors is essential learning for a project team. Visiting the different job sites of the specific contractors that have shown interest in your project and asking for approval to speak directly with the owners of those projects is considered good practice. Also recommended is looking for independent indications of contractor performance (e.g. from safety associations, government ministry reports, trade journals, benchmarking sources).

- Obtain preliminary business case approval to fund the steps of the procurement process up until the final investment decision is made. Such a business case will need to justify why the project is important, and obtain 'buy-in' from senior decision makers as to the steps that will be followed, their cost and any risks involved with the process.

  At this stage a firm fixed price for the entire project is not practical. A good practice for estimating is to use a cost range based on project uncertainties and not a specific number. This can prove extremely important in obtaining funding and in explaining any future changes. With no detailed engineering completed it is not possible to provide a complete cost and schedule to complete a specific project. Detailed engineering needs to be completed, and significant planning for construction execution and all major procurement needs to be done.

- Decide on a contracting and financing approach (inputs can include the site specific detailed feasibility study [12], potential suppliers (including fuel suppliers) and partnership models, electricity market agreements and others. See Section 4.4 of this publication).

  In some locations, off-take agreements can include the supply of services such as process heating and desalinated water in addition to the usual supply of electricity.

  The owner/operator will need to engage with potential equity partners, financiers and credit insurance organizations in preparation for the securing of the required financing arrangements. Any necessary due diligence processes will need to be completed. Note that potential equity partners and financiers are often associated with particular NPP suppliers, or at least originate in the same country. As such they need to be considered in tandem with the main plant supply agreements.

  The cost of financing is largely linked to the project's risk profile. Incomplete projects under construction invariably have a larger risk profile than those facilities that have entered a more predictable mode of operations and maintenance. It is often possible and desirable to renegotiate or even refinance a facility once it is commissioned. Some consideration can be given to this when arranging financing.

  Financing is discussed in detail in IAEA Nuclear Energy Series Nos NP-T-4.1 [46] and NP-T-4.2 [47].

- Develop a procurement strategy to establish the approach to be taken (e.g. open tendering versus selective tendering, grouping of packages, compulsory or optional requirements, scope offerings) and risk approaches. Further detail on procurement strategies is in IAEA Nuclear Energy Series No. NP-T-3.21 [3]).
- Develop detailed procurement procedures to cover all downstream activities (e.g. bid evaluation, negotiation and contracting, contract management, administration and procurement document handling).

6.3.7.3. Procurement preparation

This section describes a typical process for establishing the owner's (customer's) requirements for the particular project, determining evaluation criteria and turning over this documentation to the procurement or supply chain organization to run the actual bidding process with potential suppliers.

A large and complex set of procurement documentation is needed at this stage. This forms the basis for the contractual relationship between customers and suppliers of goods or services. It includes such items as procurement plans, requests for proposals, requests for information, requests for quotations, BISs (including owner's requirements) and evaluation criteria. It will be supplemented later by bids or proposals from suppliers (including such items as specifications, drawings, bills of quantities, etc.), contract documents, any amendments or modifications, and then later on contract closure documents.

An example of a process to follow is:

(a) Identify stakeholders, interested parties and team members

As was discussed in Section 2.3.1.1, proper stakeholder involvement is key to a large project such as a new NPP. A cross-functional sourcing team should be set up to ensure that all pertinent requirements are met. The team assists in developing the contract strategy, with a pre-qualification questionnaire and tender evaluation, and the ongoing activities of contract/supplier management once the contract has been signed. This team will typically report to a steering committee of senior executives who can help provide overall project direction.

Advantages of a cross-functional sourcing team include:

- Ability to draw on cross-functional expertise within the group;
- Ensures stakeholder views are considered in the decision making process;
- Helps establish clear communication channels;
- Presents 'one face' to suppliers;
- Formalizes governance arrangements and identifies decision makers;

- Clarifies roles and responsibilities;
- Facilitates generation of ideas;
- Facilitates organizational alignment, buy-in and compliance.

Procurement and contracting for the establishment of a large nuclear facility is a specialized activity that is not often performed by any particular organization. It involves specialists in the areas of nuclear engineering, contract management, construction management (experience from lessons learned), insurance, financing and electricity market funding, among others. Consequently, the necessary teams, specialist functions and resources required to prepare the contracts and agreements need to be contracted or secured and initiated onto the project team.

(b) Develop process evaluation criteria

An important part of the bidding process is the development of pre-qualification criteria and final bid evaluation criteria. Both technical and economic criteria are needed, and the relative importance of each criterion needs to be defined (often through criteria weightings). Different jurisdictions and projects can have substantial differences in the drivers for their projects (including different secondary procurement policies), so a single set of criteria cannot satisfy every project. An evaluation criteria guide, available in the Nuclear Contracting Toolkit[15], provides several examples that have been used on different nuclear projects.

(c) Develop and approve BIS

Section 4.1.4.3 discussed the establishment of requirements as being a key activity for any project and for nuclear facilities in particular. In preparation for the bidding or negotiation process the owner needs a documented complete list of the requirements for the facility.

The BIS is designed to contain all information that bidders need to prepare their bids. Its development will rely on much of the previous work done on the project, but will be updated to the most up to date status, and thus be the sole document that vendors will rely on in preparing their formal bids. Any specific owner's requirements for the project (see Section 4.1.4.3) need to be clearly defined in the BIS.

Given that many top international vendors are well established and able to offer comprehensive packages including an NPP, nuclear fuel supply, financing and possible equity participation, these may all need to be solicited in one procurement process. IAEA Nuclear Energy Series Nos NG-T-3.9 [48] and NP-T-3.21 [3] should be referred to for more information.

Section 3 and appendix IV of NG-T-3.9 [48] provides information on the content of a typical BIS.

(d) Formalize procurement plan

Once project requirements have been fully defined in a BIS, the procurement organization can begin implementing the formal procurement process. To help ensure clarity for the procurement organization, it is good practice to collect all project requirements into a procurement plan document, and have it approved by the responsible senior executives. Such a document could contain, for example, the following sections (adapted from NP-T-3.21 [3]):

(1) Introduction (purpose, background, objectives);
(2) Scope of procurement and exclusions;
(3) Options considered (contract options, available suppliers, etc.);
(4) Recommended procurement approach;
(5) Interfaces and communications with vendors;
(6) Procurement plan;
(7) Schedule;
(8) Milestones;
(9) Key assumptions;

[15] See https://www-legacy.iaea.org/NuclearPower/Infrastructure/NuclearContractingToolkit/procurement/criteria.html

(10) Roles, responsibilities and resources;
(11) Risks and mitigative actions;
(12) Evaluation process and scorecard;
(13) Oversight, auditing and fairness monitoring.

The procurement plan builds upon but does not repeat previously prepared documentation such as a project's business case or project management/execution plan. Procurement plans provide the methodology and approach, process and project management structure for the implementation of cross-functional procurement activities.

Following approval of the procurement plan document and its handover, the procurement organization can begin its formal activities to solicit bids for the project.

6.3.8. Radiation dose and radioactive waste management

Plans for managing radiation dose during construction, commissioning and later facility life need to be developed. These can include such items as a national dose registry, processes for radiation protection, personal protective equipment standards, dose planning procedures and others.

A strategy is needed for the handling of spent fuel and radioactive waste from the facility. Typically the national government will take the lead on national planning for disposal, including identifying the specific policies to be followed, the funding requirements and the particular responsibilities of various organizations.

The owner/operator needs to be aware of this strategy and incorporate information into the proposed BIS that reflects the strategy and its own requirements for the proposed vendor to minimize the volume and toxicity of radioactive waste that may need to be disposed of. It also needs to begin planning any specific processes or procedures necessary to handle waste once the facility begins operation. Public communications efforts are vital in this area.

6.3.9. EPR

The national government and the owner/operator need to work together on planning the necessary EPR arrangement for when the facility goes into operation. The government will need to define the responsible organizations and national coordination mechanisms, and establish any necessary regulations.

Requirements related to EPR that impact on the facility contract (e.g. requirements for specific on-site facilities, communications systems) need to be identified within the BIS.

6.3.10. Security and safeguards

The national government, regulatory body and owner/operator need to work together on planning the necessary security arrangements for when the facility goes into operation. The government will need to define the responsible organizations and national coordination mechanisms, and establish any necessary regulations. Security arrangements include development of the design basis threat that security systems need to counteract, requirements for physical protection (which may impact on facility design), requirements for incorporating safeguards systems within designs, programmes for the management of sensitive information, security clearance of personnel associated with the project and promotion of a nuclear security culture.

Requirements related to security and safeguards that are relevant to the facility contract (e.g. requirements for specific on-site facilities, communications systems, safeguards measures) need to be identified within the BIS.

6.4. PHASE 3 (CONTRACTING AND CONSTRUCTION)

Phase 3 consists of inviting bids/negotiating a contract for the NPP and then constructing the actual facility. During this phase of the project, the owner/operator will need to engage with all necessary stakeholders, regulators and key contractors to negotiate and draft all of the agreements required to move the project into execution, to obtain necessary licences and permits, to obtain final investment approval and to manage the actual construction. Various teams, specialist functions and resources will be required to be recruited and mobilized.

The NEPIO and other government organizations will continue to have a role during this phase to support any national infrastructure development initiatives and to oversee the ongoing national programme.

Table 16 in Appendix VI details the high level activities for this phase as identified in the IAEA's Nuclear Energy Series No. NG-G-3.1 (Rev. 1) [1]. The milestones do not, however, identify a typical sequence of these activities, nor provide further guidance on how to perform such activities. The following sections are designed to provide assistance in these areas.

It is necessary for the owner/operator to perform detailed planning for this phase and to revisit the high level project life cycle plan. As the establishment of the initial project plan was dealt with extensively earlier in Section 6.3.1.6, this section will only highlight the key areas that are required for Phase 3.

The IAEA Nuclear Contracting Toolkit[16] provides a framework model for navigating a major nuclear contract process. It includes the steps of:

- Strategy development;
- Procurement preparation;
- Bidding and evaluation;
- Negotiation and contracting;
- Contract management;
- Lessons learned.

Necessary project management activities and each of these steps of the contracting process will be discussed in turn in the following sections.

6.4.1. Project management activities

6.4.1.1. Planning for Phase 3

The completion of the project development activities in Phase 2 and the start of Phase 3 provides an opportunity to review and update the overall project strategy that was drafted at the beginning of Phase 2. At this stage emphasis will be placed on the following:

- **Siting**: At this time any outstanding permits, land acquisitions and studies may need to be identified and flagged as risk items and appropriate mitigations put in place. During Phase 3 all site licensing and approval processes need to be completed, baseline measurements of the site need to be taken and ongoing monitoring of the site needs to commence.
- **Stakeholder involvement**: With the transition from Phase 2 to Phase 3, the comprehensive strategy compiled for Phase 2 should be updated with a focus on the various engagements that will be initiated throughout Phase 3. This should include public involvement in the licensing process.
- **Licensing**: During Phase 3 the appropriate construction and operation licences need to be applied for and approved by the regulatory body. The preliminary licensing strategy established at the beginning of Phase 2 should be updated with the final plan for the nuclear site licence application. The plan is needed by prospective NPP vendors prior to bidding to allow them to provide accurate proposals.
- **Industrial involvement**: A detailed industrial involvement strategy is needed that identifies any requirements for technology transfer, supplier development, local content, etc. that will be placed on the prospective facility vendor. Any industrialization legislation, regulations or other binding requirements applicable to the project need to be finalized, with their implications integrated into the project plan. Refer to Ref. [16].

Approval to proceed with Phase 3 activities (preparing for contracting and eventual construction) is typically based on a number of assessments as described in Table 14. A subsequent project approval gate will be described later in Section 6.4.2.3 for the final investment decision.

[16] See https://www-legacy.iaea.org/NuclearPower/Infrastructure/NuclearContractingToolkit/index.html

TABLE 14. TYPICAL ITEMS TO BE ASSESSED FOR APPROVAL GATE THAT ALLOWS PREPARATION FOR CONTRACTING

Item	Comment
Project status report	Project status report of previous phase activities. This information will need to be made available to various stakeholders in various forms.
National nuclear power infrastructure development	The national nuclear power infrastructure should have achieved Milestone 2. If the NPP is to be constructed in a country new to nuclear power then the owner/operator should consider working in conjunction with the NEPIO to host an INIR in line with the IAEA's Milestones Approach for Milestone 2. This will ensure that the national nuclear power infrastructure is assessed in terms of its readiness to support the owner/operator in moving the project into Phase 3. Any recommendations raised during the INIR review should be closed or appropriately mitigated.
Assess project status	Assess the completeness of development work to achieve the established governance and phase gate requirements. Ensure that risks associated are flagged and appropriate mitigations put in place. Review organizational performance and correct any deficiencies for the next phase of the project.
Project feasibility	The overall feasibility of the project is reviewed to ensure that it is in line with the owner/operator's objectives. As the next phase of the project will involve the participation of numerous stakeholders and potential vendors in the preparation of contracts the owner/operator should have a strong degree of confidence that a final investment approval can be achieved.
Project plan	Project plan assessed to ensure that it is adequate and that if approved it would achieve the specified objectives for the next phase of the project. The project plan should establish a baseline against which performance can be measured.
Budget and resources for the next phase	Secure and release funding and resources for the next phase of the project.

Following review and assessment of the above items, the project would receive approval to proceed to the contracting stage. Key activities that would be progressed in parallel with the actual contracting process (which is described in Section 6.4.2) are described in Sections 6.4.1.2 to 6.4.1.5.

6.4.1.2. Finalizing project requirements

The BIS for the project that was prepared in Phase 2 (see 6.3.7.3) should be confirmed as complete and be ready to proceed to the formal bidding stage. A complete set of requirements is necessary at this point because following contract signature the cost of introducing new or changed requirements is most likely to fall to the owner/operator.

6.4.1.3. Detailed project planning

Detailed project planning is essential for Phase 3. Project plans developed in Phase 2 need to be updated and expanded to include the specific activities required in Phase 3. The initial focus will be on the contracting part of this phase, but eventually, to enable a final investment decision, a comprehensive project plan that includes construction and commissioning will be necessary.

In addition to planning for the detailed design and construction phases, in order to avoid future disputes, responsibilities for the various phases of commissioning should be explicitly addressed at this time. This would include identifying commissioning milestones and plant handover points.

Table 17 in Appendix VII.1 identifies some of the key activities that need to take place at this point. The items to be managed, as identified in Section 4, should be updated with the best available in-depth information. Project planning for the immediate next steps (the contracting process) needs to be done at a detailed level. At this point, the owner/operator has the opportunity to engage and negotiate with all necessary key vendors and stakeholders. These key vendors and stakeholders can offer essential information on the revising of the project plan.

6.4.1.4. Licensing

Nuclear licensing activities in Phase 3 initially focus on receiving regulatory approval of the preliminary safety analysis report (PSAR) for the prospective design, along with, potentially, other required licensing documents. If this is completed early in Phase 3, the owner/operator will have a good understanding of the relative ease of licensing the selected design before the major construction contracts are committed.

The PSAR for the NPP thus needs to be finalized, with any design requirements such as site integration and customized design elements that could affect nuclear safety incorporated into the design and the PSAR. Any site specific requirements and additional design features (see Section 4.1.4.3) will need to be incorporated into the design before the preliminary safety case is ready for review.

Development of the PSAR by the owner/operator requires the establishment of the licensing management function within the owner/operator organization and the developing of a comprehensive licensing plan. In some Member States the nuclear regulator may approve the plan. Any applicable processes and governance (such as a licensing manangement manual) need to be in place. Codes and standards to be applied for the project also need to be accepted by the regulatory body. This also applies to the design adaptation needs. A graded approach may be beneficial in aiding the review process but it has to be acknowledged that contractually all documentation may be subject to litigation.

Since the owner/operator carries the prime responsibility for the safety of the NPP, it is also responsible for overseeing the development and review of the licence documentation and supporting information for the application process. The majority of this documentation is normally produced by the vendor, the main contractor or/and the main designer organization. However, to exercise its responsibility for safety, the owner/operator needs to take full ownership of the documentation and review and approve it before submitting it to the nuclear regulator.

In order to review and approve the large number of documents required, the owner/operator has to develop and implement a controlled process. Good planning is thus necessary. The competence and thoroughness of the owner/operator in assessing the preliminary safety case and in establishing project oversight requirements will contribute to the efficiency of achieving licence approvals through the nuclear regulatory authority.

It is often not necessary or desirable to wait until contracts are signed before significant progress is made in reviewing the various constituents that will make up the safety case. Although these activities are to some extent conducted at risk to the owner/operator, they can be initiated as soon as the likely or preferred key NPP vendor or vendors are known. A well informed, intensive early review should allow for a significant lowering of the overall project risk. If possible, the nuclear regulator should also be requested to participate as early as possible in the process.

The regulators in some countries make provisions for NPP vendors to seek design assessments and authorizations directly with the regulator. This is often not possible in States new to nuclear power, given that extensive regulatory resources are often required for numerous applications. A gap analysis should be performed and a licensing issue register compiled to address any key or outstanding issues that will be needed to prove the integrity of the design.

Following acceptance of the design's safety case, a formal nuclear installation (e.g. construction) licence will need to be applied for as per the process established by the national nuclear regulator. In many cases this can precede the final investment decision and the signing of the contract with the NPP vendor.

Environmental licensing or approval processes will also need to process during this period.

6.4.1.5. Early site preparation

In many nuclear projects early site preparation activities are initiated by the owner/operator in advance of a formal contract with a facility vendor. These can include clearing land, relocating affected communities if necessary, establishing roadways and other transport access, establishing initial site services (e.g. water, electricity, sewage) and others. Baseline environmental data can also be collected at this time. The scope and extent of these activities is typically governed by a site preparation licence provided by the nuclear regulator.

6.4.1.6. Long term preparation for future commissioning and operations

Development of human resources and specialized processes for commissioning and operations activities in Phase 3 is a lengthy process. A key role of the owner/operator is to ensure that all of the required resources are available to support these activities when they become needed. This requires an extensive programme of key staff selection, development and qualification. Thus, at the beginning of Phase 3, even while preparing for the contracting and construction process, the owner/operator needs to begin to develop the specialist expertise to support commissioning and operations activities. Table 18 in Appendix VII.2 details some of the functions and expertise that need to be developed.

6.4.2. Contracting

6.4.2.1. Bidding and evaluation

Bidding and evaluation is the process of selecting prospective suppliers to which a bid or tender proposal will be sent, soliciting tender proposals from these prospective bidders, evaluating the proposals against defined criteria, and then ranking the proposals to identify a preferred bidder. Contract negotiation follows at the conclusion of this process.

Note that the terms ‘bid’ and ‘tender’ are often used interchangeably in a contracting process. A bid more accurately refers to the supplier submission, while a tender process is more typically used by the procurement side (the buyer).

For sole-source bidding processes, such as those involved with inter-governmental agreements, the supplier selection process is essentially pre-determined. However, owners are recommended to undertake a process of evaluating vendor proposals against their own particular requirements (e.g. cost, scope of work, owner requirements, contract terms and conditions), to ensure that they obtain what they consider an acceptable proposal.

- Supplier selection

Selection of potential suppliers for a large project is an important step, and needs to be given sufficient time and attention. NPP vendors may partner with different sub-suppliers for different projects, and need sufficient notice periods to make necessary arrangements for such partnerships. This includes meeting any owner pre-qualification requirements.

Some jurisdictions require formal notification periods or processes to initiate contracts above a certain value. Formal notice of an upcoming contract maximizes the chances that a sufficient number of competent, financially sound suppliers with adequate capacity to undertake the work will be identified, and that those identified have adequate time to prepare internally for the bidding process.

Vendor prequalification helps ensure that the potential vendor has the financial and technical competence and resources to complete the defined project and can meet all national regulatory requirements. The process looks extensively at past and current nuclear and non-nuclear projects executed by the vendor and its consortium partners. Previously proven vendor experience is a key indicator for successful project management and as such should be a key consideration.

An evaluation panel typically will assess responses to the pre-qualification questionnaire in accordance with the scoring methodology that was drawn up in advance of publishing the contract notice. Results of the scoring will be used to select the suppliers who will be formally invited to bid on the project. As this stage of the process supplier suitability is being assessed on the basis of such things as business probity and criminality, technical and professional ability and economic and financial standing.

- Invitation to tender

This stage involves delivering the tender documents to the prospective suppliers, and managing the process until the proposals are received back from the vendor and opened. It is important to maintain fairness and transparency during this stage, particularly when providing information to suppliers at meetings and/or following questions on the bid documentation. Guidance on conduct for the tendering process is included in the Nuclear Contracting Toolkit[17] and Nuclear Energy Series No. NP-T-3.21 [3].

- Evaluate and rank bids and identified preferred proposal

Bid evaluation is a key stage of the procurement process. The process should ensure that the contract award decision is objective, the decision making process is fair, transparent and auditable and the purchaser can demonstrate best value in the tender process. Following bid evaluation the proposals are ranked and a preferred bidder is identified.

Guidance on the bidding process is included in the Nuclear Contracting Toolkit[18] and IAEA Nuclear Energy Series Nos NP-T-3.9 [48] and NP-T-3.21 [3].

6.4.2.2. Negotiation and contracting

This stage involves sitting down with the highest ranked or sole-source bidder and attempting to finalize a mutually agreeable contract.

The owner/operator needs to negotiate and draft all necessary agreements or contracts in preparation for the construction of the NPP. These would be in conformance to the established contracting strategy and procurement plan as well as any relevant national legislation, regulations and international obligations and treaties. The project management team leads this activity with the support of procurement and contracting specialists. Often the highest company and sometimes even State level decision makers are involved in the later phases of the process to sign the contract.

The implications of the preferred bid for the viability of the proposed project need to be evaluated at this stage. This typically involves updating of the business case for the project with the final evaluated cost, schedule and risk management data.

6.4.2.3. Final investment decision/obtain approval to proceed to the construction stage

At this phase of the project, the owner/operator makes the key decision on whether or not to invest in the project. A final assessment of the readiness of the project is made in the context of the maturity of the national infrastructure, it is ensured that any required risk mitigation steps are in place and a decision to award the major construction contract is made. Given the level of the commitment made following the contract award, it is often not possible to opt out of the project without a significant financial penalty once this investment approval has been made.

As stated in Section 6.4.1.4, detailed project planning for Phase 3 construction activities needs to take place to support the investment decision. Project plans developed earlier need to be updated. The focus at this point is on construction and commissioning activities, with the goal of producing a comprehensive project plan for field execution. Responsibilities for the various phases of commissioning need to be explicitly addressed, with commissioning milestones and plant handover points being identified, at least at a high level.

Table 19 in Appendix VII.3 identifies some of the key activities that need to take place at this point. The items to be managed, as identified in Section 4, need to be updated with the best in-depth information available. Project planning for the immediate next steps (the construction phase, which includes detailed design and component fabrication) needs to be at a detailed level. At this point, the owner/operator has the opportunity to engage and negotiate with all necessary key vendors, manufacturers and stakeholders.

At this phase of the project a mature business case needs to be completed that demonstrates the relative feasibility of the project given the costs and supply agreements that have been negotiated with all relevant parties.

Assuming the updated business case still shows the project as viable, the bid evaluation team will prepare a contract award recommendation report. The report and the updated business case can then be forwarded for approval by the appropriate purchasing authorities and the final investment decision made to award the contract to the successful bidder.

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[17] See https://www-legacy.iaea.org/NuclearPower/Infrastructure/NuclearContractingToolkit/bid/invitation.html

[18] See https://www-legacy.iaea.org/NuclearPower/Infrastructure/NuclearContractingToolkit/bid/index.html

6.4.2.4. Award contract

Once all necessary approvals have been obtained and the necessary funding and financing agreements are in place, the NPP supply contract is awarded. Successful and unsuccessful bidders need to be informed and debriefed. In some jurisdictions an enforced 'hold period' is necessary after contract award to allow for potential legal challenges by unsuccessful bidders.

6.4.3. Construction (contract management)

This stage includes all activities from the award of the contract to its closeout. It involves the formal governance of the contract and changes to contract documentation including:

- Maintaining documentation relating to the contract;
- Providing owner oversight of manufacturing and construction activities;
- Regulating change control;
- Monitoring charges and costs;
- Checking invoices and authorizing payments;
- Reviewing reports and requesting information;
- Asset management.

6.4.3.1. Post-contract award activities

Following contract award some key initial activities need to take place. Major project integration documents (e.g. project charter, life cycle management plan, project management plan, licensing plan, staffing plans, industrial involvement strategy), the project schedule and other items may need to be updated based on the signed contract. Strategies associated with the nuclear fuel cycle (front end and back end), nuclear waste management and decommissioning and site remediation may also need to be updated based on the signed contract.

A project kick-off meeting and initial 30/60/90 day plans can assist in getting the project off to a rapid start.

The owner/operator with the support of the vendor will need to prepare all documentation required for obtaining the necessary nuclear and environmental licences. The regulatory body will be involved with any final design and safety analysis reviews and be in a position to issue construction and operation licences at the appropriate time. The vendor will need to finalize and issue site specific design information, commence procurement of the materials and equipment needed for the project and do detailed planning for its project activities. Integration of the various organizations' communications, scheduling and reporting systems needs to be achieved promptly. Owner/operator oversight of vendor and sub-supplier activities will need to commence, as will a ramping up of owner/operator staffing levels.

When appropriate, the construction site will need to be formally transferred over to the control of the successful vendor, and owner oversight of construction field activities begins. A CORR [51] that assesses the contractor and owner/operator in terms of their readiness to proceed with the construction phase can be considered at this time.

As construction proceeds, owner/operator and regulatory oversight functions (e.g. inspections, audits, surveillance) will take place, and in preparation for fuel loading, security and safeguards systems, processes and facilities will progressively be placed into service.

6.4.3.2. Managing the contract

Owners need to provide the necessary resources to successfully manage the agreed contract. The role of oversight is to ensure that the contractor is safely executing the project to the necessary quality standards, at the negotiated cost and on the agreed schedule. This includes managing owner commitments, such as ensuring sufficient resources and priority is applied to owner reviews of supplier deliverables.

Audit rights for the owner to access supplier workplaces, documents, personnel and records in order to manage the contract need to have been established as part of the contracting process (BIS and/or other contract terms) or they may become the subject of disputes. During contract execution they need to be regularly and fully exercised or they will effectively be lost.

Contract management is an often overlooked area for inexperienced organizations. If not taken seriously, contractors may utilize unclear contract terms, precedents set early in the contract's life, or unclear responsibilities between separately negotiated contracts, to make claims for unexpected 'extras', 'delays', 'unanticipated conditions' or other charges. Owners that do not take sufficient care in contract management can find themselves liable for many of these claims.

Guidance on contract management is included in the Nuclear Contracting Toolkit[19] and IAEA Nuclear Energy Series No. NP-T-3.21 [3]. IAEA Nuclear Energy Series No. NP-T-2.7 [2] provides detailed guidance on managing NPP construction. A Construction Readiness Review Service [51] is available from the IAEA that can help assess the readiness of an organization to proceed to this construction phase.

6.4.3.3. Activities of external organizations during construction

Various organizations external to the project team continue to have important roles to play during the construction period. These organizations include the national government, the NEPIO, the regulatory body, the grid operator, EPR organizations, the IAEA Safeguards Department and others. Details of their tasks are included in Table 16 of Appendix VI; examples include ensuring that international legal instruments are implemented, verifying that the safeguards infrastructure is in place, making sure that staffing for external emergency response organizations and the nuclear regulatory body is in place, and testing of off-site redundant power supplies. The project organization needs to track and expedite these as required to ensure that they do not impact on the construction and commissioning schedules.

6.4.4. Lessons learned

Effective lessons learned programmes (see Section 4.12) within nuclear organizations facilitate the continuous improvement of processes and procedures. They play a vital role in KM. For procurement and contracting, lessons should be captured at each process stage and fed back to the responsible parties so that mistakes are not repeated and improvements can be made for the next project. Typically for large capital projects such as NPPs, a formal strategic/high level post-implementation review (PIR) is conducted approximately 6–18 months after completion of the contract. The PIR is to ensure that business case objectives and project benefits have been achieved and that lessons learned have been captured for the organization.

Lessons are not learned until something changes in the way an organization operates. The challenge is that the individuals observing the lessons are often not the individuals needing to make the change. High performing organizations embrace the concept of continual improvement, and are in a constant state of lesson feedback and process improvement. Lessons learned are widely made known within the organization and externally, and a 'no blame' culture exists that encourages the reporting of issues, lessons and recommended corrective actions. Corrective action programmes play a key role in documenting and facilitating lesson feedback and improvement in nuclear organizations. To be successful, top management should give lessons learned programmes visibility, support and encouragement.

6.5. COMMISSIONING, OPERATIONS AND DECOMMISSIONING

6.5.1. Commissioning phase activities

The contract management and oversight functions and activities that were described in Section 6.4 will continue over into the commissioning phase of an NPP project, since the facility will not be considered fully complete until it has been formally commissioned and applicable documentation turned over. Commissioning for NPPs is discussed in IAEA Nuclear Energy Series Nos NP-T-2.7 [2] and NP-T-2.10 [219] and IAEA Safety Standards Series SSG-28 [238]. Data needs related to commissioning and operations are discussed in IAEA Nuclear Energy Series No. NP-T-3.21 [3].

[19] https://www-legacy.iaea.org/NuclearPower/Infrastructure/NuclearContractingToolkit/manage-contract/index.html

Key project management activities related to the commissioning phase include planning for the specific commissioning steps and managing the stepwise turnover of buildings, systems, equipment and related documentation from the construction organization to operations control. Some critical success factors for commissioning and startup include having good project integration, leadership, collaboration, team alignment, planning, capability and support tools [239].

The CII has published several guides related to planning for startup of construction projects, including two implementation resources [240, 241].

6.5.2. Contract closeout

Contract closeout is an often overlooked aspect of contract administration. The closeout process ensures that the work agreed to has been successfully completed, that the contractor has been paid, that any owner material, tools and equipment have been returned by the contractor, and that there will be no future claims under the contract for additional payments. Checklists are a common tool for organizations to ensure that their particular requirements have been met. Evidence that each requirement has been met is typically required for and included in the contract closeout file.

Some specific activities designed to be included in the contract closeout process (adapted from the Chartered Institute of Procurement and Supply (CIPS) [242]) are listed below. The confirmation of transfer of assets such as documents and intellectual property is especially important for nuclear facilities.

- Ensuring completion of all administrative matters;
- Recording that all technical issues have been completed;
- Determining the extent of any liquidated damages to be deducted from the contract price;
- Recording the end of the retention and guarantee periods and the date of the final inspection;
- Recording the date of release of retention and/or bank guarantees;
- Agreeing to a statement of specific limits on continuing contractual obligations after completion of work and any ongoing obligations following the end of guarantees or maintenance periods;
- Recording any materials reconciliation;
- Transferring any assets, including data and intellectual property, and any loan items;
- Transferring operational systems to the successful supplier;
- Recording the process of final contract payments and a summary of the financial payments made and received;
- Summarizing claims made against or received from the supplier;
- Ensuring the retention of records relating to the contract to counter any subsequent claims that may be brought.

6.5.3. Operations and decommissioning

New projects will continue to be initiated during the operations and decommissioning phases of a nuclear facility's life. Whether they will be for routine minor modifications, life extensions, refurbishments or the decommissioning process itself, such projects will benefit from following acknowledged project management principles such as those described in the previous sections of this guide.

Various aspects of decommissioning are discussed in IAEA publications such as IAEA Safety Standards Series No. GSR Part 6 [4], IAEA Nuclear Energy Series Nos NW-T-2.5, NW-G-2.1 and NW-T-2.7 [5, 6, 243], Technical Reports Series Nos 399 [244] and 411 [245], TECDOC-1394 [246], TECDOC-1476 [247] and TECDOC-1702 [248].

The CII discusses renovation and revamp projects, which are typical in operating nuclear facilities, in Refs [249–252].

7. SUMMARY AND CONCLUSION

Project management is essential to the success of nuclear projects, and the requisite skills needed may not be present within organizations particularly in cases where the organizations are embarking on their first large nuclear projects. Owner/operators need to learn from others and train and develop their staff in project management best practices so that they have the necessary skills and experience.

The list of areas to be managed as part of a nuclear project is large, and the time frame commitment in particular for a new nuclear facility runs into decades. Efforts spent on FEP and project development will pay off many times over during project execution. Many projects, both large and small, have had cost, schedule or quality issues when they proceeded into their detailed design and construction phase with low project definition.

Owner/operators need to work on developing a robust framework for nuclear project management at the earliest stages of the project life cycle. Oversight of vendor activities is crucial. The project management framework needs to be integrated into the organization's corporate management system. It should reflect and incorporate lessons learned from other nuclear and non-nuclear projects and should include and adapt international project management best practices based on local knowledge and experience.

Appendix I

NPP OWNERSHIP STRUCTURES AND INDUSTRIAL INVOLVEMENT SCHEMES

This appendix describes several NPP ownership models and industrial involvement approaches that have been used. They can be considered when developing a suitable strategy for NPP development within a country.

- **Nationally or regionally affiliated owner/operator and NPP vendor**: This model is common in some mature nuclear power countries that possess established owners/operators and NPP vendor(s). These organizations may be either privately or publicly owned. These entities often work together to develop and plan the NPP project. Such development activities are often undertaken at risk to the owner/operator and NPP vendor, as they will normally only conclude key project contracts early in Phase 3. This model has several strengths, which normally include the strong backing of the owner/operator and vendor by the State. Cost effectiveness can be an issue, since other vendors may not be in a strong position or be allowed to bid on the work.
- **Nationally or regionally affiliated owner/operator and appointed NPP vendor**: In this model the State identifies an owner/operator that seeks to appoint an NPP vendor early in Phase 3 of the project. The owner/operator is identified at the beginning of Phase 2 to manage the project development activities required during this phase. The completion of all necessary project development activities during Phase 2 greatly facilitates the owner/operator in appointing an NPP vendor and concluding key contracts in Phase 3.
- **Appointed owner/operator or build–own–operate/transfer (BOO/BOOT) model**: In this model a market regulator or executive authority appoints an owner/operator, often on the basis of a negotiated power purchase agreement. The owner/operator can be owned by the same shareholder for its full life cycle, or, in the 'transfer' version of the model ownership, is transferred to a nominated entity after specified project duration. Several practicalities require that key project development activities are concluded before major project agreements can be finalized. This results in two variations of the ownership model:
    - BOO/BOOT partner as project developer: Under this option the potential BOO/BOOT partner performs project development activities either at its own expense or through the implementation of a project development agreement. The prospective BOO/BOOT partner often owns the site, performs evaluation activities and applies for the necessary permits as the potential owner/operator. In this manner the necessary project development activities can be completed before the NPP project is defined enough to conclude the major project agreements required in Phase 3.
    - BOO/BOOT with the appointment of a separate project developer(s): Practicalities experienced during development activities such as site selection, evaluation and permitting often result in unwillingness of the potential owner/operator to develop sites at risk. For this reason it is often prudent for the NEPIO to appoint a designated project developer or developers. This project developer needs to have a high level of competence in project management and assume all Phase 2 responsibilities that would normally have been assigned to the owner/operator for this role.
      These include, among others, the following activities:
        - Site selection, evaluation and qualification;
        - Environmental studies and approvals;
        - On- and off-site infrastructure planning and approvals;
        - Grid integration planning;
        - Planning and preparation for skills and resource development, technology transfer, industrial involvement and project execution.

      Once these activities have been completed the BOO/BOOT partner can be readily appointed in Phase 3 and owner/operator responsibilities transferred.

      While this guide is also intended to assist the project developer in executing this more limited scope of activities, special emphasis should be placed on the management of the transfer of responsibilities to the owner/operator in Phase 3. This is especially critical given the high level of responsibility placed on the owner/operator and possibly even the project developer in their role in contributing to the establishment of the licensing basis of the NPP.

- **Public–private partnerships**: This model is a variation of the appointed owner/operator or BOO/BOOT model, with the exception that a portion of the equity is held by a nationally affiliated or public entity.
- **Regional market/multinational model**: In this model synergies between countries are utilized to develop a single nuclear power programme that benefits several countries. The programme will likely be driven by a host country with varying degrees of cooperation required from other participants. Any of the above ownership models can be used.

Appendix II

PROJECT PROCESSES AND THE DEMING CYCLE

As described in Section 3, there are a variety of project management frameworks and processes available that can help with various aspects of project management. These methodologies can be adapted and combined as necessary for a given organization based on individual circumstances.

It is important that nuclear project managers adopt a consistent methodology for projects within their jurisdiction. This allows practitioners to gain experience with the chosen methodology, become efficient in its use and make improvements to their internal processes on an ongoing basis.

This publication will use an adaptation of a number of international tools to describe a high quality project management process for a nuclear project. As its base is a series of ‘plan, do, check, act’ (PDCA) cycles, sometimes also referred to as ‘plan, do, study, act’ (PDSA) cycles. This characterization is derived from a business process description that was originally developed by W. Edwards Deming in the 1950s based on earlier work by Walter A. Shewhart. Deming proposed that business processes should be analysed and measured to identify sources of variations that cause products to deviate from customer requirements. He recommended that all business processes incorporate a continuous feedback loop so that managers can identify and change the parts of the process that need improvements. The IAEA uses the Deming cycle process to describe a number of its recommended processes, including those for ageing management [253] and industrial safety management [43].

A key difference between standard PDCA cycles and those for projects is that a project has a defined start and finish. As a result, processes are needed for initiating a project and for closing out a project that go beyond the traditional continuous PDCA loop (Fig. 37). This also applies to subprocesses that are meant to control various aspects of projects, although not all parts of initiate, PDCA and close might be necessary for each subprocess. For example, a subprocess may be developed to control the production of a project charter. Within that process would be instructions on how to initiate a charter document; how to plan for its preparation (the ‘plan’ step); how to write it and initially get it approved (the ‘do’ step); how to confirm that it meets requirements based on experience during initial stages of the projects (‘check’); how to implement necessary changes by requesting a revision to be initiated (‘act’); and finally back to ‘plan’ and ‘do’ for the revision process. There might not be any defined ‘close’ step other than perhaps filing the document in the records management system at the end of the project.

The rest of this section describes some of the considerations related to this adapted PDCA loop in the context of nuclear projects.

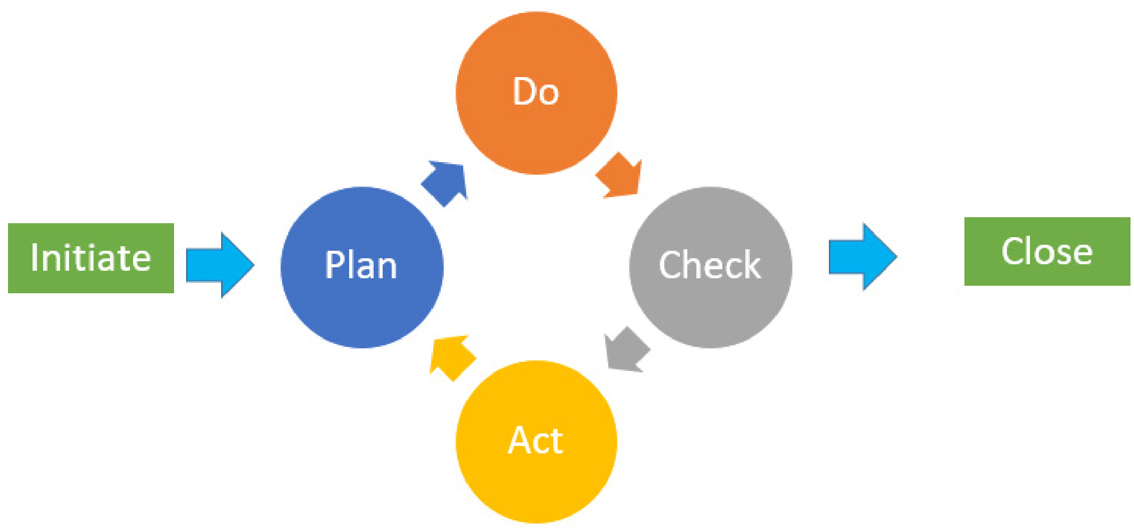

FIG. 37. Adapted PDCA loop as applied to projects and project subprocesses.

II.1. INITIATE

‘Initiate’ activities are those used to start a project or a new project phase and to define its major objectives. They also relate to project subprocesses such as the start of procurement activities.

Projects can be initiated via many different individuals or organizations. In a nuclear context these can include government bodies such as ministries of energy or science for new NPP projects or research reactors. For currently operating facilities, individuals within engineering, operations or maintenance who see improvement opportunities may be the project initiators.

II.2. PLAN

‘Plan’ activities are those that prepare for a project or process phase, establish its scope, refine its objectives and deliverables, and establish the activities, resources and timeframe needed to meet those objectives. For a project, they also can include technical feasibility studies and the planning of oversight activities that are designed to check adequate project progress is being made prior to commitment of major resources to a particular project phase or facility.

Planning can be said to be the most important step in managing a project but in many cases it is under-resourced. Inadequate definition of project scope and inadequate preconstruction planning lead to cost overruns, schedule overruns and failure to achieve the intended project scope and performance. In one estimate [254], design work hours expended before final project authorization should be from 10 to 25% of total design effort, depending on the complexity of the project. Rework resulting from after the fact ‘check’ activities is invariably at a higher cost.

Some processes that have been shown to assist in overall project planning were described in Sections 3.5 to 3.7 of this publication.

II.3. DO

‘Do’ activities are those that perform the actions necessary to complete the work defined in the project in order to meet project objectives. They include studies, engineering, design, procurement, manufacturing, transportation, construction, commissioning, quality assurance, project management, risk management and other functions and sub-functions, such as estimating or scheduling.

II.4. CHECK

‘Check’ activities are those designed to validate at regular intervals that the project overall and its sub-steps are on track to meet their objectives. Project performance can be measured and tracked via a wide variety of methods, including the following:

- Individuals or teams assigned to develop and monitor specific project metrics (i.e. standards of measurement by which efficiency, performance, progress or quality of a project’s plan, process or product can be assessed. These can include standards for cost performance, schedule performance, milestone completions, earned value, number or rate of non-conformances, human performance events, industrial safety accident rates, radiation safety events, deliverable completion rates, rework, change notices, scope changes, etc.). Colour codes (e.g. green, white, yellow and red) are a useful method to communicate whether the metric is in the expected range and where more attention should be focused. Metrics related to specific activities are discussed in Section 4 of this publication in the subsection related to the applicable area being managed.
- Project team, oversight committee meetings or challenge boards that review project progress and metrics.
- Formal readiness reviews for an upcoming project stage (including IAEA review missions such as the CORR [51]).
- Identification of project issues via the project’s corrective action programme.

- Independent assessments and self-assessment of the project, its management system and its culture for safety by internal or external personnel. This may include specialized oversight reviews of key activities such as engineering designs, vendor performance, contractor oversight processes, etc.
- Project benchmarking against external databases containing information related to similar projects (e.g. the CII's project benchmarking database).
- Benchmarking of current in-progress projects to gather lessons learned from different project organizations.
- Lessons learned reviews and documentation related to specific activities, project phases or the entire project.

This continuous monitoring provides the project team with an insight into the health of the project and identifies any areas requiring additional attention. Specific metrics for various project items being controlled are discussed in Section 4. Appendix E of PRINCE2 [110] contains a number of sample 'health checklists' that can be used at various points in a project to assess whether key project management steps are being followed. The CII has developed a tool for assessing project control metrics [255] and, as was discussed in Section 3.5, various tools for assessing the adequacy of FEP. Other references are available [256].

Such processes are consistent with IAEA Safety Standards Series No. GSR Part 2 [24] regarding the measurement, assessment and improvement of the management system (Requirement 13) and the measurement, assessment and improvement of leadership and culture for safety (Requirement 14).

Project control 'check' activities are typically established using a graded approach. The level of applied oversight normally considers such items as:

- The qualification of suppliers through the establishment and management of qualification requirements and assessments;
- The establishment and verification of inspection and test plans before commencement of work with specific emphasis on activities that cannot be tested or verified on delivery or during commissioning;
- The verification and validation of designs, software and systems as well as manufacturing and construction procedures;
- The level and frequency of testing, inspections, independent reviews and oversight;
- The level of applied expertise;
- The focusing of project controls and resources on where they are needed most;
- The level of maturity as well as the complexity of executing tasks when assigning a level of project controls.

II.5. ACT

'Act' activities are those designed to correct any deviations or issues uncovered by 'check' activities. They are the result of/response to items identified via reviews of project metrics, non-conformances, review and oversight meetings, audits, independent assessments, self-assessments, and lessons learned reviews. They may impact on the project's management system, related processes and procedures, project scope, schedule, cost, personnel, vendors or other items.

Processes should be in place to ensure that actions in this area are completed in a timely manner and that they have adequately addressed the causes of the deviation.

II.6. CLOSE

'Close' activities are those necessary to finalize all activities related to the formal closure of a project or phase. They include ensuring the complete transfer of products, services, documentation and other assets to the customer, confirming that the project met its requirements and completed its deliverables, ensuring that contract closeouts and other financial processes have been completed, required training has been completed, lessons learned have been captured and any outstanding actions have been captured in the owner's or contractor's management system, as appropriate.

Section 4.1.4.4 of this publication discusses some project management technology tools that can assist in project integration and the overall closure process. Section 4.1.8 discusses KM in more detail. IAEA Nuclear

Energy Series No. NP-T-3.21 [3] section 5.10 and its appendix I discuss data needs related to the procurement function that are a necessary part of project turnover.

Appendix III

INTERNATIONAL PROJECT MANAGEMENT FRAMEWORKS

This appendix describes a number of international project management frameworks that an organization can adapt and incorporate into its own project management system.

III.1. ISO 21500 AND 10006

ISO 21500:2012 [257] is an international project management standard developed by the International Organization for Standardization. Largely modelled on the PMI's PMBOK Guide (see Section III.2), ISO 21500:2012 aligns well with other ISO quality standards but is much shorter in length than the PMI's PMBOK Guide. The ISO is limited to the introduction of the processes, their inputs and their outputs, while the PMBOK Guide also provides details on applicable project management tools and techniques.

ISO 10006:2003 [258] provides guidance on project management processes but is not a guide to project management itself. Topics that are covered include quality management systems in projects, management responsibility, resource management, processes related to product realization and measurement, analysis and improvement. At the time of its issuance, prior to the issuance of the above described project management specific ISO 21500:2012, product related processes related to project management were deemed covered by ISO 9004:2009 [259], which generically addresses sustainable quality management system performance improvement in organizations.

III.2. PMI PMBOK GUIDE

The Project Management Institute (PMI), based in Atlanta, USA, initially published its Guide to the Project Management Body of Knowledge (PMBOK® Guide) in 1987. The PMBOK Guide is now in its fifth edition [7]. It is considered an American National Standards Institute (ANSI) standard; however, contributions to the standard have been obtained from PMI members around the world.

The PMBOK Guide contains five process groups (PGs) — initiating, planning, executing, monitoring and controlling, and closing; and ten knowledge areas (KAs) — integration, scope, time, cost, quality, human resources, communication, risk, procurement and stakeholder management. The PGs are similar to the project management processes that were described in Appendix II of this publication, and the knowledge areas are similar to the 'areas to be managed' in Section 4 of this publication, although both of these sections have been adapted specifically for nuclear projects.

There are 47 processes that cross-cut into these ten KAs and five PGs. Each process has inputs, tools and techniques, and outputs (I/TT/O). An output from a process can be used as an input to another process. Some sample processes include, for example, 'develop project charter', 'plan schedule management', 'plan risk responses', 'acquire project team', 'control communications' and 'close procurements'.

A Construction Extension to the PMBOK Guide [260] provides construction specific guidance for the project management practitioner for each of the PMBOK Guide Knowledge Areas, as well as guidance in the additional areas not found in the PMBOK Guide. The additional areas covered include:

- All project resources, rather than just human resources;
- Project health, safety, security and environmental management;
- Project financial management, in addition to cost;
- Management of claims in construction.

Various practice standards have also been published by the PMI for more detailed topics. These include standards related to estimating [118], scheduling [106], EVM [80], WBSs [104], configuration management [261] and risk management [151].

The American Management Association (AMA) has published a project management handbook [262] that aligns well with the PMBOK Guide. It should help those studying project management to understand and integrate the materials contained in the PMBOK standard, as well as project management concepts and issues that currently are not included in the PMBOK Guide.

III.3. ASSOCIATION OF PROJECT MANAGEMENT

APM's body of knowledge (APMBOK) was launched in the UK in 1988. It incorporates inward focused project management topics (such as planning and control techniques) and broader topics in which the project is being managed (such as the social and ecological environment), as well as other specific areas (such as technology, economics, finance, organization, procurement, people and general management) [56]. Not all of the broader topics will be applicable to all projects.

The APMBOK is structured around seven main topic titles (general, strategic, control, technical, commercial, organizational and people) and has 42 subitems.

III.4. PRINCE

PRrojects IN Controlled Environments (PRINCE) was initially issued in 1989 by the UK's Central Computer and Telecommunications Agency (CCTA), which was later renamed the Office of Government Commerce (OGC). PRINCE was based on PROMPT, a project management method for the development and support of IT systems that was created by Simpact Systems Ltd in 1975. In fact, PRINCE originally stood for 'PROMPT in a CCTA Environment'.

PRINCE2 was released in 1996 as a generic project management method. It was established as a common standard for IT projects in the UK and has evolved to become the de facto standard for UK government agencies. It is widely used in the private sector both in the UK and internationally, and can be applied to non-IT projects.

In 2009 the rights to PRINCE2 were transferred to AXELOS Ltd.

PRINCE2 is based on seven principles that derive from experience and provide a framework of good practice for those involved in a project. The principles are:

- Continued business justification;
- Learn from experience;
- Defined roles and responsibilities;
- Manage by stages;
- Manage by exception;
- Focus on products;
- Tailor to suit the project environment.

PRINCE2 also describes seven themes that need to be addressed continually during a project and tailored for specific circumstances. PRINCE2 defines the recommended approach to take for each theme and responsibilities for each PRINCE2 role. Tailoring can be designed, for example, to provide additional detailed documentation and process discipline for complex or high risk projects, or concise bullet-point presentations and more informal processes for simple, low risk projects. These themes are business case, organization, quality, plans, risk, change and progress.

Project processes are divided into seven typical areas of starting a project, initiating a project, directing a project, controlling a project, managing stage boundaries, managing product delivery and closing a project. Each process has defined products, required actions and assigned responsibilities (e.g. required producers, reviewers and approvers). For example, the process to create a quality management strategy under the 'initiating a project' process area is required to be completed by the project manager, reviewed by the project assurance organization and approved by project executives, senior users and senior supplier representatives.

Several aspects of project management, namely specialist aspects, detailed techniques and leadership capability, are deliberately excluded from PRINCE2 as they are considered to be well covered elsewhere (specialized and detailed techniques) or impossible to codify in a method (leadership capability).

In 2017, an update to PRINCE2 was issued [110] that places emphasis on the following:

- Tailoring PRINCE2 to the needs of organizations and project environments;
- The principles that underpin PRINCE2;
- Greater clarity on the link between the themes and principles;
- The restructuring of the themes guidance to accommodate specific examples of tailoring;
- The practical application of the guidance, with numerous examples, hints and tips.

AXELOS also provides a route map for risk management (called Management of Risk (M_o_R) [152]) within its best practice framework. Risk is further discussed in Section 4.9 of this publication.

III.5. MANAGING SUCCESSFUL PROGRAMMES

Managing Successful Programmes (MSP®) [34] is a set of principles and processes for use when managing a programme of projects. It is founded on best practice, although it is not prescriptive.

The principles in MSP advise organizations on how to:

- Organize people to ensure responsibilities and lines of communication are clear;
- Plan the work in a way that achieves results;
- Ensure that the organization benefits from undertaking the programme;
- Ensure that all interested parties (the stakeholders) are involved;
- Resolve issues that arise;
- Identify and manage risks;
- Ensure quality;
- Keep up to date information that tracks the continually changing environment;
- Audit a programme to ensure standards are being followed.

The processes in MSP describe how to:

- Identify the aim of the programme and envisaged benefits to the organization;
- Define the programme, and specify how the organization will be different after programme implementation;
- Establish the programme;
- Monitor and coordinate the projects within a programme;
- Manage the transition between the old and new ways of working;
- Close the programme and ensure the ‘end goal’ has been achieved.

III.6. INTERNATIONAL PROJECT MANAGEMENT ASSOCIATION

The International Project Management Association (IPMA) is the oldest project management association, having been established in 1965. It is a non-profit federation of independently established organizations based in different countries. Over 60 countries have IPMA members with over half of these being in Europe.

IPMA’s main focus is on its Individual Competence Baseline (ICB) product [138], which provides a definition of the behavioural competences expected from project management professionals for certification using a four level certification system. National cultural differences are addressed within a country by adding specific competence elements and content to the ICB. Certification requires a formal interview.

ICB lists 29 competence elements (divided into categories of perspective, people and practice competences) that are used by a project manager. Competence is defined as being a collection of knowledge, personal attitude, skills and experience. Each competence description consists of a brief definition, purpose, knowledge, skills and abilities and related competence elements. Competence indicator descriptions and measures are also provided and a cross-reference to ISO 21500:2012 elements is given.

Other IPMA products include an organizational competence baseline (OCB) [263] for managing projects, programmes and portfolios at an organizational level, and a project excellence baseline (PEB) [264] for managing individual projects and programmes. The latter product contains consideration of sustainability, the environment and other long term perspectives.

III.7. TOTAL COST MANAGEMENT SYSTEM

The AACE's Total Cost Management (TCM) system [35] covers the project management process from the identification stage to project closeout, and thus includes all steps that an organization should take to implement its business strategy, including those prior to an actual project being approved or executed. This includes monitoring and becoming aware of a performance issue with an asset in its asset portfolio (e.g. in the nuclear context, a particular facility or subsystem in that facility) before completing a project and delivering a modified or new asset to the organization. It also addresses managing multiple projects as a programme or project portfolio.

The TCM framework is based upon applying the PDCA cycle that was described in Appendix II in a recursive manner. The basic PDCA process is "applied for each asset and group or portfolio of assets, and then again for each project being performed to create, modify, maintain or retire such assets" [35]. For example, there would be PDCA loops for strategic asset planning, strategic asset implementation, strategic asset performance measurement and strategic asset performance assessment for each of the portfolio of enterprise assets, and then a set of PDCA loops for project planning, project control plan implementation, project performance measurement and project performance assessment for each project within the organization's portfolio of projects.

Inputs to the TCM process are an organization's costs or resources (time, money and physical resources), strategic objectives and constraints related to its working environment. Outputs of the process are a 'managed asset portfolio' of new, modified, maintained or retired assets and a portfolio of managed in-progress projects.

III.8. JAPAN'S ENGINEERING ADVANCEMENT ASSOCIATION P2M

Japan's Engineering Advancement Association (ENAA) founded a committee to introduce, develop and research project management in 1999, which led to the creation of A Guidebook of Project & Program Management for Enterprise Innovation — officially abbreviated as P2M — in 2001. P2M and its certification system resulted from Japan's enterprise need to develop more innovative approaches to the development of business. P2M is very detailed and covers both project and programme management [140].

Project management topics covered include management of strategy, finance, systems, organization, objectives, resources, risk, information technology, stakeholder relations, value and communications.

Certification and accreditation associated with P2M is undertaken by the Project Management Association of Japan (PMAJ). PMAJ is a non-profit organization established in 2005 that succeeded the Project Management Professionals Certification Center (PMCC).

III.9. AUSTRALIAN NATIONAL COMPETENCY STANDARDS FOR PROJECT MANAGEMENT

The Australian Institute of Project Management (AIPM) developed a set of project management competency standards in 1977 called the Australian National Competency Standards for Project Management (ANCSPM). ANCSPM emphasizes performance orientated recognition of competence in the workplace, and includes the following main components [139]:

- Units of competency, which are the significant major functions of the profession;
- Elements of competency, which are the building blocks of each unit of competency;
- Performance criteria, which refers to the type of performance in the workplace that would constitute adequate evidence of personal competence;
- Range indicators, which describe more precisely the circumstances in which the performance criteria would be applied.

The elements of competency are expressed by words such as 'determine', 'conduct', 'guide', 'implement' and others. There are three main elements of competency for each unit.

ANCSPM incorporates the nine knowledge areas of the PMI's PMBOK Guide directly into the knowledge part of its qualification programme.

III.10. CHANGE-DRIVEN METHODS (AGILE, SCRUM, DSDM ATERN)

Change-driven methods are iterative, incremental methods of managing the design and build activities of engineering, information technology and other business areas that aim to provide new products or services in a highly flexible and interactive manner. They are useful when dealing with rapidly changing environments (e.g. businesses 'changing their minds'), when requirements and scope are difficult to define in advance, and when it is possible to define small incremental improvements that will deliver value to stakeholders [7].

One example is their application in Scrum, an original form of agile software development. Other applications of similar approaches in the software area include extreme programming, adaptive software development, Crystal [265], feature-driven development and pragmatic programming.

The Agile Software Manifesto [266] is centred on four values: viewing communication with stakeholders as more important than standard procedures and tools, focusing more on delivering a working application and less on providing thorough documentation, collaborating more with customers, and being open to changes instead of following a plan.

The PMI's PMBOK Guide [7] refers to these methods as 'adaptive project life cycles'. They require experienced, capable individuals, an openness to consistent customer input and management openness to non-hierarchical leadership structures. A preference is given to shorter project timescales, with useable products produced quickly and iteratively improved. Adaptive projects generally work on several processes at a time, although early iterations may concentrate more on planning activities. At the end of each project iteration, the product should be ready for review by the customer. This does not mean that the customer is required to accept the product, just that it should not include unfinished, incomplete or unusable features [7].

DSDM Atern [267, 268] (Dynamic Systems Development Method) is a long established agile method, launched in 1994, that focuses on the management of agile projects. A fundamental assumption is that nothing is built perfectly first time, but that as a rule of thumb 80% of the value of the solution can be delivered for 20% of the effort that it would take to produce the total solution (the Pareto principle). Its five core practices are facilitated workshops, MoSCoW (must have, should have, could have or won't have this time) prioritization, iterative development, modelling and time boxing (a process designed to maintain focus on delivery in the short term (weeks or even days)).

DSDM Atern can be used either standalone or combined with other recognized methods such as PRINCE2, MSP and the PMI. A guide for running PRINCE2 projects with DSDM Atern is available [269].

III.11. GLOBAL ALLIANCE FOR PROJECT PERFORMANCE STANDARDS

The Global Alliance of Project Performance Standards (http://globalpmstandards.org/) is an alliance of government, industry, professional associations, national qualification bodies and training/academic institutions that have been working together since 2003 to help practitioners and organizations make sense of the many standards and certifications available globally to guide the management of projects. Its aim is to facilitate mutual recognition and transferability of project management standards and qualifications by providing the global project management community with a reliable source of comparative information.

Its products include mappings/comparisons of various project management and programme management standards (e.g. PMI, P2M, IPMA, MSP), assessment methods, approaches to categorizing projects or programmes based on their management complexity, an approach to categorizing project programmes (i.e. strategic, operational, multi-project or megaproject) and a variety of assessment tools (i.e. performance based competency standards for project managers, programme managers and sponsors).

III.12. PM² PROJECT MANAGEMENT METHODOLOGY

PM² is a project management methodology developed by the European Commission. PM² "has been created considering the environment and needs of EU institutions and projects, in order to facilitate the management of projects' complete lifecycle" [270]. It provides a governance structure, process guidelines, templates and a set of 'effective mindsets', which are attitudes and behaviours that help project teams focus on what is really important. Portfolio management and agile methods are also discussed. The PM² authors indicate that PM² can ideally be combined with the IPMA Global Standards and the IPMA Project Excellence Baseline (IPMA PEB® [265]).

Figure 38 shows project swim lane diagrams from the PM² guide [270]. It shows typical project phases, their drivers, inputs, outputs and phase gates at which approvals would be sought.

III.13. HERMES

HERMES is a project management method for projects in the context of information technology, the development of services and products, and the changing of organizational structures. HERMES supports the steering, management and execution of projects of a varying nature and complexity. As a method, HERMES is clearly structured and simple to understand with a modular, easily expandable design. It has been used in Switzerland's Federal Administration since 1975. The fifth version, HERMES 5 [271], was launched in 2012. Certification for practitioners is available at two levels.

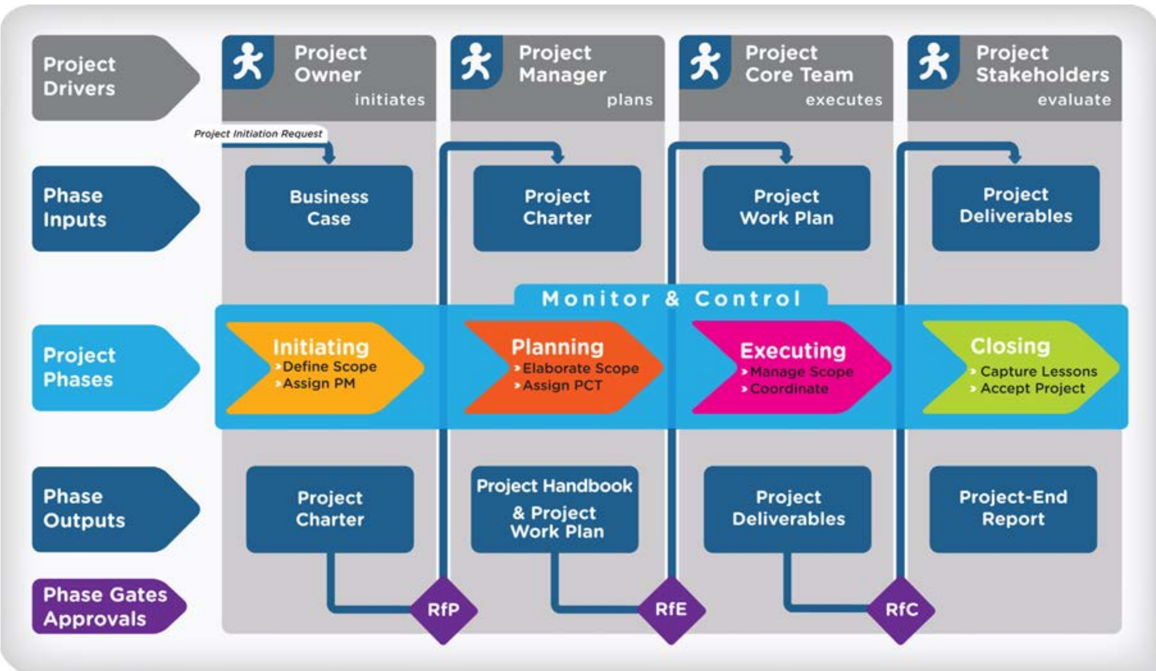

FIG. 38. PM² project swim lanes [271].

Appendix IV

POTENTIAL COMMITTEES AND WORKING GROUPS

For an NPP project, committees and working groups may be considered. The following functions can be necessary or useful:

- **Project board**: A project organization composed of senior representatives from the owner/operator's executive functions (including the project sponsor), key end users of the facility and main supplier/vendor. Sometimes it includes representatives of the government. The project board is accountable for the success or failure of the project in terms of the business, user and supplier interests. It has the authority to provide strategic direction to the project, can delegate activities to the right level and remains available as necessary to the project manager and project core team. It is also responsible for the communications between the project management team and stakeholders external to that team (e.g. corporate and programme management).
- **Project core team**: (sometimes leadership team or senior management team): A team comprised of the senior functional leads responsible for project execution. It is used to holistically advise the project director in reviewing and controlling the progress of the project so as to meet the established project objectives. It is vital to have a competent core team.
- **Investment and finance**: This group oversees the prioritization and establishment of projects, the performance of project progress reviews, and approval of strategy, planning baselines and feasibility assessments. While, in a new owner/operator organization, the authority to manage key investments may be retained by the project board, government representatives and/or shareholders, more complex/mature organizations often find benefit in having a dedicated and specialized committee for this purpose. In this case, the committee will likely reside outside of the project at a portfolio level within the owner/operator organization. Its function is closely linked with the process to ascertain and assure the sustained economic viability of the NPP.
- **Design basis and licensing management**: This group, often called design authority, oversees the establishment and management of project requirements as well as the acceptance of designs and activity specifications and any subsequent changes to them. Activity specifications include those for evaluation studies, designs, manufacturing, construction, transport, storage, installation, commissioning, operating, maintenance, decommissioning and the disposal of waste in line with an established graded approach to management systems, as discussed further in Section 5.1. By doing so the authority is responsible for ensuring that the design and licensing basis of the NPP is established and maintained at all times throughout the plant life cycle. In the case of newcomer countries, this capability may be developed during Phase 3.
- **Governance: audit, risk, compliance and oversight**: It is prudent, and often a legislated requirement, for a committee to be established tasked with the critical analysis of the project in terms of the risk it may pose to the organization and its operating environment. This committee should be separated as far as possible from the project's time schedule and production pressures. Risks should be assessed in terms of compliance with established internal criteria, legislation and regulations and take into account any likely changes to the operating environment. Compliance with best practice codes and standards should be considered.
- **Personnel: appointments and compensation**: This committee oversees the approval of organizational structures, appointments and remunerations as well as the establishment of policies and practices affecting the workforce. Where practical, consideration should also be given to the establishment of equality in employment practices across different organizations employed on the project so as to alleviate unnecessary workforce discontent.
- **Social responsibility, ethics, sustainability and stakeholder involvement**: The project organization should consider the establishment of a dedicated committee to ensure that it operates as a good corporate citizen by effectively managing its operations, maintaining ethical practices, communicating effectively with the public and managing sustained relationships with all necessary stakeholders.
- **Project planning, controlling and monitoring**: it is often necessary to establish a committee or work group responsible for the establishment and monitoring of the project plan during critical project phases. This

authority will be instrumental in managing the project in line with the schedule and budgetary baselines. This should involve all key organizations such as the design group, construction, contractors, procurement, etc.

- **Procurement and contract management**: For large value acquisitions, dedicated committee/s and or work groups may be considered for the approval of bid requests and the evaluation of tenders, as well as for the leading of negotiations with key suppliers. Committees can also be established for the approval of significant changes to contracted scope and conditions.

To operate effectively, these committees need to have documented terms of reference approved by the project or owner/operator's board that establishes their mandate and objectives and controls their composition, leadership, administration, submissions, proceedings, decision making process and reporting and records requirements. As these committees perform vital functions and services to the project, the performance of the committees and their members should be monitored, evaluated and managed.

Suitably qualified and experienced functional specialists should be appointed via a formal established process to the various committees to support the effective and efficient achievement of their specific mandates. Mechanisms should be put in place to ensure that committee members are appropriately developed, trained and exposed to lessons learned and current international industry experience.

Appendix V

PROJECT MANAGEMENT ACTIVITIES IN PHASE 2 OF AN NPP PROJECT

Table 15 provides a summary of the activities identified during Phase 2 in Milestones in the Development of a National Infrastructure for Nuclear Power, IAEA Nuclear Energy Series No. NG-G-3.1 (Rev. 1) [1]. Each of these activities needs to be managed as part of a typical NPP project and thus needs to be part of the project plan and schedule.

TABLE 15. PROJECT MANAGEMENT ACTIVITIES IN PHASE 2

Infrastructure area	Responsible organization	Activity from Ref. [1]	Comment	Reference in this publication
National position	Government	Make policy decision to develop a nuclear power project		6.3
National position	NEPIO	Ensure that the approved programme is transferred into action plans for the 19 infrastructure issues		6.3.1
National position	NEPIO	Designate owner/operator		6.3.1
Nuclear safety	Regulatory body	Fill senior positions		6.3.6.1
Nuclear safety	Regulatory body	Develop qualification requirements in national regulations/laws		6.3.6.1
Nuclear safety	Regulatory body	Specify regulations for owner/operator		6.3.6.1
Nuclear safety	Regulatory body	Develop understanding of IAEA Safety Standards		6.3.6.1
Nuclear safety	Regulatory body	Develop strategy for developing safety regulations		6.3.6.1
Nuclear safety	Regulatory body	Develop communications protocol for safety issues between regulator, owner/operator and suppliers		6.3.6.1
Management	Owner/operator	Define an organizational structure and recruit appropriate staff		6.3.1.2
Management	Owner/operator	Establish an integrated management system		6.3.1.4

TABLE 15. PROJECT MANAGEMENT ACTIVITIES IN PHASE 2 (cont.)

Infrastructure area	Responsible organization	Activity from Ref. [1]	Comment	Reference in this publication
Management	Owner/operator in conjunction with the NEPIO	Develop a financing strategy, a contracting strategy, a fuel supply strategy and a spent fuel and radioactive waste management strategy		6.3.7.2
Management	Owner/operator	Begin staff training to create culture for safety and security		6.3.10
Management	Owner/operator	Establish a nuclear security programme		6.3.10
Management	Owner/operator	Assess alternative technologies to determine which are most appropriate or preferred		6.3.1.6
Management	Owner/operator	Complete site assessment studies and select site		6.3.3
Management	Owner/operator	Complete environmental impact assessment study		6.3.3, 6.3.6.3
Management	Owner/operator	Implement a stakeholder involvement programme, especially with respect to candidate sites		6.3.1.8 & 6.3.3.1
Management	Owner/operator	Establish BISs and evaluation criteria		6.3.7.3
Management	Owner/operator	Build project management capabilities and a competent procurement team, recognizing that different contracting approaches (turnkey, split package or others) will require different levels of competence		6.3.1.2
Management	Owner/operator	Establish working relationships with the regulatory body		6.3.1.8 & 6.3.6.1
Management	Owner/operator	Train staff and establish a project management organization that will emphasize quality management and be able to ensure that all contract requirements are fully met		6.3.1.2

TABLE 15. PROJECT MANAGEMENT ACTIVITIES IN PHASE 2 (cont.)

Infrastructure area	Responsible organization	Activity from Ref. [1]	Comment	Reference in this publication
Management	Owner/operator	Institute procedures to ensure that knowledge critical to safe and secure operation will always be preserved		6.3.1.4
Funding and financing	NEPIO and owner/ operator	Arrange for project funding	Prior to inviting bids	6.3.2.1
Legal framework	Government (with support of regulatory body)	Enact nuclear safety, security, safeguards and civil liability for nuclear damage legislation	Prior to inviting bids	6.3.6.1
Legal framework	Government (with support of regulatory body)	Establish a State system for accounting for nuclear materials		6.3.6.1
Security and safeguards	Project	Incorporate IAEA and national safeguards and security requirements into BIS		6.3.6.1
Regulatory framework	Government	Ensure establishment of an independent regulatory body		6.3.6.1
Regulatory framework	Regulatory body	Acquire and train staff, including training to create a safety and security culture		6.3.6.1
Regulatory framework	Regulatory body	Establish management systems within the regulatory body		6.3.6.1
Regulatory framework	Regulatory body	Establish technical support arrangements and international relationships with other regulatory bodies		6.3.6.1
Regulatory framework	Regulatory body	Establish nuclear facility licensing system		6.3.6.2
Regulatory framework	Regulatory body	Define siting, design, construction and radiation protection requirements (regulations, codes and standards)		6.3.6.2
Regulatory framework	Regulatory body	Define criteria for approval of nuclear facility designs		6.3.6.2
Radiation protection	Regulatory body	Develop specific regulations by the regulatory body		6.3.8

TABLE 15. PROJECT MANAGEMENT ACTIVITIES IN PHASE 2 (cont.)

Infrastructure area	Responsible organization	Activity from Ref. [1]	Comment	Reference in this publication
Radiation protection	Owner/operator	Planning by the owner/ operator for monitoring and protecting workers and the public		6.3.8
Radiation protection	Owner/operator	Establish mechanisms to involve and communicate transparently with all stakeholders		6.3.8
Radiation protection	Owner/operator	Ensure radiation protection plans are reflected in the plant's design requirements	Needed prior to bidding	6.3.8
Radiation protection	Owner/operator	Plan for radiation protection staff recruitment and training and the procurement of radiation protection equipment and services		6.3.8
Electrical grid	Grid operator	Identify the requirements for connecting an NPP		6.3.5
Electrical grid	Grid operator supported by owner/ operator	Undertake detailed studies to determine any expansion, upgrade or improvement necessary to accommodate the size, technology and site that are anticipated for the new plant		6.3.5
Electrical grid	Grid operator	Develop plans for enhancing or expanding the grid to be compatible with the new NPP		6.3.5
Electrical grid	Grid operator	Develop plans to increase or strengthen regional interconnections to achieve acceptable grid reliability		6.3.5
Electrical grid	Grid operator	Develop plans to provide redundant, reliable sources of off-site power for the NPP		6.3.5
Electrical grid	Grid operator	Secure funding and/or financing to ensure that these plans are implemented on schedules compatible with the new NPP		6.3.5
Human resource development	Owner/operator	Develop sufficiently knowledgeable staff to prepare for negotiating the contract		6.3.7.1

TABLE 15. PROJECT MANAGEMENT ACTIVITIES IN PHASE 2 (cont.)

Infrastructure area	Responsible organization	Activity from Ref. [1]	Comment	Reference in this publication
Human resource development	Regulatory Body	Develop its competence, ensuring all human resources for the regulatory body will need to be in place and competent to fulfil their licensing functions.	Investigate opportunities for its staff to gain experience through cooperative arrangements with foreign regulatory bodies	6.3.6.1
Human resource development	NEPIO	Establish both a policy on national participation in the manufacturing, construction, operation and support of the NPP and a plan to put that policy into effect.		6.3.1.4
Human resource development	All organizations	Identify the knowledge and skills needed in Phase 3 and beyond and establish workforce plans to develop them.		6.3.1.2
Human resource development	All organizations	Ensure senior staff are in place or identified as soon as possible.		6.3.1.2
Human resource development	NEPIO	Coordinate the plans of the different organizations, including the owner/ operator, regulatory body, research and technical support organizations, to optimize the country's efforts as much as possible.	Consider bilateral and international training activities.	6.3.1.2
Stakeholder involvement	Government	Continue public information and consultation activities	Communicate the reasons for, and expected benefits of, nuclear power and respond to concerns raised by stakeholders; national process used for site selection, supporting the owner/operator, who should engage local stakeholders and address their issues	6.3.1.8

TABLE 15. PROJECT MANAGEMENT ACTIVITIES IN PHASE 2 (cont.)

Infrastructure area	Responsible organization	Activity from Ref. [1]	Comment	Reference in this publication
Stakeholder involvement	Regulatory body	Develop and begin to implement a stakeholder involvement programme	Explain its independent role in licensing, inspection and compliance, establish and communicate the formal process for public participation in licensing	6.3.1.8 & 6.3.6.1
Stakeholder involvement	Owner/operator	Develop and begin to implement a stakeholder involvement programme	Explain the basic technology being employed, its construction plans, its safety responsibilities and the impact on, and benefits for, the local community	6.3.1.8
Site and supporting facilities	Regulatory body	Define siting requirements		6.3.3
Site and supporting facilities	Owner/operator	Carry out additional ranking analysis needed for site selection, which narrows the list of candidate sites to a shorter list of preferred candidate sites		6.3.3
Site and supporting facilities	Owner/operator	Ensure the availability and integrity of the preferred sites		6.3.3
Site and supporting facilities	Owner/operator	Identify local legal, political and public acceptance issues and resolutions implemented or planned		6.3.3
Site and supporting facilities	Owner/operator	Identify necessary improvements and develop implementation plans for local infrastructure at the preferred site or sites, such as access, services		6.3.4
Environmental protection	Government	Implement desired enhancements or clarifications in existing environmental laws, regulations and responsibilities		6.3.6.3

TABLE 15. PROJECT MANAGEMENT ACTIVITIES IN PHASE 2 (cont.)

Infrastructure area	Responsible organization	Activity from Ref. [1]	Comment	Reference in this publication
Environmental protection	Environmental regulatory body	Develop skills and resources required to fulfil its responsibilities, and establish the interface between it and the nuclear regulatory body		6.3.6.3
Environmental protection	Owner/operator	Study the prospective impacts on people and the environment as needed to select its preferred candidate sites and to ensure that they can comply with the country's environmental laws and regulations		6.3.6.3 & 6.3.3
Emergency planning	Government	Specify the response organizations at national, regional and local levels with responsibilities for EPR and establish a national coordination mechanism		6.3.9
Emergency planning	Government	Specify the general approach for EPR on the basis of the probability and severity of possible emergencies, both safety related and security related, and establish regulations governing all EPR requirements		6.3.9
Emergency planning	Government	Start implementing new arrangements as identified in Phase 1 for strengthening EPR infrastructure		6.3.9
Nuclear security	Government	Establish legislative and regulatory frameworks for nuclear security		6.3.6.1
Nuclear security	Government and regulatory body	Develop design basis threat and nuclear security requirements for the physical protection of nuclear material and nuclear facilities		6.3.6.1
Nuclear security	Regulatory body	Establish programmes for the management of sensitive information, promotion of a nuclear security culture and trustworthiness of personnel		6.3.6.1

TABLE 15. PROJECT MANAGEMENT ACTIVITIES IN PHASE 2 (cont.)

Infrastructure area	Responsible organization	Activity from Ref. [1]	Comment	Reference in this publication
Nuclear security	Government and regulatory body	Assign roles and responsibilities for preparing for, detecting and responding to nuclear security events		6.3.6.1
Nuclear security	Regulatory body	Establish a programme to develop competencies to approve nuclear security plans and to inspect facilities to verify the plans' effectiveness		6.3.6.1
Nuclear fuel cycle	NEPIO and owner/operator	Decide on the fuel cycle strategy and incorporate information into the BIS		6.3.7.2
Radioactive waste management	Government	Lead national planning for waste disposal, including low level, intermediate and high level waste. It should establish policies, identify a responsible organization or agency to lead the national planning and give it clear terms of reference		6.3.8
Radioactive waste management	Government	Consider the extent to which geological conditions exist in the country to allow disposal of all types of radioactive waste and/or the potential for contracting for waste disposal with other countries		6.3.8
Radioactive waste management	Government	Establish plans to fully finance long term radioactive waste management, radioactive waste disposal and decommissioning		6.3.8
Radioactive waste management	Owner/operator	Develop, for inclusion in the BISs, provisions for minimizing radioactive waste volumes and toxicity, requirements for associated facilities and requirements for a decommissioning plan	Needed prior to bidding	6.3.8
Radioactive waste management	Government and owner/operator	Plan to begin or enhance the country's radioactive waste disposal programmes and facilities to accommodate operation of the first NPP		6.3.8

TABLE 15. PROJECT MANAGEMENT ACTIVITIES IN PHASE 2 (cont.)

Infrastructure area	Responsible organization	Activity from Ref. [1]	Comment	Reference in this publication
Industrial involvement	Government and industry	Establish programmes to transition to national and local suppliers as their capabilities develop		6.3.4
Industrial involvement	Owner/operator and/ or government	Assess directly, or through the supplier, the national and local capabilities to supply on schedule, at competitive prices and with appropriate quality controls and assurance, commodities, components and services for building and operating an NPP. The results should be taken into account in the BISs and evaluation criteria developed during Phase 2, which may include incentives to encourage bids promoting domestic industrial involvement		6.3.4
Procurement	Owner/operator	Establish procurement capability for pre-project activities (e.g. environmental impact assessment, siting and consulting)		6.3.7.1

Appendix VI

PROJECT MANAGEMENT ACTIVITIES IN PHASE 3 OF AN NPP PROJECT

Table 16 provides a summary of activities identified during Phase 3 in Milestones in the Development of a National Infrastructure for Nuclear Power, IAEA Nuclear Energy Series No. NG-G-3.1 (Rev. 1) [1]. Each of these activities needs to be managed as part of a typical NPP project and thus needs to be part of the project plan and schedule.

TABLE 16. PROJECT MANAGEMENT ACTIVITIES IN PHASE 3

Infrastructure area	Responsible organization	Activity from Ref. [1]	Comment	Reference in this publication
National position	NEPIO, Owner/operator, regulatory body & government	Ensure the overall development of the infrastructure to meet the national strategy		6.4
Nuclear safety	Regulatory body & owner/operator	Assess the applicability of foreign codes and standards and their consistency with national safety requirements Continue to develop culture for safety and security		6.4.1.4
Nuclear safety	Owner/operator	Prepare all documentation required for obtaining the necessary licences		6.4.3.1
Nuclear safety	Owner/operator	Establish mechanisms to maintain the knowledge of the safety design and its configuration management over the lifetime of the plant		6.4.1.6
Nuclear safety	Regulatory body	Conduct a comprehensive review and independent verification of the owner/operator's safety analysis		6.4.3.1
Management	Owner/operator	Invite, evaluate and select bids in accordance with the bid evaluation criteria		6.4.2.1
Management	Owner/operator	Negotiate contract, obtain financing, prepare licence application, complete construction and apply for an operating licence		6.4.2.2 6.4.3 6.4.1.4

TABLE 16. PROJECT MANAGEMENT ACTIVITIES IN PHASE 3 (cont.)

Infrastructure area	Responsible organization	Activity from Ref. [1]	Comment	Reference in this publication
Management	Owner/operator	Develop capability for safe operation, develop relationships with international and professional organizations, develop event reporting procedures, develop turnover procedures and maintain public support		6.4.1.6
Management	NEPIO	Maintain momentum and provide a continuing forum for communication and cooperation among the important organizations		6.4.3.3
Funding and financing	Government & owner/operator	Implement mechanisms for funding of decommissioning and radioactive waste management		6.4.3.3
Funding and financing	Owner/operator	Obtain agreement about the financing arrangements based on the contract and financing negotiation		6.4.2.3
Legal framework	Government (with support of regulatory body)	At the start of Phase 3, comprehensive nuclear legislation and all other legislation that may affect the nuclear power programme should be in force, together with mechanisms to ensure compliance. During Phase 3, all actions to implement the relevant international legal instruments should be completed	It is important to ensure/check consistency of legislation	6.4.1.3 & 6.4.3.3
Security and safeguards	Owner/operator	Work with IAEA to verify the design information provided to the IAEA, to install IAEA equipment for containment and surveillance, and to put clear communication mechanisms in place for the fulfilment of all agreements between the country and the IAEA. All elements of the safeguards infrastructure at the facility should be in place and ensured for the long term prior to nuclear material arriving at the facility	Following contract award	6.4.3.3

TABLE 16. PROJECT MANAGEMENT ACTIVITIES IN PHASE 3 (cont.)

Infrastructure area	Responsible organization	Activity from Ref. [1]	Comment	Reference in this publication
Regulatory framework	Regulatory body	Continue staff development, conduct safety and security reviews of the proposed facility, conduct licensing and inspection activities, and develop an operational oversight plan		6.4.3.3
Regulatory framework	Regulatory body	By the beginning of Phase 3, all regulations, codes and standards for nuclear facility construction should be in place, and staffing should be sufficient for efficiently licensing the NPP and providing regulatory oversight		6.4.1.3
Regulatory framework	Regulatory body	Prior to fuel arriving on-site, staffing should be sufficient for carrying out the regulatory body's emergency response role		6.4.3.3 & 6.4.1.6
Regulatory framework	Regulatory body	Regulatory requirements for operator training and certification should have been developed, and the regulatory body should confirm that the licensee has demonstrated compliance		6.4.1.6
Regulatory framework	Regulatory body	The regulatory body's plans to maintain competent staff and develop future staff should be in place. Open communications with appropriate stakeholders should be well established, including the government, the owner/operator, the public and international organizations		6.4.3.3

TABLE 16. PROJECT MANAGEMENT ACTIVITIES IN PHASE 3 (cont.)

Infrastructure area	Responsible organization	Activity from Ref. [1]	Comment	Reference in this publication
Regulatory framework	Regulatory body	Prior to commissioning, the regulatory body should issue the appropriate licence or approvals. By the end of Phase 3, the regulatory body should have developed comprehensive programmes for inspection and enforcement, and competent staff should be in place to provide regulatory oversight of the operation and maintenance of the plant by conducting inspections and enforcing regulations in accordance with these programmes		6.4.1.1 & 6.4.3.3
Radiation protection	Owner/operator	All radiation monitoring and protection programmes implemented prior to the time radioactive material first arrives on-site		6.4.1.1
Radiation protection	Owner/operator	The regulatory body should have reviewed the owner/operator's radiation protection programmes and verified their compliance with regulatory requirements, including requirements for procedures and equipment to protect workers and responders during severe accidents		6.4.1.1
Electrical grid	Grid operator	Develop arrangements to ensure coordination of grid operations with power plant operations; verify the completion of all upgrades and enhancements to the grid and interconnections; continue to analyse and improve the reliability of the grid; install and test the redundant off-site power supplies to the NPP		6.4.3.3
Electrical grid	Owner/operator & regulatory body	Ensure that there is a contingency plan for timely restoration of off-site power in the event of a major loss of grid capability		6.4.3.3

TABLE 16. PROJECT MANAGEMENT ACTIVITIES IN PHASE 3 (cont.)

Infrastructure area	Responsible organization	Activity from Ref. [1]	Comment	Reference in this publication
Human resource development	Owner/operator	Ensure all the necessary human resources are in place and competent to commission and operate the first NPP Ensure ongoing education and training programmes are well underway, including access to a full scope simulator		6.4.1.6
Stakeholder involvement	Owner/operator, regulatory body and NEPIO	Continue stakeholder communication efforts, including public involvement in the licensing process		6.4.1.1
Site and supporting facilities	Owner/operator	Confirm the site's suitability and complete all licensing and approval processes established by the nuclear regulatory body. Perform ongoing monitoring of the site before and during operation to confirm its acceptability		6.4.1.1
Environmental protection	Owner/operator	Complete all licensing and approval processes established by the nuclear regulatory body and the environmental regulatory body		6.4.3.1
Environmental protection	Owner/operator	Establish baseline data and implement the ongoing environmental monitoring programme		6.4.1.5 & 6.4.1.6
Emergency planning	Government, regulatory body & owner/operator	Test and complete emergency arrangements before the first nuclear fuel arrives on-site		6.4.2.3
Emergency planning	Government	Ensure a national plan is prepared for dealing with emergencies		6.4.2.3 & 6.4.3.3

TABLE 16. PROJECT MANAGEMENT ACTIVITIES IN PHASE 3 (cont.)

Infrastructure area	Responsible organization	Activity from Ref. [1]	Comment	Reference in this publication
Nuclear security	Owner/operator	Progressively implement security arrangements in order to secure the plant during construction and to fuel it once fuel arrives on-site Put physical protection systems into service, obtain approval for the security plan, implement a national response plan including off-site response, etc.		6.4.3.1
Nuclear fuel cycle	Owner/operator	Construct on-site fuel storage facility; receive initial fuel load Develop plans to implement the interim storage strategy, including identifying a suitable location, transport capabilities and funding arrangements. Ensure plans for interim spent fuel storage are consistent with on-site storage capabilities		6.4.1.6
Radioactive waste management:	Owner/operator	Ensure facilities for the storage or disposal of radioactive waste are fully operational and prepared to receive waste Ensure initial decommissioning plan is developed and funding is in place		6.4.3.1
Industrial involvement	Government	Continue to promote educational and industrial development for national participation in the nuclear programme		6.4.3.3
Industrial involvement	Owner/operator	Assess development of national suppliers and their potential to support operation		6.4.3.3
Procurement	Owner/operator	Establish owner/operator procurement organization to support operations and maintenance		6.4.1.6

Appendix VII

KEY ITEMS NEEDED AT CRITICAL PROJECT STAGES

This appendix contains a number of tables that detail certain key items that are needed at specific stages of a new NPP project.

VII.1. PRIOR TO PROCEEDING TO CONTRACTING

Prior to proceeding to the contracting stage the items in Table 17 are needed.

TABLE 17. ITEMS TO BE UPDATED PRIOR TO PROCEEDING TO CONTRACTING STAGE

Item	Comment
Integration	Update the project's main integration documents (e.g. charter, life cycle management strategies, project management plans) if necessary based on latest information or senior executive direction. Establish specifications and controls as necessary to guide and oversee upcoming activities. Establish all management system elements that are required for the next phase of the project and ensure integration between the different organizations involved (e.g. NEPIO grid operator, nuclear and environmental regulatory bodies, IAEA Department of Safeguards). Ensure that comprehensive national nuclear legislation is in effect. Develop project requirements as described in Section 4.1.4.3.
Scope	Update the project's PBS, WBS, WBS dictionary and OBS based on latest available information.
Time	Establish the contract and agreement preparation phase baseline schedule. Conduct schedule optimization activities such as resource levelling.
Cost	Update activity costing information and CBS with latest information. Define and estimate near term activities in more detail. Funding and financing plans for the sale of electricity, etc. should be mature at this phase and be in a format whereby they can be presented to financing institutions so as to give confidence and inform the optimization of the cost of financing of the NPP. These plans can also be presented to any potential equity investors if required. Plans to fund the contract and agreement preparation phase should be completed and ready for approval.
Quality	Establish oversight and quality control functions with the necessary expertise, resources and empowerment to maintain project oversight by adopting a graded approach to nuclear safety to: • Verify the capability of both internal and contracted project resources before work commences; • Maintain oversight over all work (including supply chain/manufacturing activities); • Verify the acceptability of all work performed.
Human resources	Strengthen, train and develop the project team for the next stage of the project. Procurement and contracting expertise is of particular importance.
Communications	Update communication strategy as required covering communication of the contracting stage of the project to the general public. Ensure communications activities required by the proposed suppliers are identified in the BIS.

TABLE 17. ITEMS TO BE UPDATED PRIOR TO PROCEEDING TO CONTRACTING STAGE (cont.)

Item	Comment
Risk	If the NPP is to be constructed in a country new to nuclear power then the owner/operator should consider working in conjunction with the NEPIO to host an INIR [52] in terms of the IAEA's Milestones Approach for Milestone 2. This will ensure that the national nuclear power infrastructure is assessed in terms of its readiness to support the owner/operator in establishing the key NPP contracts. Any recommendations stemming from the INIR review should be closed or appropriately mitigated. Incorporate lessons learned from similar projects into risk register and commence mitigative actions.
Procurement	Procurement and contracting are specialized functions and should be carefully managed by suitably qualified and experienced personnel. As procurement of nuclear facilities and/or components is often not managed regularly by many Member States, the use of international consultants as advisors should be considered.
Stakeholders	Update key stakeholders based on communications strategy. Ensure stakeholder communications activities required by the proposed suppliers are identified in the BIS.
Health, safety and environment	Define requirements for contractor prequalification related to health, safety and environment and any requirements on contractors related to oversight and reporting metrics.
Lessons learned and OPEX	Review available lessons learned and OPEX related to similar projects and incorporate mitigative actions into the project plan.
Radiation dose and radioactive waste management	Ensure national/governmental requirements regarding radiation dose management that would impact on the BIS are incorporated (e.g. any regulations regarding dose management, planning, recording, ALARA principles). Ensure that national/governmental activities associated with radioactive waste management are on track and that any related requirements that would impact on the BIS are incorporated (e.g. any requirements on the supplier surrounding waste management).
Licensing	Define vendor requirements for the licensing process and ensure they are identified as a contractual requirement (see project requirements in 6.4.1.2).
EPR	Ensure that national/governmental activities associated with EPR are on track and that any related requirements that would impact on the BIS are incorporated (e.g. any requirements on the supplier surrounding construction of an emergency operations centre).
Security and safeguards	Establish safety and security culture programmes and ensure these are identified as a contractual requirement (see project requirements in 6.4.1.2) for all contracted parties.

VII.2. IMPORTANT FUNCTIONS RELATED TO COMMISSIONING AND OPERATION THAT NEED TO START DEVELOPMENT EARLY IN PHASE 3

Due to the long timelines needed, early in Phase 3 the owner/operator needs to begin developing capability for the items listed in Table 18.

TABLE 18. IMPORTANT FUNCTIONS THAT NEED TO BE DEVELOPED IN PREPARATION FOR COMMISSIONING AND OPERATIONS

Function	Detail
Commissioning	Engineering, operations and maintenance support activities associated with facility commissioning. Construction staff and key contractors will additionally be involved in various commissioning activities ahead of the first fuel load.
Plant operations	Functions associated with facility operations, including: • Control room and field operations; • Occupational health and safety management and industrial hygiene functions; • Security operations.
Production planning and outage management	Trained and qualified staff need to be available to plan outage and on-line operations and maintenance activities (planning, scheduling, etc.).
Maintenance	Maintenance functions, including monitoring and assessing the condition of the plant as well as planning and overseeing any required maintenance for both on and off-load plant conditions.
Refuelling	In support of nuclear operations the on-site fuel storage facility needs to be available to receive the initial fuel delivery. Trained and qualified staff need to be available to support fuelling engineering, fuel procurement and fuel planning activities. Strategic issues surrounding the front end and back end of the fuel cycle need to be addressed, including any transportation related issues.
Radiation protection	Radiation protection and monitoring programmes need to be accepted by the regulatory body and be implemented prior to the arrival of radioactive material on-site.
Emergency response management	Fire, rescue and radiation emergency response functions. Integration with regional, national and international emergency response frameworks.
Environmental management	Technical staff to support the management of the site’s environment, such as establishing baseline data, implementing the environmental monitoring programme and supporting operations in dealing with the environmental regulator. Aspects related to the preliminary decommissioning plan (e.g. waste volume evaluations) will also need to be managed.
Procurement	Procurement and contract management: supplier selection, negotiation, industrial development, monitoring, shipping, receipt inspection, stores, etc.
Training	Regulatory requirements related to operator certification need to be finalized and a training and certification programme developed to ensure authorized staff are available when needed. Training and qualification standards for other operations, maintenance and engineering functions need to be developed and an appropriate programme put in place.
Regulatory and licensing management	To successfully fulfil its role the licensee needs to establish management capability to control the various licensee functions and establish and coordinate interfaces with the nuclear regulator. Typically, there are three interfacing partners in the licensing process: the owner/operator function as applicant or licensee (ultimately responsible for safety, security and safeguards), the regulatory body (approver of the licensing documentation) and the vendor who supports the owner/operator in its application (owner of the design and design licensing information). Depending on the contracting strategy, other engineering or support consultants may also be involved. As early as possible, and before the contract is signed for the first project, the owner/operator should establish a working relationship with the nuclear safety regulatory body, as well as other necessary regulatory authorities responsible for aspects such as security, safeguards, occupational safety, local building and environmental approvals.

TABLE 18. IMPORTANT FUNCTIONS THAT NEED TO BE DEVELOPED IN PREPARATION FOR COMMISSIONING AND OPERATIONS (cont.)

Function	Detail
Design management and design authority	The role of the design authority (DA) is discussed in further detail in the IAEA International Nuclear Safety Advisory Group report INSAG-19 [25]. A key item identified is how the DA integrates with the rest of a project's organization. Once an NPP's design base is established, all changes need to be approved by the DA. The owner/operator's DA holds the ultimate design authority and must have the capability and authority to reject any proposed changes that do not maintain the design integrity of the facility. Changes to the licensing basis of the facility may also have to be approved by the relevant regulatory authority. Activities managed by the DA include: • Design basis management: The DA ensures that processes are defined, established and managed to control the development or acquisition and maintenance of the NPP design basis information across all organizations involved in the NPP project. This process must provide a framework to control the interfaces between the various system and component designers and manage the evolution of the design throughout the NPP's life cycle. It must ensure that all design changes occur within the framework of a robust understanding of the design. This process must ensure the establishment, control, capture, maintenance and appropriate accessibility of the following information: — A requirement set, including requirements originating from the nuclear regulator, NEPIO, owner/operator, portfolio and programme management, site characterization and evaluation, grid planning and environmental approval. Establishment of a requirement traceability matrix to coordinate where requirements originate, their status and responsibilities for achievement. — The design intent or rationale and safety philosophies. These are a vital tool that aids understanding of the interdependencies of successive design changes on the continued safety of the NPP. — The design specifications. — Design verification information justifying how the integrity of the design has been established in terms of previous operating experience, established industry codes and standards, research and other verification tests to meet the prescribed requirements. — Manufacturing, construction, installation and commissioning procedures, specifications, codes, standards and records. — Operating and maintenance procedures, limits, specifications and records. Reviewed adequacy of the design basis in terms of relevant new international research and construction and operating experience. — Decommissioning procedures, specifications and records. • Establishment of design expertise: Establishment and preservation of and/or secure access to the required competence necessary to manage and preserve the design basis throughout the NPP life cycle. • Configuration control: The DA ensures that strict configuration control is maintained throughout the life cycle of the NPP. This requires that the physical plant is manufactured, constructed, operated and maintained in conformance to the approved design basis and its associated specifications and that a complete set of records is maintained that accurately reflects the actual status of the plant. • KM and project records: A practical and readily accessible system to capture and store information is necessary to provide an appropriate plant status and record of activities required to maintain the licensing and design basis of the plant throughout its life cycle. This can include the establishment of a geographic information system for capturing site information, as well as systems for the capture of design verification, manufacturing and construction records, operating and maintenance records, etc. See 4.1.8.
Engineering support	Engineering staff to support the facility engineering programmes, surveillance, design and reactor safety support.

TABLE 18. IMPORTANT FUNCTIONS THAT NEED TO BE DEVELOPED IN PREPARATION FOR COMMISSIONING AND OPERATIONS (cont.)

Function	Detail
Support functions	Key facility support functions, including • Financial and risk management. • Information technology services. • Communication and management of key stakeholder interfaces such as the project board, NEPIO and the organizational, portfolio and programme management offices. Coordination of internal and external release of information. • Human resource management. • Document, information and records management. • Site and facilities management. • Asset management.

VII.3. PRIOR TO FINAL INVESTMENT DECISION

Prior to the final investment decision, the owner/operator needs to update the items identified in Table 19.

TABLE 19. ITEMS TO BE UPDATED PRIOR TO THE FINAL INVESTMENT DECISION

Item	Comment
Integration	Update the project’s main integration documents (e.g. charter, life cycle management strategies, project management plans) if necessary, based on latest information obtained through the contracting process or senior executive direction. Establish specifications and controls as necessary to guide and oversee upcoming activities in line with the necessary graded approach. Establish all management system elements that are required for the next phase of the project and ensure integration between the different organizations involved. A draft project manual specific to the construction phase can provide guidance on various aspects that need to be agreed to by the negotiation teams. It can also assist with rapid startup of the next project phase and help avoid any last minute misunderstandings. It is critical to ensure that all necessary owner’s requirements (see Section 4.1.4.3) are included in the draft contract. A verification should be done to ensure that this is the case.
Scope	Update the project’s PBS, WBS, WBS dictionary and OBS based on latest available information.
Time	Establish, optimize and finalize the construction phase baseline schedule (detailed design, procurement, construction and commissioning activities). The plan/schedule should be assessed to ensure that it is adequate and that if approved it would achieve the specified objectives for the next phase of the project.
Cost	Update activity costing information and CBS with latest information. Near term activities should be defined and estimated in more detail.
Quality	Establish oversight and quality control functions with the necessary expertise, resources and empowerment to maintain project oversight by adopting a graded approach to nuclear safety to: • Verify the capability of both internal and contracted project resources before work commences; • Maintain oversight over all work (procurement, manufacturing, design, construction and commissioning); • Verify the acceptability of all work performed.

TABLE 19. ITEMS TO BE UPDATED PRIOR TO THE FINAL INVESTMENT DECISION (cont.)

Item	Comment
Human resources	Recruit, strengthen, train and develop resources for the construction stage of the project. Engineering, procurement and construction oversight expertise is of particular importance. Ensure responsibilities are clearly defined for all organizations involved on the project.
Communications	Update communication strategy as required to cover communication of the final investment decision to the general public.
Risk	Update project risk register based on latest information and transmit it to senior decision makers in support of the final investment decision. Often a project readiness assessment report is prepared that provides a final assessment of project feasibility. Some items to consider at this stage include: • Assessment of the status of the national nuclear power infrastructure development required to support the project. Any outstanding recommendations raised during the INIR Phase 2 review should be closed or appropriately mitigated. • Assessment of project status, development gaps and risks. The completeness of development work should be verified to have achieved the established governance and phase gate requirements. Risks associated with any outstanding activities should be flagged and appropriate mitigations put in place. Organizational performance should be reviewed and any deficiencies should be corrected for the next phase of the project. • Review and assess the project's financial feasibility in line with the owner/operator's objectives as established by the project board. Ensure adequate contingencies are considered and included. • A risk review should be conducted on the likelihood of any new legislative or regulatory requirements during the construction period. Any new requirements that may be introduced are likely to result in additional work that may have to be budgeted for by the owner/operator. Benchmarking against other international legislative and regulatory requirements can assist. • Consider planning to host a CORR [51] during Phase 3 at the start of the planned construction activities. This will assess the contractor and owner/operator in terms of their readiness to proceed with the construction phase of the NPP contract.
Procurement	Draft contracts that are agreed to by both parties should be available and ready for signature. Financing arrangements need to be confirmed. Procurement oversight of manufacturing and component fabrication is of particular importance in Phase 3 and so experienced personnel should be available for these functions.
Stakeholders and interested parties	Update key stakeholder lists and strategy to reflect successful bidder and project team members.
Health, safety and environment	Ensure requirements for contractor oversight related to health, safety and environment are accounted for in the project plan and budget.
Lessons learned and OPEX	Ensure lessons learned and OPEX are captured related to proposed successful bidder and its project experience. Ensure methods to capture ongoing lessons are accounted for in the project plan and budget.
Radiation dose and radioactive waste management	Ensure requirements for radiation dose and radioactive waste management are accounted for in the project plan and budget.
Licensing	Ensure that all necessary manufacturing and construction permits and licences have been obtained or are being managed in preparation for the start of manufacturing and construction activities. In preparation for the review of the preliminary safety case early in Phase 3 the licensing management function should have mature licensing management processes in place that conform to and interface with the regulatory requirements/functions. These will need to be documented in the licensing management manual and agreed by the nuclear regulator.

TABLE 19. ITEMS TO BE UPDATED PRIOR TO THE FINAL INVESTMENT DECISION (cont.)

Item	Comment
EPR	Confirm outstanding work related to EPR is accounted for in the project plan and budget. This includes coordination with regional, national and international organizations and testing emergency response capabilities.
Security and safeguards	Reinforce safety and security culture programmes and ensure these are identified as a contractual requirement (see project requirements in 6.4.1.2) for all contracted parties.

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ABBREVIATIONS

AACE	American Association of Cost Engineering
AHARA	as high as reasonably achievable
AIPM	Australian Institute of Project Management
ALARA	as low as reasonably achievable
AMA	American Management Association
ANCSPM	Australian National Competency Standards for Project Management
ANSI	American National Standards Institute
APM	Association of Project Management
APMBOK	Association of Project Management Book of Knowledge
AWP	advanced work packaging
BAC	budgeted cost at completion
BIM	building information management
BIS	bid invitation specification
BOO/BOOT	build–own–operate/transfer
CANDU	Canadian deuterium uranium (NPP design)
CANPAC	CANDU Procurement Audit Committee
CBS	cost breakdown structure
CCTA	Central Computer and Telecommunications Agency
CII	Construction Industry Institute
COMS	constructability, operability, maintainability and safety
CORR	construction readiness review
CPI	cost performance index
CPM	critical path method
CSA	Canadian Standards Association
CWP	construction work package
DSDM	dynamic systems development method
DTC	design to cost
EAC	estimated cost at completion
ECI	European Construction Institute
EDMS	electronic document management system
ENAA	Engineering Advancement Association
EPC	engineering, procurement and construction
EPR	emergency planning and response
EV	earned value
EVM	earned value management
EWP	engineering work package
FEL	front end loading
FEP	front end planning
GIS	geographical information system
ICB	individual competency baseline
ILO	International Labour Organization
INIR	integrated nuclear infrastructure review
INPO	Institute of Nuclear Power Operators
IPA	Independent Project Analysis (a company with a training Institute division)
IPMA	International Project Management Association
IPMABOK	International Project Management Association Book of Knowledge
ISO	International Organization for Standardization
I/TT/O	inputs, tools and technique and outputs
IWP	installation work package
KA	knowledge area

KM	knowledge management
KMAV	knowledge management assist visit
MSP	Managing Successful Programmes
NASA	National Aeronautics and Space Administration
NCR	non-conformance report
NEPIO	nuclear energy programme implementing organization
NUPIC	Nuclear Procurement Issues Committee
OBS	organizational breakdown structure
OCB	organizational competence baseline
OECD-NEA	Organization for Economic Cooperation and Development Nuclear Energy Agency
OGC	Office of Government Commerce (UK)
OPEX	operating experience
OPG	Ontario Power Generation
OSART	operational safety review team
OSH	occupational safety and health
P2M	Project & Program Management (for Enterprise Innovation)
PBS	plant breakdown structure
PCGI	project cost growth index
PDCA	plan, do, check, act
PDRI	project definition rating index
PDSA	plan, do, study, act
PEB	project excellence baseline
PG	process group
PIR	post-implementation review
PMBOK	Project Management Book of Knowledge (by PMI)
PMCC	Project Management Professionals Certification Center
PMI	Project Management Institute
PPE	plant parameter envelope
PRINCE2	PRojects IN Controlled Environments (by AXELOS)
PSAR	preliminary safety analysis report
PV	planned value
SAT	systematic approach to training
SMCI	standardize, measure, control and improve
SPI	schedule performance index
SRA	schedule risk analysis
VE	value engineering
WANO	World Association of Nuclear Operators
WBS	work breakdown structure

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Consultancy Meetings

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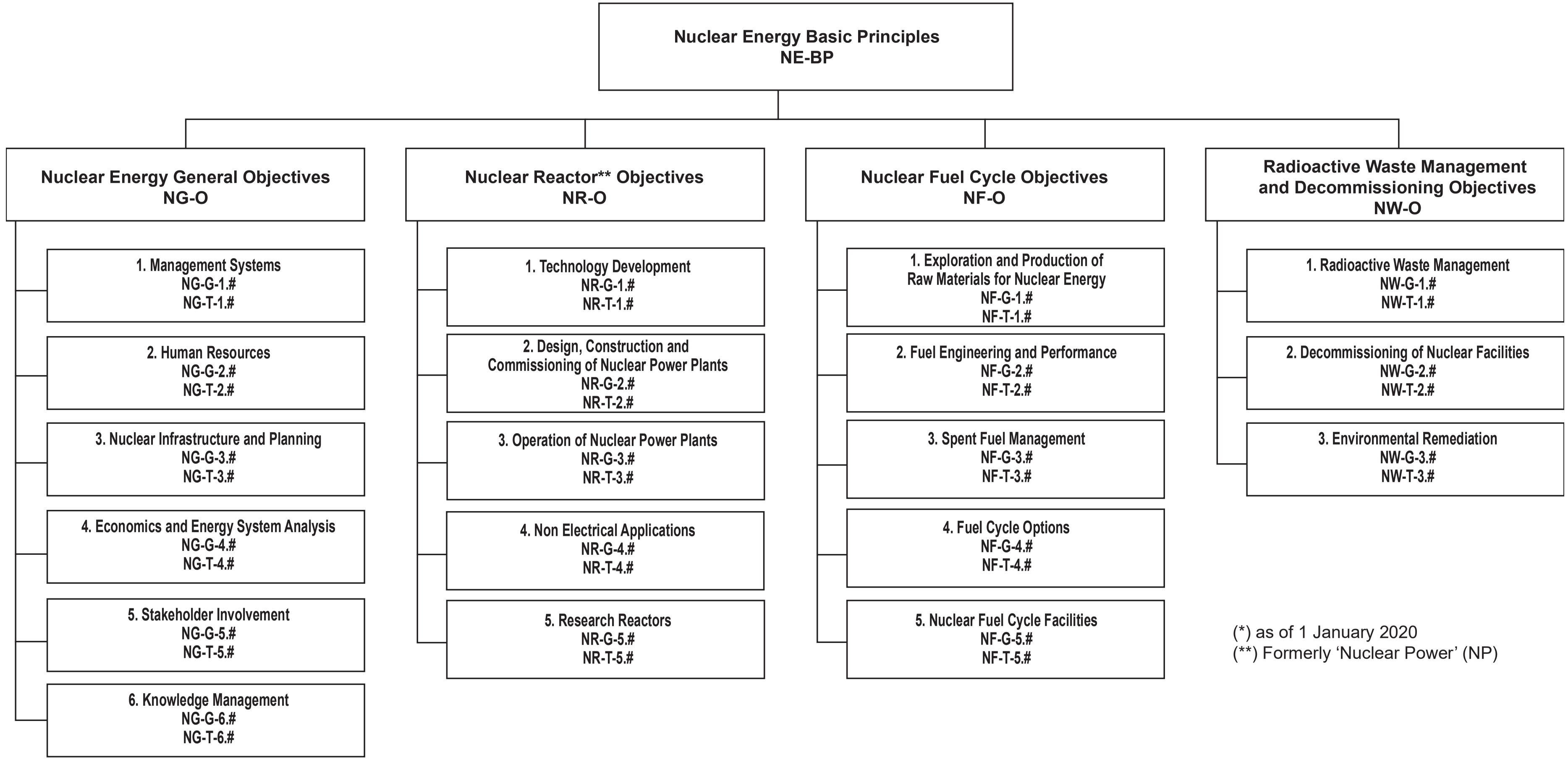

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Key

BP:	Basic Principles
O:	Objectives
G:	Guides and Methodologies
T:	Technical Reports
Nos 1–6:	Topic designations
#:	Guide or Report number

Examples

NG-G-3.1:	Nuclear Energy General (**NG**), Guides and Methodologies (**G**), Nuclear Infrastructure and Planning (topic **3**), **#1**
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