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FOREWORD

One of the IAEA's statutory objectives is to "seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world." One way this objective is achieved is through the publication of a range of technical series. Two of these are the IAEA Nuclear Energy Series and the IAEA Safety Standards Series.

According to Article III.A.6 of the IAEA Statute, the safety standards establish "standards of safety for protection of health and minimization of danger to life and property". The safety standards include the Safety Fundamentals, Safety Requirements and Safety Guides. These standards are written primarily in a regulatory style, and are binding on the IAEA for its own programmes. The principal users are the regulatory bodies in Member States and other national authorities.

The IAEA Nuclear Energy Series comprises reports designed to encourage and assist R&D on, and application of, nuclear energy for peaceful uses. This includes practical examples to be used by owners and operators of utilities in Member States, implementing organizations, academia, and government officials, among others. This information is presented in guides, reports on technology status and advances, and best practices for peaceful uses of nuclear energy based on inputs from international experts. The IAEA Nuclear Energy Series complements the IAEA Safety Standards Series.

This report updates the IAEA publication Risk Management of Knowledge Loss in Nuclear Industry Organizations, which was issued in 2006. The current report is based on the experiences of operating organizations in Member States. It is intended to increase awareness of the need to develop a strategic approach and action plans to address the potential loss of critical knowledge and skills in nuclear organizations, in particular in nuclear power plants. It provides practical guidance for conducting risk assessments and implementing a strategic approach to improve the skills and competences of new and existing workers.

First, it considers common challenges of workforce development for nuclear facilities, in particular for nuclear power plants, taking into account linkages between traditional human resource development programmes and knowledge management programmes.

Second, it provides practical guidance on the establishment of an organizational competence loss risk assessment process and defines key roles and responsibilities of potential knowledge management teams for its successful implementation.

Third, it collects lessons learned from knowledge loss risk management programmes at nuclear power plants, including considerations of knowledge transfer and retention methods, tools and motivational factors.

Fourth, it provides case studies from nuclear power plants as examples for practical guidance on how to retain, transfer and utilize captured critical knowledge, and how to integrate a knowledge loss risk assessment into an organization's management system.

The IAEA officer responsible for this report was V. Kolomiiets of the Division of Planning, Information and Knowledge Management.

EDITORIAL NOTE

CONTENTS

1. INTRODUCTION

1.1. BACKGROUND

Nuclear projects usually last for many years or decades, and can be divided into numerous phases involving different stakeholders.

The formation of a nuclear knowledge management (NKM) programme, and its implementation within a nuclear facility, ensures that a nuclear power plant can be operated — for a long period of time — as a highly reliable, efficient and safe plant. Managing knowledge across all operational phases means ensuring the availability of the competent human resources (HR) that are required for safe operation throughout the nuclear facility lifetime, taking into account changes that inevitably occur with time, for example, organizational changes, the evolution of information systems and related media and formats, and changes in information technology (IT) infrastructures.

There is an evident risk that in the absence of knowledge transfer plans, essential knowledge can be lost between different phases of a nuclear facility lifetime, for a variety of reasons, if it is not properly codified and/or transferred in advance. The most evident risk is that for every phase of a nuclear project, a different workforce is employed. For example, some competences needed during the design phase may not be required during operation, but at the operation stage, new competences will be needed. When moving from one phase of a nuclear facility lifetime to another, independently of other risk factors, knowledge gaps, such as personnel attrition, diminishing job tenures, decreasing availability of skills on the market for the nuclear sector and reducing knowledge transfer between generations, can be created.

Organizational and workforce changes are not the only risks related to knowledge preservation in a nuclear organization. Some projects related to IT and data management might implement different information systems, with different media storage formats that require constant upgrades.

All these risks can be mitigated with careful planning and a clear strategy for the long term preservation of knowledge. The organizational evolution of nuclear power plants requires upfront planning of the competences needed at each phase, and the simultaneous creation of knowledge transfer plans for core competences and skills. In addition, organizational knowledge must be captured and codified at each phase. Together with a well defined process for knowledge capture and transfer, a range of IT and information management tools, for supporting the creation and transfer of knowledge as standardized and codified knowledge, needs to be collected through well established processes [1].

The IAEA recognizes — and also reminds Member States — that there is a need to focus on the implementation of a knowledge loss risk management (KLRM) methodology to provide assurance that knowledge preservation and knowledge transfer programmes are properly taken into account throughout the different phases of a nuclear project. This means that for all possible phases of a nuclear power plant's life cycle (i.e. design, fabrication and construction, commissioning, operation, extended long term operation and decommissioning), knowledge management (KM) and knowledge transfer from one phase to another need to be carefully planned and executed [2].

The distinctive characteristics of nuclear energy give rise to special requirements for the development and maintenance of a competent workforce. In all countries with a nuclear programme, there exists a substantial need for nuclear facilities to be safely operated, maintained and, in time, decommissioned. A knowledgeable and skilled workforce is an essential element in the implementation and safe operation of all nuclear facilities, as well as in nuclear technology and in research and development (R&D) [3].

The nuclear workforce of the twenty-first century forms a significant international, commercial and scientific community. Surveys conducted in some countries indicate that the future demand for global employment in nuclear related activities will increase to tens or hundreds of thousands of skilled workers [3]. At the same time, an ageing workforce is increasing the risk of critical knowledge loss. The IAEA understands the importance of these processes, and at its General Conference in 2002, a resolution on Strengthening the Agency's Activities Related to Nuclear Science, Technology and Applications (GC(46)/Res/11/B) was adopted [4]. Based on this, the IAEA launched its NKM programme. An important aspect of the NKM programme was to foster the ability of Member States to manage the risks related to knowledge loss due to shortages in personnel and to recognize that preserving and enhancing nuclear knowledge is vital to the continued and expanded safe utilization of all nuclear technologies for peaceful purposes.

1.2. OBJECTIVE

The objective of this publication is to provide a methodology to enable KLRM to ensure the safe, reliable and efficient operation of nuclear facilities. This report focuses on aspects of knowledge loss risk associated with employee attrition in nuclear power plants and provides guidance on how to mitigate them. The described methodology has proved its usefulness in a number of nuclear power plants and can be easily adopted by any nuclear related organization. The aims of the publication are to:

— Increase *awareness* among nuclear organization managers, highlighting the need to develop a strategic approach and action plans to identify and reduce the risks of organizational and individual knowledge loss in order to ensure the sustained safety and efficiency of nuclear organizations;
— Increase the *capability* of nuclear organizations to proactively manage the risks and mitigate the negative impacts of critical knowledge loss;
— Provide *methodological support* and determine *practical approaches* for building sustainable KLRM within nuclear organizations.

1.3. SCOPE

This publication addresses the establishment, implementation and improvement of KM programmes and focuses on providing specific methods and tools for managing critical knowledge loss in nuclear related organizations.

The users of the current publication are expected to be managers of nuclear power plants and related nuclear organizations responsible for KM, human resource development (HRD) and training system establishment, as well as policy and decision makers at any level, including governments.

Nuclear industry managers can adopt the methodology as it is provided here, or modify the processes and tools outlined to meet the specific needs of KLRM at their organizations.

Cooperation with IT and quality assurance (QA) specialists is considered crucial for sustainable KLRM.

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

1.4. STRUCTURE

Section 2 describes the link between KLRM and a strategic approach for workforce development, and how this development process can be incorporated into the integrated management systems of nuclear organizations. Section 3 explains the roles and responsibilities of the main stakeholders of KLRM and describes methodologies that focus on the identification of organizational competences and the risks of individual knowledge loss. Section 4 discusses anticipated future knowledge gaps, and Section 5 provides a summary and conclusions.

Annexes I–V are reproduced from Ref. [5], because of their usefulness and applicability to this current publication.

Annexes VI–X provide examples of best practices (case studies) of effective KLRM gathered from nuclear power plants and nuclear related organizations.

2. STRATEGIC APPROACH TO WORKFORCE DEVELOPMENT

2.1. WORKFORCE DEVELOPMENT CHALLENGES, RISKS AND GAPS

2.1.1. Challenges of expanding nuclear power programmes

The IAEA regularly estimates the future nuclear electricity generating capacity in the world. By 2030, the number of operating nuclear reactors is projected to increase by approximately 90 from the 448 reactors that were operating at the end of 2016. Most of the growth will occur in countries that already have operating nuclear power plants.

The accident at the Fukushima Daiichi nuclear power plant in Japan is expected to delay the growth of nuclear power, but not to reverse it. The IAEA annually publishes a low and a high projection for global growth in nuclear power. According to the Agency's 2015 projections in the high case, the global nuclear power capacity is expected to grow from its current level of 381.7 GW(e) to 632 GW(e) by 2030 — an increase of about 70% in 15 years. In the low case, the nuclear capacity in 2030 will be 385 GW(e), i.e. maintaining approximately its present level. These figures account for retirements, and therefore the actual new capacity added in the next 15 years will be about 150 GW(e) in the low case and 300 GW(e) in the high case. Extending these projections into the future results in nuclear capacity growing to 964 GW(e) in the high case by 2050, and net zero growth in the low case. These growth rates are slower than those projected in 2013, particularly for the low projection. Factors contributing to this decline in growth include: earlier than anticipated reactor retirements, delayed new builds and increased costs attributable to the implementation of additional safety related modifications. Nevertheless, interest in nuclear power remains strong in some regions, particularly in countries with developing economies and energy needs. The continued growth suggests that the fundamentals supporting the use of nuclear power have not changed [6].

Continuous growth of the global nuclear infrastructure requires a pragmatic approach to a KM programme from any and all stakeholders. There is a lack of a nuclear workforce for R&D activities, nuclear power plant construction, operation and decommissioning. How to build necessary competence, retain accumulated experience and organize sophisticated transferring to the new generation are important concerns for current and future developments.

2.1.2. Challenges of an ageing workforce in the nuclear industry

It is well recognized that many nuclear power plant operators face a challenge with the loss of experienced workers and the knowledge and skills that they possess. Often, this knowledge is undocumented and the skills require years of training and experience to develop. This loss may be caused by a variety of factors including: retirement of long term employees, internal transfers and promotion of employees or resignation of employees who leave the nuclear industry. The same risks of competence loss are valid for the outsourcing and consultant companies involved in nuclear programmes and projects.

The situation of an ageing workforce has similar trends in developed and developing countries; therefore, the situation is becoming increasingly critical due to loss of key experts not only from the nuclear sector but also from traditional engineering fields, such as welding, mechanics, chemistry, construction, electric, instrumentation and control.

A study by a team from Los Alamos National Laboratory [3] simulated HRD needs for several scenarios in the Russian Federation and the United States of America. Figure 1 shows the magnitude of the prospective demand for operations personnel (i.e. operating staff retained for plant operations following the construction phase) in the USA where additional plants are built to retain the market share. Starting from the 56 000 US nuclear workers (as of 2006), the graph shows separately the staff needs to replace retiring personnel and to cater for additional, new capacity, indicating a demand, by 2030, of approximately 19 000 new positions and a total of 63 000 new hires, the remaining 44 000 of these to replace retiring employees. The main outcome of this analysis was that there is a large need for education and training of new employees.

At the same time, nuclear education must play an important role in a new engineer's development. The amount of newcomers needed to cover the demand is extremely high. However, the problem of ageing highly qualified academic staff is even more crucial, and retention and transfer of scientific knowledge is a big challenge.

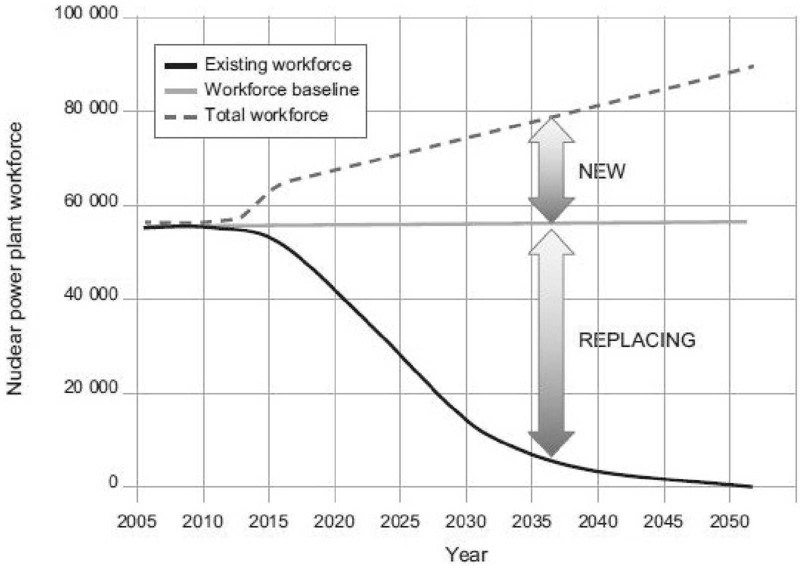


FIG. 1. Estimates of the operating personnel needed for retaining the market share in nuclear power in the USA [3].

In general, the demand for nuclear knowledge and skills set against a generally ageing workforce implies that the nuclear industry has to take a more formal approach than in recent years to manage its HR, including developing strategies and programmes, to capture, retain and transfer nuclear knowledge and skills.

2.1.3. Recruitment of the next generation

One of the most important recruitment issues is to attract technical talent to the nuclear plant operations community. As new facilities are constructed and other necessary nuclear infrastructure and technology begin to emerge, the ability to attract new talent and the need to have the requisite knowledge resources for provision of training will affect the ability to bring new facilities and support activities on-line in a timely enough manner to keep pace with the energy demand.

A shortage of talent is a risk that many businesses are currently facing. Replacing a key expert may cost an amount that is similar to, or twice as much as his or her annual salary. There is no doubt that nuclear organizations need to increase their focus on retaining the right talent and creating systems that encourage their talent to develop the right skills. By making the right moves today, organizations can greatly reduce the risk of losing top talent and assure that they will be able to respond effectively to the business opportunities that a recovering economy offers in the future.

In order to be more flexible and sustainable, nuclear organizations need to adopt talent management practices that allow them to change the skill sets of their employees and to motivate them to change their behaviour. The key practices that will accomplish great agility include assuming the traditional job description approach to talent management and adopting a skill based motivation system that includes pay for skills and skill acquisition.

Overall, the future belongs to organizations that can manage a flexible and motivated workforce. This can only be accomplished by incorporating policies and practices that encourage talent to be agile while motivating them to perform well.

2.1.4. Other factors and risks

Other factors and risks that should be considered in workforce development include:

- Ageing of nuclear workers (average age increase, risk of earlier retirement);
- Loss of nuclear workers (critical knowledge holders);
- Non-availability of ready-to-work recruits on the labour market;
- Internal and external mobility of the workforce;

— Weaknesses in cooperation with educational and training organizations;
— Contractor issues (knowledge transfer as a requirement for contracts needs to be addressed).

2.1.5. Future knowledge gaps in the workforce

Many Member States are experiencing an impact on the changing geoeconomic environment in their region. A large number of these changes require organizations to add or modify existing technologies and/or programmes. To anticipate future knowledge gaps, an organization must have a clear understanding of the business objectives and their impact on the future skill sets (competences) needed in the organization. In the a strategic approach to workforce development (see Fig. 2), the focus on business unit planning provides an organization with the framework to consider these impacts during the WFP process.

FIG. 2. Strategic approach to workforce development.

In the USA, there has been additional focus on cyber security and upgrading analogue equipment to digital equipment. The following areas have been of particular interest:

— Grid modernization;
— Generation mix and carbon management;
— New build (new nuclear power plants and technologies);
— Regulation and policy changes (e.g. impacts arising from the Fukushima Daiichi accident);
— Ageing industry workforce;
— Mergers and acquisitions;
— Adoption of new technology.

Each of these areas will have an impact on the type of workforce skills and competences needed in the future. Therefore, knowledge that once was considered critical may not be needed any longer for a given technology and/or following an organizational change. When conducting risk assessments, as part of an overall strategic approach to WFP, consideration of future competences and skills will be required.

2.1.6. Future knowledge gaps related to technology

Technology continues to evolve, and the risk associated with the obsolescence of information systems and record management systems must also be considered to avoid loss of codified knowledge over time. Many of the existing global nuclear projects started in an era in which knowledge was codified using hard copies and paper documents (which require special handling and care for long term preservation), whereas they now mostly use computer based systems. Migration from one media to another can be an expensive and sometimes problematic process, with significant risks. However, in the digital age, migration often becomes inevitable owing to media obsolescence (e.g. media failure over time, lack of hardware to access media and lack of software to interpret the data on media).

Therefore, the long term preservation of information and evolution of organizational structures of a nuclear project are key aspects to be considered at an early stage when planning KM for all phases of a nuclear project. As it is not possible to foresee the entire technological evolution of information management, the knowledge assets of the project should be captured and codified using open, extensible and standardized technologies and media formats, which will ensure that knowledge will be available across all phases.

2.2. WORKFORCE DEVELOPMENT APPROACH

Coherent intervention by governments, industry, universities and R&D organizations remains vital to avoid the risk of HR shortages in some countries and to maintain the stock of skilled and competent workers. It is also necessary in order to ensure a flow of new recruits that is sustainable in the long term.

A strategic approach for workforce development means a systematic process of interconnection between the economic and safety goals of a nuclear power plant with organizational knowledge asset provided by sufficiently qualified workforce [7].

Many nuclear organizations recognize that a strategic approach is effective in addressing the broad array of workforce issues that many organizations face. While this publication focuses on managing the risk associated with potential loss of nuclear knowledge, the interactions between KM and other initiatives of HRD programmes should be considered. HRD programmes may include the following:

— Workforce planning (WFP);
— Recruitment programmes;
— Talent acquisition initiatives;
— Training programmes;
— Succession planning and leadership development;
— KM;
— Organizational competence management.

The concept of a strategic approach to workforce development is shown in Fig. 2. In the context of workforce development, KLRM (as a set of KM tools) is a systematic process for the identification of gaps in organizational competences due to potential staff attrition. After evaluation of the knowledge loss threats, an action plan should be developed to mitigate these risks.

For example, if a potential for knowledge loss is identified, solutions may involve a recruitment initiative and/or developing a formal training module. The pending retirement of an experienced engineer may require recruitment, training and succession planning. There are some other examples in which an integrated, strategic approach is taken to ensure the overall effectiveness of nuclear programmes, and further details of an HR and WFP approach are described in the IAEA publication Workforce Planning for New Nuclear Power Programmes [7].

As part of WFP, knowledge transfer and retention begin at the time of hiring and moves through the employee life cycle. A general life cycle of knowledge transfer for a nuclear specialist is shown in Fig. 3.

Newly hired employees complete initial training for their positions as part of the required new hire orientation and integration. Many positions require certification and/or qualifications through extensive, formalized training programmes. Upon completion of those programmes, employees qualified to perform their tasks are considered independent workers. These individuals are capable of performing their jobs; however, they may not be as proficient as key experts in the field.

KM can accelerate the acquisition of technical capabilities by a new employee and help to transfer critical and unique knowledge, thus shortening the competence development time.

For this reason, the KM culture plays a specific and important role in workforce development. The establishment of motivation mechanisms will encourage highly qualified staff to share knowledge and skills, which will lead to strengthening of knowledge sharing and knowledge flow, which is an essential basis for safety culture [8].

The following actions can be implemented within a nuclear organization in order to build and improve a knowledge sharing culture:

— Cooperation among organizational units;
— Motivation to serve in the organization in the long term;
— Provision of young specialist career plans and promotion;
— Provision of key expert skills certification and rewards;
— Provision of teamwork rewards;
— Implementation of social programmes.

Motivational factors for knowledge transfer are further discussed in Section 3.6.

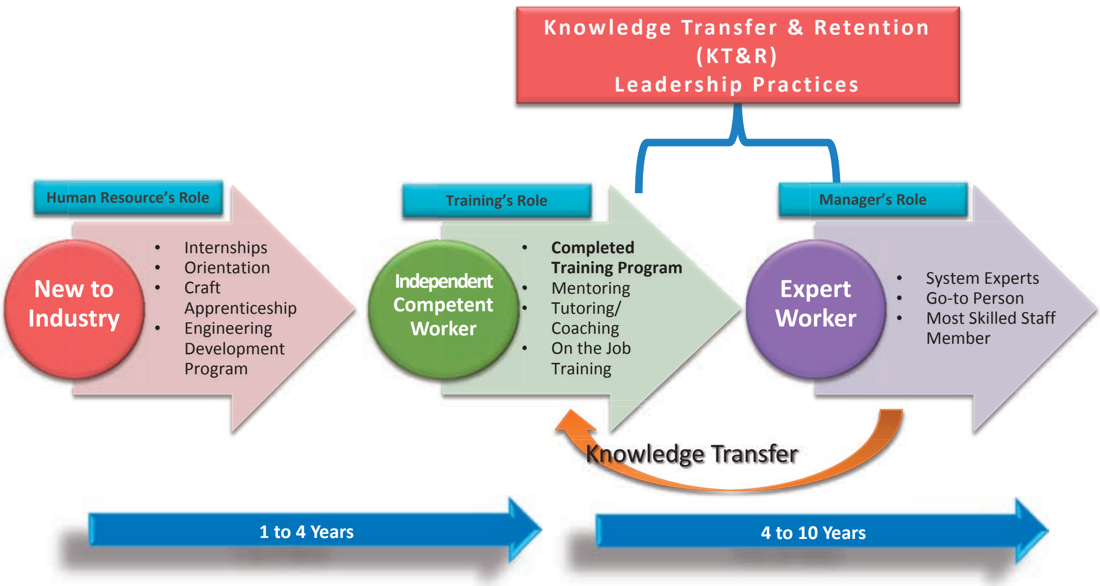


FIG. 3. Workforce planning and KM continuum.

3. KNOWLEDGE LOSS RISK MANAGEMENT METHODOLOGY

The necessity to maintain organizational competence for nuclear power plants is widely recognized by Member States, given the nature of the business (high hazard, low risk) and the life cycle of 100 years or more. They recognize the importance of continuing the safe and efficient operation of existing nuclear power plants, of continuing the support for R&D and educational institutions, and of supporting the expansion of nuclear power [9].

Experience accumulated in Member States demonstrates that transformations of nuclear organizations during a life cycle may result in a loss of knowledge and skill. The common challenge is to maintain and enhance institutional knowledge.

This report provides a KLRM methodology as an effective supporting tool for nuclear power plant managers in identifying and understanding the level of risk. It also gives guidance on how to develop a sustainable strategy and plan aiming to mitigate these risks and to ensure the continuity and effectiveness of day to day operation.

3.1. ROLES AND RESPONSIBILITIES OF A KNOWLEDGE MANAGEMENT TEAM

In order to efficiently and effectively implement a KM strategy and to build a new KLRM process in a nuclear power plant, some new roles and responsibilities are needed. These can be part of existing duties or assigned as separate roles, depending on the scope, size and duration of the KLRM initiative.

Nuclear power plants that have already implemented successful KLRM recommend that it is important, from the beginning, to define the main stakeholders of the process and to establish a KM team including them. A KM team can be a formally independent group with defined roles and responsibilities, or a group formed on a community of practice approach with assigned functions. A community of practice approach is when a voluntary group of peer practitioners share lessons learned, methods and best practices in a given discipline or for specialized work. Some nuclear power plants have found it important to establish a KM board (steering committee) for resolving cross-cutting KM issues.

The main KM participants and stakeholders are:

(a) Internal participants:
- Representatives from structural departments (e.g. HR, QA, IT and the main technical departments);
- Managers, officials and employees.

(b) External participants:
- Representatives of external organizations, counteragents and contractors;
- External experts and consultants.

(c) Main stakeholders:
- Nuclear power plant senior managers;
- KM board (steering committee);
- Heads of departments;
- Line managers;
- KM process owners and responsible bodies.

A KM team should function in an open and collaborative environment involving all departments and units and thus encouraging employees in the sharing of knowledge. The goal of the KM team is to support heads of departments in the KLRM methodology, to choose applicable tools and to apply them for successful knowledge retention (KR) and knowledge transfer, and to regularly analyse and report on achieved results. It is very important to show the benefits of KLRM integration and to obtain support from the senior managers of the nuclear power plant.

The main functions of the KM team are:

- Coordination of KLRM activities;
- Resource allocation;
- Planning of activities;

— Performance of activities;
— Activity control;
— Provision of methodological support to departments.

For successful implementation in some organizations, certain roles and permanent positions have been created, for example, a chief knowledge officer. Other organizations have created roles based on a project orientated approach for a few years until KLRM has become embedded throughout the organizational processes as part of its organizational structure, and others have chosen not to introduce these new roles as new responsibilities. Experience shows that the most admired and successful KM initiatives are those where the new roles and responsibilities have been recognized and performed (see Table 1).

Successful implementation of KLRM includes two levels of analysis:

— Upper level: Organizational competence loss risk assessment;
— Lower level: Individual knowledge loss risk assessment (KLRA).

These two approaches, which support each other and help to address the risks of loss of specific organizational competences and individual knowledge loss within nuclear organizations, are discussed in Sections 3.2 and 3.3.

TABLE 1. ROLES AND RESPONSIBILITIES OF A KM TEAM

Role	Responsibilities
Knowledge manager	A senior position with strategic responsibility for promoting and implementing KM that: determines the needs of the KM team and allocates resources for the KM programme, implements the programme and evaluates and continuously improves the KM system of the nuclear organization; determines a strategy together with senior management; reports to senior management on competence gaps, competence risks and future competence needs.
KM coordinator	A senior position with responsibility for implementing, analysing and promoting KM that: administers the KM tools and relevant internal policy procedures, organizes KM meetings, supports training, creates and evaluates key performance indicators and annual reports to the board and coordinates IT support and internal communication; collects data for reporting and takes responsibility for the KM budget.
Knowledge officer	A senior position with supporting responsibility to the KM manager that: provides analysis of the most crucial knowledge domain, competence risks and launches KLRM activities in the departments of first priority; cooperates with knowledge sponsors and lead experts; defines gaps and proposes solutions for mitigating risks.
Knowledge sponsor	A function assigned to the supervisor of the department that: coordinates KM activities internally and forms collaboration between the KM team and departments; conducts regular assessment and integrity checking of KLRM in the management system.
Chief information officer	A senior position with strategic responsibility for information management and IT (KM database structure, knowledge mapping, knowledge databases and document management system).
Lead expert	A position that: identifies an expert in their area and determines the level of risk of knowledge loss; prioritizes necessary actions and tasks relating to expert availability and formal processing of experience reports (or other forms of knowledge transfer and preservation).

3.2. ORGANIZATIONAL COMPETENCE LOSS RISK ASSESSMENT

In this section, a methodology on how to initiate organizational competence loss risk assessment is proposed. The methodology helps managers of nuclear organizations to understand and address risks related to competence gaps on a regular basis and to respond to them proactively.

Organizational competence loss risk assessment is a 'top to bottom' approach, which can be easily implemented in any organization with a well defined process and HR structure, for example, a nuclear power plant [10]. This approach shows the links among the business goals of the organization, core processes, subprocesses, organizational competence needs and available HR. It can be applied independently or together with KLRA — the use of both is recommended.

Organizational competence loss risk assessment is a three step process, as outlined below (see Fig. 4).

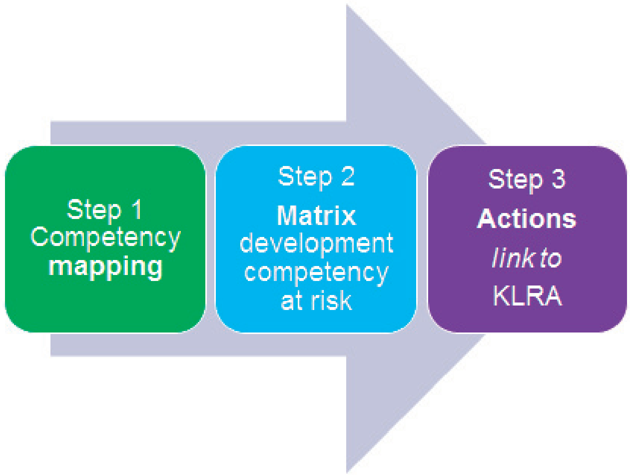


FIG. 4. Organizational competence loss risk assessment process. KLRA — knowledge loss risk assessment.

3.2.1. Step 1: Competence mapping

This step focuses on collecting the initial information that is needed for the following competence at risk assessment. A mapping process helps to visualize current organizational functions and competences and thus to identify the strengths and weaknesses of an organization in relation to current business goals.

The analysis of business processes and subprocesses results in the identification of competences within the organization. The identification of competences requires ongoing review and updating as the environment that affects business operations is constantly changing owing to internal and external circumstances. New challenges and demands are faced by organizations that need managers to find available competences and HR resources [11].

While creating a competence map, it is useful to take into account any information that helps to identify organizational competences that contribute to overall organizational competence. The following sources of information on the organization can be useful:

- Regulatory staffing requirements;
- Mission and business goals;
- Organizational structure;
- Roles and responsibilities;
- Workforce plans;
- Staff positions;
- Job descriptions.

Nuclear organization managers at all levels can create a competence map for their units, departments or divisions on the basis of organizational structures, organizational processes and subprocess, and ongoing and future projects, taking into account the requirements for staff positions needed for successful process implementation. Top, line and middle level managers and the KM team can be involved in this exercise. A simplified example with further explanation of organizational competence map development is shown in Fig. 5.

To create an organizational competence map, managers need to use sources of relevant information such as the following:

— Inputs:
- Policy with the defined business goals of the organization;
- Defined processes and subprocesses supporting the business goals (usually, a nuclear power plant has core, supporting and managerial processes);
- List of active and planned projects;
- Organizational HR structure and positions list;
- Available HR.

— Outputs:
- Organizational competence map;
- Defined gaps in organizational competence needed for successful business processes.

When an organizational competence map is defined, it can be easily transferred into a list of organizational competencies (see the example in Table 2).

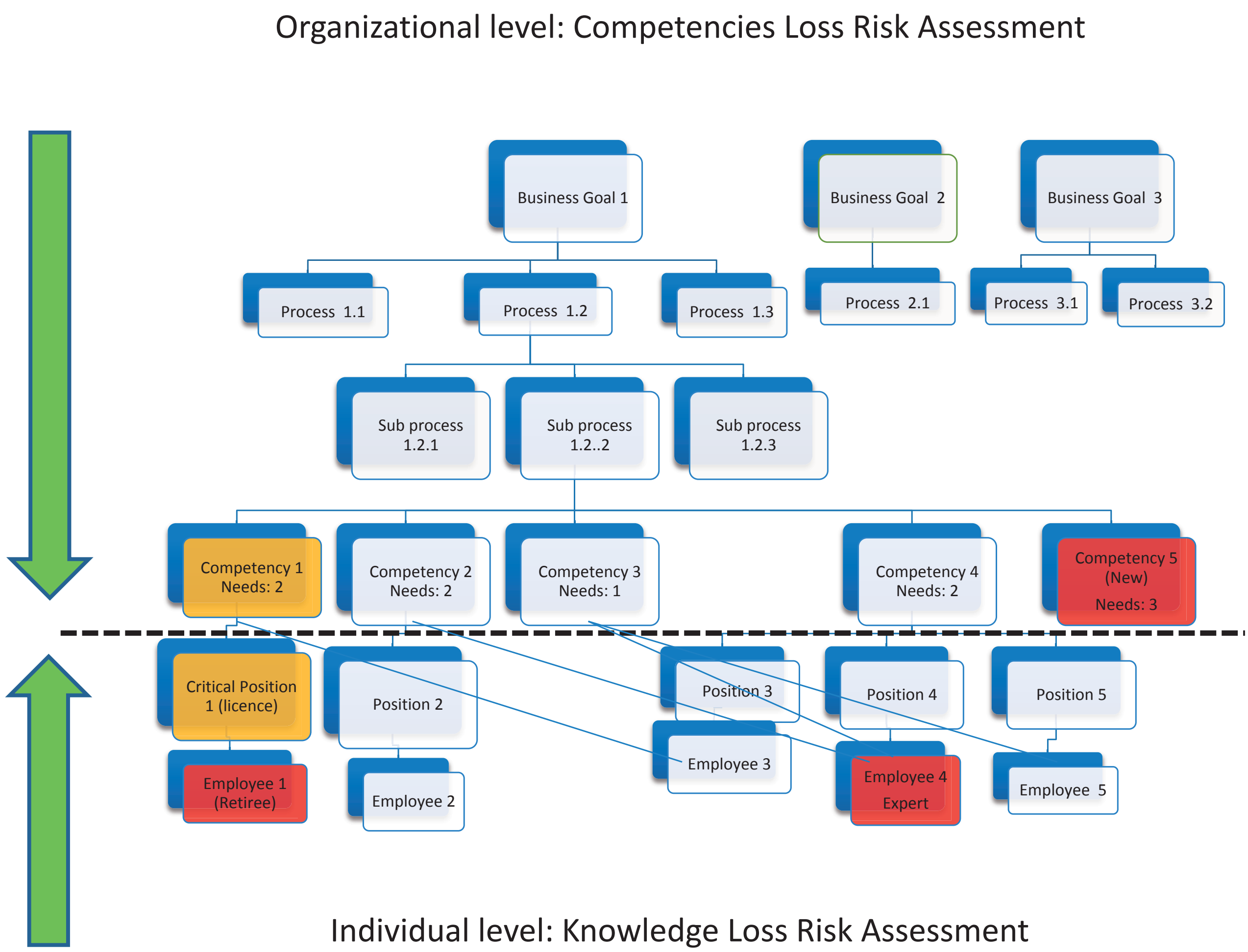


FIG. 5. Example of an organizational competence mapping approach to the availability of HR.

TABLE 2. COMMON PROCESSES AND ORGANIZATIONAL COMPETENCES FOR NUCLEAR POWER PLANTS

Process	Organizational competences
(1) Business operations	Strategy and corporate management
	Audit and compliance
	Communication
	Contracts and procurement
	Finance and budget
	HR
	Legal assistance
	Administrative operations
	Project management
(2) Construction and installation	Assembly engineering
	Civil engineering
	Nuclear building engineering
	Non-nuclear building engineering
	Building services engineering
	Site management, logistics and transportation
	Construction site management
	Facilities management and maintenance
	Supply and store management
(3) Control and data acquisition	Control systems and engineering
	IT systems coordination
	Instrumentation and control technology, adjusting and testing
(4) Engineering of systems	Design engineering and configuration control
	Engineering support
	Technical integration engineering
	Quality engineering
	Diagnostics systems engineering
	Reactor systems engineering
	Turbine systems engineering
	Remote handling technologies
(5) Science and technology expertise	Nuclear physics calculation
	Computational modelling and analysis
	Probabilistic and deterministic safety analysis
(6) Operation	Reactor operations
	Testing and commissioning

TABLE 2. COMMON PROCESSES AND ORGANIZATIONAL COMPETENCES FOR NUCLEAR POWER PLANTS (cont.)

Process	Organizational competences
	Turbine operation
	Operations and maintenance planning
	Spent fuel management
	Radioactive waste management
	Training and operating experience
	Water chemistry treatment
	Electrical engineering
	Technological systems operation
	Instrumentation and control systems operation (as low as reasonably achievable)
(7) Safety and security	Nuclear safety engineering and assurance
	Occupational and environmental health
	Security and access control
	Emergency management
	Fire protection engineering
(8) Maintenance	Outages planning
	Maintenance management
	Project coordination

A mapping approach will help managers to find the most important and even critical competences of a nuclear organization on unit, divisional and departmental levels, to estimate available HR and identify gaps and needs without implementation of deep analysis. It helps to see the whole picture of available competencies and adapt to organizational changes. For example, starting a new project may require new competences from the organization, or redistribution of available HR to cover new competence demands, and thus increases pressure on staff load and may even affect core organizational processes.

3.2.2. Step 2: 'Competence at risk' matrix development

At this stage, managers create a competence matrix based on the available HR. They provide an assessment of the current workforce in the organization or department, identify core and non-core functions, provide assessment of future competence gaps due to changes in the organizational structure, personnel rotation, ageing and retirement, and identify options to address any potential knowledge loss issues (e.g. process improvements, reorganization and elimination of non-core activities).

This helps to create a snapshot of the current situation and predict future risks due to staff attrition or rotation.

- Inputs:
  - Map or list of organizational competencies;
  - Available HR of an organization (unit, division or department).
- Output:
  - Matrix with needs for and availability of competences for successfully running the organizational processes.

The matrix should be developed on the assumption that one person can cover one organizational competency, although, in practice, it often happens that key experts possess knowledge, skills and experience that cover several organizational competences. Such a situation gives nuclear organizations a reserve of competences that is very important for successful performance.

Managers should assess current organizational competences and future needs, and provide simple analysis of how the available HR addresses organizational competence needs. A matrix gives managers information about what is missing and which competences are currently at risk. At the same time, new competence demands arise from new projects or new tasks such as expanding capacity, decommissioning, restart, major modifications, performance improvement and long term operation. The matrix helps to see not only the current situation, but also to predict future organization competence deficits and assess possible negative impacts on organizational performance. It is important to take into account future attrition trends and time lags in recruitment and training. In addition to the map shown in Fig. 5, an example of a matrix developed for a full scope simulator unit is shown in Fig. 6.

Competence	1 (reactor)	2 (turbine)	3 (electric)	4 (licensing)	5 (I&C)	Time	Note/link to KLRA
Current needs/ availability	2/2	2/2	1/2	2/3	3/0		
Employee 1 (licensed)	X					Short term	Retiree, action needed
Employee 2		X					
Employee 3	X			X		Medium term	Will move in 4 months, action needed
Employee 4		X	X	X		Long term	Will move in 6 months, action needed (expert)
Employee 5			X	X			
Future status	2/1	2/1	1/1	2/1	3/0		
Risk identified	At risk	At risk		At risk	At risk		

FIG. 6. Example of an organizational unit competence at risk matrix. I&C — instrumentation and control; KLRA — knowledge loss risk assessment. An 'X' indicates that the employee possesses the competence in question.

While building a matrix, managers can also identify key experts in different fields. Some of them can be close to retirement age or planning to leave the organization soon. Short term prediction can help to show how attrition can impact organizational competence, core and supporting processes and ultimately business goals.

Corrective actions (step 3) to strengthen competences can be initiated immediately, focusing on the identification of key experts and the preservation and transfer of critical knowledge. In other words, it is connected to the low level analysis known as individual KLRA, which is described in Section 3.3. Long term initiatives can be implemented by developing an action plan for sustainable organizational competence development.

3.2.3. Step 3: Actions

Based on the analysis results, managers should develop a strategic plan addressing organizational competence and knowledge loss, and perform corrective actions.

Step 3 often initiates strategic changes or a modification in HR policies and programmes, such as:

— Inputs:
  - Staff recruitment programmes.

— Training and retraining programmes:
  - Staff rotation;

- Succession plan modifications;
- Implementation of KLRA in accordance with Section 3.3.

— Outputs can be:
  - Determination of prioritized lists of competences at risk;
  - Identification of critical positions;
  - Detection of key experts at risk (in addition to KLRA);
  - Estimation of costs to retain and/or renew key experts.

Implementation of corrective actions on a regular annual basis may be considered, as a proactive response to future competence risks.

3.3. INDIVIDUAL KNOWLEDGE LOSS RISK ASSESSMENT

In this section, the methodology and tools to address specific knowledge loss associated with individual experts nearing retirement or employee rotation, and being promoted or leaving the organization (or industry) for other reasons, are provided. Management can adopt or modify these processes and tools to meet the specific needs of the organization. This approach has proved its usefulness as a basic methodology of KLRA and has been adopted by many nuclear power plants and other nuclear related organizations worldwide [5]. Case studies of good practices of KLRM are shown in Annexes I–V.

Attrition related knowledge loss threats can be identified, prioritized and addressed using the following process to determine a total risk factor for each employee in the organization. This total risk factor is based on a projected attrition date, which could be related to retirement, transfer or other attrition (attrition risk factor) and criticality of knowledge and skills (position risk factor).

The three step process outlined below has been successfully implemented by many nuclear organizations. Figure 7 shows a diagram of the critical KR process. KR roles and responsibilities are outlined in Annex I.

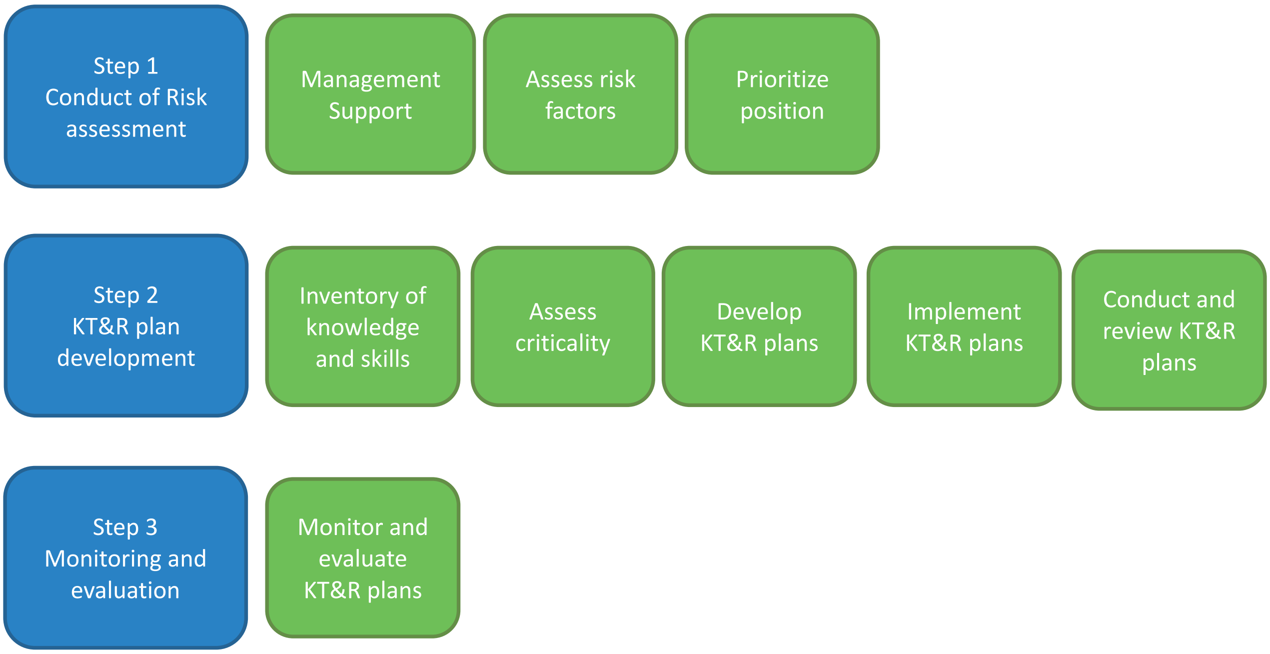


FIG. 7. Diagram of three step process for KR. KT&R — knowledge transfer and retention.

3.3.1. Step 1: Conduct knowledge loss risk assessment

KLRA is designed to identify positions and individuals that have the greatest and the most imminent potential of knowledge loss.

An attrition risk factor is based on the expected retirement or other attrition date. The date can be provided by the employee or calculated based on the age and tenure data. Table 3 lists the criteria used to assign the attrition risk factor.

Once managers have identified the attrition risk factor, the next step is to consider the position risk factor, which relates to the criticality of the role and the knowledge and expertise required to complete the work requirements. It is an estimate of the difficulty or level of effort required to replace the employee in the position. Managers and supervisors are responsible for making these ratings based upon the criteria listed in Table 4.

The position risk factor criteria are based on the unique and critical knowledge and skills possessed by the employee and estimate the difficulty or effort required to refill the position. In assigning the factor, the manager should consider each employee's responsibilities and background, formal and informal roles, collateral duties, reoccurring assignments (e.g. outage related duties, problem solving or troubleshooting assignments) and other factors suggesting that the employee may have unique and critical knowledge and skills. Department managers may want to consult other work group members, key plant customers or interested parties in order to determine ratings.

When determining the position risk factor, the influence on the performance of the position itself in the current organizational structure should also be considered. For example, some positions assume critically important functions for the organization, such as the unit shift supervisor and other positions related to safety, key decision maker positions and some focal points or even nuclear code analysts.

TABLE 3. ATTRITION RISK FACTOR CRITERIA

Attrition risk factor	Criteria
5	Projected attrition date within the current calendar year or next fiscal year
4	Projected attrition date within the third calendar year from now
3	Projected attrition date within the fourth calendar year from now
2	Projected attrition date within the fifth calendar year from now
1	Projected attrition date within (or greater than) the sixth calendar year from now

TABLE 4. POSITION RISK FACTOR CRITERIA

Position risk factor	Criteria
5	Critical and unique knowledge or skills; mission critical knowledge and skills with the potential for significant reliability or safety impacts; organization or site specific knowledge; knowledge undocumented; requires 3–5 years of training and experience; no ready replacements available.
4	Critical knowledge and skills; mission critical knowledge and skills; some limited duplication at other plants or sites and/or some documentation exists; requires 2–4 years of focused training and experience.
3	Important, systematized knowledge and skills; documentation exists and/or other personnel on-site possess the knowledge and skills; recruits generally available and can be trained in 1–2 years.
2	Procedural or non-mission critical knowledge and skills; clear, up-to-date procedures exist; training programmes are current and effective and can be completed in less than 1 year.
1	Common knowledge and skills; externally hired recruits possessing the knowledge and skills are readily available and require little additional training.

The total risk factor of an employee is determined on the basis of the guidelines provided in Table 5.

The total risk factor provides an overall assessment of attrition related risks for knowledge loss. The total risk factor is computed by multiplying the attrition risk factor by the position risk factor (see Table 6).

Each nuclear power plant's management team should collectively review the results of the risk assessment. Experience has shown that a critical review of the position risk factor assigned by the department manager is important for ensuring accurate ratings. Often, there is a tendency to rate high performing employees as having unique and critical knowledge and skills. A high level of performance is *not* the basis for a high position risk factor, and such a rating should be adjusted to the actual risk. After completing the collective review, the management team identifies where a KR plan is needed and assigns responsibilities for a development plan (typically, to the employee's supervisor or manager).

TABLE 5. TOTAL RISK FACTOR

Total risk factor	Priority
20–25	High priority: Immediate action needed; specific replacement action plans with due dates will be developed to include: KR plan, KM assessment, specific training required and on the job training or shadowing with incumbent.
16–19	Priority: Staffing plans should be established to address the method and timing of replacement, recruitment efforts, training and shadowing with current incumbent.
10–15	High importance: Look ahead to the position will be filled, work will be accomplished and competence will be covered; college recruitment, training programmes, process improvements and reinvestment.
1–9	Important: Recognize the functions of the positions and determine the replacement need.

TABLE 6. EXAMPLE OF TOTAL RISK FACTOR COMPUTING

Overall assessment	Risk factor	Score
Projected attrition within 1 year	Attrition factor	5
Critical/unique knowledge/skills	Position risk factor	5
Total risk factor = 5 × 5 = 25		

3.3.2. Step 2: Develop a knowledge retention plan to capture critical knowledge

The KR plan is designed to identify and prioritize the critical knowledge in each high priority position based on the KLRA. On this basis, managers can determine the approach to capture and transfer the knowledge.

Once the risk assessment has been completed, the next step is to address potential knowledge loss for each high priority employee (total risk factor of 20–25) through implementing KR plans by:

— Identifying the critical knowledge or skill, knowledge holder and responsible person for the actions (e.g. a leader).
— Indicating if a knowledge risk assessment questionnaire has been completed, which also identifies the plan of how to acquire, transfer and retain the knowledge.
— Identifying the critical knowledge that must be managed, what actions will be taken, who owns each action and due dates. These actions can be included in an employee's annual performance plan as either a business goal or a development goal.

When developing knowledge and retention plans (Annexes II and III) to retain and transfer critical or unique knowledge, the following factors should be considered:

- Length of time that the knowledge will be relevant;
- Types of knowledge involved (i.e. explicit versus tacit);
- Timing of knowledge loss;
- Cost (cost–benefit analysis may be needed);
- Employee motivation and ability to share knowledge;
- Successor motivation to acquire knowledge;
- Capability for acquiring knowledge.

In many cases, KR plans will include an interview with the employee ('elicitation' process) utilizing a trained elicitor. The knowledge and skills in question may be of many different types, for example: task and equipment related knowledge and skills; facts or information about specific people, vendors, projects and locations; and unique pattern recognition knowledge and problem solving skills.

The interviews are based on questionnaires designed to assist the elicitor and employee in identifying the specific areas where critical or unique knowledge may exist. Guidelines for conducting interviews and suggested questions are contained in Annex II.

The first priority is to identify, capture and retain critical knowledge held by employees nearing retirement. However, it is important to develop and implement a KR plan for any employee with a position risk factor of 5. These employees may be promoted, transferred or leave the organization for other reasons, causing a loss of critical knowledge.

3.3.3. Step 3: Monitor and evaluate

Periodic reviews should be conducted to monitor the implementation status of the KR process. It is desirable to finalize such a review annually, during the fourth quarter.

Specifically, this step should include, as a minimum:

- Review of previous KR plans and progress.
- Identification of related emerging issues including coordination.
- Periodic updates of KLRM internal policy documents and relevant procedures.
- Periodic updates of KLRM templates, forms and questionnaires.
- Setting up and analysis of key performance indicators or metrics, for example:
  - Number of experience reports;
  - Quality of experience reports (scale 1–5);
  - Number of interviews (debriefings);
  - Ratio of experts at risk and experts evaluated (interviewed);
  - Number of on the job training and succession plans;
  - Number of experts at risk (high risk of loss);
  - Amount of knowledge at risk (high risk of loss);
  - Number of knowledge transfers into the training materials or technical documentation;
  - Number of KM portal or database visits.

The criterion for successful KLRM implementation can be, for example, more than 80% of the KR plans being fulfilled.

3.4. EMPLOYEE SELF-ASSESSMENT OF KNOWLEDGE RETENTION

This process was developed to identify critical information on the job and tasks performed by employees who are going to leave the organization. This facilitates the gathering of additional information pertinent to an individual's skills, knowledge and duties in order to maintain knowledge that is critical to safe and efficient operation.

Often, the expert employee possessing critical knowledge and skills also plays a critical role in the day to day operations of the nuclear power plant and, therefore, his or her time is valuable and limited. Processes such as the one outlined in Section 3.3 are effective, but may require significant resources and time. The following process can be much less time consuming if utilized by nuclear power plants as self-assessments to identify specific risk of knowledge loss. This approach should be used to address potential knowledge loss when employees are transferred, promoted, retired, etc. The process can facilitate the gathering of additional information pertinent to the individual's knowledge, skills and duties, to support the continued safe and efficient operation of the nuclear power plant.

This activity could be a part of the performance appraisal system and thus motivate experts to estimate and share their unique knowledge. An employee can categorize the importance of knowledge using the guidelines shown in Fig. 8.

A self-assessment KR survey can be assigned for implementation by defined key experts through the IT systems of the nuclear organizations, integrated into content management systems or enterprise resource planning systems, reviewed by peers and approved by line managers. Sometimes, separate knowledge portals are used for this reason; more details can be found in the IAEA publication Development of Knowledge Portals for Nuclear Power Plants [12]. Using this automatization will help to save time and capture tacit knowledge and expertise from departing staff. See Fig. 9 for an example of a KR plan.

The self-assessment consists of blocks of questionnaires focusing on the employee task assessment, which provides general information on the employees related to their current job tasks as well as information regarding meetings they attend, emergency positions they hold and specific information about *major* tasks performed by the employee. These major tasks may include activities they perform as part of their day to day job or may be collateral duties, such as outage assignments.

Once the employee has completed the employee task self-assessment, department managers and supervisors should review the tasks performed by the individual and decide whether additional assessments are needed. The completed self-assessment is retained by the manager and is used to address the challenges created by pending personnel changes as well as potential knowledge loss.

The implementation of the self-assessment approach is detailed in Annex V.

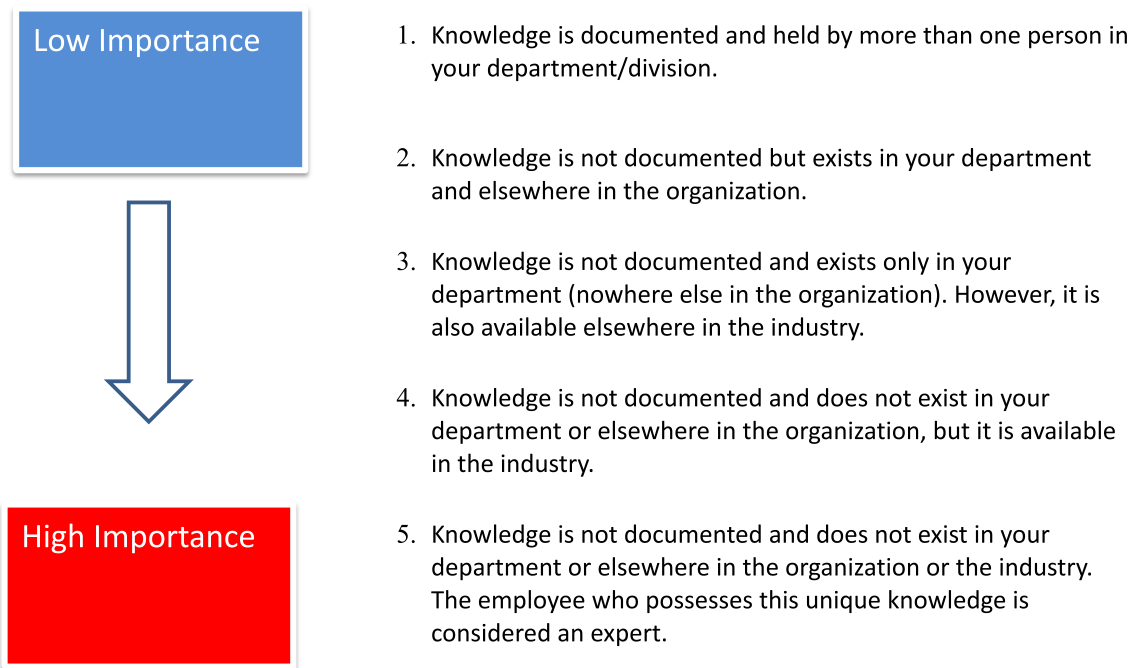
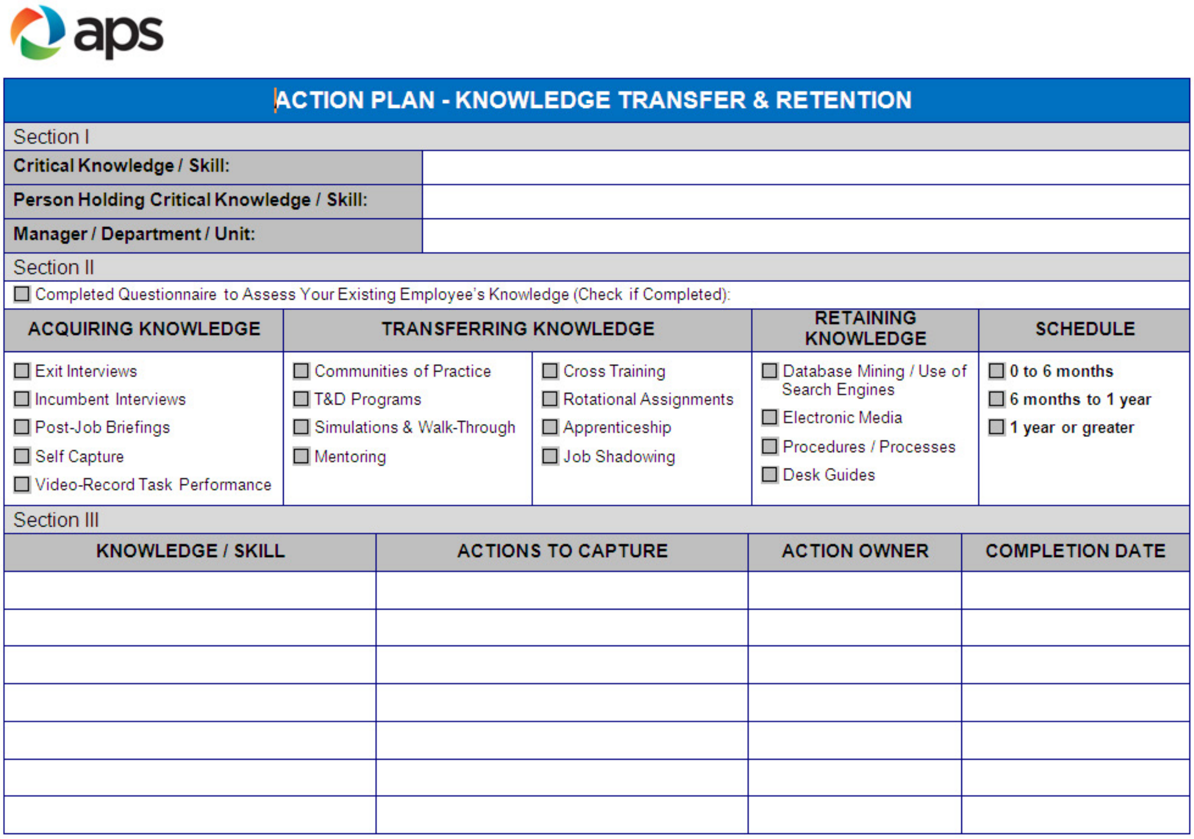


FIG. 8. Guidelines for unique knowledge identification.



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ACTION PLAN - KNOWLEDGE TRANSFER & RETENTION

Section I

Critical Knowledge / Skill:	
Person Holding Critical Knowledge / Skill:	
Manager / Department / Unit:	

Section II

☐ Completed Questionnaire to Assess Your Existing Employee's Knowledge (Check if Completed):

ACQUIRING KNOWLEDGE	TRANSFERRING KNOWLEDGE		RETAINING KNOWLEDGE	SCHEDULE
☐ Exit Interviews	☐ Communities of Practice	☐ Cross Training	☐ Database Mining / Use of Search Engines	☐ 0 to 6 months
☐ Incumbent Interviews	☐ T&D Programs	☐ Rotational Assignments	☐ Electronic Media	☐ 6 months to 1 year
☐ Post-Job Briefings	☐ Simulations & Walk-Through	☐ Apprenticeship	☐ Procedures / Processes	☐ 1 year or greater
☐ Self Capture	☐ Mentoring	☐ Job Shadowing	☐ Desk Guides	
☐ Video-Record Task Performance				

Section III

KNOWLEDGE / SKILL	ACTIONS TO CAPTURE	ACTION OWNER	COMPLETION DATE

FIG. 9. Example of a web application of the KR plan of Arizona Public Service. T&D — training and development.

3.5. METHODS AND TOOLS TO SUPPORT KNOWLEDGE LOSS RISK MANAGEMENT

A summary of knowledge preservation approaches covering methods and tools appropriate for each process is given in Table 7 for tacit, implicit and explicit knowledge existing at an individual, group or department, organizational or industry level and focused on projects, technologies or processes.

TABLE 7. KNOWLEDGE PRESERVATION METHODS AND TOOLS

How to acquire knowledge		Description
A1	Exit interview	Meeting to capture knowledge from employees when they resign; the leader, the departing employee and the employee taking on those responsibilities meet as often as possible to discuss and take notes on the departing employee's job knowledge.
A2	Incumbent interview	Interview conducted with an employee to document knowledge of a specific job or task.
A3	Post-job briefing	Immediate briefing conducted after a specific job, task or activity has ended to capture lessons learned, skills and knowledge while fresh in an employee's mind.
A4	Self-assessment	Employees document their knowledge of a specific job, task, activity or development to capture the knowledge and/or skills needed to complete the activity.
A5	Video recording of task performance	Video recording of an employee performing a job, task, activity or development that is better captured by a visual demonstration than as a written explanation or description.

TABLE 7. KNOWLEDGE PRESERVATION METHODS AND TOOLS (cont.)

How to transfer knowledge		Description
T1	Community of practice	Employees with a specific interest in the knowledge of a job, task, activity or development meet to share learning or key tasks from employees who have more knowledge or some unique knowledge of the activity.
T2	Training and development programme	Transfer of work related skills, knowledge and information in a class or series of classes, to become familiar and/or proficient in the subject.
T3	Simulation and walk through	Transfer of work related skills, knowledge and information in a simulated workplace setting or as a 'dry run' of the actual job, task, activity or development.
T4	Mentoring (formal)	Teaching relationship between two employees where one is the 'learner' (mentee) and the other is the 'teacher' (mentor); the mentor provides one on one coaching and oversight so that the mentee gains the knowledge needed to perform or manage a job, task or activity.
T5	Mentoring (informal)	A less structured teaching relationship between seasoned and less experienced employees.
T6	Cross-training	Training on how to perform a job, task, activity or development in another job function, department, discipline or organization.
T7	Rotational assignment	Job assignment or series of assignments that provide(s) the experience necessary to develop an employee and provide(s) exposure to key responsibilities in a number of functions; employees generally move into new positions with new duties and supervisors.
T8	Apprenticeship	Learning a trade by practical experience from skilled workers.
T9	Job shadowing	Observation of a job, task, activity or development to gain exposure to and understanding of the job.
T10	Hire retirees as consultants or contractors (short duration)	Rehire previous employees to transfer their knowledge or skill to another employee or to document their knowledge or skill.
How to retain knowledge		**Description**
R1	Database and search engines	Databases and search engines for retention and retrieval of job, task, activity or instructions.
R2	Electronic media (audio and video recordings or intranet web sites)	Video and digital photographs for retention and retrieval of step by step documentation of infrequently performed jobs, tasks, activities or developments; department web sites used for retaining and retrieving lessons learned.
R3	Written procedures and processes	Department procedures and policy guidelines to capture and retain job, task, activity or development knowledge or work instructions.
R4	Desk guides	Documents providing details of a job or task; they do not replace procedures but act as 'how-to' references with practical insights on job performance.

Some knowledge transfer methods, such as mentoring and coaching, transfer the knowledge from the *mind* of one employee to another. Although direct transfer of knowledge has advantages, it also has drawbacks; for example, knowledge is not captured in a sustainable and accessible format. When selecting a transfer method, you may need a secondary method to ensure that knowledge is captured.

Further information on the methods and tools for KLRM are given in the IAEA publication Comparative Analysis of Methods and Tools for Nuclear Knowledge Preservation [13].

3.6. MOTIVATIONAL FACTORS FOR KNOWLEDGE TRANSFER

Nuclear organization managers should pay attention to the important question of how to motivate key experts to share their knowledge and skills, to retain them and to transfer them to the next generation.

Factors that may influence employees' *willingness* to share knowledge include:

- They are honoured to be recognized as an expert.
- They believe they have an obligation to share their knowledge with others because of the benefits received during their careers.
- They believe it is the right thing to do.
- They see it as part of their job.

Factors that may influence employees' *unwillingness* to share knowledge [14] include:

- They consider their knowledge to be their personal intellectual property.
- They are concerned about losing their status or even their job.
- They fear no longer being needed.
- They feel isolated from the company.
- They believe they do not have any valuable knowledge to share.

The most common motivational factors for employees to stay at a company and actively collaborate over a long period of time include:

- The challenging and diverse nature of their work;
- Career growth, learning and development;
- Working with knowledgeable people;
- Fair pay;
- Supportive management;
- Being recognized, valued and respected;
- Benefits;
- Meaningful work;
- Pride in the organization, its mission, its culture and its product;
- Pleasant working and social environments;
- Autonomy and creativity;
- Flexibility in working conditions, working hours, dress code, etc.;
- Location;
- Job security and stability;
- Being part of a friendly team;
- Empowerment;
- Organizational loyalty;
- Inspiring leadership;
- Awards;
- Good balance between work and private life.

4. SUMMARY AND CONCLUSIONS

The KM tools and KLRM processes presented in this report are intended for use by nuclear power plants and other nuclear related organizations to assist in managing the risk of knowledge loss caused by the attrition of experienced personnel.

Guidelines on the establishment of a regular process and possible solutions for risk mitigation are given. It is important to mention that the processes and tools are easily adaptable and can be modified to meet the needs of a wide range of organizations (e.g. operating organizations, R&D organizations, technical support organizations, regulatory bodies and governmental organizations).

Attrition related to the KLRA process (see Section 3.3) has been successfully utilized by the Tennessee Valley Authority nuclear organization in the USA. This includes all three nuclear power plants (Browns Ferry, Sequoyah and Watts Bar) and the corporate office in Chattanooga Tennessee. In addition, the process has been benchmarked by a number of other organizations and agencies (e.g. Entergy, Bruce Power, Ontario Power Generation, Nuclear Regulatory Commission and Institute of Nuclear Power Operations) [5]. However, implementation is often a weak point. Best practices of KLRM implementation as a regular process and/or successful project were identified during KM assist visits [15] and are shown in Annexes I–V.

It is also important to highlight that these tools and processes are not standalone initiatives. KM is *not* intended to replace existing systems, processes or programmes, but rather is intended to increase the overall benefit by providing an integrated approach to managing critical competence and knowledge of nuclear organizations.

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Annex I

KNOWLEDGE RETENTION ROLES AND RESPONSIBILITIES

THE THREE STEP PROCESS

	Line organization			Human resources	
	Employee	Manager/supervisor	Senior leadership	Human resources consultant	Workforce planning
STEP 1: Conduct of knowledge loss risk assessment					
Preparation of management team and appropriate managers and supervisors		Reviews process and roles	Reviews process and roles Involves appropriate staff	Briefs and consults	
Assessment of the total risk factor for each position	Communicates anticipated retirement date to human resources and/or manager	Notifies human resources of known plans or changes in employee's anticipated retirement Assesses position risk factor	Reviews and approves factors	Consults as needed Facilitates timely review Notifies workforce planning of revised factors	Maintains attrition projections and factor ratings Computes total risk factor Provides reports
Prioritization of positions		Identifies targeted positions and notifies human resources / workforce planning	Reviews and approves	Consults as needed Notifies workforce planning of targeted positions	Records targeted positions Provides reports
STEP 2: Determination and implementation of plans to capture critical knowledge or adapt to its loss					
Inventory knowledge and skills 'clusters' of the identified employee	Participates in inventory as requested	Conducts inventory Requests support as needed		Consults as needed May provide/broker support for interviews and initial inventory	
Assessment of the criticality of each of these knowledge/ skill clusters	Supports assessment as requested	Assesses criticality Requests support as needed		Consults as needed May provide/broker support for initial assessment of criticality	

THE THREE STEP PROCESS (cont.)

	Line organization			Human resources	
	Employee	Manager/supervisor	Senior leadership	Human resources consultant	Workforce planning
Development of knowledge retention plans	Supports plan development as requested	Develops knowledge retention plans Requests support as needed		Consults as needed Provides support for initial knowledge plan development	
Coordination and review of knowledge retention plans		Coordinates planned actions Revises knowledge development plans and provides human resources/ workforce planning with current plans Requests support as needed	Reviews and approves knowledge development plans Facilitates coordination as needed	Facilitates timely review and revision of plans Provides workforce planning with copies of final plans	Maintains a record of what knowledge retention plans have been developed Maintains copies of knowledge retention plans
Implementation of knowledge retention plans	Supports implementation as requested	Implements knowledge retention plans	Supports implementation as requested	Supports implementation as requested	
STEP 3: Monitoring and evaluation					
Monitoring and evaluation of action plans and priorities		Provides updates and current status of plans to management and human resources/workforce planning Identifies issues	Reviews progress Provides support, redirection and coordination as needed	Facilitates review at least semi-annually Coordinates plans, issues, etc., as needed	Updates records Reports metrics

Annex II

GUIDE TO IDENTIFICATION OF ‘AT RISK’ KNOWLEDGE

II–1. INSTRUCTIONS

The purpose of this publication is to help individuals identify their critical skills and knowledge, especially those unique items of knowledge and skills that might be lost when an individual leaves the organization. While managers/ supervisors or others can use this guide to inventory the knowledge and skills of an employee, it is written as though the employee were being asked to respond.

Several points need to be considered when the individual works through these questions:

(a) Knowledge or skill can mean several different things. We want to use a very broad definition that could include anything that new employees would need to know to do a job like yours (except for the exclusions noted below). Consider all your responsibilities and contributions — both formal and informal roles, collateral duties and recurrent assignments (e.g. outage related duties, problem solving or trouble shooting assignments), areas where others often seek your expertise, etc.
(b) Do not include standard skills that are common to your particular job or that are assumed for a particular certification or degree (e.g. journeymen electricians are expected to be able to read a blueprint, etc.). If you are not sure if it is common, include it.
(c) Some of the questions will appear to ask the same thing in several different ways. We do this on purpose to make sure we do not miss valuable information. When the answer is something you have already discussed, simply say so rather than repeat the information again.
(d) When we ask you to describe or list things, give us a general description and not a detailed description. Do not try to tell us how to do something. We will come back and gather this level of detail later. For now we are just trying to build lists to evaluate and prioritize.
(e) For each major piece of knowledge, try to give us some sense of how important it is and how much trouble attrition may cause. Tell us if the knowledge is written down somewhere or not, who knows it besides you, what would be likely to happen if no one knew this, how long it takes someone to learn it, etc.
(f) The questions in Section II–3 will produce lists. In many cases these lists will already exist in job descriptions, training programmes, preventive maintenance procedures and/or in various databases. If so, simply refer to the appropriate source or list and tell us how to find it. In other words, there is no need to try to rewrite the list in the interview.

II–2. GENERAL QUESTIONS

(a) What kinds of knowledge or skills do you now have that the organization will miss most when you leave?
(b) If you had to leave the organization suddenly and only had one day left to brief your replacement, what would you put on your list of things to tell them?
(c) Looking back, what things do you wish you had been taught early on in your job that you eventually learned the hard way?
(d) What are the key resources (procedures, manuals, etc.) that you use to do your job?
(e) What roles do you play (or what ‘hats’ do you wear)? What have been frequent collateral duty areas and recurrent assignments (e.g. outage related duties, problem solving or trouble shooting assignments)? In what areas do others often seek your expertise?
(f) Are there some important types of at risk knowledge that will take a long time for someone else to learn? What are they?
(g) What pieces of knowledge are you most worried about ‘slipping through the cracks’ when you leave?
(h) How did you learn the things you know? What were the critical training programmes, work assignments, etc.? What is unique about your background compared with the typical employee in positions like yours?

II–3. QUESTIONS ABOUT TASKS

These questions tend to produce lists. Remember, there is no need to recreate lists that already exist.

(a) *How to test and maintain equipment*: What are the types of equipment that you must know in order to test, maintain, or repair? Produce lists or logical groupings of equipment along with the tasks associated with each type (e.g. installation, assembly/disassembly, test, preventive maintenance, diagnosis and repair). If you were training new employees who will later replace you, how would you prioritize this list?

(b) *How to use special tools*: What types of special tools must you know how to use to do your job? These would be tools that are unique to your type of work. If you were training new employees who will later replace you, how would you prioritize this list?

(c) *Operation of special equipment*: What types of special equipment must you know how to operate to do your job (e.g. lifts, bucket trucks, cranes, test devices)? If you were training new employees who will later replace you, how would you prioritize this list?

(d) *Operation of system devices*: What types of system operation task (energize, de-energize, switching, tag-out, isolation, etc.) must you master to do your job? If you were training new employees who will later replace you, how would you prioritize this list?

II–4. QUESTIONS ABOUT FACTS OR INFORMATION

(a) *Geographical information*: Describe any special geographical information you may have about where things are located and how to get to particular locations. This includes the easiest way to get to locations. Describe any such information that may be common to an experienced employee but would prove to be critical if not known by an inexperienced employee.

(b) *Inventories*: Describe any special information you may have about the location or existence of spares, materials, tools and equipment. Describe any such information that may be common to an experienced employee but would prove to be critical if not known by an inexperienced employee.

(c) *People facts*: Describe any special information you may have about key contacts for expert advice, decisions and permissions, getting something processed or expedited. Describe any such information that would prove to be critical if not known by an inexperienced employee.

(d) *System equipment facts*: Describe any special information you may have about where to locate maps, lists, drawings, vendor manuals, design data, calculations, etc. Describe any such information that would prove to be critical if not known by an inexperienced employee.

(e) *Vendor information*: Describe any special information you may have about how to order parts, materials and services, where and how to get equipment repaired, calibrated, etc. Describe any such information that would prove to be critical if not known by an inexperienced employee.

II–5. QUESTIONS ABOUT PATTERN RECOGNITION KNOWLEDGE

(a) *Complex trouble shooting and diagnosis*: Describe or list any non- standard (i.e. uncommon) knowledge that you possess or have developed about the diagnosis of complex problems. These often involve interaction among several pieces of system components. Name the pieces or types of equipment or describe the type of failure or fix.

(b) *Diagnostic short cuts*: Describe or list any special knowledge that you may have about specific pieces of equipment or unique pieces of equipment that would lead to rapid diagnosis of failure. Name the pieces or types of equipment or describe the type of failure or fix.

(c) *Predictive patterns*: Describe or list any special knowledge you think you may have about patterns of equipment performance deterioration that predict major system failures. In other words, these are patterns that are not obvious and would easily be missed by inexperienced personnel. Are there different patterns for particular pieces of equipment? Are there phenomena (sounds, readings, etc.) that might be thought to indicate a problem but which are actually routine?

(d) *Failure patterns*: Describe or list any special knowledge you may have about failure patterns for particular pieces of equipment that would lead you to undertake pre-emptive inspection or replacement. Name the pieces or types of equipment or describe the type of failure or fix. Are there any annual or seasonal patterns that are not obvious?

(e) *History of major errors*: Describe any historical knowledge (lessons learned) you have that might help avoid a repeat of a major error in the future. Describe the type of failure, related equipment and time-frame.

Annex III

KNOWLEDGE RETENTION PLAN

III–1. DIRECTIONS

Knowledge retention plans should be developed for knowledge and skills identified as most critical. Plans may include methods to retain the critical knowledge and skills and actions necessary to mitigate the negative impact of losing the knowledge and skills.

III–2. OPTIONS

A variety of alternatives can be used to address impending loss of critical knowledge and skill. These include:

(a) Staffing:
New hire or transfer;
Current employee to assume responsibilities.

(b) Documentation and codification:
New or revised procedures;
Checklists, inventories, etc.;
Performance support systems;
Shared folders, intranet, job aids;
Videotaped instructions and
demonstrations;
Photographic records;
Concept maps.

(c) Education and coaching:
Classroom and simulator training;
Computer based training,
video based and alternative delivery;
Directed self-study;
On the job training and qualification;
Targeted work assignments;
Coaching, shadowing and mentoring;
Apprenticeship programmes.

(d) Process re-engineering:
Process improvement;
Update equipment;
‘Smart’ tools and technology;
Task, product or service termination.

(e) Alternative or shared resources:
Agency/site/department expert;
Rotational or ‘visiting’ staff;
Multiple skills, cross-training,
collateral duties;
Contractors, part-timers, retirees.

III–3. COORDINATION

Some actions included in knowledge retention plans need to be coordinated with other groups in order to be completed. In other instances, a potential knowledge loss issue at one site or within one group may suggest a more widespread threat. To complete the knowledge retention plan or to address broader issues, coordination should occur with such groups as:

(a) Site training;
(b) Other sites;
(c) Key leadership and succession planning;
(d) Peer teams;
(e) Recruitment;
(f) Employee technical training and organizational effectiveness;
(g) Process and methods;
(h) Corporate office.

This coordination should be addressed as part of the development of the knowledge retention plan. As needed, senior management addresses coordination or implementation issues, which cross major sites or divisions.

TABLE III–1. EXAMPLE

At risk knowledge or skill	Action (Steps which will be taken to retain this critical knowledge/ skill and/or minimize the impact of its loss)	Assigned to:	Target date(s) for completion	Status and issues
Mary is designer of ... and an expert on ... client database (in Microsoft Access)	Develop up-to-date documentation of database Complete Microsoft Access training Mary to cross-train Mike on database All — include these activities in performance review and development	Mary Mike Mary and Mike Mike, Mary and supervisor	30 July 30 July 30 Sept. By quarterly review	

TABLE III–2. KNOWLEDGE RETENTION PLAN

Employee ____ **Position** ____

Position risk factor ____

Summary and situation assessment:

At risk knowledge or skill	Action (Steps which will be taken to retain this critical knowledge/skill and/or minimize the impact of its loss)	Assigned to:	Target date(s) for completion	Status and issues

Plan prepared by: ____ **Date:** ______________________________

Reviews (as needed): ____ **Date:** ______________________________

Reviewed by: ____ **Date:** ______________________________

Reviewed by: ____ **Date:** ______________________________

Reviewed by: ____ **Date:** ______________________________

Additional notes or coordination needed: ____

____

____

Annex IV

EXAMPLE OF KNOWLEDGE RETENTION PLAN FOR MECHANICAL ENGINEERS

Employee: John Q. Smith **Position:** Mechanical Engineer, Mechanical Design, Sequoyah NPP

Total risk factor: 20

Summary and situation assessment:
Position risk factor = 4, attrition risk factor = 5. The incumbent has detailed knowledge of piping analysis and expertise in the application of T-Pipe software. The software is unique to Sequoyah and little duplicate knowledge exists. While a graduate engineer could become proficient in approximately 6 months, it is estimated that 2 years of on the job training is needed to respond quickly to urgent questions relating to piping analysis. In addition to the T-Pipe software, the incumbent must have extensive knowledge of the class II computer system. A degree in either mechanical or civil engineering is recommended when considering a replacement.
Currently Frank Jones is being cross-trained on the T-Pipe system. In addition, Jane Franks is somewhat knowledgeable and could be considered for backup along with two employees in the corporate office (Leo Lee and Oscar Free) who have past experience with T-Pipe and extensive piping analysis experience. Since T-Pipe is unique to Sequoyah NPP, no external training is available. However, the American Society of Mechanical Engineers offers training in piping analysis.

At risk knowledge or skill	Action (Steps which will be taken to retain this critical knowledge/skill and/or minimize the impact of its loss)	Assigned to:	Target date(s) for completion	Status and issues
Rigorous and alternative piping analysis, component qualification of code components and pipe rupture skills	Identify replacement candidate Replacement to attend ASME training on piping analysis and code requirements Replacement to receive on the job training on T-Pipe, code requirements and Sequoyah specific procedures/criteria	Mechanical design deputy supervisor replacement Supervisor, incumbent and replacement	Dec. 2004 Sept. 2005 Ongoing	Jones selected with Franks being trained as backup
Development plans	Supervisor assigns ‘trail task’ under direction of incumbent Replacement completes qualification under mentorship of supervisor	Supervisor and incumbent Replacement	Ongoing Sept. 2005	
	Include mentor responsibilities in performance review and development of the supervisor and establish goals to complete training for replacement Recruit and hire individual for replacement	Section manager and supervisor Section manager	Dec. 2004 July 2005	

At risk knowledge or skill	Action (Steps which will be taken to retain this critical knowledge/skill and/or minimize the impact of its loss)	Assigned to:	Target date(s) for completion	Status and issues
Documentation	The incumbent will develop piping analysis, component qualification and pipe rupture reference library of handbooks, procedures, criteria and processes in conjunction with the replacement	Incumbent	July 2005	

Plan prepared by: Al Bert, Mechanical Design Dept. Supervisor **Date:** 6 Nov. 2004

Reviews (as needed): ______ **Date:** ______

Reviewed by: John Q. Smith **Date:** 10 Nov. 2004

Reviewed by: Andrew Lang, Human Resources Manager **Date:** 10 Nov. 2004

Reviewed by: Site Vice President **Date:** 15 Nov. 2004

Additional notes or coordination needed: ______

Annex V

EMPLOYEE SELF-ASSESMENT — KNOWLEDGE RETENTION PROCESS

This process was developed to capture critical information on the job and tasks performed by (organization name) employees who are leaving or transferring to other organizations. These forms facilitate the gathering of additional information pertinent to the individual's skills, knowledge and duties in order to maintain knowledge critical to the safe and efficient operation of (organization name).

The assessment of an employee's critical knowledge consists of two steps: the employee self-assessment and the employee task assessment. The employee self-assessment is geared to obtaining general information from the employee on their current job tasks as well as information regarding meetings they attend, emergency positions they hold, etc. The employee task assessment provides more specific information about 1–5 *major* tasks that the employee participates in. These major tasks may include activities they perform as part of their everyday job or they may be collateral duties such as outage assignments.

Critical knowledge can either be apparent, where the individual is recognized as 'the' expert in a task or area, or it may be deep seated, where critical steps are so ingrained in the individual that they may or may not recognize them as critical. This method of knowledge retention is a self-elicitation method that may need to be followed up with more detailed review of the employee's information.

Once an employee has given his/her notice of termination or transfer, their manager should give them both the employee self-assessment form and the employee task assessment form to complete. The employee should complete the forms and return them to their manager as quickly as possible so that they can be reviewed. The employee should copy and complete the employee task assessment form for each major task they perform. Typically, no more than five tasks should be critical enough to be documented. In the event that the employee is unable to complete these forms (owing to death/disability or termination for cause), the supervisor will provide as much information as he/she is able to.

Once the employee has completed both the employee self-assessment and the employee task assessment, department managers and supervisors should review the tasks performed by the individual and make a decision as to whether additional assessment is needed.

Once all assessments are complete, the completed assessments should be forwarded to the department manager.

When asking employees to complete the self-assessment, it should be stressed to them the value they bring to the organization and how important it is to the future of (organization name) to make sure that their transition goes as smoothly as possible and that critical tasks are captured and risk analysed.

EMPLOYEE SELF-ASSESSMENT FORM

Name:	Title:
Department:	Supervisor:

Please return this completed assessment to your supervisor/manager

(1) List below all the meetings that you attend and the function that you perform at those meetings. Indicate the frequency of these meetings and the approximate duration of each. Indicate whether you have preparatory work to do prior to the meetings and if so, give details and time involved.

Meeting name	Frequency	Duration	Role

(2) List below any memberships you have for industry groups, associations or peer groups

Group	Role	Frequency of meeting

(3) List below any emergency response positions:

(4) List below your outage role(s):

(5) Do you support outages at other sites (shared resources)? ❒Yes ❒No
If yes, what site(s)?
What function do you perform?

(6) List below commitments you have to participate on a benchmarking trip or an assessment:

Event	Location	Date

(7) What skills and knowledge do you possess that may be considered unique and may be difficult to replace? Please consider identifying someone that you think may be able to perform these functions with appropriate training or turnover.

(8) What open actions do you have assigned to you (e.g. problem evaluation report, corrective actions, self-assessment findings)? Consider attaching copies of open items.

(9) What functional titles (formal or informal), such as refuel floor coordinator, training coordinator, budget coordinator, technical contract manager, or other ongoing task force or team project department do you hold and how much of your time is devoted to these activities?

(10) What approval authorities do you have that must be transferred to another (e.g. timesheet approval, contracts)? Specifically identify what must be turned over.

(11) What certifications or qualifications do you possess that are derived from external or internal training or processes (e.g. professional engineer, reactor operator, senior reactor operator, shift technical advisor)?

(12) What direct interface do you have with other departments that will need to be done by someone else in the future? Training, process expertise, the ‘go to’ person on a certain issue.

ANNEX VI

CASE STUDY: KNOWLEDGE LOSS RISK MANAGEMENT AT ČEZ GROUP, CZECH REPUBLIC

VI–1. INTRODUCTION

One of the most serious risks in nuclear safety is missing knowledge, and managing nuclear knowledge in a responsible manner is a contribution to the safety culture of a nuclear power plant. Knowledge holders have an obligation to transfer their knowledge and experience to the next generation. Knowledge management (KM) needs to be clearly connected to other processes within the company and written knowledge (e.g. experience reports) needs to be effectively communicated and included in training. Implementing KM requires a sensitive approach (and management of any change), strong leadership support and the definition of clear roles. It is not only an innovation in managerial approach, but also a necessity when dealing with complex knowledge loaded technologies such as those in the nuclear industry.

VI–1.1. ČEZ Group

ČEZ Group is an established, integrated energy corporation with operations in a number of countries in central and south-eastern Europe and Turkey, with its headquarters in the Czech Republic. Its principal businesses encompass the generation, trade and distribution of electricity and heat, trade in and sales of natural gas, and coal extraction.

ČEZ is the owner and operator of two nuclear power plants: Temelín and Dukovany (see Table VI–1).

TABLE VI–1. ČEZ NUCLEAR POWER PLANT DATA

Plant data	Temelín	Dukovany
Installed capacity (MW)	2 × 1000	4 × 510
Commissioned (year)	2002	1985–1988
Reactor type	WWER 1000	WWER 440

VI–1.2. Reasons to initiate knowledge loss risk management

In the years 2007 and 2008, KM emerged as one of the prime concerns in the human resources (HR) management system at ČEZ. Based on KM best practice data surveys and analyses, a detailed concept was proposed and implemented, primarily in the nuclear production units.

The main target of knowledge loss risk management (KLRM) implementation was to increase safety and to reduce the risks associated with a possible loss of unique knowledge.

Reasons to start KLRM included:

- Generational replacement (retirement of experts and ageing staff);
- Process improvement based on experience;
- ‘Brain drain’: increasing demand from outside the country for skilled professionals;
- Construction of new nuclear power sources and increasing security requirements;
- Improvement in transfer of knowledge and experience (use of lessons learned).

VI–1.3. Main objectives of knowledge loss risk management implementation

The main objectives of KLRM implementation included the following:

— To identify, maintain and develop unique knowledge;
— To share critical knowledge and best practices;
— To set up a succession planning system for knowledge holders with potential for knowledge loss;
— To create an effective system for knowledge record sharing and updates.

The idea was to implement KLRM within the production division and extend it into other divisions. The main focus was on the ageing staff of Dukovany, where the average age of an employee was 47 years, and Temelín, where the average age was 43.6 years.

VI–2. PROCESS DESCRIPTION

The process owner was the HR department, and KLRM was incorporated into an integrated management system. A process model was developed with the assistance of consultants from Proneos GmbH and Boston Consulting Group.

VI–2.1. Knowledge management process model

The KM process model used at ČEZ is shown in Fig. VI–1.

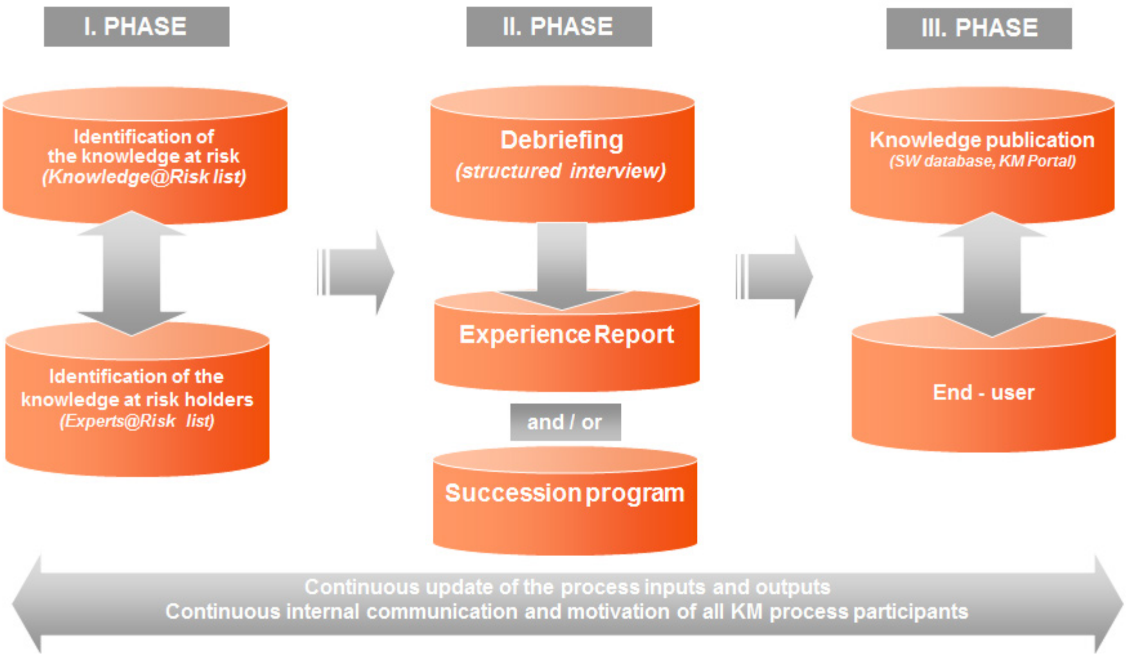


FIG. VI–1. Knowledge management process model in ČEZ. KM — knowledge management; SW — software database.

VI–2.2. Process tools

The process tools at ČEZ include:

— Experience reports (for knowledge capture);
— Succession programmes (for knowledge transfer);
— Debriefing: structured interviews (for knowledge identification and capture);

— Expert profiles (professional expert identification);
— Databases and intranet (for sharing);
— Communities of practice (for sharing);
— Tutoring (for sharing).

VI–2.3. Process roles

The process roles at ČEZ are shown in Fig. VI–2.

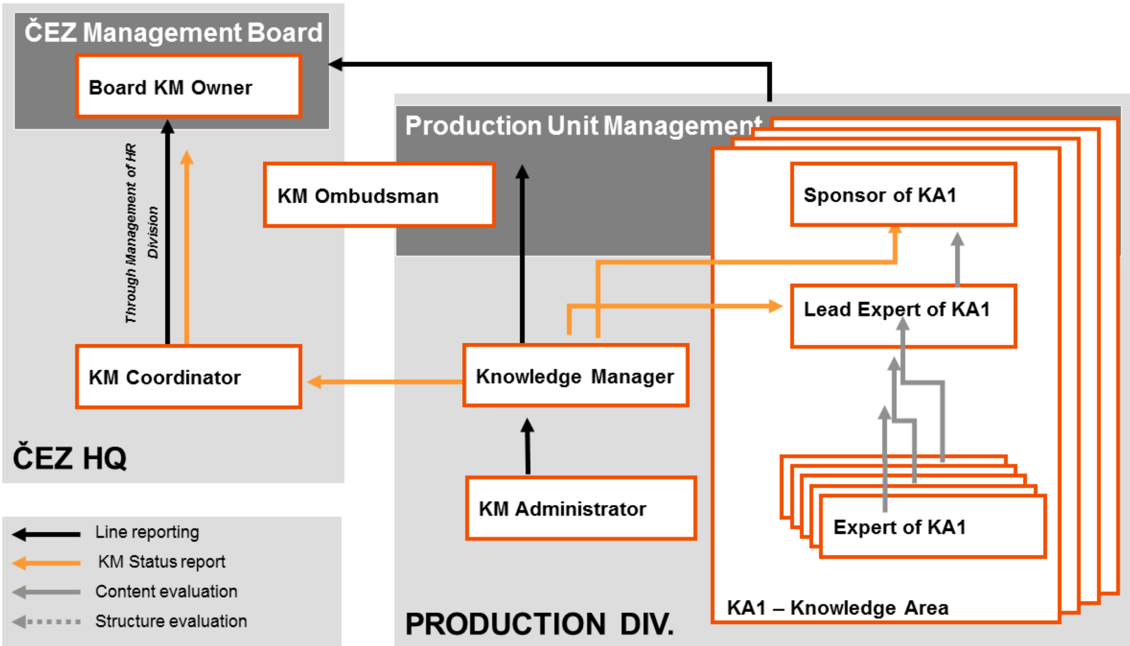


FIG. VI–2. Knowledge management roles in ČEZ. DIV. — division; HQ — headquarters; HR — human resources; KM — knowledge management.

As an example of a role description, the knowledge manager represents a key role in the KLRM process. The main responsibilities of this position include:

— Management of all activities and processes related to KLRM at the unit;
— Supervision of standards of quality of KLRM;
— Identification of important meetings and topics related to KLRM;
— Updating of the ‘knowledge at risk’ list and the ‘expert at risk’ list;
— Support of experts and encouragement to share their unique knowledge;
— Monitoring and evaluation of risk of loss of knowledge;
— Initiation of the process of debriefing interviews;
— Reporting to the KM coordinator;
— Support of key performance indicator setting;
— Support of expert motivation.

VI–2.4. Knowledge loss risk assessment

Knowledge loss risk assessment was a valuable method for identifying critical knowledge. The focus was on critical knowledge, based on the results of a risk assessment. Preservation of critical knowledge was important in order to ensure the continuous success and safety of the organization and its units.

About 80 experts (unique knowledge holders) were identified at each nuclear power plant. Both the ‘knowledge at risk’ list and the ‘expert at risk’ list were regularly updated by knowledge managers and lead experts.

The assessment steps were the following:

(a) *Knowledge identification and prioritization.* Within each knowledge area, critical knowledge was identified and captured. This was essential for the successful and safe operation of the unit. Both positive and negative experiences were considered.
(b) *Assessment criteria.* Uniqueness and specificity of the knowledge in terms of the loss risk degree was the main assessment output. During the process of completing the ‘knowledge at risk’ list and the ‘expert at risk’ list, the following structure was used:

— Knowledge description (definition);
— Knowledge area (in relation to processes and units such as maintenance, operations and physics);
— Knowledge uniqueness (scale of 1–5);
— Applicability for the future (scale of 1–5);
— Knowledge holder (expert name);
— Risk of loss (e.g. due to retirement, scale of 1–5);
— Recommended tools for knowledge capture (experience report, debriefing, communities of practice, etc.);
— Notes.

VI–3. SUPPORTING DOCUMENTS

After 18 months of KM process implementation and improvements, KM became a part of the ČEZ internal legal documentation and methodology, and the following were produced:

— A safety and environmental protection policy: “We manage our key and unique knowledge”;
— An action plan for safety culture improvement: “Build and develop knowledge management — transfer knowledge and minimize personnel risks”;
— Directive No. SM_0142: “Knowledge management”;
— Guidance documentation and methodology.

VI–4. OUTCOMES (LESSONS LEARNED) — CRITICAL SUCCESS FACTORS OF KNOWLEDGE LOSS RISK MANAGEMENT

KM implementation requires effective support and investment in the six areas or dimensions described in Sections VI–4.1 to VI–4.6.

VI–4.1. Leadership and confidence

Leadership plays a key role in ensuring success in almost any initiative within an organization. Its impact on KM was even more important because it is a relatively new discipline. After five years of KM implementation, it could be said that without the managerial support, nuclear KM as a measurable and effective process could never be established within a company.

VI–4.2. Culture and cooperation

Cultural issues concerning KM initiatives usually arise from the following factors: lack of time, unconnected reward systems, lack of common perspectives and informal communication.

VI–4.3. Content and structure

The structured content included: maps of knowledge areas, written experience reports shared in a common database and updated expert profiles. Establishing effective and usable content involved processes put into place to acquire, manage, validate and deliver relevant information when and where it is needed.

VI–4.4. Processes and organization

KM at ČEZ had a common interface with other HR processes (workforce planning, succession planning, rewards and compensation, performance management, training and development, tutoring, etc.). A KM methodology was part of corporate KM documentation. From the very beginning of KM implementation, the roles with responsibilities (i.e. board KM owner, KM coordinator, knowledge manager, sponsors of knowledge areas and lead experts) were defined. If there is no overall ownership of knowledge and learning within an organization and the leadership does not support the process, it will be difficult to sustain any sharing behaviour.

VI–4.5. Technology and infrastructure

Matching the KM IT system with the KM objectives was essential. A proposal for a technical solution for support of the standard KM processes of knowledge capture, storage, sharing and utilization within the nuclear power plant was established first. Then, a proposal for specific tools and their integration into other existing IT systems was implemented after the completion of the project. An important consideration is that if it takes more than three clicks to find knowledge on the system, users will get frustrated. The principle here is *the right knowledge in the right place at the right time.*

VI–4.6. Consistency and persistence

Implementation plans based on time schedules, monitoring of inputs and outputs of the project, resource planning (both human and financial) and setting up of key performance indicators were the most important conditions for a successful rollout.

VI–5. MOTIVATION

The major challenge in KM is the motivation of people to share knowledge with others. Offering our experts the combination of the services and products given in Table VI–2 proved to have a positive impact on the encouragement of employees to share knowledge.

TABLE VI–2. COMBINATION OF SERVICES AND PRODUCT OFFERED BY ČEZ

Offer	Combination of services and products
Training and development	Premium hard skills training Premium soft skills training Coaching Language lessons
Foreign business trips	International conferences (workshops)
Contests	Best experience report (annually)
Personal awards	Public relations, interviews, articles, presentation of experts in company magazine, intranet, etc. Expert certificate awarded by top manager Informal meetings (dinners)
Financial rewards	Rewards for exceptional contributions and participation in projects
Extra health and fitness care	Work life balance

Annex VII

CASE STUDY: KNOWLEDGE LOSS RISK MANAGEMENT AT ROSATOM, RUSSIAN FEDERATION

VII–1. INTRODUCTION

VII–1.1. Rosatom at a glance

The Rosatom State Atomic Energy Corporation of the Russian Federation consolidates more than 350 enterprises and institutions engaged in nuclear fuel cycles, applied and basic science, nuclear and radiation safety, nuclear medicine and activities related to composite materials. The company's nuclear power complex engages in various fields, such as uranium mining, uranium enrichment, nuclear machine engineering, nuclear fuel fabrication, electricity generation, electricity export and import, and service and maintenance of nuclear power plant components, as well as nuclear power plant design, engineering and construction. In addition, it operates a nuclear weapons complex and a fleet of nuclear icebreakers, a container ship and maintenance ships. Rosatom is the largest power generating company in the Russian Federation, producing 18.3% of the country's total generation of electricity. It has a leading position in the world market of nuclear technologies, with the highest number of nuclear power plants constructed outside the country. It is also globally important for uranium reserves, mining and production, and nuclear electricity generation, with its one third share of the world market in global uranium enrichment services and covering 17.7% of the global nuclear fuel market.

Rosatom is also a global technology leader in the nuclear power industry. Its activities include all key regional segments of the world market. At the time of writing, 34 nuclear power plant units are under construction outside the Russian Federation and 8 within it. Fuel fabricated by JSC 'TVEL' (part of Rosatom) is used for 14 nuclear power plants all over the world. Legal framework agreements have been established with 54 countries.

Rosatom and its organizations cover the entire life cycle of nuclear technology. Considering the above mentioned organizational structure and the long life cycle of nuclear technology (in some cases, more than 60 years), Rosatom gives special attention to the issue of knowledge preservation and transfer. In order to maintain its potential for innovation, Rosatom considers knowledge loss risk management (KLRM) to be a priority.

VII–1.2. Retaining critical knowledge at Rosatom

Rosatom comprises organizations providing services at different stages of nuclear technology life cycle development. These are research institutes, nuclear power plants, companies producing specialized equipment, companies involved in fuel production, and companies and organizations dealing with radioactive waste management. Consequently, the focus and format of knowledge preservation activities are closely linked to the goals and scope of the activities of each specific organization.

As an example, in research institutes, knowledge preservation activities are focused on the preservation of competences and capabilities in specific areas of nuclear technology, which are normally assigned to different research sectors (departments, divisions and laboratories). Usually, knowledge preservation activities in a research sector are performed by a working group consisting of researchers who develop a knowledge map for particular scientific or technical areas (areas of the expertise sector) and define the critical knowledge to be preserved. The working group focuses mainly on the development of a suitable map of expertise in the technical area, and the collection and preservation of knowledge (e.g. on digital media) for further sharing within the organization. The scientific and technical councils of research institutes normally play a key role in defining the criticality of the knowledge to be preserved and in reviewing the content of the codified knowledge obtained as a result of the preservation process.

Equipment manufacturing companies focus on a different kind of critical knowledge — the specialized knowledge and skills (mainly tacit) of professional workers — which cannot be preserved and transferred by knowledge codification. This knowledge can be transferred from masters (key experts) to young professionals through mechanisms for transferring tacit knowledge, which include masterclasses, specialized training and mentoring. Transfer of specialized tacit knowledge of key experts is critically important for producing high quality non-standard equipment.

The different approaches used for preserving critical knowledge are illustrated in Sections VII–2 and VII–3 for two successful projects: in Rosatom research institutes and in equipment manufacturing companies (JSC Atomenergomash's 'Bridge of Generations' project).

VII–2. MANAGING CRITICAL KNOWLEDGE IN APPLIED AND FUNDAMENTAL SCIENCE

VII–2.1. Background

Science & Innovation LLC is a management company established in 2011 to coordinate the activities of 14 research and development (R&D) institutes (with around 15 000 employees) within Rosatom's Innovation Management Division that are engaged in the development of new chemical, electrical and nuclear power technologies. The primary tasks of the company are to identify priority areas to be focused on, to develop a roadmap of new technologies to be developed within Rosatom by 2030 and a projection for 2050, and to define the solutions that will be needed.

A knowledge preservation programme was established within the company to preserve scientific and research competences in order to increase the efficiency of R&D activities.

VII–2.2. Process description

A model of the knowledge preservation process developed within the project is shown in Fig. VII–1. The process owner was the Innovation Management Division. The model was developed according to IAEA recommendations and includes:

— Identification of critical knowledge;
— Risk assessment of critical knowledge loss;
— Development and implementation of programmes to preserve critical knowledge;
— Assessment of quality of critical knowledge.

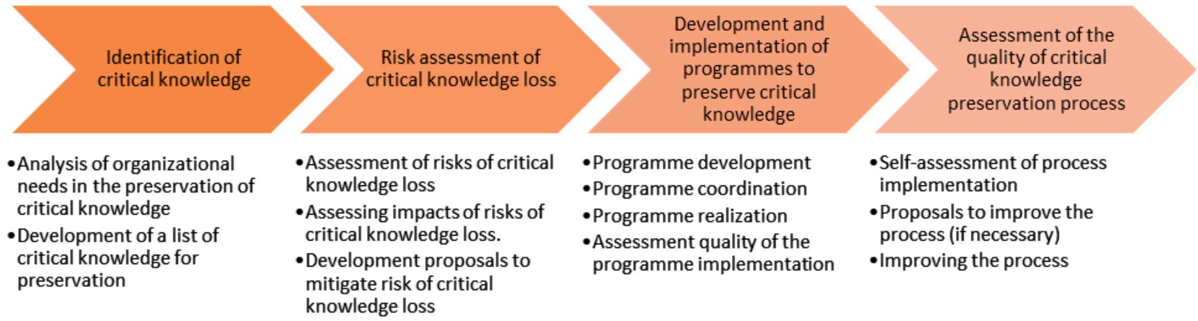


FIG. VII–1. Critical knowledge preservation process at Rosatom.

VII–2.3. Process participants

The key participants of the knowledge preservation process governed by ZAO Science & Innovation were the following:

— Head of the organization (director general or deputy director general) responsible for knowledge management (KM) in the organization.

— Members of the scientific and technical council of the organization.
— A working group including a focal point, appointed by the head of the organization and working group members. The working group should include the following specialists: scientific secretaries, information technology (IT) specialists, human resources (HR) specialists and information management specialists (scientific and technological information).
— Experts (the holders of critical knowledge).
— Knowledge recipients (young specialists).

VII–2.4. Roles of the process participants

The main roles of the process participants are presented in Table VII–1.

TABLE VII–1. ROLES OF PROCESS PARTICIPANTS WITHIN ROSATOM

Participants	Roles
Head of the organization	Appointing a focal point and approval of the working group Approving the knowledge loss risk management report Approving an action plan on critical knowledge preservation Approving the results of critical knowledge preservation (procedures, instructions, training materials, etc.) Ensuring critical knowledge preservation Providing training for personnel involved in KM Ensuring the organizational culture supporting preservation of critical knowledge
Members of the scientific and technical council	Reviewing of documentation on critical knowledge preservation Making recommendations on determination of critical knowledge Making recommendations on determination of critical knowledge holders Organizational support in work with critical knowledge holders Making recommendations to determine the receivers of critical knowledge Recommending participants of critical knowledge preservation programmes for promotion Providing information support to the knowledge preservation programme Communicating with the working group
Working group	Identifying critical knowledge Determining critical knowledge recipients Assessing risk of knowledge loss Developing programmes for critical knowledge preservation Implementing organizational and technical measures in accordance with the critical knowledge preservation programme Performing self-assessment of the KM programme implementation Reporting development Communicating with the scientific and technical council
Experts (the holders of critical knowledge)	Communicating with the working group Developing proposals to determine the recipients of critical knowledge Performing knowledge transfer according to incoming requests Participating in the mapping and codification of critical knowledge Consulting on specific issues related to competence Transferring personal knowledge to young specialists by personal example and/or through communication Providing training of personnel in accordance with the KM programme Developing training programmes and curricula Identifying problems in the training process

VII–2.5. Knowledge loss risk management

In order to assess the risks of knowledge loss and to identify critical knowledge in the organizations of the Innovation Management Division in 2013, knowledge mapping was performed using the form given in Table VII–2.

TABLE VII–2. INFORMATION COLLECTED FOR KNOWLEDGE MAPPING AT ROSATOM

Item	Category	Subcategory
1	Area of research	
2	List of topics	
3	Result of intellectual activities	
4	Responsible subdivision	
5	Head of responsible subdivision	
6	Knowledge holders	Field of expertise
		Age
7	Knowledge presentation	Scientific technical information portal
		Other
8	Young specialist	

The organizations should provide a description of each research topic (Item 2 of Table VII–2) including the components given in Table VII–3.

TABLE VII–3. CONTENT OF A DESCRIPTION OF A RESEARCH SECTOR AT ROSATOM

No.	Item	Content
1	History of research sector development	History of knowledge development, including key milestones, facts, events and processes that have led or influenced the results achieved in the field of critical knowledge preservation
2	Problem definition	Definition of basic concepts, data, characteristics and aspects of critical knowledge preservation; analysis of relevance, originality, scientific, economic and industrial prospects
3	Possible solutions (with detailed description of the selected solution)	Presentation of possible solutions and a detailed description of the presented solution according to the selection criteria (see Item 4)
4	Criteria for selection of the presented solution	Description of the specific indicators for selection of the optimum solution
5	References to research and development reports	References to research and development reports and product descriptions
6	References to publications	References to publications and monographs or presentation of the material within the body of a video module
7	List of the key experts	List of the key experts in the field of critical knowledge preservation

VII–2.6. Sharing preserved knowledge and technologies

During pilot project activities to implement a system to preserve critical knowledge in the organizations of Rosatom, a specialized procedure to capture critical knowledge with the purpose of developing multimedia products was developed, tested and approved. The developed multimedia products preserved critical knowledge and were intended for the training of young employees using e-learning platforms under the Innovation Management Division. The multimedia products may also be used for promoting specialized knowledge and technologies and for commercial purposes.

The developed procedure had six steps (see Fig. VII–2). Working groups implementing this procedure typically included knowledge managers, an IT specialist and a psychologist.

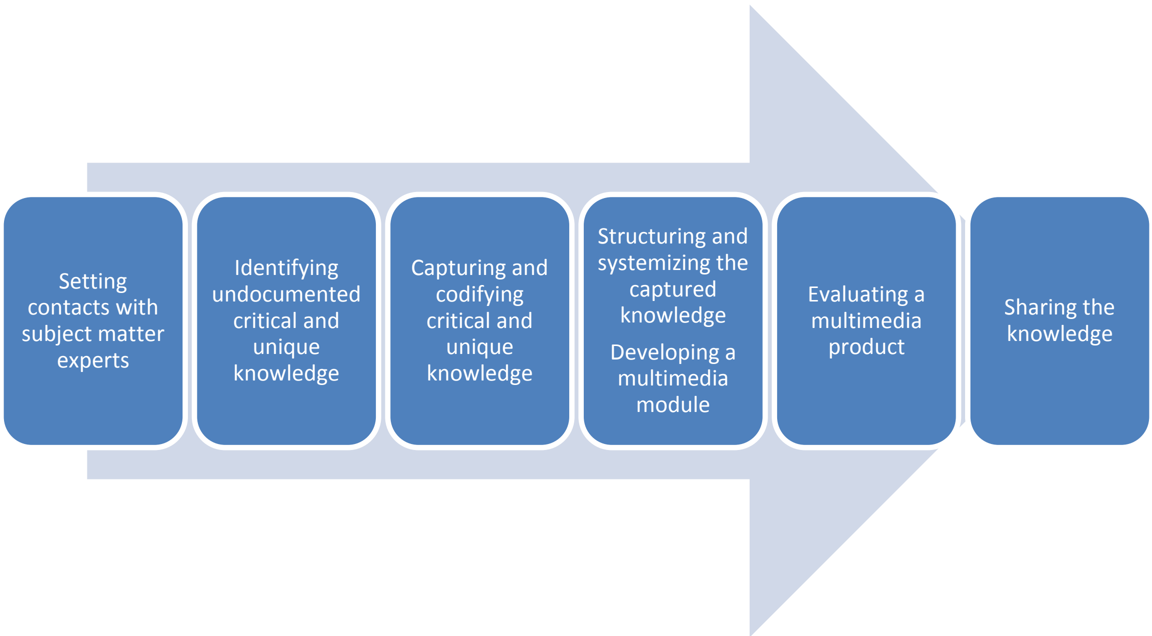


FIG. VII–2. Block diagram of the 'work with experts' procedure at Rosatom.

Objectives and goals were set up for each step of the 'work with experts' procedure as shown in Table VII–4.

TABLE VII–4. OBJECTIVES AND GOALS FOR EACH STEP OF THE 'WORK WITH EXPERTS' PROCEDURE AT ROSATOM

Step	Objective	Tasks
1	Establish contact with experts, to create a favourable psychological environment for further collaboration	Request materials from experts to review critical issues Exchange contact data Set up portal registration Agree on objectives, goals, timelines and project deliverables Develop preliminary concept maps
2	Identify uncodified critical knowledge	Develop a structure of the scenario Allocate topics to experts Initiate development of concept maps (by experts) Identify critical video issues Initiate development of visual materials and texts (by experts) Prepare questions for video interviews

TABLE VII–4. OBJECTIVES AND GOALS FOR EACH STEP OF THE ‘WORK WITH EXPERTS’ PROCEDURE AT ROSATOM (cont.)

Step	Objective	Tasks
3	Capture and codify critical and unique knowledge	Prepare and film video interviews Initiate development of a common concept map (with experts) Develop a scenario (including graphic material)
4	Structure, systemize and preserve knowledge	Develop a multimedia module with the preserved knowledge
5	Evaluate the multimedia module	Evaluate the multimedia module using experts Gather missing material Finalize the multimedia module Coordinate with the customer and obtain approval
6	Share the captured knowledge	Use the developed multimedia module as necessary

VII–2.7. Rosatom’s mentoring system

The Rosatom project ‘Development and Roll-out of the Mentoring System’ was launched in 2013 to ensure a systematic approach to the transfer of industry specific and critical knowledge to a new generation of employees and to improve and accelerate the adaptation of new employees to production specifics.

The project’s background can be summarized as follows:

- There were strict requirements for the professional level of personnel to ensure strategic development of the industry in a competitive environment.
- Many industry job positions required significant additional on the job training for graduates.
- Preservation and transfer of industry specific knowledge and expertise were vital for reliable and safe production.
- Unique industry specific expertise was a competitive advantage on the external market.
- There was a risk of knowledge and expertise loss due to ageing of personnel in the nuclear industry.
- Knowledge and expertise transfer was still not at a mature level in many organizations.

The developed concept of the mentoring system was based on best industry practices and was closely connected to the personnel development policy. Five employee categories were identified as a target group for mentoring (see Table VII–5).

TABLE VII–5. EMPLOYEE CATEGORIES FOR MENTORING AT ROSATOM

No.	Mentoring type	Prerequisites for implementation	Goals and objectives
1	Mentoring for students during practical training	High recruitment needs within the organization (optional type of mentoring)	Shortlisting the best students for future employment Primary adaptation of future employees to the corporate culture and specifics of production Promotion of the Rosatom employer brand among students of industry orientated educational institutions
2	Mentoring for newly hired young workers and professionals	Mandatory for all newly hired workers	Acceleration of professional and social adaptation to reach the required performance level for the newly hired workers Increase the retention rate of newly hired workers during their first year of employment

TABLE VII–5. EMPLOYEE CATEGORIES FOR MENTORING AT ROSATOM (cont.)

No.	Mentoring type	Prerequisites for implementation	Goals and objectives
3	Mentoring for young professionals for the transfer of industry specific core expertise	Identified risk of core expertise loss in the organization (optional type of mentoring)	Ensuring sustainability of the organization through preservation, transfer and application of core expertise Retention and development of young professionals
4	Mentoring for managers assigned to a new management level	Mandatory for all newly assigned managers	Acceleration of adaptation to a new management level Reduce the risk of inefficient management decisions
5	Mentoring for the talent pool	Mandatory for all high potential workers	Facilitation of leadership development Preparation of complex and strategic challenges in the future

Effective implementation of the mentoring programme requires specific actions on an annual basis from all involved parties, whose roles and responsibilities are specified in Table VII–6.

TABLE VII–6. PARTICIPANT ROLES AND RESPONSIBILITIES AT ROSATOM

Participant	Roles
Mentoring board	Includes the managers and human resource staff responsible for the organization and experts (internal and external, if required) Decides whether mentoring types are a priority for the organization Approves annual action plans (roadmaps) Approves mentor lists Executes progress review and result evaluation
Human resources facilitator	Drives implementation of mentoring programmes Ensures administrative support Helps in forming mentor–mentee pairs Initiates development measures for mentors if required
Head of department	Ensures organizational support Participates in mentor selection Evaluates mentor effectiveness Initiates development measures for mentors if required
Mentor	Develops a mentoring plan and guides training of the mentee Ensures expertise and performance increase of the mentee Evaluates mentee performance and competences
Mentee	Agrees on learning goals with the mentor Executes the mentoring plan Takes the initiative in cooperation with the mentor Reports on mentoring plan execution and results

The mentoring system was launched in 2013 as a pilot project at 17 of Rosatom’s companies, the full implementation of the system took place in 2014.

VII–2.8. Supporting documents

During implementation of the pilot activities in 2012, the following guidelines were developed and were introduced in the scientific organizations of the Innovation Management Division:

— Administrative procedures for critical knowledge preservation;
— Guidance for preservation of critical and unique knowledge.

VII–2.9. Outcomes

The procedure described above was tested in 2012–2013 in five scientific organizations of the Innovation Management Division. More than 300 holders of critical and unique knowledge were identified and nine pilot multimedia modules were prepared, which were on critical issues in the main areas of basic and applied nuclear science. A typical interface of a multimedia module is presented in Fig. VII–3.

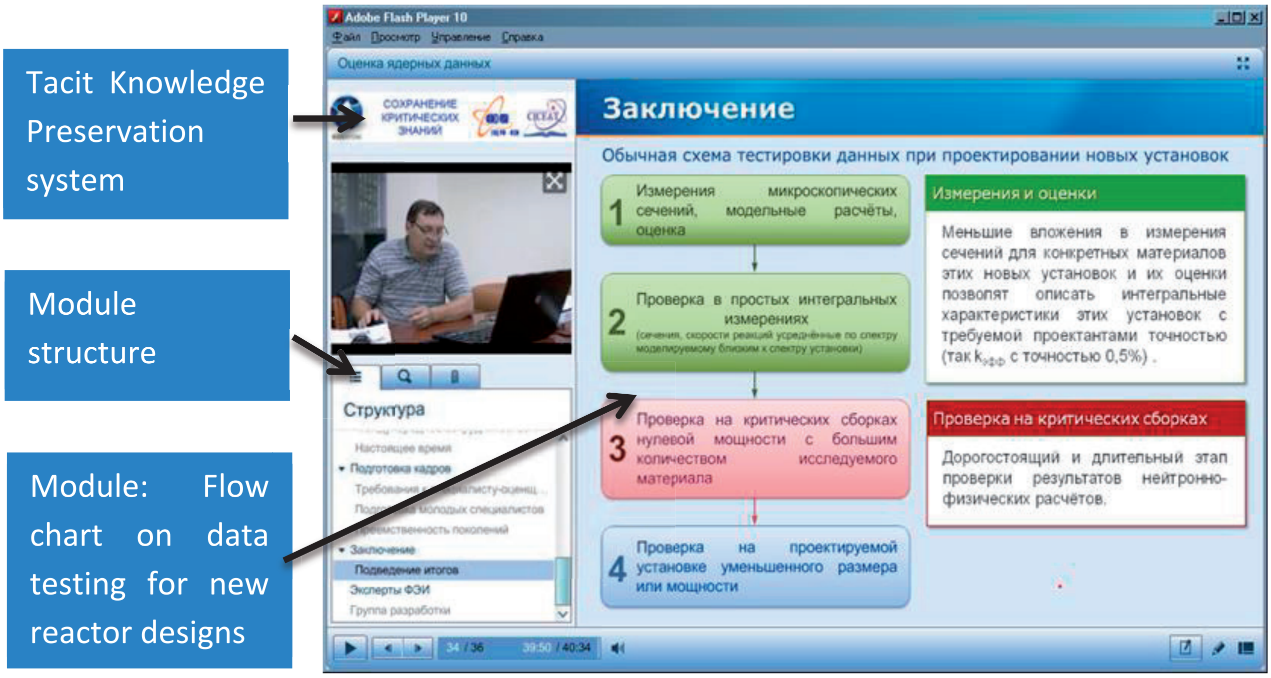


FIG. VII–3. Screenshot of a Rosatom multimedia module.

During the pilot implementation, all enterprises of Science & Innovation LLC developed organizational knowledge maps covering the main areas of applied and fundamental science. Other project activities included master classes, scientific and technical seminars and workshops and specialized training sessions.

According to the 'Programme to create the system of corporate knowledge of Rosatom for 2012–2015', the system described above is being transmitted to other divisions of the nuclear industry with a goal to have it fully implemented in the Rosatom organizations in the near future.

VII–3. JSC ATOMENERGOMASH 'BRIDGE OF GENERATIONS' PROJECT

VII–3.1. Background and general project information

The Atomenergomash Group of Companies (JSC Atomenergomash, AEM Group and AEM), the machine building division of the Rosatom State Atomic Energy Corporation, is one of the leading power machine building companies in the Russian Federation. The group of companies supplies efficient and complex solutions that include the design, production, supply, assembly, engineering and service of equipment for nuclear and thermal power plants, and for gas and petrochemical industry enterprises. JSC Atomenergomash incorporates more than 50 Russian Federation and foreign companies, including production enterprises, engineering centres, and scientific and research organizations. Unique production capacity, a strong research base and wide ranging expertise are the basis for the success and sustainable development of the AEM Group.

In the years 2009–2012, managing knowledge loss was identified as the critical issue for many employees who possessed critical knowledge on the main production processes and who were close to retirement age (or in some cases, at retirement age). This situation created a clear internal threat to the reliable and safe business processes that included design, production, assembly and service of equipment for the nuclear industry due to the risk that the loss of those employees could lead to the loss of a substantial amount of knowledge and corporate memory. At the same time, the share of young people being recruited into the AEM Group was not sufficient.

The risk of knowledge loss should be monitored during the next 10–15 years, taking into consideration a lack of existing practice in managing the retention and transfer of knowledge as well as low motivation of 'possessors of knowledge' for the preparation of their 'replacements'.

The Atomenergomash 'Bridge of Generations' project was established with the intention to mitigate the loss of critical knowledge at the AEM Group, and started with two pilot projects at ZIO-Podolsk (Podolsk) and SverdNIIKhimmash (Yekaterinburg). The demographics of the employees involved are given in Table VII–7. During the implementation of these pilot projects, the IAEA methodology on KLRM was successfully applied.

The goal of the 'Bridge of Generations' project was to develop a methodology and to implement an organizational approach, directed towards the management of critical knowledge loss risk, assessment of the risks of loss of critical knowledge, creation of conditions to ensure the succession of knowledge holders and retention of the best practices in the enterprises of JSC Atomenergomash.

The implementation of the 'Bridge of Generations' project was very important to JSC Atomenergomash, as the main aim of the project was to create favourable conditions for the development and high competitiveness of the enterprises of the AEM Group. The project was to enhance the professional level of staff without increasing the cost of external training, as well as to improve and hasten the adaptation of new employees to the specifics of production. In addition, the corporate knowledge base to be created would allow retention and transfer of unique project experience.

The results of the project were intended to increase the effectiveness of the organizational HR policy and to achieve the following strategic goals:

— Creation of organizational conditions for the retention and transfer of critical knowledge within JSC Atomenergomash;
— Retention of critical knowledge and technologies;
— Reduction of the average age of personnel;
— Development of young specialists and increase in the level of active involvement by staff in group processes.

The project targeted all employees of the company, as well as potential employees. Participation in the project was: an opportunity for employees, especially young ones, for their professional development, career advancement and enrolment in reserves of managerial personnel; an opportunity for participation in the strategic projects of the company; an opportunity to become a developer of author programmes and courses; and an opportunity to participate in a special retirement programme.

TABLE VII–7. AVERAGE AGES OF LINE MANAGERS AT SVERDNIIKHIMMASH AND ZIO-PODOLSK

Company	Average age of line managers (years)	
	2009	2012
SverdNIIKhimmash	55	47.5
ZIO-Podolsk	47	45.5

VII–3.2. Process description

The ‘Bridge of Generations’ project was expected to:

— Identify unique and critical knowledge and technologies;
— Manage knowledge sharing within the organization;
— Increase the motivation for knowledge sharing;
— Support training and staff development.

A flow chart of the complete process is presented in Fig. VII–4.

Step I of the process included the identification of experts who may have unique or critical knowledge and skills important to the main design and production processes. The key players during this step were the line managers responsible for critical knowledge identification (unique knowledge factor, critical knowledge factor and attrition factor). At the end of the step, a list of experts with unique and critical knowledge was developed, as well as a list of young employees with a high professional potential to play the role of recipients of knowledge and skills (see Tables VII–8 and VII–9).

Participation in research and scientific activities as well as level of qualification (e.g. PhD) were also taken into consideration.

During step II, a special expert council played a main role. The council performed an assessment of all potential participants in the project, and, jointly with technical divisions and the HR group, identified employees for release, experts with unique and critical knowledge and a final list of knowledge recipients.

Step III was dedicated to the transfer and retention of knowledge and skills and included a broad range of different KM tools and techniques, for example, concept maps, coaching and mentoring, exit interviews, master classes, training and knowledge codification.

The pilot projects at ZIO-Podolsk (Podolsk) and SverdNIIKhimmash (Yekaterinburg) were launched by the JSC Atomenergomash director general. Further steps of the projects were regulated by the enterprise participants

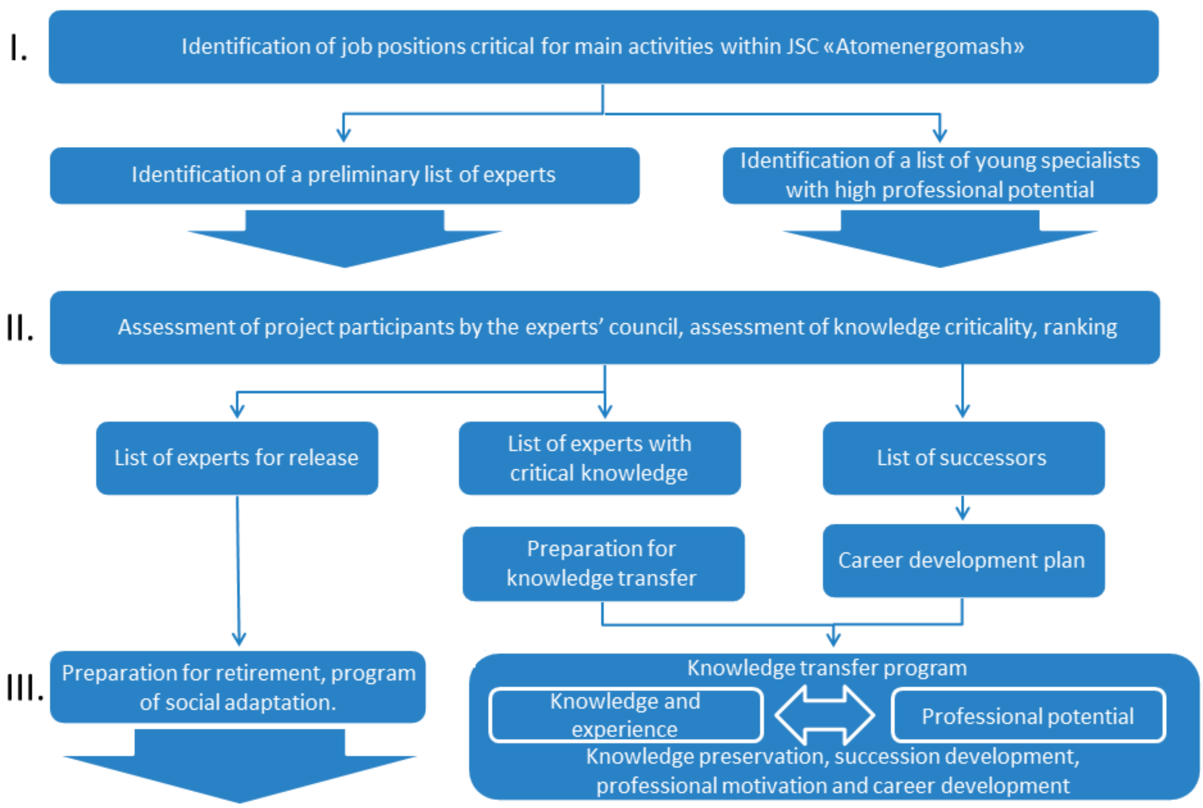


FIG. VII–4. Knowledge loss risk management at JSC Atomenergomash.

according to the approved KLRM programme. The ‘Bridge of Generations’ project was implemented by JSC Atomenergomash and its enterprises, without the involvement of external consultants.

TABLE VII–8. INSTRUMENTS USED FOR SELECTION OF THE ‘HOLDER’ OF KNOWLEDGE AT JSC ATOMENERGOMASH

Area of appraisal	Measurement system	Instrument
Motivation for knowledge codification and transfer	Typological model of motivation to work	Questionnaire
Level of health	Self-appraisal by interval scale	Form
Pedagogical skill	Self-appraisal by interval scale	Form
Successful project experience	Self-appraisal by interval scale	Form
Critical knowledge	Free-form	Form

TABLE VII–9. INSTRUMENTS USED FOR SELECTION OF THE ‘SUCCESSORS OF KNOWLEDGE’ AT JSC ATOMENERGOMASH

Area of appraisal	Measurement system	Instrument
Motivation for knowledge codification and transfer	Typological model of motivation to work, self-assessment, appraisal by manager	Questionnaire, form for self-assessment and for manager appraisal
Successful project experience	Self-assessment by normative scale, formal appraisal by manager	Form, manager questionnaire
Loyalty	Self-assessment, expert appraisal by manager, periodic appraisal of loyalty	Form, manager questionnaire, loyalty test
Innovativeness	Self-assessment, expert appraisal by manager	Form, manager questionnaire
Professional technical skills	Self-assessment, expert appraisal by manager	Form, manager questionnaire

VII–3.3. Supporting documents

The terms of reference of the project approved by the JSC Atomenergomash director general provided the organizational framework of the process for identification, retention and transfer of critical knowledge and technologies. The process was also supported by the following:

- A knowledge transfer and retention process model (organizational flow chart of the project);
- Orders of the enterprise participants to start up the local projects (with appointment of responsible persons);
- Approved lists of ‘possessors of knowledge’ and ‘successors of knowledge’;
- Knowledge assessment questionnaires;
- Expert council records;
- Action plans for the development of employees;
- Action plans for knowledge transfer and retention;
- Approved annual action plans (roadmaps).

The project activities were supported by standard IT solutions such as internal portals, bulletin boards and enterprise media (to publicize the project activities). Special IT tools are under consideration and are being developed within the pilot project at OKB GIDROPRESS (Podolsk, Moscow region).

VII–3.4. Outcomes (statistics)

The project involved the following six companies of JSC Atomenergomash:

— ZIO-Podolsk (Podolsk, Moscow region);
— GIDROPRESS (Podolsk, Moscow region);
— SverdNIIKhimmash (Yekaterinburg);
— TSKBM (Saint Petersburg);
— CNIITMASH (Moscow);
— OKBM AFRIKANTOV (Nizhny Novgorod).

Within the ‘Bridge of Generations’ project, nearly 160 employees were identified as ‘possessors of unique and critical knowledge’ and 87 as ‘possessors of knowledge’. More than 100 ‘successors’ were selected for knowledge transfer and retention. The project had a significant impact on the organizational sharing knowledge culture — many employees who did not formally participate in the project attended master classes, lectures by leading experts and open forums and discussions.

VII–3.5. Motivation

The project provided the following types of motivation for participants:

— Professional development and career advancement;
— Enrolment in the reserve of personnel of Atomenergomash and other companies;
— Participation in strategic projects of the company;
— Opportunities to become developers of programmes and courses;
— Opportunities to participate in a special pension programme;
— Remuneration based on key performance indicator results.

Annex VIII

CASE STUDY: KNOWLEDGE LOSS RISK MANAGEMENT AT PALO VERDE NUCLEAR GENERATING STATION, UNITED STATES OF AMERICA

VIII–1. INTRODUCTION

VIII–1.1. Structure of Palo Verde Nuclear Generating Station

Palo Verde Nuclear Generating Station is the largest power generating station in the United States of America. It is operated and managed by Arizona Public Service Company, and has seven owners: Arizona Public Service Company, Salt River Project, Southern California Edison, Public Service of New Mexico, El Paso Electric Company, Los Angeles Department of Water & Power and Southern California Public Power Authority. Its primary purpose is to provide electricity to the south-western area and western grid of the USA.

Palo Verde Nuclear Generating Station is a three unit nuclear power plant. All three units are of the Combustion Engineering System 80 pressurized water reactor design, with an installed capacity of 1410 MW each, and were commissioned in 1985, 1986 and 1987.

VIII–1.2. Reasons to start knowledge loss risk management

In the years 2008 and 2009, knowledge loss risk management (KLRM) emerged as a critical process for understanding the risk due to knowledge loss that the station was exposed to. This was resulting in poor plant performance and regulatory oversight. Based on knowledge management (KM) best practices and analyses, a detailed process was implemented at the station.

The main target of KLRM implementation was to increase safety and to reduce the risks associated with a possible loss of unique and critical knowledge. The reasons to start KLRM included:

- Generational replacement (retirement of experts and ageing staff);
- Decrease in plant performance;
- Loss of unique and critical knowledge;
- Increasing demand for nuclear workers in the USA;
- Improvement of transfer of knowledge and experience (capture of institutional knowledge).

VIII–1.3. Main objectives of knowledge loss risk management implementation

The main objectives of KLRM implementation included:

- To identify and maintain unique and critical knowledge;
- To establish a knowledge transfer and retention process for individuals who have unique and critical knowledge;
- To create an effective culture of knowledge and training;
- To establish a process for assessing each employee at the station and making them understand the potential risk of knowledge loss;
- To provide support and training to leaders on how to identify and manage unique and critical knowledge that may be at risk.

All Palo Verde Nuclear Generating Station employees and key contractors were assessed, with the average age of employees being 46 years in 2016.

VIII–2. PROCESS DESCRIPTION

The process owner was Palo Verde Nuclear Generating Station human resources (HR) department. KLRM was incorporated into the annual workforce planning process and was generally conducted once per year, with monitoring of plans on a quarterly basis (see Fig. VIII–1).

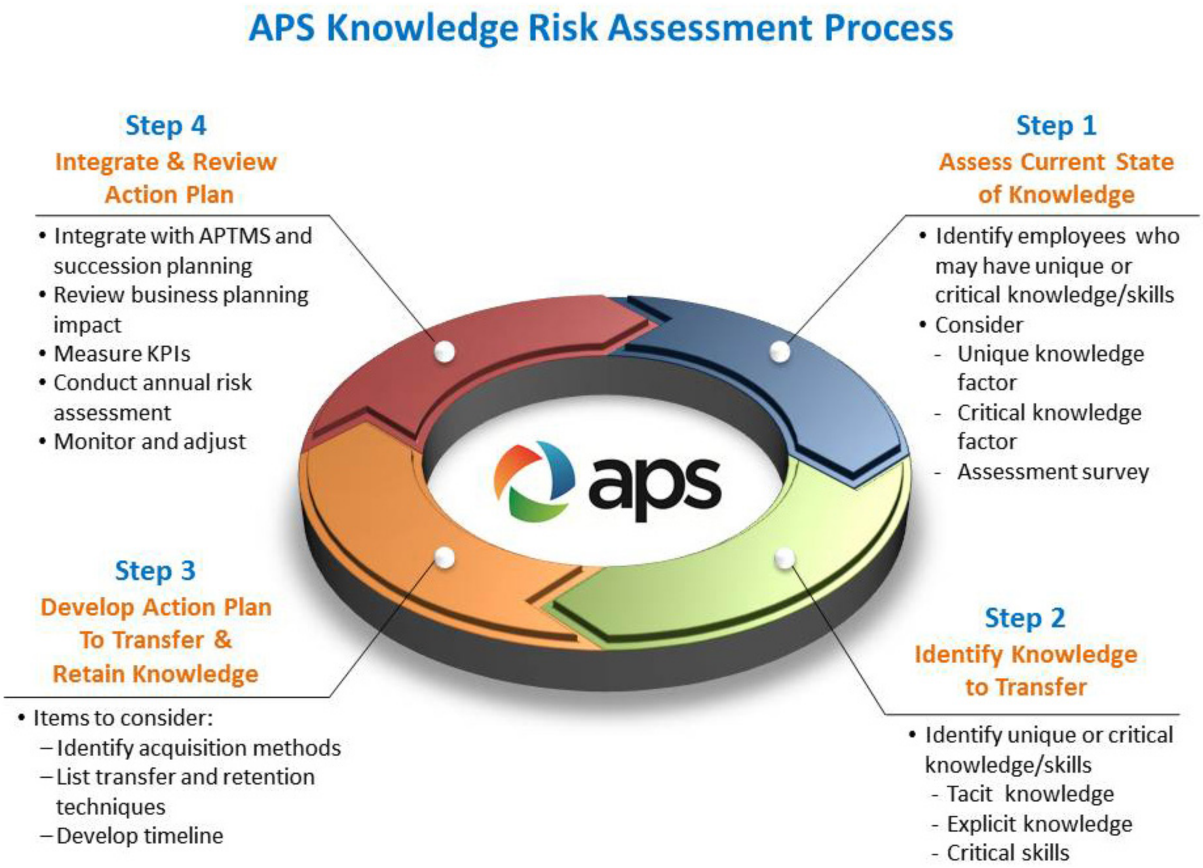


FIG. VIII–1. Knowledge risk assessment process at Arizona Public Service. APTMS — Arizona Public Service Talent Management System; KPI — key performance indicator.

VIII–2.1. Process tools

A set of web based tools was established to assist the process role owners (see Section VIII–2.2) with the risk assessment procedure. These tools were maintained on the company's intranet web site. The web page is shown in Fig. VIII–2.

The tools available on the web site included the following:

— Leaders' guide on knowledge transfer and retention;
— Knowledge transfer and retention process model;
— Knowledge transfer and retention action plan template;
— Knowledge assessment questionnaire.

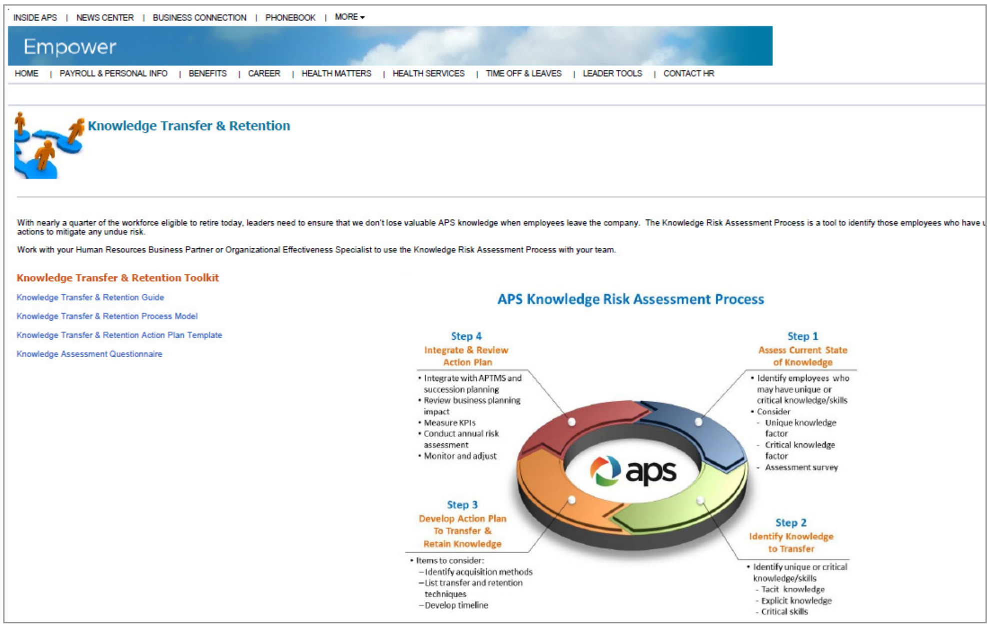


FIG. VIII–2. Web based tools on knowledge loss risk assessment at Arizona Public Service. APTMS — Arizona Public Service Talent Management System; KPI — key performance indicator.

VIII–2.2. Process roles

Process roles included:

— Manager/supervisor of employee, who conducts the risk assessment and action plan;
— HR business partner, who facilitates the risk assessment process;
— KM programme manager/HR director, who provides programmatic oversight of the process;
— Employee/expert, who participates in the risk assessment process and transfer of knowledge.

Figure VIII–3 identifies the process and roles for each position involved in the knowledge risk assessment process at Palo Verde Nuclear Generating Station .

VIII–2.3. Knowledge loss risk assessment

Each employee and key contractor was assessed based on step 1 of the process model. During the process of completing the knowledge risk assessment, the following structure was used:

— Job title/description (elements of the position);
— Knowledge area (operations, maintenance, engineering, etc.);
— Knowledge uniqueness (scale 1–5);
— Knowledge criticality (scale 1–5);
— Knowledge at risk (description of at risk knowledge);
— The above information was entered into a tracking form (see Fig. VIII–4).

Based on Fig. VIII–5, employees who were identified as being high risk had to complete an action plan to mitigate and manage the knowledge at risk.

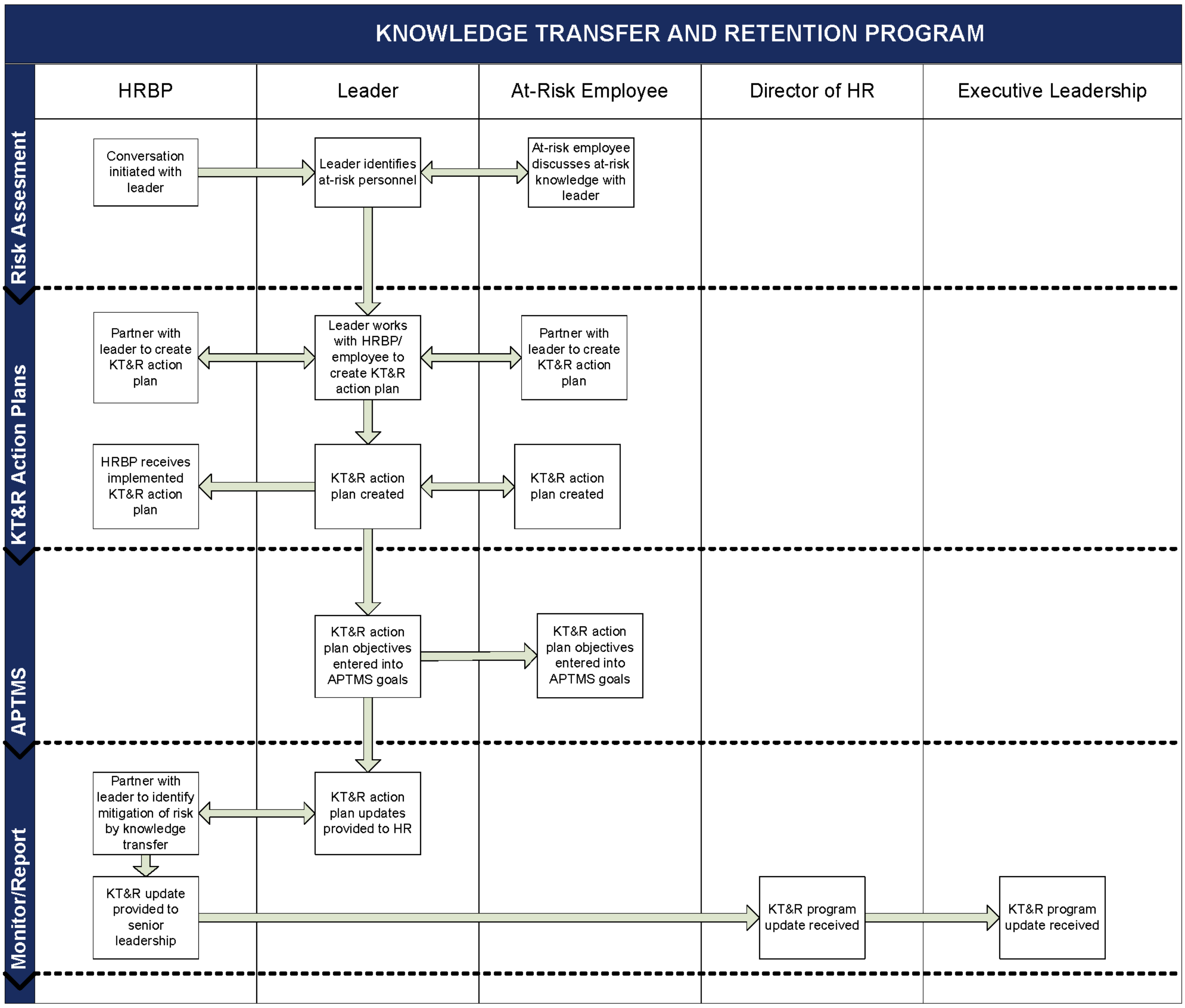


FIG. VIII–3. Process and roles for each position involved in the knowledge risk assessment process at Palo Verde Nuclear Generating Station. APTMS — Arizona Public Service Talent Management System; HR — human resources; HRBP — human resources business partner; KT&R — knowledge transfer and retention.

aps

Log to Assess and Track Critical or Unique Knowledge

Help APS retain critical knowledge and increase operating efficiency.

Assessing your employees and developing action plans to transfer and retain their critical or unique knowledge or skills.

EMPLOYEE NAME	DEPT. (UNIT)	JOB TITLE	AT-RISK KNOWLEDGE / SKILL	KNOWLEDGE RISK PRIORITY (High-Medium-Low)	CRITICALITY (1 TO 5)*	UNIQUENESS (1 to 5)*	ACTION PLAN DEVELOPED (Y/N)	DATE ACTION PLAN COMPLETED	ACTION PLAN IN APTMS (Y/N)

FIG. VIII–4. Knowledge risk assessment structure at Arizona Public Service. APS — Arizona Public Service; APTMS — Arizona Public Service Talent Management System; DEPT. — department.

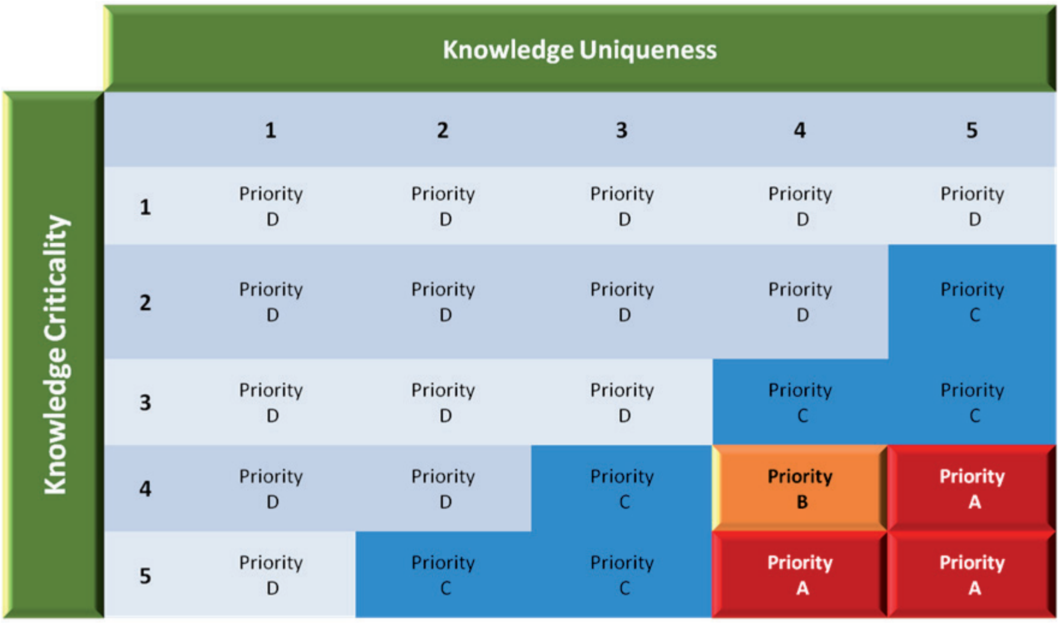


FIG. VIII–5. Knowledge at risk diagram of Arizona Public Service.

VIII–2.4. Risk levels

The following risk levels were established:

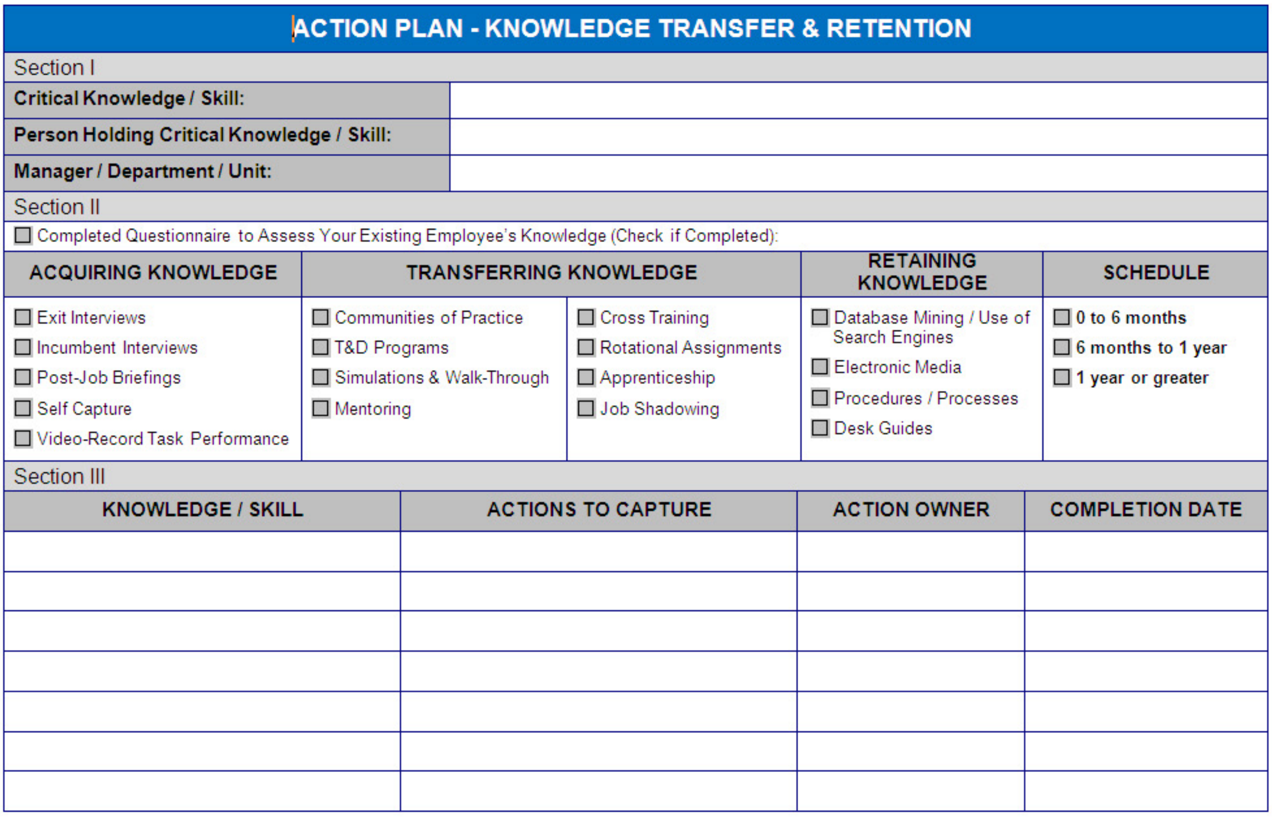
- Priority A — High risk — *Critical*. Immediate development of an action plans is due. The action plan must show how the organization will retain and transfer critical or unique knowledge; for example, it determines the specific training required or sets up on the job training or shadowing with the knowledge holder.
- Priority B — High risk — *Business important*. A plan must be established to address the method and timing of knowledge replacement, training others or shadowing the current knowledge holder.
- Priority C — Medium risk — *Limited bench strength*[1]. Consider potential impacts on the organization if it were to lose this knowledge from the department. Consider college recruitment, training programmes and/or process improvements. It should be determined whether the risk level would increase if a few of these individuals left the organization. If that is the case, action plans should be developed to mitigate that risk.
- Priority D — Low risk — *Acceptable*. No action is required.

By using the method described above, Palo Verde Nuclear Generating Station was able to identify employees who may not be at risk of retirement, but who had critical and unique knowledge. This allowed the organization to make a sophisticated assessment of knowledge at risk. From this process, a comprehensive action plan was developed and monitored (see Fig. VIII–6).

This process was a valuable method to help in the identification of critical knowledge at all levels of Arizona Public Service. Preservation of critical knowledge is important in order to ensure continuous success and safety of a nuclear power plant.

Palo Verde Nuclear Generating Station has been performing risk assessments since 2009. Table VIII–1 identifies the number of employees assessed and the results of those assessments.

[1] Companies use the term 'bench strength' to describe staff who could, in terms of their competences and preparedness, step into key roles within the company if their current incumbents should leave.



ACTION PLAN - KNOWLEDGE TRANSFER & RETENTION	
Section I	
Critical Knowledge / Skill:	
Person Holding Critical Knowledge / Skill:	
Manager / Department / Unit:	
Section II	
☐ Completed Questionnaire to Assess Your Existing Employee's Knowledge (Check if Completed):	

ACQUIRING KNOWLEDGE	TRANSFERRING KNOWLEDGE		RETAINING KNOWLEDGE	SCHEDULE
☐ Exit Interviews	☐ Communities of Practice	☐ Cross Training	☐ Database Mining / Use of Search Engines	☐ 0 to 6 months
☐ Incumbent Interviews	☐ T&D Programs	☐ Rotational Assignments	☐ Electronic Media	☐ 6 months to 1 year
☐ Post-Job Briefings	☐ Simulations & Walk-Through	☐ Apprenticeship	☐ Procedures / Processes	☐ 1 year or greater
☐ Self Capture	☐ Mentoring	☐ Job Shadowing	☐ Desk Guides	
☐ Video-Record Task Performance				

Section III

KNOWLEDGE / SKILL	ACTIONS TO CAPTURE	ACTION OWNER	COMPLETION DATE

FIG. VIII–6. Web based tools on knowledge transfer and retention action plan at Arizona Public Service. T&D — training and development.

TABLE VIII–1. RESULTS OF EMPLOYEE ASSESSMENTS AT PALO VERDE NUCLEAR GENERATING STATION

Year	Total number of employees	High risk (categories A and B)	Medium risk (category C)
2009	2441	10	26
2010	2410	36	37
2011	2377	28	49
2012	2277	24	n.a.
2013	2254	20	45

VIII–3. SUPPORTING DOCUMENTS

After 5 years of the knowledge risk assessment process, improvements to the supporting documentations were made, which currently consist of the following:

— Leaders' guide on knowledge transfer and retention;
— Knowledge transfer and retention process model;

— Knowledge transfer and retention action plan template;
— Knowledge assessment questionnaire.

VIII–4. OUTCOMES AND LESSONS LEARNED

VIII–4.1. Critical success factors of knowledge loss risk management

The KM implementation required effective support and investment in the following:

— Executive leadership set the expectation and operational focus on KM;
— Human resource professionals executed the process and ensured a quality assessment was conducted;
— Leaders actively engaged in the risk assessment process;
— Knowledge holders were involved in the process to ensure that unique and critical knowledge was retained.

Robust training programmes were formulated to ensure explicit knowledge was transferred and was part of the overall KM strategy. Action plans were monitored to ensure critical and unique knowledge gaps were properly managed.

VIII–4.2. Integrated knowledge management approach

Having an integrated KM system is necessary to ensure that knowledge is effectively documented, managed and transferred to those individuals who are required to obtain it. Figure VIII–7 identifies the integrated approach, the information technology systems at Palo Verde Nuclear Generating Station and elements of the KM programme.

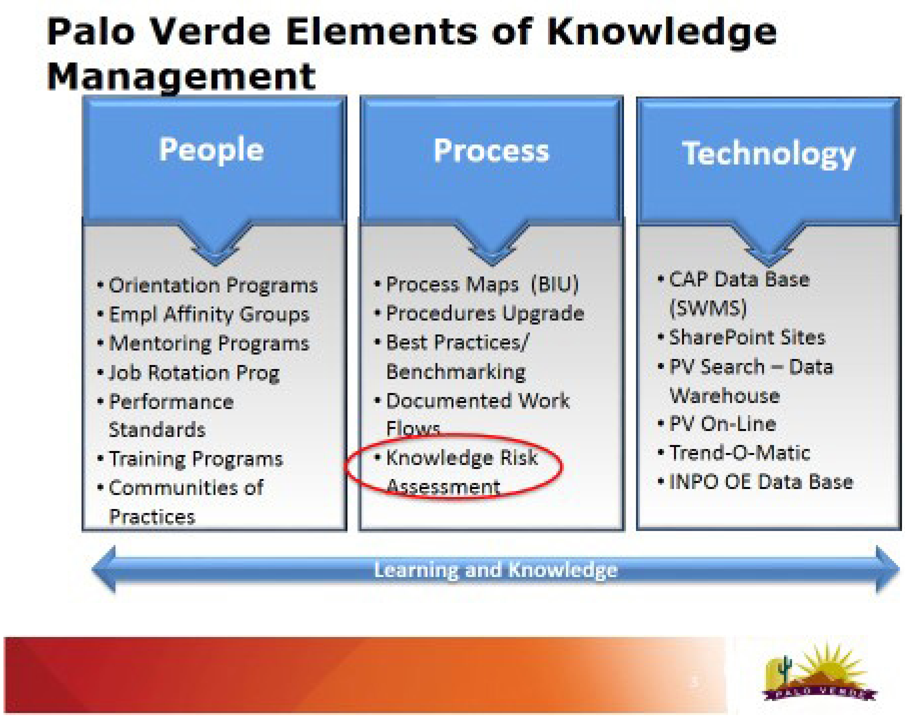


FIG. VIII–7. Elements of KM at Palo Verde Nuclear Generating Station. BIU — Business Integration University; CAP — corrective action programme; Empl — employee; INPO — Institute of Nuclear Power Operations; OE — operating experience; Prog — programme; PV — Palo Verde; SWMS — Station Work Management System.

VIII–5. MOTIVATION

Over six years (2008–2013), Palo Verde Nuclear Generating Station improved its performance, receiving an ‘excellent’ rating during evaluation by the Institute of Nuclear Power Operations. Part of the station’s key objectives was to lead the industry in knowledge and training. This included the KM elements identified. Employees were rewarded based on the station’s performance. They recognized that knowledge risk assessments and the corresponding action plans helped to achieve those objectives.

VIII–6. KNOWLEDGE AND THE PALO VERDE NUCLEAR GENERATING STATION LEADERSHIP MODEL

The Palo Verde Nuclear Generating Station leadership model states that knowledge is fundamental and should be shared. The organization sees knowledge as the foundation of their work, and believes that increased plant, industry, business and technology knowledge will improve decision making. Knowledge can be exchanged between colleagues and within the industry. Knowledge also contributes to staff development, and can be sought outside formal learning environments, as opportunities to learn accompany every task performed. While the organization does make use of courses and formal programmes such as their mentoring and job rotation programmes, they also look for opportunities for knowledge transfer such as those presented by cross-training and outage support.

Palo Verde Nuclear Generating Station considers the following in their work:

- Knowledge transfer and retention principles;
- Knowledge gaps;
- Staff development;
- Sustainable learning;
- Innovative solutions;
- The sustainability of their leadership pipeline;
- The consequent long term viability of safely and efficiently generating electricity at the plant.

Annex IX

CASE STUDY: KNOWLEDGE LOSS RISK MANAGEMENT AT SOUTH UKRAINE NUCLEAR POWER PLANT, UKRAINE

IX–1. INTRODUCTION

In Ukraine, the National Nuclear Energy Generating Company Energoatom is subordinate to the Ministry of Fuel and Energy. The ministry formulates State policies, and represents and promotes the interests of Ukraine regarding nuclear power performance to the IAEA and other international organizations. Nuclear power has a prominent place in the Ukrainian economy. The industry employs more than 38 000 people. In recent years, 69% of the installed capacity of Ukraine’s nuclear power plants has been used to generate around half of the country’s electricity; nuclear has an approximate overall share of electricity generation of 47%. Currently, there are 15 operating power units in Ukrainian nuclear power plants: 13 with WWER-1000 (PWR) reactors and 2 units of the newer subtype of the WWER-440 reactor. Two additional units are under construction.

One of the operating nuclear power plants is the South Ukraine Nuclear Power Plant. Table IX–1 lists its reactor types.

TABLE IX–1. SOUTH UKRAINE NUCLEAR POWER PLANT REACTOR TYPES

Unit	Reactor type	Installed capacity (MW)	Year of commissioning
1	WWER 1000/302	1000	1982
2	WWER 1000/338	1000	1985
3	WWER 1000/320	1000	1989
Total number of staff: 4500			

IX–1.1. Knowledge loss risk management history

Development of knowledge loss risk management (KLRM) at the South Ukraine Nuclear Power Plant started in 2009 owing to the implementation of the IAEA’s technical cooperation programmes UKR00/9 and UKR00/10 on strengthening nuclear knowledge management. The IAEA methodology on KLRM was taken as the basis for critical knowledge identification and risk assessment. The main purpose of KLRM was to reduce the risks of critical knowledge loss through identification of key experts at the nuclear power plant and to take actions to preserve knowledge.

The average age of an employee at the South Ukrainian Nuclear Power Plant in 2009 was 42 years old, and was projected to increase until 2018. This was seen as a reason to begin KLRM.

The main objectives of KLRM implementation were:

- To adopt a test IAEA KLRM methodology in accordance with Ukrainian nuclear power plant specifics;
- To incorporate KLRM into an integrated management system as a regular human resources (HR) process.

As there is a significant number of South Ukraine Nuclear Power Plant staff (4500 employees), it was agreed to test the KLRM methodology within the following three pilot departments:

- Training centre (103 employees);
- Instrumentation and control (I&C) department (625 employees);
- Electric department (545 employees).

IX–2. PROCESS DESCRIPTION

The implementation of the KLRM (assessment) was initiated and carried out by the training centre. At the same time, the following departments played an active role:

— HR;
— Quality assurance (QA);
— Information technology (IT) support.

During the pilot project, it was identified that the future process owner of the KLRM should be the HR department, supported by the training centre.

IX–2.1. Knowledge loss risk management organizational model

The organizational model of the KLRM process is shown in Fig. IX–1. The roles of the main players were the following:

— HR department: To provide knowledge loss risk assessment (KLRA) in technological departments;
— QA department: To provide quality control and regular checks of the KLRA;
— IT department: To provide information support;
— Training centre: To provide methodological support in implementing KLRM;
— Technological departments (I&C, electric, reactor, turbine, etc.): To implement the KLRM methodology for identification of key experts and areas of critical knowledge for further preservation and codification.

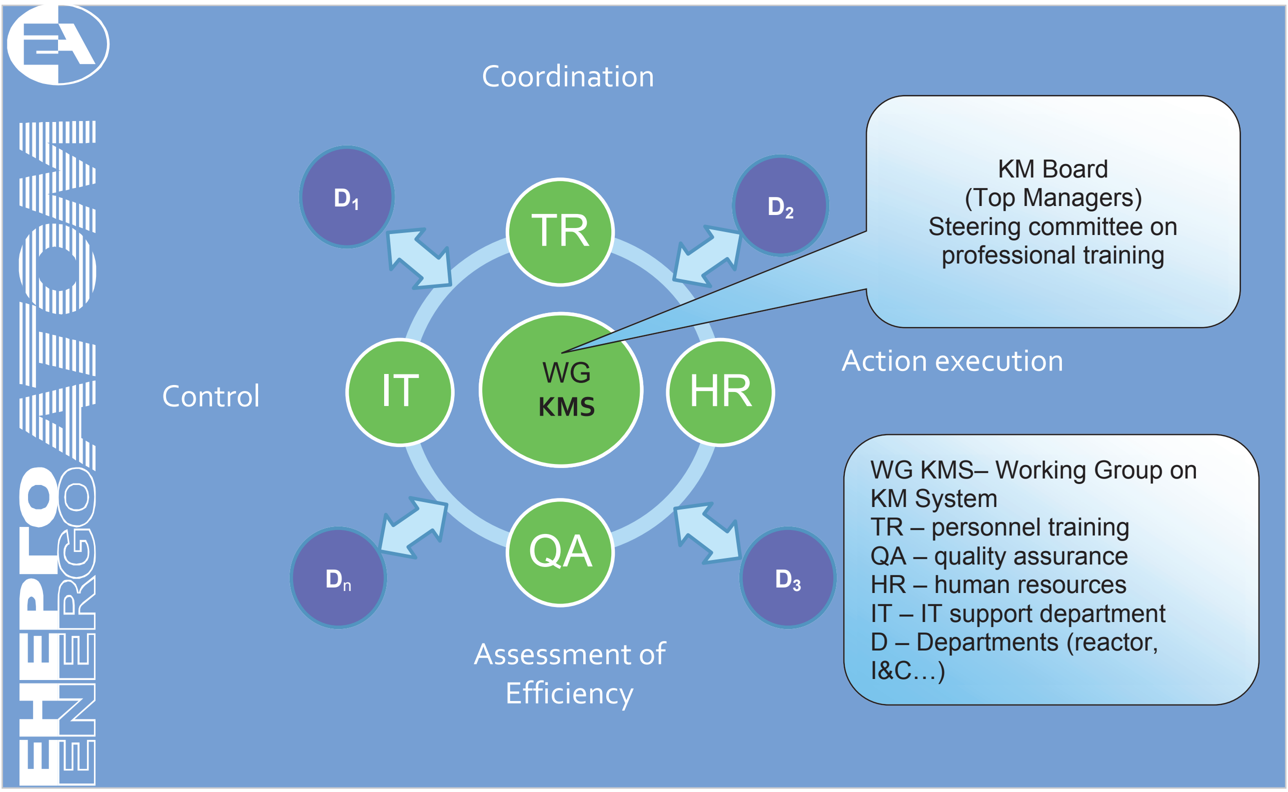


FIG. IX–1. Organizational model of the KLRM process. IT — information technology; I&C — instrumentation and control; KM — knowledge management.

IX–2.2. Manager support

During an IAEA KM assist visit, a meeting was organized with senior nuclear power plant managers. This helped to highlight the importance of risks related to knowledge and competence loss and their impacts on organizational performance. It was concluded that support from top management was urgently needed to facilitate KLRM activities.

IX–2.3. Knowledge loss risk assessment

The KLRA process was based on the IAEA methodology. The factors that were taken into account were:

— Attrition risk factor (close to retirement, score 1–5);
— Position risk factor (position criticality, score 1–5);
— Total risk factor (obtained by multiplying the attrition risk factor by the position risk factor, score 1–25).

During the KLRM implementation, it became evident that KLRM for operative personnel was not so important because of the availability of reserved, fully defined processes and procedures and a highly systematic approach to training implementation. However, KLRM was urgently needed for the technical support departments (I&C, electric and maintenance), which had a significant number of key experts on specific technical systems and a lack of clear procedures.

It was also concluded that, on the basis of practical experience, it is important to distinguish the position risk factor from the unique knowledge factor of an individual.

In some cases, the position is critical for the organization (managers or key specialists). In other cases, key expert knowledge can be critical for the organization.

In cooperation with the IT department, an automated report from the HR database was developed; this gave a full picture of the staff close to retirement in all departments.

KLRM is currently not incorporated as a process in the integrated management system of the South Ukrainian Nuclear Power Plant, although its efficacy has been proved and has received approval from the managers of the tested departments.

The implementation of the KLRM was carried out by the staff of the South Ukrainian Nuclear Power Plant only (members of a project working group), and external organizations were not involved.

IX–2.4. Team for knowledge loss risk management implementation

The team for KLRM implementation included:

— A full scope simulator instructor, as coordinator of the project (training centre), for methodology adaptation, guide development and key expert knowledge mapping;
— A deputy head of the training centre, as a facilitator and contact person with other departments and as a main analyst of the key experts and critical knowledge inside the training centre;
— A psychologist, as a moderator of interviews (training centre);
— An IT specialist, as IT support and for development of an IT tool (IT department);
— An HR specialist on staff planning (HR department);
— An HR specialist on HR (HR department);
— A QA specialist, as an independent process reviewer (QA department);
— Head of the I&C department, as a main analyst of key experts and critical knowledge;
— Head of the electric department, as a main analyst of key experts and critical knowledge.

Local media, the corporate web site and radio station, and the organization’s intranet were used for sharing information regarding KLRM activities.

IX–3. SUPPORTING DOCUMENTS

In relation to the KLRM process, a number of documents were developed by the South Ukrainian Nuclear Power Plant during the project:

- A guide on the steering committee on professional training;
- A procedure on KLRA in nuclear power plant departments;
- A procedure on the interviewing of highly qualified personnel;
- A procedure on the reserve and substitution of highly qualified personnel;
- A procedure on ‘on the job’ training;
- A procedure on staff mentoring.

IX–4. OUTCOMES

The statistics for KLRM implementation in the South Ukraine Nuclear Power Plant, including how many departments and employees were checked, are shown in Table IX–2.

TABLE IX–2. SOUTH UKRAINE NUCLEAR POWER PLANT KNOWLEDGE LOSS RISK MANAGEMENT STATISTICS

Department	Total number of employees	Number of key experts	Actions
Training centre	105	2	Reserve and substitution
Instrumentation and control	625	20	Interview, knowledge mapping, reserve and substitution
Electric	545	8	Interview, knowledge mapping, mentoring
Maintenance	800		Plan

The following lessons were learned:

- Top management support (top to bottom) is crucial.
- Middle management for KLRM is needed.
- Formalization of KLRM as a process is required for its sustainability.

Annex X

CASE STUDY: KNOWLEDGE LOSS RISK MANAGEMENT AT KOZLODUY NUCLEAR POWER PLANT, BULGARIA

X–1. INTRODUCTION

Kozloduy Nuclear Power Plant is the only nuclear electricity generating station in Bulgaria. The site includes six reactors: four are being decommissioned and two are in operation. Currently, Kozloduy Nuclear Power Plant is a subsidiary of Bulgarian Energy Holding EAD. The technical data for this plant are given in Table X–1.

TABLE X–1. KOZLODUY NUCLEAR POWER PLANT TECHNICAL DATA

Installed capacity	Commissioned		Reactor type
	Unit 5	Unit 6	
2000 MW	1988	1993	WWER 1000/B320

X–1.1. Reasons to start knowledge loss risk management

Bulgaria has operated Kozloduy Nuclear Power Plant for more than 40 years. During these years, much knowledge and experience has been accumulated in the minds of the employees. Based on the best practices of knowledge management (KM), Kozloduy Nuclear Power Plant implemented a special project for evaluation of the risk of knowledge loss and for capturing of critical tacit knowledge. The project was carried out during the years 2009–2011.

The reasons for starting the knowledge loss risk management (KLRM) included the following:

- Many experts possessing critical knowledge have already retired or plan to retire in the next few years.
- These experts will be replaced by young employees who do not possess such experience and corresponding critical knowledge.
- It is a very important goal for any nuclear power plant to guarantee continuity.
- There will be challenges related to new serious projects, such as upgrading of unit power or extension of unit lifetime.
- Activities for decommissioning units 1–4.

The integrated management system and KLRM as its substantial part are powerful tools for achieving this goal. Therefore, the main motivation for the implementation of KLRM at Kozloduy Nuclear Power Plant was the concern that valuable skills, expertise and corporate knowledge could be lost owing to retirement and other forms of attrition associated with an ageing workforce.

X–1.2. Main objectives of knowledge loss risk management implementation

The following were the main objectives of KLRM implementation:

- To identify, capture and preserve unique and critical knowledge, accumulated over the years;
- To transfer identified tacit knowledge into an explicit form;
- To describe and implement a process for application of the plant KM system;
- To establish a corporate culture of knowledge sharing.

Professional experience, especially undocumented knowledge, obtained over more than 40 years of operating four water cooled water moderated power reactor (WWER) 440 units and two WWER 1000 units was intended to be converted into documented knowledge and used in the decommissioning of units 1–4, and in the extension of the operational lives of units 5 and 6.

The KM team focused mainly on experts possessing unique knowledge who were ageing or leaving the organization for whatever reasons. The average age of an employee at Kozloduy Nuclear Power Plant at the time of the implementation was 45 years.

X–2. PROCESS DESCRIPTION

X–2.1. Integrated management system of Kozloduy Nuclear Power Plant

The Kozloduy Nuclear Power Plant integrated management system included: three management, four core and twenty-one supporting processes. One of the supporting processes was training and KM, which consists of a package of activities for corporate KM and for assuring, monitoring and maintaining the competence of personnel in compliance with applicable standards (see Fig. X–1).

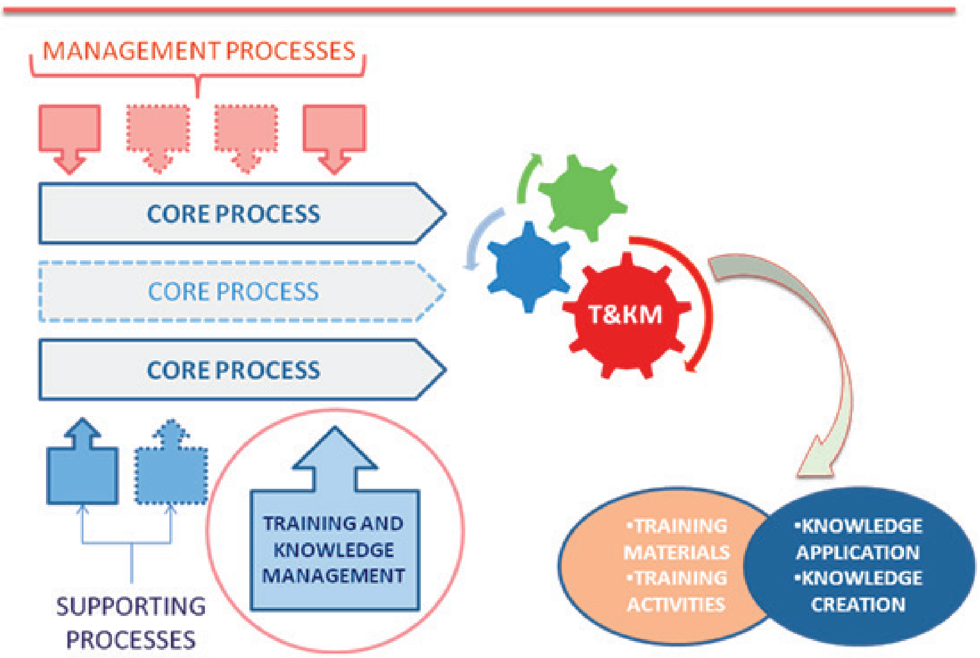


FIG. X–1. Description of the training and KM processes at Kozloduy Nuclear Power Plant. T&KM — training and knowledge management.

X–2.2. Process fundamentals

Kozloduy Nuclear Power Plant developed a separate strategy for KM and for implementation of knowledge loss risk assessment in particular. The strategy was based on IAEA methods, but the applied methodology was significantly modified to reflect the plant specifics (see Fig. X–2).

A four step process was adopted with the final goal being to guarantee the availability and access to existing corporate tacit knowledge, in order to:

- Determine whether loss of undocumented knowledge is a problem, and identify workers for whom knowledge ought to be captured;
- Specify corrective measures and develop a plan to elicit, store, retrieve and present knowledge;

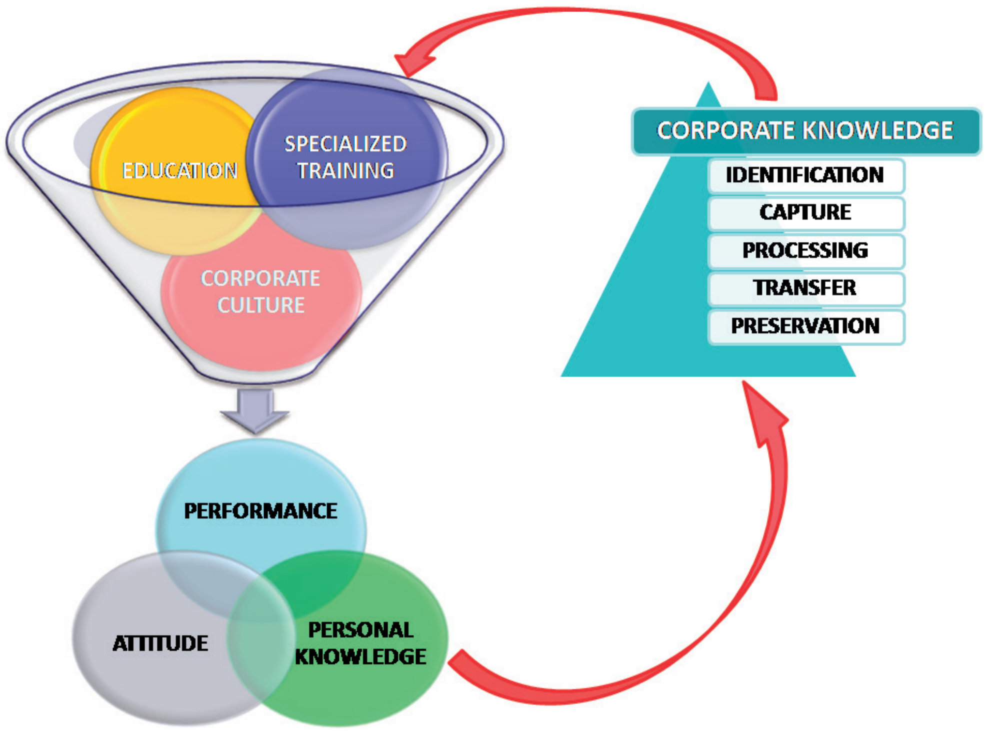


FIG. X–2. Corporate KM cycle at Kozloduy Nuclear Power Plant.

— Elicit and categorize expert knowledge and create knowledge modules;
— Perform corrective measures and deliver current knowledge modules to potential users.

X–2.3. Process model

The owner of the supporting process training and KM was the training centre, which was responsible for the management of the process. The human resources, quality assurance and information technology departments provided technical support, and all other departments were involved in the first and last steps.

The KLRM system was strongly supported by the senior management of Kozloduy Nuclear Power Plant (see Fig. X–3).

X–3. KNOWLEDGE LOSS RISK ASSESSMENT

X–3.1. Methodology

The design of KLRM was supported by the IAEA. The assessment methodology was based on the following three types of input data:

— Resignation factor: A variable based on planned resignation and unplanned resignation;
— Position factor: A variable based on professional experience or qualification and educational background;
— Personal factor: A variable based on the available personal capabilities, merits and specific expertise, knowledge and skills including soft skills.

The range of values of these variables was between 0 and 10. After mathematical processing of input data according to a special algorithm, the final result was a metric expression of knowledge loss risk: the total risk factor (see Fig. X–4).

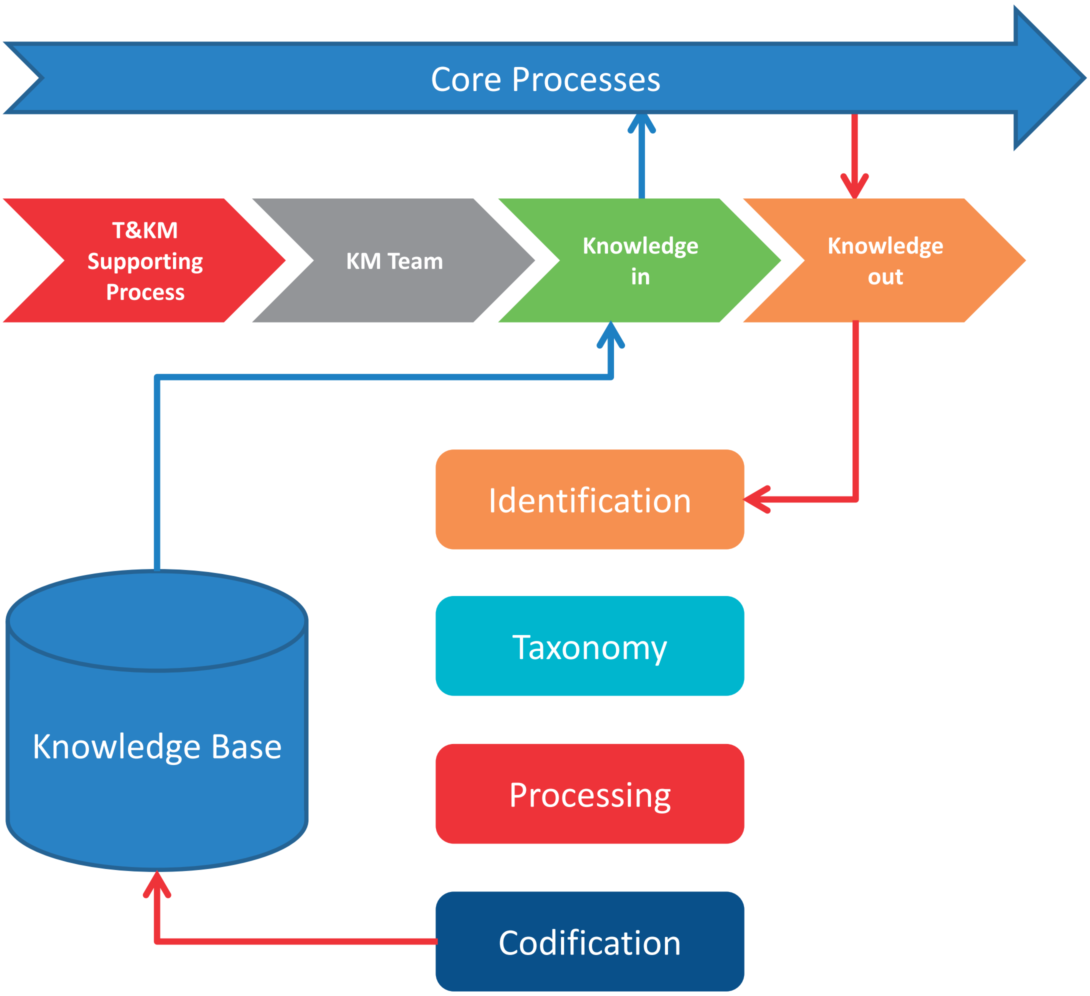


FIG. X–3. KM as a supporting process for nuclear power plant core processes at Kozloduy Nuclear Power Plant. KM — knowledge management; T&KM — training and knowledge management.

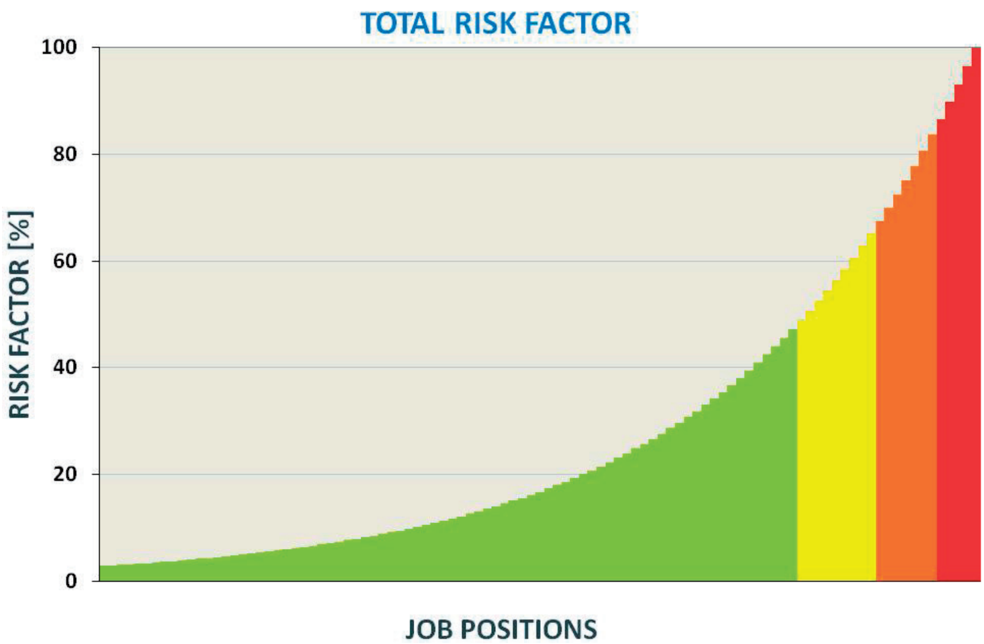


FIG. X–4. Total risk factor at Kozloduy Nuclear Power Plant.

FIG. X–5. Range of total risk factor at Kozloduy Nuclear Power Plant. OJT — on the job training.

The range of the total risk factor was normalized between 1% (minimal risk) and 100% (maximal risk). This range was divided into four zones, marked with different colours (see Fig. X–5):

— Red zone: urgent actions should be undertaken.
— Orange zone: short term actions should be specified and implemented.
— Yellow zone: medium term corrective measures should be planned and performed.
— Green zone: no need for special actions and routine procedures should be followed.

X–3.2. Knowledge loss risk management tools

The KLRM methodology was implemented through a specially developed software tool called Tacit Knowledge Monitoring (TKM). TKM is a web based application that provides user friendly data input, algorithmic calculation of the total risk factor, registration of corrective measures and a number of personal and group inquiries including concept maps. See Figs X–6 and X–7 for examples taken from TKM.

The plant local area network, intranet portal, corporative and local media, and subject related public events were used as dissemination tools for the KLRM.

X–4. SUPPORTING DOCUMENTS

The following guides, procedures and instructions were developed as supporting documentation:

— A strategy for KM in Kozloduy Nuclear Power Plant;
— A KM system;

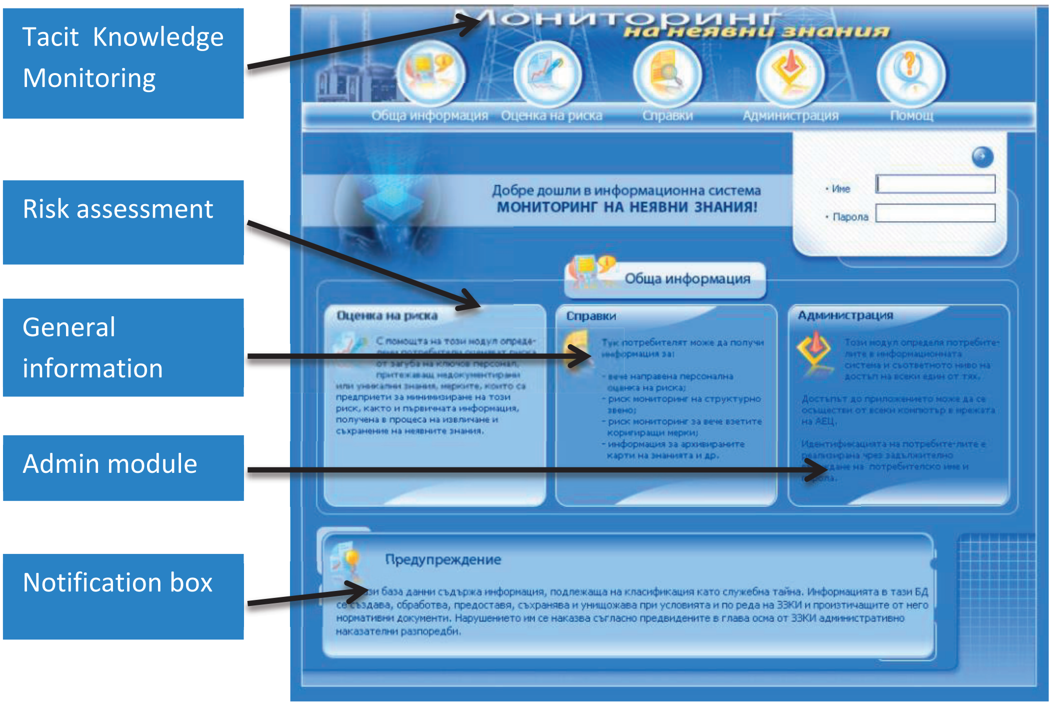


FIG. X–6. Snapshot of the TKM home page.

— Guidance for working with the database Monitoring of Tacit Knowledge;
— Methods for implicit knowledge capturing.

X–5. OUTCOMES

X–5.1. General statistics

In 2016, two years after the KLRM implementation, 225 employees from 16 departments were checked and corrective measures were assigned for 58 of them.

According to the above mentioned classification, the distribution of identified people was as follows:

— Red zone (urgent actions): 5 persons:
- Immediate nomination of successor: 4;
- Overlapping of job position: 1;
- Full knowledge map: 1 (concept map);

— Orange zone (short term measures): 9 persons:
- Establishment of staffing plan;
- Intensive on the job training, coaching of and shadowing by successors;
- Partial knowledge map (concept map);

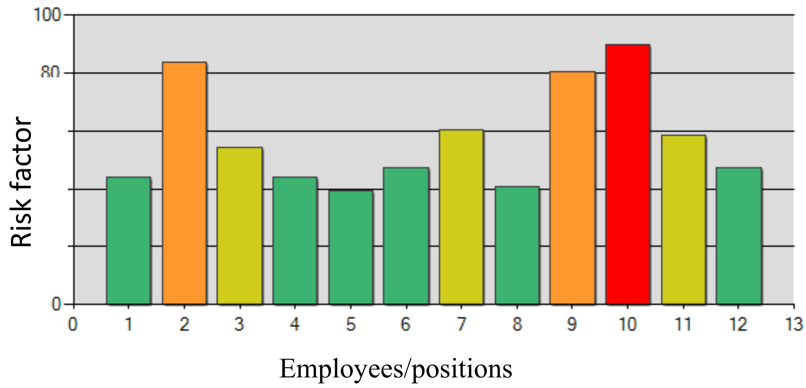
— Yellow zone (medium term measures): 44 persons:
- Overview of staffing plan and possible outside recruitment;
- Implementation of target orientated training programmes;
- Seeking potential specific tacit knowledge.

REFERENCE TO THE RISK MONITORING STRUCTURAL UNIT

Structural unit — Safety and Control
Date — 06.03.2013

No.	Name	Position	Risk factor
1	T******* I.	Head of Chemical Engineering Department	43.92
2	B******* K.	Chief expert on Nuclear Safety of units 5 and 6	83.62
3	T******* M.	Chief expert on Analysis and Assessment of Safety	54.44
4	B******* T.	Chief specialist on the Physical Protection	43.92
5	M******* V.	Chief Inspector Defence Mobilization	39.45
6	G******* R.	Defectoscopist	47.18
7	G******* Y.	Head of Industrial Safety Department	60.60
8	T******* A.	Chief Inspector on Emergency Preparedness	40.89
9	M******* M.	Head of Nuclear Safety and Radiation Protection Department	80.68
10	P******* G.	Expert metrologist	89.82
11	P******* S.	Chief expert on Metrological Insurance	58.47
12	T******* Tc.	Chief Inspector on Fire Safety	47.18

(a)



(b)

FIG. X–7. Snapshot of TKM — group inquiry. (a)Table view; (b) Histogram view.

X–5.2. Positions found to be most at risk for knowledge loss

The positions found to be most at risk for knowledge loss were in the following areas:

- — Mid level managers in general;
- — Maintenance of electrical equipment;
- — Maintenance of mechanical equipment;
- — Radiation protection;
- — Non-destructive testing.

X–5.3. Crucial aspects

The preservation and transfer of knowledge between generations had taken place in a spontaneous process over the years. The purpose of KM was to clarify the scope of such process, to define and systematize activities and to increase effectiveness. From this point of view, the crucial aspects of KM were the following:

— Establishment of a specific ‘open knowledge’ culture that postulated tacit knowledge as a common property of the people;
— Identification of valuable tacit knowledge and recognition of techniques for elicitation;
— Methods and tools for conversion of raw material to practical applicable knowledge modules.

X–6. MOTIVATION

In principle, Kozloduy Nuclear Power Plant consider that their staff members have a culture of sharing knowledge with younger, less experienced colleagues. They willingly become mentors and instructors, trainers and coaches. Standard approaches for motivating staff to share knowledge are also applied. It is also worth highlighting that, at the time of writing, Kozloduy Nuclear Power Plant do not consider it necessary to look for extra motivational tools.

ABBREVIATIONS

HR	human resources
HRD	human resources development
IT	information technology
I&C	instrumentation and control
KLRA	knowledge loss risk assessment
KLRM	knowledge loss risk management
KM	knowledge management
KR	knowledge retention
NKM	nuclear knowledge management
QA	quality assurance
R&D	research and development
TKM	tacit knowledge monitoring
WFP	workforce planning

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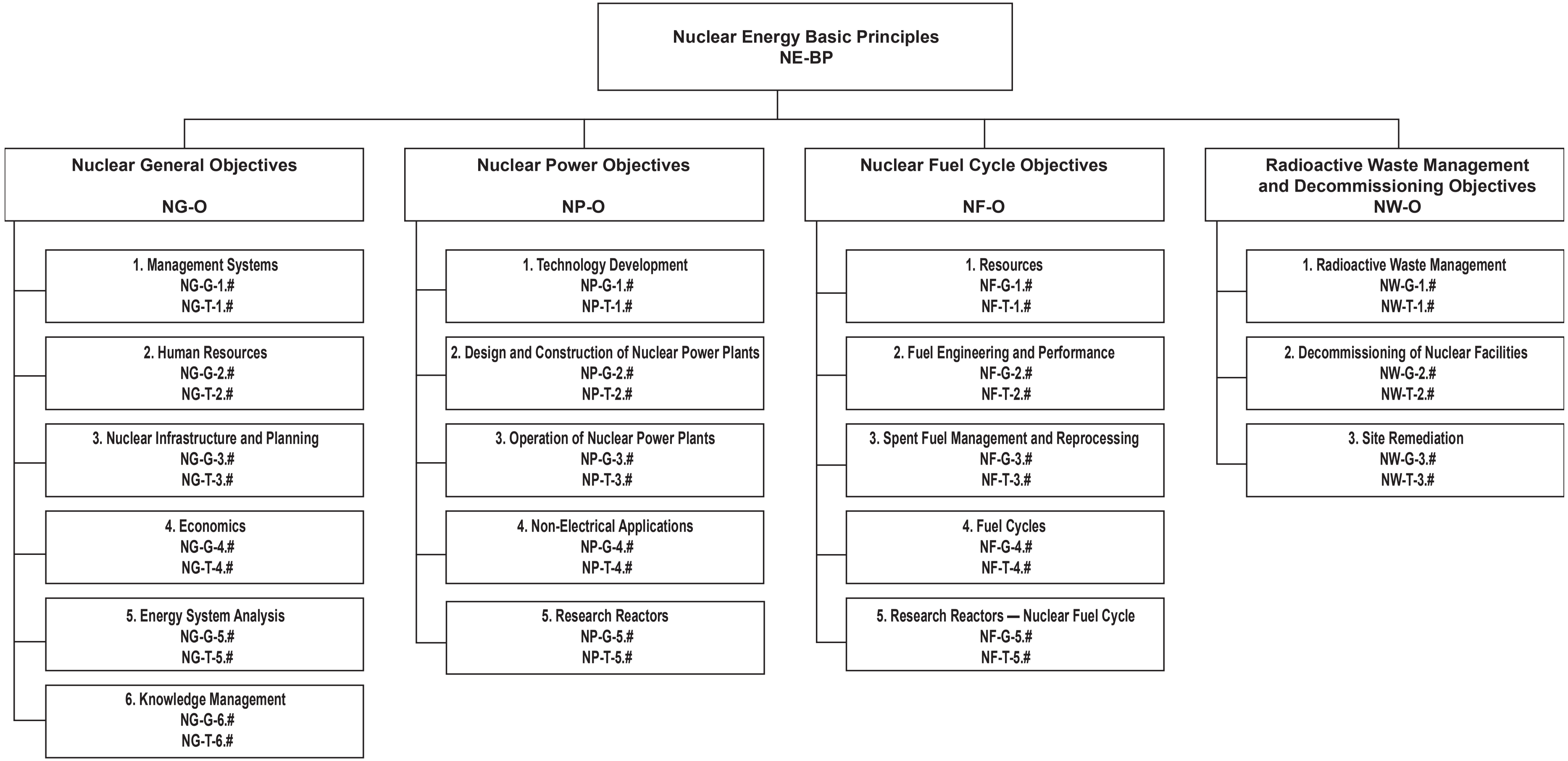

Key

BP: Basic Principles
O: Objectives
G: Guides
T: Technical Reports
Nos 1-6: Topic designations
#: Guide or Report number (1, 2, 3, 4, etc.)

Examples

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NF-T-3.6: Nuclear Fuel (**NF**), Report (**T**), Spent Fuel Management and Reprocessing (topic **3**), **#6**
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