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Lessons Learned Programmes for Effective Knowledge Management in Nuclear Organizations

LESSONS LEARNED PROGRAMMES FOR EFFECTIVE KNOWLEDGE MANAGEMENT IN NUCLEAR ORGANIZATIONS

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LESSONS LEARNED PROGRAMMES FOR EFFECTIVE KNOWLEDGE MANAGEMENT IN NUCLEAR ORGANIZATIONS

INTERNATIONAL ATOMIC ENERGY AGENCY
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For further information on this publication, please contact:

Nuclear Knowledge Management Section
International Atomic Energy Agency
Vienna International Centre
PO Box 100
1400 Vienna, Austria
Email: Official.Mail@iaea.org

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FOREWORD

Organizations learn lessons in a continuous process as they gain experience. The lessons learned through experience provide new or updated knowledge to the organization. As nuclear organizations strive to create a strategic knowledge management programme, they need to carefully evaluate existing approaches and practices relating to lessons learned and identify methods to effectively capture and utilize experience based organizational knowledge.

Before formal knowledge management programmes were introduced, several knowledge and experience sharing practices and processes had been common in nuclear organizations. At the same time, these practices and processes were not always systematic and comprehensive. It was recognized that a successful knowledge management programme builds on those beneficial practices and processes with the goal of developing and sustaining critical organizational knowledge.

The practice of sharing important lessons learned, both within the organization and with external organizations, became an integral part of the business for nuclear power plant operators after the Three Mile Island accident and Chernobyl accident. The analysis of the Three Mile Island accident revealed that the accident could have been prevented had the Three Mile Island personnel been aware of similar technical issues that were observed in another nuclear power plant in the United States of America. Nuclear power plants around the world recognized the importance of sharing lessons learned for the benefit of safety and reliability of the entire nuclear industry.

While most nuclear power plants use structured processes to learn from their own internal experiences and from the experiences of external organizations both within and outside their country, this may not be the case with many other nuclear organizations. The approaches, the level of use, the impact and the benefits derived in organizational learning vary depending on the intensity of efforts made by an organization.

This publication provides practical guidance to nuclear organizations interested in developing a systematic lessons learned programme that is useful to their strategic knowledge management initiatives. The publication provides five case studies from nuclear operating organizations in France, India, Japan, the Republic of Korea and the Russian Federation. In addition, a case study from a nuclear engineering organization in France explains the approach used to utilize and disseminate lessons learned from new nuclear projects, and another case study from an oil and gas industry in Norway explains its experience of using artificial intelligence assisted lessons learned that offer innovative solutions and enable large volumes of information to be organized for efficient identification and retrieval. These case studies serve as useful examples of good practices being followed in the nuclear industry.

The IAEA is grateful to the experts who contributed to the drafting and review of this publication. The IAEA officer responsible for this publication was A. Ganesan of the Division of Planning, Information and Knowledge Management.

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CONTENTS

1. INTRODUCTION

1.1. BACKGROUND

Throughout the nuclear industry, competence is defined as a combination of knowledge, skills and attitudes. The knowledge component can be categorized into explicit knowledge, implicit knowledge or tacit knowledge:

- Explicit knowledge can be readily articulated, codified, stored and accessed;
- Implicit knowledge is the application of this explicit knowledge, that is gained either through incidental activities, or without awareness that learning is occurring;
- Tacit knowledge is the knowledge an individual possesses that is gathered from personal experience and context and is most difficult to express or define.

IAEA Nuclear Energy Series No. NG-G-6.1, Guide to Knowledge Management Strategies and Approaches in Nuclear Energy Organizations and Facilities [1], in section 2.3 explains the above types of knowledge in detail. In some cases, this knowledge may be useful in supporting day to day activities. The more significant knowledge may be essential to maintain the ongoing operational and safety practices to meet the requirements. For the most significant knowledge, where failure to maintain and implement it correctly would result in a direct and immediate challenge to safety or operational and commercial viability, would be regarded as critical knowledge. Figure 1 below summarizes the typical knowledge categories.

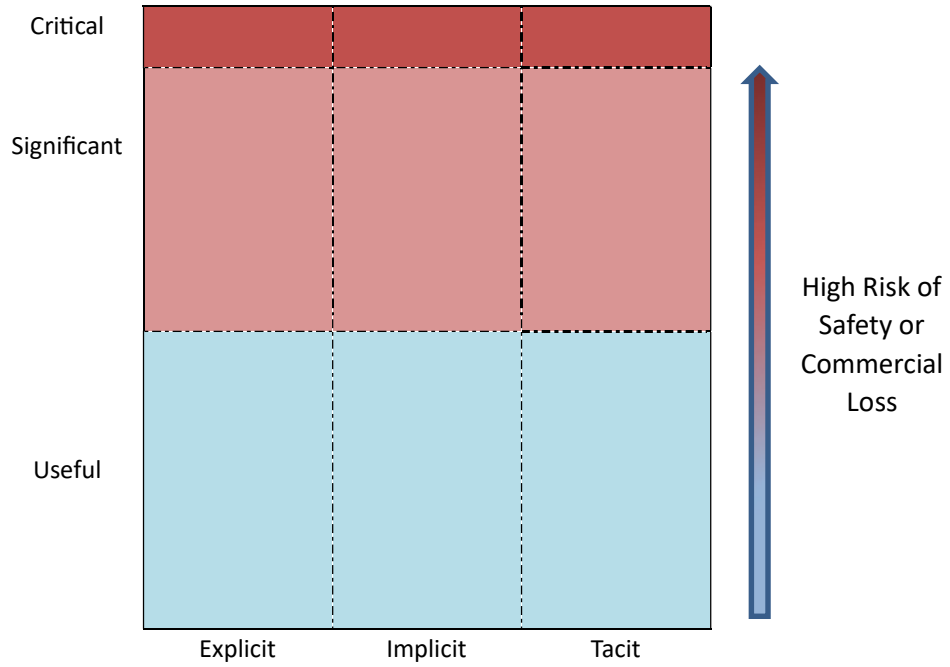

FIG. 1. Knowledge categories [2].

An effective and useful knowledge management programme focus on transfer and capture of significant and critical organizational knowledge. IAEA-TECDOC-1999, Mentoring and Coaching for Knowledge Management in Nuclear Organizations [2], provides guidance to use two of the most important techniques for knowledge transfer. Another important aspect of an organizational knowledge management programme is to ensure systematic transfer and capture

of knowledge and experiences from individual(s) and from organizational learning that comes from the experience of events, incidents, good practices etc.

A nuclear organization gains new knowledge and experiences from:

- Experiences of its personnel, both individuals and teams;
- Lessons learned through the conduct of business activities;
- Lessons learned from events or incidents, both consequential and non-consequential;
- Industry experience and improvement opportunities derived from external sources.

Both negative outcomes and experiences as well as positive success stories and achievements offer useful learning opportunities. An improved work procedure or process in one department or organization may be useful in another department or organization and organizations use benchmarking visits to learn and adopt these practices in specific areas.

This publication provides guidance to nuclear facilities and organizations interested in developing a systematically derived lessons learned programme that is useful to their strategic knowledge management initiative. This publication provides several case studies as examples from different types of nuclear organizations and it supports the emulation of good practices and successful approaches.

This publication introduces the readers to what constitutes an effective lessons learned programme by helping answer the following key questions:

- Are the existing organizational procedures/processes adequate to effectively capture the lessons learned and does it support transfer and creation of organizational knowledge?
- What are the knowledge management challenges that an organization faces and is a new or an improved lessons learned programme a solution?
- What are the opportunities available to transform individual and team experiences and knowledge into organizational assets?
- How to develop an effective lessons learned programme that is useful to develop and sustain organizational knowledge?
- What are the approaches by different types of nuclear organizations to capture, analyze and use experiences and lessons learned?

Some nuclear facilities or organizations may have a formal lessons learned programme but it may not be effectively yielding knowledge management benefits. Some nuclear facilities and organizations may not have a formal lessons learned programme at all. This publication helps to close this gap by providing generic guidance to set up an effective lessons learned programme in nuclear facilities and organizations with the objective of supporting strategic knowledge management initiatives.

1.2. OBJECTIVE

The objective of this publication is to:

- Provide insights and guidance for developing a beneficial lessons learned programme that supports strategic knowledge management goals;
- Identify and analyze various beneficial practices, processes and approaches used by nuclear facilities and organizations to efficiently convert individual and organizational experiences and lessons learned into organizational knowledge;
- Provide case studies of successful approaches that can serve as examples for emulation.

1.3. SCOPE

This publication is intended for organizations that either directly or indirectly support the use of nuclear energy and other nuclear applications and activities, including:

- All facilities involved in the nuclear fuel cycle for a nuclear power programme, including both the front end (e.g. mining, extraction, enrichment and fuel fabrication, nuclear power plants (NPPs)) and the back end (e.g. waste management, storage and disposal facilities);
- Organizations transporting radioactive material;
- Organizations involved in radiation protection activities;
- Organizations concerned with the regulation of such facilities and activities;
- Research and development organizations;
- Suppliers or contractors for nuclear facilities;
- Technical support organizations;
- Government ministries;
- Education and training organizations;
- Governments and organizations considering the introduction of nuclear programmes.

For the purpose of this publication, the term ‘nuclear facilities’ includes facilities concerned with the front end of the nuclear fuel cycle, such as those involved in mining, extraction, enrichment and fabrication of fuel, as well as NPPs, and those concerned with the back end, including waste management, storage and disposal. The term ‘nuclear organization’ includes NPPs, research and development organizations, educational institutions, regulatory authorities, design and technical support organizations, waste processing and disposal organizations, and decommissioning services organizations.

This publication will be of use to those involved in the development of a lessons learned programme that is useful to their knowledge management initiatives, including:

- Head of nuclear organizations;
- Department managers and supervisors having responsibility for implementing knowledge management activities or lessons learned and corrective action programmes;
- Staff involved in knowledge management activities or lessons learned and corrective action programmes.

1.4. STRUCTURE

This publication consists of six sections.

Section 2 explains the relevance and importance of lessons learned for a knowledge management programme. It also explains the internal and external sources from where lessons learned are derived.

Section 3 explains the three-stage process involved in a lessons learned programme. It provides guidance by using six steps to systematically develop a lessons learned programme that supports organizational knowledge management.

Section 4 discusses some of the common challenges involved and provides guidance to overcome them.

Section 5 considers the specifics of implementation of lessons learned programmes in diverse types of nuclear organizations.

Section 6 summarizes the key aspects of the publication.

In the Appendix, Table 2 provides typical questions that can be used by organizations to evaluate their current lessons learned programme and to decide on whether to improve it or develop a new one.

In the Annexes, seven case studies demonstrating practical applications of lessons learned programmes are included to illustrate the different approaches and their merits. Five of the case studies are from nuclear power operating organizations in France, India, Japan, Republic of Korea and Russian Federation. One case study from a nuclear engineering organization in France explains the approach used to utilize and disseminate lessons learned from new nuclear projects and another case study from an oil and gas industry in Norway explains their use of Artificial Intelligence (AI) assisted lessons learned that offer innovative solutions and enable organizing large volumes of information for efficient identification and retrieval. These case studies serve as useful examples to emulate some of the good practices being followed in the industry.

2. EXPERIENCES AND LESSONS LEARNED FOR ORGANIZATIONAL KNOWLEDGE MANAGEMENT

The IAEA Safety Standards Series No. GSR Part 2, Leadership and Management for Safety [3], under Management of Resources, Requirement 9 (provision of resources) in para. 4.27 states that "The knowledge and the information of the organization shall be managed as a resource." The lessons learned programme in nuclear organizations is one of the key programmes that helps integrate experience based knowledge gained from relevant stakeholders, both within and external to the organization, into business activities, processes and management systems.

As a nuclear organization commences its operations or functions, it and its personnel gain new experiences, offering an opportunity to create new or improve existing organizational knowledge. Therefore, there is a direct link between the organizational learning from experiences and knowledge management. Figure 2 explains the cycle of knowledge transfer and knowledge management taking place in organizations using the [1]SECI model. The cycle starts with tacit-to-tacit knowledge transfer across people through social interaction in the first quadrant. In this quadrant, techniques such as coaching, mentoring, shadowing and communities of practice (CoP) help transferring knowledge from more experienced to less experienced staff.

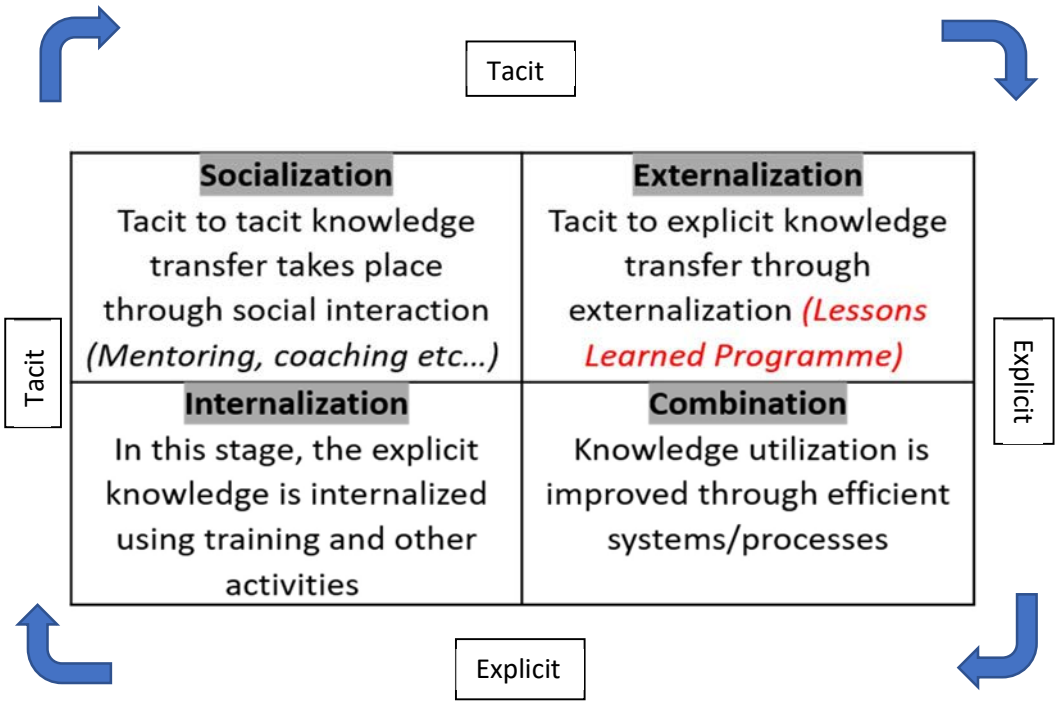

FIG. 2. Organizational knowledge transfer using SECI model.

Followed by this, in the second quadrant, efforts are made to convert the tacit knowledge into explicit, documented knowledge. In the second quadrant, the lessons learned programme is an important technique to help an organization to document the knowledge gained from

[1] SECI Model: Created by the Japanese researchers Takekuchi and Nanaoka to explain the process of knowledge transfer taking place in an organization using four quadrants with each representing Socialization, Externalization, Combination and Internalization (SECI) respectively.

experiences through externalization. This publication provides guidance to effectively use this technique.

2.1. CONTRIBUTION OF LESSONS LEARNED PROGRAMME TO KNOWLEDGE MANAGEMENT

Learning from experiences and aiming for continuous improvement has been a practice in all successful organizations and the concept was well utilized by all industries, including nuclear, to improve performance. From a nuclear safety standpoint, IAEA Safety Standards Series No. SSG-50, Operating Experience Feedback for Nuclear Installations [4], provides recommendations for establishing, implementing, assessing and continuously improving an operating experience programme for nuclear installations to prevent or minimize the risk of future events by learning from events that have already occurred at the installation or elsewhere.

With the introduction of knowledge management, it has been recognized that the outcomes of lessons learned programmes are critical resources for organizational knowledge management as they reflect individual experiences and collective knowledge. The main goal of a lessons learned programme is to achieve enhanced organizational performance by improving equipment, human and business performance. It has to be recognized that improved organizational performance is often achieved through improved training, procedures, policies and documented knowledge derived from a strategically developed lessons learned programme as shown in Fig. 3. It is also important to recognize that improved training, procedures, policies and documented knowledge complement improved equipment, human and organizations performance and vice versa. From a knowledge management perspective, the documented knowledge and improved training and human resource development activities are valuable outputs of a strategically developed lessons learned programme.

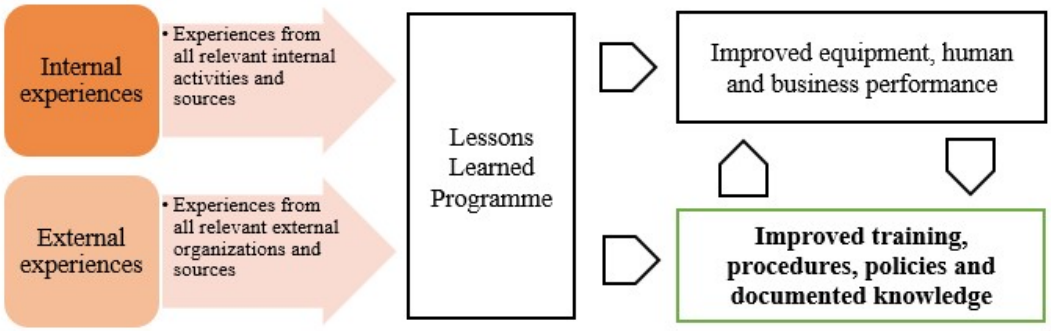

FIG. 3. Contribution of lessons learned programme for knowledge management.

In nuclear facilities such as NPPs, successful lessons learned programmes have significantly contributed to improved equipment and human performance. The equipment reliability of currently operating NPPs is significantly higher than that of their predecessors, thanks to the contribution of industry operating experience. The lessons learned programmes of NPPs have, in the last four to five decades, contributed to substantial improvements of construction material and changes to both design and configuration of structures, systems and components (SSCs). For example, the experience gained about operating NPPs steam generators from the 1970s to the 1990s resulted in significant improvement to the construction material of its tubes, the chemistry control and the overall steam generator life management programme. In other words, the knowledge gained by years of industry experience in steam generator performance and issues coupled with advancements in science and technology has contributed to the

development of much more reliable and safe steam generators for NPPs worldwide. Almost all major SSCs of NPPs have achieved improved design, operational and safety performance by utilizing knowledge gained from industry experience. The contribution of lessons learned programmes of the operating fleet of NPPs to the overall industry performance is significant and resulted in the substantial increase in safety and commercial performance over the years.

Human performance is critical to nuclear business like to any high-risk industry. Since the days of Three Mile Island and Chernobyl accidents, for the past four to five decades, the analysis of events that happened in NPPs, both consequential and non-consequential, has revealed several improvement opportunities to reduce human error. The use of error prevention tools such as self-check, peer check, independent verification, concurrent verification and procedure use became prevalent in control rooms and other critical activities of NPPs.

2.2. SOURCES TO OBTAIN LESSONS LEARNED

Figure 4 explains the sources of knowledge that can be derived from both an organization's internal and external experiences. The internal sources of experiences usually fall under one of the following three domains:

— Human resources;
— Core and support business processes;
— Science and technology including experiences from SSCs.

The lessons learned from each of these domains not only provide useful knowledge to activities in their own domain, but also to other domains. For example, a team of personnel that handled a project of replacing a reactor vessel head of a pressurized water reactor (PWR) type NPP may, using their collective experiences, suggest specific design improvements to one or more components used in the reactor vessel head or improvements in relevant work management processes. In another example, a lesson learned from a critical nuclear component failure in an NPP may call for improvement in human performance and/or business processes. These are explained in detail in subsequent sections.

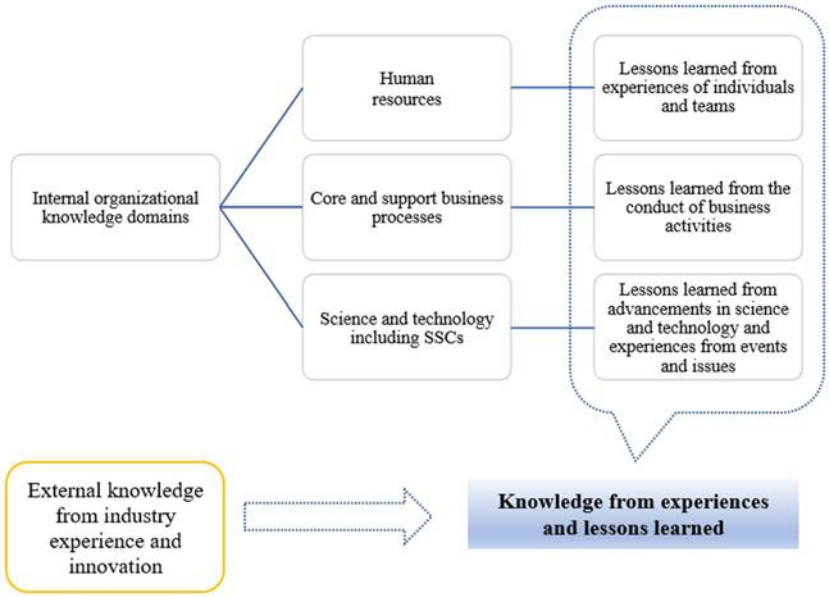

FIG. 4. Sources of knowledge for a lessons learned programme.

In addition to the knowledge and experience that comes from within the organization, there is important experience and knowledge that comes from external industries and organizations. The volume of information, particularly critical lessons learned, coming from external sources is significantly larger than internal information. Therefore, a strategically developed lessons learned programme needs to carefully consider the sources of external information and the methodology to use them effectively. This aspect also highlights the importance of sharing internal experiences with external counterparts as this benefits the industry as a whole.

2.2.1. From experiences of individuals and teams

Employees, individually and as teams, gain significant experience as they work for a nuclear facility or an organization. The real success of an organization's knowledge management programme depends largely on the effectiveness of transferring this experience-based knowledge to the next generation. Many organizations only realize the need to transfer experience-based knowledge from employees when they are about to retire or before leaving the organization. In this situation, the limited time available makes it less effective to capture experience-based knowledge from employees. The process of knowledge transfer and knowledge capture ought to be continuous and is to be considered an integral part of the organization's training and human resource development strategy.

There are two ways to utilize the knowledge of individuals or teams for organizational benefits. One way is to transfer knowledge from people to people focusing on difficult to transfer tacit knowledge. The other way is to capture the knowledge of individuals and teams in the form of documents and procedures, etc. This is explained in Fig. 5. Both complement each other to support, sustain and manage organizational knowledge. A successful lessons learned programme is a key contributor to the latter.

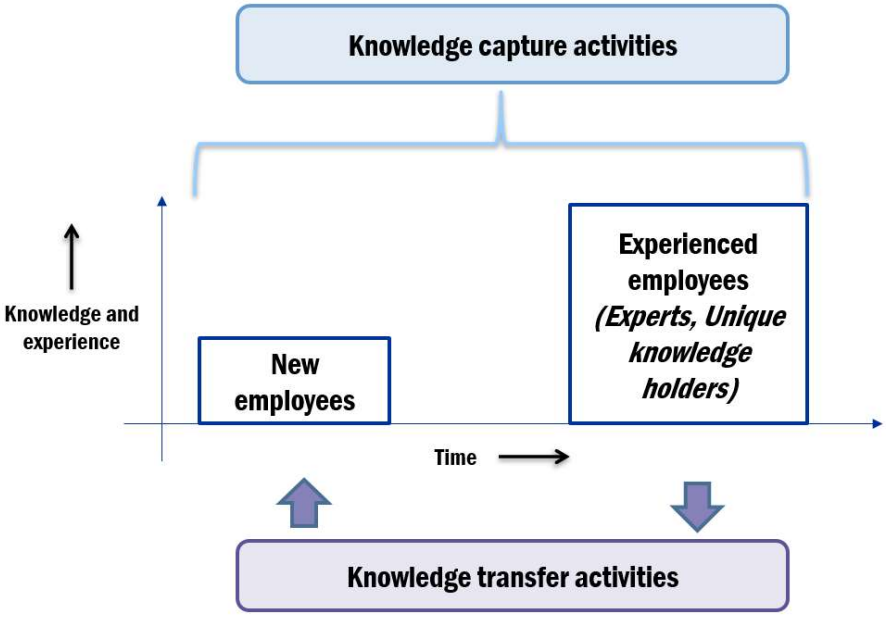

FIG. 5. Knowledge management strategies to utilize individual or team knowledge and experiences.

Transfer of knowledge from more experienced to less experienced personnel ought to happen on a continuous basis to ensure seamless knowledge flow across generations of employees in nuclear facilities and organizations such as NPPs, whose operating life cycle often exceeds 60 to 80 years. The organizational knowledge management strategy [1] needs to consider suitable

knowledge transfer techniques for various levels of employees in various departments and sections based on organizational knowledge transfer objectives.

Some of the important knowledge transfer techniques used are:

— Mentoring;
— Coaching;
— Shadowing;
— Communities of Practice.

The knowledge transfer initiatives focus on the transfer of critical organizational knowledge and try to tackle the difficulty to codify tacit knowledge.

The knowledge capture activities, on the other hand, aim to document the knowledge gained by individuals and teams by virtue of their experience and use them for improving the organizational knowledge base to achieve performance improvement. There are several techniques to capture knowledge possessed by individuals and teams including:

— Post job review or after action review;
— Video recording;
— Elicitation interviews;
— Storytelling;
— Experience reports or job guides.

The organizational knowledge management strategy considers one or more of the above techniques to systematically capture the lessons learned from simple to complex tasks or activities and from personnel who possess critical knowledge.

From a lessons learned programme point of view, the post job review or after action review plays a significant role to proactively capture the lessons learned. During a post job review or after action review, the personnel involved in a work or activity come together and discuss the lessons learned with the aim of:

— Understanding what went well and how it can be sustained or improved;
— Identifying the issues faced and their causes and contributors with the aim of making improvements in future.

The output of those reviews is documented information consisting of a list of issues, causes and potential solutions to overcome them. In many situations, the team that executes the task would be in an advantageous position to identify the causes and solutions. For example, in maintenance activities, the maintenance team is able to provide practical solutions to problems including changes to procedures. In other situations, e.g., if the solution involves engineering changes or design changes, the team may need support from other departments or organizations to identify solutions.

Sometimes, a single task is performed for several days, weeks or months in a project mode. In NPPs, for example, some long-duration tasks, such as major equipment maintenance or replacement, are performed for several days or weeks. These tasks may have several sub tasks involving multi-disciplinary personnel. If an attempt is made to capture the lessons learned for such activities after completion, personnel involved may have forgotten important experiences. Therefore, it is important to schedule several post job review sessions, preferably immediately after completion of each sub task.

Techniques such as elicitation interviews, storytelling and development of experience reports or job guides are used to extract knowledge from personnel identified to possess critical organizational knowledge, usually based on a knowledge loss risk assessment process [5]. The focus of these techniques is to extract unique knowledge from experienced personnel.

For achieving success, it is important to create processes that provide easy access and clear directions to personnel on how to share their experiences besides encouraging and motivating them. Some NPP organizations have instituted processes to capture the experiences of individuals through online portals [6]. The online portal provides a platform for employees to enter their feedback during or after the completion of a task.

The most significant benefit to organizations and institutes from systematically capturing experience-based knowledge from experts holding critical knowledge is the ability to disseminate it within the organization through improved procedures, processes and training programmes.

2.2.2. From business activities

Nuclear facilities and organizations have formal business processes to execute various activities, which often cut across sections and departments within an organization. For example, NPPs have a process to plan, prepare, execute, and control all activities performed in the station, which is called work management process or system. NPPs use customized software applications to implement the work management process, which deals with all types of planned and unplanned work activities. It helps to integrate work activities of various departments and optimizes the time spent on each task. It also helps to monitor the preparation, resources needed, progress of work and the completion. This work management process is designed to:

— Ensure the preparation, including the human and material resources, needed for successful completion of work activities are in place;
— Ensure the work activities are scheduled to optimize time and utilize resources efficiently;
— Monitor work activities from start to end and provide information for performance analysis.

Analysis of information available from work management processes can provide useful insights about performance shortfalls including weaknesses in personnel performance, work procedures and also in the work management process. Some examples of useful information that can be gathered from a work management process are:

— Planned duration versus actual duration of work activities, which helps to identify the causes for delays and scheduling conflicts, if any;
— Planned man-hours versus actual man-hours spent on work activities, which helps to identify personnel performance, work procedure and logistical issues, if any;
— Spare parts used and cost of work activities;
— Chronological record of work activities on SSCs, which helps to focus on those SSCs involved in the maintenance and repair for maximum number of times and to identify the causes;
— Number of work activities for which actual radiation dose exposure exceeds the planned radiation dose exposure. This helps to identify causes and contributors for shortfalls in radiation dose planning and management.

Careful consideration of information needed for analysis of performance shortfalls, and ensuring the process is custom developed with the required elements to capture that information, is important. It is also important to ensure that the needed information is provided in a format that is easy to capture and use to identify performance shortfalls. Usually, software applications are designed to provide both standard and custom reports. While standard reports are useful to analyze anticipated performance issues, the custom reports can be tailored to identify specific unanticipated issues. Organizations analyze business process information continuously as well as at fixed time intervals. They provide useful insights for improvement to organizational issues including human and equipment performance.

2.2.3. From advancements in science and technology and experiences from events and issues

The advances in science and technology through research and development offer opportunities to improve performance and economics of existing facilities and their SSCs. For example, many NPPs around the world have introduced changes to secondary system components such as turbines, moisture separators and reheaters to achieve efficiency improvements and thereby enhancing the power output of the NPPs without increasing the reactor power. This offered significant financial benefits.

Lessons learned from experiences such as events, incidents, accidents, internal and external reviews, performance assessments, audits, etc. are valuable for preventing the recurrence of similar events and to ensure continuous learning environment across the organization.

As a nuclear facility starts operating, it experiences events, both consequential and non-consequential, due to many factors including human errors, component failures, malfunction and design weaknesses in plant systems and components etc. Analysis of these events, both minor and major, enable facilities to identify improvement opportunities and gain new or improved knowledge, which can be used for improving SSCs and human performance, business processes and training programmes.

NPPs have instituted systematic processes to capture and analyze their events with a purpose to learn from those experiences.

Nuclear facilities and organizations conduct internal reviews such as self-assessment reviews and audits to identify performance shortfalls. The lessons learned programme of the facility and organization needs to provide a platform to systematically address the identified gaps from these reviews.

Some organizations create summary reports to capture and disseminate lessons learned from specific activities or from generic issues. For example, after a refueling outage, some NPPs issue a report highlighting the major lessons learned including good practices and opportunities for improvement.

2.2.4. External knowledge from industry experience

Sections 2.2.1 through 2.2.3 explore the possibilities of learning from an organization’s internal experiences. There is also a significant scope for learning from an organization’s external experiences.

From an NPP perspective, the following external sources of knowledge are important:

- International organizations such as the IAEA, World Association of Nuclear Operators (WANO), etc., providing operating experience, as summarized in SSG-50 [4], from a fleet of nuclear facilities operating around the globe;
- Owner groups of NPPs such as PWRs, Boiling Water Reactors (BWR) and Pressurized Heavy Water Reactors (PHWR) or Canada Deuterium Uranium (CANDU) that share both generic and specific issues relevant to a particular type and design;
- Suppliers, designers, vendors, manufacturers and technical support organizations (TSO), both within and outside the country;
- Contract organizations that provide operation, maintenance and engineering services [7].

International organizations such as the IAEA and WANO have been collecting, analyzing and providing valuable operating experience information to their members as summarized in SSG-50 [4]. This enables all NPP operating organizations to learn from the experience of others and helps the entire industry to achieve improved performance. For example, the incident of a secondary system steam pipeline rupture in Mihama NPP in Japan created significant awareness of a phenomenon called flow accelerated corrosion (FAC) and operating NPPs around the world started to analyze wall thinning happening in potential secondary system pipelines. Following the knowledge gained from the experience of this incident, NPP operating organizations around the world performed substantial reviews of their secondary systems to understand potential vulnerabilities to FAC.

There are owner groups for different types of NPPs such as BWR, PWR, and PHWR and they work closely with the operating organizations and design and engineering organizations. They facilitate sharing of experiences within their design groups and analysis of issues and events faced by their stakeholders to achieve improved design and performance. This allows all stakeholders involved in a particular type of NPP design, using collective knowledge and experience, to make significant improvements, including innovative design and operational changes.

External reviews by organizations like the IAEA, WANO etc., help organizations gain an independent external perspective to issues faced by them. The collective experience of peers who perform the review enables the organization to gain new knowledge and perspective on critical issues that affect safety and performance. It also provides a platform to identify good practices that help to achieve excellence in specific areas. These good practices are useful sources of experience-based knowledge for the entire industry.

Benchmarking another organization or department to improve on specific areas is another way of learning from external experience. For example, some NPP organizations may be consistently achieving excellent results in a particular area like outage management or fuel performance. It provides an opportunity for other NPP organizations to visit these NPPs and learn specific approaches and methods to improve their own performance in those areas.

3. GUIDANCE TO SET UP AN EFFECTIVE LESSONS LEARNED PROGRAMME

Before providing guidance to set up a lessons learned programme, it is important to study the respective process to establish such a programme. Section 3.1 explains the process involved in detail.

3.1. PROCESS INVOLVED IN A LESSONS LEARNED PROGRAMME

Typically, the process to capture lessons learned involves the following three stages as shown in Fig. 6:

- Identification of issues and good practices;
- Analysis of issues and good practices to identify causes, contributors and actions to mitigate the problems and to improve the organization's performance;
- Implementing and monitoring actions.

Figure 6 shows the three stages and activities involved in this process.

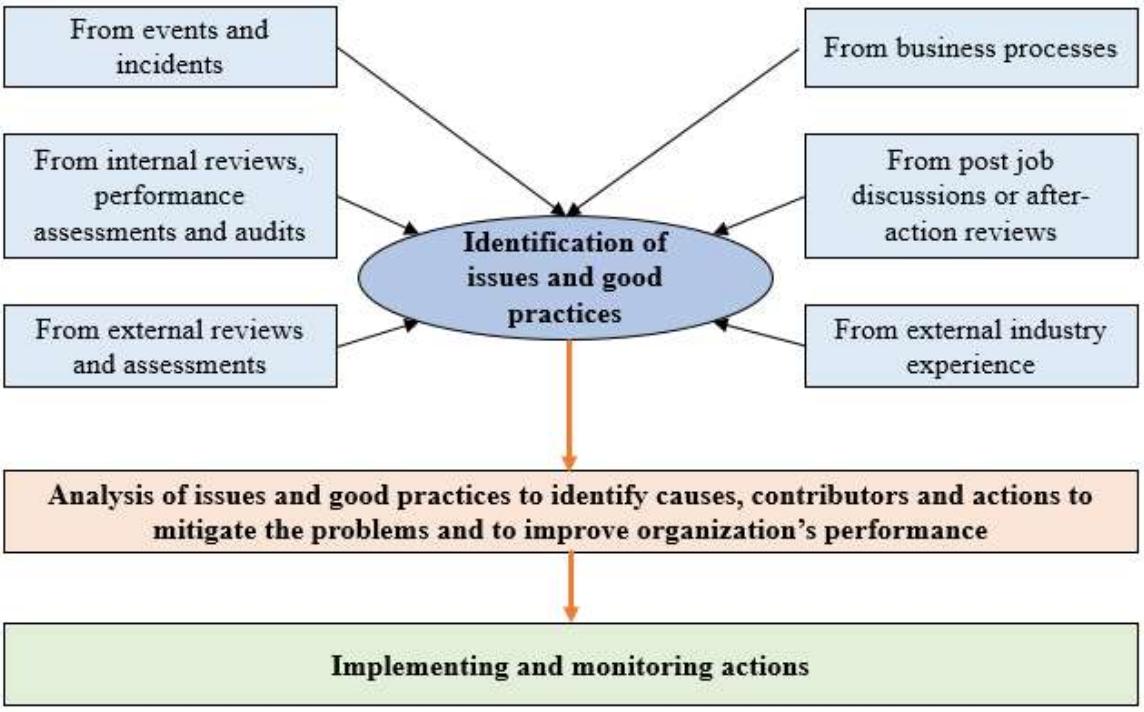

FIG. 6. Typical process involved in a lessons learned programme.

3.1.1. Identification of issues and good practices

Identifying the relevant sources for learning from experience is the important first step depending upon the type of organization, nature of external business collaborations and other factors. Figure 6 provides six major areas from where the majority of lessons can be tapped. Section 5 provides guidance to identify the sources of learning from experiences for various types of nuclear organizations. Involving relevant sections/departments and identifying key stakeholders to contribute to the programme is crucial to the success in identifying relevant issues and good practices.

There is also potential to leverage the good practices or areas where the organization is performing at levels exceeding expectations. Examples could be actions and behaviours that contributed to significant financial/human resource savings or critical knowledge gains in activities/jobs that resulted in significant savings in time and effort or improved quality of work. The goal is to identify the possibilities to replicate those actions and behaviours in other activities/areas for the overall benefit of the organization.

In order not to miss opportunities to learn from experiences, the identification of issues ought to be encouraged and supported throughout the organization. Best performing organizations are trying to identify all organizational issues, not only equipment deficiency. This includes:

— Human performance issues;
— Industrial safety deficiencies;
— Weaknesses and deficiencies in procedures and documentation;
— Issues and weaknesses in business processes.

This allows the organization to take into account all existing issues, look into them individually and collectively and to prioritize them for appropriate action and resolution.

The volume of information handled at this stage is very large. Therefore, this is typically handled by customized software applications.

3.1.2. Analysis of issues and identifying actions

The initial screening of identified issues is performed to evaluate their causes and contributors. For the majority of the issues, the causes and contributors are evident and therefore an apparent cause evaluation (ACE) is conducted to determine the extent of the condition, which provides clarity on the possibility of similar issues in other areas of the facility or organization. Identifying the extent of condition accurately requires thorough knowledge of the issue that is being analyzed and the knowledge of the plant or facility. An ACE provides limited information and suggestions of corrective actions. For complicated issues or complex events, a root cause analysis (RCA) is conducted. RCA is a systematic and elaborate process using appropriate investigation methods and techniques to logically determine the root cause(s) and contributing factors. The RCA determines what happened, how it happened, and why it happened. IAEA-TECDOC-1756, Root Cause Analysis Following an Event at a Nuclear Installation: Reference Manual [8], provides guidance to perform an RCA. Examples of investigation tools and techniques include:

— Interviewing;
— Task analysis;
— Change analysis;
— Barrier analysis;
— Cause and effect diagrams or fishbone diagrams;
— Fault tree analysis;
— Event tree analysis;
— Failure mode and effect analysis (FMEA);
— Pareto charts;
— Scatter diagrams;
— Affinity diagrams.

Experience has shown that the highest quality RCA is a result of a focused investigation where a well sponsored and dedicated team is brought together for a short but focused period of time to perform the analysis.

In many cases, individual issues do not have any significance in terms of their contribution to performance improvement or additional knowledge gain. However, when they are aggregated and analyzed at periodic time intervals using a common cause analysis approach, it may reveal significant underlying organizational issues including knowledge gaps. For example, there may be several separate instances of non-consequential human errors but when analyzed collectively, they may reveal big gaps such as lack of knowledge or skills of workers or weaknesses in training evaluation and assessment.

Analyzing good practices or good achievements uses the same methods that are used for analyzing issues or events. It is important to identify how benefits derived from those practices can be leveraged for larger organizational performance improvements and knowledge gains.

After finding the causes of an event or a problem, actions/solutions need to be identified to mitigate the situation and to leverage the benefits of good practices. In many cases, identifying actions for technical issues are a straightforward process. However, for organizational and human performance related issues, identifying actions that are feasible, practical is more important. Actions need to be assigned to owners with a clear timeline. Actions, typically, result in learning lessons and consequently making improvements in one or more of the following areas:

- Improved human performance;
- Improved business processes;
- Improved performance of SSCs.

In order to achieve and sustain the above, actions will be needed in one or more of the following areas and they contribute to the organizational knowledge management:

- New or improved training;
- Human resource development activities such as mentoring, coaching etc;
- Development of new or improved facility operation and maintenance procedures, documents and policies.

3.1.3. Implementing and monitoring the actions

The actions identified are implemented by integrating them into relevant business processes, with action owners facilitating the implementation. Tracking the status of planned actions periodically provides an opportunity to identify the issues that are impediment to successful completion. The monitoring is accomplished through periodic review meetings involving all stakeholders responsible for the actions.

Some actions may need to be addressed immediately and therefore need to be expedited, implemented, documented, and closed as soon as possible. Closure documentation needs to clearly state that the intended corrective action was completed satisfactorily. Any additional documentation also needs to be attached or easily retrievable, meaning that there is a clearly documented path provided for the reviewer to follow in order to obtain the data.

Some actions may take longer to expedite or may need more detailed engineering solutions. For example, modifications to a safety related component or the development of a new practical

training programme to support skills development may need longer time periods to implement. Sometimes, significant changes to business processes may require additional human resources and infrastructure and therefore may need more time to implement. These long-term actions are to be carefully planned as their implementation may be linked with other activities like procurement, plant or process system shutdown and other internal and external organizational reviews and approvals.

Documenting and preserving the information gained from a lessons learned programme and integrating it in the organization's information technology (IT) platforms or in relevant portals is important throughout the process to ensure the same information is available for personnel to reference and use in their day to day work activities. Consequently, some NPP organizations have created portals [6] that host past experiences to be used in their just-in-time briefings before commencement of plant activities. This supports effective learning from past incidents/issues.

3.2. STEPS INVOLVED TO SET UP A LESSONS LEARNED PROGRAMME THAT SUPPORTS ORGANIZATIONAL KNOWLEDGE MANAGEMENT

This section provides a step-by-step guidance to help users to set up their own lessons learned programme that aligns with the objectives of the organization's knowledge management.

Knowledge management initiatives or programmes are developed with due consideration to organization's safety and long-term business objectives and needs. A strategically developed knowledge management programme considers different knowledge transfer techniques such as mentoring, coaching, communities of practice and knowledge capture activities such as lessons learned programmes. It also considers to what extent these techniques are to be deployed and methods to monitor the effectiveness of these techniques. The IAEA's Nuclear Energy Series publication NG-G-6.1 [1] provides guidance and a roadmap to set up a strategic knowledge management programme.

The inputs required to develop a systematic lessons learned programme need to be aligned with the organization's strategic knowledge management initiative. If an organization does not have a strategic knowledge management initiative at the time of establishing a lessons learned programme, it is prudent to develop one beforehand.

The guidance to develop a lessons learned programme involves the following six steps:

- Define the objective and scope of the programme;
- Identify the stakeholders involved;
- Create the processes, procedure and infrastructure;
- Provide orientation and training;
- Launch the programme;
- Monitor, evaluate and improve the programme.

These six steps are elaborated below. Table 2 in the Appendix provides an easy to use format that lists key questions to be asked and the relevant guidance to support those questions for each of the six steps.

3.2.1. Defining the objective and scope

The objective of the lessons learned programme is to be defined by considering the organization's knowledge management policies, strategies and plans. In order to establish clear objectives and scope, consider asking the following questions:

- How can a lessons learned programme be useful to support the organizational knowledge management objectives?
- How can a lessons learned programme help the organization to achieve performance improvement?
- How can the experience of individuals and teams working in the organization be collected and used?
- Is it necessary to collect the experience of individuals and teams for all activities? If not, then what criteria is to be followed to identify useful activities?
- Which information needs to be collected from individuals and teams?
- Which business processes are used in the organization?
- How can experiences and lessons learned be collected from those business processes?
- What are the criteria for reporting events and issues?
- What is the process to collect recommendations from internal and external reviews?
- Which department/agency is responsible for collecting and analyzing the information?
- What is the frequency for analyzing the information?
- What type of IT platform is suitable for establishing the programme?

3.2.2. Identifying the involved stakeholders

Typically, a central agency or department takes the lead to manage the lessons learned programme. In NPPs, the operating experience team usually plays this role. Depending on the size of the organization and the lessons learned programme, the team ought to be staffed with an adequate number of people. The central agency takes overall responsibility of the programme, which includes:

- Collecting all issues/events/good practices from identified sources;
- Analyzing the information and identifying the causes and solutions;
- Identifying actions, including action owners and developing action plans;
- Monitoring and tracking the implementation of action plans;
- Issuing periodic reports including the achievements of the lessons learned programme and the issues faced.

In order to implement the second and third item of the above list, the central agency may need the support of subject matter experts (SME) from other sections or departments and therefore, arrangements need to be made to gain the expertise of SMEs, i.e., through committees consisting of SMEs that analyze significant facility events.

3.2.3. Creation of processes, procedures and infrastructure

Nuclear facilities and organizations use management systems and they interact with core and support processes. These processes both offer and gain valuable lessons from the lessons learned programme. Therefore, it is important to integrate the activities of lessons learned programmes with the organizational core and support processes.

The process involved in a lessons learned programme consists of the three stages that address all relevant functions and is explained in section 3.1. To achieve this objective, the organization

first needs to determine how the important experiences of an organization can be captured and utilized?

The main infrastructure to be established is the IT platform, which needs to be designed for user's convenience to enter their experience-based information. The system also has to be convenient for users to fetch lessons learned from past issues/events whenever they are looking for such information.

Creating simple procedures that can be referenced by users when providing or fetching information may attract more contributors and users to the programme. These procedures need to consider the expectations of personnel and describe their roles and responsibilities at sectional, departmental and organizational level. Once established, they need to be communicated using the organization's training and other communication portals.

3.2.4. Orientation and training

Active involvement of personnel across the organization is critical to the success of a lessons learned programme. Therefore, training and orientation needs to focus on imparting not only the knowledge needed for understanding the procedures, process involved and the roles and responsibilities of various stakeholders, but also the importance and benefits of the programme for the organization's knowledge management.

The orientation and training need to be planned in the following two ways:

— As part of initial induction training to new recruits. This is the best opportunity to sensitize new recruits about the importance of their contribution to a lessons learned programme and the expectations from them;
— As part of continuous learning, organizations conduct several training sessions. This is an effective way to train and orient the experienced employees about the lessons learned programme.

3.2.5. Launching the programme

The launch of the programme ought to be planned carefully after ensuring all activities from section 3.2.1 through 3.2.4 are successfully completed and the IT platform is tested adequately to ensure reliable service. Sometimes inadequately designed IT platforms, coupled with unclear instructions, create unfavorable mindsets among personnel, which may be detrimental to the successful implementation of the programme.

Sometimes, it is beneficial to launch the programme on a pilot scale to observe and correct the problems/issues faced before launching it at the organizational level. For example, the programme can be initially launched at a particular section or department and later moved to other sections and departments.

It is also important that senior managers and leaders in the organization support and encourage personnel to participate and contribute to the programme.

3.2.6. Monitor, evaluate and improve the programme

Periodic monitoring and evaluation using a set of performance metrics and thorough feedback from key stakeholders helps to understand the issues associated with the programme and to make changes that can bring useful benefits. Selecting the right monitoring parameters,

conducting timely and appropriate feedback surveys are key to success. Table 1 below provides some examples of indicators that can be used to monitor the programme at the following three levels:

— Activity level. This helps identifying issues arising from inadequate participation or contribution from personnel or issues with systems and infrastructure;
— Drivers and enablers level. These indicators identify critical factors that are contributing to the success and weaknesses of the programme and thereby enable the organization to leverage those areas more intensively;
— Business benefits level. These high level indicators inform the organization about large scale benefits derived from the programme.

TABLE 1. PERFORMANCE MONITORING OF LESSONS LEARNED PROGRAMME

Level of Measurement	**Indicator**
Activity level	Number of experiences/issues/events/good practices shared by employees
	Number of experiences/issues/good practices identified from business activities
	Number of internal events/activities reviewed for identifying lessons learned
	Number of external experiences/issues/events/good practices reviewed for internal organizational learning
	Number of actions identified based on analysis of internal experiences
	Number of actions identified based on analysis of external experiences
	Number of actions completed on time
Drivers or enablers level	Percentage of staff participating at the level of organization/department/section
	Number of external organizations whose lessons learned are used for internal learning
	Number of occasions the organization identified issues with existing documented information or realized the need to have documented information
Business benefits level	Number of actions identified to improve training
	Number of actions resulted in new learnings/new knowledge gain
	Number of actions identified to update/create documented knowledge
	Number of times mistakes/errors/delays happened in works/activities on account of not learning from previous experiences
	Financial loss in works/activities on account of not learning from previous experiences

The indicators given in the table are not a complete or comprehensive list. Users are expected to identify more indicators that are relevant to their organization. The indicators are typically calculated on a quarterly, half yearly or yearly basis and the trends, rather than absolute values, are important to consider for evaluation purposes.

4. KEY FACTORS FOR A SUCCESSFUL LESSONS LEARNED PROGRAMME

The success of any knowledge management programme centers around the ability to:

- Successfully transfer knowledge across people;
- Use the experience-based knowledge gained by the organization and its people for the benefit of the organization's current and future activities.

The lessons learned programme is a key factor to support the latter.

Whilst it is important to have the right infrastructure and suitable processes to share, analyze and identify actions, it is imperative to ensure the organizational lessons learned programme is supported by all employees. The biggest contribution to success comes from their active participation and sharing their experiences.

Some of the encountered difficulties common in implementing a successful lessons learned programme are:

- Generating sufficient involvement and interest by individual employees to report and share their experiences and knowledge;
- Creating a culture where personnel feel encouraged to report incidents/events and share knowledge and experience;
- Providing recognition for knowledge sharing in the organization;
- Perceiving the programme as an additional process and burden;
- Generating appropriate management support and encouragement from managers and supervisors.

The keys issues that contribute to the failure of lessons learned programmes and some tips to overcome them are discussed in this section.

4.1. ORGANIZATIONAL CULTURE

The experience gained by anyone in an organization can be used to improve its performance and long-term sustainability. Reporting and sharing of information are fundamental for the organization's nuclear safety culture. NPPs, as part of nurturing the nuclear safety culture, promote a learning and knowledge sharing culture. The IAEA-TECDOC-1329, Safety Culture in Nuclear Installations: Guidance for use in the Enhancement of Safety Culture [9], reinforces this aspect. Therefore, it is important to create a favourable environment so that employees feel empowered and encouraged to share and reveal their experience based knowledge.

To foster the favourable environment, it is necessary to cultivate a culture valuing the following characteristics:

- Transparency: Everyone feels comfortable to share their experience and their mistakes;
- Capacity to pause and reflect: To, occasionally, step back and reflect on the activities performed compared to initial expectations and identify the improvement paths;
- Empowerment: Personnel involved in specific work activities know the processes and techniques they need to apply and, therefore, feel empowered to report and share their experiences;

— Knowledge sharing: Promote the advantages of sharing knowledge as opposed to controlling knowledge;
— Systematic feedback: Providing feedback to the contributors of the programme assures the continued programme support and participation by employees.

4.2. OWNERSHIP, GOVERNANCE AND OVERSIGHT

The results or benefits derived from a lessons learned programme are not instantly visible. It may take a long time – sometimes even a few years – to realize the benefits. At the same time, the human resources, infrastructure and financial support needed to operate a successful lessons learned programme is significant. Therefore, these programmes are sometimes perceived as a burden and, therefore, ignored or pursued with short term objectives. Understanding the importance and relevance of the programme from all levels of the organization is critical for its success. Based on the understanding, organizations need to own, get involved and support the programme.

The way to induce the organization's cultural change necessary for the programme's success is through its leaders and senior management.

Responsibilities of personnel involved in the programme are to be clearly defined and a lead agency responsible for the programme is to be assigned. If there is a knowledge management department, ideally this programme needs to be under their responsibility. In some organizations the human resources or training department takes care of knowledge management activities.

Identifying responsible personnel in each department to function as lead coordinators is useful as they can be a single point of contact to identify issues that are impediment to effective contribution from personnel to the programme. They can also act as champions and promote the benefits of the programme.

A governance procedure describing the roles and responsibilities of personnel involved, including sponsorship from top management, needs to be in place to ensure the deliverables of the programme are clear to all stakeholders.

Support and oversight from senior management of the organization is vital for the success to the programme. Periodic surveys to understand the feedback from employees would help to explain any real underlying issues.

4.3. RECOGNITION

Recognizing the contributions of personnel to the programme is an important way to nurture it. Managers and supervisors are encouraged to provide positive recognition for employees/groups whose performance exemplifies their personal accountability in identifying problems (i.e., generating an issue report for low level non-consequential human performance errors). Examples for positive recognition may include 'Good Catch Awards', a recognition during routine team meetings, or a fleet-wide recognition through news articles.

Some organizations reward the contribution of individuals in their annual performance appraisal system.

4.4. QUALITY OF INFORMATION

One of the fundamental issues with the lessons learned programme is the challenge to capture information and knowledge accurately without losing its context. Care needs to be taken while writing down experiences of personnel to make sure the context and accuracy are well captured. The language style used need to be simple and easy to understand. Pictures, videos, drawings and other supplemental aids are useful to capture knowledge more accurately. It is also helpful to validate the knowledge captured with the owners wherever applicable. There are several tools available such as elicitation interviews, knowledge maps, concept maps, and process maps that support effective knowledge capture.

A case study from Tokyo Electric Power Company (TEPCO), Japan provided in Annexure V explains their innovative approaches to learn from past incidents with an example of a 2002 incident. Their approach to visualize the incident and related information, as it happened in the past, helps to convey the information easily and accurately.

4.5. INFORMATION TECHNOLOGY INFRASTRUCTURE

Organizations develop customized IT platforms to manage their lessons learned programme. It is central to all activities that are required to be performed. Therefore, it has to be designed carefully by taking into account the specific organizational and personnel requirements for the programme.

Some organizations create several standalone IT platforms to manage separate applications that are not linked to each other. In such situations, personnel may have to enter the same information into several IT applications and this is not only creating potential for inconsistency but it is also time consuming and contributes towards losing interest in the activity. Also, in such situations, personnel need to access multiple IT applications to retrieve the information they are interested in. Therefore, it is a good practice to reevaluate the architecture of existing IT applications, considering better integration of data or application interfaces.

Considering the large volume of data and information handled and long timelines involved in managing the lessons learned in nuclear organizations, artificial intelligence (AI) and machine learning concepts are being used to enhance effective and efficient use of information.

A case study from the Norwegian oil and gas industry explains their experience of using AI-assisted lessons learned, which offers innovative solutions and enables organizing large volumes of information for efficient identification and retrieval. The ontology generated through this innovative method of language analysis is as good as one generated through the traditional method of domain knowledge analysis using SMEs.

5. APPROACHES IN NUCLEAR ORGANIZATIONS

5.1. OPERATING ORGANIZATIONS

The practice of sharing important lessons learned, both internally and with external organizations, became an integral part of the business to the NPP community after the Three Mile Island and Chernobyl accidents. The analysis of Three Mile Island accident revealed the fact that the accident could have been prevented, had the personnel been aware of issues related to pressurizer relief valves that were observed in a similar plant within the United States of America. The analysis of the Chernobyl accident revealed that good practices in the form of human error prevention techniques followed in some NPPs were not known in many other NPPs. Therefore, NPPs around the globe recognized the importance of sharing lessons learned for the benefit of safety of the nuclear industry as a whole.

Requirement 24 of IAEA Safety Standards Series No. SSR-2/2 (Rev. 1), Safety of Nuclear Power Plants: Commissioning and Operation [10], states that "The operating organization shall establish an operating experience programme to learn from events at the plant." Paragraph 5.27 of SSR-2/2 (Rev. 1) [10] further states that "[the operating organization] shall obtain and evaluate available information on relevant operating experience at other nuclear installations to draw and incorporate lessons for its own operations." Therefore, nuclear operating organizations are required to have a well-structured operating experience programme which captures learnings from events that happened in both external and their own organizations. The general process is as follows:

- Collect information on anomalies, deviations, incidents, events and accidents;
- Identify the causes and contributors;
- Learn the lessons and disseminate them to all relevant persons;
- Set up corrections (corrective and/or preventive) or improvement actions;
- Conduct effectiveness reviews.

Figure 7 provides typical operating experience and corrective action programmes in an NPP operating organization, which includes the following three processes:

- A process to learn from both internal and external experiences;
- A process to use the lessons learned systematically;
- A process that monitors the effectiveness of learning.

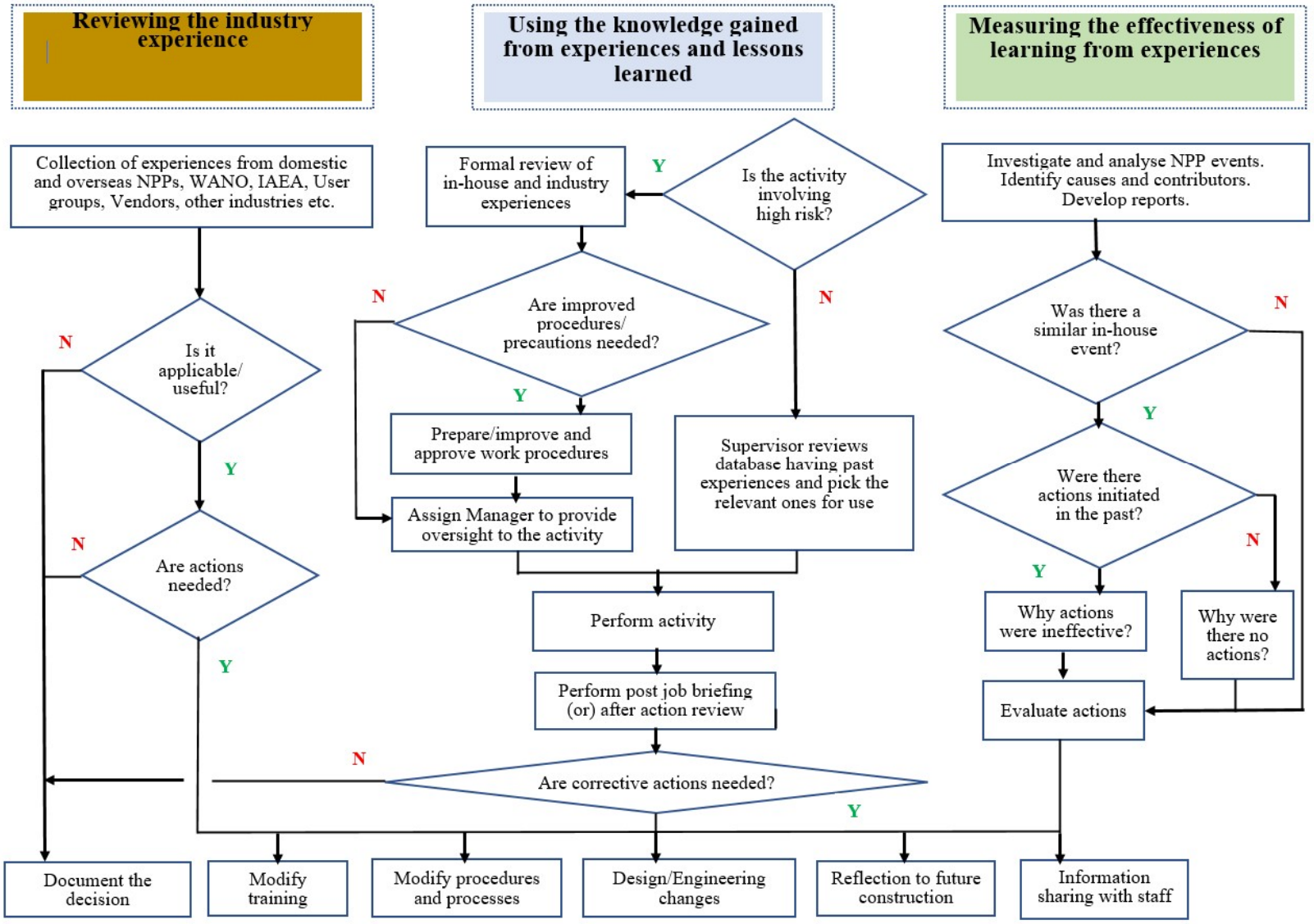

FIG. 7. Typical process of lessons learned programme in NPP operating organizations.

The bottom of the flow diagram leads to various possible corrective actions and, therefore, the lessons learned are inherited for improving organizational learning and performance of the facility.

Some operating organizations recognize the additional benefits in terms of performance improvement that can be derived from a lessons learned programme and they use the intranet or a web-based system, either customized to suit their needs or procured as a standard software application, to manage their operating experience programme. The features such as filters, report generation, or auto alerts for delayed corrective actions are some of the common features that enable efficient use.

Some NPP operating organizations have established processes to capture low level events (LLEs) and near miss events (NMEs). This allows them to capture events of lower significance or consequence that had the potential to develop into safety significant events but were prevented due to plant design features and/or preventive actions of an operator. Apart from correcting causes of these low-level events, analysis are carried out to identify their common causes, which provide an opportunity for significant performance improvement.

Although nuclear operating organizations have an established programme to learn from their internal and from external experiences, it may not be utilized effectively to support their knowledge management initiatives. Therefore, it is important to thoroughly examine the existing programme for opportunities for improvement, for example:

— Analyzing events and issues can reveal knowledge gaps and training weaknesses, thereby improving training, human resource development, and initiating specific knowledge transfer initiatives like mentoring, coaching and shadowing;
— NPPs rely on procedures to execute their activities. Lessons learned often identify weaknesses or errors in plant procedures and also reveal the need for new procedures for certain activities previously performed from memory of personnel, thereby helping in the documentation or updating of knowledge.

There are five case studies from nuclear operating organizations provided as Annexes at the end of this publication, offering insight on how lessons learned programmes are being used by these organizations.

In Annex I, the case study from Electricite de France (EDF), France, explains their efforts to share their project experience from the new European Pressurized Reactor (EPR) projects to their project implementation team and the owner-operator group.

In Annex II, the case study from Korea Hydro and Nuclear Power (KHNP), Republic of Korea, explains their experience of developing a knowledge management system (KMS) to support organizational learning and knowledge transfer. The case study highlights the challenges they faced due to loss of critical knowledge possessed by experienced experts and how they managed to gain them back.

In Annex III, the case study from Nuclear Power Corporation of India Limited (NPCIL), India, explains their operating experience programme that includes experience sharing from their experts across the fleet and learning lessons from LLEs and NMEs.

In Annex IV, the case study from Rosenergoatom, Russian Federation, explains the knowledge management and lessons learned practices in their fleet of NPPs. This case study focusses on

their efforts to gain organizational knowledge from their operating experience and critical knowledge holders.

In Annex V, the case study from Tokyo Electric Power Company, Japan, explains the new education and training facility that incorporates lessons learned exhibitions related to past incidents or accidents, including the Fukushima Accident, to learn more effectively.

5.2. OPERATING ORGANIZATIONS IN EMBARKING COUNTRIES

Member States embarking into a new nuclear energy programme have unique knowledge management challenges and issues. Capturing and transferring knowledge from several stakeholders involved in new nuclear builds such as the engineering, procurement and construction (EPC) contractor, manufacturers, design and TSOs is a significant task to accomplish. A substantial number of important lessons are learned during design, construction and commissioning of the plant that are useful to operators, regulators, and the TSOs that are going to operate, regulate and support the safe and reliable operation for several decades to come. Key lessons learned in new build projects often originate from various areas, including:

- Design and engineering changes including the rationale for making those changes before the construction begins;
- Improvements and modifications to plant layout and design during construction including the rationale for making those changes;
- Experiences and lessons learned from the construction and commissioning of the plant;
- Lessons learned from international organizations like IAEA, WANO, etc.;
- Lessons learned from owner groups (e.g. PWR, BWR, etc.) and from vendors and manufacturers.

Design and construction of new NPPs provide unique opportunities for learning and they are useful for the safe, reliable and economical operation of NPPs in the long run. The lessons learned during design, construction and commissioning of the plant are to be carefully captured, analysed and used for improving the NPP performance. Several engineering and design changes are carried out during construction based on experience and encountered challenges. It is important to capture these changes in relevant plant documents, drawings and procedures. It is also important to capture the rationale for making such changes for the understanding of future generations. Therefore, the lessons learned programme for nuclear operating organizations in embarking countries needs to focus on systematically capturing the lessons learned from design, construction and commissioning coming from various sources such as the EPC contractor, design and engineering organizations, manufacturers of NPP equipment and components, and international organizations. Figure 8 provides the potential source organizations from where useful lessons learned can be obtained.

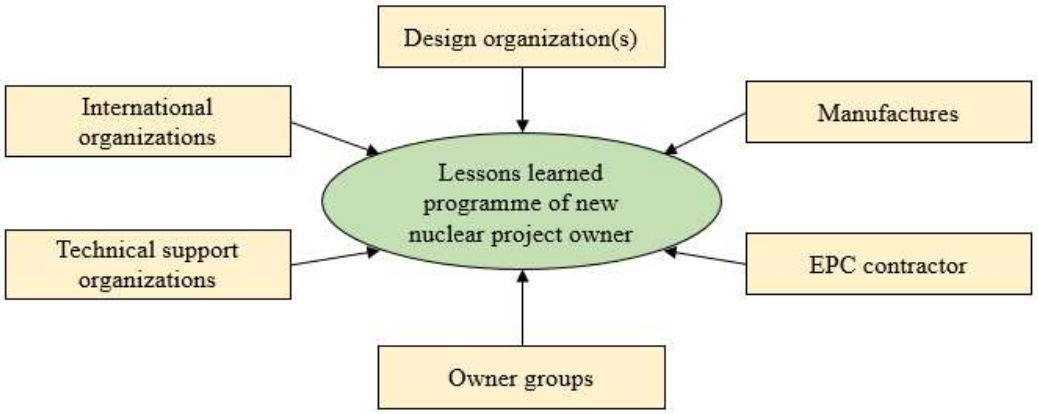

FIG. 8. Typical sources of lessons learned for embarking countries.

The volume of information from these sources is extremely high and it is challenging to maintain them using a paper-based information management system. Modern NPPs use plant information models [11] to organize and manage design, engineering and construction information efficiently with less effort. The benefit of such systems is that they can be utilized for effective lessons learned programmes.

5.3. VENDOR ORGANIZATIONS

Nuclear vendor organizations dealing with the design and construction of NPPs and other nuclear facilities have multiple sources for learning. Like large engineering organizations they employ highly qualified staff possessing specialized engineering skills and knowledge needed for large nuclear facility design and construction. Experience gained from execution of nuclear facility construction projects generates valuable knowledge useful for improving design and construction methodologies resulting in substantial financial and time savings. Therefore, the main objective of their lessons learned programme needs to focus on capturing the experience-based knowledge and skills of employees.

As shown in Fig. 9, numerous external sources provide valuable lessons for vendor organizations.

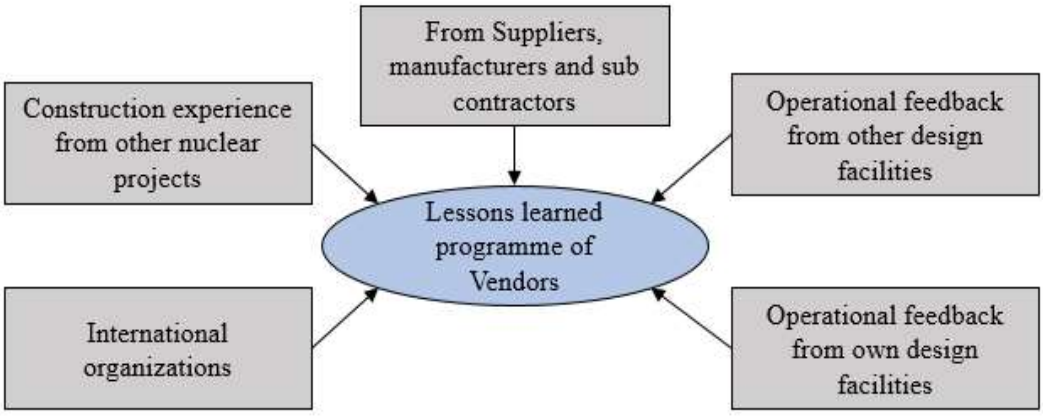

FIG. 9. Typical external sources of lessons learned for vendor organizations.

They include:

- Lessons learned from manufacturers, suppliers and sub-contractors: Vendor organizations outsource some of their business activities and deal with a range of manufacturers who supply equipment and components used in nuclear facilities. The feedback and experiences coming from these service providers can contribute substantially to improve nuclear facility design, construction and performance.
- Lessons learned from the experience of operational nuclear facilities: The operating experience feedback from nuclear facilities designed by the vendor and other similar designs is especially useful to make design improvements. In many cases, the vendors form user groups that provide a platform for both nuclear facilities and vendors to share their experiences. For example, the PWR, BWR and CANDU Owners Group (COG) share experiences among similar type NPPs.
- International organizations: The experiences international organizations such as the IAEA and WANO gather from their members offer valuable industry experience and useful lessons for vendors. In addition, they provide updated guidance documents and industry standards that are important for sustained safety and business continuity.
- Construction experience from other nuclear projects: The construction phase of a nuclear facility like NPP typically spans 5 to 6 years and there were relatively few NPPs constructed in Europe and North America over the last 20 to 30 years. This means, the generation that constructed NPPs in these regions might have retired leading to a potential loss of certain construction skills and knowledge within the organizations involved. In the eastern part of the world, countries like The People's Republic of China and the Republic of Korea continue constructing new NPPs using innovative approaches that save time and money. Therefore, there is a great potential to learn from other design construction projects.

A case study provided in Annex VI explains the approaches taken by Framatome, France to learn the lessons from their EPR projects effectively. The process setup has shown operational results, enabling Framatome to continuously improve the safety, quality and performance of projects.

5.4. TECHNICAL SUPPORT AND SERVICE ORGANIZATIONS

TSOs [12], depending upon their objectives and capabilities, cater for different types of nuclear organizations such as NPPs, radioactive waste management, design, and regulatory organizations. They deal with complex design and engineering services that require knowledgeable workers who are highly qualified and experienced in specific areas. Therefore, capturing experience-based knowledge from individuals is one of the important objectives of lessons learned programmes in these types of organizations. Additionally, they profit significantly from the experiences and feedback from their user organizations and networks.

Figure 10 highlights typical external sources of information for organizations that need to explore possibilities to gather relevant information from these sources.

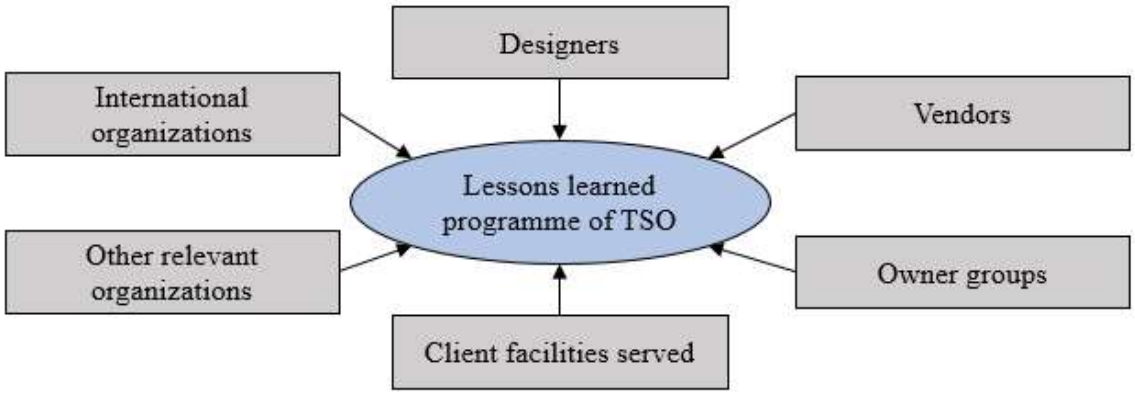

FIG. 10. Typical external sources of lessons learned for TSOs.

5.5. REGULATORY BODY

Requirement 15 of the IAEA Safety Standards Series No. GSR Part 1 (Rev. 1), Government, Legal and Regulatory Framework for Safety [13], states that "The regulatory body shall make arrangements for analysis to be carried out to identify lessons to be learned from operating experience and regulatory experience, including experience in other States, and for the dissemination of the lessons learned and for their use by authorized parties, the regulatory body and other relevant authorities." Section 3 of SSG-50 [4] provides recommendations to emphasize the role of the regulatory body in operating experience feedback. IAEA-TECDOC-1899, Effective Management of Regulatory Experience for Safety [14] provides detailed guidance to establish an operating experience programme in regulatory bodies. Regulatory organizations use knowledge-based workers who are highly qualified and experienced to perform various regulatory functions described in IAEA Safety Standards Series No. GSG-13, Functions and Processes of the Regulatory Body for Safety [15].

Requirement 15 of GSR Part 1 (Rev. 1) [13] in Paragraph 3.4 further states that "The regulatory body shall establish and maintain a means for receiving information from other States, regulatory bodies of other States, international organizations and authorized parties, as well as a means for making available to others lessons learned from operating experience and regulatory experience." The IAEA is in the process of developing a safety guide to support the management of regulatory experience.

Therefore, for regulatory bodies, in addition to capturing experience-based knowledge from implementing various regulatory activities, there are other important sources of lessons learned coming from several external sources that need to be systematically gathered, analyzed and used. International organizations like the IAEA are important sources for regulatory bodies as they offer a platform to learn, discuss and implement changes in nuclear regulations on technical, legal and environmental issues. Figure 11 provides typical learning sources for regulatory bodies.

FIG. 11. Typical external sources of lessons learned for regulatory body.

Establishing regulatory bodies or enhancing the capabilities of existing regulatory bodies in newcomer countries and developing competent staff to regulate their first NPP involves considerable time and effort. Often, the new staff receive training and are sometimes seconded to regulators or organizations in other countries to gain experience. The lessons learned programme, therefore, needs to carefully consider the systematic capture of knowledge gained by individuals and use it to develop and improve the organization's procedures and processes. The experience and lessons learned when a new nuclear facility like an NPP is undergoing a licensing process for construction and commissioning, is also a valuable knowledge asset for a regulatory body.

5.6. ORGANIZATIONS DEALING WITH NON-POWER APPLICATIONS

A considerable number of IAEA Member States are utilizing nuclear and radiation technologies for non-power applications including research reactors, research laboratories dealing with industrial, medical, food and agricultural applications using nuclear techniques. In most cases, these organizations or institutes deal with very specific nuclear expertise and it is unlikely that other similar organizations or institutes exist within the same country. Therefore, the risk of knowledge loss can have a significant impact on the sustainability of business and economic penalty. While many of the organizations or institutes may not have formal processes and programmes in place to capture experiences and lessons learned, there are considerable benefits to having one.

To strengthen their lessons learned programme, industry and education providers can complement each other.

5.7. INTERNATIONAL ORGANIZATIONS

International organizations like the IAEA and WANO are important sources of collective experience and knowledge. International organizations are normally involved in a collaborative effort to collect information related to performance, events and good practices from their member organizations. They share the collected information for the benefit of all members through suitable platforms, provide feedback as well as industry wide analysis to the member organization to ensure safety and reliability in operation.

These organizations have dedicated staff and use a web-based system to collect and disseminate the experiences including good practices. They also offer recommendations to their member organizations based on the analysis of the collected information. These are issued either for a

specific member organization or for all members in the form of periodic reports with common recommendations.

The IAEA, for example, administers three separate incident reporting systems to collect, analyse, maintain and disseminate reports from participating countries on safety related events at NPPs [16], research reactors [17] and fuel cycle facilities [18]. These systems allow contributors to share operating experience and lessons learned with the international nuclear community to help prevent occurrence or recurrence of events at nuclear facilities.

After the Chernobyl accident, the importance of learning from each other among all the NPPs at an international level was realized and WANO was established in 1989. WANO gathers valuable experience-based information from all operating NPPs and shares it with its members. They also provide useful lessons learned based on analysis of the collected information through their reports.

6. CONCLUSIONS

The experience-based knowledge used for making improvements in the past can be useful for future improvements and innovation and, therefore, needs to be preserved.

Continuous learning is one of the important attributes of good performers and is especially important in the nuclear industry. A strategically developed knowledge management programme needs to focus on leveraging all available learning opportunities within an organization to effectively create and enhance knowledge.

This publication explains the technique of effective learning from experiences and provides guidance for developing a lessons learned programme that is useful to develop and sustain organizational knowledge for organizations interested in developing a new lessons learned programme as well as for improving exiting lesson learned practices.

The case studies provided in the Annex are useful to understand how different nuclear organizations use lessons learned programmes for achieving their knowledge management objectives.

Table 2 provided in the Appendix is useful for those interested in developing a lessons learned programme. It can be used as a checklist to ensure all elements needed for a successful lessons learned programme are considered.

Seven case studies from different types of organizations are provided in the Annex and they are useful to understand different approaches followed to capture lessons learned in different situations in different nuclear organizations.

— Annex I: EDF, France explains the new project experience from EPR sharing with project team and owner-operator group;
— Annex II: KHNP, Korea explains their experience of developing a KMS to support organizational learning and knowledge transfer;
— Annex III: NPCIL, India explains their operating experience programme that includes experience sharing from their experts across the fleet;
— Annex IV: Rosenergoatom, Russian Federation explains the knowledge management and lessons learned practices in their fleet of NPPs;
— Annex V: TEPCO, Japan explains their innovative approaches to learn from past incidents with an example of the 2002 incident;
— Annex VI: Framatome, France explains their lessons learned programme used to effectively learn from their EPR project;
— Annex VII: The Norwegian oil and gas industry explains their experience of using AI assisted lessons learned that offer innovative solutions and enable organizing large volumes of information for efficient identification and retrieval.

APPENDIX TECHNICAL GUIDANCE FOR DEVELOPING A LESSONS LEARNED PROGRAMME

Table 2 provides typical questions that help to systematically develop a useful lessons learned programme. These questions can be used by organizations to evaluate their current lessons learned programme or to develop a new one.

TABLE 2. TECHNICAL GUIDANCE FOR DEVELOPING A LESSONS LEARNED PROGRAMME

Steps	Key questions to be asked	Guidance
Objective and scope of the programme	— What does the organization want to achieve from its lessons learned programme? — What kind of information and knowledge is or can be made available based on the organization's past experience to support its knowledge management programme? — Does the organization have a structured lessons learned programme? — If yes, are the objectives aligned with the objectives of its knowledge management programme? — Does the lessons learned programme adequately consider learning opportunities available in all three domains explained in Section 2.1 through 2.3? — Does the lessons learned programme adequately consider opportunities available from relevant external organizations?	— The objective and scope of the programme depends on the potential opportunities available to capture lessons learned and its usefulness. — Focus on long term needs rather than immediate ones to set the scope and objective. — It is always good to start on a small scale and increase the scope and size of the programme based on feedback. — Inputs from performance audits, plant or facility performance reports, as well as internal and external review reports often provide useful insights to set the right scope and objectives for the programme.
Stakeholder's involvement and support	— Are the participating departments/ sections clearly identified? — Is the responsible person(s) in each department/section clearly identified? — Are the roles and responsibilities of individuals and teams clearly identified? — Is the scope of personnel to identify and report their experiences and lessons learned clearly defined? — Is the responsibility of analyzing the issues/events/incidents clearly defined? — Are the personnel identified for performing analysis trained on relevant techniques? — Are the corrective actions based on lessons learned monitored to ensure its timely completion? — Is there a clear ownership for implementing corrective actions? — Are there stakeholders external to the organization? If yes, are there mechanisms to collaborate effectively with those stakeholders?	— It is beneficial to identify a central agency or department to play a lead role in implementation of the programme. — The lead agency is to be adequately staffed and it depends upon the size of the organization & the programme. — It is also beneficial to identify lead personnel in each of the department/sections to coordinate activities within the department/section. — Creating a map of all involved stakeholders will be beneficial. — In nuclear facilities such as NPPs, lessons learned are best identified in the field.

TABLE 2. TECHNICAL GUIDANCE FOR DEVELOPING A LESSONS LEARNED PROGRAMME, cont.

Steps	Key questions to be asked	Guidance
Process and infrastructure	— Is the lessons learned process integrated into the organization's core and support business processes? — Is the process simple and clear to use? — Is the process to collect, analyze and identify actions from both internal and external experiences clearly defined and established? — Is there adequate infrastructure (IT and other services) in place to support the lessons learned programme? — Are the tools and techniques to be used for analysis clearly defined? — Can we test the process and techniques on a small or pilot scale?	— It is important to integrate the lessons learnt programme with the organization's core & support processes. — Set criteria and guidance for identifying issues/events/improvement opportunities. — Set criteria and guidance for analyzing issues and events. Simple, but widely used RCA methods can be considered for use. — Nuclear facilities such as NPPs use a guidance manual to define and communicate the policies, process and techniques to be used. — Process, platforms and methods: Make it simple so that it supports easy and efficient use by the users.
Training	— Are the people involved trained to understand the intent of the lessons learned programme and the process involved? — Does the training programme take into account the needs of different stakeholders involved? — Does the training material, facilities and delivery support effective training? — Are there suitably qualified and experienced people available to train? — Is the attendance to this training satisfactory? — Do the department/section managers sponsor their personnel to attend this training?	— Keep on-demand training. — Design the training programmes to clearly communicate the objective & scope of the lessons learned programme across the organization. — Specific training on techniques such as RCA to personnel involved in analysis need to be provided on a regular basis. — Sponsorship and attendance of personnel to training events to teach the process and techniques involved in lessons learned programme is an indication of support by the managers and leadership for this programme.

TABLE 2. TECHNICAL GUIDANCE FOR DEVELOPING A LESSONS LEARNED PROGRAMME, cont.

Steps	Key questions to be asked	Guidance
Communication and implementation	— Are there clear communications to personnel to report and analyze experience-based information? — Are managers and leaders communicating the importance of the lessons learned programme, particularly for the nuclear industry? — What strategies are used to convince personnel to share issues/events that are predominantly negative in nature? — How are the lessons learned from both internal and external experiences communicated to relevant personnel? Is the effectiveness of this communication measured? — Are there efforts in the organization to identify the issues with respect to implementation? Does the organization have the management commitment & the resources to implement the programme?	— Communicating the purpose and importance of the programme for the nuclear industry and creating awareness among personnel is key to success. Management support and commitment are key to sustain the programme successfully. — Deploy a network of lessons learned experts within the organization that can provide support to others to implement the process. — Managers, leaders and supervisors in the organization demonstrate as role models to inculcate the right behaviours of sharing/reporting experiences/issues. — Build on success!!
Monitoring and evaluation	— Does the organization identify suitable indicators to monitor and evaluate the programme? — Do the indicators match the objectives of the lessons learned and knowledge management programme? — Are the indicators being monitored and evaluated periodically? — Are the lessons learned from analyzing the indicators used for making improvements to the programme? — Do you benchmark other organizations to identify opportunities for improving your programme?	— Section 3.2.6. provides guidance for setting up a useful performance monitoring programme. It can be used to set the right indicators. — Benchmarking other organizations to understand the successful and useful ways and practices helps towards continuous improvement. — Transparency is the key factor for an efficient process and sponsoring.

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ANNEX I.

ELECTRICITE DE FRANCE, FRANCE

I-1. INTRODUCTION

Operational experience is a general process of learning from past events in order to improve the future and includes to:

- Collect information on anomalies, deviations, incidents, accidents, good practices;
- Search for causes and contributors;
- Learn the lessons;
- Set up correction (corrective and/or preventive) or improvement actions;
- Capitalize on the lessons learned from the analysis.

It is a process of continuous improvement allowing to strengthen the know-how, the control on the activities and the control on the results.

EDF is currently engaged worldwide in the construction of several EPRs, which are at different project phases. Two are in operation in China (Taishan 1 & 2), two are within the commissioning phases in Finland (Olkiluoto 3) and France (Flamanville 3) and two are in the construction phase in the United Kingdom. Furthermore, some EPR projects are under development as shown in Fig. I-1.

FIG. I-1. EPR projects worldwide.

Through the design, procurement, construction and commissioning of these EPR projects, several positive and negative experiences were made. It is considered to be of the utmost importance to capture and integrate these operational experiences in order to:

- Improve safety;
- Secure the project costs and schedules;
- Prepare the upcoming projects.

For this reason, a dedicated operational experience project for new builds was created to enhance the existing lessons learned process.

I-2. DESCRIPTION OF THE EXPERIENCES AND LESSONS LEARNED PROGRAMME

As shown in Fig. I-2, from the beginning, the lessons learned programme is structured around three key missions to support the projects and engineering entities as described below:

- To deliver quickly (short loop) the operational experience to the projects (pushing the lessons learned to other projects) through:
  - Detecting notable events whose lessons can be transferred to others;
  - Informing the other projects about these events and propose short-term improvements;
  - Quickly sharing the good practices between the different actors;
  - Supporting the RCA;
- To manage the high-stakes operational experience for interested projects (pulling the lessons learned from the projects) through:
  - Defining the high-stakes operating experience themes based on the project and engineering entities requests. Such high-stakes operating experience usually have a high impact in terms of safety, performance or risk mitigation;
  - Driving the production and integration of this high-stakes operating experience, by establishing internal orders between project's service providers and receivers;
- To manage the digital transformation of the new nuclear operating experience to operate a modern operating experience (information) system integrated within our engineering sequences & project activities, serving the performance of new nuclear engineering through:
  - Capitalization of information: operating experience data (such as events, findings, non-conformance, good practices) collected massively and systematically in all processes & project phases to build a broad knowledge base;
  - Treatment and integration of the lessons learned: Processed tools to guide step by step.

Some of the key features and benefits derived are:

- Producing multilevel analysis to learn the lessons;
- Defining and monitoring of the implementation of improvement plans through:
  - Short term solutions;
  - Evolution of processes, standards, products;
  - Arrangement of operating experience sharing (operating experience data and analysis disseminated & accessible for all engineering units);
- Collaborative platforms facilitating experience-based exchanges between communities.
- Easy & fast access to information at the right time for engineering units (push & pull) through:
  - Digital monitoring of the implementation of the new nuclear operating experience.

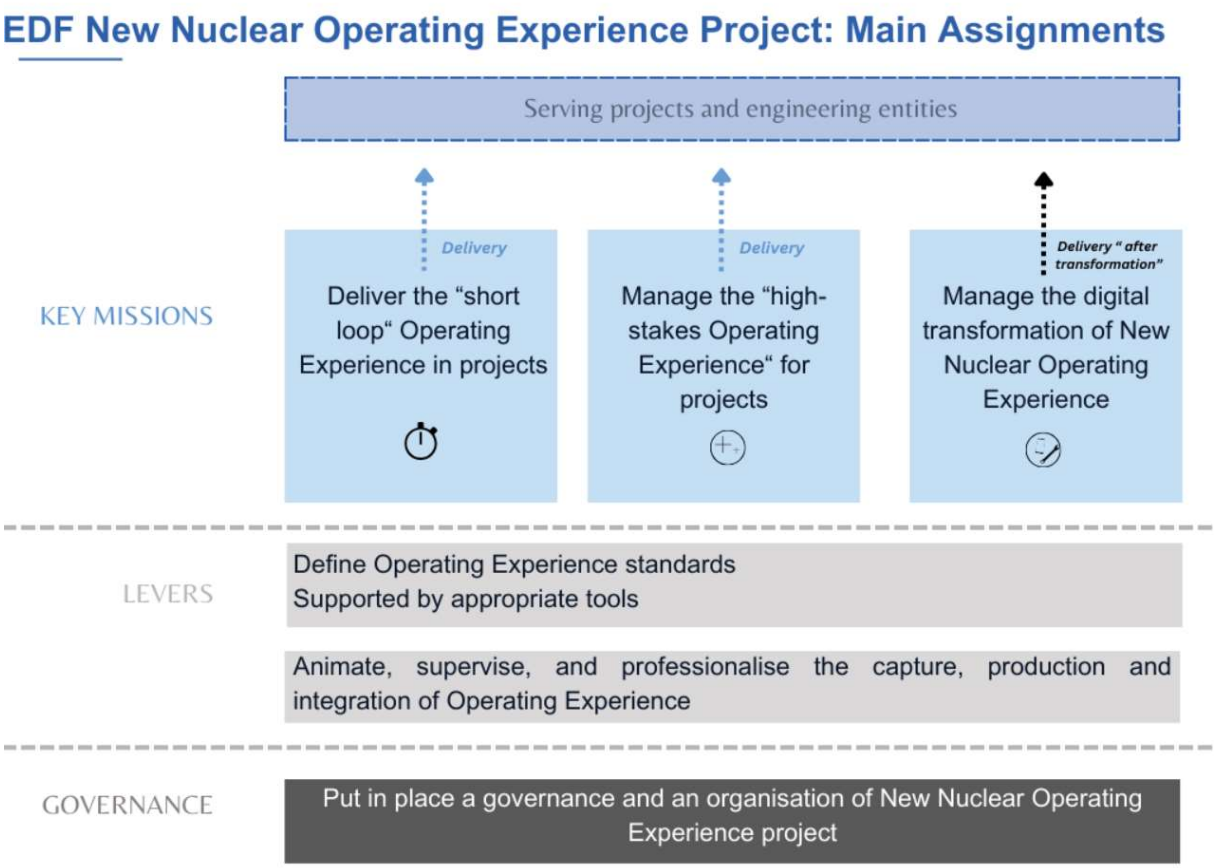

FIG. I-2. EDF New nuclear operating experience project: Main assignments.

Finally, as shown in Fig. I-3, the EPR Owner Operators Group (EPROOG) has been created in order to:

- Collectively address evolving safety requirements and strategies to meet them;
- Forge robust relationships foreseeing partnership opportunities in co-development projects;
- Promote good practices and lessons learned for efficient EPR implementation engineering, construction, commissioning, pre-operation;
- Share operator's knowledge and experience for boosted EPR operating performance.

FIG. I-3. EPROOG: EPR Owner Operators Group.

I-3. CONCLUSIONS

EDF's new nuclear operating experience project strengthens the integration of operating experience from EPR projects by mobilizing all current and future EPR project and engineering entities of the new nuclear division.

ANNEX II.

KOREA HYDRO AND NUCLEAR POWER, REPUBLIC OF KOREA

II-1. INTRODUCTION

Korea Hydro & Nuclear Power (KHNP) was established in 2001, as the result of a corporate spin-off from Korea Electric Power Company (KEPCO). Although the history of KHNP is less than 20 years, construction and operational experiences have been accumulated since 1970s. KHNP has developed several programmes in order to systematically manage procedures, guidelines, and operating experiences.

The NPPs are aging, experienced employees are retiring or nearing retirement age. Mid-career staff turnover as well as the entry of new staff challenged the management of business know-how acquired through experiences. Additionally, there was a lack of motivation and systematic approach for experienced individuals to transfer critical knowledge to others. This is the main contributor for missing the opportunity for converting tacit knowledge into explicit knowledge.

As the existing knowledge management programmes in KHNP were mainly focusing on explicit knowledge such as data accumulation from work processes and the analysis of operating experiences, KHNP has established a strategic plan to create and share intellectual assets from the tacit knowledge in the organization in 2015. This plan included a systematic approach to create and share knowledge as shown in Fig. II-1.

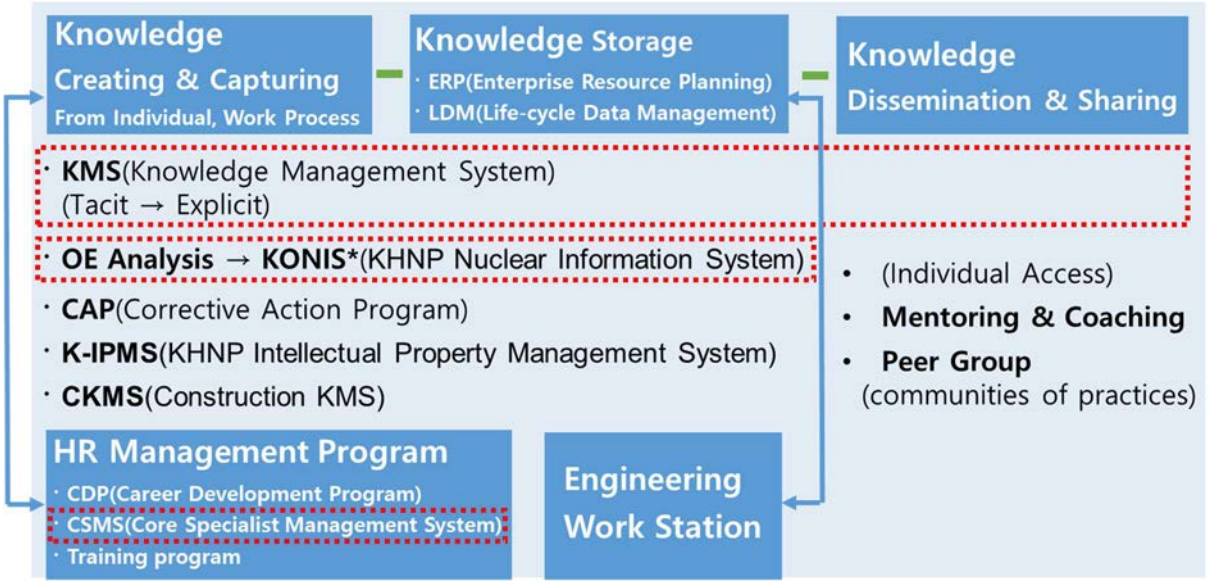

FIG. II-1. Overview of KHNP knowledge management programmes.

II-2. DESCRIPTION OF THE EXPERIENCES AND LESSONS LEARNED PROGRAMME

II-2.1. Knowledge Management System

To effectively create and share intellectual assets from the tacit knowledge in the organization, KHNP investigated current issues of knowledge management and decided to establish a new knowledge management system (KMS), which is focusing on utilization of tacit knowledge.

KHNP has developed a KMS aligning with the company's long-term management strategy. There are three areas to establish a KMS including organization, system, and contents. Detailed information of each area are described below. Figure II-2 shows three important areas to develop a KMS.

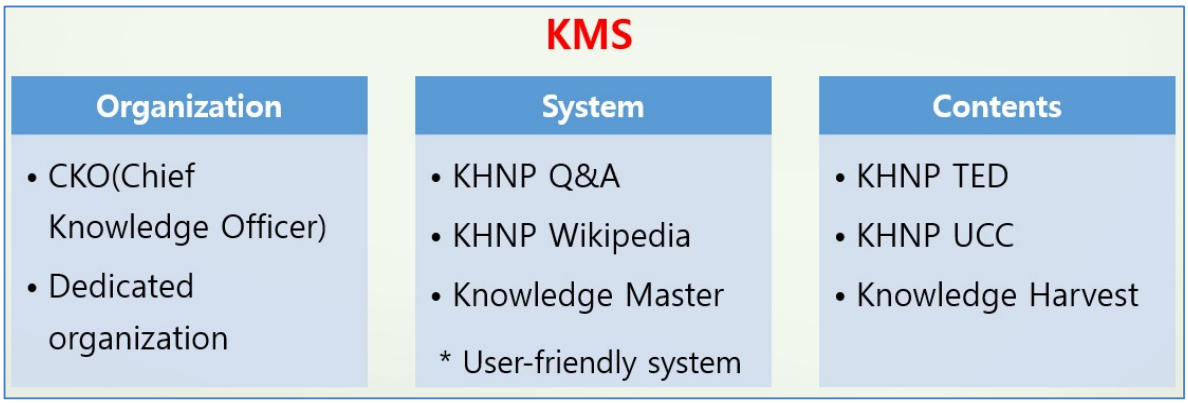

FIG. II-2. Three areas for developing KMS.

To develop a KMS, KHNP firstly benchmarked both government organizations and other companies in 2015. Government organizations included utility companies such as those for electricity and water. One of the private companies to benchmark was Samsung SDS, which specialized in cloud services and knowledge management in Korea. Secondly, KHNP developed a web-based system on the intranet and manuals to operate the system. After developing a KMS, KHNP held a briefing session to introduce the KMS to all employees. To attract many users at the initial stage, KHNP held promotional events and rewarded those who actively participated with additional mileage. Lastly, the company conducted an effectiveness evaluation of this programme in 2019. Figure II-3 shows the milestones of the KMS development.

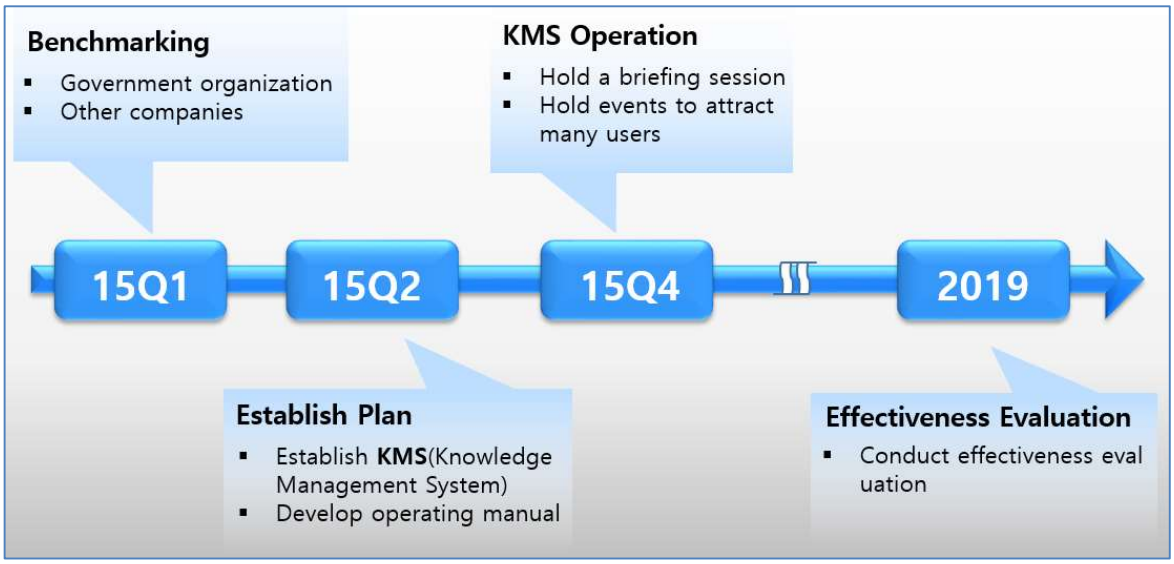

FIG. II-3. Milestones.

The KMS consists of three areas including organization, system, and contents. Organization includes human and organizational resources to operate and manage the KMS. The system is a web-based programme on the intranet providing several essential functions. The content offers interesting items to attract many users. The details are described below.

A dedicated organization was required to properly operate and manage the KMS. KHNP established both the contents management team and the system & security control team operating under the Chief Knowledge Officer (CKO). The roles and responsibilities of the CKO are to promote and utilize systematic knowledge management. The Executive Vice President of the strategy division was nominated as CKO. Figure II-4 shows an organization chart of the KMS.

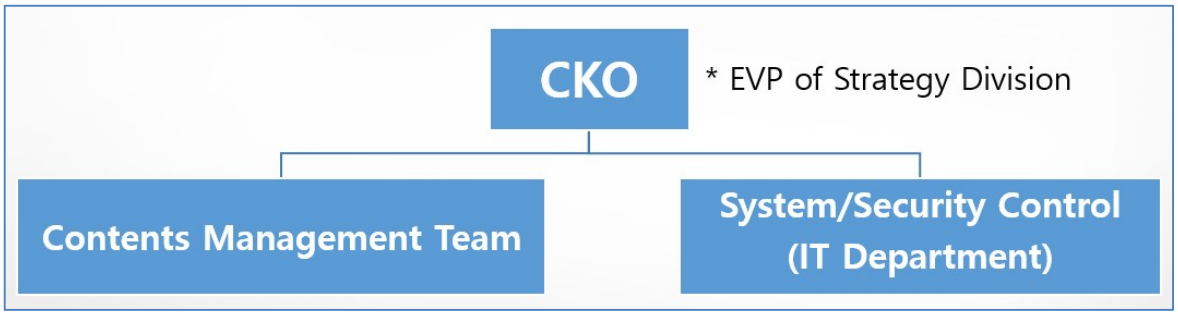

FIG. II-4. Organization chart.

To design the KMS on the intranet, several essential functions were needed to utilize tacit knowledge. Firstly, KHNP created a web page for employees to ask and answer work-related questions. As most tacit knowledge was not embedded in the procedures and guidelines, encouraging Q&A sessions was the priority on this programme. The company benchmarked NAVER, which is Korea's favourite portal. Secondly, the company created a KHNP Wiki on the web page in order to effectively share know-how of tasks by benchmarking Wikipedia. The last essential function was the selection of knowledge masters. There are two to three masters in each area who were offered financial (mileage) or non-financial compensation. All essential functions on the web were designed as a user-friendly system. Figure II-5 shows the configuration of KMS on the web.

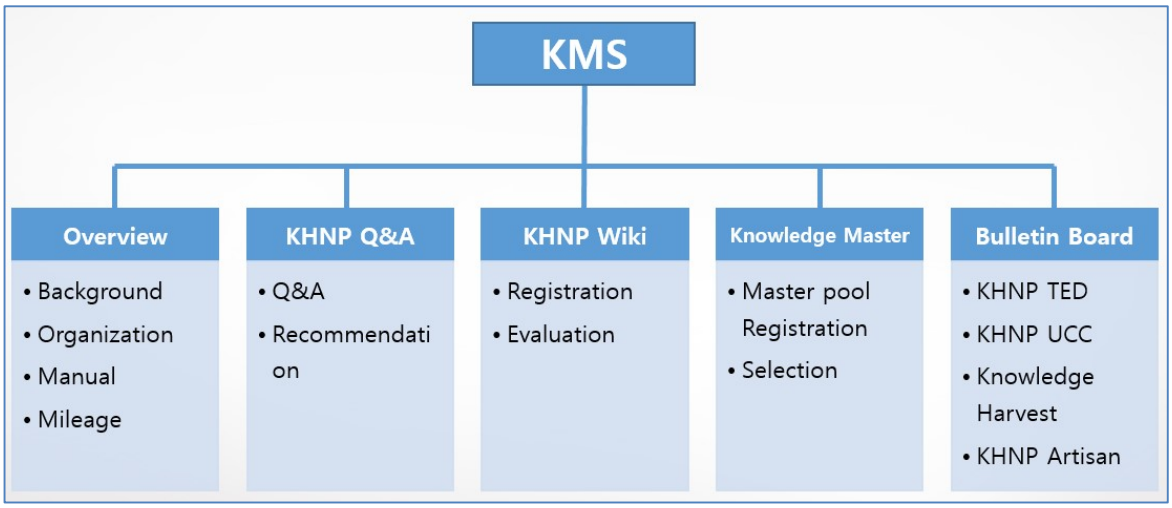

FIG. II-5. Configuration of KMS on the web.

The last area of KMS is content, which is essential to attract users. KHNP added several interesting items to the content. The first content is KHNP TED (Technology, Entertainment, Design) providing individual lectures like TED to share valuable information. It also benchmarked TED. The second content is KHNP UCC (User Created Content). KHNP encouraged employees to make videos of their own skills and know-how to share with others. The third content is knowledge harvest to prevent loss of know-how from retirees. It is very useful to improve new employee's competencies through know-how training. The last content is KHNP artisan, which is the selection of employees with outstanding knowledge and skills in particular areas such as experts on presentation skills, taking photos, playing musical instruments, painting, etc.

II-2.2. KHNP Core Specialist Management System

Furthermore, to manage human resources effectively, KHNP created the Core Specialist Management System (CSMS), which is a management programme of core specialists in the company such as SMEs and engineers. One of the reasons to establish CSMS was to maintain core expertise even in a situation of position turnover across the fleet. Although various systems exist in KHNP, consistent and systematic management is required to be in line with career development systems and principles. The purpose of CSMS is to identify the organization's core competencies and to foster strategic core human resources for corporate competitiveness and long-term growth. So, KHNP integrated the existing in-house expert system in 2018 to foster professional human resources systematically.

The process of CSMS is divided into the following five steps:

— Select core tasks;
— Pool of candidates;
— Select experts;
— Activities;
— Evaluation.

The detailed information of each step is described in Fig. II-6.

FIG.II-6. Process of CSMS.

II-3. CONCLUSION

KHNP KMS provides an internal platform for employees to share their knowledge from unique experiences as well as to facilitate on-line discussion.

In the early stage of KMS operation, employees participated quite actively in the programme thanks to promotional events, but the number of shared knowledges has gradually decreased. After operating the KMS for 3 years, KHNP conducted an effectiveness evaluation in 2019.

According to the result of the evaluation, several weaknesses were identified. Since answering questions on the KMS was not mandatory for knowledge masters, it usually took about 1 month to receive answers. Additionally, some content of anonymous answers undermined credibility. Outcomes from KMS were poor compared to the number of KMS visits. For example, the monthly visit on KMS was about 1,800 times, however the number of Q&A and shared knowledge was less than 20 and 5 items respectively. The quality of shared knowledge was not sufficient for personnel to gain unique experience, which may have caused the lack of users' interest. Motivation and encouragement need to be reinforced to identify, collect and share critical knowledge from experiences across the fleet.

Currently, as there are similar systems in KHNP such as KONIS (KHNP Nuclear Information System), K-IPMS (KHNP Intellectual Property Management System), CKMS (Construction KMS), their integration or consolidation need to be considered to organize knowledge in an effective and more structured way.

ANNEX III.

NUCLEAR POWER CORPORATION OF INDIA LIMITED, INDIA

III-1. INTRODUCTION

Nuclear Power Corporation of India Limited (NPCIL) is a Public Sector Enterprise under the administrative control of the Department of Atomic Energy (DAE), Government of India. NPCIL is responsible for the design, construction, commissioning and operation of nuclear power reactors. NPCIL is presently operating twenty two commercial nuclear power reactors with an installed capacity of 6780 MW. The reactor fleet comprises of two BWRs, eighteen PHWRs and two VVER type PWRs. Currently NPCIL has eight reactors under various stages of construction totaling 6200 MW capacity. NPCIL was formed in 1987 and through interaction with International Organizations such as IAEA, WANO and COG realized that operating experience is a valuable source of information for learning and improving the safety and reliability of NPPs. The use of operating experience is one of the important aspects of plant safety culture and its timely use can prevent occurrence of adverse events. NPCIL launched its operating experience programme for using both internal and external experiences. It defined roles and responsibilities to personnel within the organization to manage it. It started in a modest way and then used digital information technology to improve it. This ensured timely dissemination of operating experience to all concerned personnel and implementation of corrective actions. There were also various sub- programmes introduced with time to enhance the effectiveness.

NPCIL realized the need for a wider programme encompassing knowledge management with the operating experience programme being a sub-set of this wider programme. Teams were constituted under the leadership of senior management for revisiting existing processes and procedures for knowledge management, learning, training and qualification activities and finalization of new processes /procedures for the NPCIL workforce. The focus was on:

- Enhancement in effectiveness of existing work practice of information exchange and learning;
- Development and implementation of KMS/tools for knowledge capture and dissemination programmes;
- Capturing and disseminating new knowledge elements for newly added reactor technology;
- Automation of new work practices to capture knowledge elements at their source;
- Monitoring of knowledge dissemination and information development programmes.

The organization structure was changed with the inclusion of a Knowledge Management Group. This group included dedicated individuals for managing, monitoring and evaluating the various aspects of knowledge management. The established knowledge management programme aims to conserve and disseminate the knowledge which has been gained over a period of more than 50 years involving construction, commissioning, and operation of plants with different technologies.

III-2. EXPERIENCES AND LESSONS LEARNED PROGRAMME OF NPCIL

NPCIL’s experiences and lessons learned programme is covered by several programmes such as a station operating experience management programme and ‘flash’ reports.

III-2.1. Operating experience sharing programme at stations

The NPCIL operating experience programme is designed for timely sharing and using both internal and external experiences. It has guidelines issued by the corporate office for the entire fleet describing its governing principles and the programme. In detail, it describes the process of screening, evaluation, implementation and effectiveness review methods as well as roles and responsibilities.

Each station receives in-house or external operating experience either through a corporate office or direct access to the website and has an Operating Experience Review Committee (OERC). The screening is coordinated by the Member-Secretary of OERC and conducted by subject experts from various departments generating operating experience feedback reports. OERC meets at least once a month and reviews the operating experience feedback reports. The committee records the conclusions and sends it to group heads and section heads for actions at their end. The proposals accepted by OERC are monitored and reviewed quarterly by a higher-level committee named the Station Operation Review Committee (SORC) for effectiveness.

The operating experience of worldwide NPPs including NPCIL are screened and evaluated with respect to their potential to affect:

— Nuclear safety;
— Personnel safety;
— Plant reliability;
— Relevance to the station.

The operating experience inputs are obtained from any of the following sources:

— IAEA's Incident Reporting System (IRS);
— WANO;
— COG;
— Flash reports of NPCIL stations;
— Significant events of NPCIL stations;
— Modifications of other stations;
— Radiological overexposure investigations reports;
— International and internal industrial safety events.

The actions based on the relevant operating experience may be any of the following:

— Dissemination of information;
— Procedural change;
— Formal training;
— Changes in surveillance frequency or method;
— Corrective action in field;
— Adoption of a new practice;
— Minor modifications required;
— Major upgrades.

The operating experience programme operates through a web based computer programme called Operating Experience Management. Processing of operating experience documents by various agencies is performed in electronic format. An online operating experience document movement system is established to track the status of each document from the time of receipt

and registration to final dissemination/disposal time. The programme has the following features:

- Provision exists to transfer operating experience documents through system;
- Filters are available to view the status of operating experience documents;
- Transfer and reminder emails are auto generated for operating experience review/dissemination.

Some of the initiatives that contribute to the success of NPCIL's operating experience programme are:

- Monthly sectional level discussion meetings in operation and maintenance sections;
- Line management training for operating experience dissemination through line managers;
- Operation crews conducting monthly crew meetings for discussing the latest operating experience among crew members;
- One day operating experience information dissemination (OEID) programme arranged by the station training centre;
- Briefing of station operating personnel about the relevant operating experience during the simulator training;
- Training on operating experience as an integral part of induction training, refresher training and licensing and qualification programme;
- The Health, Safety and Environment (HSE) department at headquarters, which issues operating experience reports to all stations and projects with a focus on industrial safety. The source of the operating experience may also be a non-nuclear industry event.

The knowledge about operating experience is also checked during interviews conducted for licensing and qualification programmes or interviews conducted for promotion to higher positions. This also works as a feedback mechanism to the operating experience programme.

III-2.2. Flash report management system

To disseminate information about a unit outage or safety significant event, an online flash report management system has been developed in-house and implemented in NPCIL, which enables prompt sharing of operational events and learning points among NPCIL stations. The affected station provides the information to Directorate of Operations within 24 hours of its occurrence. A flash report is issued after approval by the Executive Director/Director (Operation) and distributed to all the operating stations.

Thereafter, based on event analysis, the corporate office issues final recommendations to all stations for taking appropriate preventive actions to avoid a recurrence of similar events.

The flash report recommendations contain a brief description of the event, actions taken, analysis of the event and recommendations in the form of actions to be taken by all/applicable stations. The flash report is displayed on the NPCIL web page, which is accessible to all employees.

Prompt information allows stations to take timely corrective actions to prevent recurrence of the event in the fleet. Stations are expected to take recommended actions and provide feedback on the identified action items applicable to them within 15 days from the date of issue of the flash report recommendations to the Executive Director /Director (Operation).

III-2.3. Knowledge management at NPCIL

The knowledge management group of NPCIL is based at the corporate office of the headquarters and manages and conducts activities to establish and enhance knowledge management aspects of the fleet. At corporate level, the programme focuses on sharing and preservation of knowledge related to change in design, significant lessons learned, international experience and insights into various aspects of the entire life cycle.

To ensure knowledge collection and dissemination, a corporate portal has been established known as PRITHVI with a specific knowledge management corner.

III-2.4. Fleet wide platform: PRITHVI

PRITHVI is a common fleet wide interface for knowledge and information exchange for NPCIL related activities. It is an intranet portal that is accessible for all operating stations, construction projects, and headquarters. It allows function related information input by employees for ongoing construction projects and operating stations. It also acts as the interface for relevant national and international websites. It allows management of a large knowledge base and knowledge elements generated through learning from experiences, lessons learned, training and qualification processes.

The knowledge management group at headquarters along with training centers at the plant sites ensures the:

— Identification, development and management of technical, managerial and organizational knowledge including experiences in the area of nuclear power generation;
— Design and development of procedures including course curriculum, required for imparting extensive initial training to new engineers or refresher training to experienced engineers at nuclear power projects and stations with particular care taken to include experiences and lessons learned into the curriculum;
— Management and controlled distribution of published documents in Technical Knowledge Resource Centre (Library);
— Development of knowledge management tools including web-based automated tools, e-learning and training packages, etc.;
— Transformation of tacit knowledge gained by experienced and retired workforce into documents that can be referred to later so that the knowledge is not lost with the departure of that workforce.

III-2.5. Other major experience-based learning programmes

Lecture series by domain experts

Domain experts from different areas of specialization conduct series of lectures addressing their past experiences and how the same have been addressed for future use. The subject coverage of lectures depends on the level of the audience. To evaluate effectiveness, a feedback session along with a quick assessment session is also conducted towards the end of the programme.

For arranging the programme, efforts are made to identify areas which require strengthening. This is achieved either through input from the employees or based on the operating experience programme. Subsequently, domain experts are identified who have been actively working on the subject matter and are familiar with the details of the subject.

Discussions on hot topics

Discussions are organized periodically on topics or areas of concern involving all concerned persons from both headquarters and stations. The area of concern is identified based on several similar events occurring at different stations within the fleet. Discussions may be held through physical or virtual meetings. For example, if there are several events related to the ventilation system at more than one station, a meeting is organized to share concerns, best practices or procedures of other stations and come up with solutions for the fleet.

Document series

Documents are generated by senior personnel/domain experts in consultation with the knowledge management group to document and preserve the knowledge that has been gained over the years by means of experiences, lessons learned, problems encountered and the necessary remedial actions implemented. This method proved to be quite effective in sharing and preserving tacit knowledge which has been gained over years of practical experience in different areas related to various stages of NPP design, construction, commissioning and operation. The main focus of these documents is to streamline the knowledge which is primarily related to the design stage of the plant and certain aspects which are applicable for stations across the fleet.

For preparation of these documents, persons having sufficient knowledge in their area of expertise are identified. In addition, persons having worked in the same area are identified who are associated with the domain experts in order to ensure that all critical information is captured and can be utilized by other personnel in the future.

To achieve a timely outcome, a schedule is prepared to assure that certain working hours are dedicated towards preparation of these documents without impacting initial functions.

Low level event management system

For several years, NPCIL NPPs depended on the analysis of events and significant events to get critical information to feed the organizational learning loop. However, operating performance of NPPs improved and the number of reportable events in NPPs came down. Due to the reduced number of events, latent shortcomings in the work practices or plant conditions remain undetected. It was realized that the cumulative effect of these latent shortcomings or LLEs can result in the slow decline in safety performance of NPPs.

To address latent weaknesses, which may be precursors to significant events and are often exhibited as LLEs, NPCIL set up an LLE management system to ensure organizational learning. The system has the following features:

— LLEs include all deficiency reports (DRs) except those related to preventive maintenance or condition monitoring. LLEs may cover deficiencies related to material condition, housekeeping, job observations, audits, corporate peer review (CPR), CPR follow-up review, etc. Near misses are reported in the LLE system;
— Corrective action management system (CAMS) software has several modules including an LLE module. LLEs can be identified and fed into the software module by all station personnel;
— An LLE coordination committee, which is constituted at each station with a convener, sectional LLE coordinators and a member-secretary. This committee meets at least once a month to review all LLEs reported during the month;

— A quarterly report on the review and analysis of reported LLEs in the quarter, which is prepared and presented to the station management. The trend, analysis, actions taken and its effectiveness is reviewed in these meetings. The presentations made in the meeting are based on trend analysis of category/sub-category of LLEs. The generic issues identified during the reported quarter are discussed in the meeting. These issues are communicated to all concerned agencies for taking corrective actions;
— A fleet wide LLE report, which is issued annually by the headquarters, covering all aspects of the programme with trends and analysis.

Regular campaigns conducted by the stations on the generic issues for creating awareness among the plant personnel. The duration of each campaign may be monthly or quarterly. The campaign may involve displaying topics and slide shows on the station intranet, placing posters at prominent places in the plant, holding discussions during meetings, coaching by line managers during field visits, etc.

Figure III-1 below shows the trend of LLE identification in the entire fleet:

FIG. III-1. Trend of LLEs.

Note: The LLEs increase in recent past is due to various reasons including addition of new Units.

III-3. CONCLUSIONS

A robust operating experience programme using a digital information management system ensures the experiences and learnings are utilized in a timely manner. It prevents recurrence of events and drives improvements based on better practices of other stations. It also ensures optimization of resources.

Capturing the experience of domain experts through talks, lectures and documenting their knowledge goes a long way in conserving valuable knowledge for use by future generations.

LLE management plays a vital role in capturing lessons learned to prevent the occurrence of significant events.

ANNEX IV.

ROSENERGOATOM, RUSSIAN FEDERATION

IV-1. INTRODUCTION

Rosenergoatom, the NPP operating organization in the Russian Federation, implemented knowledge management as a system. The purpose is to increase operation and economic efficiency with the use of intellectual capital.

Realizing that intellectual capital is the foundation for creation and protection of the organization's values, the management has implemented the knowledge management policy in the Electric Power Division (by Order of Concern No 9/961-P dated July 13, 2017). The Policy promotes initiatives, procedures and tools to make full use of the organization's intellectual capital.

To improve the KMS, the document 'Regulation in the KMS in JSC Concern Rosenergoatom' was introduced (by Order of Concern No 9/1560-P dated November 14, 2018). It establishes the goals and objectives of the KMS, basic principles and approaches applied, requirements for its structure, functions and responsibilities.

The above documents constitute the fundamentals of knowledge management in Rosenergoatom, which are followed by all branches and subsidiaries when implementing their own projects.

When analyzing Rosenergoatom's approach to knowledge management activities it might be concluded that an integrated approach is applied that combines all main methods in the field of knowledge management recommended by the IAEA, the methods of ROSATOM, as well as its own developments.

The following sections present examples of successful implementation of knowledge management programmes in the organization in the period 2018-2021.

IV-2. PRESERVATION OF CRITICAL KNOWLEDGE OF THE PERSONNEL

To preserve critical knowledge of the organization's personnel in accordance with the 'Procedure for preserving critical knowledge of personnel' POR-UID.06.03.03, the following activities are held annually.

IV-2.1. Identification and prioritizing the areas

Identifying and prioritizing the areas where personnel critical knowledge preservation will be carried out is an important exercise. The following areas are identified as priority for the period from 2018-2021:

- Instrumentation and control;
- Chemical technologies;
- Radioactive waste handling;
- Equipment maintenance;
- Internal inspections and labour safety;
- Ensuring of safety and reliability of NPPs;

— Nuclear fuel consumption modes;
— Nuclear safety monitoring;
— Operation;
— Safety system modernization based on diversity principle to prevent common cause equipment failure;
— Ensuring of safety and reliability of NPP hydraulic facilities;
— Ensuring safety of refuelling at VVER-1000 units;
— Modernization of equipment for shielding of the working rod middle section of the refuelling machine in order to increase safety during adjustment, maintenance and repair of the first section;
— Independent nuclear oversight;
— Fire safety;
— Operation of electrical equipment;
— Provision and implementation of personnel training;
— Training on full-scope simulator of main control room (MCR) operators and reactor shop personnel;
— Analysis of NPP operation in grid frequency control mode;
— Electricity metering system;
— Management of operations.

IV-2.2. Identification of individuals possessing critical knowledge

For identification of individuals and their critical knowledge retention, questionnaires, structured interviews and knowledge mapping technique are used. The results include:

— New or updated technical documents;
— Normative documents;
— Training materials;
— Memos on non-standard situations;
— Software tools;
— Databases.

When the formalization process is completed, documented knowledge becomes a part of the organization's regular document flow.

IV-2.3. Transfer of critical knowledge

Individuals holding critical knowledge are recruited as mentors for promising young workers and as part-time instructors.

To improve the quality of work and maintain a highly qualified workforce, employees are trained in materials included in documented critical knowledge.

To retain knowledge, NPPs develop local documents in the field of knowledge management that are adapted to their needs, for example 'Regulations on the organization and conduct of work to preserve critical knowledge on Kalinin NPP personnel' 00.--.PL.0020.58.

Critical knowledge retention activities are acknowledged as 'particularly important' and are included in key performance indicator (KPI) cards of responsible employees.

A number of the organization's branches (NPPs) provide one-time bonuses to knowledge experts for mentoring.

To motivate personnel for ‘knowledge sharing’ knowledge management activities are covered in media (e.g., articles in newspapers, TV and radio broadcasts).

At annual meetings, interested parties from all organization’s NPPs share their best practices and experience in knowledge management (e.g., a questionnaire for interviewing critical knowledge experts, developed by Balakovo NPP psychological support specialists).

IV-2.4. Mentoring

The mentoring process in Rosenergoatom is planned and organized according to methodology guidelines for the development of mentoring system in ROSATOM, The State Atomic Energy Corporation.

The following types of mentoring are used effectively for:

- Newly hired young workers – mentoring contributes to their effective adaptation;
- Interns – based on the results of internship the most promising students are selected for staffing;
- Transfer key knowledge and skills – helps to minimize the risk of critical knowledge loss, e.g., due to retirement of key personnel;
- Participants of development programmes – ensures security of critical positions.

IV-3. INFORMATION TECHNOLOGY FOR KNOWLEDGE MANAGEMENT

A software package IPPK6 ‘Preservation of critical knowledge’ was implemented and put into commercial operation within the organization, which automated the below knowledge retention process stages:

- Determination of priority areas for critical knowledge preservation;
- Appointment of employees responsible for critical knowledge preservation process;
- Elaborating the list of critical knowledge experts;
- Risk assessment of knowledge loss;
- Planning knowledge preservation activities;
- Identification of critical knowledge and knowledge map visualization;
- Planning of related tasks with establishing deadlines, responsible employees and control over work performance;
- Preparing reports on knowledge management implementation.

All employees involved in knowledge management activities are notified through the automated software package which ensures full involvement of managers and employees. It tracks the implementation of planned activities and generates and coordinates reporting documents for all stages of the knowledge management process at NPPs and headquarters.

IV-4. EFFECTIVE USE OF OPERATING EXPERIENCE

The goal of the operating experience programme is to effectively and skillfully apply the lessons learned from industry and personal experience to improve safety and reliability of an NPPs operation. Effective use of operating experience includes reviewing both own (internal) and industry (external) experience to reveal weaknesses and to develop plant specific corrective actions which will minimize the likelihood of similar events occurring.

Operating experience information is a significant and valuable contribution to operational safety and reliability. Therefore, appropriate guidelines and procedures are developed for analysis and competent personnel and other resources are provided for its application.

Below are examples of an effective operating experience programme in Rosenergoatom.

IV-4.1. Use of World Association of Nuclear Operator's programmes

The WANO operating experience programme allows the use of operating experience of other NPPs. In particular, it informs about events occurred at other plants and assists personnel in taking appropriate measures to prevent the repetition of similar events at their NPPs.

The WANO technical support and exchange programme allows the exchange of information to improve reliability and safety. This programme consists of four activities: sharing good practice, exchange visits, NPP performance indicators, technical support missions.

WANO technical support missions are conducted annually in a number of the organization's branches on various topics.

IV-4.2. Use of industry-wide system for analysis and use of operating experience

The system constitutes and organizes a set of processes and resources of Rosenergoatom, such as providing, collecting, storing, processing, analyzing, and disseminating information and drafting feedback on operating experience.

The goal of the system is to effectively use the lessons learned from internal and external operating experience to improve safety, reliability and efficiency of NPP operation.

A plant-level operating experience programme allows the use, preservation and sharing of operating experience in each subject area combined with knowledge, skills and abilities of qualified workers and SMEs.

IV-4.3. Practical skills training during full-scope simulator training sessions to consolidate and transfer operating experience

Full scope simulator (FSS) instructors review events from operating experience in which operation disturbance occurred due to human errors. They analyze these events and develop step-by-step scenarios how to conduct operation in order to avoid such mistakes. Based on this, An FSS training scenario is developed, and, after the training material is approved, initial and/or continuous training is carried out to consolidate skills and knowledge of plant personnel.

IV-4.4. Use of operating experience in continuous training of operating personnel

A procedure for analysis and use of operating experience has been developed in the organization. It is applied by NPP training center personnel for training programmes, continuous training programmes and training materials. The main steps of the procedure are as follows:

— Registration and review of all documents received by training centres on operating experience, incidents at NPPs (including international and national industry experience);
— Rating of received information by importance and applicability at a particular NPP;

— Changing (when necessary) of training programmes/continuous training programmes, training materials;
— Development of new or revision of existing training materials taking into account the selected operating experience information;
— Conducting classroom training and/or simulator training using operating experience information.

As a result of applying this procedure, initial and continuous training programmes are being updated taking into account the selected operating experience information messages which are important for reliable and safe operation of NPPs.

IV-5. CONCLUSIONS

Based on the considered knowledge management examples, the following factors are the key for success of knowledge management programme implementation in Rosenergoatom:

— Use of the best international, domestic and industry practices in the field of knowledge management;
— Adherence to established rules, procedures, and documentation;
— Involvement of personnel at all levels of knowledge management activities;
— Management support to knowledge management initiatives including senior managers of the organization;
— Recognition of the value of intellectual capital;
— Effective use of operating experience;
— Use of knowledge management practices in personnel training system;
— Development of mentoring activities;
— Motivation of personnel involved in knowledge management activities;
— Development of IT infrastructure for automation and support of knowledge management processes;
— Systematic approach to identifying, retaining and preserving critical unique knowledge of personnel;
— Sharing experience and best practices in the field of knowledge management;
— Development and application of knowledge management practices in work processes.

The combination of the above key success factors contributes to achieving the main goal of the organization’s KMS – increase of operation and economic efficiency through the use of intellectual capital while ensuring safe and reliable operation of NPPs.

ANNEX V.

TOKYO ELECTRIC POWER COMPANY, JAPAN

V-1. INTRODUCTION

The most important lessons learned from Tokyo Electric Power Company (TEPCO) Holding's 2011 Fukushima nuclear accident were summarized in its 'Reassessment of the Fukushima Nuclear Accident and Nuclear Safety Reform Plan' as insufficient severe accident measures which rooted from the lack of the following 3 main issues: (1) safety awareness, (2) technical capabilities, and (3) ability to communicate safety issues with stakeholders. In order to fulfil the responsibility of Fukushima revitalization, TEPCO has pledged to promote nuclear safety reforms in accordance with our unchanged resolution to "Keep the Fukushima Nuclear Accident firmly in mind; Work towards a safer today than we were yesterday, and a safer tomorrow than today; we call for NPP operators that keep creating unparalleled safety."

To achieve this goal, a Nuclear Education and Training Center was established in 2016 to accelerate the development of education and training aiming for the world's highest level of nuclear safety. In addition to the technical oriented education and training facilities for specific technical knowledge and skills related to such areas in mechanical, electrical, radiation protection, etc., a new facility simulating hazardous work environment to experience directly the risk hidden in the work field was added in 2018. This facility also includes lessons-learned exhibitions related to past incidents or accidents to learn from mistakes and failures and never repeat them, including the Fukushima Accident.

V-2. DESCRIPTION OF THE EXPERIENCES AND LESSONS LEARNED PROGRAMME

Past incidents and lessons-learned exhibitions in the new facility are used during an annual gathering event for all personnel to be reminded, learn, or share thoughts of the past mistakes and to never repeat such mistakes. This is accomplished in a dynamic learning environment which uses the sense of seeing (via exhibitions), hearing (videos), touching (artifact), learning, thinking and discussions among all participants.

The following is a sample case of a station-wide learning event of TEPCO's past incident (8.29 Event Reflection at Kashiwazaki Kariwa Nuclear Power Station, 2018).

V-2.1. Purpose

The purposes of the 8.29 event reflection programme are to:

- To understand the issues surrounding the handling of regulatory inspection result, etc., by TEPCO's nuclear division (8.29 Event) and the significant impact caused by TEPCO to the Japanese society;
- Reassurance by all TEPCO Nuclear Divisions not to repeat similar incidences ever again.

V-2.2. Steps involved

The steps involved in the 8.29 event reflection programme are:

- Step I: Know what happened through videos and panel exhibitions;
- Step II: Learn the impact and time sequence through panels and quizzes;
- Step III: Hear what it was like back then through personnel interview videos;
- Step IV: Discuss what specific actions need to be taken now.

V-2.3. Description

The description of the 8.29 event reflection programme includes:

- Event reflection period is September to December 2018;
- Venue: Lessons-Learned and Past Trouble Exhibition Corner, Hazard Simulation Training Facility;
- Expected participants: All personnel of Kashiwazaki-Kariwa NPS: 1060 out of 1168 (90% attendance) personnel attended the programme.

V-2.4. Programme effectiveness (questionnaire results)

The results of the questionnaire on the effectiveness of the programme include that:

- With respect to the time allotted for this event: More than 80% answered appropriately;
- With respect to the content of the event (for achieving its objective): More than 95% of both administrative and technical personnel answered satisfactorily.

V-2.5. Key comments from the participants (questionnaire results)

Positive comments received:

- From watching videos: Able to understand better with the actual documents and videos;
- From watching videos: Actual experiences heard from involved personnel through videos were effective and resonated with my heart;
- From group discussions: It was good to hear about what they honestly think and how they see TEPCO's situation, especially from inexperienced, younger personnel;
- From personnel not working for TEPCO at the time of incident: Good to discuss what it was like to cope with the situation back then and effective to better understand what really happened;
- From participants: Excellent idea to do such reflections here and move away from the working office;
- From participants: Good support from Nuclear Education and Training Center personnel, especially on facilitating the group discussions;
- From participants: More than half of my group were not in TEPCO back then; need to learn continuously including the background, etc.;
- From a witness of the incident: Reminded me of what happened back then; also made me think to work in a way so that all personnel who will take over after me will not experience this again in the future.

Comments for improvement from participants:

- Can save more time if e-learning and videos were done beforehand;
- More effective if more stories from directly involved personnel of the incidents are shared;
- Difficult to hold discussions without a facilitator;
- Some technical information was difficult to understand for non-technical personnel;
- It is better to clarify expectations based on positions and roles.

Lessons learned from this event (by Nuclear Education and Training Center):

- Many employees who were working for TEPCO during the incident did not remember what happened. This may be due to the fact that the past reflections, which were expressed in the office by each group, were not done in an effective manner;
- Participants tend to be more interested in the background and the actual situation of the event than the general, superficial information of what happened;
- Leaders play key roles in how reflections are shared with subordinates (e.g., with enthusiasm, passion, etc.); facilitators sometimes play a key role;
- Group discussions allowed sharing of experiences and knowledge by senior managers; younger employees shared their honest feelings and impressions as they were much less involved;
- The level of depth of the discussion depends on a leader of the group. Thus, the group composition needs to be considered carefully and support has to be provided if necessary.

V-3. CONCLUSIONS

The 8.29 event, which occurred in 2002 was reflected every year in different ways in TEPCO. However, the last reflection described in the above case showed that in spite of the large social impact TEPCO made and annual company-wide reflection by each group, many personnel, including those who were working at the time of the incident, did not clearly remember sufficient details to transfer the knowledge and experience of this incident to the younger, inexperienced employees who were not working for TEPCO at the time. The above new reflection method of coming to the new facility that has exhibits and other supporting tools offers an opportunity to share experiences directly, discuss and brainstorm together on what went wrong and how in the future all new employees and veterans can work more effectively. The facilitator plays a key role in making sure that the discussions and learnings and findings by all participants are effective. The questionnaire results show that participants were satisfied of this reflection method which also proves that it was better use of time than the previous reflection methods.

ANNEX VI.

FRAMATOME, FRANCE

VI-1. INTRODUCTION

Capitalizing and reusing the knowledge from lessons learned is a major concern of Framatome, to continuously improve the quality, safety, and performance of our projects, particularly in the nuclear industry's long-term projects.

This case study is focused on European Pressurized Reactor (EPR) projects and aims to explain how Framatome' s lessons learned process works.

The lessons learned process has been running on EPR projects since 2007. It has been audited, optimized and relaunched by the knowledge management programme, initiated in 2017 by Framatome with the ambitious objective to become a benchmark in nuclear industry within 10 years.

The original approach of the EPR lessons learned process is to convert the lessons learned from events, activities and people experiences into online forms, which are processed and converted into reference material (e.g., standards, instructions, etc.). The lessons learned thus become explicit and reusable organizational knowledge.

VI-2. LESSONS LEARNED NETWORK

The lessons learned process is under the responsibility of a lessons learned process owner, relayed locally by a network of lessons learned delegates, set up in the organization's disciplines (e.g., piping, instrumentation and control, project management, etc.) and EPR projects to:

- Explain, guide and promote the lessons learned process locally;
- Manage lessons learned process for their unit;
- Report to management and knowledge management programme.

The realization of lessons learned relies on a network of knowledge owners, set up in the organization by a knowledge management programme to maintain the knowledge on a key domain (process, tool, discipline, etc.). Knowledge owners are in charge to develop and maintain a knowledge base.

VI-3. LESSONS LEARNED PLATFORM

An online platform has been set up and defined as a standard to gather EPR lessons learned. Standardizing the lessons learned tool provides key benefits such as:

- Speaking the same language and sharing the same structure (standard lessons learned template/metadata);
- Sharing knowledge more easily across units;
- Managing interface topics;
- Searching efficiently for lessons learned from a central database with standard filters and common search tool;
- Minimizing maintenance costs.

VI-4. LESSONS LEARNED PROCESS

The standard process to manage lessons learned on EPR projects as shown in Fig VI-1 is explained in detail below:

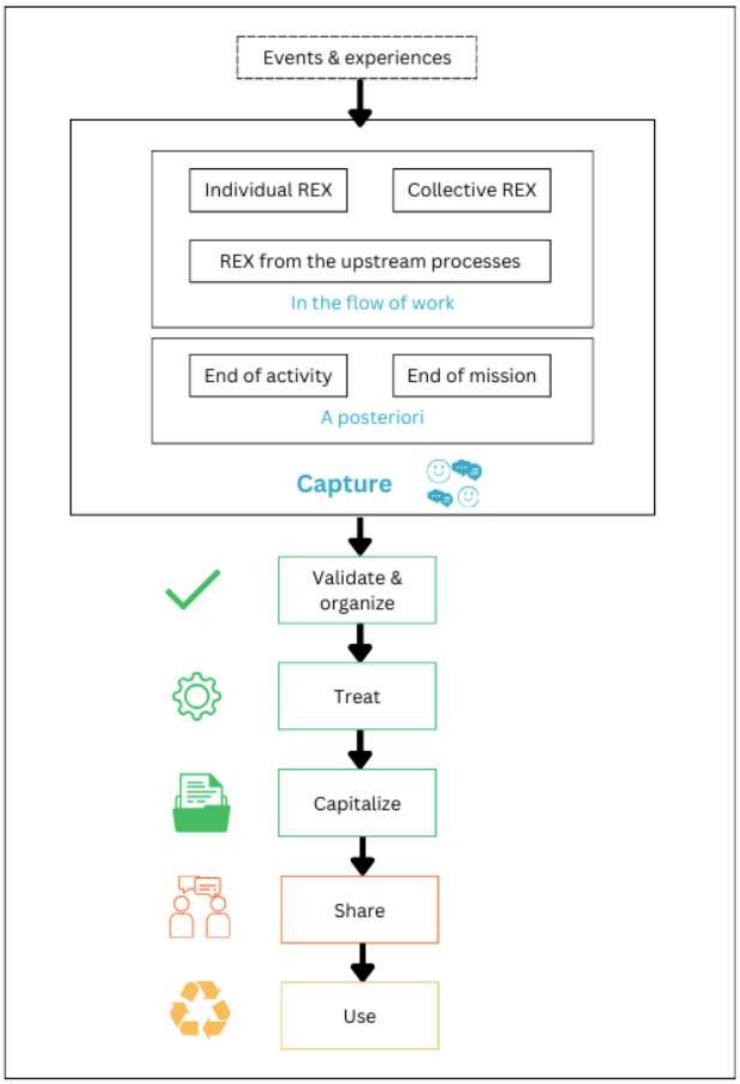

FIG. VI-1. Lessons learned process diagram.

VI-4.1. Capture

Lessons learned can be proposed by anyone at any time, but are preferably captured at one of the following key moments:

- When an employee ends a mission on a project or leaves a team, an interview is conducted by the manager of the entity to identify relevant lessons learned;
- When an activity or a project phase ends, through a post-job review meeting or a dedicated lessons learned brainstorming workshop.

A standard template is proposed to identify lessons learned topics, based on the following questions:

- Which significant events are to be captured?

— What went well (successes, good practices) and what can be learned from it so it can be repeated in future?
— What did not go well (difficulties, reworks, delays, etc.) and what can be learned from it, so it does not repeat in the future?
— What could be improved/optimized?

Lessons learned can also emerge from quality/safety events.

VI-4.2. Validation and organizing the information

Lessons learned are submitted through the lessons learned platform to the organization's lessons learned delegate of the unit. He/she organizes periodic lessons learned committees with internal stakeholders (e.g., experts, managers, knowledge owners, etc.), to:

— Analyze and validate the relevant lessons learned;
— Process the lessons learned: define the action plan and assign a task manager, priority level, and budget.

For dealing with issues that cut across many disciplines/departments, lessons learned transverse committees are also organized to manage interface or generic topics.

VI-4.3. Action plan

Each task manager completes the actions assigned to him/her. The lessons learned delegate initiates and coordinates a lessons learned action plan. Lessons learned committees make sure all lessons learned action plans progress in a timely manner.

VI-4.4. Capitalization

Lessons learned outputs are capitalized by the relevant knowledge owner(s) in the most appropriate location in their knowledge base(s). We thus ensure that lessons learned will be taken into account in all future activities and that the lesson is retained for a prolonged period in the organization.

The support to realize the lessons learned is often standardized (e.g., method, guideline, checklist, work instruction, etc.). Its development has been pushed by operational excellence and knowledge management programmes since 2017.

VI-4.5. Sharing

Lessons learned need to be shared by email or during weekly team meetings, but also in the form of presentations. Lessons learned can also be shared within the relevant community or during training.

VI-4.6. Use

To close the loop of the lessons learned process, the knowledge gained needs to be applied to current/upcoming activities. As lessons learned are centralized in a unique database, it is easy to find them by using advanced search filters (e.g., by topic, project, team, etc.). The lessons learned database is also indexed in the organization's federated search engine and gathers all documents, events, people directories, wikis, etc.

When a new project starts, the lessons learned database and the knowledge base's content are analyzed for applicability and an implementation plan is prepared by the lessons learned delegate in collaboration with the configuration management team.

VI-5. RESULTS & BENEFITS

- 26 lessons learned delegates are named on disciplines and EPR projects;
- Around 300 employees ending their mission on an EPR project have been interviewed to collect their lessons learned (since 2018);
- 3730 lessons learned have been collected (since 2007);
  - 82% have already been analyzed, processed and implemented in standards, or transferred to our partners;
  - 99% have already been analyzed for applicability by EPR-UK project. The implementation of relevant lessons learned is going on;
  - Same work has started for EPR2 (next generation EPR project).

Example of a success story: A mission was organized to the EPR Finland site at the end of the hot functional tests commissioning phase to collect lessons learned. Six lessons learned workshops were conducted during three days with the local teams. Seventy significant lessons learned were captured and transmitted to other EPR projects. For example, the EPR France project has retained around twenty major lessons learned, which have been taken into account to improve the performance of the commissioning tests.

VI-6. CONCLUSION

The lesson learned programme setup on EPR projects is now well established and has shown good operational results, enabling Framatome to continuously improve the safety, quality and performance of projects.

ANNEX VII.

ARTIFICIAL INTELLIGENCE ASSISTED LESSONS LEARNED IDENTIFICATION AND RETRIEVAL -A CASE STUDY FROM NORWAY

VII-1. BACKGROUND

Virtually no Floating Production Storage and Offloading (FPSO) projects were delivered on time or on budget. This straightforward but astonishing reality highlights the challenges of requirements elicitation, management and eventual contract fulfilment within the oil and gas industry domain. This project is a step in the research for an improved method to elicit requirements and lessons learned in the subsea oil industry and apply them to project execution, with the aim to improve execution costs through significant cost-of-quality reduction. The method is non-industry specific and can be applied in any domain.

VII-2. SUMMARY

The project is of innovative nature for the industry and is considered, by the experienced practitioners consulted, to have large potential for improving the lessons learned elicitation quality and completeness. The initial application on the body of the lessons learned database has been an enabler for the retrieval of 'forgotten' instances that, at least on one occasion, have crossed the line from 'potential risk' to 'actual risk' and could have been remaining undetected until the negative occurrence materialized in full.

Most important is the capability, enabled through the Simple Knowledge Organization Scheme (SKOS), of retrieving concepts that are semantically linked without having to query on exactly the correct term. This has augmented the capability of the engineer to connect his/her search to many relevant domain topics, even those previously unknown to the individual, that are now presented for him/her to assess their relevance for the problem at hand.

The first real-time application during a major subsea project conceptual design review has enabled the discovery of one 'forgotten' lessons learned, unknown to the project team, and the relevant mitigation action to be included in the design at an early stage.

First example: in an early test of the project, one query of choice has been the noun 'contraction'. The system returned among the items with the shortest semantic distance its antonym: 'expansion'. This is quite a simple and obvious connection, which is general and might even be non-domain dependent. Figure VII-1 shows a two-dimensional plot of the semantic query 'contraction' in which the distance among the text boxes in the graph is proportional with the semantic distance among the terms contained by each box.

Among the other terms semantically close to 'contraction', the system returned 'upheaval buckling'. This term has a specific connotation in the subsea pipeline industry, describing the phenomenon where a pipeline, partially or totally trenched and thus impeded in its free movement, exhibits a sharp bend protruding from the soil in a location that gives way to the pipe that the hot flowing oil has thermally elongated. The pipeline exhibits the localized buckling behavior typical of its being a slender structure (diameter/length ratio > 20).

This connection is not at all trivial and only a small percentage of practitioners in the subsea industry is familiar with the term 'upheaval buckling'. Of relevance is the clustering of highly correlated concepts like ovalization, deformation and collapse.

The AI assisted retrieval has indeed provided an augmentation to the human analysis capabilities.

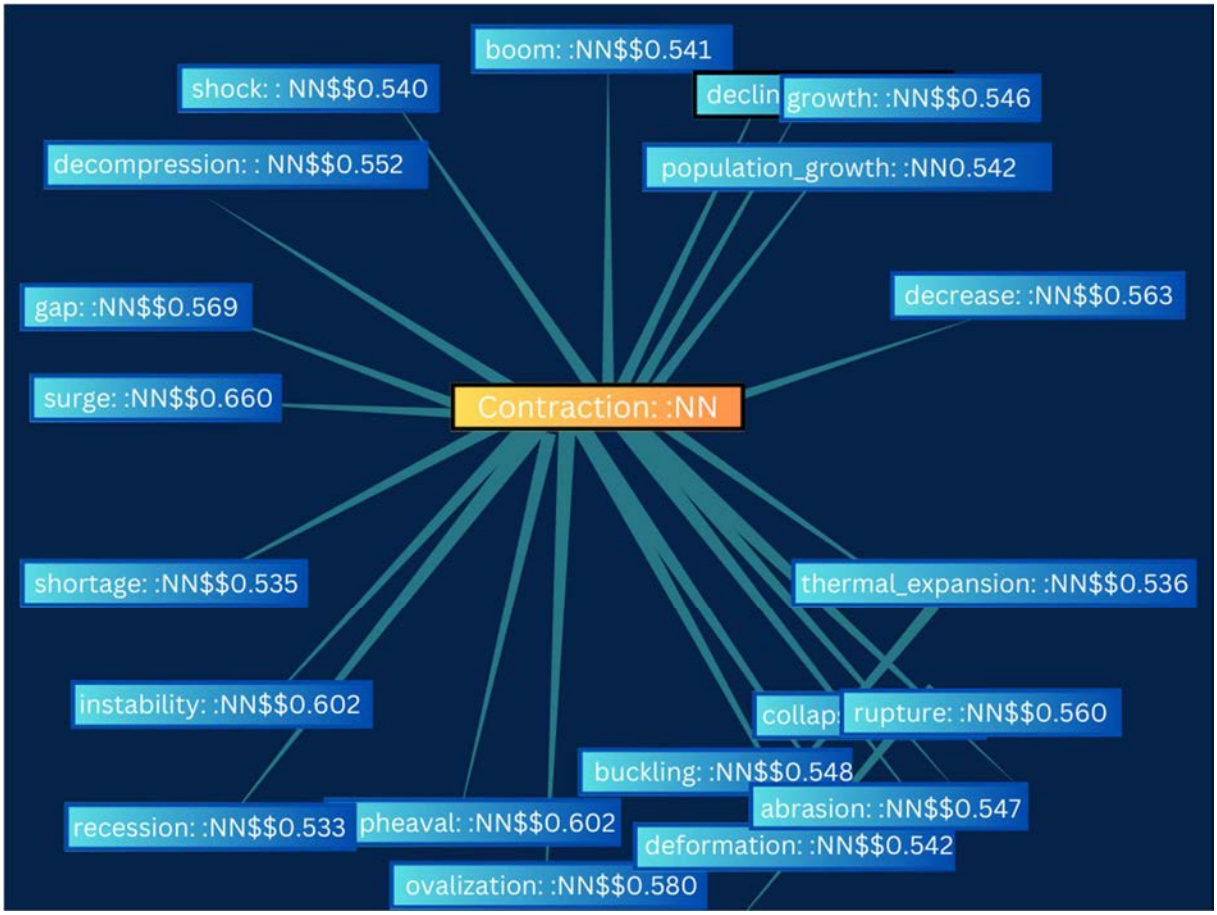

FIG. VII-1. A 2-dimension plot of the semantic query 'contraction'.

Support Vector Machine (SVM) learning algorithms have been used for this project, as they provide an effective learning paradigm to satisfy our objectives. SVMs can be thought of as methods for constructing classifiers with theoretical guarantees of optimal predictive performance in terms of classification accuracy on unseen data.

Semantic kernel functions for SVM learning have provided the method capable of correctly identifying semantic similarities and correlations between the domain and the textual phenomena (such as assertions), thus conveying results of a quality equivalent in consistency and accuracy to an analysis performed by a trained practitioner.

In synthesis, natural language processing and machine learning can be used to enable automatic semantic annotation of requirement documents by locating sentences expressing requirements or lessons learned and assigning specific (ontological) types to them.

VII-3. METHOD

VII-3.1. Foundation

The approach of inferring relations by applying domain knowledge to a natural language text is instinctively appealing. After all, it is what we do when we submit a document to an expert to have it explained to us or commented. We expect the expert in the domain to point us to the

meaning of each section and the connections it has in relation with the overall text and the domain in general.

This approach, although well ingrained in our human behaviours, is subject to at least two major flaws, i.e., limitations in quality and completeness. The experts need to have all the available domain knowledge at their disposal (quality) and they need to be in a position to examine the whole text (completeness) to return the correct answer we are looking for within a reasonable response time.

For large projects with more than ten thousand pages of information, it is self-evident that this approach is unmanageable in a fully deterministic way unless the time needed of the approval process is measured in years.

As the documents content can be fully indexed and semantically organized for the underlying AI system, explicit inferences can be drawn.

Notice how these inferences will augment the engineer information about the domain (experience) and be made available in future cases in a dynamic learning environment: this process allows capitalizing the overall accumulated experience over the processed material and accessing it in an automatic self-machine-learning fashion.

In this way, an overall ontology is built by exploiting the actual use of expert's language and it is not a filtered and biased reconstruction of the knowledge made by individuals.

VII-3.2. Simple Knowledge Organization Scheme buildup

Once the sources have been acquired, it was important to provide a structure for the concepts they are dealing with. This is what we intend by creating an organization scheme, designed through applying the SKOS standard. SKOS is a classification standard used to represent term and document lists, controlled vocabularies and thesauri. SKOS is fully capable of supporting the publication and use of KOS within a decentralized, distributed information environment such as the worldwide (semantic) web.

VII-3.3. Lexicalizing further the concept schemes

As SKOS provides a collection of mapping properties that express relationships between concepts in different schemes, we mapped each concept to a set of domain terms, automatically derived from the corpus.

VII-3.4. Example of Simple Knowledge Organization Scheme concept taxonomy

As an example, four real world physical parameters were chosen as presented in Table VII-1 to show how a small excerpt of the simple taxonomy of the domain of interest is organized.

TABLE VII-1. A PRACTICAL SIMPLIFIED SUBSET TAXONOMY OF THE SUBSEA OIL INDUSTRY DOMAIN

Field description	**Design parameters and prerequisites**	**Subsea production system**	**Technical risk and safety management**
— Field layout	— Design water depth	— Scope and supply	— RAMS
— Coordinates	— Design life	— Tie-in and tooling	— Safety system
— Water depth	— System availability	— Controls	— Systems shutdown levels
— Fluid common	— Design weight	— Chemical distribution system	
— Flow forecast	— Installation	— Electrical distribution system	
— Sand production	— Dropped objects	— Umbilical function list	
— H2S content	— Over trawlability	— Umbilical system	
— CO2 content	— Design pressures	— XMT	
— Seawater for water	— Wellhead shut-in Pressure	— Production	
— Injection specification	— WAG system	— Water and gas injection	
— Environmental conditions	— Gas lift/ Injection		
— Soil conditions	— Water Injection		
	— Design temperatures		
	— Material selection		
	— Insulation and Hydrate management		

VII-3.5. Concepts validation

Over 95% of the terms automatically identified by the corpus analysis phase within the domain specific SKOS hierarchy, in a fully unsupervised fashion (i.e., without any doctoring or previous training), were valid in the domain of interest. The validity was ascertained by having the list reviewed by domain experts who validated each term as belonging to the domain and current use. Given the automatic nature of the applied process, this is an unequivocal success.

This has indeed a high significance. The ontology generated through the innovative method of language analysis is as good as one generated through the traditional method of domain knowledge analysis.

The new method has multiple advantages:

- Reduced cycle time;
- The knowledge base can be quickly and easily expanded;
- Information found to be unreliable or incorrect can be easily purged;
- All the metadata is available and linked, enabling deep dives in search of the concept source, if needed.

A semantic distance ranking is now possible, uncovering the possibility to identify clusters of closely related concepts. Such clusters can be of help in risk management efforts to assess consequence propagation paths.

VII-4. RESULTS

The ontology was applied to the lessons learned database, the repository of learnings accumulated in past projects, to supply a test bed for usability and real-life application of the technology in the relevant industrial environment.

The ontology has been built and validated, with a better-than-expected adherence of the SARB/SKOS results with domain expert's opinion. The use of the retrieval interface confirmed the potential exhibited by the technology for augmenting the analysis capability of the engineering team.

An example of query output via the graphic user interface (GUI) is presented in Figs. VII-2 and VII-3, where the closest match to the query of interest is represented graphically at the center in a two dimensional graph that conveys the semantic distance from each result and among all the results as distance on the plane. This method is able to convey the semantic associations of the various terms returned and augments the awareness of the operator to classes of phenomena, since clustering of results on the plane indicate a cluster of results tightly connected to each other. The complete metadata set for each result is available by simply clicking on the result of interest. This action returns a window showing the sentence that triggered the result and returns all available metadata for collection in export baskets enabling register compilation.

In the algorithm training phase, only 31 of the 1576 identified concepts were considered incorrect by the human review panel, an accuracy of over 98%, exceeding the performance of a trained engineer.

The system enabled the use of previously unretrievable explicit knowledge in an 'as-is, where-is' solution, eliminating the reformatting and management cost otherwise unavoidable in similar endeavours.

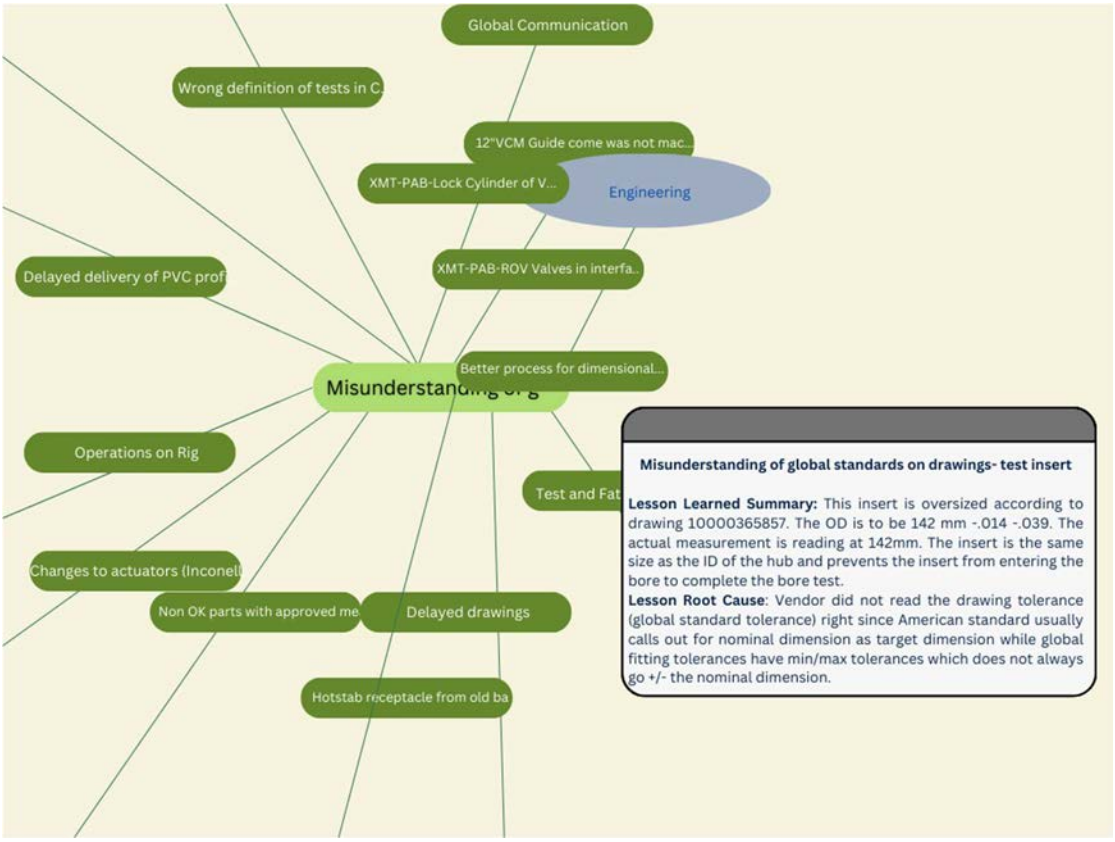

FIG. VII-2. Semantic Graph: Example of one of the results on the query 'standards' in the Lessons Learned A-Box.

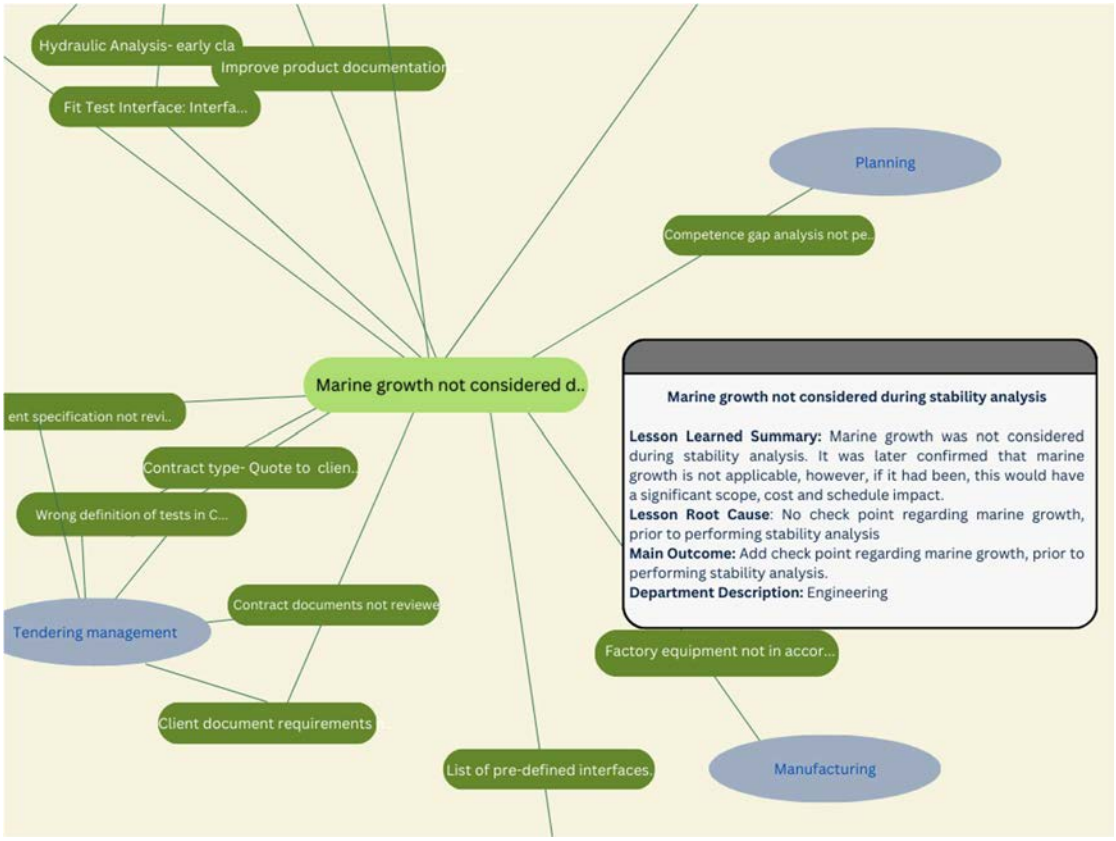

FIG. VII-3. Semantic Graph: Example of one of the results on the query 'marine environment' in the Lessons Learned A-Box.

LIST OF ABBREVIATIONS

ACE	Apparent Cause Evaluation
AI	Artificial Intelligence
BWR	Boiling Water Reactor
CANDU	Canada Deuterium Uranium
CKO	Chief Knowledge Officer
COG	CANDU Owners Group
CoP	Communities of Practice
CSMS	Core Specialist Management System
EDF	Electricite De France
EPC	Engineering, Procurement and Construction
EPR	European Pressurized Reactor
EPROOG	EPR Owner Operating Group
FAC	Flow Accelerated Corrosion
FSS	Full Scope Simulator
IT	Information Technology
KEPCO	Korea Electric Power Company
KHNP	Korea Hydro &Nuclear Power
KMS	Knowledge Management Systems
KPI	Key Performance Indicator
LLE	Low Level Event
MCR	Main Control Room
NME	Near Miss Event
NPCIL	Nuclear Power Corporation of India Limited
NPP	Nuclear Power Plant
OERC	Operating Experience Review Committee
PWR	Pressurized Water Reactor
RCA	Root Cause Analysis
SSCs	Structures, Systems and Components
SKOS	Simple Knowledge Organization Scheme
SME	Subject Matter Experts

SVM	Support Vector Machine
TEPCO	Tokyo Electric Power Company
TSO	Technical Support Organization
WANO	World Association of Nuclear Operators

CONTRIBUTORS TO DRAFTING AND REVIEW

Abe, R.	Tokyo Electric Power Company, Japan
Ariyanto, S.	National Nuclear Energy Agency (BATAN), Indonesia
Buckau, G.	Karlsruhe Institute of Technology, Germany
Choffel de Witte, I.	IRSN, France
Condori, J.	Instituto Peruano de Energía Nuclear, Peru
Daifuku, K	Electricite de France, France
Dobrinoiu, C.	Institute for Nuclear Research, Romania
Drury, D.	International Atomic Energy Agency
Ganesan, A.	International Atomic Energy Agency
Gharsah, J.	Libyan Atomic Energy Establishment, Libya
Glockler, O.	International Atomic Energy Agency
Herath Muqiyanselage, B.	Sri Lanka Atomic Energy Board, Sri Lanka
Inoue, J.	Tokyo Electric Power Company, Japan
Kalsi, H.	Nuclear Power Corporation of India Ltd, India
Karseka Yanev, T.	International Atomic Energy Agency
Kim, K.Y.	Korea Hydro and Nuclear Power, Republic of Korea
Kudratov, V.	Ministry of Energy, Uzbekistan
Marfak, T.	Moroccan Agency for Nuclear and Radiological Safety and Security (AMSSNuR), Morocco
Martiri, L.	Nuclear Regulatory Authority of Argentina, Argentina
Mignon, N.	Framatome, France
Mrazova, H.	International Atomic Energy Agency
Ngadiron, N.	Malaysian Nuclear Agency, Malaysia
Okada, T.	Tokyo Electric Power Company, Japan
Oscar, A.M.	Consultant, Italy
Palmer, D.	Independent Consultant, United Kingdom
Pakdee, K.	Office of Atoms for Peace, Thailand
Piciaccia, L.	The Norwegian Radiation and Nuclear Safety Authority, Norway
Rothschild, T.	Electricite de France, France

Sapozhnykov, L.	Ministry of Energy and Environmental Protection, Ukraine
Schmidt, U.	BGZ - Gesellschaft für Zwischenlagerung mbH, Germany
Szabo, V.	Nuclear Regulatory Authority of the Slovak Republic, Slovakia
Tikhonov, N.	VNIIAES, JSC, Russian Federation
Tea, B.Z.	International Atomic Energy Agency
Vankov, P.	Bulgarian Nuclear Regulatory Agency, Bulgaria
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