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# A brief review on the Nuclear Knowledge Management and associated risk factors

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***Abstract:***

*The objective of this paper is to review on specialized education and essential training for development and implementation of knowledge management model in the field of nuclear science and technology. These are considered as the basic requirements for young professionals in current or future leading roles in managing Nuclear and Radiation Safety Centers. Lack of a proper knowledge management program is one of the alarming signs of a decline in safety culture in any nuclear organization. This review focuses on methodologies and practices and explores various aspects related to nuclear knowledge management including knowledge creation, obtaining, maintaining, preserving and transfer, challenges and benefits, culture influence, relationship with human resource development, Information Technology, and associated knowledge loss risk. Performing this knowledge management may be useful for many of the countries rapidly developing nuclear and radiation technologies and may encourage people 'forward thinking' and enable to apply theory and awareness in daily work. The role of international cooperation, IAEA is emphasized.*

***Keywords:*** *knowledge management, need for knowledge, nuclear knowledge management, IAEA, nuclear safety, risk of knowledge loss*

## 1. Introduction

We all must have heard the phrase "knowledge is power"as well as an asset. So what is knowledge ? It can be coined as a mix of experiences, values, contextual information, understanding and interpreting the facts or information for an effective and purposeful use. In our day-today life or in working place, we apply knowledge for problem solving, learning, decision making, planning, forming opinions etc. Education itself is a knowledge driven process occurs mainly in any accredited academic institute. So no-doubt knowledge is a vital resource for human development and survival and must be managed carefully. Creating knowledge is a human process that must exist before it can be managed or used. Knowledge creation value chain can be mapped as




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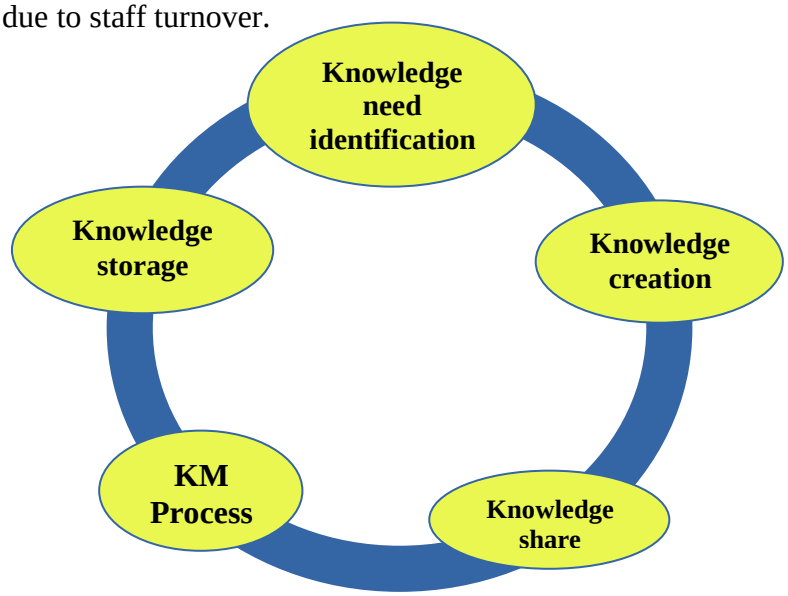
Date of submission 25-12-2025 Date of acceptance 30-12-2025

Each stage has associated management system. Successfully managing the knowledge is crucial for any organizational goal and objectives and is recognized as an important element for sustaining competitive advantage and improving performance. This review focuses on the steps required for enhancing the Knowledge Management skill in any nuclear organization to improve its overall safety, operation efficiency and performance.

**Knowledge management (KM):** Within an organization, knowledge management is the integrated, systematic approach of identifying, managing, storing, using, and sharing collective information, creating new knowledge as well as preserving all the information assets of the organization for effective and better utilization. The assets may include documents, policies, databases, expertise, and the experience of employees etc. The three fundamental Components of Knowledge Management are People, Processes and Technology. People is the most important component to stimulate, nurture and share the acquired knowledge utilizing appropriate skills and experience. Processes help to find the methodologies for creating, capturing and sharing the knowledge. Technology is the key factor to store and make knowledge accessible with the help of computers and associated equipment. Hence with the help of technology people can work together without being located together. One of the few holistic KM frameworks for standardization is Fraunhofer Reference Model. This model sets up a link between Knowledge Management and general organizational design areas. If important knowledge is captured, preserved and transferred, benefits to the organization will be gained. A key objective of knowledge management is to create values from an organization's intangible, as well as its tangible assets to reduce the risk of losing knowledge due to staff turnover.



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VOL. 01 | NO. 29 | DEC. JAN. 2026
Date of submission 25-12-2025 Date of acceptance 30-12-2025

**Nuclear Knowledge (NK):** Knowledge pertaining specifically to nuclear science and technologies and other related activities like nuclear power plant, use of ionizing nuclear radiation, radioactive waste management, radiation protection activities, transport of radioactive material etc. is defined as Nuclear Knowledge (NK). NK is also very important in medicine, food (irradiation of food), biology (genetics, insect control), industry, electricity production, R&D, and other various consumer products. As the nuclear technology exist in dual (peaceful and non-peaceful) nature, it often requires significant government supports and monitoring due to its much complex infrastructure in both micro and macro level and high development costs for establishing nuclear facilities with state of the art sophisticated components. If KM is implemented properly, it ensures that a nuclear power plant can be operated for a long period of time as a highly reliable, efficient and safe plant. In a nuclear institute, organizational experience is developed by capturing, storing and sharing the important knowledge, information and learning which the employees may have gained over many years or decades in running the industries, working individually or in collaboration as teams. But before Nuclear Knowledge Management (NKM) was invented, there were processes, arrangements and activities to develop and transfer the knowledge, experiences and data that people use every day, although not all systematic or comprehensive. So the basic steps for Implementing Knowledge Management into a Nuclear Organization around the world in the early 2000s were Education and training on nuclear safety is one of the most important features of any education and training program in the field of nuclear technology.


**Nuclear Knowledge Management (NKM):** It is the integrated, systematic approach applied to all stages of Nuclear knowledge cycle combining human resources, information and communication technology, process and document management system. But why Knowledge Management is Important to Nuclear Sector ? There are several reasons, for example it improves safe operations, protects nuclear safety boundaries, achieves benefits in organizational performance and standards through effective management of resource knowledge, maximizes the transfer of nuclear knowledge from one generation to the next, reinforces and protect commercial capacity or intellectual property, facilitates innovation to achieve improvements in the safe, and economical operation, as well as achieves responsible use by identifying and protecting sensitive knowledge from improper use. The main



Excel Publication
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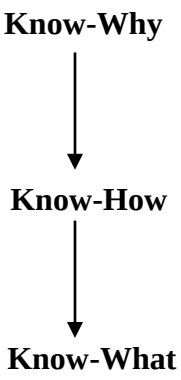
VOL. 01 | NO. 29 | DEC. JAN. 2026
Date of submission 25-12-2025 Date of acceptance 30-12-2025

stakeholders, in charge of capturing, preserving and transferring NK includes government, regulators, training and academic institute, R&D organization, international bodies, vendors, operators, suppliers, public, NGO, consultants etc. The 3 main levels of NK are (i) Know-what (for sufficient understanding of technology), which is at the bottom of the pyramid, (ii) Know-how (without this it is not possible to ensure safe and efficient operation of nuclear technology) and (iii) Know-why (without this it is not possible to generate new nuclear knowledge), that is at the top of the pyramid.




**Establishment of International Atomic Energy Agency (IAEA):** We all know that the nuclear industry is based on knowledge, which is developed and accumulated over decades of research and progress of nuclear technologies. Nuclear research started at the beginning of 20$^{th}$ century with the pioneering works by scientists Piere and Marie Curie, Ernest Rutherford, Niels Bohr just to name a few. Then nuclear era started in 1942 when the world's 1$^{st}$ self sustaining, man-made nuclear reactor was build by scientist Enrico Fermi and his team at the University of Chicago. This was considered as a crucial step in the Manhattan Project. International Atomic Energy Agency (IAEA), which is an intergovernmental organization for promoting the peaceful use of nuclear energy and prohibiting its use for any military purpose, including nuclear weapons, is regarded as the repository of nuclear data. It was established in 1957 as an autonomous organization within the Security Council of United Nations System, and is headquartered at the UN Office at Vienna, Austria. The organization assist IAEA member states to promote and preserve nuclear education and training in all areas of nuclear technology, monitor peaceful uses of atomic energy, provide guidance and methodologies for planning, designing and implementing NKM programs and develop tools continuously to capture, store and share NK for benefits of future generation.



Excel Publication
Impact factor: 5.136 (IIFS)

VOL. 01 | NO. 29 | DEC. JAN. 2026
Date of submission 25-12-2025 Date of acceptance 30-12-2025

**Main elements of Nuclear Knowledge Management (NKM):** This depends on type of nuclear organization having different levels of efficiency and effectiveness. IAEA adopted Fraunhofer reference model for nuclear field like nuclear power plants, nuclear R&D organizations, nuclear educational institutes etc and defined 8 main elements of Knowledge Management.

Area 1 → Policy and strategy**,** Area 2 → Human Resource Processes, Area 3 → Training and competence development. Area 4 → Methods, procedures and documentation process, Area 5 → Technical Solutions, Area 6 → Capture, Retention and Transfer of knowledge, Area 7 → Organizational Culture to support KM, Area 8 → Internal / External Collaboration for KM

**NKM Policy and stategy:** It becomes obvious that every nuclear organization needs to formulate and implement an overall strategy to provide a frameworks of KM principles in the workspace. It is not sufficient to become just a knowledge enabled organization but must identify the key issues, needs to be addressed within the organization, and provide a framework for managing the common situations widely recognized in nuclear industry. Some examples are aging of the industry workforce and threat of loss of knowledge and experiences including R&D, aging of existing nuclear facility, expansion of nuclear power (newly build) etc. Main elements of NKM strategy are

- Business strategy
- Safety management
- Human resource management
- Information technology and communication
- Quality management
- Risk management
- Public relations

Efficient management can be achieved through establishment of an effective NKM system which must include people, process and technology operating with in an organizational culture (encompassing an organization's traditions, values, visions, norms, attitudes and behavior). The scope of an efficient NKM should include a wide range of elements mainly in 3 typical areas, that are (i) Maintaining and protecting existing NK, (ii) Sharing NK and (iii) Developing new NK.



Excel Publication
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VOL. 01 | NO. 29 | DEC. JAN. 2026
Date of submission 25-12-2025 Date of acceptance 30-12-2025

**Roadmap for NKM Implementation :**

1. Orientation and Awareness
2. Analysis of Safety Requirements and Business Needs
3. Policy and Strategy
4. Design and Launch
5. Expand and Support
6. Institutionalization
7. Evaluation and Continuous Improvement

**Development of the maturity of a KM programme**

Step 1: Orientation and awareness involves the understanding of basic KM concepts along with the understanding of how KM can help drive change and increase organizational performance.
Step 2: Analysis of safety requirements and business needs is the next step to implement a successful KM program.
Step 3: During this step the organization begins to make plans on how to utilize KM approaches to deliver the intended improvements or change. These begin with developing a proper policy/strategy.
Step 4: A successful KM implementation requires a number of prerequisites at the start of a project.
Step 5: This is the operational phase of the program/project. Expand and support, builds on the project launch and continues with the further implementation of KM in the organization.
Step 6: Institutionalization means KM techniques and approaches become a normal part of organizational activities. This may take several years to achieve.
Step 7: Evaluation and continuous improvement is a process that continues to look at each step and provides a critical review of the outcomes.

**Nuclear Organizational Culture:** Culture influences activities in all aspects of the organization varying from country to country. As because the culture is dynamic, it changes over time, moves from very preliminary stage to maturity. In any nuclear industry, organizational culture is associated with **safety culture** (term is adopted by IAEA). It is defined as "the assembly of characteristics and attitudes in organizations and individuals which establishes that as an overriding priority, nuclear safety issues receive the attention warranted by their significance". In any nuclear organization, safety culture should be the



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Date of submission 25-12-2025 Date of acceptance 30-12-2025

motto for 'every task', 'every person' and 'every day'. Universal features of safety culture can be recognized at 3 levels, they are (i) policy, (ii) management and (iii) individuals.

**Nuclear Information management (NIM):** Information management (IM) can be explained as collection and management of information (both electronic and physical) from one or more sources and distribution of that information to one or more audiences. This focuses on ability of organization to capture, manage, preserve, store and deliver the right information to the right people at right time for effective decision-making, improving efficiency and achieving organizational goals. The principles behind IM are (i) Information assets are corporate assets and (ii) Information must be made available and shared. There are large variety of sources of Nuclear related information like meeting, conferences, discussion, books, articles, reports, results of scientific experiments, data from nuclear power plants, medical data, video recordings etc. In documentation form, all these information are available in reviewed journal articles, books, bibliographic references, theses and dissertations (Doctoral, Master's, Bachelor's), unpublished reports, papers, soft documents, multimedia and audio-visuals, patents etc.

**Historical aspects of Managing Nuclear Information:** Although several managing institutes for nuclear information was established in USA, USSR and in Europe but access to this information was very restricted due to sensitivity. In 1960, cold war started between 'Capitalist' and 'Socialist' allies. So it was necessary to create an "effective mechanism for sharing and exchanging Nuclear Information (NI)". Only solution is "an inter-government approach with a system managed by an international organization". In 1968, USA and USSR made a proposal to develop international nuclear information system (INIS) at IAEA. This is the information system that covers the literature published worldwide on the peaceful uses of nuclear science and technologies.

**International Nuclear Information System (INIS):** Domain of the nuclear knowledge incorporates nuclear and high energy physics, atomic and molecular physics, plasma physics, chemistry, material science, earth science, radiation biology, fossil fuels, nuclear medicine, radiology, engineering etc. Most stages of the INIS operation are decentralized, only data processing and product development are centralized in INIS scientists at IAEA Headquarter in Vienna, Austria. Three main INIS products are (i) INIS bibliographic data base (more than 4 million indexed references from 1970 onwards), (ii) INIS full text non convention literature (NCL) collection and (iii) INIS multilingual thesaurus. Primary objective of INIS has been to



Excel Publication
Impact factor: 5.136 (IIFS)

VOL. 01 | NO. 29 | DEC. JAN. 2026
Date of submission 25-12-2025 Date of acceptance 30-12-2025

promote the exchange of information between member states and also to involve in nuclear knowledge preservation in an effective methodology.

**Preservation of Information:** Main targets are selecting most valuable information for future, ensuring the information remains readable, accessible and understandable as well as managing technological modification. This consists of several important steps, like


**Capturing Information for preservation :** By this process, paper of documents, e-documents, forms etc. are collected and transformed into accurate, retrievable, digital information. Finally the information are delivered into business applications and databases for immediate action. Document scanning, quality assurance and indexing (OCR/ICR) technology have made the documents indexing not only easier but it can convert the scanned image into full text also.

**Structuring and Organizing Information:** There are mainly two levels of organizing information. One is a structured description of a whole collection that can be achieved by using technology. Rest one is structured description of information of an item within a collection, that can be achieved by assigning metadata (structured kinds of information that describe, explain, locate and make it easier to retrieve, use or manage an information resource).

**Storing, Accessing and Maintaining Information:** Digital information must be stored in a reliable and controlled environment. Life of storage is cut short by 3 factors mostly, (i) durability, (ii) usage, storage and handling and lastly (iii) obsolescence. One should consider to make two copies of content on separate media (DVD, CD etc) and store the media copies in different location. For accessing the information, continued usability of a digital resource, retaining all qualities of authenticity, accuracy and functionality is essential. One of the main requirements is that the interface should be web based (independent from the operational system-portability), multilingual and allow searching by using structured metadata across the full text. DIALOG and STN use Z39.50 international standard protocol. The four main process to maintain digital information are, (i) Refreshing (copying from one storage medium to another), (ii) Migration (transferring digital information from one hardware and software setting to other or transfer from one computer generation to other), (iii) Replication (creating



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duplicate copies of data on one or more systems) and (iv) emulation (recreation of technical environment required to view or use a digital collection).

**Information Technology in KM:** In any nuclear organization, IT is associated with databases, web portals, e-mails, collaboration tools and document management systems, that help systems to publish, store, index and retrieve documents. The purposes of knowledge engineering are (i) allowing knowledge to be shared and structured, (ii) providing an interface with other IT system that contain knowledge, (iii) allowing users to find and access knowledge, (iv) carrying out decision making and problem solving activities to replicate human thought process.

**Role of Human Resources in NKM:** Human Resources Management is one of the crucial factors for better public management in a nuclear industry. The successful operating of the specialized system and the implementation of necessary reforms, increasingly depends on human resources in the public and state administration. It is very important for strategic approach of managing workforce issue, workforce planning, recruitment, training and development, coaching and mentoring, retention, succession planning, leadership development etc. The fostering of professionals in nuclear R&D is a long-term process due to the technical complexities of the field. Hence, education and training should be provided to the competent R&D personnel in a systematic and continuous manner. This highlights the requirement for a capacity building program based on a specialized education and training system.

**Risk Management of knowledge loss:** In any organization, knowledge is constantly being created and shared. Unfortunately, this relevant knowledge could be often lost if it was not properly documented in due time. The worse situation is when a large segments of the retired workforce (with all the knowledge and information they have contributed) could out-pass the replacement. This poses a dual risk: loss of nuclear safety knowledge and accumulated experience as well as lack of qualified personnel to continue the ongoing work. Therefore, it is of highest importance to ensure that there are enough new entrants, relocation and mobility to allow knowledge transfer and meet future workforce demands. This is crucial for the companies/organization to conduct a knowledge loss risk assessment, develop and implement plans to preserve critical knowledge (“Minimum knowledge required for a nuclear organization to operate”- as defined by IAEA), monitor and evaluate organizational knowledge loss risk. Other than organizational and workforce challenges, there are also risks


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VOL. 01 | NO. 29 | DEC. JAN. 2026
Date of submission 25-12-2025 Date of acceptance 30-12-2025

related to knowledge preservation in a nuclear organization. Some projects related to IT and data management might implement different information systems, with different media storage formats that require constant upgrades. All these risks can be mitigated with careful planning and a clear strategy for the long term preservation of knowledge. After the identification of the possibility of knowledge loss, personalized knowledge transfer technique may be selected. These techniques can be, descriptions, professional summary, practical knowledge transfer, mentoring, interviews etc. More over institute should provide assurance that knowledge preservation and knowledge transfer programs are properly taken into account throughout the different parts of a nuclear project. This means that for all possible stages of a nuclear power plant's life cycle (i.e. design, fabrication and construction, commissioning, operation, extended long term operation and decommissioning), knowledge management (KM) and knowledge transfer from one phase to another need to be meticulously planned and executed.

**Knowledge LossRisk Factor Assessment:** A Knowledge Loss Risk Assessment is designed to identify workers for whom the potential for knowledge loss is greatest and most impending. Assessment ratings are based on two factors, they are (i) Attrition Risk Factor and (ii) Position Risk Factor. Total Risk Factor is then defined as an estimate of the effort and urgency necessary to effectively manage the risk of knowledge loss and is calculated as the Attrition Risk Factor multiplied with Position Risk Factor.

**Attrition risk factor** × **Position Risk** = **Total Risk Factor**

**Conclusions:** This review explained various basic aspects and elements related to Nuclear Knowledge Management (NKM) which is an essential tool for identifying, preserving, acquiring, developing, sharing, using and evaluating the state of the art knowledge in a consistent way in the field of Nuclear research and technology. In concluding, let it be emphasized that**,** a successful implementation of the NKM plan integrated with international training programs for nuclear-related professionals, will help in improving the effectiveness and efficiency of both at the national level and in the various organizations in the nuclear sector, including the nuclear safety and security. The management in a nuclear and radiation regulatory body organization might be difficult due to several major obstacles within the organization such as rapid change of the internal environment, cultural, structural,



Excel Publication
Impact factor: 5.136 (IIFS)

VOL. 01 | NO. 29 | DEC. JAN. 2026
Date of submission 25-12-2025 Date of acceptance 30-12-2025

technological and human resource aspect. But because of awareness and insights to create new knowledge, identification of the importance of knowledge management and various means of nuclear education and training like face-to-face training, hands-on training, these difficulties could be overcome and hence be applied to the emerging challenges.

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