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Mini Review

Multi Criteria Decision Analysis Support for Nuclear Waste Management

Pavan Kumar Singh[1*], Durgesh Wadhwa[2], Gurjot Singh[3]

[1]Department of Physics, Teerthanker Mahaveer University, Moradabad, India; [2]Department of Basic and Applied Sciences, Sanskriti University, Mathura, India; [3]Department of Physics, SGT University, Gurugram, India

ABSTRACT

Nuclear waste management includes reducing all types of radioactive waste, categorising it, and identifying acceptable disposal procedures in accordance with Best Available Techniques (BAT). The impact of dangerous materials like chemicals, plastics etc. on plant and animals life is the world's major worries when it comes to nuclear waste disposal. Screening, prioritising, rating, or selecting alternatives based on human perception in terms of multiple, often competing criteria is part of the MCDA (Multi Criteria Decision Analysis). The paper offers a hierarchy of objectives, indicators, value ratios, weights, and a judge able aggregation process for evaluating the performance of various waste management strategies. Furthermore, analyzed in different sections of paper and focused to the decision-supporting process, context, in particular problem structuring, objective hierarchy, measure modelling, robustness analysing, and result interpretation. The purpose of this paper is to show how the MCDA may be used to assist a decision on atomic waste management regulations in a less newcomer nation that is considering nuclear technology in the future.
Keywords: Energy; Nuclear; Spent nuclear fuel; Technology; Waste

INTRODUCTION

Nuclear power stations are operational in 31 nations worldwide. According to current estimates, more than 45 nations are considering power nuclear programs in future. The expertise acquired from commercial nuclear energy use over the last almost six decades has sparked the development of a variety of nuclear fuel cycles. Most industrially deployed nuclear technologies rely on an open or partially closed NFC (Nuclear Fuel Complex), with the recycling plutonium. All NFC variants, including sophisticated closed NFCs with multiple fissionable material recycling, have one thing in common: radioactive waste is generated at both the front-end and back-end phases of the fuel generation process. Furthermore, there are established, well-proven technologies that, when used at each stage of NFC, can ensure the safe disposal of high-, intermediate-, and low-level waste [1-4].

The general legal framework in each nation governs the handling of radioactive waste. Although technically viable and potentially allowing total waste separation from the biosphere in the future, this method comes with a high cost. The SAPIERR proposed model is based on the IAEA (International Atomic Energy Agency) Safety Requirements publications' requirements. On the strong foundation of established and well-tested IAEA international transport rules, the rapid worldwide advancement in this field might serve as a model for transnational geological disposal regulations scrutiny[5-9].

Underground storage vaults are a long-term project that can only be completed after decades of research and development on procedures for designing, constructing, operating, and licencing the repository site, as well as the decommissioning of existing fuel storage facilities. Meanwhile, there may be a need for appropriate national temporary storage capacity and long-term licencing laws. Such strategic pauses, on the other hand, may be appealing for three reasons:

- After the short-lived fissile material contained in waste bulk have decayed, the radioactivity and heat load of HLW naturally decreases, making SNF management and disposal much easier.

Correspondence to: Dr Pavan Kumar Singh, Department of Physics, Teerthanker Mahaveer University, Moradabad, India, E-mail: om.pavansingh@gmail.com
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- Public approval, which may be a key issue in some countries and can be achieved while having individuals to participate in decision-making process.
- Cost-share allocation models have taken a long time to adopt due to economic concerns.

R and D projects on technically, economical, and organizational elements of regional SNF facilities have been supported by international organisations such as the IAEA and the European Community.

Application context

The decision problem formulation is a sequence of three that includes:

- A set of potential alternative solutions that describe the possible actions that a decision maker can take.
- A set of points of view under which the potential actions are analysed, evaluated, and compared, including various future scenarios.
- The context of the issue application is described in this section.

It is worth noting that evaluating the technical quality and reliability of repository locations is a difficult R and D challenge. In practice, the scope of R and D activities is determined by unique national circumstances. IAEA fundamental concepts are consequently employed to create an objective hierarchy tree. These guidelines for selecting a nuclear waste management plan are grouped in 3 categories:

- Useful
- Responsible
- Long-term usage

Technical experts, local governments, neighboring nations, and national or worldwide environmental groups can all contribute their thoughts and judgments to the framework.

Collected Spent Nuclear Fuel (SNF) reserves and nuclear waste management benefits and drawbacks

Nuclear waste generated by nuclear power plants is, in theory, relatively little in comparison to waste generated by other large-scale energy-generating technologies. Safe storage necessitates preventing fuel deterioration that might jeopardise safety functions. SNF reprocessing is a waste management strategy that involves separating fissile material from SNF and reloading it into nuclear power reactors as a new fuel component. Because HLW is primarily fission products and small actinides, it is vitrified into borosilicate glass during reprocessing, sealed inside massive steel cylinders approximately 1.3 m in height and is stored temporarily stored before being buried. Reprocessed fuel hulls and end-fittings are compacted to minimise volume and are often mixed and disposed of as Intermediate-Level Waste (ILW).

SNF stocks in tonnes of metal generated and continuous storage held in NEA member nations in the reference year 2016 and 2015 (Sweden, Japan, and Belgium). In addition, foretold future inventory between 2020 and 2030 are included in this table. The IAEA technical series report a guidebook on spent fuel storage covers variables to consider while evaluating SNF storage solutions.

Waste management techniques are among the key considerations that must be made during the deployment of nuclear energy initiatives. According to this paper, three types of stakeholders will be included in regional SNF storage system:

- A group of client nations interested in moving their SNF to the hosting country.
- A group of third-country parties interested in the storage system.

The reasons of any organization could be technical, economical, legal, social, or organizational. Third regions could have a vested purpose in upcoming SNF preservation requirements or since many regions shares boundaries with both producers and customers and may be compelled to allow SNF passage over their boundaries. Customers can choose from a variety of regional storage options.

The implementation framework for international and national SNF storage facilities

From the perspectives of economics, safety, the environment, and security, regional cooperation and initiatives may present both appealing and problematic opportunities for member states. The following are some of the new problems that concerned nations may face:

- Safety criteria and standards, safeguards and physical protection, fuel acceptance criteria, long-term system and stored fuel stability, site selection, infrastructure aspects, storage technology, licensing, operations, transportation, decommissioning, and research and development.
- Financial resources and circumstances, economic assessment, possible host nations, and consumers.
- Issues of political and popular acceptability.
- Legal and organizational issues.

As a result, in all aspects of the project analysis, a trade-off between possible advantages and risks must be established. In Figure 1, the key decisions and the important result is shown w.r.t. SNF [10].

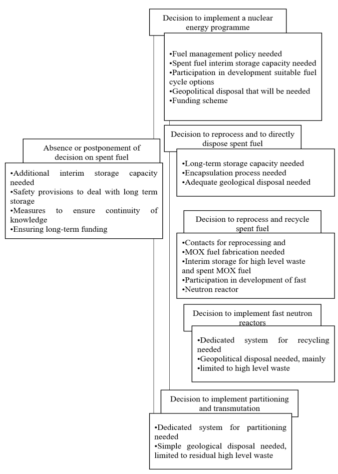

Figure 1: The above figure shows the key decisions and important result w.r.t SNF.

A technical benefit could be the ability to use advanced technologies, to share knowledge, to transfer technology, to optimize design, to improve quality and safety aspects, to reduce the number of storage facilities, to reduce global radiographic risk and environment issues, and to improve security against sabotage or terrorist attacks due to more robust security measures.

Shared efforts can result in economic benefits, such as the transfer of cash from the consumer to the host nation and the profit of the operation facility. Local taxes, job opportunities, and the construction of local infrastructure can all provide significant economic advantages to the town that hosts the plant.

Institutional benefits might include the establishment of a worldwide framework, bolstering the will to find answers to global problems, demonstrating the viability of international treaties and conventions, and so on.

Information on Multiple-Criteria Decision-Making (MCDM) background

Alternatives should be identified as the following stage. Conflicting criteria are frequently used in this procedure[11]. Ranking alternatives and choosing the most appealing one can be done in a non-formalized fashion, relying on expert intuition and experience, or utilising a MCDM tool. MCDM aids in the organisation of the problem and the identification of potential conflicts. Trading-off throughout the decision-making process is facilitated by a structured depiction of the issue scenario. The structured approach appears to be more appealing since it allows for a quantitative comparison of options and justification of the choice of the most convenient trade-off option. The two major types of MCDM are:

- MCDA
- MODM

These two groups differ in their approaches to

- The structure of the multi criteria problem to be addressed.
- The method of solving the problem. MODM seeks for a set (often infinite) of all potential alternatives, whereas MCDA solves the problem by picking the best alternative among the supplied alternative set (ranking technique).

The MCDA methods may be used to rank and pick the most appealing option. These approaches have previously been widely used to aid decision-making in a variety of fields, including nuclear engineering. Finding the optimal decision rule that incorporates the experts' opinions is a basic challenge. Using a combination of performance metrics and expert preference values, this algorithm will rank a finite collection of recognised alternatives.

Nuclear waste management strategy selection using the MCDA decision-making framework

Problem description: Experts weigh here on the economic, technical, institutional, public, and political acceptance elements of various nuclear waste management alternatives. In fact, there is rivalry between different aspect-oriented regions and even to measures within a single area, which might result in a decrease of long-term hazards while raising short-term dangers, for example. In all of the aforementioned elements, there are currently no uniform, accurate, and widely acknowledged numerical criteria or techniques for comparing nuclear waste treatment solutions. The identification of the most promising option is a wicked issue that requires consideration of expert judgments and decision-maker preferences.

Problem structuring: It must embrace various goals, intents, values, and standards in a consistent manner. The analysis must be based on agreement on both the hierarchy of needs and the fundamental principles. The basic principles serve as a guide for deploying the appropriate technological solutions.

Determining high-level and low-level goals: Clear objectives are required for conscious decision-making. The IAEA's nuclear energy fundamental principles (BP) will be used to construct the goal structure tree. Beneficial, responsible, and sustainable usage of BP are the three primary types. Advantages and openness are two BPs in the beneficial use category.

Two BPs are included in the sustainable usage category:

- Resource efficiency
- Continuous improvement

This relates to the efficient use of materials and the use of atomic power in such a way that it continuously improves protection, stability, economies, and diffusion susceptibility while reducing global effects *via* advancements in research and technology. Humanitarian and ecological preservation, stability, non-proliferation, and long term commitment in conformity with globally established criteria are the four BP in the third area, responsibly use.

Employ the IAEA further created specific atomic wastes organization goals, which it suggested at different stages of atomic project development. The essential assumptions and goals may be adjusted to a particular scenario and function as a basis for developing less particular solving and practice-oriented lower-level goals and standards. The parameter set provided here is based on a two-level objective structure and will be used to compare atomic wastes treatment strategy options.

The author has discussed about the nuclear waste management. This implies isolating or diluting radioactive waste so that the rate or concentration of radionuclides returned to the biosphere is safe. Better still, our modern nuclear power plants generate no extra waste. While these cutting-edge power plants do not yet exist, our study suggests that they are a viable option in the future.

DISCUSSION

Each step of the atomic fission, which is the technique of generating energy using atomic elements, creates radionuclides, as the author has described. Uranium ore is mined and milled as part of the power system, processing and enrichment of the ore into nuclear fuel, use of the fuel in the reactor, treatment of used fuel removed from the reactor after use, and finally waste disposal. The fuel cycle is generally divided into two parts:

- Front end
- Back end

Radioactive wastes are a serious concern in this area. Nuclear waste management is important because nuclear waste is the most pressing issues facing atomic industry. It must be controlled in a way that protects human health while also minimising the impact on the environment. All waste generated by nuclear power plants is controlled. The trash is decontaminated, shredded, compacted, dried, and solidified as part of the treatment process. Packaging is for safe storage and disposal; most radioactive waste must be packaged in specially designed containers. This makes it easy to handle and carry, by which nuclear waste can be managed.

CONCLUSION

The author has concluded about the MCDA decision support for nuclear waste management. MCDA can assist in the comparative evaluation of choices. The scale range, on the other hand, may be determined in a variety of ways and adjusted as needed during the analysis. Scales represent differences in desire for choice performance level on criterion. Stakeholder/expert valuations, along with option performance indicators, make up a major portion of the proposed MCDA method's input. Because this paper only analyses a limited amount of fully defined options, the MAVT approach was used for consolidation. The MAVT approach includes converting every regional characteristic grading scale into a universal scales and combining signals, values units, and high-level subjective values with a various improvements judgment aggregate operation on the overall results. Our study suggests that they are a viable option in the future.

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