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Temporary Management of Spent Nuclear Fuel during Decommissioning of an NPP

Nthato Jay-Aar Raboshaga*, Akhona Tshangela, Michael Atogo, David Scott Kessel, and Chang-Lak Kim
KEPCO International Nuclear Graduate School, 1456-1 Shinam-Ri, Seosaeng-Myeon, Ulju-Gun, Ulsan
**Corresponding author: rnthato@yahoo.com*

1. Introduction

Prior to the decommissioning of an NPP, a temporary management of spent fuel has to be selected. In this project, two methods were investigated, which are transshipment and Spent Fuel Pool Island. Transshipment entails moving spent fuel from one NPP to another, whereas Spent Fuel Pool Island involves modifying an existing spent fuel pool by isolating it from the rest of the plant, thus making it self-reliant in providing the necessary requirements to storing spent fuel independently. The objective of this research project was to investigate the alternative temporary management of spent fuel methods in preparation for Kori Unit 1 decommissioning. It is also to make recommendations on the most suitable temporary management of spent nuclear fuel method during decommissioning of an NPP by employing Analytical Hierarchical Process (AHP) systems engineering decision-making tool.

2. Reference Reactor

The reference reactor is Kori Unit 1, a PWR, located at the Kori nuclear power plant complex. Kori Unit 1 has a fuel assembly capacity of 562, and currently storing 328 fuel assemblies. After the final cycle when all the fuel has been transferred to the spent fuel pool, the total number of spent fuel assemblies will be 485. Kori NPP complex, which comprises of Kori unit 1, 2, 3, and 4; Shin-Kori unit 1, 2, 3, 4, 5 and 6, with Shin-Kori units 5 and 6 approved for construction in recent months. This NPP complex has a total capacity of 8,154 assemblies, currently storing 5 677, with an 82% full capacity. The expected saturation year is 2042, after installing high-density racks, excluding Shin Kori 5 and 6, which has not yet been constructed. [1]

3. Transshipment Concept

Transshipment in this project was limited to the movement of spent nuclear fuel from one NPP to another within the Kori complex. Since the inception of successful operation of NPP's in South Korea, there have been over 160 transshipment projects of spent fuel assemblies that have transported close to one thousand fuel assemblies successfully to neighboring NPP's. It is suggested to transport SF to Shin-Kori 1, using two KN-12 containers, capable of carrying 12 assemblies. For 1 cycle of transportation process, fuel loading and fuel storing activity takes 5 days with each transport container respectively [1]. The total number of fuel assemblies supposed to be transported to empty the SFP of Kori 1 is estimated to be 485 assemblies which need 57 cycles of transportation including damaged fuels. The total transportation period is expected to take about 19 months. Adequate risk management has been taken into account for the transshipment of spent fuel. Accidents, emergencies, training for personnel, and safe cask storage of spent fuel with adequate shielding have also been taken into account. In terms of politics and public acceptance, when transportation of spent fuel occurs within the Gijang County the utility is not required by law, to do public consultations. The total estimated cost for the transshipment of spent fuel from Kori Unit 1 was estimated to be $3,878,953. [2]

4. Spent Fuel Pool Island Concept

The majority of nuclear plants currently engaged in decommissioning found significant benefits tied to replacing their original SFP cooling and cleanup system with a unit tailored to shutdown conditions. These decommissioning-specific systems referred to as nuclear islands are simpler, smaller, and more localized to the SFP area. This approach significantly reduces the required plant maintenance and monitoring program. In the framework context, SFPI can be categorized into an NPP related facility because the regulation criteria for SFPI have not yet been prepared in South Korea. To modify SFP into SFPI, design change permit by the regulatory body is required and should be completed before starting the decommissioning process. A total cost of $11,157,000 was estimated for SFPI operation for Kori unit 1 and 318 days are required for the total project period. SFPI will start operation in 2023 before decommissioning commences. Despite many advantages of the SFPI for SF management, a project of this nature has not yet been done in South Korea, and thus there are some uncertainties about its application to Kori unit 1. [2]

5. Spent Fuel Management Approach

The spent fuel management approach followed in this research is depicted in Figure 1. Following the final shutdown of an NPP, fuel has to be stored in the pool for a minimum of five years after leaving the reactor. After that period of time, a temporary spent fuel management concept has to be applied, it can either be transshipment or SFPI. Subsequently, spent fuel has to be transferred to spent fuel dry storage casks before a final disposal of spent fuel has been constructed. This paper is focused on the temporary management of spent fuel immediately after decommissioning, and thus dry cask storage and final disposal do not form part of the scope of this research.

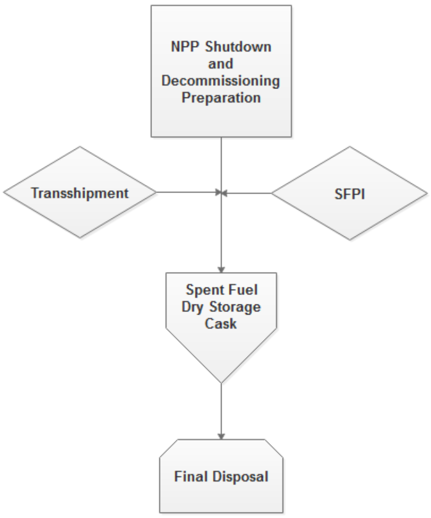


Figure 1 Spent Fuel Management Approach

6. Systems Engineering Decision Making

The systems engineering decision-making tool used is the Analytical Hierarchical Process developed by Thomas Saaty in the 1970's and has been widely used for multi-criteria decision-making. AHP is a general theory of measurement used to derive a ratio of scales from discrete and continuous paired comparisons, comparing alternatives with respect to criterion [3]. Super Decisions software was used to carry out the AHP calculations. AHP was used to select which method of temporary spent fuel management was the most optimal for Kori unit 1 decommissioning plan, the schematic of the process is shown in Figure 2.

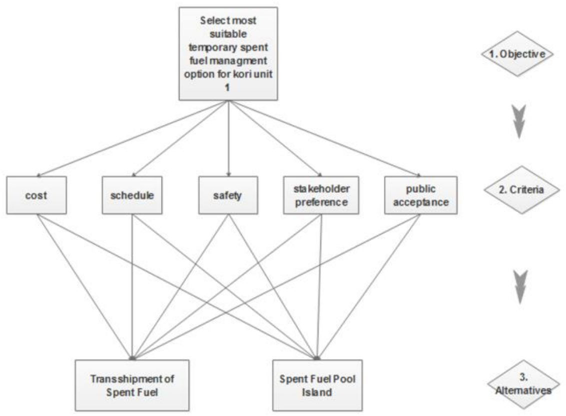


Figure 2 AHP decision making process for temporary management of spent Fuel

5.1 AHP Pairwise Comparisons and Simulation

When performing the pair comparisons of the criteria, the intensity of importance scale was employed, as depicted in Table 1. The first step involved comparing criteria against each other to establish which were most important in this decision making. For instance, referring to Figure 3, safety has a score of 7 when paired with cost; this means that safety is considered to have demonstrated very strong importance over costs. In the nuclear industry, safety is important, and millions have been spent to ensure the safety of personnel. The other pairwise comparisons of criteria are shown in Figure 3 as well. The pairwise comparisons for the two alternatives in terms of criteria were done and are illustrated in Figure 4 [4]

Table 1 AHP intensity of importance scale

Intensity of importance	Definition
1	Equal importance
2	Weak
3	Moderate importance
4	Moderate plus
5	Strong importance
6	Strong plus
7	Very strong or demonstrated importance
8	Very, very strong
9	Extreme importance

The objective was to select a preferable temporary spent fuel management option. Pairwise comparisons were done by expert members of the team, who had specialized in researching each criterion intensively, followed by the team consensus on each criterion. The criteria used to compare the two options were cost, schedule, safety, stakeholder preference and public acceptance. The two alternatives as mentioned are SFPI and Transshipment of spent nuclear fuel.

Figure 3 Pairwise comparisons in terms of importance of criterion.

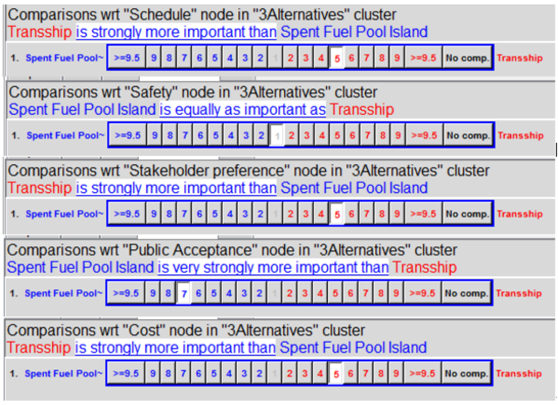
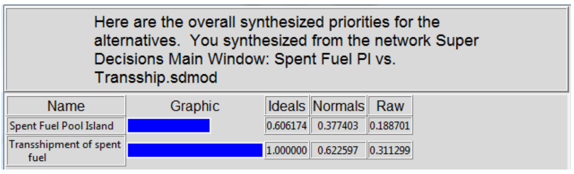


Figure 4 Pairwise comparison for the alternatives based on criteria

The result of the simulation is shown in Figure 5, and transshipment is the preferred temporary management of spent fuel option. The score from AHP gives a result of normalized Eigenvector, with the highest Eigenvector signaling the preferred option. Transshipment had a normalized Eigenvector score of 0.623, while SFPI had a score of 0.377.

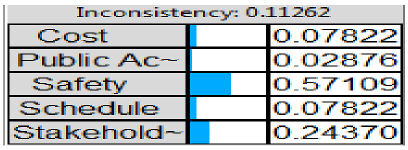


Here are the overall synthesized priorities for the alternatives. You synthesized from the network Super Decisions Main Window: Spent Fuel PI vs. Transship.sdmod

Name	Graphic	Ideals	Normals	Raw
Spent Fuel Pool Island		0.606174	0.377403	0.188701
Transshipment of spent fuel		1.000000	0.622597	0.311299

Figure 5 Results of the AHP

To verify the consistency of the comparisons, a value of inconsistency, rounded off to 0.1 and below is the acceptable limit when performing pairwise comparisons [4]. Figure 6 below depicts the results of the value of inconsistency for the simulation, it shows that the inconsistency score is 0.11262, which is 0.1, and thus the criterion comparisons are verified.



Inconsistency: 0.11262

Cost		0.07822
Public Ac~		0.02876
Safety		0.57109
Schedule		0.07822
Stakehold~		0.24370

Figure 6 Value of Inconsistency

6. Conclusion

Based on the criteria studied, transshipment would be recommended as the preferable temporary management of spent fuel during decommissioning of an NPP in the Kori complex, while dry storage casks are being manufactured, his enables the decommissioning activities to continue with limit cost and schedule overruns.

Acknowledgements

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