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The Derivation of Evaluation Criteria of Nuclear Fuel Cycle

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1. Introduction

The purpose of an analysis on diverse nuclear fuel cycles is to select the optimum nuclear fuel cycle suitable for the environment of one's own country. Accordingly, diverse evaluation criteria and evaluation indicators are necessary [1].

In addition, individual evaluation criteria can be explained with various evaluation indicators. For example, the evaluation criteria for economic feasibility can be explained with evaluation indicators such as the unit cost or total cost.

However, if too many evaluation indicators are included in one evaluation criterion, the evaluation is not easy, and if too few evaluation indicators are established, the evaluation criteria cannot be explained sufficiently, and thus the evaluation can be distorted. Accordingly, not only should the evaluation indicators be composed of an appropriate number of units, but they should also not be overlapped, and ambiguous evaluation indicators should be dropped out and necessary evaluation indicators must be included. This study suggests the evaluation criteria and evaluation indicators derived using a factor analysis.

2. Screening of evaluation criteria

The methods used to deduct evaluation indicators are largely of three kinds: a method using the evaluation indicators already developed through a literature investigation, a method used to establish evaluation indicators with a top-down method after making a list of evaluation criteria by investigating the opinions of experts [2], and a bottom-up method using the data after adding the evaluation indicators collected by investigating the opinions of experts and the general public with a statistical method to the list of evaluation indicators derived in the preceding studies. The third method is actually a hybrid method that mixes the top-down method and the bottom-up method [3].

The hybrid method is the method whose value in use is high in countries where public acceptance is recognized as an important factor in the decision of alternatives to the nuclear fuel cycle, and is useful to heighten the reliability of the produced consequence by scientifically conducting an empirical analysis on the preliminary evaluation criteria and evaluation indicators.

In this paper, the third method was used, and using the factor analysis, which is the statistical method, grouping was conducted on the evaluation indicators, which have homogeneous characteristics with the same evaluation criteria. The large merit of the factor analysis is that it can include necessary evaluation criteria and drop out evaluation indicators whose importance is low. Namely, by screening the evaluation indicators with the systematic method, the objective evaluation criteria and evaluation indicators can be derived.

3. Factor analysis

3.1 Samples

The samples were randomized with the nuclear experts and local residents in the area of nuclear power plants.

The group of people surveyed included professors of nuclear power related departments of domestic universities and nuclear power specialists who work in nuclear power related institution, professors of general departments in domestic universities, and the local residents (people at large) in the area of nuclear power plants. The professors in nuclear power-related departments and the people who work in nuclear power-related institutions were set up to be a nuclear power specialist sample group, and the professors in general departments and the local residents in the area of nuclear power plants were set up to be the sample group of the people at large.

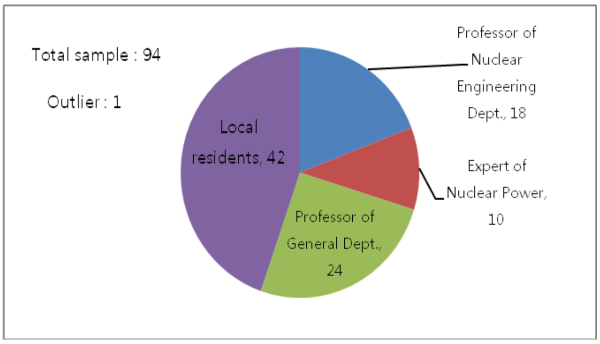

Figure 1. Samples

The reason why the local residents in the area of power plants were brought in as the sample of people at large is because they are more interested in the nuclear fuel cycle than the local residents in other areas, and they are expected to answer actively the questionnaires; thus, the reliability of the result of statistical treatment can be heightened. The respondents to the questionnaires were a total of 94 persons, as shown in Fig. 1, and 1 person had many items not answered, so it was treated as invalid.

3.2 Mathematical model

For a factor analysis on the evaluation criteria of the nuclear fuel cycle, a mathematical model is necessary, and if expressed as a general expression, it looks like Equation (1) [4].

$$x - \mu_i = b_{i1}F_1 + b_{i2}F_2 + \cdots + b_{iq}F_q + \varepsilon_i \,, \quad i = 1, 2, \cdots, n \qquad (1)$$

Here, $x' = (x_1, x_2, \cdots, x_n) \sim N_m(\mu, \sum_i)$ with μ : mean and $\sum_i$: covariance matrix, N_m : multi-variate normal distribution, $F_1, F_2, \cdots, F_q$: common factor, $\varepsilon_1, \varepsilon_2, \cdots, \varepsilon_n$: specific factor

Equation (1) can be arranged into Equation (2) using a vector.

$$x - \mu = BF + \varepsilon \qquad (2)$$

Here, F_j (0, 1) ~ mutually independent random variable with μ = 0, δ^2 = 1,

ε_i ~ mutually independent random variable with δ^2 = ϕ_i, ϕ_i : variance

3.3 Factor Analysis Results

As in Table 1, from the list of the 6 evaluation criteria and 50 evaluation indicators, a total of 5 evaluation criteria and 24 evaluation indicators were extracted. Namely, the safety (technological feature) evaluation criteria and the risk management were analyzed as homogeneous evaluation criteria, and were integrated as the evaluation criteria of safety (technological feature), and evaluation indicators whose attributes are overlapped and evaluation indicators which have a low factor score were dropped out.

4. Conclusions

As a result of a factor analysis, 5 evaluation criteria (① safety (technological feature), ② environmental impact ③ economic feasibility ④ sociality ⑤ institution) and 24 evaluation indicators were selected. Particularly, the level of legislation for the management of radioactive waste, the level of establishment of safety standards of the country, and the level of application of international safety standards were analyzed to be qualitative evaluation indicators that should be considered in the aspect of the institution.

Table 1. The derived evaluation criteria and indicators

Criteria	Requirements	Evaluation indicators
Economic feasibility (3 indicators)	Price competitiveness	Unit cost, total cost
	Cost of R&D facilities	Investment cost
Environmental impact (5 indicators)	Pollution level of natural resource	Greenhouse gas emissions, Degree of natural resource pollution
	Waste generation amount	Low-level waste amount, High-level waste amount
	Toxicity	Toxicity level
Safety (6 indicator)	Radiation exposure doses for radiological workers	Radiation exposed dose rates
	Facility safety	Facility and process safety level
	Process efficiency	Throughput efficiency, Resource recovery rate
	R&D period	Lead time(Month)
	Licensing difficulty level	Lead time(Month) for licensing
Sociality (6 indicators)	Social acceptance	Public acceptance, Confidential relationship for local government
	Proliferation resistance	Intrinsic barriers, Legal and institutional barriers
	Energy security	Nuclear energy ratio
	Nuclear international diplomacy	Influence level for the ROK-U.S atomic energy agreement
Institution (4 indicators)	Radioactive waste management	Legislation level regarding HLW management law, Legislation level regarding ILLW management law
	Institution level	National level of safety standards, Application level of international safety standards

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