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A STATISTICAL APPROACH FOR DERIVING KEY NFC EVALUATION CRITERIA

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This study suggests 5 evaluation criteria (safety and technology, environmental impact, economic feasibility, social factors, and institutional factors) and 24 evaluation indicators for a NFC (nuclear fuel cycle) derived using factor analysis.

To do so, a survey using 1 on 1 interview was given to nuclear energy experts and local residents who live near nuclear power plants. In addition, by conducting a factor analysis, homogeneous evaluation indicators were grouped with the same evaluation criteria, and unnecessary evaluation criteria and evaluation indicators were dropped out.

As a result of analyzing the weight of evaluation criteria with the sample of nuclear power experts and the general public, both sides recognized safety as the most important evaluation criterion, and the social factors such as public acceptance appeared to be ranked as more important evaluation criteria by the nuclear energy experts than the general public.

KEYWORDS : Nuclear Fuel Cycle, Evaluation Criteria, Evaluation Indicator, Factor Analysis, Screening Factor, Factor Score, Descriptive Statistics, Nuclear Safety

1. INTRODUCTION

Recently, due to the influence of the accident at the nuclear power plant in Fukushima Japan, countries have become more divided in their preferences regarding nuclear power.

While the countries that prefer the development of nuclear power technology stress the role of nuclear power, the countries that do not prefer nuclear power claim that the development of nuclear power technology should be reconsidered due to concerns about the safety of nuclear power plants and the problem of spent fuel.

The problem of the treatment and disposal of spent fuel becomes an important factor that determines the sustainability of nuclear power [1]. An advanced nuclear fuel cycle such as pyroprocessing, which can reduce the amount of spent fuel, is recognized as a promising technology [2]. However, to develop such an advanced nuclear fuel cycle, it is necessary to first evaluate the technological and economic validity, and to do so, objective evaluation criteria and evaluation indicators are necessary [3].

The purpose of analyzing diverse nuclear fuel cycles is to select the optimum nuclear fuel cycle suitable for the environment of one's own country, and to maintain nuclear power sustainability [4]. Accordingly, since the nuclear fuel cycle should be evaluated with regard to various factors such as politics, the economy, and society, diverse evaluation criteria and evaluation indicators are necessary [5].

An evaluation of the nuclear fuel cycle is conducted from the selection of various evaluation criteria. Intuitively, safety (technological features), economic feasibility, environmental features, and nuclear non-proliferation can be used as evaluation criteria [6], and such individual evaluation criteria can be explained with various evaluation indicators [7].

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 [8]. Accordingly, not only should the evaluation indicators be composed of an appropriate number of units, but they should also not overlap. Ambiguous evaluation indicators should be dropped out and necessary evaluation indicators must be included [9].

For example, the securement of land for a high-level radioactive waste (HLW) repository is an important matter that advanced nuclear power nations and the international communities are concerned about. It is difficult for the government to independently determine a reasonable policy, and there is likely to be social conflict because of NIMBYism against nuclear power by the residents of the country. Accordingly, evaluation indicators such as public acceptance should be necessarily considered.

Another example, since pyroprocessing extracts plutonium together with neptunium and curium, is the difficulty in separating only plutonium, and thus proliferation resistance is large. In addition, high level waste (HLW) materials with a long half-life such as plutonium (Pu), neptunium (Np), and curium (Cm) are mostly recycled as the raw material of Sodium-cooled fast reactor (SFR) nuclear fuel, and only the nuclides of short half-life like Cesium (Cs) and strontium (Sr) remain, which can largely reduce the scale of an HLW repository. Accordingly, when evaluating the pyroprocessing nuclear fuel cycle, the proliferation resistance can be an important evaluation indicator [10]. The aim of this study is to suggest the key evaluation criteria and evaluation indicators derived using a factor analysis.

2. SURVEY OF PRECEDING STUDIES

Since the 1990s, countries with advanced nuclear energy programs have derived various evaluation criteria and evaluation indicators to analyze diverse nuclear fuel cycles, such as public acceptance, eco-friendliness, and safety. Recently, nuclear energy research institutions have been developing screening methods and factor analysis, which is a statistical method to derive reasonable evaluation criteria. For instance, in 2012, ANL (Argonne National Laboratory) hosted a seminar, and derived 9 high-level evaluation criteria (① nuclear waste management, ② nuclear proliferation risk, ③ nuclear material security risk, ④ safety, ⑤ financial risk and economics, ⑥ environmental impact, ⑦ resource utilization, ⑧ development and deployment risk, and ⑨ institutional issues) [11].

In addition, in 2012, OECD/NEA collected the opinions of experts from countries with advanced nuclear power programs, and derived 2 general upper level evaluation criteria (① government and public acceptance, ② technological features and economic feasibility) and detailed evaluation criteria. The detailed evaluation criteria of the government and public acceptance criterion include the security of energy supplies, non-proliferation, public acceptance, environmental effects, waste management, transport, and legal and regulatory aspects. The technical and economic evaluation criteria include the development of fast reactors and fuel cycles, technological challenges and industrial acceptability for different systems, retrievability of waste, safety aspects, costs, and economic development [12].

In addition, INPRO (International Project on Innovative Nuclear Reactors and Fuel Cycles) chose a total of 7 evaluation criteria (① economic feasibility, ② infrastructure, ③ waste management, ④ proliferation resistance, ⑤ physical protection, ⑥ safety, ⑦ environment) to evaluate the sustainability of nuclear energy. In 1999, the IAEA derived the evaluation criteria of sociality, economic feasibility, and the environment, and GEN IV chose the evaluation criteria of sustainability, safety and reliability, and economic feasibility [2].

After reviewing the evaluation criteria of foreign countries, it appears that they mostly chose similar evaluation criteria.

The evaluation criteria chosen in common were determined to be safety, sociality, economic feasibility, and environmental impact. Such evaluation criteria have been recognized as important items to be considered when evaluating the alternatives to the nuclear fuel cycle since the latter half of the 1990s.

3. DEFINITION AND PROPERTIES OF EVALUATION INDICATORS

Evaluation indicators can be largely classified into three categories: ad hoc indicators, indicators based on data, and composite indicators. Ad hoc indicators are indicators temporarily made when the government needs to justify a policy. Indicators based on data are indicators developed through factor analysis, and composite indicators are indicators that mix various items. The indicators that evaluators are greatly interested in are indicators based on data [13].

The factors that influence the choice of evaluation indicators are the level and the feasibility of the measurement. The feasibility is the possibility of collecting data required for analysis.

In other words, the measurement level is the problem of choosing the yardstick for the measurement indicators. The yardstick which corresponds to the characteristics of the concerned indicator should be a nominal scale, ordinal scale, interval scale, or ratio scale [14].

In addition, the basic elements of the evaluation indicators are the definition of the indicator, the weight, and the rating interval. The weight means the evaluation weight of each indicator when putting the scores together, and the rating interval means the expression of the rating to the extent of the evaluation [15].

4. THE METHOD OF SCREENING EVALUATION CRITERIA

The evaluation criteria list is generally first made by using the usual procedure, as shown in Fig. 1, and reasonable evaluation criteria and evaluation indicators are chosen through a factor analysis with this list [16].

The methods used to derive evaluation indicators are largely of three kinds: a literature investigation to find indicators which have already been developed, a top-down method in which expert opinion is used to construct the list, and a bottom-up method using the list of evaluation indicators derived in preceding studies.

In this paper, the third method was used, and factor analysis was used to group evaluation indicators which have homogeneous characteristics with the same evaluation criteria [17].

The benefit of factor analysis is that it can identify necessary evaluation criteria and reject evaluation indicators whose importance is low [18]. By screening the evaluation indicators with this systematic method, objective evaluation criteria and evaluation indicators can be derived.

The ANL research institute in the US presently uses a matrix analysis method to deduct reasonable evaluation criteria. This method can derive important evaluation criteria by using the correlation between the evaluation criteria and the evaluation indicators. The drawback of this method is that it needs a large workforce and time to collect the opinions of the experts. On the other hand, since factor analysis uses a statistical method, it is possible to deduct reasonable evaluation criteria and evaluation indicators with comparatively less workforce and time [19]. However, sampling should be carried out carefully and outliers should be eliminated [20].

The AHP(analytic hierarchy process) method, which is a typical multiple criteria decision making method, can be used as another method of deriving evaluation criteria [13]. This method can derive reasonable evaluation criteria by setting the hierarchy of the evaluation criteria and the evaluation indicators. The benefit of this method is that the relation between the evaluation criteria and evaluation indicators can be expressed vertically. However, this method makes it cumbersome to collect the judgment of experts, and it cannot directly reflect public acceptance.

In this paper, to overcome such problems, a survey on the evaluation criteria and evaluation indicators was performed. Opinions were collected from various groups, including nuclear power experts and the general public, to calculate the weight of the evaluation criteria, and a list of comprehensive evaluation criteria and evaluation indicators was made.

The reason why opinions were collected from both experts and the general public is to derive objective evaluation indicators reflecting the public acceptance as much as possible.

Fig. 2 shows the method of deduction of the evaluation criteria of the nuclear fuel cycle conducted in this study, and Table 1 describes the merits of this study method.

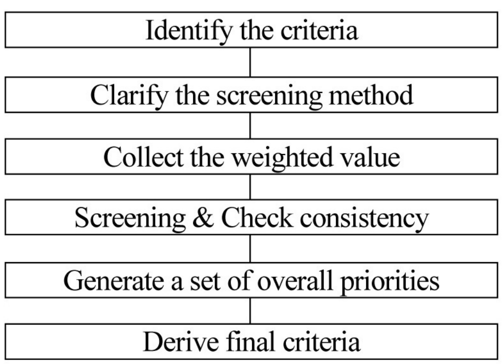

Fig. 1. The General Derivation Procedure of Evaluation Criteria

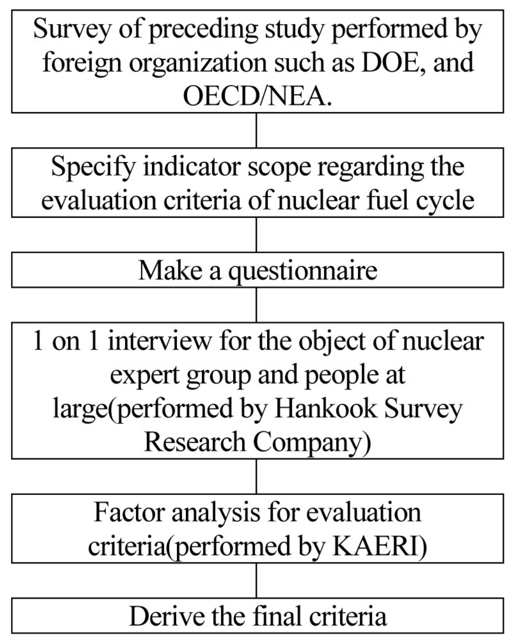

Fig. 2. KAERI's Approach for Determining the Evaluation Criteria of Nuclear Fuel Cycle

Table 1. Comparison of the Method of Deduction of Evaluation Criteria

Evaluation lead	Screening Method		Merits and demerits
IAEA(1999), GEN IV (1999), ILK(2004), OECD/NEA (2001)	Judgment of expert by discussion among the experts	Merit	·Easy to prepare evaluation criteria suitable for the development of the country excluding the opinions of amateurs ·Exclusion of prejudice of amateurs
		Demerit	·Excessive necessity of cost and time for several meetings of experts ·Difficult to form national social consensus due to subjective judgment of minority
KAERI(2012)	Statistical method (factor analysis)	Merits	·Scientific and reasonable method of deduction · Possibility of grouping of systematical evaluation indicators · Reflects public acceptance · Needs a little cost and time
		Demerits	· Existence of possibility to reflect the prejudice of amateurs

5. EMPIRICAL ANALYSIS

5.1 Samples

The sample survey was conducted by Hankook Research Co. Ltd. in Korea, and the samples were randomly selected from nuclear experts and local residents in the area of nuclear power plants.

The method used to carry out this study is judgment sampling under a non-probability sampling method mixed with stratified sampling, which is one of the probability sampling methods. The reason why the judgment sampling method was chosen is that it can be appropriate when the survey researcher already has prior knowledge of the questionnaire. The detailed sampling process is as follows.

First, the samples were divided into four groups, including 18 nuclear engineering professors, 10 nuclear experts, 24 intellectuals (professors of non-nuclear engineering dept.), and 42 local residents, based on the judgment sampling method. Secondly, by the stratified sampling method, the samples were approximately composed of 60% experts and 40% ordinary people. Thirdly, the residents near nuclear power plant sites were assumed to be ordinary people. To be more concrete, the local resident list from the Dong office was sorted by birth date, and then samples were selected from the stratified group with a random sampling method by using the program developed by Hankook Research Co. Ltd at Seoul.

The group of people surveyed included professors of departments of domestic universities related to nuclear power, nuclear power specialists who work in nuclear power related institutions, professors of general departments in domestic universities, and the local residents 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 assigned to the nuclear power specialist sample group, and the professors in general departments and the local residents in the area of nuclear power plants were assigned to the sample group of the people at large. 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 were expected to actively answer the questionnaires; thus, the statistical reliability could be heightened.

However, since people at large lack knowledge of the nuclear fuel cycle, the reliability of their answers to the questionnaires can be diminished. Accordingly, education about the nuclear fuel cycle was carried out for the persons in charge of the interview to minimize response errors.

A total of 94 people responded to the questionnaire, as shown in Fig. 3. One person had many items not answered, so that questionnaire was treated as invalid.

5.2 Analysis on Weight of Evaluation Criteria of Nuclear Fuel Cycle

In the case when many evaluation criteria exist, the weight of the evaluation criteria should be calculated with quantified numerical values to make the decision easy [21]. However, a scientific calculation method is required to express the relative importance of the evaluation criteria with a quantified numerical value.

Fig. 4 shows the results of the calculation of the rank-sum weight using Equation (1) with the entire samples, whereas Fig. 5 is the calculation of the rank reciprocal weight using Equation (2) with the sample of the specialist group [22].

$$W_i = \frac{N - R_i + 1}{\sum_{i=1}^{n}(N - R_i + 1)} \tag{1}$$

$$W_i = \frac{1/R_i}{\sum_{i=1}^{n}(1/R_i)} \tag{2}$$

Here, N = a highest-rank, R_i= the rank of i-factor

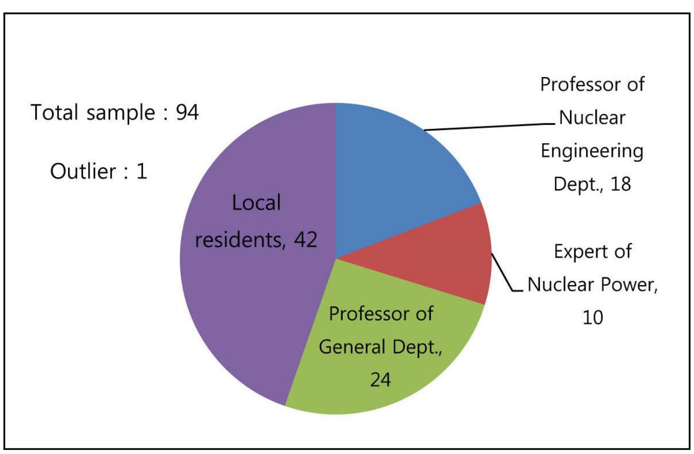

Fig. 3. Samples

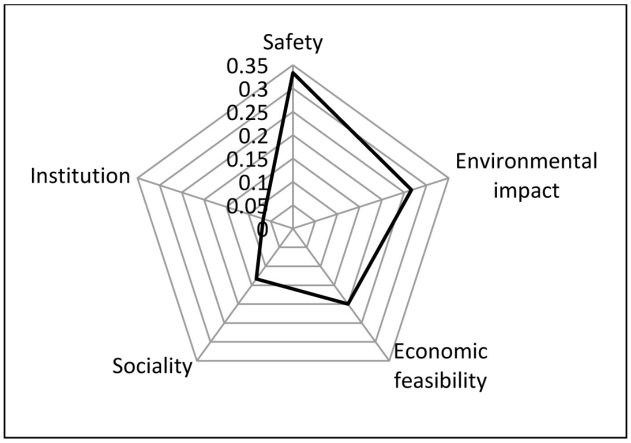

Fig. 4. Rank-sum Weight of Evaluation Criteria

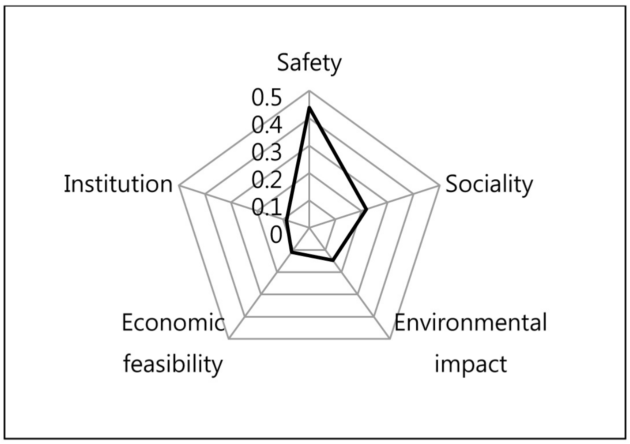

Fig. 5. Rank Reciprocal Weight of Evaluation Criteria

As shown in Fig. 4 and Fig. 5, the evaluation criteria of safety (technological feature) appeared to be the most important factor. The reason for this tendency is judged to be people's interest in the accidents at the nuclear power plant in Fukushima, Japan.

In addition, it was found that social factors such as public acceptance appeared to be recognized as a more important evaluation criterion by the nuclear energy experts than the general public.

5.3 Factor Analysis

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 (3) [23].

$$x - \mu_i = b_{i1}F_1 + b_{i2}F_2 + \cdots + b_{iq}F_q + \varepsilon_i\ , \quad i = 1, 2, \cdots, n \qquad (3)$$

Here, $x' = (x_1, x_2, \ldots, x_n) \sim N_m(\mu \sum_i)$ with μ being the mean and $\sum_i$ being the covariance matrix, N_m is the multivariate normal distribution, $F_1, F_2, \ldots, F_q$ is the common factor, and $\varepsilon_1, \varepsilon_2, \ldots, \varepsilon_n$ is the specific factor

Equation (3) can be arranged into Equation (4) using a vector.

$$x - \mu = BF + \varepsilon \qquad (4)$$

Here, F_j (0, 1) is the mutually independent random variable with $\mu = 0$, $\delta^2 = 1$, ε_i is the mutually independent random variable with $\delta^2 = \phi_i$, ϕ_i variance

In addition, the variance of x_i is shown in Equation (5) [23].

$$\mathrm{var}(x_i) = b_{i1}^2 + b_{i2}^2 + \cdots + b_{iq}^2 + \phi_i \qquad (5)$$

Here, $h_i^2 = b_{i1}^2 + b_{i2}^2 + \cdots + b_{iq}^2 + \phi_i$ is the common factor variance or communality, ϕ_i is the specific variance, and $b_{ij} = \mathrm{cov}(x_i, F_j)$is the factor loading

While the communality is the sum of the squares of all factor loadings of a particular variable, the Eigen value that expresses the degree of explanation of a particular factor is the sum of the squares of the factor loading of all variables about a particular factor.

The factor extraction models are principal component analysis, principal factor analysis, and maximum-likelihood factor analysis. Out of these, the principal component analysis which was used in this paper is mostly commonly used.

The average and standard deviations for the weight of evaluation indicators used as variables are in Table 2.

Factor analysis is a method of multivariate analysis that can screen the evaluation indicators, and can select only the necessary evaluation criteria [24]. In this study, the factor analysis was conducted with the following procedure. ① A survey was conducted through 1 on 1 interviews, and as a measurement yardstick, a 7- point Likert Type Scale was used. The response data were used as the input data of the factor analysis. ② Using the response data about the importance of evaluation criteria, the weight of the evaluation criteria was calculated. ③ Descriptive statistics of evaluation indicators were calculated. ④ To deduce the valid evaluation criteria, the VARIMAX method, which is an orthogonal oblique, was used [25]. ⑤ The factor scores of the evaluation indicators were analyzed. Specifically, the evaluation indicators whose factor loading belongs to the same factor were grouped with the same evaluation criteria, and with a factor score of 0.5 as the criterion, the evaluation indicators were screened for inclusion. If the factor loading is 0.5 or more, it can be chosen as an evaluation indicator, and if it is less than 0.5, it is dropped out of the list of evaluation indicators [14]. ⑥ The final evaluation criteria and evaluation indicators of the nuclear fuel cycle were selected through the review of inside experts.

As factor analysis software, the SPSS 20 statistical package was used.

Table 2. Descriptive Statistics of Evaluation Criteria

Criteria	Variables	Mean	Std. Dev.	Criteria	Variables	Mean	Std. Dev.
Economic feasibility	x1	4.5053	1.4417	Safety	x26	6.7311	0.8094
	x2	4.7634	1.3862	Sociality	x27	4.4516	1.3311
	x3	4.7096	1.5363		x28	5.3548	1.2738
	x4	4.7741	1.3997		x29	5.5161	1.1943
	x5	4.4838	1.4641		x30	5.1290	1.4005
	x6	4.9784	1.5946		x31	4.9677	1.2807
	x7	4.9677	1.5283		x32	5.4838	1.3072
	x8	4.9247	1.4613		x33	5.2473	1.4792
	x9	4.9032	1.4375		x34	5.2150	1.4207
	x10	5.1935	1.3534		x35	5.2043	1.4261
Environmental impact	x11	5.8709	1.3369		x36	4.9892	1.4483
	x12	5.9139	1.3076		x37	4.7849	1.3339
	x13	5.5376	1.5918		x38	4.8279	1.3482
	x14	5.6236	1.1601	Risk Management (merged with "Safety" after doing factor analysis)	x39	5.5268	1.2734
	x15	6.2043	1.0060		x40	4.7956	1.3796
	x16	5.7526	1.1946		x41	4.7849	1.3339
	x17	5.8602	1.1849		x42	4.5053	1.4189
	x18	5.2473	1.1946		x43	4.8817	1.3975
	x19	5.0537	1.2884		x44	4.8172	1.3983
	x20	4.9032	1.5112	Institution	x45	5.6236	1.3014
	x21	5.0107	1.4256		x46	5.4623	1.3477
	x22	6.1935	1.1156		x47	5.4623	1.3717
Safety	x23	6.4946	0.9849		x48	5.4731	1.3153
	x24	5.6881	1.1885		x49	4.9784	1.4668
	x25	5.3870	1.3354		x50	5.2795	1.3299

5.4 The Result of Factor Analysis

Figures 6-10 show the calculation results of factor scores from factor analysis with both the whole samples and the expert samples.

In addition, Tables 3 to 6 show the results of the screening of the evaluation indicators through factor analysis, and the √ mark means a dropout from the evaluation indicators. The screening was conducted with the factor analysis dividing the people into the entire group and the expert group, and only the evaluation indicators that were chosen in both groups selected as the final evaluation indicators.

At last, as shown in Fig. 11, from the list of the 6 evaluation criteria and 50 evaluation indicators, a total of 5 evaluation criteria and 24 evaluation indicators were extracted. The safety (technological features) evaluation criteria and the risk management were analyzed as homogeneous evaluation criteria, and were integrated as the evaluation criteria of safety (technological features). Evaluation indicators whose attributes overlap and evaluation indicators which have a low factor score were dropped out.

In addition, through the Eigen value of the factor analysis, it was found that the 5 evaluation criteria appeared to be reasonable because the Eigen values of the 5 factors were greater than 1.

The final evaluation criteria and evaluation indicators are shown in Table 7.

In addition, for the development of the pyroprocessing technology, the ROK-U.S. Atomic Energy Agreement

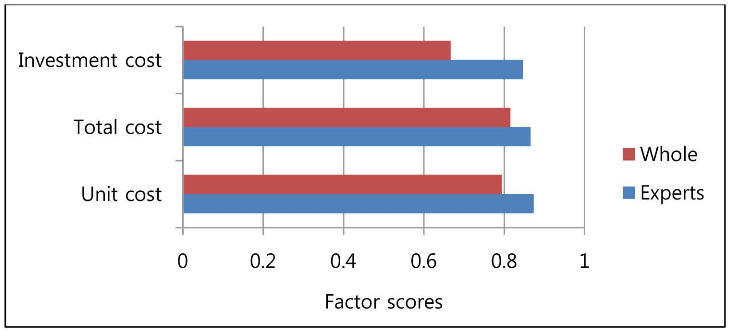

Fig. 6. Economic Feasibility Factor Scores

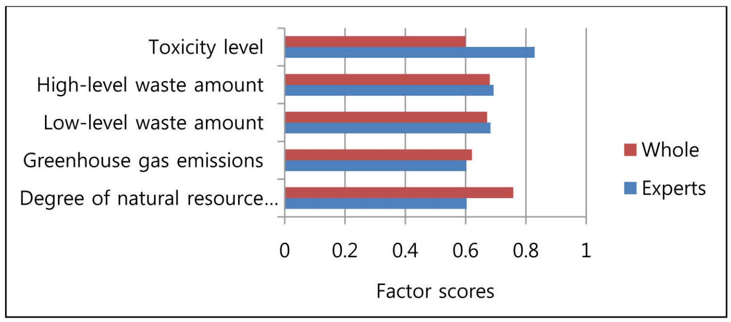

Fig. 7. Environmental Impact Factor Scores

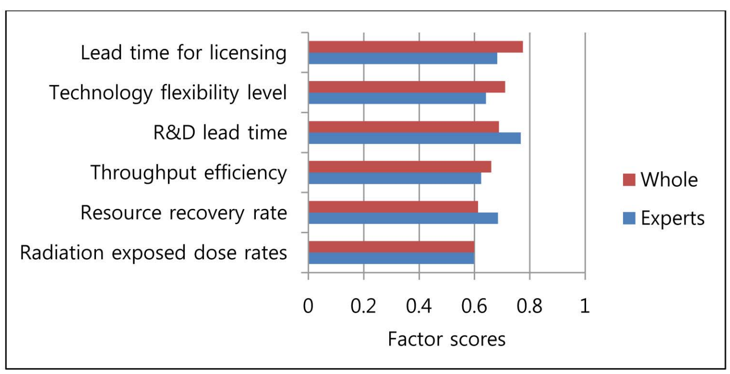

Fig. 8. Safety and Technology Factor Scores

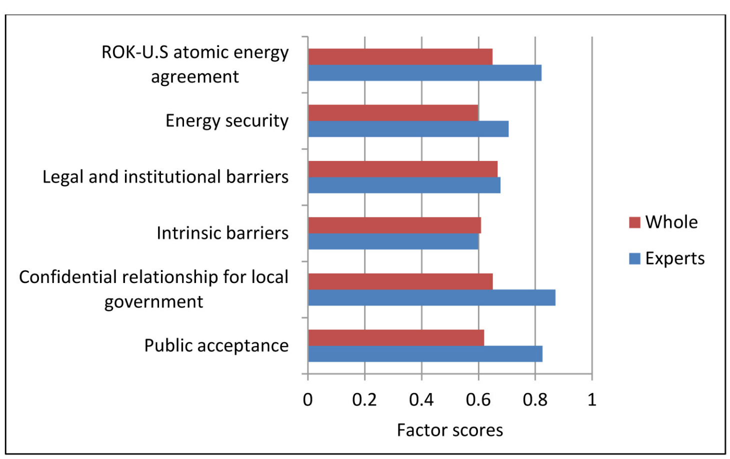

Fig. 9. Social Factor Scores

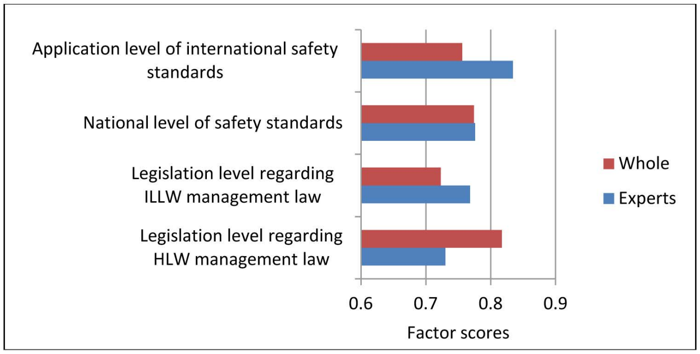

Fig. 10. Institutional Factor Scores

Table 3. Evaluation Criteria and Indicators of Economic Feasibility

Criteria	Requirements	Evaluation indicator	Screening	
			Whole- sample	Experts
Economic feasibility (10)	Price competitiveness	X1. Unit cost		
		X2. Total cost		
		X3. Operation period		√*
		X4. Efficiency (input/output)		√
	Cost of R&D facilities	X5. Investment cost		
	Resource consumption	X6. Material consumption		√
		X7. Pu utilization	√	√
	Domestic technology utilization	X8. Availability of domestic technology		√
	Uranium supply	X9. Availability of uranium supply		√
	Value of recovered raw material	X10. Credit		√

(*: The √ mark means a dropout from the list of evaluation indicators).

Table 4. Evaluation Criteria and Indicators of Environmental Impact

Criteria	Requirements	Evaluation indicator	Screening	
			Whole- sample	Experts
Environmental impact (12)	Pollution level of natural resource	X11. Degree of natural resource pollution		
	Waste generation amount	X12. Recalcitrant waste generation rate		√
		X13. Greenhouse gas emissions		
		X14. Low-level waste amount		
		X15. High-level waste amount		
		X16. Minor Actinide amount	√	√
	Waste storage	X17. Waste storage period	√	√
	Waste transportation	X18. Traffic distance	√	√
		X19. Shipping time	√	√
	Land	X20. Possessory area	√	
		X21. Excavation volume	√	
	Toxicity	X22. Toxicity level		

Table 5. Evaluation Criteria and Indicators of Safety and Sociality

Criteria	Requirements	Evaluation indicator	Screening	
			Whole- sample	Experts
Safety (4)	Radiation exposure doses for radiological workers	X23. Radiation exposed dose rates		
	Process efficiency	X24. Resource recovery rate		
		X25. Throughput efficiency		
	Facility safety	X26. Facility and process safety		
Sociality (12)	Human resource utilization	X27. Employment	√	√
	Social acceptance	X28. Public acceptance		
		X29. Confidential relationship for local government		
	Macroeconomics	X30. Social ripple effect	√	√
	Social cost	X31. Compensation expenses	√	√
	Proliferation resistance	X32. Intrinsic barriers		
		X33. Legal and institutional barriers		
	Energy security	X34. Nuclear energy ratio		
	Nuclear security risk	X35. Influence for nuclear security	√	
	Nuclear international diplomacy	X36. Influence level for the ROK-U.S atomic energy agreement		
	Medical welfare	X37. Application for medical industry	√	√
	Creation of new technology	X38. Creation level of new Bio tech, Nano tech, and information tech.		√

Table 6. Evaluation Criteria and Indicators of Risk Management and Institution

Criteria	Requirements	Evaluation indicator	Screening	
			Whole- sample	Experts
Risk management (6) (This criterion was integrated with "Safety"	Technology readiness	X39. TRL(Technology Readiness Level) index	√	√
	R&D period	X40. Lead time(Month)		
	Technical development flexibility	X41. Technology flexibility level	√	
	Licensing difficulty level	X42. Lead time(Month) for licensing		
	Policy change	X43. Risk level due to policy change		√
		X44. Flexibility level due to policy change		√
Institution (6)	Radioactive waste management	X45. Legislation level regarding HLW management law		
		X46. Legislation level regarding ILLW management law		
	Institution level	X47. National level of safety standards		
		X48. Application level of international safety standards		
	Multilateral Nuclear Approach	X49. Multilateral cooperation level		√
	Realizability	X50. Policy realizability		√

should be included in the evaluation criteria of sociality. For the environmental effect evaluation criteria, considering waste production was chosen as an important evaluation indicator due to the influence of waste on the environment. For the safety evaluation criteria, the safety of facilities was chosen as an evaluation indicator, and in consideration

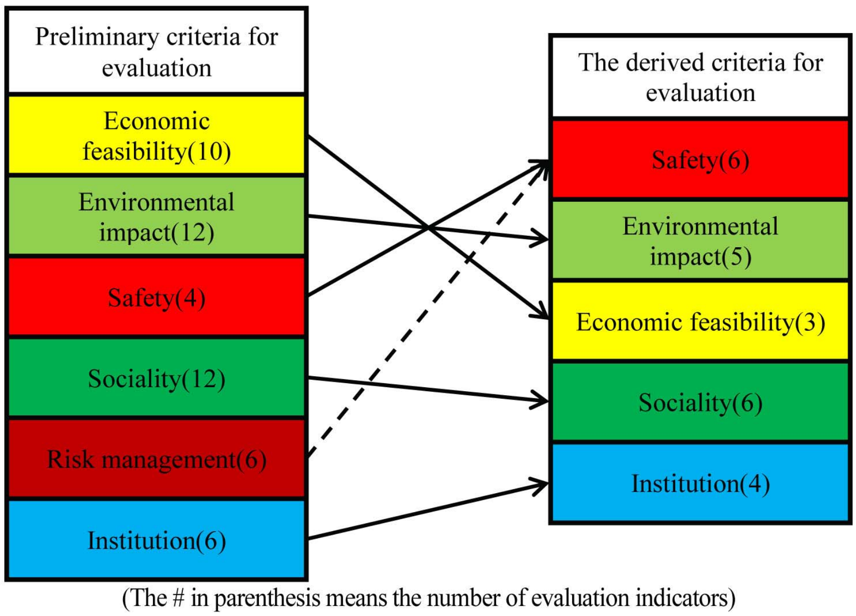

Fig. 11. Consequence of Factor Analysis

Table 7. The Final 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

of the burden of research and development, the time needed for research and development was selected as the evaluation criteria related to the technological feature.

The evaluation indicator of the institution evaluation criteria includes the level of legislation of the waste related laws and safety standards. This is because IAEA has a trend to improve the international safety standards continuously for the safety and sustainability of nuclear power.

6. CONCLUSION

This study conducted a factor analysis to derive the necessary evaluation criteria. Input data for the factor analysis were prepared using survey data obtained from nuclear experts and the local residents in the area of the power plants.

As a result of the factor analysis, 5 evaluation criteria (① safety and technology, ② environmental impact, ③ economic feasibility, ④ social factors, ⑤ institutional factors) and 24 evaluation indicators were selected.

Particularly, the level of legislation for the management of radioactive waste, the establishment of safety standards in the country, and the application of international safety standards were found to be qualitative evaluation indicators that should be considered.

Selected evaluation indicators can be measured quantitatively or qualitatively depending on the attributes that the evaluation criteria have. For instance, economic feasibility evaluation indicators can use quantitative numerical values such as the unit cost, total cost, and investment cost. On the contrary, since the institutional evaluation indicators are difficult to be expressed as a quantitative numerical value, they can be measured with a qualitative value. Accordingly, derived evaluation criteria and evaluation indicators include both quantitative measured values and qualitative measured values.

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