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시스템엔지니어링에 기반한 원자력 사업대상국가 평가방법 연구

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Study on Prioritizing the countries for BOT nuclear power project using Analytic Hierarchy Process

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Abstract : Developing Build-Own (or Operate)-Transfer (BOT) nuclear power project carrying large capital in the long term requires initially well-made multi-decision which it prevents sorts of risks from unexpected situation of target countries. In order to analyze the feasibility of project country, the Analytic Hierarchy Process is adopted. Firstly, the factors influencing the success of BOT nuclear power project in overseas countries were investigated through the literature survey for the country risk and were evaluated by expert interview for estimating comparative weight through pairwise comparison between such factors. Finally, it is developed comparative database of alternate countries with respect to each factor. This analytic method enables the developer to select and focus on the country which has preferable circumstance so that it enhances the efficiency of the project promotion. Also, it enables the developer to quantify the qualitative factors so that it diversifies the project success strategy and policy for the target country.

Key Words : Analytic Hierarchy Process, factor, alternative, risk cube, BOT, nuclear power project, goal, pairwise comparison, country, multi decision making. prioritizing, comparative importance.

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1. Introduction

Developing Build-Own(or Operate)-Transfer (BOT) nuclear power project, which is synthetic and complex industry, requires system engineering skill(e.g. Risk Cube Model, Analytic Hierarchy Process, etc.) for managing efficiently interrelated components toward some common objective.[1] Especially, in promoting overseas nuclear power project, initial well-made decision prevents sorts of risks from unexpected situation of targeted countries. Since the nuclear power project in most case is practically implemented by Government to Government cooperation, so the key concern for efficient systematical management would be focused on the country environment at planning stage. Therefore, prioritizing and evaluating the feasibility of country for identification of optimal project region is very meaningful activity.

This study proposes factors influencing the success of BOT nuclear power projects and their weighting method using Analytic Hierarchy Process(AHP) to find the optimal country which developer intends to develop.

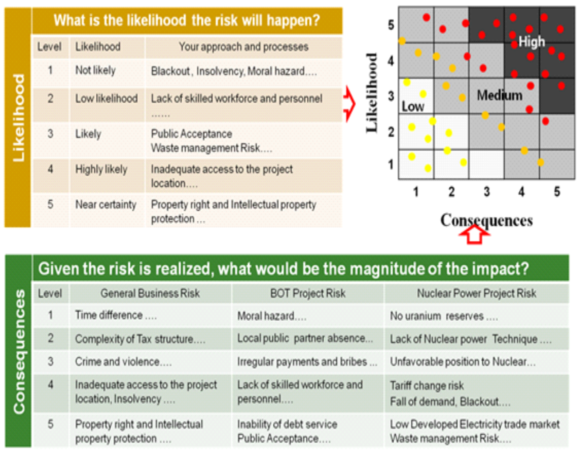
2. Need analysis

2.1 Feature of BOT nuclear power project

BOT is a business type that private or public sectors finance, design, construct, and operate power plant during the concession contract. During the contract period, developer and its investor recover its investment, operating and maintenance expenses in the project implemented a particular form of project financing. The operating period of a project is very long, and associated with a number of stakeholders of the project country. Therefore, BOT project faces various risks from unfamiliar environment of project country and has requirement of integrating opinions from various stakeholder.

2.2 Risk Identification and allocation

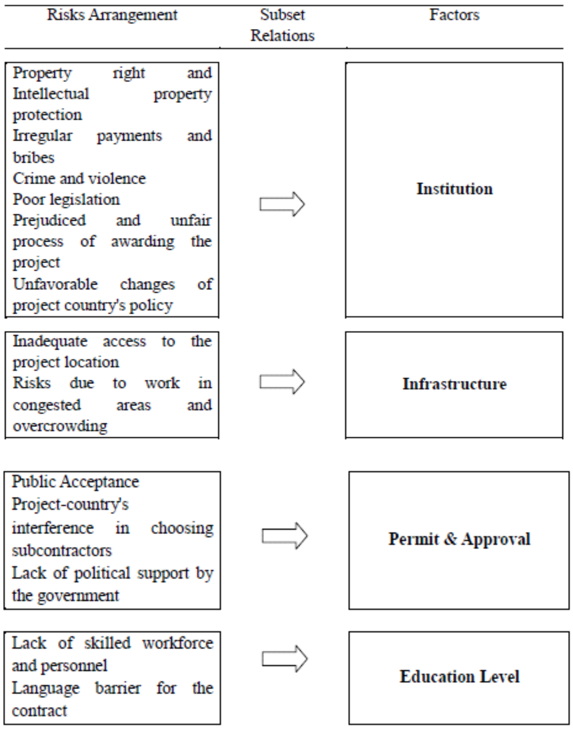
In order to analyze the feasibility of project country, it is necessary to find the efficient methodology to investigate the risks influencing the BOT project success. The risk type was classified by three division: (a) General Business Aspect, (b) BOT Business Aspect, (c) Nuclear Power Project Aspect and these risks are selected by risk cube model as the below figure 1.



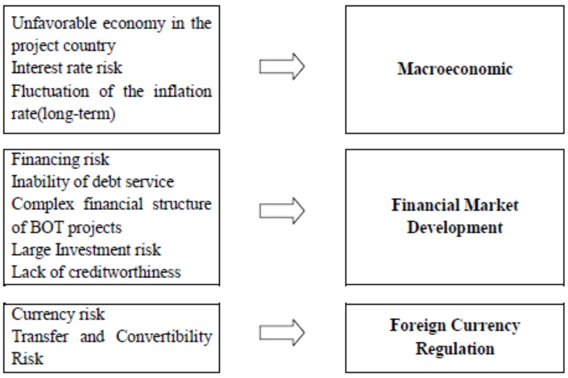
[Figure 1] Risk selection by risk cube model

The figure shows risk mapping matrix where the vertical axis indicates increasing probability of occurrence of the identified risk item and the horizontal axis the increasing consequence of the risk actually occurring.

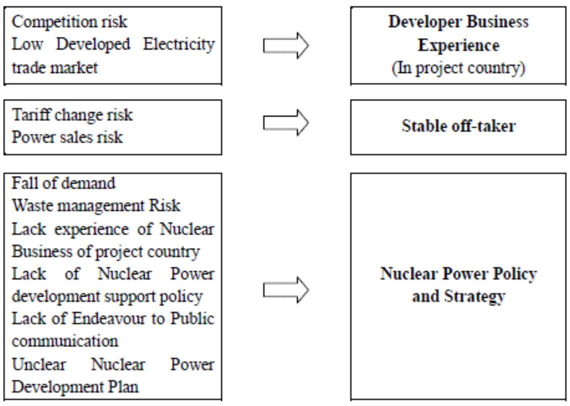
The risks selected by risk cube model were categorized by their similarity as the following:



[Figure 2] General Business Risks in overseas country



[Figure 3] BOT Business Risks in overseas country



[Figure 4] Nuclear Power Project Risks in overseas country

The selected risks were connected to representative factor. Total 10 factors influencing the success of project development were used in analysis.

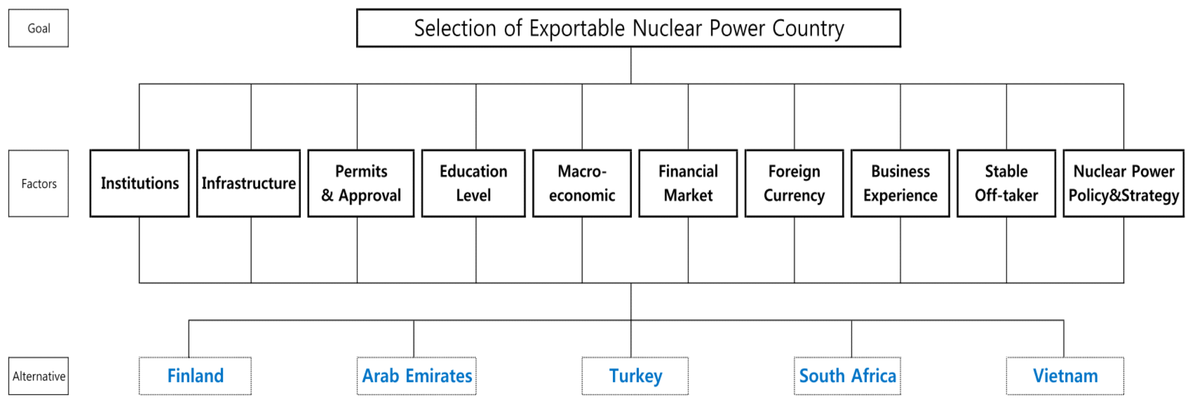
3. System architecting

3.1 Analytic Hierarchy Process

It is used the Analytic Hierarchy Process for solving multiple criteria decision making problems. AHP is a multiple criteria decision-making method that helps the decision-maker facing a complex problem with multiple conflicting and subjective criteria. It was originally developed by Prof. Thomas L. Saaty(1977). It simplifies preference ratings among factors (decision criteria) using pairwise comparisons, derives priorities among criteria & alternatives and provides measures of judgment consistency[2].

3.2 Application of factors and alternatives

The factors were considered whether it has availability before preliminary feasibility study of project for minimizing sunk cost, quantitative and practical criteria for evaluating the alternatives, additionally, whether it enables developer to do prompt evaluation for country and periodically update data provided by authoritative literature or not. Each factor shall be mutually independent for alternatives evaluation. For selecting alternatives, several potential countries which BOT project is currently promoted were considered. Analytic hierarchy structure composed of these elements is as the figure 5.



[Figure 5] The Analytic Hierarchical Structure for evaluating exportable nuclear power region

4. Decision Analysis and Support

4.1 Research Methodology

Pairwise comparisons by expert-oriented survey are made with the grades ranging from 1-9 to determine the relative weights of factors as the Figure 6 below(A basic, but very reasonable, assumption: If attribute A is absolutely more important than attribute B and is rated at 9, then B must be absolutely less important than A and is valued at 1/9). Also, it is calculated Consistency Ratio (CR) to measure how consistent the judgments have been relative to large samples of purely random judgments.(if CR>0.1, untrustworthy)

Classfication	Institutions	Infra-structure	Permit & Approval	Education	Macro-economic	Financial Market	Foreign Currency	Experience	Stable Off-taker	Nuclear Policy
Weighting										

Consistency Index	:	Consistency Ratio (O.K < 0.1)	

☐ Pairwise Comparison Matrix

Matrix	Institutions	Infra-structure	Permit & Approval	Education	Macro-economic	Financial Market	Foreign Currency	Experience	Stable Off-taker	Nuclear Policy
Institutions	1									
Infrastructure	#DIV/0!	1								
Permit&Approval	#DIV/0!	#DIV/0!	1							
Education	#DIV/0!	#DIV/0!	#DIV/0!	1						
Macroeconomic	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	1					
Financial Market	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	1				
Foreign Currency	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	1			
Experience	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	1		
Off-taker	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	1	
Nuclear Policy	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	1

[Figure 6] AHP excel tool for determining the relative weights

The 40 nuclear experienced working level employee(average 5.4 years) from various countries participated in the interview, however, Only 20 consistent responses among them were reflected to survey results with average consistency ratio 0.0875.

<Table 1> Status of Interviewee and Consistency Index

No	Country	Organization	Yr	CR
A	Vietnam	Nation Research Institute of ME	4	0.0501
B	Malaysia	AELB	3	0.0997
C	Malaysia	Research Co.	1	0.0817
D	Turkey	Istanbul Technical Univ	1	0.0663
E	Kenya	Electricity Utility Company	1	0.0951
F	U.A.E	ENEC	1	0.0949
G	Kenya	Radiation Board	10	0.0943
H	Vietnam	Electricity of Vietnam	10	0.0915
I	Korea	KEPCO	5	0.0827
J	Korea	KEPCO	3	0.0907
K	Korea	KEPCO E&C	10	0.0936
L	Korea	KHNP	9	0.0910
M	Korea	KEPCO E&C	6	0.0795
N	Korea	KHNP	4	0.0995
O	Korea	KHNP	10	0.0818
P	Korea	Samsung C&T	6	0.0825
Q	Korea	KEPCO KPS	5	0.0993
R	Korea	KNF	8	0.0997
S	Korea	KNF	5	0.0845
T	Korea	Samsung C&T	6	0.0919
		Average	5.4	0.0875

Sorts of country report and academic database and statistical yearbooks were reviewed for developing comparative database of alternate countries with respect to each factor.[3]

In institution, infrastructure, education level, macroeconomic and financial market development factors for evaluation of each country, it is referred to the scale of Global Competitiveness Index, the scale from 1 to 7 is modified and compared to 1 to 9 (AHP scale) by the method of linear interpolation. In the other hand, country evaluation for permit & approval factor is referred to ease of doing business index by IFC and foreign currency regulation factor was done by global portal credit of Standard & Poor's.

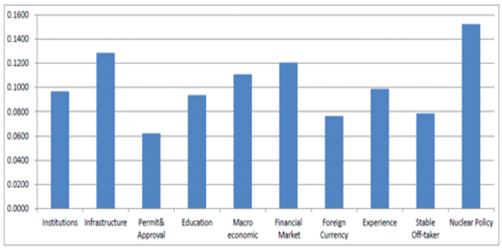
According to the IAEA report preference, Business Experience factors in evaluation of each country is estimated by the similarity degree of overseas BOT nuclear power project. Off−taker factor is related with likelihood of long−term Power Purchase Agreement (PPA) execution in project country. Nuclear Power Policy & Strategy is related with development plan, operating project, public communication program, radioactive waste management and repository by project country.

4.2 Integration and Evaluation

Also, it is required of distributing the adequate weight of each factor in the whole and developing comparative database of countries with respect to each factor to eventually enable developer to make integrated decision.

As to the respondent's view, the first rank was nuclear policy and strategy factor with 0.1523 weight, the following rank was infrastructure factor with 0.1285 weight and third rank was financial market factor with 0.1206, least important factor was permit & approval with 0.0623 and this figure is less than the first rank figure by half as the figure 7.

Classfication	Institutions	Infrastructure	Permit& Approval	Education	Macro economic	Financial Market	Foreign Currency	Experience	Stable Off-taker	Nuclear Policy
Weighting	0.0969	0.1285	0.0623	0.0937	0.1108	0.1206	0.0764	0.0989	0.0786	0.1523



[Figure 7] Factor Weight and Priority

Developing comparative database of alternate countries with respect to each factor is as figure 8. The name of country is anonymous in this step. Consequently, Country D has priority of institution, education level, foreign currency, nuclear policy and strategy factor. Also, Country E has priority of infrastructure, permit & approval, Macroeconomic, Experience, Stable off−taker, While, Country B has priority of financial Market development and has priority of stable off−taker and nuclear policy and strategy factor with same importance of high ranker. However, Others have no priority among factors.

Classfication	Institutions	Infrastructure	Permit& Approval	Education	Macro economic	Financial Market	Foreign Currency	Experience	Stable Off-taker	Nuclear Policy
Country A	0.1487	0.1800	0.1176	0.1729	0.1842	0.1630	0.0600	0.1476	0.1624	0.0988
Country B	0.1806	0.1520	0.2008	0.1527	0.1566	0.2784	0.1314	0.0477	0.3161	0.3130
Country C	0.1209	0.1105	0.0610	0.1276	0.1292	0.1277	0.0478	0.3142	0.0429	0.0988
Country D	0.3006	0.2528	0.2008	0.3189	0.2365	0.2429	0.4544	0.0477	0.1624	0.3130
Country E	0.2491	0.3046	0.4199	0.2280	0.2936	0.1880	0.3065	0.4427	0.3161	0.1765
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

[Figure 8] Comparative weight of countries to each factor

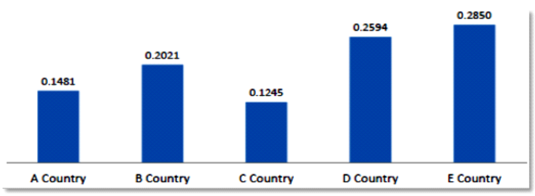
4.3 Decision Making

Then, multiplying the weight of each alternative by the weight of factor yields the overall weights of alternatives as the below figure 9.[4]

Classification	Institutions	Infrastructure	Permit& Approval	Education	Macro economic	Financial Market	Foreign Currency	Experience	Stable Off-taker	Nuclear Policy	Best Alternatives	Ranking
Weighting	0.0969	0.1285	0.0623	0.0937	0.1108	0.1206	0.0764	0.0989	0.0786	0.1523	1.0	
A Country	0.1487	0.1800	0.1176	0.1729	0.1842	0.1630	0.0600	0.1476	0.1624	0.0988	0.1481	4
B Country	0.1806	0.1520	0.2008	0.1527	0.1566	0.2784	0.1314	0.0477	0.3161	0.3130	0.2021	3
C Country	0.1209	0.1105	0.0610	0.1276	0.1292	0.1277	0.0478	0.3142	0.0429	0.0988	0.1245	5
D Country	0.3006	0.2528	0.2008	0.3189	0.2365	0.2429	0.4544	0.0477	0.1624	0.3130	0.2594	2
E Country	0.2491	0.3046	0.4199	0.2280	0.2936	0.1880	0.3065	0.4427	0.3161	0.1765	0.2850	1

[Figure 9] Ranking and estimating best alternates

Each weight of factors is combined with the weight of alternative for final estimation of country prioritization. Consequently, Country E has the top priority for overseas BOT nuclear power project and Country D has second priority, Country B is ranked to third place, and then Country A and C sequence. The each weight figure of country is not important but meaningful to distinguish the comparative importance for the goal.



[Figure] 10. Country viability for BOT nuclear power project

4. Conclusions

To summarize, this study features are focusing on project country feasibility than project at planning stage and application of multi-criteria decision making tool for numerous consideration elements of nuclear power industry. It is also focusing on setting the criteria through identifying, arranging, allocating risks and evaluating alternatives through timely updating reliable data from authorized agency.

Analytic method enables the developer to select and focus on the country which has preferable circumstance so that it enhances the efficiency of the project promotion by minimizing the opportunity cost. Also, this study enables the developer to quantify the qualitative factors so that it diversifies the project success strategy and policy for the targeted country. Although the performance of this study is has limitation due to the short time, small sampling and security of materials, it still has the possibility to improve the analytic model more systematically through further study with more data.

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