Development of a Framework for Assessing Safety Contribution of Nuclear Safety Research

Phil Seo Kim [a], Man-Sung Yim [a*]
[a]*Department of Nuclear and Quantum Engineering, Korea Advanced Institute of Science and Technology, 305-701, Guseong-dong, Yuseong-gu, Daejeon, Korea*
[*]*Corresponding author: msyim@kaist.ac.kr*

1. Introduction

After Fukushima accident, anxiety about nuclear energy safety was soared. In response of this situation, Korea government is investing current research funds in a variety of safety-related research projects.

Nuclear R&D projects in the ROK are carried out and managed by these three government organization. Their main nuclear R&D areas are: 1) MSIT's "Nuclear Energy Technology Development Program", 2) MOTIE's "Nuclear Power Program", and 3) NSSC's "Nuclear Safety Development Program". And each Nuclear R&D program contains nuclear safety research. For example, MSIT's "Nuclear Energy Technology Development Program" can be divided into 4 categories; Nuclear Safety, Future Nuclear Reactor System, Nuclear Fuel Cycle, Korea's Original Nuclear Technology [1].

Table 1 Nuclear R&D Program for various ministries

Nuclear Energy Technology Development Program	Nuclear Power Program	Nuclear Safety Development Program
- Nuclear Safety - Future Nuclear Reactor System - Nuclear Fuel Cycle - Korea's Original Nuclear Technology	- Nuclear Innovative Technology - Nuclear Safety & Advancement - Nuclear Power Plant Equipment & Operational Performance - R&D Planning, Management and Evaluation - Nuclear Environment & Decommissioning	- Development of Nuclear Safety Regulatory Technology - Development of Radiation Safety Regulatory Technology - Development of Natural Environment Radiation Safety Technology - Development of Radiological Emergency Preparedness & Response Techniques
Ministry of Science, ICT (MSIT) National Research Foundation (NRF)	Ministry of Trade, Industry & Energy (MOTIE) Korea Institute of Energy Technology Evaluation and Planning (KETEP)	Nuclear Safety and Security Commission (NSSC) Korea Foundation of Nuclear Safety (KoFONS)

However, as there is no specific assessment of whether safety-related study can contribute to nuclear safety, this research attempts to analyze safety related research of nuclear power has improved safety. And first step of this study is to develop a framework for assessing safety contribution of nuclear safety research.

2. Methods and Results

2.1 Literature Review –Logic Model

Typically a logic model framework is used to evaluate the efficiency and effectiveness of an R&D program. A logic model can be easily broken down into four categories :

- Input
- Process / Activities
- Output
- Outcome

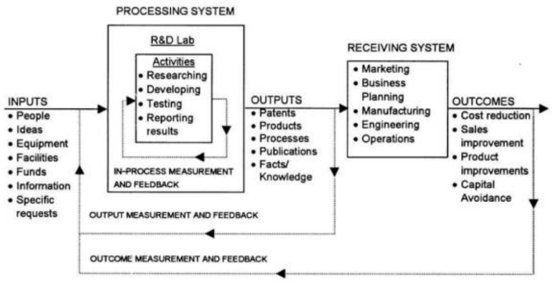

Figure 1 R&D Logic Model[2]

And KISTEP developed a logic model to evaluate the efficiency of overall "Nuclear Technology Development Program" R&D project investment. They reported papers and patents as outputs [2]. Detailed contents are shown in Figure 2.

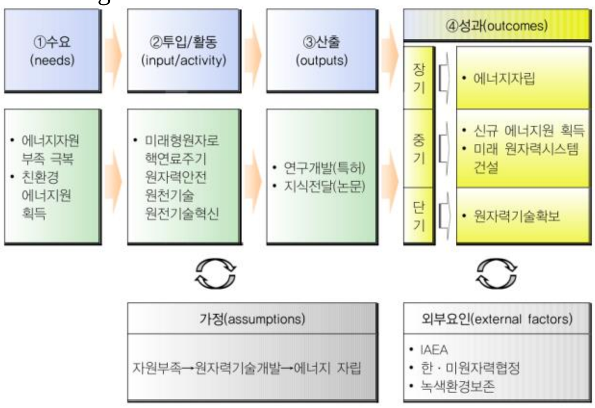

Figure 2 KISTEP Logic Model [3]

However, because this logic model was developed for a comprehensive "Nuclear Energy Technology Development Program", this is not appropriate for evaluating the safety contribution of nuclear safety research.

2.2 Developing a Safety Contribution Measurement Framework

To make a first step trying to assess safety contribution of nuclear safety research, it is necessary to design a new logic model that defines the safety contribution of the nuclear safety research project.

The developed logic model for safety contribution measurement is shown below.

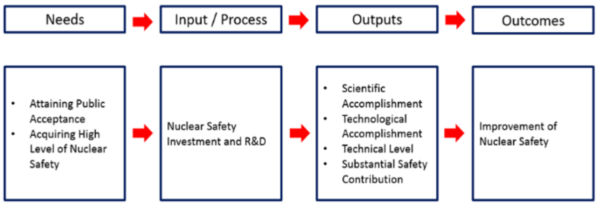

Figure 3 Logic model for safety contribution

In this study, government contributions were selected as an input. And in this study, output is divided into 4 categories; scientific accomplishment, technological accomplishment, technical level, and substantial safety contribution. These outputs are the main factor for evaluating the safety contribution. The outcome can be said to result in an improvement of nuclear safety.

2.3 Indicators for safety contribution evaluation

The following criteria, and sub-criteria were chosen as factors to evaluate nuclear safety contributions the information of these criteria is shown below.

Table 2 Indicators for safety contribution evaluation

Criteria	Sub-criteria
Scientific Accomplishment	• SCI (Science Citation Index) level papers • International Research Collaboration
Technological Accomplishment	• Technical Guidance • Intellectual Property Registration
Technical Level	• Technology readiness Level • Technical Reach Level Compared with the World's Best
Substantial Safety Contribution	• Contribution to Safety Improvement through Technological Advancement • Contribution to the Overall Safety of Nuclear Power Plants

The substantial safety contribution is a qualitative indicator to evaluate safety contribution. There are two sub-criteria in this main criterion: 1) Contribution to safety improvement through technological advancement 2) Contribution to the overall safety of nuclear power plants. These two indicators best represent how this study sees nuclear safety.

First, we recognize that when there is an enhancement in the safety technology, this will directly contribute to preventing various severe accident scenarios. Second, is when there is not a significant technical improvement, but the technology does contribute to the safety improvement of the overall nuclear power plant. And this criteria would be assessed by the survey.

2.4 AHP Survey

Since the relative importance of the indicators in the use of the eight indicators for assessing safety contribution to nuclear safety projects may vary, it is necessary to calculate the weight for each detailed indicator accordingly. For this purpose, this study uses the widely used AHP (Analytic Hierarchy Process) decision making techniques.

2.5 Survey Result

The questionnaires were given to experts in the nuclear industry and researchers (KINS, KAERI, KINAC, KHNP) and academic professors. A total of 57 nuclear experts participated in the survey.

Because AHP is a way of calculating weights through decision makers' opinions, inconsistent pairwise comparison of survey respondents can produce false relative weights. Therefore, there is a need for a method to determine whether the survey respondent is consistently applying a good pairwise comparison. Saaty presented the concept of consistency ratio (CR) as a way of assessing consistency in AHP [4]. A consistency test was conducted on 57 responses. The number of survey respondents according to the consistency ratio is shown in the following table.

Table 3 Number of responses according to consistency test

Consistency Ratio	Number of Responses
$0 \leq CR < 0.1$	14
$0.1 \leq CR < 0.15$	9
$0.15 \leq CR < 0.2$	5
$0.2 \leq CR$	23
Wrong Response	6
Total	57

Saaty suggested that it is better to calculate the weight by using only the questionnaire response within the standard of consistency ratio of 0.1[4]. However, not only is there a large number of reports with a consistency ratio of up to 0.2, but because this pairwise comparison survey was conducted for people recognized as experts in the field of nuclear energy, we also looked at the integrated weights of $0.1 \leq$ CR 0.15 groups (groups considered to be relatively consistent) to determine the extent, if any, of difference in final weighting between the two groups. In addition, to evaluate the largest number of expert respondents in a meaningful way, we added a third group which was the combined results of all 23 respondents with consistent and relatively consistent responses.

Thus, the integrated weighting determination were performed for three cases:
1) Groups with 0 ≤ CR < 0.1
2) Groups with 0.1 ≤ CR < 0.15
3) Groups with 0 ≤ CR < 0.15

Table 4 Relative weight for 0≤CR<0.1 group

Criteria	Sub-criteria	Relative weights
Scientific Accomplishment	SCI level paper	0.04882
	International research collaboration	0.06047
Technological Accomplishment	Technical guidance	0.09409
	Intellectual property registration	0.05637
Technical Level	Technical readiness level	0.12039
	Technical reach level compared with the world's best	0.06133
Substantial Safety Contribution	Contribution to safety improvement through technological advancement	0.20010
	Contribution to the overall safety of nuclear power plant	0.35842
Number of responses	14	
Integrated CR	0.00062	

Table 5 Relative weight for 0.1≤CR<0.15 group

Criteria	Sub-criteria	Relative weights
Scientific Accomplishment	SCI level paper	0.07108
	International research collaboration	0.05944
Technological Accomplishment	Technical guidance	0.05116
	Intellectual property registration	0.08311
Technical Level	Technical readiness level	0.12676
	Technical reach level compared with the world's best	0.07689
Substantial Safety Contribution	Contribution to safety improvement through technological advancement	0.1926
	Contribution to the overall safety of nuclear power plant	0.33896
Number of responses	9	
Integrated CR	0.03004	

Table 6 Relative weight for 0≤CR<0.15

Criteria	Sub-criteria	Relative weights
Scientific Accomplishment	SCI level paper	0.05694
	International research collaboration	0.06048
	Technical guidance	0.07674
Technological Accomplishment	Intellectual property registration	0.06793
Technical Level	Technical readiness level	0.12316
	Technical reach level compared with the world's best	0.06718
Substantial Safety Contribution	Contribution to safety improvement through technological advancement	0.19704
	Contribution to the overall safety of nuclear power plant	0.35053
Number of responses	23	
Integrated CR	0.00473	

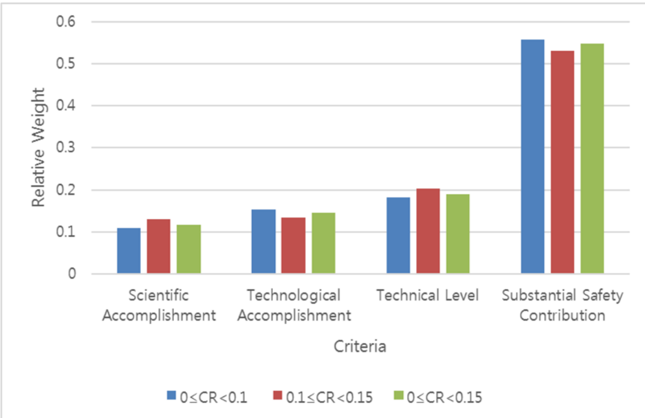

Figure 4 Relative weight comparison for different group

Looking at the tables and graph above, we can see that the weights for each group show a similar tendency. In all three groups, there is a high degree of importance in the order of substantial safety contribution, technology level, technical performance, scientific achievement. In addition, it was confirmed that the difference in the absolute value of the weights is insignificant.

3. Conclusions/ Future Work

This study is meaningful as a first attempt to quantitatively evaluate the contribution of safety in nuclear safety R&D, and it is necessary to continuously update the currently developed evaluation methodology.

In addition, it is important to establish the main criteria when applying the AHP method. Therefore, it is necessary to secure the objectivity of the main criteria selected through expert consultation. Further research will be done to further reduce the error and bring more reliable conclusions if the data are further reflected. If the validity of the criteria is secured later, we will contribute to the maturation of the methodology by directly evaluating safety research.

ACKNOWLEDGEMENT

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