Nuclear Engineering and Technology 50 (2018) 1168–1172

Contents lists available at ScienceDirect

Nuclear Engineering and Technology

journal homepage: www.elsevier.com/locate/net

Original Article

Development of the nuclear safety trust indicator

SeongKyung Cho

Myongji Univ., South Korea

ARTICLE INFO

Article history:
Received 29 March 2018
Received in revised form
19 June 2018
Accepted 6 July 2018
Available online 12 July 2018

Keywords:
Nuclear safety
Trust
Safety schema
Risk communication
Indicator
Q methodology

ABSTRACT

This study went beyond making an indicator simply based on theoretical arguments, and explored a wide spectrum of different types of perceptions about energy safety to make a concept of energy safety for the Korean society. The energy safety schemata of people can be divided into three types. Type1 is concern about multi-level risks-responsibility-centric, type2 is concern about security and personal burden-expertise-centric, and type3 is concern about health and personal burden-responsibility-centric. Questions were designed on the basis of the characteristics, differences and commonalities of the three types of perceptions, explored through the Q methodology, and Koreans'perception of nuclear safety was examined. Based on the results of this research the following components of trust in nuclear safety were derived, risk perception, responsibility, honesty, expertise and procedural justification. The items for specifically evaluating them were developed, and factor analysis was conducted, and as a result, the validity of each item was proven. The components of the nuclear safety trust indicator do not exist independently, but influence each other continuously through interactions. For this reason, rather than focusing on any one of them, laws and systems must be improved first so that they can move together in one big frame.

1. Introduction

Due to the continued controversies and anxiety about nuclear safety, social conflicts cannot avoided but be spread in the process of formulating and pursuing related policies. These social conflicts will deplete limited human and economic resources in the course of arguments, and produce a concern that they will have negative impacts on enhancing actual safety. It is aggravated as the gaps, resulting from the essential differences between experts' approach to nuclear safety or nuclear risks and citizens'approach, grow.

Public interest in safety is increasing, and the demand for a higher level of safety is getting stronger. Nuclear safety is at its core. The boundary between perception of safety and risk is ambiguous, and it is true that there are controversies over the numbers elaborately calculated in scientific and technological terms. However, trying to unconditionally meet diverse safety demands from various directions with ambiguous principles may rather endanger safety. Accordingly, it is very meaningful to secure the standards for mediating emotional or ideological disputes that destroy healthy disputes by developing a nuclear safety trust indicator that the society can relate to. Also, as the minimum mechanism for controlling the social side effects of handling the nuclear safety issue politically, the nuclear safety trust indicator can play its part.

Accordingly, to measure the trust in nuclear safety, this study attempts to develop an indicator that can measure citizens'perception of the safety of nuclear power plants and their demand for it, and propose a method of contributing to the policy process based on the measurement and result analysis of the developed indicator.

2. Research methodology

To develop a nuclear safety trust indicator, various kinds of literature on safety and trust were reviewed. Media coverage focused on nuclear safety issues was explored, and the data, which were officially utilized during the public opinion poll regarding Shin-Kori 5 and 6 nuclear power plants, were analyzed in a variety of ways. Additionally, various data was investigated to understand overseas energy policy decision-making processes and the laws and institutions related to the information disclosure concerning nuclear safety.

To understand the concept of safety in people's perception on this basis, the Q methodology was used to explore different types of energy safety schemata. 57 citizens were selected as the through P sampling, and the answers to Q questions were collected online

E-mail address: charmsae@mju.ac.kr.

https://doi.org/10.1016/j.net.2018.07.002

from November 14, 2017 to November 15, 2017. In the Q methodology, the P sample itself is a variable, and unlike the general statistical method, it is not intended to generalize the research results, but to understand the phenomenon, so the number of samples and the method of selecting the samples are not fixed. Here, citizens are defined as subjects for research, and the panel of Korean research is used to extract proportional allocation based on gender, age, and educational background. To ensure the reality of the different type of energy safety schemata, unforced sorting was used to measure the degree of consent on an 11-point scale. And the result of Q sorting was analyzed using the CENSORT program. For the CENSORT program used here, the maximum number of P samples is 80.

Meanwhile, to develop a nuclear safety trust indicator, a survey was conducted. The proportional allocation method by region, gender and age was used to receive responses to the survey from 1023 people. The online survey through e-mail was conducted for 4 days from November 21, 2017 till November 24, 2017, and the sampling error is ±3.1%p(95% confidence level). Also, factor analysis was conducted based on the survey result to develop the nuclear safety trust indicator.

3. Theoretical discussions

The concept of trust can be interpreted multi-dimensionally depending on targets, and diverse viewpoints can be verified with regard to components. Information, influence and control are presented as components of trust [1], and consideration, respect, risk calculation and control ability, a sense of calling, ability and the order of the civil society are presented as components of trust [2]. Also, some scholars conceptualizes trust with focus on responsibility, trustworthiness and ability [3]. Similarly, ability, openness, consideration and consistency are presented as the basic concepts of trust [4]. Some scholars regard expectations of performance, a sense of duty and a sense of responsibility as important attributes of trust [5]. Others present, as components of trust, ability, sincerity, openness, utilizability, acceptance, consistency, fairness and discrimination [6]. It can be said that these conceptual definitions are focused on the characteristics and expectations of the targets of trust. Meanwhile, some scholars define trust as a subjective probability based on predictability while viewing trust in relation to uncertainty [7]. Some argue that the risk concept must be explicitly included in the concept of trust [8]. It means that trust is also subjective and judgmental like risk. Also, some argue that it is desirable to measure trust in the institutions that are targets of trust on another level [9].

Although trust is a concept frequently used in our daily lives, it tends to be defined differently depending on dimensionality and function. nevertheless, what many researchers accept is that trust can be defined as a psychological state of accepting vulnerability based on positive expectations about others'intentions or behavior [10]. Rousseau et al. divided trust into two types based on various grounds. One is the relational trust based on the relationship between the truster and the counterpart, and the other is the calculative trust based on the restrictions of the counterpart's past or future behavior. In general, the former is classified as trust, and the latter as confidence. Meanwhile, Luhmann [11] conceptualizes the trust function as reducing present uncontrollable complexity in return for future benefits resulting from cooperation. Based on these universal views, trust will be explained here as giving a positive value through subjective value judgment in a social relationship.

According to the analysis of studies on trust in the risk management area, antecedents of trust belong to one of the following categories [12]. Most of the items used for measurement are ordinarily related to the attributes of trustworthiness, that is, honesty, concern, competence, transparency and responsibility, etc. Antecedents related to ability, including expertise and experience, are also used. In addition, situational attributes like procedural fairness are used as antecedents. Meanwhile, the categories of consequences can be summarized as risk perception, benefit perception, policy support, risk acceptance, affective responses & intention, etc.

Viewed in this context, trust in nuclear safety is differentiated from the targets of trust that were handled previously. That is, ‘nuclear safety,’the target of trust, can hardly be specific as a target. Accordingly, it is necessary to specify the target as the main agent that judges nuclear safety with authority. This study attempts to conceptualize trust in nuclear safety as giving a positive value to nuclear safety in the relationship with the main agent that judge nuclear safety with authority although it cannot fully understand nuclear safety rationally.

4. Analysis of energy safety schema types

The energy safety issue starts with scientific, technological and engineering discussions. However, the issues derived from there have value-judgmental characteristics in essence. It can be said that the subjectivity of the main agent of judgment is a very important factor. An appropriate method of measuring subjectivity scientifically and statistically is the Q methodology [13].

Concern about risks, concern about burden, Trust in main agents responsible for safety, including government, operators, regulators and experts, and risk assessment were selected as the criteria for designing Q questions. Concern about risks refers to people's concern about the several risks likely to occur in the process of producing electric power from energy sources. That is, concern about health, concern about the environment, concern about security, concern about accidents, concern about climate change and concern about changes in the ecosystem are examples. Concern about burden refers to concern about the various types of costs that must be paid because a certain energy source is selected. It includes concern about personal burden, concern about social burden and concern about the burden of the next generation. The trust in the main agents refers to the level of trust on the main agents who makes energy-related policy decisions, and the main agents who assesses the risks occurring in the process of utilizing the energy source. That is, it can be divided into trust in the policy decision makers and trust in the risk assessment main agents. Risk assessment means according to which criteria risks are assessed, and whether it is possible to manage risks so that the inherent risks will not take place. Expectations about risk controllability and the criteria for judging risks are included.

As shown in Table 1, the energy safety schemata of people can be divided into three types. 26.3% is type 1 (concern about multi-level risks-responsibility-centric), and 19.3% is type 2 (concern about security and personal burden-expertise-centric), and 1.8% is type 3(concern about health and personal burden-responsibility-centric). 52.6% of people do not have any energy safety schema. It means that a considerable number of people do not have any socioculturally structured frame of consciousness about the energy safety issue. That is, it can be concluded that the experience of the energy safety issue, information on it, knowledge of it and interaction with the outside are quite minimal. Interaction with the outside means communication with others and perception and judgment in a given context. Accordingly, it can be regarded as a natural phenomenon that controversies over the energy safety issue are frequent, and diverse arguments are at loggerheads.

The concern about multi-level risks-responsibility-centric energy safety schema looks at energy safety based on a strong concern about risks. In particular, it pays attention to health and environment, and examines various aspects of accidents from probability

Table 1
Energy safety schema Q factor matrix.

P samples	Q Type 1	Q Type 2	Q Type 3	h2
1	0.1384	0.7433*	−0.1813	0.6045
2	0.5257	0.6069	0.2440	0.7043
3	0.2150	0.4939*	0.3715	0.4283
4	0.6379*	0.3347	0.2320	0.5728
5	0.8228*	0.3067	0.2320	0.7734
6	0.4677*	0.3585	0.1845	0.3813
7	−0.1258	0.3915	0.2548	0.2340
8	0.0540	0.5435*	0.2221	0.2989
9	0.0331	0.5706*	0.3630	0.4585
10	0.6407*	0.0680	0.2382	0.4719
11	0.4460	0.2681	0.6328	0.6711
12	0.6893*	0.3045	0.3470	0.6882
13	0.2133	0.6058*	−0.0454	0.4146
14	0.3048	0.4940*	0.1435	0.3575
15	0.7141*	0.2726	0.2007	0.6245
16	0.3798	0.4995	0.4606	0.6059
17	0.1441	0.0130	0.2251	0.0716
18	0.5513	0.4258	0.1836	0.5190
19	0.2795	0.3933	0.1307	0.2499
20	−0.4787*	−0.1451	−0.0249	0.2508
21	0.4622	0.4067	0.4828	0.6121
22	0.4242	0.6183	0.4785	0.7912
23	−0.1070	0.5473	0.5190	0.5804
24	0.1540	0.6394*	−0.0590	0.4360
25	0.0648	−0.0055	−0.2826	0.0841
26	0.4912	0.5638	0.1464	0.5806
27	0.3549	0.2486	0.6727*	0.6403
28	0.4020*	0.1034	0.2753	0.2481
29	−0.2385	0.1311	−0.0570	0.0773
30	0.7193*	0.3334	0.3259	0.7348
31	0.1860	0.7294*	0.3397	0.6820
32	0.4360	0.1334	0.6023	0.5706
33	0.6292*	0.3215	0.3204	0.6019
34	0.5735	0.2003	0.5189	0.6382
35	0.6435	0.1077	0.5594	0.7386
36	0.1304	0.1274	−0.3452	0.1524
37	0.1126	0.7531*	0.0702	0.5848
38	0.1535	0.2798	0.0582	0.1053
39	0.4795*	0.0719	0.0120	0.2353
40	0.6689*	0.1332	0.1973	0.5040
41	0.4031	−0.0304	0.5309	0.4452
42	0.5816*	0.3354	−0.0593	0.4542
43	0.4138	0.5710	0.5571	0.8076
44	0.4498	0.3912	0.4863	0.5919
45	0.4804	0.4495	0.4041	0.6769
46	0.1262	0.6933*	0.0025	0.4966
47	0.4048	0.2287	0.4210	0.3934
48	−0.0800	−0.1574	−0.1102	0.0433
49	0.4081	0.6469	0.3129	0.6829
50	0.4527	0.4325	0.2749	0.4675
51	0.4740*	0.0345	−0.1156	0.2393
52	0.3975	0.1853	0.2058	0.2347
53	0.4871*	0.3163	0.3785	0.4086
54	0.3782	0.4674*	0.3923	0.5154
55	0.3135	0.4342	0.4561	0.4949
56	0.0496	0.1663	0.1774	0.0616
57	0.4013	0.2033	0.6293	0.5984

*People with the same characteristics.

and impact to resilience. In addition, it turned out that there was a great concern about genetic deformation. In the large scheme, people show concern about climate change, but they pay more attention to the occurrence of unfamiliar natural disasters likely to be caused by climate change than the causes of climate change and removal thereof. But they do not show any concern about security. On the other hand, they do not assign any special meaning to the burden that individuals, the society and the next generation must bear. Meanwhile, they show uniform concern about policy decision makers and main agents of risk assessment, and especially they picked expertise as a factor affecting safety.

The concern about security and personal burden-expertise-centric energy safety schema places more importance on security than environment, and pays more attention to expertise than responsibility. In particular, trust in experts was high with regard to risk assessment. People had much concern about the personal burden with focus on the cost they must pay.

The concern about health and personal burden-responsibility-centric energy safety schema reacts sensitively to the personal burden based on a strong concern about risks. People are most concerned about health, and pay attention to not only payment of personal expenses, but also inconveniences. On the other hand, they place more importance on the influence of responsibility on safety than the influence of expertise or honesty, and they are somewhat negative about the role of the media in relation to risk assessment.

The result of exploring the energy safety schemata confirmed that perception is based on concern about risks in all types. Of course, there was a difference. Depending on types, focus was placed on health, environment or security. But concern about climate change was very little. The two types of energy safety schemata, excluding the concern about multi-level risks-responsibility-centric energy safety schema, have concern about burden in common, but they tend to have no concern about social burden or burden on the next generation, and they paid attention only to personal burden.

Exploration of the energy safety schemata confirmed that the expertise and responsibility of policy decision makers are important factors to trust in safety. But they had no concern about the possibility of risk control.

Given these results, to build trust in energy safety, information on the influence on health, environment and security, the probability and influence of accidents, and recoverability must be provided first. Also, policy decision makers must have expertise and responsibility, and risk assessors must have competence as experts and communicate effectively.

5. Development and analysis of the nuclear safety trust indicator

Exploration of energy safety schemata confirmed that perception is based on concern about risks in all types. The targets of concern include the influence on health, environment and security, the probability and influence of accidents and recoverability. Also, it turned out that expertise and responsibility are important factors to trust in safety. Meanwhile, several media coverages revealed that in case of nuclear power generation in Korea, honesty has continued to be concerned about.

Through theoretical discussions and exploration of energy safety schema types, this study attempts to recognize that risk perception, responsibility, honesty, expertise, and procedural justification of the policy decision making process are important factors of trust in nuclear safety, and verify if it has validity and trustworthiness as an indicator through factor analysis.

As shown in Table 2, as a result of the factor analysis of the criteria for judging trust in nuclear safety, five common factors were extracted. The eigenvalue of the first common factor is 9.365, the second eigenvalue 3.527, and the third eigenvalue 2.487, the fourth eigenvalue 1.344, and the fifth eigenvalue 1.120. Also, the commonality value of the common factors of individual variables was considerably high. The 22 judgment factors of trust in nuclear safety can be divided into five common factors. Eigenvalue is a value that shows the explanatory power of each common factor extracted through factor analysis. In general, common factors with an eigenvalue being 1 or greater are regarded as common factors worthy to be analyzed.

As shown in Table 2, there are five common factors. The first

Table 2
Factor matrix.

Variable	Risk perception	Honesty	Responsibility	Expertise	Procedural justification	h^2
Nuclear power generation has a bad influence on our health.	**0.854**	0.184	−0.061	−0.145	−0.039	0.789
Nuclear power generation has a bad influence on the natural environment of Korea.	**0.910**	0.166	−0.092	−0.108	−0.071	0.881
Nuclear power generation has a bad influence on our future generations.	**0.865**	0.209	−0.111	−0.120	−0.115	0.832
Nuclear power generation has a bad influence on the ecosystem of Korea.	**0.913**	0.173	−0.094	−0.123	−0.059	0.890
Nuclear power generation has a bad influence on greenhouse gas emissions.	**0.832**	0.049	−0.044	−0.094	0.053	0.708
Nuclear power generation is risky even if there is no accident.	**0.766**	0.165	−0.080	−0.183	−0.018	0.654
Policies related to nuclear power are made according to legal procedures in Korea.	−0.057	−0.129	0.255	0.254	**0.846**	0.864
Korea's policies related to nuclear power are made based on the diverse opinions of all sides.	−0.063	−0.150	0.245	0.179	**0.875**	0.885
Nuclear power plant operators have the expertise necessary for making right judgment about nuclear safety.	-.0247	−0.139	0.281	**0.762**	0.200	0.779
Nuclear safety regulatory agencies have the expertise necessary for making right judgment about nuclear safety.	−0.094	−0.131	0.290	**0.832**	0.129	0.819
Nuclear power experts have the expertise necessary for making right judgment about nuclear safety.	−0.192	−0.082	0.244	**0.835**	0.115	0.813
Agencies managing nuclear waste like spent fuel have the expertise necessary for making right judgment about nuclear safety.	−0.204	−0.169	0.284	**0.824**	0.124	0.845
The government sometimes commits immoral acts in relation to nuclear safety.	0.021	**0.775**	−0.097	0.029	−0.041	0.614
Nuclear power plant operators sometimes commit immoral acts in relation to nuclear safety.	0.214	**0.870**	−0.127	−0.120	−0.134	0.852
Nuclear safety regulatory agencies sometimes commit immoral acts in relation to nuclear safety.	0.188	**0.893**	−0.154	−0.146	−0.074	0.883
Nuclear power experts sometimes commit immoral acts in relation to nuclear safety.	0.247	**0.836**	−0.134	−0.191	−0.080	0.821
Agencies managing nuclear waste like spent fuel sometimes commit immoral acts in relation to nuclear safety.	0.265	**0.853**	−0.142	−0.156	−0.058	0.846
The government will fulfill its responsibilities to protect citizens from nuclear risks.	0.126	−0.051	**0.777**	0.092	0.071	0.636
Nuclear power plant operators will fulfill their responsibilities to protect citizens from nuclear risks.	−0.195	−0.187	**0.808**	0.268	0.189	0.834
Nuclear safety regulatory agencies will fulfill their responsibilities to protect citizens from nuclear risks.	−0.126	−0.176	**0.854**	0.283	0.143	0.877
Nuclear power experts will fulfill their responsibilities to protect citizens from nuclear risks.	−0.191	−0.148	**0.820**	0.311	0.156	0.852
Agencies managing nuclear waste like spent fuel will fulfill their responsibilities to protect citizens from nuclear risks.	−0.201	−0.192	**0.826**	0.289	0.157	0.868
Eigen value	9.365	3.527	**2.487**	1.344	1.120	

Bold are factors with the same characteristics.

common factor includes six variables, i.e. the bad influence of nuclear power plants on health (0.854), the bad influence of nuclear power plants on the natural environment (0.910), the bad influence of nuclear power plants on future generations (0.865), the bad influence of nuclear power plants on the ecosystem (0.913), the bad influence of nuclear power plants on greenhouse gas emissions (0.832), and the inherent risks of nuclear power plants (0.766). The second common factor includes 5 variables, i.e. the possibility of the government's immoral acts related to nuclear safety (0.775), the possibility of operators' immoral acts related to nuclear safety (0.870), the possibility of regulatory agencies' immoral acts related to nuclear safety (0.893), the possibility of nuclear power experts' immoral acts related to nuclear safety (0.836), and the possibility of nuclear waste management agencies' immoral acts related to nuclear safety (0.853). The third common factor includes 5 variables, i.e. the governments' fulfillment of responsibilities for protecting citizens from nuclear risks (0.777), operator' fulfillment of responsibilities for protecting citizens from nuclear risks (0.808), regulatory agencies'fulfillment of responsibilities for protecting citizens from nuclear risks (0.854), nuclear experts' fulfillment of responsibilities for protecting citizens from nuclear risks (0.820), nuclear waste management agencies' fulfillment of responsibilities for protecting citizens from nuclear risks (0.826). The fourth common factor is four variables. Expertise of nuclear safety related operators (0.762), expertise of regulatory agencies related to nuclear safety (0.832), expertise of nuclear experts (0.835), and expertise of nuclear waste management agencies (0.824). The fifth common factor includes policy decision making related to nuclear power according to legal procedures (0.846) and policy decision making related to nuclear power based on the diverse opinions of all sides (0.875).

This factor analysis confirms first that the composition of the nuclear safety trust indicator is valid. Given the results of the factor analysis, the first criterion for judging trust in nuclear safety can be said to be risk perception. That is, it means that depending on how bad influence nuclear power generation has on health, the natural environment, future generations, the ecosystem and greenhouse gas emissions and how risky nuclear power generation is even if there is no accident, trust in nuclear safety may vary. Honesty is the second criterion for judging trust in nuclear safety. In other words, how immoral acts the government, operators, regulatory agencies, nuclear experts and nuclear waste management agencies commit in relation to nuclear safety can become the criterion for judging trust in nuclear safety. The third criterion for judging trust in nuclear safety is responsibility. It means that how much the government, operators, regulatory agencies, nuclear experts and nuclear waste management agencies fulfill their responsibilities to protect citizens from nuclear risks can influence the judgment of trust in nuclear safety. The fourth judgment criterion is expertise. Whether operators, regulatory agencies, nuclear experts and nuclear waste management agencies have the expertise necessary for making right judgment about nuclear safety can become the criterion for judging trust in nuclear safety. The fifth criterion for judging trust in nuclear safety is procedural justification. It shows that depending on whether policies related to nuclear power are made according to legal procedures, and based on the diverse opinions of all sides, trust in nuclear safety may vary.

6. Conclusion including suggestions

This study began because of the realization that as nuclear safety has become a powerful social issue, trust in nuclear safety is becoming increasingly important. It seems that risk and safety are regarded as scientific and technological issues, but actually depending on from which angle the numbers are derived, there are different opinions even on the same numbers. Of course, the fact that there are arguments about a certain issues based on diverse opinions indicates that the society is healthy to that extent. If such arguments lead to an excessively emotional battle or ideological dispute devoid of rationality, however, the social cost will be considerable, and the damages will be felt by citizens. Accordingly, to turn healthy arguments into the driving force behind better risk control, a safe society and the security of citizens, an indicator, which everyone can relate to, for judging trust in nuclear safety is necessary.

In particular, this study went beyond making an indicator simply based on theoretical arguments, and explored a wide spectrum of different types of perceptions about energy safety to make a concept of energy safety for the Korean society. Questions were designed on the basis of the characteristics, differences and commonalities of the three types of perceptions(concern about multi-level risks-responsibility-centric, (concern about security and personal burden-expertise centric, concern about health and personal burden-responsibility-centric energy safety schema) explored through the Q methodology, and Koreans' perception of nuclear safety was examined. Based on the results of this research, and the various social views on nuclear power, the following components of trust in nuclear safety were derived, i.e. risk perception, responsibility, honesty, expertise and procedural justification. And the items for specifically evaluating them were developed, and factor analysis was conducted, and as a result, the validity of each item was proven.

The nuclear safety trust indicator can be measured in terms of risk perception, responsibility, honesty, expertise and procedural justification. Of course, it is necessary to think about whether each number can be expressed as an indicator. Also, it is necessary to flexible respond to the issue of applying weights depending on social conditions and circumstances. The author concluded that evaluating each score independently rather than summing up the scores of risk perception, responsibility, honesty, expertise, and procedural justification as a single score is a concrete way to build and sustain nuclear safety trust. The components of the nuclear safety trust indicator, i.e. risk perception, responsibility, honesty, expertise and procedural justification, do not exist independently, but influence each other continuously through interactions. Accordingly, even if there is a problem with one of them, there will be negative interactions, which will absolutely lower the confidence level. For this reason, rather than focusing on any one of them, laws and systems must be improved first so that they can move together in one big frame. Even now there are a considerable number of laws and systems related to nuclear safety. As individual laws and systems have different lead agencies and they tend to be managed separately, however, they cannot but be focused on formalities rather than improving safety regardless of their original intents. Accordingly, it is important to review relevant laws, integrate what need to be integrated and abolish what must be abolished, and enact necessary laws quickly through thoroughgoing analysis and verification. Of course, what must precede all this is to recognize the value of trust in nuclear safety, and induce everyone involved, i.e. the government, regulatory agencies, operators and nuclear power experts, to understand that enhancing trust in nuclear safety is an urgent issue.

Trust in nuclear safety must be continuously secured and spread apart from the question of whether to stop or continue nuclear power generation or how much energy will come from nuclear power generation. The key is to provide correct information and knowledge in a timely fashion and communicate with stakeholders including citizens through various channels. And policy decisions must be made according to rational procedures, and safety must be regulated based on principles without any realistic loopholes. To this end, it is necessary to look at laws and systems, technologies and people, and operations and communication issues within the big frame of nuclear power generation and nuclear safety rather than making modifications to each component. Then, it will be possible to solve the real-life problems, not just improving images.

Acknowledgments

This work was granted financial resources from the Korea Energy Economics Institute.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.net.2018.07.002.

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