Quantification of Overestimated Risk on Nuclear Power by Using Probabilistic Weighted Function

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1. Introduction

Nuclear energy is one of the most promising, and realistic alternative energy source because it has superior economics than other energy sources, and also highly environment-friendly properties.

But nuclear power has not been welcomed much by the public, even it has evident, and objective advantages. This low public acceptance of nuclear power often incurs high social costs.

There are a lot of reasons for low public acceptance of nuclear power. Trust, voluntary choice, controllability, and lack of information-knowledge are usually considered as main factors. It is a kind of complicated problem which cannot be analyzed simply.

Even though, it can be described as a sentence, "People are still afraid of nuclear power." Actually, the safety level of nuclear power plant is quite reasonable these days, because the engineered safety features and systems are well established in nuclear power plant. A little amount of fear of public can be understood because nuclear power plant cannot be perfect. But their fear seems like overestimated much more than actual risk of nuclear power plant. Obviously, there is a huge gap between actual risk of nuclear power plant and perceived risk of public.

In this study, differentiation between actual risk and perceived risk of nuclear power is mainly focused.

2. Prospect Theory

2.1. Expected utility theory and prospect theory

In traditional economics, humankind is assumed to be perfectly reasonable and selfish, so they always choose the best solution which can maximize their own utilities. This is the main idea of "Expected utility theory." But it cannot explain the whole behavior of people. People behave like unreasonable many times; low public acceptance of nuclear power can be an example of that.

Tversky and Kahneman tried to explain and analyze those kinds of unreasonable human behaviors. "Prospect theory" is the result of their study.

The theory mainly consists of "Value function" and "Probability weighting function."

In this paper, probability weighting function has been used to show why people have overestimated risk on nuclear power plant, and the degree of overestimated ratio.

2.2. Probabilistic weighted function

From the expected utility theory, risk can be described as

$$\text{Risk} = \text{Probability} * \text{Consequence} \quad (1)$$

For the same hazard, risk is affected by probability, and it has linearity. It means that if probability is changed to 0.5 from 0.1, the risk will be increased as 5 times more than before.

But this cannot explain the whole nature. Even if core damage frequency of nuclear power plant has been diminished 0.1 times than before, people will not feel they are 10 times safer.

Probabilistic weighting function describes that how objective probability can affect to human actually. In that function, nonlinearity is existed between them. For range of low probability, probability will be overestimated to human, and for high probability, it will be underestimated.

The common form of probabilistic weighting function can be describes as

$$w(p) = \frac{p^r}{[p^r + (1-p)^r]^{1/r}} \quad (2)$$

'p' is an actual probability, 'r' is a coefficient, and w(p) is weighted probability from actual probability.

Then, actual risk will be

$$\text{Risk} = p * C \quad (1)`$$

For same actual probability, weighted risk will be

$$Weighted\ Risk = \frac{p^r}{[p^r + (1-p)^r]^{1/r}} * C \quad (3)$$

3. Overestimated Risk on Nuclear Power

By using probabilistic weighted function, weighted risk was calculated. The consequence is same for both cases, so only probability was compared. The difference between probabilities tells that the difference between risks.

Core damage frequency of common generation 3 nuclear power plant is usually evaluated as $1 * 10^{-4}$ per

reactor-year. This value was chosen for actual probability. Coefficient 'r' was taken as 0.65.

For those values, the weighted probability is $2.5 * 10^{-3}$ per reactor-year. It means that the probability of nuclear accident is overestimated as 25 times more to public.

Radioactive material release frequency of common generation 3 nuclear power plant is usually evaluated as $1 * 10^{-5}$ per reactor-year. For this values, the weighted probability is $5.62 * 10^{-4}$ per reactor-year. The probability of radiation release accident is overestimated as 56 times more to public.

4. Discussion and Conclusion

As shown above, the risk of nuclear power plant is overestimated much to public. Through continuous endeavor of many nuclear engineers, nuclear power plant has high reliable safety features and inherent safety design. The actual risk of nuclear power plant is quite low reasonably but it is hard to deliver the actual fact to public due to incongruence problem between reality and human perception.

Further progress on engineered safety will make the nuclear power plant much safer. It will be still hard to make close the gap between actual risk and perceived risk of human due to human nature.

To be sure, make the nuclear power plant safer is the first priority of nuclear engineer. However, effort for improving public understanding on nuclear power should be going on together.

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