CHAPTER 11

Determination of Optimal Security Measures in Nuclear Energy Investments: Strategy Recommendations for Emerging Markets

Hasan Dinçer[1]

Serhat Yüksel[2]

Duygu Yavuz[3]

1. Introduction

Energy investments have become essential for the economic development of countries. Since electricity is actively used in the production process, energy is considered as one of the most important raw materials of industrial production. In other words,

1 The School of Business, İstanbul Medipol University; hdincer@medipol.edu.tr

2 The School of Business, İstanbul Medipol University; serhatyuksel@medipol.edu.tr

3 The School of Business, İstanbul Medipol University; duygu.yavuz@std.medipol.edu.tr

the increase in energy prices also increases the cost of the production process (Sun et al., 2022). This situation causes inflation in the country. Since this problem will increase the uncertainty, it leads to deepening of the problems in the economy. On the other hand, industrial production will also shrink because of insufficient energy supply (Dinçer et al., 2022a,b,c). As a result, the profitability of the companies will decrease, and shrinkage will occur in the country's economy. In summary, for the economic development in the country to be sustainable, low cost and uninterrupted energy supply must be provided (Li et al., 2022; Wu et al., 2022).

Nuclear energy projects are also an important type of investment that serves this purpose. These projects have very important advantages compared to other types of energy. First, no carbon gas is emitted in nuclear energy investments (Ding et al., 2021). This is an important advantage especially compared to the use of coal. In addition, 24-hour electricity generation is possible in nuclear power projects. This is an important advantage for renewable energy types that are affected by climatic conditions (Yüksel et al., 2021). Finally, thanks to nuclear energy projects, countries can produce their own energy. In this way, external dependence on energy is eliminated. This contributes to minimizing the risks faced by energy importing countries. In summary, nuclear energy projects have a very important role in the economic development of countries (Meng et al., 2021).

On the other hand, there are some disadvantages in nuclear energy projects. A significant amount of radioactive waste is generated in the production of nuclear energy. Unless these wastes are disposed of correctly, they pose a danger to people's health (Li et al., 2022). There is no clear consensus in the literature on how these wastes can be managed in the most correct way. Another risk in nuclear power projects is the possibility of the plant's explosion. In the previous nuclear power plant accidents, very serious problems were experienced. In this context, it is vital to take the right precautions to eliminate the explosion risk of nuclear power plants (Yüksel et al., 2022a,b,c).

Accordingly, in this study, it is aimed to identify optimal security measures in nuclear energy investments. Within this framework, four different criteria are selected with the help of analyzing similar studies in the literature. These selected criteria are weighted by considering decision-making trial and evaluation laboratory (DEMATEL) methodology. As a result of this analysis, it can be possible to generate specific and effective strategies to manage this dangerous problem.

There are mainly five different sections in this study. The second section includes necessary information about the explosion risk of nuclear power plants. The third section explains some previous accidents. In the fourth section, an analysis has been performed by using DEMATEL methodology. In this framework, the literature has been reviewed and four different criteria are selected. After that, by implementing the steps of DEMATEL, the weights of these items are computed. The final step gives information about the discussions and conclusions.

2. Explosion Risk of Nuclear Power Plants

Climate change worries those who have the greatest knowledge about it. Some of the most knowledgeable nuclear energy experts are the least worried. Renewable energy sources like wind, sun, and water cannot provide the necessary electrical energy. Nuclear energy has been a major energy source for the past 35-40 years because of its reliability and the fact that it provides all the electrical energy required by the world's population (Zhao et al., 2022). According to what the wastes of nuclear and coal are founded on, if one person's lifetime use of electrical energy was used to calculate how much waste nuclear energy would produce, the whole waste would be the size of a tiny coke bottle. This waste may be safely kept in reactor tanks since it poses no health or environmental risks

(Yüksel and Dinçer, 2022). In contrast, coal would provide this energy demand, but the quantity of carbon dioxide emissions and trash it would produce would be excessive (Amidu, et al., 2021).

The public has concerns over nuclear power plants not only because of the likelihood that they could cause accidents, but also regarding the management of radioactive wastes that will be created because of their operation (Basu, 2019). During the generation of nuclear power, a variety of radioactive wastes are produced, each of which must be disposed of or stored in accordance with specific regulations. If these procedures are followed precisely, the negative effects of nuclear waste on both human health and the natural environment may be kept to a bare minimum (Gharari et al., 2018). There are other sources of radioactive waste besides nuclear power plants. A wide variety of industries, including medicine, agriculture, and manufacturing, as well as nondestructive material testing and the generation of nuclear waste, all make use of radioactive elements (Zhang et al., 2019).

It is important to keep in mind, in relation to the potentially dangerous nature of nuclear power plants, that the most serious nuclear accident in the history of the world, the Chernobyl nuclear catastrophe, was brought about by human error (Aliyu et al., 2015). If we are to adopt the premise that accidents are the result of human error, then we need to persuade people not to drive because of the possibility that they would be involved in an accident (Shen et al., 2018). Nuclear energy sources, also known as nuclear energy, are a form of energy that is generated because of a process that occurs inside the nucleus of an atom (Ding et al., 2016). Electrical energy is now the most significant source of energy in the world. The production of this kind of energy likewise relies heavily on nuclear power facilities, making them the most significant source (Yamashita, & Suzuki, 2013).

Oil, coal, and natural gas are just a few examples of the non-renewable energy sources that may be utilized to generate electricity

(Saleh & Cummings, 2011). On the other hand, it is a well-known reality that the reserves of such energy sources will be depleted in the not-too-distant future, and it is also a well-known fact that such energy sources harm the environment far more than nuclear energy does (Mukhtarov et al., 2022). Nuclear power plants, which are an alternate energy source that is also more effective, are what the nations of the globe utilize to accomplish this goal. Nuclear power plants are the primary source of electricity generation in several nations throughout the globe at the present time (Keller & Modarres, 2005). The nation-state of France serves as the best illustration of this principle. These power plants provide around 80 percent of France's required electrical output, making them essential to the country's economy.

3. Nuclear Lives Worldwide in Last Year's Diseases and Their Consequences

Nuclear power plants are far safer than is often believed, and they are the only kind of power plant that can generate electrical energy nonstop for the whole 365 days and 24 hours of each year, regardless of the weather or any other external factors (Vitázková & Cazzoli, 2013). Obviously, in addition to all these occurrences, the effects of nuclear catastrophes are also quite significant and eye-catching in their scope and magnitude. The emission of radiation has a significant negative influence not only on human life but also on the surrounding environment (Denning & Budnitz, 2018). However, the fact that nuclear power facilities of the latest generation are inherently safer cannot be overlooked. In this piece of research, the effects that the catastrophe at the Chernobyl Nuclear Power Plant has had over the last four decades were investigated. In addition to that, some information on several other accidents is provided.

Because of advancements in technology, the use of radioactive materials in a variety of domains, including the military, medicine, the energy sector, and industry, has become more common. Nuclear power facilities were one of the most notable developments of the 20th century. Since the construction of the first nuclear reactor in 1954, people have been concerned about the prospect of a nuclear disaster occurring. Although nuclear power is supposedly a risk-free source of energy, our planet has been subjected to significant harm as a result of catastrophic nuclear mishaps and radiation levels that have deviated significantly from the usual during the last century. To accurately assess the level of destruction inflicted by these nuclear accidents, several different scales were devised. When we look at the last 40-45 years, there are 4-5 accidents that have taken place.

3.1. Accident at the Chernobyl Nuclear Power Plant

The accident that happened at the Chernobyl nuclear power plant is recognized as the largest disaster in the history of the peaceful use of nuclear energy owing to the large region that it touches and the damages that it creates. This is because the event caused widespread radioactive contamination. In the case of the Chernobyl nuclear power plant, in addition to the environmental pollution that the accident caused, another factor that needs to be mentioned is the effects of nuclear power plant accidents on other countries, the necessary precautions taken, and international relations. This is because nuclear power plant accidents can have a significant impact on the environment. The nuclear radioactive fallout catastrophe caused by Chernobyl is not just a concern for public health, but it is also a problem on an international scale, having repercussions for the economies of nations as well as their foreign policies. The disaster that occurred at the Chernobyl nuclear power facility was caused by the lethal interaction of three factors: a flawed architectural design; an unlawful operation; and an unauthorized experiment (Denton, 1987).

The fact that the experiment is being carried out by illegal and unauthorized personnel is the most essential aspect of this situation. It is of the utmost importance that there be a nuclear disaster caused by humans. The early opening of the reactor and the attempt to improve the reputation of the shift chief in the senior management at the time of the experiment may also be proven to be among the causes that contributed to the occurrence of this catastrophe. Considering that the Chernobyl nuclear power plant released significant doses of radiation for a period of ten days after the catastrophe, the radiation was able to travel over a very large region due to the effects of the weather.

To perform the necessary repairs, Unit 4 of the reactor was shut down. When the electrical power supply to the base station was turned off, a test was carried out to determine whether the reactor would still be able to provide sufficient electrical power to power its emergency devices and keep the core of its own hardware from overheating during the period of transition leading up to the activation of the emergency power supply. Employees began the test despite the lack of suitable safety procedures or operating systems that would advise the operator of the hazards associated with electrical testing. Because of this lack of understanding, operators have been taking activities that are not in accordance with safety protocols. As a consequence of this, the power surge led to the explosion, which in turn led to the destruction of practically the whole reactor. The reactor building was damaged, and as a result, the fire inside of it led to an excessive discharge of radioactive material.

3.2. Tomsk-7 Explosion

Accidents at the Tomsk-7 nuclear power station took place in the city of Tomsk, which is located in Siberia. During the process of cleaning a tank with nitric acid, an accident took place. Clouds of radioactive gas were produced as a direct consequence of the explosion that occurred in the tank. The severity of the collision was not as severe as one may have expected. The severity of the collision was graded as a 5.

3.3. Fukushima Incident

In 2011, an accident at the Fukushima nuclear power plant took place close to the city of Sendai in Japan. An earthquake measuring 9.0 on the Richter scale struck around 130 kilometers away from this city, which led to the disaster that took place. Because of the earthquake and the tsunami, the nuclear power plant that was affected by these natural disasters had the second worst accident in its entire existence. The rapid and effective shutting down of the reactors in the aftermath of the earthquake prevented a more severe nuclear accident. However, because of the Tsunami's influence, the increasing water level led the Turbine building to become flooded. In the days that followed, radioactivity leaked out of the power plants as a consequence of explosions and fires that occurred in a variety of locations inside the facilities. Additionally, a nuclear emergency was proclaimed by the Japanese government later that day. The order to evacuate the area was given to around one hundred thousand persons who lived in the surrounding area of the plant. There is also a significant danger in the nations that are nearby.

3.4. Tokaimura Accident

There are fifteen nuclear facilities in the town of Tokaimura, which is located northeast of Tokyo. One of them is the Japanese reprocessing plant. In 1999, a reactor known as Joyo performed a test run to create mixed oxide fuel for evaluation purposes. In the normal course of events, the uranium yellow paste dissolves in nitric acid. However, to expedite the procedure and save expenses, personnel at three different factories packed the tanker with 16.6 kilos of uranium, even though they were only allowed to load 2.4 kilograms. Following a chain reaction that lasted for twenty hours and resulted in the production of a significant number of neutrons and, therefore, gamma rays, critical mass was attained. Since the accident released radioactive particles into the atmosphere, including iodine 131, 161 people had to be removed from the facility's ventilation system, and approximately 310 thousand people who lived within a 10-kilometer radius of the facility were told not to leave their homes.

4. Optimal Security Measures in Nuclear Energy Investments

In this study, it is aimed to determine optimal security measures in nuclear energy investments. For this purpose, selected criteria are weighted with the help of DEMATEL methodology. This approach is taken into consideration to find more significant weights in the process (Zhang et al., 2020; Dinçer et al., 2020). Additionally, the causal relationship among the items can be understood by using this technique (Gökalp et al., 2022). In the analysis process, firstly, important criteria are selected based on the literature evaluation. The details of these criteria are given in Table 1.

Table 1: Selected Criteria

Criteria	References
Financial Issues (FUE)	Dong et al. (2022); Wan et al. (2022)
Organizational Effectiveness (OIF)	Kou et al. (2022); Kostis et al. (2022)
Qualified Personnel (QRS)	Zhang et al. (2022); Qiu et al. (2020)
Technological Development (TGT)	Du et al. (2020); Cheng et al. (2020)

Financial issues may have an impact on the prevention of nuclear power plant accidents. In addition to this issue, organizational effectiveness of the nuclear energy investors can have a significant role in this regard. Thirdly, there is a strong need for qualified personnel to minimize the risks of the accidents. Finally, technological developments have a positive contribution to minimize the explosion risk in nuclear power plant.

After that, expert evaluations are collected for these four different factors. In the evaluation process, experts considered five different scales that are "no effect-0", "some effect-1", "normal effect-2", "high effect-4" and "very high effect-5". Table 2 gives information about the details of the evaluations.

Table 2: Evaluations of the Experts

E1				
	FUE	**OIF**	**QRS**	**TGT**
FUE	0	2	1	1
OIF	1	0	2	1
QRS	2	3	0	1
TGT	4	4	4	0
E2				
	FUE	**OIF**	**QRS**	**TGT**
FUE	0	1	2	1
OIF	2	0	1	1
QRS	2	3	0	1
TGT	4	4	4	0
E3				
	FUE	**OIF**	**QRS**	**TGT**
FUE	0	2	2	1
OIF	2	0	2	1
QRS	3	2	0	1
TGT	4	4	4	0

Next, the direct relation matrix is created by taking the average values of the expert evaluations. The details of this matrix are given in Table 3.

Table 3: Direct Relation Matrix

	FUE	OIF	QRS	TGT
FUE	0	1.66667	1.66667	1
OIF	1.66667	0	1.66667	1
QRS	2.33333	2.66667	0	1
TGT	4	4	4	0

After that, the normalization process has been implemented by dividing all values in direct relation matrix to the maximum row sum. Table 4 explains the details of the normalized matrix.

Table 4: Normalized Matrix

	FUE	OIF	QRS	TGT
FUE	0	0.13889	0.13889	0.08333
OIF	0.13889	0	0.13889	0.08333
QRS	0.19444	0.22222	0	0.08333
TGT	0.33333	0.33333	0.33333	0

In the following process, direct relation matrix is created as in Table 5.

Table 5: Direct Relation Matrix

	FUE	OIF	QRS	TGT
FUE	0.12617	0.25389	0.23658	0.13472
OIF	0.24812	0.13194	0.23658	0.13472
QRS	0.32121	0.3491	0.14348	0.15115
TGT	0.56517	0.57831	0.53888	0.1402

In the final step, the weights of the factors are calculated by considering the sums of the rows and columns. The details of the analysis results are demonstrated in Table 6.

Table 6: Weights of the Criteria

Criteria	Weights
Financial Issues (FUE)	0.23449
Organizational Effectiveness (OIF)	0.24062
Qualified Personnel (QRS)	0.24713
Technological Development (TGT)	0.27776

It is concluded that the technological development is the most essential factor to handle the risk of nuclear power plant explosion. The analysis results also show that the qualified employee also plays a critical role in this framework.

5. Discussions and Conclusions

This study aims to define optimal security measures in nuclear energy investments. Within this context, selected criteria are evaluated with DEMATEL. Within this framework, four different criteria are selected with the help of analyzing similar studies in the literature. Financial issues may have an impact on the prevention of nuclear power plant accidents. In addition to this issue, organizational effectiveness of the nuclear energy investors can have a significant role in this regard. Thirdly, there is a strong need for qualified personnel to minimize the risks of the accidents. Finally, technological developments have a positive contribution to minimize the explosion risk in nuclear power plant.

It has been identified that technological investments are the most critical strategy in managing the explosion risk in nuclear power plants. For this purpose, countries should especially focus on thorium-based nuclear power plants. In this regard,

it is recommended that countries make investments to acquire proton accelerator technology. In this way, both the explosion risk of nuclear power plants will be eliminated, and it will be possible to generate less harmful wastes. Unlike uranium, thorium is not a dangerous element. In other words, this element does not cause explosion in nuclear power plants.

Energy policies are very important for the development of sustainable development goals of countries. Nuclear energy projects also help countries to increase their energy independence. On the other hand, nuclear power generation is not affected by different climatic events. This also contributes to uninterrupted energy use. In summary, nuclear energy projects have a very important role in increasing the investments of countries. On the other hand, there are some risks in nuclear energy investments. The most important risk is the possibility of explosion of the nuclear power plant. Nuclear power plant accidents have also caused some negativities. Therefore, it is necessary to take effective measures against the explosion risk in nuclear power plants.

Because the power plant is the location where energy production takes place, it is of utmost significance in this supply chain; hence, the other links in this chain are often disregarded. Nevertheless, every location must be a safe facility that is managed by knowledgeable professionals. Building all the facilities near one another is one way to tackle the transportation issue; this may need more expenditure. The theory behind the operation of the power plant is essentially the same as that of the steam boiler: The heat that is released by nuclear fuel causes water or another material of a similar kind to get heated. The material that has been heated evaporates, which ultimately turns a propeller. In addition to that, this produces electrical current. When stated in this manner, it could seem to be a simple task; nevertheless, when you consider how hazardous the heat source is, it becomes clear that a great deal of care must be taken to ensure the safety of the workers. When all these systems are linked, the reactor ultimately becomes useful.

These systems include thick walls, systems that prevent leakage, systems that offer emergency cooling of the reactor, and many more systems.

Technicians and management are responsible for maintaining every system designed to avoid accidents. An incompetent technician or a boss who wants to be liked by someone else might quickly sabotage these systems' advantages. That country's stability might even have an impact on the security of these systems: Technicians' educational standards may decline with time, the resources allotted to the plant may deteriorate, or these factories may be actively sabotaged/attacked in places where political stability is lacking. To summarize, there is no one-size-fits-all solution to the problem of system security.

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