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A Review at Two Nuclear Reactor Problems in Asia

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Abstract

The development of nuclear power plants (NPP) is often a heated debate, especially in developing countries [1]. In relation to this, it is worth the public's attention that lately, it seems that there have been increasingly frequent press releases from various parties representing the government regarding plans to build the first nuclear fission reactor in Indonesia in the not too distant future. Reportedly there will be a large amount of additional energy supply planned (around 100 GW to be built in Indonesia within the coming decade). For this reason, the authors would like to invite readers to take a moment to look at two nuclear reactor problems in Asia, the first is the case of the failed Bataan reactor in the Philippines Islands, and the next is the natural disaster that damaged the reactor at the Fukushima NPP, 2011 [2].

Keywords: Nuclear Power Plants; Bataan Reactor; Fukushima; Developing Countries.

1 | Introduction

The development of nuclear power plants (NPP) is often a heated debate, especially in developing countries. Concerning this, it is worth the public's attention that lately, it seems that there have been increasingly frequent press releases from various parties representing the government regarding plans to build the first nuclear fission reactor in Indonesia in the not-too-distant future. Reportedly there will be a large amount of additional energy supply planned (around 100 within the coming decade), and although 75% of it will most likely be generated from renewable energy sources, the rest will be obtained from nuclear (fission) reactors. This is the statement that was read in various media some time ago.

For this reason, the authors would like to invite readers to take a moment to look at two nuclear reactor problems in Asia, the first is the case of the failed Bataan reactor, and the next is the natural disaster that damaged the reactor at the Fukushima NPP, 2011 [2].

2 | Failed Bataan Nuclear Power Plant

The Bataan Nuclear Power Plant in the Philippines is a classic example of a major infrastructure project that has had a major impact on a country's economy.

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The Bataan Nuclear Power Plant (NPP) in the Philippines was an ambitious project initiated by the Ferdinand Marcos regime in the 1970s. The project was driven by the global energy crisis at the time and the desire to achieve energy independence. However, the project failed and left many questions.

2.1 | Bataan Nuclear Reactor Background

In the 1970s, President Ferdinand Marcos had a vision to make the Philippines an advanced industrial nation. One of his ambitious projects was the construction of a nuclear reactor in Bataan. This project was expected to meet the increasing energy needs and encourage industrialization.

The construction of this nuclear reactor involved cooperation with the Westinghouse Electric Company of the United States. The Bataan nuclear reactor was designed with a capacity of 620 megawatts and was expected to be operational in the early 1980s.

2.2 | Intriguing Process

- Contract with Westinghouse: The Philippine government signed a contract with the American company Westinghouse to build the Bataan nuclear power plant. This decision was made without a transparent bidding process, sparking allegations of corruption.
- Rushed Construction: The Bataan nuclear power plant was built very quickly, without regard to strict safety standards. This was due to political pressure from the Marcos government to complete the project immediately.
- Soaring Costs: The construction costs of the Bataan nuclear power plant continued to balloon far beyond initial estimates, becoming a heavy burden on the country's finances.
- Public Protests: The project was opposed by a large portion of the Filipino public who were concerned about the negative impacts on the environment and health.

2.3 | Causes of Failure

Some of the main factors that led to the failure of the Bataan nuclear reactor project include:

- Corruption: Allegations of corruption involving government officials and project contractors were rife. Project funds that were supposed to be used for the construction of the reactor were allegedly misappropriated for personal gain.
- Political Pressure: The project was carried out amidst unstable political conditions. Demonstrations and protests against the project escalated, especially after the nuclear accident at Three Mile Island, United States.
- Cost Increase: The cost of building the nuclear reactor continued to balloon far beyond initial estimates. This made it difficult to obtain funding.
- Earthquakes: The Philippines is an earthquake-prone country. Fears of earthquakes that could damage the nuclear reactor further increased the risk of the project.
- EDSA Revolution: The fall of the Marcos regime in 1986 and the change of government caused the project to stall. The new government decided to stop the project due to various considerations, including security, environmental, and financial issues.

2.4 | Impact of the Bataan Nuclear Power Plant Failure

The failure of the Bataan nuclear reactor project had a very significant impact on the Philippine economy:

- Large Foreign Debt: The project left a very large foreign debt, reaching about 30% of the Philippines' total foreign debt at that time. This debt became a heavy burden on the Philippine economy and hampered other development efforts.
- Hampered Economic Growth: The failure of the project hampered the Philippines' economic growth. Funds that should have been used for the development of other productive sectors were forced to be allocated to pay debts.
- Environmental Damage: Although the project was not completed, the infrastructure development that had been carried out could have a negative impact on the environment.
- Investor Distrust: The failure of the project also damaged foreign investors' confidence in the investment climate in the Philippines.

2.5 | Lessons Learned

The failure of the Bataan nuclear reactor project provides valuable lessons for other countries planning to build nuclear reactors. Some of the lessons learned include:

- Transparency and Accountability: It is important to ensure transparency and accountability at every stage of the project.
- Community Participation: The community must be involved in the decision-making process and given complete information about the project.
- Comprehensive Risk Analysis: The risks associated with the project must be identified and analyzed comprehensively.
- Financial Sustainability: The project's funding sources must be ensured to be secure and sustainable.

3 | Earthquake, Tsunami, and Fukushima Nuclear Crisis: A Chain of Events Analysis

The Fukushima Daiichi disaster in 2011 began with the shifting of two major faults off the coast of Japan [2]. This shift triggered a magnitude 9.0 earthquake, one of the strongest earthquakes ever recorded. The earthquake then triggered a 40-meter tsunami that hit the Fukushima Daiichi nuclear power plant (NPP).

3.1 | Chain of Events Leading to the Crisis

- Cooling System Failure: The tsunami disabled the nuclear power plant’s emergency cooling system, causing the reactor temperature to rise dramatically.
- Hydrogen Explosion: The extreme heat triggered a reaction between water vapor and zirconium inside the reactor, producing flammable hydrogen gas. The hydrogen explosion caused severe damage to several reactors.
- Release of Radioactive Material: The reactor failure released large amounts of radioactive material, including iodine-131 and cesium-137, into the environment.

3.2 | Environmental and Health Impacts

- Soil and Water Contamination: Soil and water around the Fukushima Daiichi Nuclear Power Plant are contaminated with radioactive materials, causing long-term impacts on ecosystems and agriculture.
- Cancer Risk: Radiation exposure increases the risk of various types of cancer, especially in children.

- Mass Evacuations: Hundreds of thousands of residents around Fukushima were forced to evacuate to avoid radiation exposure.

4 | Emergency Management and Rehabilitation Challenges in Fukushima

The Japanese government immediately carried out a mass evacuation of residents living within a 20-kilometer radius of the Fukushima Daiichi Nuclear Power Plant. However, the evacuation and evacuation process did not go smoothly. Many residents had difficulty finding temporary housing and getting assistance.

4.1 | Soil Contamination and Decontamination

One of the main efforts in Fukushima's rehabilitation is soil decontamination. The Japanese government has set a target to reduce the level of radioactive contamination in the soil to a level that is safe for humans. One method used is to strip the top 10 cm of contaminated soil.

4.2 | Challenges in Rehabilitation

- Long Time: The decontamination and rehabilitation process takes a very long time and is very expensive.
- Psychological Impact: Residents affected by the disaster experience deep psychological trauma.
- Economic Problems: Many industries and businesses in Fukushima have suffered huge losses due to this disaster.

Lessons Learned

The Fukushima disaster is a valuable lesson for the world about the importance of strengthening nuclear power plant safety and disaster preparedness. Some of the lessons learned include:

- The Importance of Emergency Cooling Systems: Emergency cooling systems must be very well designed and resilient to various types of disasters.
- Need for Re-evaluation of Safety Standards: Nuclear power plant safety standards need to be continuously evaluated and updated to meet new challenges.
- Community Preparedness: Communities need to be equipped with the knowledge and skills to deal with disasters, including evacuation and self-protection.

4.3 | Fukushima as a Black Swan

The Fukushima Daiichi nuclear disaster in March 2011 was one of the most tragic events in the history of nuclear energy. A massive earthquake and subsequent tsunami triggered a series of cooling system failures at the nuclear power plant, resulting in a large-scale release of nuclear radiation. This event not only caused enormous material losses, but also long-term impacts on the environment and human health.

The Fukushima disaster fits the definition of a black swan [3, 4]. An earthquake and tsunami of this magnitude in an area previously considered relatively safe from major earthquakes was a highly unexpected event. The impacts were far-reaching, ranging from mass evacuations, and environmental contamination, to a crisis of confidence in nuclear energy.

5 | Discussion Understanding the Black Swan Theory

Nassim Taleb, in his book "The Black Swan", introduced the concept of a "black swan" to describe an event that has three main characteristics:[3, 4]

i. Unexpected: The event is highly unlikely to occur based on past experience or existing knowledge.

ii. High impact: When it occurs, the event has a very significant and wide-ranging impact.

iii. Retrospective explanation: After an event occurs, people tend to look for explanations or patterns that can explain the event, as if the event could have been predicted beforehand.

Skewness in the Probability Curve

Traditional probability theory often assumes that major events have very small probabilities. However, in reality, the world often presents extreme events that far exceed our expectations. The Fukushima disaster is a classic example of "skewness" in the probability curve, where the right tail of the curve (representing extreme events) is much thicker than traditional statistical models would predict.

5.1 | The Limitations of Science in Anticipation

Despite advances in science, we still cannot predict with certainty when and where major earthquakes will occur. Current earthquake prediction models have a low level of accuracy. Furthermore, the combination of an earthquake and tsunami on a scale as large as the one that occurred in Fukushima is a very complex event and difficult to anticipate.

The Fukushima disaster has made us aware of the importance of being prepared for unexpected events. We need to build more resilient and flexible systems and infrastructure. We also need to develop a mindset that is more open to the possibility of extreme events.

The Fukushima disaster is a valuable lesson in the limitations of human knowledge and the importance of being prepared for uncertainty. This event shows that even events considered highly unlikely can occur and have a huge impact. By understanding the concept of black swans, we can better anticipate risks and build a safer future.

5.2 | The Trans-scientific Nature of Fission Reactors and the Challenge of Predicting Catastrophic Failures

Nuclear fission reactors, while offering a powerful source of energy, present a unique challenge to risk assessment and management due to their inherent trans-scientific nature (cf. this term was suggested by Prof Alvin Weinberg, father of fission reactor for peace). Unlike many technological systems, the behavior of fission reactors can exhibit emergent properties and non-linear dynamics that defy easy prediction and control.

The concept of "trans-scientific" highlights the limitations of traditional scientific methods in fully understanding and predicting the behavior of complex systems. In the context of nuclear reactors, trans-scientific aspects arise from:

i. Emergent Behavior: Nuclear fission is a complex process involving intricate interactions between nuclear particles, materials, and thermodynamic forces. These interactions can lead to emergent phenomena, such as instabilities and oscillations, that are not easily predictable from the behavior of individual components.

ii. Non-linear Dynamics: The chain reaction process within a reactor can exhibit non-linear behavior, meaning small changes in initial conditions can lead to disproportionately large and unpredictable outcomes. This makes it difficult to accurately model and simulate potential accident scenarios.

iii. Uncertainties and Limitations of Knowledge: Despite decades of research, there are still fundamental uncertainties in our understanding of nuclear fission processes, particularly in extreme conditions such as those encountered during severe accidents. These knowledge gaps limit the accuracy of risk assessments and the ability to predict the full spectrum of potential failure modes.

The Fukushima Daiichi Accident: A Case Study

The Fukushima Daiichi nuclear disaster in 2011 serves as a stark reminder of the challenges posed by the trans-scientific nature of nuclear reactors. While the initial trigger was a natural disaster (the earthquake and tsunami), the subsequent cascading failures and core meltdowns were driven by complex interactions within the reactor systems, including:

- Loss of Electrical Power: The tsunami disabled the emergency power systems, leading to a loss of cooling capacity.
- Hydrogen Buildup: The lack of cooling led to the generation of hydrogen gas, which eventually caused explosions in the reactor buildings.
- Reactor Core Meltdowns: The extreme heat caused the reactor cores to melt, releasing radioactive materials into the environment.

These events unfolded in a complex and non-linear fashion, highlighting the limitations of traditional risk assessments that may not fully capture the potential for cascading failures and unforeseen consequences.

The Path Forward

Addressing the trans-scientific nature of nuclear reactors requires a multi-pronged approach:

- Advanced Modeling and Simulation: Developing more sophisticated models and simulation tools that can capture the complex dynamics of nuclear systems, including potential non-linear behaviors and emergent phenomena.
- Robustness and Redundancy: Designing reactor systems with enhanced robustness and redundancy to mitigate the impact of unforeseen events and increase resilience.
- Continuous Learning and Adaptation: Continuously monitoring reactor performance, analyzing operational data, and incorporating new knowledge into risk assessments and safety procedures.
- Open and Transparent Communication: Fostering open and transparent communication between scientists, engineers, regulators, and the public to ensure a shared understanding of the risks and uncertainties associated with nuclear power.

By acknowledging the inherent limitations of our understanding and embracing a culture of continuous learning and adaptation, we can strive to improve the safety and reliability of nuclear power systems while mitigating the risks associated with their transcientific nature.

5.3 | Why black-swan Events like the Fukushima Disaster cannot be Predicted in the Business-as-usual Scheme such as ISO-31001

Recently there is a book written by R. Alamsyah that seems to suggest that all problems related to previous nuclear reactor disasters and accidents have been already handled properly and anticipated in the risk management framework such as ISO-31001 [5].

R. Alamsyah's assertion that ISO-31001 adequately addresses the risk of nuclear accident events like the Fukushima disaster is a dangerous oversimplification [6]. While ISO-31001 provides a valuable framework for identifying, assessing, and mitigating risks, it has inherent limitations that make it ill-equipped to handle truly unpredictable and catastrophic occurrences.

The Nature of Black Swan Events:

- Unpredictability: By definition, black swan events are unforeseen and unexpected. They lie outside the realm of normal expectations and therefore cannot be easily incorporated into traditional risk assessments.
- High Impact: These events have severe consequences, often with cascading effects that can cripple systems and cause widespread devastation.

- Retrospective Understandability: Only after a black swan event occurs can we often understand its underlying causes and potential triggers. This makes proactive prediction and mitigation extremely difficult.

5.4 | Limitations of ISO-31001 [6]

- Focus on Known Risks: ISO-31001 primarily focuses on identifying and managing known risks – those that can be reasonably anticipated based on historical data, expert judgment, and scenario planning.
- Difficulty in Quantifying Low-Probability, High-Impact Events: Black swan events, by their nature, have low probabilities of occurrence. This makes it challenging to accurately quantify their potential impact within the framework of traditional risk assessment methodologies.
- Reliance on Historical Data: ISO-31001 often relies on historical data to inform risk assessments. However, black swan events, by definition, have no historical precedent.

5.5 | The Fukushima Example

It shall be quite clear that the Fukushima disaster serves as a stark reminder of the limitations of risk management frameworks in the face of truly unpredictable events.

- Unforeseen Tsunami: The devastating tsunami that triggered the Fukushima meltdown was an event of unprecedented magnitude, exceeding the design parameters of the nuclear plant's seawall.
- Cascading Failures: The initial tsunami triggered a cascade of failures, including power outages, cooling system malfunctions, and ultimately, multiple reactor meltdowns. These cascading effects were difficult to anticipate within the existing risk assessment framework.

6 | Concluding Remarks

The Bataan nuclear reactor failure is a classic example of how large infrastructure projects can fail if not managed properly. The failure of this project provides valuable lessons about the importance of careful planning, transparency, and community participation in every development project.

In addition to the Bataan reactor operating failure case, the Fukushima disaster is one of the worst nuclear disasters in history. Although several years have passed, its impact is still felt today. This disaster is a reminder to all of us about the importance of maintaining environmental safety and protecting human life.

Moreover, while ISO-31001 is a valuable tool for managing known risks, it cannot be considered a panacea for preventing black swan events [3, 4]. The Fukushima disaster highlights the critical need for:

- Robustness and Redundancy: Designing systems with inherent robustness and redundancy to withstand unforeseen shocks.
- Scenario Planning for Extreme Events: Developing and regularly testing scenarios that push the boundaries of conventional thinking, considering low probability but high-impact events.
- Continuous Learning and Adaptation: Continuously reviewing and updating risk assessments in light of new information and emerging threats.

Ultimately, effectively managing the risk of black swan events requires a combination of robust risk management frameworks, a culture of continuous learning, and a willingness to acknowledge and address the inherent limitations of our predictive capabilities.

These are some things that can be of concern to national policymakers, especially those that will have an impact on the lives of many people in the long term in the future.

Without intending to criticize any party, let us recall the text of Article 33 of the 1945 Indonesia Republic's Constitution which among other things states that "the earth, water, and land in this country must be managed as well as possible for the benefit of the people and the people." In other words, it is certainly not wise for the government to choose a type of technology that distances the community from the energy supply process, and also has minimal or no prospects for technology transfer from developed countries to technicians in developing countries. Not to mention the dependence on foreign debt and also the dependence on the supply of uranium raw materials, which in itself carries the risk of obstacles in the supply chain, if Indonesia is one day hit by an embargo, for example.

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Data Availability

The datasets generated during and/or analyzed during the current study are not publicly available due to the privacy-preserving nature of the data but are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that there is no conflict of interest in the research.

Ethical Approval

This article does not contain any studies with human participants or animals performed by any of the authors.

References

[1] Iwan Kurniawan, L. Wilardjo et al. Pembangunan PLTN: demi kemajuan peradaban? -- preface by Abdurrahman Wahid. Jakarta: INFID, WALHI dan Yayasan Obor Indonesia, 1996.

[2] Natalia Novikova, Julia Gerster, Manuella G. Hartwig (eds.) Japan's triple disaster: Pursuing justice after the great East Japan. 1st edition. New York: Routledge, 2023.

[3] Nassim N. Taleb. STATISTICAL CONSEQUENCES OF FAT TAILS. Stem Academic Press (2020). ISBN: 978-1-5445-0805-4

[4] Nassim N. Taleb. The Black Swan.

[5] R. Alamsyah. Regulasi Keselamatan PLTN. Jakarta: Penerbit Buku Kompas, 2023

[6] Terje Aven & Enrico Zio. Knowledge in Risk Assessment and Management. New York: Wiley.