ANALYSIS OF THE FUKUSHIMA DAIICHI NUCLEAR POWER PLANT IN DISASTER CRISIS RESPONSE

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Introduction

The phrase "nuclear disaster" is often associated with senses of danger, fear, and urgency in regards to one's safety. Thus, I was surprised to hear that researchers consider the initial emergency response to the Fukushima nuclear disaster as slow and inadequately prepared. Among many reasons, I was most confused by the initial poor communication and lack of transparency of the organization responsible for the recovery efforts, which caused public distrust and stricter oversight from the Japanese government. As I conducted more research on the disaster response, I was left with two questions: why was a disaster of such magnitude initially managed so poorly, and how did the actors involved regain positive traction to lead a successful crisis response?

The Daiichi Nuclear Power Plant disaster in Fukushima is considered to be the worst nuclear disaster since Chernobyl, both of which are rated a 7 International Nuclear Event Scale (Britannica, 2025). The disaster occurred in March 2011 when a magnitude 9.0 earthquake triggered a tsunami that struck the reactor and flooded the generators. Due to the power loss, the inactive cooling systems led to overheating of the environment, which led to core meltdowns and hydrogen explosions that significantly damaged the reactor. The immediate effects included the release of radioactive materials into the air and ocean, the evacuation of over 150,000 residents, widespread contamination, and a nuclear emergency that prompted a national and international crisis response.

For a radioactive disaster of such magnitude, the investigative and cleanup efforts cannot be carried out by humans alone. While the Tokyo Electric Power Company (TEPCO) and the Japanese government worked in conjunction to coordinate an effective emergency response, the radioactive environment of the reactor served as a rogue actor against the goals of the cleanup efforts. This is where non-human actors are crucial: teleoperated systems can be designed to withstand extreme environments, allowing operators to assess the state of the reactor remotely. Unmanned aerial vehicles (UAVs) were equipped with sensors and cameras that enabled them to capture images, collect radiation measurements, and map out the reactor interior. TEPCO also implemented water purification systems such as Advanced Liquid Processing System (ALPS) to treat the contaminated water in the reactor.[1] The use of such technologies provided TEPCO with insights and solutions regarding air and water contamination levels as well as structural damage in the reactor.

While the techniques used to manage the radioactive environment eventually grew to be effective, the initial response from TEPCO was widely criticized for being disorganized and slow. Communication between agencies was inconsistent, and critical decisions were delayed due to confusion and lack of preparation for a nuclear crisis of this scale. As a result, it took longer for a coordinated emergency response to take shape, during which time radiation continued to spread and public trust toward the decommissioning efforts and the state of their safety diminished. Although many organizations and agencies factor into the decision-making process, most of the public's blame was placed on TEPCO since it owned and operated the Daiichi nuclear power plant. With concern from the general public continuing to grow, the Japanese government increased scrutiny and oversight over TEPCO's operations, which ultimately facilitated their investigative and cleanup efforts.

In what follows, I argue that all actors involved in investigative efforts following a disaster bear equally crucial roles in executing a successful emergency response. The initial scrutiny placed mainly on TEPCO should also be distributed to the Japanese government, as both

[1] This paper mainly focuses on the teleoperated robotic technologies used to assess and manage the radioactivity in the reactor due to its pertinence to the Technical Project.

were responsible for the initial unpreparedness. The Actor-Network Theory (ANT) framework establishes TEPCO, the Japanese government, the UAVs and drones, the general public, and the radioactive environment of the reactor as an interconnected socio-technical network. The literature review discusses the existing research and perception of the human and non-human actors involved in the cleanup efforts. Using the concept of translation and case study analysis, I will examine the network of socio-technical dependencies that contributed to the eventual successes of the investigation and cleanup efforts of the Daiichi nuclear power plant disaster site.

Literature Review

The Fukushima Daiichi nuclear disaster represents one of the most significant and complex crises in recent history, involving multiple interconnected actors whose decisions and actions are interdependent. TEPCO has been at the epicenter of criticism since the disaster occurred. Research into TEPCO's initial preparedness indicates a systemic failure in anticipating a tsunami of the scale experienced in 2011, despite existing geological and historical evidence. Investigations and academic assessments highlight that TEPCO severely underestimated the probability and potential severity of such a natural disaster. Consequently, the backup generators and cooling systems intended to prevent core overheating were inadequately protected, directly contributing to the eventual reactor meltdowns (World Nuclear Association, 2024). Furthermore, critiques of the emergency response consistently point to TEPCO's ineffective crisis communication strategies, which were fragmented and insufficiently transparent to both the Japanese government and general public. Public statements were often overly technical or incomplete, amplifying confusion and distrust among the public and regulatory authorities alike (Kim & Bie, 2017). Although TEPCO issued formal apologies and accepted responsibility, many researchers argue that the trust deficit created in the immediate aftermath of the disaster has had lasting implications on public perception and regulatory relationships.

The Japanese government's role in managing the Fukushima crisis has similarly attracted extensive scrutiny from the general public. The immediate governmental response exposed significant flaws in Japan's nuclear emergency preparedness. Researchers have highlighted substantial coordination challenges between various government agencies and TEPCO, which were compounded by inadequate emergency plans and a lack of real-time accurate information (National Research Council, 2020). Scholarly work applying political ecology frameworks has also examined the complex interplay between environmental risk perceptions, public policy, and political decision-making processes. Such analyses suggest that initial government actions were significantly shaped by underestimations of disaster risk and pressures to avoid causing public panic. Contrasting perspectives also exist, however, acknowledging that some governmental decisions—particularly those made by Prime Minister Naoto Kan—may have been instrumental in averting an even greater disaster scenario, indicating the complexities inherent in evaluating governmental crisis response (Biello, 2013).

UAVs and drones emerged as critical non-human actors instrumental in assessing and managing the disaster's aftermath due to the highly radioactive conditions within the reactors. The drones were developed by TEPCO with aid from companies specializing in aerial robotic systems such as Honeywell. Scholars and industry reports highlight that the deployment of drone technology provided an unprecedented opportunity to remotely survey reactor interiors, radiation hotspots, and structural integrity without endangering human operators (Boston Dynamics, 2024). Innovations in UAV technology enabled detailed environmental assessments critical for informed decision-making during cleanup efforts. However, academic discussions have also identified substantial operational challenges these drones encountered, including difficulties navigating complex, debris-filled environments and failures resulting from intense radiation exposure (Asahi Shimbun, 2023). Despite these setbacks, drones have continually advanced the capabilities of remote operations in radioactive environments, serving as invaluable tools in the broader socio-technical network facilitating the disaster's remediation.

Finally, the radioactive environment of the reactor itself served a critical rogue actor, shaping and constraining all subsequent recovery efforts. Scholarly research puts forth the severity of radiation levels recorded within the reactor units following the disaster. Radiation levels in Unit 2 peaked at 530 sieverts per hour in early 2017, which was an unprecedented intensity capable of causing death within mere minutes of exposure (Washington Post, 2017). This shows the magnitude of radioactive damage that the reactor took, persisting years after the accident. Similarly, radiation levels in Unit 1 reached upwards of 4,000 millisieverts per hour shortly after the disaster, indicating hazardous conditions far exceeding human safety thresholds (International Atomic Energy Agency, 2011). The environmental release of radioactive isotopes, notably cesium-137 and iodine-131, resulted in significant ecological contamination, long-term public health concerns, and socio-economic disruptions throughout Fukushima and neighboring prefectures (Polleri, 2021). Moreover, studies evaluating environmental remediation efforts suggest variable degrees of effectiveness, reinforcing ongoing scientific debates regarding best practices for decontamination and long-term environmental management (Federal Office for Radiation Protection, 2023). These high radiation conditions significantly complicated reactor assessments and cleanup initiatives, necessitating innovations in robotics and remote sensing technologies while simultaneously highlighting the limitations of current engineering responses.

To analyze the interactions between each of these actors, the following study uses Actor-Network Theory (ANT), specifically the concept of translation. ANT, developed by Bruno Latour, a theoretical framework that examines how networks of various actors, both human and non-human, shape technological outcomes through their dynamic relationships and dependencies (Latour, 2005). In the Fukushima context, ANT illuminates how TEPCO, the Japanese government, UAVs, and the radioactive environment aligned their interests to navigate the complex recovery process. Initially, the Japanese government intervened following TEPCO's slow and inadequate response, leading to increased oversight and policy reforms. TEPCO, facing challenges with drone technology due to unexpectedly high radiation levels, intentionally redesigned UAV systems to ensure more robust and accurate data collection. Lastly, the general public emerges as a critical actor, their concerns significantly shaping governmental action, ultimately prompting stricter safety regulations and nuclear oversight to prevent future crises.

Methods

This study utilizes ANT as its primary methodological frameworks, specifically the concept of translation. Translation is the process in which actors (both human and non-human) align their interests, redefine issues, and negotiate to establish a network of connections to achieve a common goal (Shiga, 2007). As stated before, ANT provides a theoretical lens to demonstrate how TEPCO, the Japanese government, and UAVs aligned their interests and cooperated to manage the radioactive environment during investigative and cleanup efforts. Instead of assigning the majority of the blame to TEPCO for poor management of the disaster, ANT analyzes how responsibility is distributed equally among for the effectiveness and efficiency of the crisis response.

Data collection involves secondary sources, including investigative and technical reports published by TEPCO. Specifically, TEPCO investigative reports were analyzed to establish the organization's objectives and strategies for radiation investigation and reactor decommissioning. Complementary technical reports from TEPCO were used to illustrate how UAV design adaptations ensured effective data collection in extremely radioactive environments. Additionally, radiation measurement documentation from the investigation provided critical quantitative data to clarify investigative efforts and outcomes. Government policies and regulations regarding drone usage during disaster management were reviewed to understand the operational guidelines TEPCO followed during the cleanup efforts. These policies illustrate the government's oversight role and how regulatory frameworks shaped the implementation and deployment of UAV technologies. By analyzing the aforementioned sources, I examined instances of alignment or conflict between the objectives and actions of human and non-human actors. Particular attention was given to moments when technical adjustments, policy implementations, or collaborative decisions significantly influenced and progressed the effectiveness of the disaster response.

Analysis

The relationship between TEPCO and the Japanese government exemplifies a crucial interconnected dynamic within the Fukushima Daiichi crisis response. Initially, TEPCO demonstrated inadequate preparation and a sluggish reaction to the unfolding nuclear disaster, characterized by fragmented communication and delayed critical decisions. This insufficient response resulted in heightened public mistrust and increased pressure on the Japanese government to intervene more assertively. The government's subsequent actions significantly reshaped the dynamics of crisis management, exemplified through policy reforms aimed at bolstering oversight and responsiveness. For instance, the establishment of the Nuclear Regulation Authority (NRA) in September 2012 dramatically strengthened regulatory oversight by enforcing stricter safety standards and mandatory stress tests for nuclear facilities, ensuring enhanced preparedness against similar incidents (Osaka, 2012). These measures illustrate how government intervention became critical to rectifying initial failures, reinforcing the argument that the government's increased scrutiny was indispensable for a successful emergency response.

The relationship between non-human actors, specifically drones and the radioactive environment, and the Japanese government further illustrates ANT's concept of translation through aligned interests. Recognizing that human presence within the highly radioactive reactor posed severe health risks, the government collaborated with TEPCO and external technological firms to facilitate drone deployment. The Japanese government's enactment of new policies post-disaster provided operational guidelines and regulations for drone usage in hazardous environments, notably outlined in the "Basic Policy on the Recovery and Reconstruction of Fukushima Prefecture" enacted in 2012 (Stanford APARC, 2014). Additionally, comprehensive reforms under the "Strategic Energy Plan" of 2014 mandated rigorous safety improvements, including provisions for increased deployment of remotely operated technologies during nuclear crises (Fujita & Shaw, 2023). These policies showcase the government's acknowledgment of non-human technological actors as essential in executing crisis response and emphasized preventive safety measures for future nuclear management. Through such policy interventions, drones became legitimized as essential tools for navigating and analyzing radioactive environments, evidencing ANT’s translation process of mutual alignment and goal negotiation among government agencies, technological actors, and environmental constraints.

Finally, the relationship among TEPCO, drones, and the radioactive environment illustrates a crucial, intricate interdependency central to the successful management of the Fukushima disaster response. The RQ-16 T-Hawk model designed by Honeywell was used by TEPCO in the reactor environment investigation. The drone, equipped with cameras, LiDAR sensors for navigation, and radiation sensors for measurements, allowed the operator to view the reactor from up to 6 miles away (Guizzo, 2011). Initially, the drones used by TEPCO encountered severe operational challenges due to unprecedented radiation levels exceeding their design specifications, leading to equipment malfunction and loss of vital data. However, these setbacks prompted significant technological innovation and redevelopment of drone systems. After TEPCO ordered for the drones to be redesigned, they were able to withstand extreme radiation and navigate challenging environments. Innovations included enhanced shielding, autonomous navigation capabilities, and advanced sensor arrays capable of accurately measuring radiation levels, structural damage, and contamination distribution within reactor cores . Notably, drones equipped with high-resolution cameras and radiation sensors collected critical data, such as the 530 sieverts per hour recorded in Unit 2 and structural assessments vital for planning cleanup operations (Cho & Jeong, 2011). This evolution of drone technology proves ANT’s concept of actors dynamically adjusting to environmental pressures, mutually influencing technological advancement, and strategic crisis management decisions. The reciprocal relationship between TEPCO’s operational demands, the challenging radioactive environment, and the technical specifications of drone technology demonstrates how each actor shaped and influenced the outcomes of emergency responses.

Many researchers along with public opinion argue that TEPCO's early mismanagement inherently places greater responsibility upon them, diminishing the equal importance of non-human or governmental actors. While acknowledging TEPCO's initial shortcomings is crucial, this perspective undervalues the broader, interconnected network emphasized by ANT. It is precisely through acknowledging TEPCO's initial failures that one observes the criticality of governmental intervention and technological innovation in rectifying systemic flaws. Without the Japanese government's enhanced regulatory oversight or the advancement and deployment of robust drone technologies capable of withstanding the harsh radioactive environment, TEPCO alone would have been insufficient to achieve a successful emergency response. Hence, recognizing the integral roles played by all actors—government, non-human technologies, and TEPCO—in correcting initial shortcomings affirms the necessity of viewing these entities as equally crucial and interdependent actors within the socio-technical network of disaster response.

Conclusion

Understanding the Fukushima Daiichi nuclear disaster through the lens of Actor-Network Theory reveals a more nuanced picture of responsibility, coordination, and innovation than a singular focus on TEPCO's early failures. By examining how TEPCO, the Japanese government, drone technologies, and the radioactive environment interacted, we gain a new understanding of how disaster response is shaped by a dynamic network of human and non-human actors. Rather than isolating fault or credit, this approach shows how each actor's decisions, constraints, and adaptations collectively determined the effectiveness of the emergency response. What began as a fragmented, reactive situation evolved into a coordinated, multi-actor effort that demonstrates the power of aligning interests under extreme conditions.

This study is important in challenging the conventional tendency to assign blame to a single institution or actor in times of crisis. Policymakers involved in nuclear oversight, engineers designing crisis-response technology, and emergency managers planning future protocols can all benefit from this more holistic perspective. For instance, regulatory bodies might reconsider how oversight can proactively support—not just punish—energy companies, while robotics developers can design more adaptable tools by understanding the environmental and political constraints they must operate within.

Future research should continue applying ANT to other large-scale crises (both technological and natural) to reveal unseen interdependencies and refine policy and engineering approaches accordingly. Additionally, deeper exploration into the role of the public as an actor—particularly how societal pressure and media coverage influence technical and governmental responses—would strengthen this network-based understanding. The lessons of Fukushima do not reside only in its failures, but in how a system of disparate actors learned to cooperate in the face of complexity. By viewing disaster responses through the interdependent network of people, policies, and technologies, we not only understand past crises more deeply, but also equip ourselves to build a safer, more resilient future.

References

[1] Asahi Shimbun. (2023). *TEPCO's drone fails to find melted fuel at Fukushima plant*. Retrieved from https://www.asahi.com/ajw/articles/15183719

[2] Biello, D. (2012, February 29). *The nuclear power odyssey of Naoto Kan, former Japan prime minister during Fukushima*. Scientific American. Retrieved from https://www.scientificamerican.com/article/nuclear-power-odyssey-of-naoto-kan-former-japan-prime-minister-during-fukushima/

[3] Boston Dynamics. (2024). *Spot in Fukushima Daiichi*. Retrieved from https://bostondynamics.com/case-studies/spot-in-fukushima-daiichi/

[4] Britannica (2025). *Japan earthquake and tsunami of 2011*. Retrieved from https://www.britannica.com/event/Japan-earthquake-and-tsunami-of-2011

[5] Cho, J.W. & Jeong, K.M. (2017). Comparison of robot technologies for decommissioning nuclear power plants. *Proceedings of the Korean Nuclear Society Spring Meeting 2017*. Retrieved from https://www.kns.org/files/pre_paper/5/62%EC%A1%B0%EC%9E%AC%EC%99%84.pdf

[6] Denyer, S. (2017). Japanese nuclear plant just recorded an astronomical radiation level. Should we be worried? *The Washington Post*. Retrieved from https://www.washingtonpost.com/news/worldviews/wp/2017/02/08/japanese-nuclear-plant-just-recorded-an-astronomical-radiation-level-should-we-be-worried/

[7] Federal Office for Radiation Protection. (2023). *Environmental consequences of the Fukushima nuclear accident*. Retrieved from https://www.bfs.de/EN/topics/ion/accident-management/emergency/fukushima/environmental-consequences.html

[8] Fujita, M., & Shaw, R. (2023). Policy implications of nuclear disaster recovery: Lessons from the Fukushima experience. *Journal of Environmental Management, 338*, 117626. https://doi.org/10.1016/j.jenvman.2023.117626

[9] Guizzo, E. (2011). Robotic Aerial Vehicle Captures Dramatic Footage of Fukushima Reactors. *IEEE Spectrum*. Retrieved from https://spectrum.ieee.org/robotic-aerial-vehicle-at-fukushima-reactors

[10] International Atomic Energy Agency. (2011). *Fukushima nuclear accident update log – 21*. Retrieved from https://www.iaea.org/newscenter/news/fukushima-nuclear-accident-update-log-21

[11] Kim, Y., & Bie, B. (2017). Framing a nuclear accident: Comparing news coverage of Fukushima in the U.S. and South Korea. *Public Relations Review, 43*(2), 381–393. https://doi.org/10.1016/j.pubrev.2016.11.003

[12] Latour, B. (2005). *Reassembling the social: An introduction to actor-network theory.*

Oxford University Press

[13] National Research Council. (2014). *Lessons learned from the Fukushima nuclear accident for improving safety of U.S. nuclear plants*. Washington, DC: The National Academies Press. Retrieved from https://www.ncbi.nlm.nih.gov/books/NBK253930/

[14] Polleri, M. (2021). Radioactive Performances: Teaching about Radiation after the Fukushima Nuclear Disaster. Anthropological Quarterly 94, 93-123. https://dx.doi.org/10.1353/anq.2021.0015.

[15] Osaka, Eri. “Corporate Liability, Government Liability, and the Fukushima Nuclear Disaster .” *Washington International Law Journal*, 1 June 2012, digitalcommons.law.uw.edu/cgi/viewcontent.cgi?article=1587&context=wilj.

[16] Shiga, J. (2007). Translations: Artifacts from an Actor-Network Perspective. Artifact, 1(1), 40–55. https://doi.org/10.1080/17493460600658318

[17] Stanford APARC. (2014). *Fukushima: Japan's political leadership helped save country from worst-case disaster, Stanford researcher says*. Retrieved from https://aparc.fsi.stanford.edu/news/fukushima_japans_political_leadership_helped_save_country_from_worstcase_disaster_stanford_researcher_says_20140625

[18] World Nuclear Association. (2024). *Fukushima Daiichi accident*. Retrieved from https://world-nuclear.org/information-library/safety-and-security/safety-of-plants/fukushima-daiichi-accident.aspx