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Policy Review and Regional Development in Disaster Mitigation (Case Study: 2004 Aceh Tsunami and 2011 Tōhoku Tsunami)

Philia Christi Latue[1], Susan Manakane[2], Heinrich Rakuasa[3]
Herzen University, Russian Federation | philiachristilatue@gmail.com[1]
Pattimura University, Indonesia | uchanmanakane@rocketmail.com[2]
University of Indonesia, Indonesia | heinrich.rakuasa@yandex.ru[3]

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Abstract

The geological location of Indonesia and Japan means that both countries experience frequent disasters. On December 26, 2004, Aceh, located on the northern tip of the island of Sumatra and the westernmost province in Indonesia, was hit by a tsunami that left 166,000 people dead or missing and 500,000 people displaced. While on March 11, 2011, the Great East Japan Earthquake and Tōhoku Tsunami with a magnitude of 9.0 occurred and resulted in approximately 15,800 fatalities and 220,000 displaced persons. This study uses a descriptive comparative study method by reviewing policies and regional development in disaster mitigation after the Aceh Tsunami (2004) and the Tōhoku Tsunami (2011) occurred. Policies related to disaster mitigation in Aceh show that tsunamis were never considered in urban planning before the 2004 Aceh Tsunami, while Japan has developed them since 1896 after the Great Meiji Sanriku Tsunami occurred. Existing disaster mitigation policies in Aceh's spatial planning have also not been implemented optimally and consistently. Japan's policies and regional development in disaster mitigation can be a lesson learned as Japan is considered worldwide as a model country in the field of tsunami preparedness and resilience.
Keywords: Aceh, Disaster Mitigation, Japan, Policy, Tsunami

Introduction

Indonesia and Japan share a similar geologic location. Both countries are located at the confluence of various world tectonic plates and the Asia Pacific Ring. Indonesia is at the confluence of the Eurasian Plate, Indo-Australian Plate, and Pacific Plate, while Japan is at the confluence of the Eurasian Plate, Philippine Plate, Pacific Plate, and North American Plate (Ibrahim et al., 2022).

These conditions cause Indonesia and Japan to experience frequent disasters, such as earthquakes, tsunamis, volcanic eruptions, floods, and tidal waves. On December 26, 2004 an earthquake with a magnitude of 9.1 occurred near the Sunda Trench, off the coast of Sumatra Island, Indonesia. The earthquake generated a large tsunami that spread across the Indian

Ocean, causing extensive damage to the coastal areas of countries that face the Indian Ocean, including Indonesia, Thailand, Sri Lanka, India and even some East African countries (Matsumaru et al., 2012). In Indonesia, the cities of Banda Aceh and Meulaboh in West Aceh Regency were the two main cities heavily affected by the Indian Ocean tsunami (Syamsidik et al., 2021). The location of the 2004 Indian Ocean Tsunami can be seen in Figure 1.

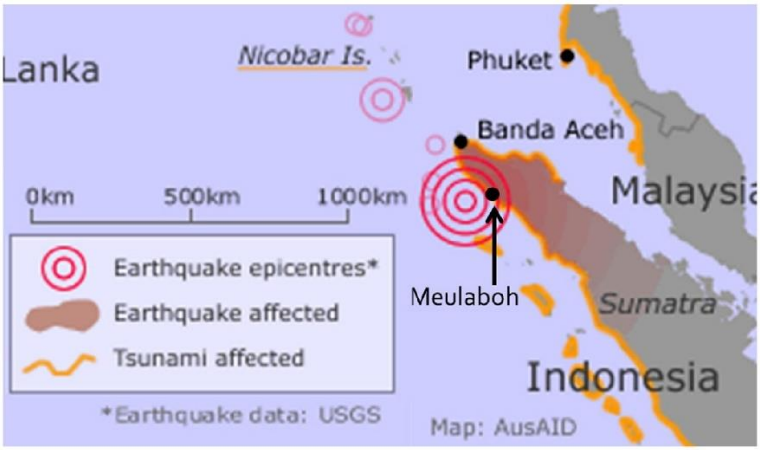
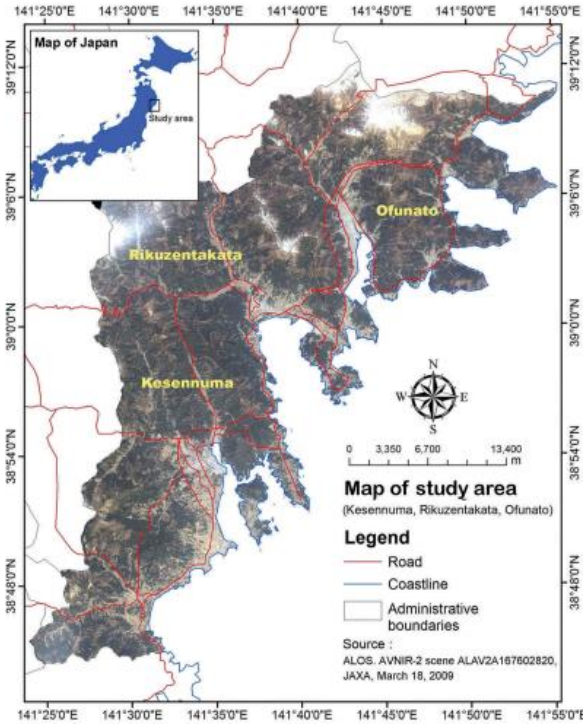


Figure 1. Location Map of the 2004 Indian Ocean Tsunami (Matsumaru et al., 2012)

The Rehabilitation and Reconstruction Agency reported more than 166,000 people dead or missing. The tsunami hit the coastal city of Banda Aceh with a height of 6-12 m and traveled 2 km inland from the coast, reaching as far as 4 km in some places (Matsumaru et al., 2012; Rahiem et al., 2021). Thousands of buildings were washed away. Urban infrastructure such as roads, electricity, clean water, and telecommunications, as well as public services such as education, health, and public transportation, were severely damaged (Fuady et al., 2021).



F*igure 2. Location Map of the 2011 Tohoku Tsunami (Sambah & Miura, 2016)*

The total number of displaced people in Indonesia reached 500,000. The tsunami struck about 30 minutes to an hour after the earthquake, but many people in Banda Aceh City were unable to escape in time because the city was not prepared for the tsunami. Residential areas along the coastline of Banda Aceh City were developed on low-lying land and not providing higher ground for evacuation was a major factor that amplified the damage. The west coastal area also suffered severe damage with tsunami heights of approximately 15 - 30 m (Amri & Giyarsih, 2022).

While on March 11, 2011, the Great East Japan Earthquake and Tōhoku Tsunami occurred with a magnitude of 9.0 and resulted in approximately 15,800 fatalities, 6,100 injured, 2,500 missing, and 220,000 displaced (Strusińska-Correia, 2017). Kesennuma Region in Miyagi Prefecture and Rikuzentakata and Ofunato Regions in Iwate Prefecture were the most severely affected areas (Sambah & Miura, 2016). The area affected by the Tōhoku Tsunami can be seen in Figure 2.

According to Strusińska-Correia, (2017),several factors contribute to the intensification of this catastrophic disaster, including: (i) poor evacuation response of citizens due to natural disasters, false sense of security provided by coastal protection structures, partial ignorance of tsunami warnings issued and underestimation of tsunami-related hazards, and (ii) failure of structural countermeasures, which are designed to withstand the impact of much weaker tsunamis. This review aims to look at the policy and regional development undertaken in terms of disaster mitigation in Aceh and Japan.

Literature Review

Tsunamis are natural disasters caused by major disturbances on the ocean floor, such as undersea earthquakes, submarine volcanic eruptions, marine landslides, or external factors such as asteroid collisions at sea (Sugandhi et al., 2023). These disturbances trigger massive shifts in the mass of water in the ocean, resulting in huge waves that propagate at high speed across the ocean and eventually reach the shore (Behrens et al., 2021). When tsunami waves reach shallow waters near the coast, the initially flat and long waves suddenly become taller and can cause massive flooding in coastal areas. Tsunamis have tremendous energy and can cause significant damage to coastal infrastructure, homes and the environment. The speed, height and strength of tsunami waves can have devastating impacts and often result in loss of life and major economic losses (Susilorini et al., 2021). In order to reduce their impact, it is important to have an effective early warning system and proper disaster mitigation planning, so that people living in areas at risk of tsunamis can take measures to save themselves when an early warning is given (Horspool et al., 2014).

Policy and regional development play an important role in tsunami disaster mitigation. Efforts to reduce the impact of tsunami disasters involve a range of actions including planning, regulation, public education, early warning and resilient infrastructure. The following is an overview of policy and regional development in tsunami disaster mitigation:

1) Preparation of Spatial Plans and Coastal Zoning: The government needs to develop spatial plans that take tsunami disaster risk into account. This involves coastal zoning that limits the types of activities and developments in high-risk areas. Construction of residences, businesses and other infrastructure should consider safe locations and elevations from the shoreline (Latue & Rakuasa, 2022).

2) Building and Construction Regulations: Policies governing construction and building standards in coastal areas are essential. Buildings should be designed to withstand the forces and pressures generated by tsunami waves. The use of strong materials and appropriate construction methods can help reduce damage (Rakuasa & Mehdila, 2023).
3) Early Warning System and Public Education: Rapid notification to the public of a potential tsunami is key. Effective early warning systems, such as sirens, text messages and warning systems through social media, should be developed and integrated with good evacuation plans. Public education on warning signs and evacuation measures is also important. (Rakuasa et al., 2022)
4) Coastal Defense Infrastructure Development: The development of coastal defense infrastructure, such as dikes, protective walls and water parks, can help reduce the impact of tsunami waves on densely populated coastal areas. This infrastructure should be designed and constructed taking into account the characteristics of the area and potential threats (Rakuasa & Lasaiba, 2023).
5) International Cooperation and Scientific Research: International cooperation in terms of data, research and technology exchange is important in understanding and addressing tsunami threats more effectively. Scientific research on tsunami behavior and mitigation should also be enhanced (Pakniany et al., 2022).
6) Simulation Model Development: The development of computer simulation models to predict tsunami impacts and identify vulnerable areas can help in mitigation planning. The data and information obtained from these models can help in decision-making.
7) Capacity Building and Training: Capacity building of disaster management officers and evacuation personnel is essential. Training on emergency response, evacuation and first aid measures should be provided regularly.
8) Integration of Mitigation in Sustainable Development: Tsunami disaster mitigation efforts should be integrated into the sustainable development plans of coastal areas. This includes considering the impacts of climate change and sea level rise in long-term planning (Rakuasa & Salakory, 2022; Latue & Latue, 2023)

In order to reduce tsunami disaster risk, cross-sectoral cooperation, community participation and appropriate policy implementation are essential. Sustained efforts in tsunami disaster mitigation can help protect lives, property and the environment in coastal areas.

Research Method

The method used in this review is a comparative descriptive study with a qualitative approach using secondary data from relevant sources, such as articles (national and international), news portals, and relevant institutions. Aceh Province in Indonesia and Miyagi and Iwate Prefectures in Japan have experienced major earthquakes and tsunamis that resulted in loss of life and infrastructure damage. This review will describe policies and regional development in disaster mitigation after the Aceh Tsunami (2004) and Tōhoku Tsunami (2011) occurred.

Aceh Province, specifically the city of Banda Aceh, has now recovered and prepared itself as a disaster-prepared area (Figure 3). Various policies related to disaster mitigation have been made and this certainly affects the development of the region. As a city that has just recovered from the 2004 earthquake and tsunami, Banda Aceh City still has a lot of homework to do, starting from the application of the concept of disaster risk reduction to the realization of a resilient and sustainable city (UPTB GIS- Banda Aceh, 2017).

Figure 3. Satellite Images of the Banda Aceh Municipality Damaged in 2004 and Recovered in 2012 (UPTB GIS- Banda Aceh, 2017)

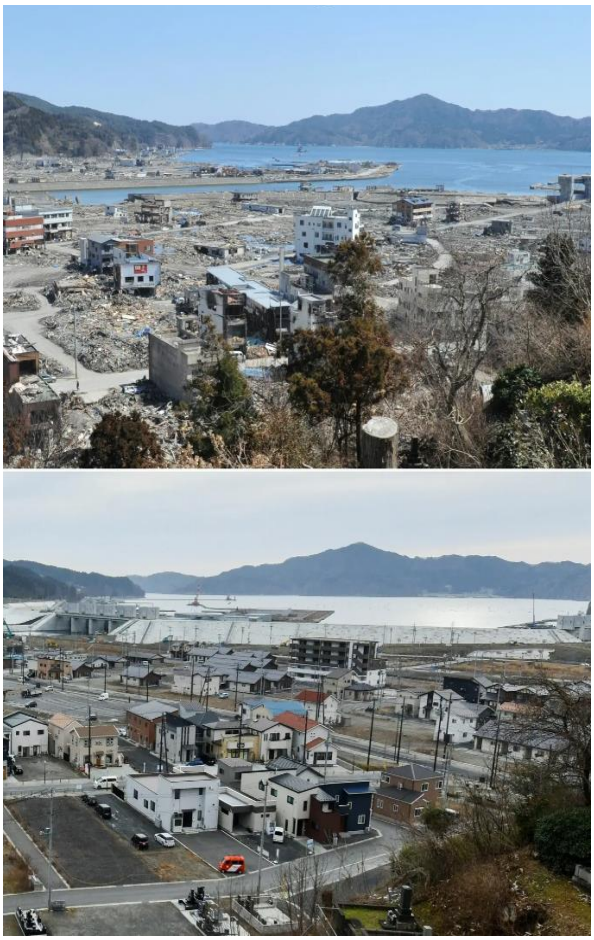


Figure 4. The combination photo shows the damage (top) caused by the March 11, 2011 tsunami seen from a hill overlooking Otsuchi city, Iwate prefecture on April 6, 2011 and the same area (bottom) almost 10 years later on January 28, 2021 (Barak, 2021).

Elsewhere, Japan also experienced similar conditions. The earthquake and tsunami caused Iwate and Miyagi Prefectures to lose most of their population and severely damaged infrastructure, and Japan is now recovering (Figure 4). Japan has implemented multiple

systems in disaster risk reduction efforts, ranging from early warning systems, the construction of 400 kilometers of sea walls, coastal forests, waterways, and the establishment of safe zones for residents. This multi-system implementation proved to be effective in that the number of casualties was significantly reduced when the tsunami struck in 2011. From the potential death toll at that time, which was predicted in the disaster scenario to be around 200,000 people, it could be reduced to 20,000 people (Fuady et al., 2021). Since 1896 after the Great Meiji Sanriku Tsunami occurred until today, Japan has continued to develop disaster mitigation in its territory.

From the review of these two regions, an overview of disaster mitigation that has been carried out in each region will be obtained. Given that Aceh and several cities in Japan have the same disaster potential, the process of learning and sharing best practices in disaster mitigation will be mutually beneficial. This review is also expected to be a reference for better disaster mitigation planning for other areas that have similar potential.

Results and Discussion

The cities of Banda Aceh and Meulaboh were two areas that were severely damaged by the tsunami that hit Aceh in 2004. Spatial planning plays an important role in the rehabilitation and reconstruction process after such a major disaster. Two documents were examined to look at the spatial planning of Banda Aceh City (Dafrina & Susilo, 2019). Further comparison of the RTRW of Banda Aceh City based on the Qanun (Regional Regulation) issued can be seen in Table 1.

Table 1. Comparison of RTRW of Banda Aceh City based on Qanun (Regional Regulation) issued (Syamsidik & Arief, 2015)

Aspect Review	Qanun No. 3 Year 2003 (Before Tsunami)	Qanun No. 4 Year 2009 (After Tsunami)
Number of City Centers (CBD)	I (BWK City Center)	(2 PK)
Number of sub-CBD and Neighborhood Centers	3 Sub- BWK)	2 Sub-CBD (Sub PK) and 9 Neighborhood Centers
Tsunami Disaster Concept	None	Available
Evacuation Route	None	Existing, included in the spatial structure
Green Belt Designation	None	Available
The types of disasters mentioned	Abrasion and Floods	Tidal waves, floods and tsunamis
Population and density estimates at the end of the RTRW validity period	307,695 people with a population density of 31-100 people/km2 at the end of 2010	482,131 people with a density of 78 people/km2 for the end of 2029

Policies related to disaster mitigation have been implemented. The concept of disaster mitigation is more directed towards three types of disasters, namely tidal waves, floods and tsunamis, while there is no specific direction based on earthquakes. Qanun No. 4/2009 mentions the development of mangrove forests along the coast with a width criterion of at least

130 times the average tidal range. The tidal range on the coast of Banda Aceh is 1.5 m, so there should be about 195 m of mangrove forest along the coast. However, in reality there is no significant thickness of mangrove trees along the coastal area. In fact, in some places they have been cut down due to the development of coastal areas for fishing port infrastructure.

In addition, population control in relation to tsunami disaster mitigation is mentioned in Article 18 Paragraph 2 of Qanun No. 4 of 2009, which states that areas at risk of tsunami disaster need to be limited in population distribution and density. This paragraph is quite dilemmatic considering that the definition of tsunami disaster risk is shared by the entire administrative area of Banda Aceh City. At this stage it appears that the concept of tsunami disaster risk is not sufficiently elaborated and gives it a biased meaning. Restrictions on population distribution and density are also missing and not definitively stated. In other parts of the qanun, it is mentioned that high-density residential areas are directed to coastal areas north of Banda Aceh city, such as in Gampong Ulee Pata, Lamkuwueh, Asoe Nanggroe, Lamjabat, Ulee Lheue, Blang Oi, and Alue Naga. Therefore, the control of population density in this RTRW is not very clear. More detailed technical guidelines governing population density control mechanisms are not yet available. On the other hand, the population in the coastal areas of Banda Aceh City shows an upward trend over time (Figure 5).

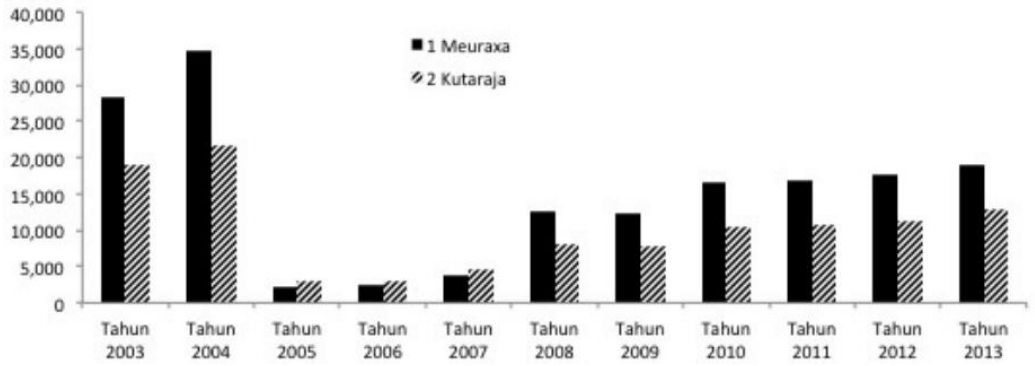


Figure 5. Population Development in Meuraxa Subdistrict and Kutaraja Subdistrict (Syamsidik & Arief, 2015)

Meuraxa and Kutaraja sub-districts had high coastal populations before the 2004 tsunami. Then, these two sub-districts were classified as destroyed by the tsunami (Ibrahim et al., 2023). However, these two sub-districts again experienced an increase in population every year after the tsunami occurred. Furthermore, the spatial planning of Meulaboh City in the West Aceh District RTRW after the tsunami was revised and a new Qanun No. 1 of 2013 was issued, which is planned to be a reference for the spatial planning of West Aceh District from 2012 to 2032. In this RTRW, 10 roads have been designated as evacuation routes and 8 locations as evacuation sites for tsunami disasters. However, these evacuation facilities have not estimated the shortest time of arrival of tsunami waves based on various tsunami scenarios, which is around 35 minutes (Syamsidik et al., 2015).

In addition to tsunami hazards, the RTRW of West Aceh District also manages other disasters, namely floods and residential fires. However, similar to the city of Banda Aceh, West Aceh District does not specify the control of coastal settlements and there is no definitive direction on tsunami mitigation using the green belt concept. The absence of directives to

control population growth and settlement in coastal areas has an effect on population growth in coastal areas. Based on population data in sub-districts directly adjacent to the Indian Ocean, there is a trend of increasing population over time, especially in Johan Pahlawan sub-district where Meulaboh City is located.

In terms of spatial planning, there are two major challenges faced by Aceh during post-tsunami rehabilitation and reconstruction (Syamsidik dan Arief, 2015), namely (i) reorganizing the coastal area with a focus on mitigating future tsunami disasters, (ii) finding the right formula for relocating coastal residents that can answer the aspirations of the community, land availability, and reduce the risk of future tsunami disasters. Efforts to reorganize coastal areas have actually been initiated by the Aceh-Nias Rehabilitation and Reconstruction Agency (BRR Aceh-Nias) by introducing the concept of green belts where initially it was determined that the zone within 500 meters of the coastline would not be allowed to rebuild settlements (Meilianda et al., 2019). However, in the end, this concept ended up failing in many places. Eleven years of rehabilitation and reconstruction in Aceh eventually saw a number of settlements spring up in the same areas around the tsunami-affected coast, such as in the cities of Banda Aceh, Aceh Besar, Aceh Jaya and Aceh Barat. However, best-practices were also found in several locations, such as Neuheun in Aceh Besar, Gampong Padang Seuraheet in Aceh Barat, and the relocation of Pulo Raya residents in Aceh Jaya. All three locations were successfully relocated to areas relatively far from the coastline.

Regional Policy and Development in Japan

Until March 11, 2011, Japan was regarded worldwide as a model country in the field of tsunami preparedness and resilience. A comprehensive tsunami defense system, including structural and non-structural tsunami barriers, emergency management supported by early warning systems, and the concept of tsunami-resistant cities, has been developed over many years, starting after the Great Meiji Sanriku Tsunami in 1896, and is based on local tsunami and teletsunami events experienced.

After the Great East Japan Earthquake (Tōhoku Tsunami) in 2011 occurred, the Japanese Government established two bodies that are planned to be carried out within 10 years and are cooperation between the central government and local governments at the prefectural and municipal levels: (i) the Reconstruction Design Council in June 2011, serving as an advisory body that proposed two recovery visions "Seven principles for a reconstruction framework" and "Toward reconstruction - hope beyond disaster", and (ii) the Reconstruction Agency in February 2013 that is responsible for planning, coordinating, and implementing reconstruction in accordance with two guidelines issued by the government: "Basic measures in reconstruction in response to the Great East Japan Earthquake" and "Basic guidelines for reconstruction in response to the Great East Japan Earthquake" (Strusińska-Correia, 2017).

In December 2011, the Local Development Law for Tsunami Disaster Prevention was also issued. This means that a legal framework was established that allows the establishment of tsunami warning zones and the formation of plans to promote community development for tsunami damage mitigation based on new flood level estimates made by each prefecture in consideration of the Tōhoku Tsunami (Ogata, 2016).

The Tōhoku tsunami made the Japanese government realize the importance of preparing evacuation plans based on the worst possible flooding (Strusińska-Correia, 2017). Hazard maps based on new flood zones were calculated, created and published to the population. Tsunami alarms caused by large earthquakes and evacuation drills were improved to make them more practical. In addition, the policy for improving evacuation facilities was reviewed. The basic policy for evacuation during a tsunami is to evacuate outside flood areas or high places before the tsunami hits land. In areas that are difficult to follow, emergency and temporary evacuation sites should be secured by establishing evacuation buildings (Sugawara, 2021).

The MLIT Municipal Bureau presented basic urban development policies to facilitate evacuation from tsunamis in Policies for the Development of Tsunami-Resistant Urban Development Plans (June 2013). In this document, the Bureau identifies areas that are difficult to evacuate, estimates the number of people who will have difficulty evacuating, and then indicates procedures for studying the necessary measures, including the designation of tsunami evacuation buildings and securing evacuation routes (Ogata, 2016).

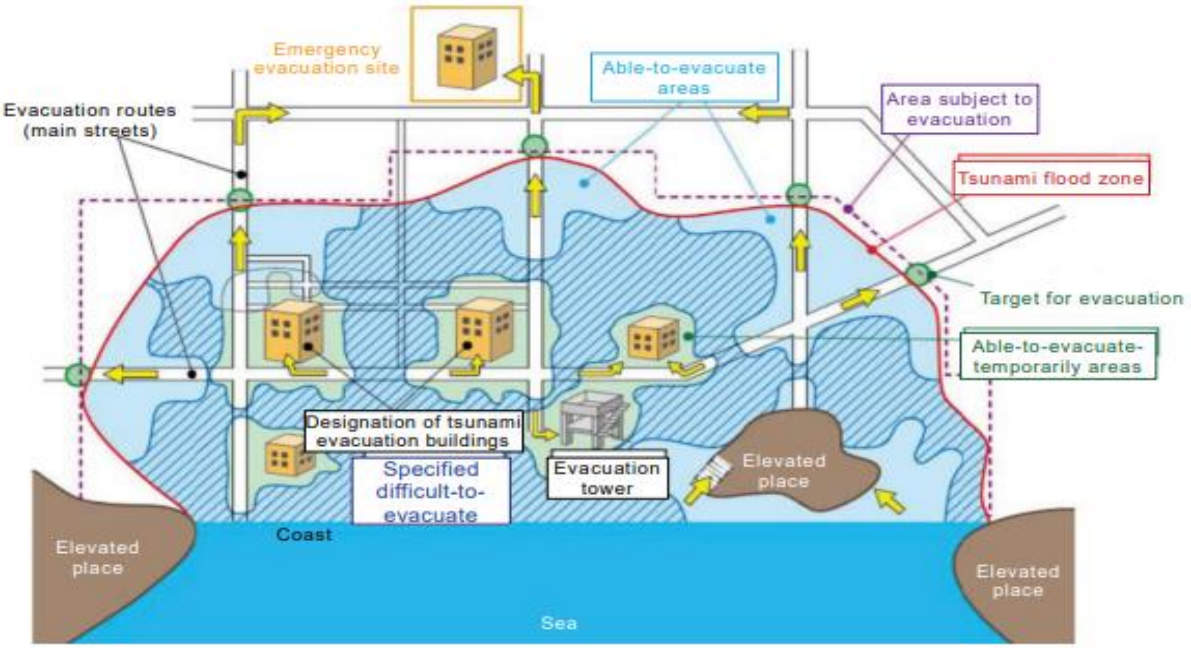
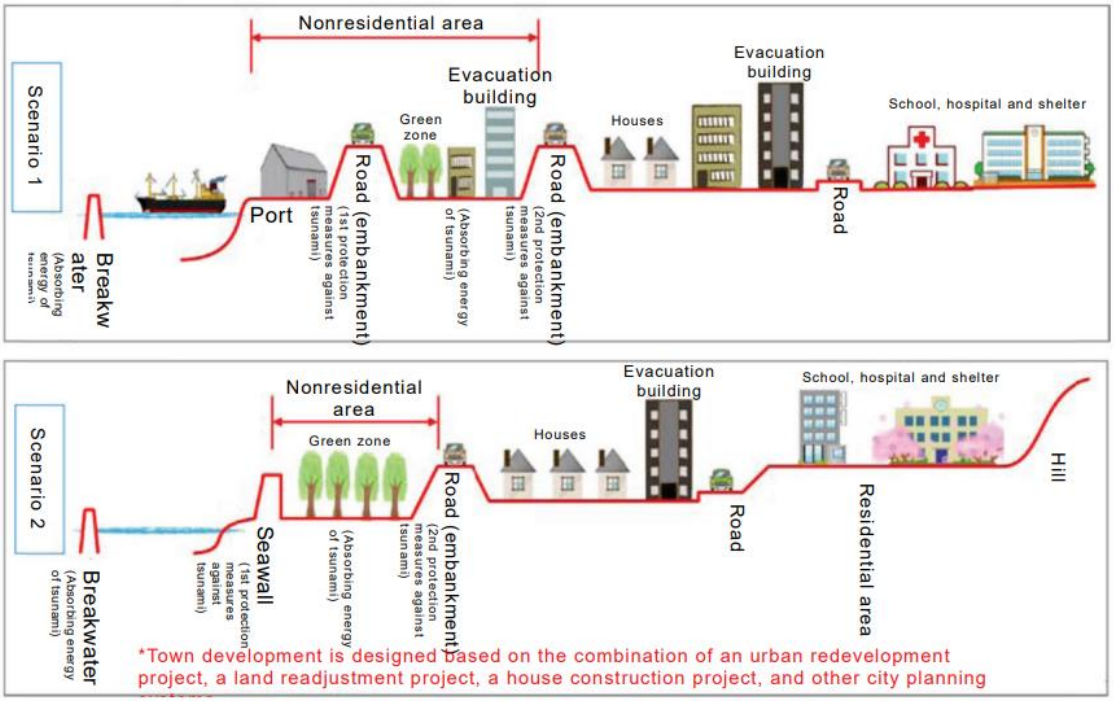


Figure 6. Fundamental Urban Development Policy to Facilitate Evacuation from Tsunami (Ogata, 2016)

Figure 7. Re-examination of Evacuation Sites and Routes in Minami City, Tokushima Prefecture (Ogata, 2016)

Another thing related to evacuation, the Japanese government conducts meetings with residents through workshops. It is important to reflect the opinions of residents who are evacuees and form consensus with them when obstacles to evacuation routes need to be identified and measures, including improvements to tsunami evacuation facilities, need to be implemented. In Minami City, Tokushima Prefecture, for example, when evacuation sites and routes needed to be re-examined based on tsunami flood zones published by the prefecture, meetings with residents were held in each district to explain policies, exchange opinions between residents and local governments, to identify problems and necessary measures for evacuation sites and routes (Figure 7).

In addition, the Japanese Government also conducted restoration and created 2 scenarios (Figure 8). However, it is not easy for existing municipalities to strongly promote such policies with only a few exceptions, such as Kushimoto City, Wakayama Prefecture, where residents voluntarily move to high places with low flood risk. So that disaster mitigation facilities, such as municipal offices, fire departments and hospitals, also do not lose their functions in responding to disasters, they are moved to higher ground.



Gigure 8. Visualization of the restoration plan for Ishinomaki City, Miyagi Prefecture (Ogata, 2016)

The creation of sea walls is also being done by developing new construction technologies of tsunami-resistant and durable sea walls (Figure 9). The slope and crown cover should consist of finer and thicker concrete blocks equipped with notches for better locking, which will prevent the units from being washed away by the tsunami impact. The armor units to be used have a thickness of 50 cm and a mass of 2 tons. Greater soil and foundation improvements are required at the toe radius of the seaward embankment to protect it from scouring. As of May 2016, 27 prefectures have established estimated tsunami flood zones according to the Local Development Law for Tsunami Disaster Prevention, 4 prefectures have established tsunami

warning zones, and 6 municipalities have developed Plans for Promoting Tsunami-Resistant Local Development. As for evacuation by car, the Expert Panel of the Central Disaster Prevention Council reported that it still supports evacuation by foot in case of flooding because there is a risk of road blockage due to collapsed houses, falling objects, uneven surfaces as well as congestion, and traffic accidents. However, it was also reported that it should be discussed in light of the actual conditions of each region.

Figure 9. Complete Section of 7.2m High Sea Wall TP (Tokyo Peil) in Iwanuma, Miyagi Prefecture (Strusińska-Correia, 2017)

The research on Policy Review and Regional Development in Disaster Mitigation with Case Studies of the 2004 Aceh Tsunami and the 2011 Tōhoku Tsunami has a number of significant benefits in the context of disaster mitigation and regional development. Here are some of the key benefits of the research:

1. Development of More Effective Policies: This research helps identify weaknesses and strengths in existing policies and regional development in the face of disasters. By understanding the failures and successes of the case studies, governments and other stakeholders can take steps to improve and strengthen policies that are more effective in reducing disaster risks in the future.
2. Improved Early Warning System: From this research, various aspects of the early warning system for disasters such as tsunamis need to be improved. These include expanding the range of warnings, increasing the speed of warnings and providing more effective means to convey warnings to communities. This helps to reduce the level of loss of life and property damage due to disasters.
3. More Sustainable Regional and Environmental Management: This research highlights the need for more thoughtful management of the region and environment in the face of disasters. By considering disaster risk factors and potential hazards in regional planning, development can be more sustainable and reduce negative impacts on the environment.
4. Improved Community Response to Disaster Threats: The Aceh and Tōhoku tsunami case studies taught communities about the importance of preparedness and rapid response when facing disasters. The research helped raise people's awareness of potential disaster hazards and educated them on actions to take to protect themselves and others.
5. Lessons from Past Experience: This research provides valuable lessons from past disasters. The experiences from Aceh and Tōhoku serve as a reference to understand how such

disasters developed, how communities reacted, and what did and did not work in disaster management. These lessons serve as a basis for strengthening mitigation and preparation strategies in the future.

6. Improved Collaboration and Coordination: The research also raised awareness of the importance of good collaboration and coordination between the government, aid agencies, NGOs and communities. The involvement of all these parties is key to improving emergency response and post-disaster recovery more effectively.
7. Contribution to Scientific Knowledge: This research contributes to scientific knowledge on disaster mitigation and regional development. The results can be used as a reference and source of knowledge for researchers, academics and practitioners in the field of disaster and regional development.

Overall, the research on policy review and regional development in disaster mitigation with case studies of the 2004 Aceh Tsunami and the 2011 Tōhoku Tsunami provides valuable insights to improve preparedness and response to future disasters. By understanding lessons from the past, communities and governments can work together to create a safer and more sustainable environment for everyone.

Conclusion

Policies related to disaster mitigation in Aceh show that tsunamis were never considered in urban planning before the 2004 Aceh Tsunami, while Japan had been developing them for many years, starting after the Great Meiji Sanriku Tsunami of 1896. The reconstruction process in Aceh after the 2004 tsunami saw some fundamental changes in spatial planning. Key features included the inclusion of urban evacuation in the transportation network as well as the establishment of safe spots. However, when compared to Japan's reconstruction process after the 2011 tsunami, Aceh does not have a clear concept of tsunami mitigation in its coastal areas. The Tōhoku region that was rebuilt after the 2011 tsunami had a number of physical constructions built in anticipation of the tsunami, namely the construction of sea walls. This was not the case in Aceh. However, the hard structures approach adopted in Japan is not the only way to mitigate tsunamis. The arrangement of coastal areas with soft structures, such as the establishment of green belts, can be an alternative to tsunami disaster mitigation if implemented properly.

The disaster mitigation policies that have been developed have also not been consistently and optimally implemented even though these efforts are mentioned in the current RTRW in Aceh. Japan, on the other hand, is considered worldwide as a model country in tsunami preparedness and resilience. This can be a lesson learned for other countries, including Indonesia. Disaster mitigation needs to be carried out through good cooperation between the government, communities, stakeholders, the private sector and philanthropy. Disaster literacy also needs to be done to increase disaster awareness.

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