Disaster mitigation in Indonesia: between plans and reality

M Fuady¹,*, R Munadi², M A K Fuady¹
¹Department of Architecture and Planning, Faculty of Engineering, Universitas Syiah Kuala, Indonesia
²Department of Electrical Engineering, Faculty of Engineering, Universitas Syiah Kuala, Indonesia

*E-mail: mirzafuady@unsyiah.ac.id

Abstract. Indonesia is one of the most vulnerable countries in the risk of natural disasters from the standpoint of geography, geology, climatology and demography. The geographical position of Indonesia is located at the confluence of 3 main tectonic plates and includes the Pacific Ring of Fire, and has more than 500 volcanoes, of which about 128 are still active. Some of the disasters that caused severe damage, large casualties and high losses included the earthquake and tsunami in Aceh (2004), the earthquake in Yogyakarta (2006), the earthquake in Padang (2009), the earthquake in Lombok (2018) and earthquake, tsunami and liquefaction disasters in Palu (2018). For this reason, it has become a necessity for the Indonesian people to learn from this disastrous experience of disaster by identifying all aspects related to risk and vulnerability to improve the ability of communities to cope with disasters. This study, which is based on the results of a study of a number of disaster studies, seeks to revisit several disaster events in Indonesia with a special review of the concept of disaster mitigation and its application to minimize disaster risk in urban areas. The results of the study show that the concept of disaster mitigation has been planned in several cities in Indonesia but there are still weaknesses in its application when a disaster occurs. This result is expected to be one of the references in improving the quality of urban disaster mitigation planning in Indonesia.

1. Introduction

From the documentation of the National Disaster Management Agency (BNPB) it is known that 2,564 disasters have occurred throughout 2018. The disasters that occurred in Indonesia throughout 2018 have caused the death of 3,349 people. This amount is still lower than in 2017 which reached 2,862 disasters [1]. However, the impact of the disaster in 2018 was greater and claimed more lives than the previous year.

There are 11 earthquakes with magnitudes above 7 on the Richter Scale (SR) that have rocked Indonesia in the last 15 years. In addition to the death toll, there were also 21,064 people injured, 1,432 people missing and as many as 10.2 million people displaced by the disaster. Three major disasters in 2018 that occurred in several parts of Indonesia with the emergence of large numbers of casualties were (a) successive earth shaking which occurred in West Nusa Tenggara; (b) earthquake, tsunami and liquefaction in Central Sulawesi; and (c) tsunamis in the Sunda Strait due to underwater avalanches and eruptions of Mount Anak Krakatau. Figure 1 is the diagram of the number of disaster events in Indonesia and the large earthquakes that have occurred in the last 15 years [2].
In 2004, several districts and cities in Aceh were severely damaged by earthquake with accompanied by tsunami. Victims who died from the biggest earthquake in Indonesia in the last few decades claimed more than 160,000 lives. The earthquake also caused tsunami in Thailand and even in Sri Lanka. One year later, the Nias archipelago had a turn to be shaken by earthquake with magnitude 8.7 SR. Most of the earthquakes that hit Indonesia have the potential to cause tsunami, but only a few really did have tsunami. It is summarized in Figure 2.

Figure 2. Earthquake Disaster in Indonesia in 2004-2018 with a magnitude above 7 SR.

The 2004 Aceh earthquake was the largest in Indonesia with magnitude of 9.3 on the Richter Scale (RS) and had the worst impact in the last 15 years. After that Indonesia seems to continue to shake and it was not long before Situbondo, East Java, was hit by earthquake with magnitude 6.4 SR. Still fresh
in memory, on September 28, 2018, Palu and Donggala were rocked by an earthquake with a magnitude of 7.4 SR that was accompanied by tsunami. More than 2,000 people died as a result of the disaster. Still in the same year, Lombok was also hit by an earthquake with a magnitude of 6.9 SR [2]. From the factual explanation above, it is realized that disaster as a series of events that threaten and disrupt human life, has become a familiar phenomenon that is known by the people of Indonesia. For this reason, the government has also prepared various regulations and policies in disaster management as stated in Law No. 24 of 2007 concerning Disaster Management. Disaster management mandated in the law contains activities such as prevention, mitigation, preparedness, early warning, emergency response, rehabilitation, and reconstruction [3]. All of these activities are carried out in a series of holistic-continuous work with a framework for the success of development.

However, because this disaster management policy is included in the imperative policy model, namely centralized social policy, where all social objectives, types, sources, and number of social services, all have been determined. So often the role of development planning is mostly carried out by the government and feels foreign in its application in the community. Although various efforts to disseminate information and disaster education continue to be improved, there are still some weaknesses in the implementation of disaster mitigation plans that must be improved. For this reason, research is conducted on the implementation of disaster mitigation plans to determine the reality of the implementation of the plan in the community. The study based on the results of a number of studies on disasters in several cities in Indonesia seeks to re-express disaster events in Indonesia with a special review of the concept of disaster mitigation and its application in urban areas. The results of the study show that the concept of disaster mitigation has been planned in several cities in Indonesia but there are still weaknesses in its application when disaster occurs. The benefits and contributions of this research can be one of the references in improving the quality of urban disaster mitigation planning in Indonesia.

2. Literature review

As an archipelagic country, Indonesia is formed by the interaction of the complex earth's main plates, namely the Indo-Australian Plate, the Eurasian Plate and the Pacific Plate. From the south side the Indo-Australian Plate moves north at a speed of 6-7cm / year pounding the stable Eurasian Plate along the Sunda Trench. While the Pacific Plate from the east side, pounding eastern Indonesia along the Trench of New Guinea-Pacific with speeds up to 11cm / year. The interaction between the earth plates results in the formation of faults of the earth's crust or faults either in the sea (Mentawai Fault in Sumatra; Sula-Sorong Fault in Maluku-Papua; Flores Fault north of Flores) or on land (Sumatra Fault; Cimandiri-Baribis Fault and Opak fractures, on Java Island, Palu-Koro Fault, in Sulawesi and Sorong Fault and Tarera-Aiduna, in Papua) as displayed by Figure 3 [4].

![Figure 3](image.png)

**Figure 3.** Map of earth's main plates position in Indonesia [4].
Places where the plates interact, along the trough and fractures of the earth's crust, are the source of earthquakes, both on land and at sea. If the earthquake occurs under the sea, it can trigger a tsunami if the epicenter is relatively shallow (<65Km) with an earthquake strength of more than 6.5 SR. As a result of the underwater earthquake that occurs due to the shift of the plate, especially along the subduction zone of the plate or fault, it can generate tsunami. Therefore, several Indonesian waters have the potential to be hit by tsunamis such as the west coast of Sumatra, southern Java, the west coast of Sulawesi, Gorontalo bay, northern part of North Sulawesi, the west coast of Sangihe-Talaud archipelago, west coast, north and east Halmahera and in the northern Papua. Figure 4 shows the coastal areas that have the potential to be hit by the tsunami in Indonesia.

![Figure 4. The coastal areas that have the potential to be hit by the tsunami in Indonesia [4].](image)

Earthquakes are geological phenomena in the form of vibrations on the surface of the earth due to collisions of tectonic plates, or in the form of volcanic eruptions that cause material eruptions or melt magma. These earthquakes are known as tectonic earthquakes and volcanic earthquakes. Both of these earthquakes often cause harm to humans, both in the form of property victims or fatalities, so it can be a disaster for humans. In Indonesia there are 7000 earthquakes per year, including 50-60 times the earthquake that can be directly felt by humans. The biggest problem with the earthquake is that humans with their knowledge and technology to date have not been able to predict when an earthquake will occur [5].

A number of earthquake parameters can be measured and examined, then from recorded earthquake data will be analyzed for the return period of the earthquake. This return period is usually in multiples of 50 years. However, this calculation is especially for large earthquakes, such as those that occurred in Aceh in 2004. For small earthquakes almost every day occurs. The facts mentioned above provide an overview of a potential disaster. Disaster victims usually occur as a result of secondary impacts, namely from the collapse of buildings and landslides of slopes that afflict buildings and vehicles. So the most important thing about earthquake evaluation is disaster mitigation, and not the period of the earthquake that will occur.

Disaster mitigation can be interpreted as an effort to review the condition of disaster-prone areas, so that the potential for disasters and vulnerability of the region can be evaluated. Re-examination of an area may start from the distribution of earthquake areas such as dividing Indonesia into 6 earthquake regions. This division is based on the distribution of recorded tectonic earthquakes, starting from region 1, the lowest seismic region, to region 6, the highest seismic region. The division of the earthquake area above is mainly based on the distance of the region to the epicenter.

Large earthquakes can cause tsunamis, which are sudden movements of water caused by changes in sea level. These changes are caused by three main sources, namely tectonic earthquakes, volcanic eruptions, and avalanches that occur on the seabed. Tsunamis are categorized as long waves because the ratio between water depths to wavelengths is very small, so the vertical acceleration of water particles is ignored because the value is smaller than the acceleration of gravity. The vertical movement of water particles has no effect on the pressure distribution. Tsunami wavelengths can reach 240 km in open sea such as the Pacific Ocean with an average wavelength of 4600 m with wave
velocities reaching 760 km/hr. When the tsunami waves are on the high seas, the tsunami height is less than 0.4 meters and the wavelength on the high seas ranges from 10 - 500 km causing the ship sailing not to feel the tsunami [6].

3. Methodology
This research is a type of qualitative research conducted by evaluating disaster events in several regions in Indonesia and conducting a review of the implementation of disaster mitigation plans to find out the implementation of mitigation plans when a disaster occurs. This study examines two case locations, namely (a) disaster that occurred in Banda Aceh in 2004 and the application of a post-disaster mitigation plan; and (b) the disaster that occurred in Palu in 2018. The data used is disaster data from official government agencies and notes of a number of studies which are listed in the reference list.

4. Discussion

4.1 Earthquake and tsunami disasters in Aceh
After the massive earthquake that followed by tsunami on December 26, 2004, many small earthquakes still occur in Aceh for up to 15 years. Even noted, in three days there could be earthquake up to 140 times in the province of Aceh. This tectonic earthquake occurs because of the movement of the earth's plate, where Aceh is on the path of the meeting of two earth plates, namely the Indo-Australian and Eurasian plates. Aftershocks continue to occur now to stabilize the earth's plate after a strong earthquake at the end of 2004.

The major disaster that struck Indonesia on December 26, 2004, began with an earthquake measuring 9.3 Mw (magnitude) centered on the Indian Ocean, west of the island of Sumatra, Indonesia. This earthquake caused a tsunami with a height of 30 meters and resulted in 230,000 deaths in 14 countries, of which 130,000 occurred in Banda Aceh, Indonesia. As the capital city of Aceh Province, Banda Aceh City is the city with the largest population where before the tsunami there were around 239,000 people spread across 9 sub-districts [7]. The four sub-districts of Banda Aceh City are directly adjacent to the Andaman Sea and the Indian Ocean, and two of these sub-districts, namely Meuraxa and Kutaradja Sub-district, suffered severe damage due to the 2004 tsunami disaster. These two regions are also sub-districts that have a high population in the coastal area [8]. Figure 5 illustrated the before-after comparison.

The combination of the earthquake and tsunami at the end of 2004 caused the biggest human casualties and losses in the history of human life on earth to date, with the most fatalities occurring in Aceh. On that day, like a nightmare, this region was devastated by the devastating earthquake and tsunami. Hundreds of thousands of human lives floated, houses were destroyed. Road and bridge infrastructure are in ruins. It has been almost 15 years. Now, Aceh is already improving. Damaged buildings were rebuilt. However, how is the readiness of the people of Aceh to face the earthquake and tsunami after life has returned to normal [9].
Figure 5. Satellite image shows part of Aceh Province before and after Tsunami in 2004 [7].

At the beginning of Aceh's rehabilitation and reconstruction, the government made a development blueprint for Aceh after the tsunami. One recommendation, the coastal area of Aceh that was hit by the tsunami became a green belt and was forbidden to occupy. But when the government offered the community to move to a safe area from the tsunami, residents refused. Coastal residents do not want to be relocated to places far from the sea. As fishermen who go out to sea as livelihoods, they refuse to become farmers.

Finally, the government decided they could stay there. In 2007, assistance for fishermen began to arrive. Some help boats and fishing gear. Some other residents began to return to the fields, planting rice and watermelons. The fields were rehabilitated with the help of NGOs. Similarly, the houses were rebuilt with assistance from abroad. When remembering the earthquake, the minds of most of the people of Aceh returned to the 2004 tsunami. Again, the horrors of the waves would roll them up so that they could cause even panic, pale and back-minded thoughts of the 2004 disaster. But in panic, they could not think of saving themselves. For this reason, the Banda Aceh city government continues to actively prepare the psychology of the community to face disasters and not panic when saving themselves. Community psychology readiness is very important to reduce disaster risk.

This is different from the people in Simeulue District, Aceh. Residents in Simeulue are better prepared and understand the earthquake and tsunami. If a strong earthquake, women, parents and children immediately fled to high ground, while a number of young people will move to the seafront to monitor sea water. Awareness of life in areas prone to earthquakes and tsunamis has been given since babies passed songs on swings. After the 2004 tsunami, the government built around 50 units of tsunami warning sirens in all vulnerable areas in Indonesia. Of these, six are in Banda Aceh and Aceh Besar. However, most Acehnese cannot hold on to this warning system. Tsunami sirens have not been used as a benchmark, because tsunami warning sirens have had several problems. Once a tsunami siren sounded loud in June 2007 but there was no earthquake. Hearing the tsunami sirens, the people in Baitussalam and Darussalam, Aceh Besar and the people in Syiah Kuala, Banda Aceh panicked and ran away from the sea. After successfully escaping a few kilometers, it was discovered that the siren sounded itself because of a system error.

The error occurred when an earthquake with a magnitude of 8.5 SR on April 11, 2012. Although the Meteorology, Climatology and Geophysics Agency (BMKG) said the earthquake had a potential tsunami, but none of the sirens sounded, even though in each simulation, nine minutes after the earthquake occurred if potentially tsunami, the siren will ring. Of the six sirens in Aceh, at that time, it was only heard at the Aceh Governor's office. Even then it just rings after the officer turns on
manually. These various errors make the people not trust the sirens. If a strong earthquake occurs, even though the siren does not ring, residents will immediately save themselves to a high place [10].

4.2 Disasters in the city of Palu

Palu is the capital of Central Sulawesi Province as well as an economic and activity center in Central Sulawesi Province. The position of Palu City around the Palu Koro Sesar makes this city very vulnerable to the risk of earthquakes and tsunamis. As one of the cities in Indonesia that has a high level of vulnerability to tsunami hazards, several tsunamis hit Palu City, namely: (a) December 1, 1927 tsunami triggered by an earthquake at the hammer bay with a wave height reaching 15 meters which resulted in 14 deaths, 50 injuries and severe damage in Palu City, Biromaru and its surroundings; (b) Parigi tsunami earthquake May 20, 1938; (c) the Tambu earthquake and tsunami on August 14, 1968; and (d) the 1996 Tolitoli earthquake and tsunami [11].

Furthermore, on September 28, 2018, a magnitude 7.4 earthquake occurred again followed by a tsunami that hit the west coast of the northern part of Sulawesi Island. The epicenter was 26 km north of Donggala and 80 km northwest of Palu with a depth of 10 km. Earthquake shocks were felt in Donggala Regency, Palu City, Parigi Moutong Regency, Sigi Regency, Poso Regency, Tolitoli Regency, Mamuju Regency even to Samarinda City, Balikpapan City, and Makassar City. The earthquake triggered a tsunami up to 5 meters in the city of Palu.

In general, the earthquake feels strong intensity for 2-10 seconds. Taking into account the location of the epicenter and the depth of the hypocenter of the earthquake, it appears that this shallow earthquake occurred due to activity in the Palu Koro fault zone. This fault is the most active fault in Sulawesi and can also be called the most active in Indonesia with a movement of 7 cm per year. The earthquake that occurred was a type of shallow earthquake due to the Palu Koro fault activity, which was generated by deformation with the movement mechanism of the strike-slip synistral structure.

As a result of the earthquake shock, some time after the peak of the earthquake, symptoms of liquefaction occurred (liquefaction of the soil) which took a lot of casualties and material. The two most obvious places to experience this disaster are the Petobo Village and Balaroa Housing in Palu City. Balaroa is located in the middle of the Palu-Koro fault.

![Figure 6. Petobo Village Area in Palu City before and after the disaster of liquefaction in 2018][12]

When liquefaction occurs, there is an increase and decrease in land surface. Some parts collapsed 5 meters, and some parts rose to 2 meters. In Petobo, hundreds of houses are buried in black mud with a height of 3-5 meters. After the earthquake, the land in the area quickly turned to mud which immediately dragged the buildings above it, as captured in Figure 6. In Balaroa, the house collapsed, like being sucked into the ground. Reports and liquefaction recordings also emerged from the border...
of Sigi Regency with the City of Palu. Mud emerges from beneath the surface of the ground and shifts the ground to tens of meters and finally sinks the building and victims alive, as can be seen in Figure 7. According to the data, liquefaction that occurred at Balaroa Housing sank around 1,747 housing units, while in Petobo Urban Village around 744 houses were drowned [12].

![Image](image_url)

**Figure 7.** Balaroa Housing Area in Palu City before and after the disaster of liquefaction in 2018 [12].

The earthquake that occurred in Central Sulawesi was then declared potentially tsunami by the Meteorology, Climatology and Geophysics Agency (BMKG) so that a tsunami early warning was issued for the coastal areas of Donggala Regency, Palu City and part of the northern coast of Mamuju Regency. The tsunami is predicted to have a height of 0.5 - 3 meters with the arrival time in Palu City at 18.22 WITA. At 6:27 p.m. there was a 6 cm sea level rise on the coast of Mamuju Regency.

According to BNPB, this tsunami is caused by the presence of sediment in the sea which reaches 200-300 meters. The sediment has not been consolidated so strongly that when it was rocked by the earthquake there was a landslide. In other places besides Donggala, there was a local earthquake that made the tsunami not as big as in Donggala. In Palu Bay, which is closer to the epicenter, it is estimated that it first experienced a 1.5 m high tsunami. At 18.37 WITA, BMKG ended the tsunami early warning due to this earthquake.

The latest fact states that the highest tsunami point was recorded at 11.3 meters, occurring in Desa Tondo, Palu Timur, Kota Palu. While the tsunami lowest point was 2.2 meters, occurred in Mapaga Village, Donggala Regency. Both at the highest and lowest points, tsunamis hit the coast, hit settlements, to buildings and public facilities [13]. Long before this disaster occurred, the city of Palu actually had an earthquake and tsunami contingency plan document, which was planned in 2012 [13]. In this plan a scenario of a 7-magnitude earthquake with a depth of 10 km in Donggala was made, which would cause people to panic, and run up the hill. It was also stated that the estimated number of victims was 2,000 people, the bridge collapsed, roads were damaged, electricity was damaged, clean water was blocked, telecommunications was cut off, logistics was limited. It turns out that the scenario occurred on September 28, 2018.

Based on contingency plans, every year there should be a disaster simulation based on that scenario. This simulation will then be evaluated. However, the simulation was not carried out so that there was no evaluation of the contingency plan, even though contingency planning had been made at no small cost. Disaster-related policies sometimes become unpopular and avoided due to consideration of uncertainty about the arrival of disasters. Although the determination of an area in a risk map or disaster map is based on regional scientific research, there are still policy makers who do not heed it. Sometimes investment considerations are more prioritized than safety, so areas at risk can turn out to be feasible to build.
In the Palu City Spatial Plan, the area along Palu Bay is included in an area that has the potential for natural disasters. However, in the 2030 Space Pattern Plan the Palu Bay Area is dominated by Settlement Areas. The concentration of economic growth in the potential disaster area is agreed not to be used again and proposed as a protected area. Suggestions submitted are for areas included in disaster-prone areas so that the Spatial Pattern map is converted into a Protected Area section with specifications for Earthquake and Tsunami Disaster Prone Areas.

A review and revision of the Palu City Spatial Plan was carried out to anticipate the potential impact of the disaster. A review of more than 1 (one) time in 5 (five) years in major force conditions, namely, large-scale natural disasters, massive economic development in disaster-prone areas, changes in the country's territorial boundaries stipulated by legislation. Regulations need to be formulated with strict (criminal) sanctions stating that Protected Areas with Earthquake and Tsunami Hazard Prone specifications are no longer permitted as built-up areas, especially Strategic Areas of Economic Growth.

4.3 Disaster mitigation in Japan

Disaster education to the community is an important thing in minimizing disaster risk. An example is the experience of the Chilean state in educating and raising awareness of citizens of disasters. This can be seen in the declining number of deaths of 13 people in the 8.4 SR earthquake and 4.5 meter tsunami that occurred in 2015. The number of victims was very small compared to 500 deaths in the 8.8 SR earthquake five years earlier. The small number of victims is supported by the fact that the Chilean people already know how to deal with disasters thanks to the disaster knowledge that is included in the education curriculum.

In line with the Chilean state, the Japanese government also realizes the importance of disaster education for its citizens. However, when the earthquake that occurred in Honshu, Japan on March 11, 2011, it recorded a lot of damage and casualties. The earthquake was the biggest earthquake that ever happened in Japan. The Japanese disaster response system in this case looks inefficient, compared to China's experience in dealing with the 2008 Wenchuan earthquake, namely the importance of centralized strength in dealing with large-scale disasters.

In this earthquake-tsunami disaster, the Japanese government did not seem to solve many problems, especially with regard to the nuclear crisis. Coordination between the Government (emergency headquarters response), Tokyo Electric Power Company, and nuclear and industry security agencies are not organized enough. Information is not simultaneously shared after a disaster, delayed decision making. Finally, Japan, and perhaps all nuclear countries in the world, are not really ready for the nuclear crisis [14].

Experience in other countries shows that large scale disasters cannot be overcome only by local capacity but assistance from outside the affected area is indispensable. During this earthquake, the area that was damaged / affected was so extensive that local government groups for cities and prefectures became paralyzed. Not only the public sector, but also many private sectors are unable to provide services during disasters due to damaged infrastructure. These services include providing energy, food and water, and medical care.

In the future, there is a need for thorough preparation in disaster management, including: (a) Information systems. All parties need to understand hazard information all the time. This guarantee of continuous and valid information distribution is the duty of official functional institutions such as the Meteorology and Geophysics Agency. This information is also expected to be a form of early warning for the parties concerned, so that each party will be able to determine the follow-up of the information correctly; (b) Warning system. Efforts to create disaster preparedness in the public should also be equipped with an effective warning system for the community, in the sense that it is guaranteed to be obeyed by the community. Warning methods directed at safeguarding public memory should also be created as a way to stay in control of various social behaviors and create self-awareness; (c) Response mechanism. Planning disaster response mechanisms must be carefully and comprehensively established. Evacuation and SAR procedures, the condition of the affected area, the assessment team,
the mechanism of activation of the installation and special infrastructure, preparation of distribution of aid, shelter and planning for the activation of emergency programs for airports, ports and land transportation are minimal matters that must be covered in response mechanisms disaster [15].

5. Conclusion
As a disaster-prone country, Indonesia is very late in anticipating and handling the impact of disasters. This can be proven by the government's delay in issuing regulations in the form of laws that regulate disaster management in a sustainable or sustainable manner. Previously, regulations were only ad hoc so that disaster management was carried out partially and was not well coordinated according to the disaster management cycle.

However, with the presence of the disaster law, it can treat the needs of civil society who add integrated disaster management. Because, there have been several paradigm changes in disaster management, including a linear to cycle paradigm, from responsiveness to management, from caricative to empowerment, and from managing impacts to reducing risk.

With the presence of this policy, it is hoped that disaster management will be better in the future, the capacity of the community will increase, the lives of victims will recover quickly and be better, the community empowered and responsive to disasters can be achieved rather than seeing the disaster as destiny. The monitoring and evaluation efforts of all interested parties, especially the community, are very important elements related to the budget and implementation of policies for the welfare of the Indonesian people.

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