# Tsunami Disaster Preparedness in Tambakrejo Village, Sumbermanjing Wetan Distric, Malang, Indonesia

Usman, Fadly
Department of Urban and Regional Planning, Faculty of Engineering, Brawijaya University

Eddi Basuki Kurniawan
Department of Urban and Regional Planning, Faculty of Engineering, Brawijaya University

M. Fathoni
Faculty of Health Sciences, Brawijaya University

Rozikin, Moch
Faculty of Administrative Sciences, Brawijaya University

https://doi.org/10.5109/7183421

出版情報：Evergreen. 11 (2), pp.1182-1189, 2024-06. 九州大学グリーンテクノロジー研究教育センター
バージョン：

# Tsunami Disaster Preparedness in Tambakrejo Village, Sumbermanjing Wetan Distric, Malang, Indonesia

Fadly Usman[1*], Eddi Basuki Kurniawan[1], M. Fathoni[2], Moch Rozikin[3]

[1]Department of Urban and Regional Planning, Faculty of Engineering, Brawijaya University, Indonesia

[2]Faculty of Health Sciences, Brawijaya University, Indonesia

[3]Faculty of Administrative Sciences, Brawijaya University, Indonesia

E-mail: fadlypwk@ub.ac.id

(Received November 29, 2023; Revised February 24, 2024; Accepted April 17, 2024).

**Abstract**: The southern coast of Java Island, especially in the Sumbermanjing Wetan District, Malang Regency, is included in the tsunami-prone geological disaster area. Sumbermanjing Wetan District is directly adjacent to Indian Ocean where the seismic gap zone produces geological processes and high-intensity seismic activity can trigger tsunami waves along the southern coast of Java Island. Based on disaster risk assessment documents of Malang Regency in 2013-2017, Sumbermanjing Wetan District has the highest potential exposed population, compared to other Districts in Malang Regency. This research focuses on evacuation plans for coastal areas from the threat of the tsunami in the post-pandemic period. The research sub-variables are related to the analysis of temporary shelters such as building area, building type, ease of access, building construction and building capacity. Meanwhile, the evacuation routes that become sub-variables are road class, road pavement type, road quality and road width. Meanwhile, the sub variable for life in the new normal era is the implementation of health protocols while still filling the basic needs of refugees. Implementation of the health protocol in evacuation activities will have an impact on reducing the capacity of each available shelter. In this research, additional distribution of shelters took the form of using fields as temporary shelters that could optimize the implementation of health protocols. With this addition, it has an impact on the travel time from residential areas that are at risk of being affected by the tsunami to temporary shelters. There are two villages that are not served, when viewed from the travel time of about 15 minutes from the residential area to the shelter, so it is necessary to add appropriate shelters as an anticipation of the tsunami disaster.

**Keywords:** tsunami; post-pandemic period; evacuation; shelter; health protocol

## 1. Introduction

The pandemic period has had a very significant impact on all economic sectors, especially the tourism industry. Society and the government face harsh conditions, especially in economic activities limited by stringent health regulations. In these problematic pandemic conditions, the tourism sector is also faced with the risk of being affected by natural disasters. Volcanoes are at risk of eruption; hilly areas are at risk of landslides. At the same time, coastal regions risk being affected by hurricanes, tidal floods and the threat of tsunami waves. Therefore, efforts need to be made to increase preparedness, both structurally and non-structurally. The Indonesian archipelago, which stretches from west to east, is located between the world's main fault lines, such as the Indo-Australian and Eurasian faults, as well as the Indo-Pacific fault, so Indonesia's position is often referred to as the Pacific Ring of Fire[1)]. Indonesia is on three major active plates, namely the Eurasian Plate, the Indo-Australian Plate, and the Pacific Plate[2)], so both the government and society must always be alert to the risk of disasters due to shifts in the world's main plates. The natural conditions at the meeting of these plates certainly make Indonesia rich in natural products in the form of oil and other mining minerals. Still, on the other hand, Indonesia is, of course, faced with the risk of natural disasters, whether in the form of catastrophe due to tectonic or volcanic activity[3)]. Tsunami waves can come suddenly if the faults shift suddenly[4)]. The intensity of the plate movement is so high that experts say that the potential for a tsunami event is around 10 to 50 years, with a wave height of about 3 m or more[5)]. In Indonesia itself, large-scale seismic activity can occur every two years. In fact, since the early 1800s or the beginning of the 19th century, more than 50% of the world's tsunami events have occurred in Indonesia[6)]. As an archipelagic country, Indonesia has 17,504 islands with a coastline of 99,093 km, so Indonesia is called the largest archipelagic country in the world. However, several studies show that tsunami disaster mitigation efforts in coastal areas are rarely carried out[7], because Indonesia not only has the longest coastline but is also at risk of being affected by tsunami waves, most often[8]. Several studies show that more than 40% of coastal areas in Indonesia have a high level of vulnerability to tsunami waves, starting from the north of Sumatra, such as Aceh, Padang, Nias, Bengkulu, then the west of the island of Java, such as Banten, Pangandaran, Pacitan, Blitar, to Banyuwangi. Of the 273 coastal cities in Indonesia, it turns out that 150 coastal towns are at high risk of tsunami disasters.

In several decades, tsunami events in Indonesia have had an extensive impact and even entered the category of national disasters, such as the earthquake and tsunami in Flores (1992), Banyuwangi (1994), Biak (1996), Maluku (1998), Banggai (2000), Aceh (2004), and Nias (2005), Pangandaran (2006), Bengkulu (2007), Mentawai (2009), Palu (2018), and Banten (2018)[4].

The Ministry of Public Works has mapped several areas with high earthquake potential categories which have the potential to cause tsunami waves. Eight provinces on the south coast of East Java are at increased risk of tsunami disaster, including Trenggalek, Banyuwangi, Jember, Pacitan, Malang, Blitar, Lumajang and Tulungagung. The tsunami disaster that hit the south coast of East Java Province on June 2, 1994, in Lampon Village, Banyuwangi, was a massive tsunami. The tsunami wave started with an earthquake magnitude of 7.8; the earthquake point was about 3 km from Pancer Beach in Banyuwangi, which had a depth of 33 km. The tsunami also hit Lampon Village around 50 minutes after the earthquake, destroying more than 1,500 houses and causing 250 deaths and 400 injuries. The height of the Banyuwangi tsunami in Lampon Village was 5.4 m7). Measurement results at another point about one kilometre from Lampon village showed that the wave height reached 9.1m[1].

Malang Regency is ranked 31st among 273 coastal districts in Indonesia, with a disaster probability of 2.5% of tsunami disasters with wave heights of around 3 m or more. The maximum tsunami height on the coast is within the return period: 100 years, 4.7 m wave height; 500 years, 9.1 m wave height; and 2,500 years, 25.8 m wave height, and the higher the tsunami wave, the longer the return period[9].

Based on documents on the Malang District Disaster Risk Study for 2013-2017 and studies on spatial planning of Malang District, the area vulnerable to geo-tsunami disasters is the entire coast of southern Malang District. The total area at risk of tsunami in Malang is around 4.63% of the area of East Java province. The tsunami disaster in Malang Regency falls into the categories of a medium threat level, high loss rate, medium response level, and high disaster risk level.

This research aims to determine the area affected by the tsunami in Tambakrejo Village, Sumbermanjing Wetan District, Malang Regency. The research focuses on distributing potential buildings as shelters and the road network for evacuation. A study of community preparedness in Tambakrejo Village is also an essential parameter in the research[10], it can be used to consider evacuation efforts if a tsunami occurs. As a coastal tourist area, Tambakrejo Village is busy with tourists, so it is necessary to conduct an extensive study of shelter services in safe locations from the threat of tsunami waves[11].

## 2. Literature Review

Sumbermanjing Wetan District is one of the 33 districts in Malang Regency. This district is about 30 km from the capital city of Malang Regency to the southeast. The government centre is in Argotirto Village, but the economic centre is in Sumbermanjing Wetan District.

Astronomically, Sumbermanjing Wetan District is located between 112.4031 to 122.4634 East Longitude and 8.2411 to 8.1443 South Latitude. The administrative area of Sumbermanjing Wetan District consists of 15 villages, 40 sub-villages, 113 hamlets and 514 neighbourhoods. The overall area of Sumbermanjing Wetan District is around 259.25 km2 and is the largest district or approximately 8.04% of the total area of Malang Regency. The topography of most of the area is a hilly plateau with an altitude between 0-650 meters above sea level and a slope of less than 40%. The central, northern and eastern parts are valley areas, while the southernmost tip area stretches the sea, beaches, and coral islands. The villages of Sitiarjo, Tambakrejo, Tambaksari, and Sidoasli are four densely populated residential villages along the coastal area of Malang Regency. Generally, the soil condition in Sumbermanjing Wetan District is a latosol type, with most of it being greyish. This type of soil makes the soil structure in Sumbermanjing Wetan District fertile so that it is suitable for agricultural and plantation land. Residents widely use this land as rice fields of 912.81 Ha and dry land for settlements, gardens and fields of 4,872.89 Ha. The amount of land usage affects disaster vulnerability. Using rice fields, parks, and fields also influences disaster vulnerability because most villagers work in agriculture.

Earthquakes and tsunamis are tricky to handle regularly, mainly if a disaster occurs during a pandemic with strict health protocols. So, paying attention to parameters often used when disasters occur during the pandemic is deemed necessary[12][13]. When a disaster occurs during a pandemic, the community will face two simultaneous disasters, namely the natural disaster itself and strict regulations during the pandemic. The government needs to organize society to minimize loss of life after natural disasters and survive the spread of disease during a pandemic[14,15]. Figure 1 shows an analysis of tsunami evacuation in the new normal era. Of course, people's behaviour and activities will be very different, especially regarding preparedness and emergency response activities[16]. This research uses GIS to delineate the affected areas when a tsunami occurs. The extent of shelter service coverage is the leading study in the research, the aim of which is to determine the travel time and extent of service coverage of each available shelter[17–19].

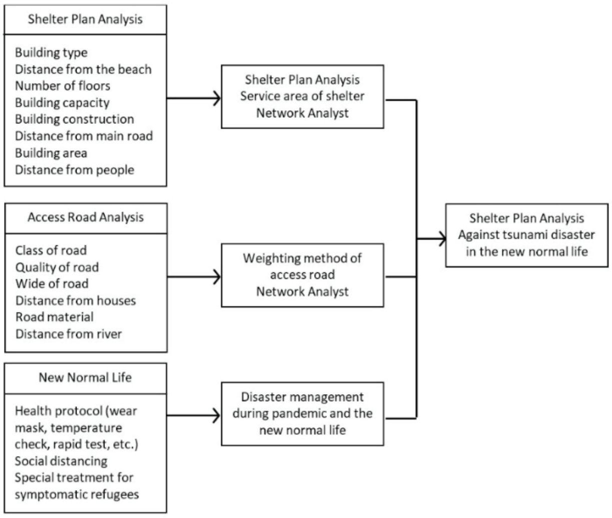


**Fig. 1:** Research flowchart

When a disaster occurs, and at the same time as a pandemic, it will impact shelter capacity due to the implementation of health protocols with applicable social distance rules. Using data analysis in a spatial format makes it easier for people to reach shelters based on the distance and travel time to reach the shelter. Shelter plan analysis assesses, selects, designs, and evaluates public buildings that may be used as shelters during disasters[17) 20)]. Calculation of classification in the analysis of temporary shelters using the scoring technique with the Sturgess method[21) 22)]. The technical approach used in this research is to assess the distribution of buildings based on the indicators in Table 1. The total scoring results from all parameters will indicate the most suitable temporary shelters so that they can eliminate buildings that are not suitable for temporary shelters[23) 24)]. Potential temporary shelters with very suitable and sufficient classifications will be chosen as temporary shelters when a disaster occurs in the new normal era.

Optimizing the use of spatial data and GIS in evacuation analysis has been described in several studies[25) 15,26)]. Figure 1 is a flowchart of the study implementation in research. The primary analysis involved deciding on evacuation centres, evaluating the feasibility of evacuation routes, and considering the implementation of new daily routine routes of evacuation[27)].

## 3. Result and Discussion

### 3.1 Temporary Evacuation Shelter

Researchers analyse potential buildings' distribution as shelters and refer to the tsunami possible area map published by the Japan Meteorological Agency[28,29)]. Several criteria are used when evaluating building such as type of building, distance to the beach, number of floors, building capacity, building structure, distance to the main road, outside the building's garden, and distance to the village[14)].

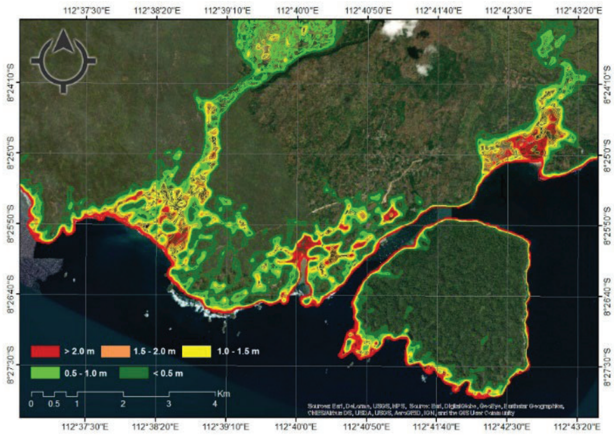


**Fig 2:** Location of Tambakrejo Village, Sumbermanjing Wetan District, Malang Regency

Table 1. Assessment of potential buildings as shelters in Tambakrejo Village

| No | Building Types | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Score |
|---|---|---|---|---|---|---|---|---|---|---|
| **1** | **Sendangbiru Flat** | 3 | 5 | 5 | 5 | 5 | 5 | 5 | 1 | **34** |
| **2** | **Tambakrejo Village Hall** | 5 | 5 | 1 | 5 | 5 | 5 | 3 | 5 | **34** |
| 3 | GPdI (Pentecostal Church in Indonesia) Nazaret | 3 | 5 | 1 | 1 | 3 | 5 | 1 | 5 | 24 |
| **4** | **GKJW (East Java Christian Church) Jemaat** | 3 | 5 | 1 | 5 | 5 | 5 | 3 | 5 | **32** |
| 5 | GKJW Sendangbiru Seru | 3 | 5 | 1 | 1 | 3 | 3 | 1 | 3 | 20 |
| 6 | GKJW Sendangbiru Kali Timbang | 3 | 5 | 1 | 1 | 3 | 5 | 1 | 5 | 24 |
| **7** | **GKJW Tambakrejo** | 3 | 5 | 1 | 3 | 5 | 3 | 5 | 5 | **30** |
| 8 | GPT (Tabernacle Pentecostal Church) Victory Tambakrejo | 3 | 5 | 1 | 1 | 3 | 5 | 1 | 3 | 21 |
| **9** | **Baiturrohman Mosque** | 5 | 5 | 3 | 3 | 5 | 5 | 3 | 5 | **34** |
| 10 | Agung Zamzam Murtaqo Mosque | 5 | 1 | 3 | 3 | 3 | 5 | 3 | 3 | 25 |
| **11** | **Al Ikhlas Mosque** | 5 | 5 | 1 | 1 | 5 | 5 | 5 | 1 | **28** |
| 12 | Miir Mosque | 5 | 3 | 1 | 1 | 5 | 5 | 1 | 3 | 24 |
| 13 | Nurul Falah Mosque | 5 | 3 | 3 | 3 | 3 | 5 | 1 | 3 | 26 |
| **14** | **Al Falah Mosque** | 5 | 1 | 3 | 5 | 5 | 5 | 5 | 5 | **34** |
| **15** | **Cheng Ho Mosque** | 5 | 5 | 1 | 5 | 5 | 5 | 5 | 1 | **32** |
| 16 | SDS TPN (Elementary School) Sendangbiru | 3 | 1 | 1 | 5 | 3 | 3 | 3 | 5 | 24 |
| 17 | Sendangbiru Health Center | 3 | 1 | 1 | 1 | 3 | 3 | 1 | 5 | 18 |
| **18** | **Baitul Muttaqin Mosque** | 5 | 5 | 1 | 5 | 5 | 5 | 5 | 1 | **32** |

**Description:**

1. Building type: public buildings (5), semi-public buildings (3), private buildings (1)
2. Distance from the beach: Far (5), medium (3) and, near (1)
3. Number of floors: more than 2 floors (5), 2 floors (3) and, 1 floor (1)
4. Building capacity: more than 200 (5), between 100-200 (3) and, less than 100 (1)
5. Construction conditions: concrete structures (5), brick walls (3) and, without concrete structures (1)
6. Distance from the main road: near (5), medium (3) and, far (1)
7. Area of the building yard: more than 1000 m2 (5), between 250 – 1000 m2 (3) and, less than 250 m2 (1)
8. Distance from settlements: near (5), medium (3) and, far (1)

As shown in Fig. 2, the green color is the boundary of the area with the potential to be inundated by a tsunami while the red color is an area at high risk of being exposed to tsunami waves with an inundation depth of more than 2 meters. The assessment is conducted based on certain criteria in accordance with the conditions of each assessment variable as previously described. Meanwhile, the values used are: 1 (low), 3 (medium) and 5 (high). For example, the distance from the coast, the farther from the coast means the farther from the reach of the tsunami waves, so the value is high or 5. Another example is the distance from residential areas, considering that the goal of a tsunami evacuation is to reach a temporary shelter immediately so that the closer with settlements, the higher the value[30) 31)].

In this study, there are 18 potential buildings consisting of schools, health centers, mosques, prayer rooms, churches, village halls, and there are also government buildings that are rented out, such as minimalist rental flats (See table 1). Buildings with high assessment scores can be recommended as temporary evacuation shelters. In this study, there are 9 buildings that have high scores, in the form of mosques, churches, village halls, and also flats[21)]. The Cheng Ho Mosque, which is synonymous with Chinese ethnic culture and after being assessed, was in the selected category. This is due to the good structure of the building, adequate yard area and easy access because it is on the main road. When a disaster occurs, a temporary evacuation site really needs a large yard. This aims to build public kitchens and provide logistical needs needed by refugees such as food, medical equipment, and others.

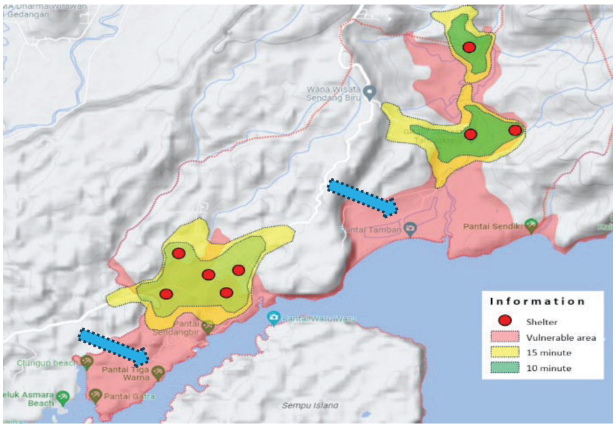


**Fig. 3:** Service area using ArcGIS network analyst

Figure 3 is a shelter service area based on the assessment in table 1 while the delineation of areas at risk of being affected or vulnerable areas (red blocks in the picture) refers to Fig. 3 and the 20 m elevation topographic terrain from Google Map. Also based on the picture above, it can be seen that the distribution of the available shelters is not sufficient enough to accommodate the affected population to the available shelters[12,32,33)]. Several shalters are located in areas that are prone to being affected by the tsunami, such as Tambakrejo Village Hall, GKJW (East Java Christian Church) Tambakrejo, GKJW Sendang Biru, Sendang Biru Flat, and Baitul Muttaqien Mosque. Tamban Village and Kampungbaru Village (blue arrow in Fig. 3) are residential areas that are in a disaster-prone zone and it takes more than 15 minutes to reach the shelter. In this study, the speed of walking time is 1 m/s so that 10 minutes will cover 900 meters and 15 minutes can cover 1200 meters.

### 3.2 Evacuation Road to Shelter

Tambakrejo Village is one of the villages located on the south coast of Java Island which was inaugurated in 1897. Most of Tambakrejo Village people work as fishermen and some as farmers. Tamabkrejo Village is divided into two hamlets, Tamban Hamlet and Sendang Biru Hamlet. Because the distance between the two hamlets was quite far, the village goverentment built offices into two sections, Tambakrejo Village Hall in Tamban Village and Sendang Biru Village Hall in Sendang Biru Village. Tamabakrejo Village is directly adjacent to Sitiarjo Village to the west, Tambaksari Village to the east, Kedung Banteng Village to the north, and the Indian Ocean to the south. The distance from the village to the capital city of Sumbermanjing Wetan District is 28.4 km and has a distance of 69 km to the capital city of Malang Regency. The area of Tambakrejo Village is 2,700 ha with a total residential area of 146 ha. Land area with a mild erosion rate of 45 ha and a moderate erosion rate of 65 ha with a slope of 15 degrees. Tambakrejo Village area consists of two parts, the area on Java Island and the area on Sempu Island. Similar to the temporary evacuation site, the evacuation route to the shelter must be considered carefully. Several important considerations in determining the evacuation route are moving the affected population as soon as possible to the evacuation site[34)]. Referring to Fig. 4 above, there are several buildings which are still in the yellow zone, which means they can still be reached by the tsunami waves. This is due to the consideration that the capacity of the building is quite large with good structural conditions and buildings that have two floors or are not buildings with one floor. Meanwhile, for other evacuation sites, they are indeed quite far from the shoreline and also quite far from settlements but still close to the main vehicle routes[35)].

There are six parameters that are taken into consideration for conducting an assessment of the observed object including the road as accessibility to the shelter. The six parameters are: (1) road class, (2) road quality, (3) road width, (4) road material, (5) distance from settlements, and (6) distance from the river. Meanwhile, the roads to be assessed are all roads in Tambakrejo Village, Malang Regency. Table 2 is an assessment of several roads in Tambakrejo Village. In contrast to the designation of buildings as temporary evacuation sites or shelters, the assessment of the road network does not aim to eliminate these road sections but to provide recommendations to the local government if it turns out that the road sections are of poor quality with limited width so they can be improved. Improving the quality of roads will certainly have an impact on the travel time when evacuating to a safe place for refugees.

Table 2. Assessment of road in Tambakrejo

| No | Road Section (Accessibility) | 1 | 2 | 3 | 4 | 5 | 6 | Score |
|---|---|---|---|---|---|---|---|---|
| 1 | JLS (Southern Route) to Blitar regency | 5 | 5 | 5 | 4 | 1 | 5 | 25 |
| 2 | JLS toLumajang regency | 5 | 5 | 5 | 4 | 1 | 5 | 25 |
| 3 | Clungup Tambakrejo | 3 | 3 | 3 | 3 | 3 | 5 | 20 |
| 4 | Tambakrejo village hall road | 2 | 3 | 3 | 3 | 5 | 3 | 19 |
| 5 | Sendangbiru village hall road | 2 | 3 | 2 | 3 | 5 | 3 | 18 |
| 6 | Sendangbiru yard street | 2 | 3 | 3 | 3 | 5 | 5 | 21 |
| 7 | Pondokrejo to Marine Station FPIK UB | 3 | 5 | 3 | 3 | 3 | 5 | 22 |
| 8 | Pondokrejo to Sitiarjo | 3 | 5 | 4 | 3 | 3 | 5 | 23 |
| 9 | Sendangbiru, Perlimaan JLS | 4 | 5 | 4 | 3 | 3 | 1 | 20 |
| 10 | Sendangbiru, Kampungbaru | 3 | 3 | 4 | 3 | 5 | 1 | 19 |
| 11 | Sendangbiru, Harbour | 3 | 3 | 3 | 3 | 3 | 1 | 16 |
| 12 | Pelabuhan road | 2 | 3 | 3 | 2 | 3 | 1 | 14 |
| 13 | Makam road | 1 | 1 | 1 | 2 | 5 | 5 | 15 |
| 14 | Kondangbajul to Sendangbiru | 3 | 3 | 3 | 3 | 5 | 5 | 22 |
| 15 | Kondangbajul to Tamban | 3 | 3 | 3 | 3 | 5 | 5 | 22 |
| 16 | Kondang Buntung beach road | 1 | 1 | 2 | 2 | 1 | 5 | 12 |
| 17 | Sendangbiru beach road | 2 | 3 | 3 | 2 | 3 | 5 | 18 |
| 18 | Tamban beach road | 2 | 3 | 3 | 2 | 3 | 5 | 18 |
| 18 | Sendiki beach road | 2 | 3 | 3 | 5 | 3 | 5 | 21 |
| 20 | Sendiki parking area beach road | 2 | 3 | 3 | 5 | 1 | 5 | 19 |

**Description:**
1. Road class: national or provincial (5), district (4), arterial (3), collector (2), and local (1)
2. Road quality: good (5), moderate (3) and, bad (1)
3. Road width: more than 12 m (5), 6-12 m (4), 4-6 m (3), 2-4 m (2) and, less than 2 meters (1)
4. Road material: concrete castings (5), smooth asphalt (4), stones with rough asphalt (3), cobbles (2), and soil (1)
5. Distance from settlements: near (5), moderate (3), and far (1)
6. Distance from the river: far (5), moderate (3), and near (1)

Poor quality roads, narrow, hollow, bumpy, will certainly become an obstacle and reduce the walking speed of the evacuees. This will certainly have an impact on the travel time for refugees from residential areas to temporary evacuation sites. Regarding the consideration of the distance from the road to the river, this refers to some literature which states that tsunami waves entering land via rivers will come faster than those passing through the coast, so this must be watched out for[36) 37)].

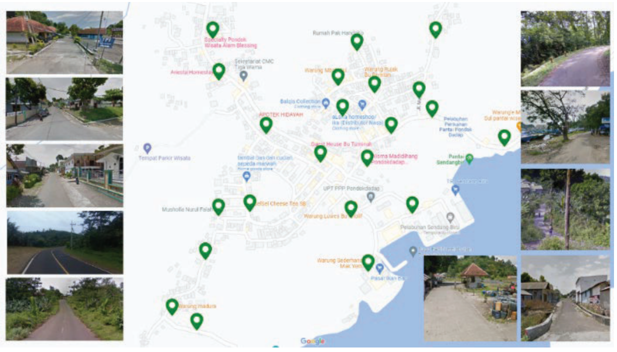

**Fig. 4:** The road network in Tambakrejo Village

In table 2, several roads have a very limited width, even less than 2 meters and this of course makes it difficult for refugees to move to a safe place. However, there are also roads with a width of more than 12 m which are national roads such as the southern causeway that connects Malang Regency with Blitar Regency to the west or with Lumajang Regency to the east. Figure 4 shown a photo mapping of the street in Tambakrejo Village.

Referring to the results of the assessment of several road sections that can be used as evacuation routes, several road sections can be used as the main road network leading to the shelter, but most of them are local level access roads and neighborhoods in densely populated residential areas. If you refer to Fig. 3 about the safe zone from the risk of being exposed to tsunami waves, the safe zone boundary has a distance of more than 1 to 2 km from the shoreline.

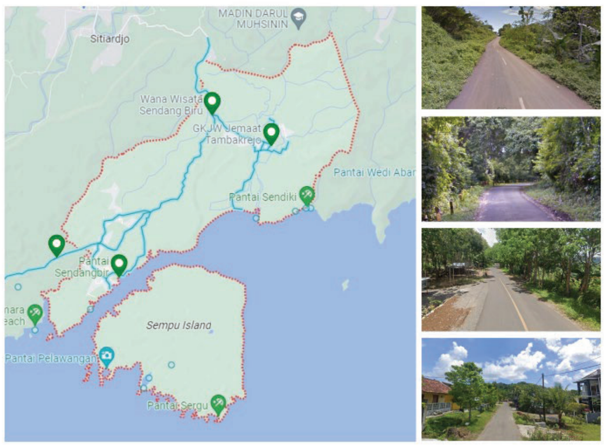


**Fig. 5:** Availability of main accessibility in Tambakrejo

It is necessary to conduct a study using a network analyst so that the distance traveled from residential areas to the shelter can be known with certainty. The farthest reach of a temporary shelter can also be calculated using geographic information system software using the network analyst extension[38)].

Figure 5 shown a photo mapping of the main evacuation routes in Tambakrejo Village. Roads with codes 1 and 3 are main roads while roads with codes 2 and 4 are roads that are in densely populated residential areas.

### 3.3 Additional Shelter Evacuation and Optimization in Post Pandemic Period

Important points in emergency response activities when a disaster occurs during a pandemic such as conducting health protocols by using masks, washing hands, checking body temperature, conducting rapid tests and antigen checks. Meanwhile, activities related to social restrictions or social distancing such as keeping a distance of 1 meter or more from other people, not crowding or in groups. Meanwhile, preventive measures related to refugees who are infected with mild, moderate and severe symptoms require special treatment according to the conditions they are experiencing. Of course, it is very different from normal conditions such as pre-pandemic conditions. During a pandemic, they put forward strict health protocols and regulations that are not simple, such as social distancing, using masks, washing hands, and so on[39].

Table 3. Field assessment as temporal shelter

| No | Building Types | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Score |
|---|---|---|---|---|---|---|---|---|---|---|
| **1** | **Sendangbiru yard** | 5 | 5 | 1 | 5 | 5 | 5 | 5 | 3 | **34** |
| **2** | **SMP (Junior High School) 4 yard** | 5 | 5 | 1 | 5 | 5 | 5 | 3 | 5 | **34** |
| 3 | TPI Sendangbiru parking area | 3 | 5 | 1 | 1 | 3 | 5 | 1 | 5 | 24 |
| **4** | **Sendiki beach parking area** | 5 | 5 | 1 | 5 | 5 | 5 | 3 | 5 | **32** |
| **5** | **Makam three junctions yard** | 5 | 5 | 1 | 5 | 5 | 5 | 5 | 3 | **34** |
| 6 | Goa Cina parking area | 3 | 5 | 1 | 1 | 3 | 3 | 1 | 3 | 20 |
| **7** | **Tambakrejo Village yard** | 5 | 5 | 1 | 5 | 5 | 5 | 5 | 3 | **34** |
| 8 | Sendangbiru beach parking area | 3 | 5 | 1 | 1 | 3 | 3 | 1 | 3 | 20 |

**Description:**

1. Building type: public buildings (5), semi-public buildings (3), private buildings (1)
2. Distance from the beach: Far (5), medium (3) and, near (1)
3. Number of floors: more than 2 (5), 2 floors (3) and, 1 floor (1)
4. Building capacity: more than 200 (5), 100-200 (3) and, less than 100 (1)
5. Construction conditions: concrete structures (5), brick walls (3) and, without concrete structures (1)
6. Distance from the main road: near (5), medium (3) and, far (1)
7. Area of the building yard: more than 1000 m2 (5), 250 – 1000 m2 (3) and, less than 250 m2 (1)
8. Distance from settlements: near (5), medium (3) and, far (1)

If all health protocol regulations are implemented, it will have an impact on reducing shelter capacity and will also have a direct impact during the evacuation process from a place that is at risk of being affected by a disaster to a place that is safe from the risk of a tsunami wave disaster. We refer to the implementation of social distancing and health protocol provisions, the need for evacuation shelters can double to triple and this is very inconsistent with the availability of temporary evacuation shelters. Additional shelters that involve financing, such as the construction of new buildings specifically for evacuation sites, improving the quality of existing buildings, and the others, are always constrained by the availability of funds, both self-managed and funded by the government.

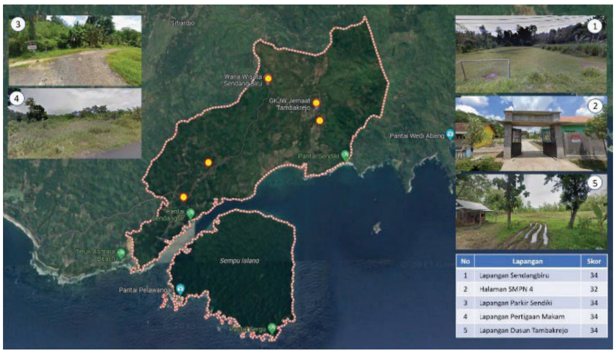


**Fig. 6:** Field distribution as evacuation

The most rational effort is an evacuation site that is in the field in a safe zone from the reach of the tsunami waves and not in a particular building. This certainly makes it easier for the process of setting up tents, public kitchens, logistical warehouses and others, including an isolation room for refugees with symptoms and indications of being infected with the virus. So, it can be said that the selection of the field as the evacuation site is the cheapest and most rational for now. Table 3 and Figure 6 show the distribution of fields as evacuation shelters. Based on the results of the assessment with several parameters, there are 5 fields that can be used as temporary evacuation shelters by implementing health protocols. The selection of fields or open land as a place of refuge is an option that deserves consideration when the government's funding priority for coping efforts is still limited to administrative efforts and not on construction activities which actually involve multi-stakeholders, across Regional Apparatus Organizations, and even across Ministries. Several parking lots were eliminated because they were too close to the beach and at risk of being directly affected by the tsunami waves. Meanwhile, several other field locations were chosen because they have adequate area and easy access from settlements as well as from the main road.

## 4. Conclusion and Future Work

Based on the results of research on Tsunami Disaster Preparedness in Tambakrejo Village, Sumbermanjing Wetan, Malang Regency, there are several important findings as conclusions. There are several potential buildings that can be used as evacuation sites consisting of public buildings, semi-public buildings, and possible private buildings.

In this research, the total of 18 buildings have been assessed for their feasibility and there are only 9 buildings that are feasible and can be used as temporary evacuation shelters. The research results show that building parameters, such as the strength of building construction, distance from the beach, ease of access, land area, and several other parameters, ultimately reduce the number of potential buildings as shelters. This will reduce the number of possible shelters that can be used to evacuate when a disaster occurs. The reduction in the number of shelters was also due to implementing health protocols during the pandemic, thereby drastically reducing building capacity.

The results of the spatial analysis show that, with a travel time of 15 minutes, the shelter is too far to be reached by all residential areas. Tamban Village and Kampungbaru Village are residential areas that are outside the service area. This shows that the distribution of shelters is not sufficient to serve residential areas in Tambakrejo Village. In future research, numerical analysis and agent-based simulation can be performed to find out exactly how long it takes from residential areas to shelters. Tsunami drills can also be carried out, such as simulating walking from the area.

## References


1) U. FADLY, and K. MURAKAMI, "STUDY on reducing tsunami inundation energy by the modification of topography based on local wisdom," *Journal of Japan Society of Civil Engineers, Ser. B3 (Ocean Engineering)*, 68 (*2*) I_66-I_71 (2012). doi:10.2208/jscejoe.68.I_66.
2) K. Pakoksung, A. Suppasri, and F. Imamura, "Tsunami wave characteristics from the 1674 ambon earthquake event based on landslide scenarios," *Geotechnics*, 3 (*3*) 700–718 (2023). doi:10.3390/geotechnics3030038.
3) S. Karima, W. Kongko, H. Khoirunnisa, W. Hendriyono, and M. Wibowo, "Potential tsunami hazard on the coast of the indonesia's new capital candidate," *IOP Conf Ser Earth Environ Sci*, 832 (*1*) 012044 (2021). doi:10.1088/1755-1315/832/1/012044.
4) D.M. Salmanidou, A. Ehara, R. Himaz, M. Heidarzadeh, and S. Guillas, "Impact of future tsunamis from the java trench on household welfare: merging geophysics and economics through catastrophe modelling," *International Journal of Disaster Risk Reduction*, 61 102291 (2021). doi:10.1016/j.ijdrr.2021.102291.
5) A. Suharyanto, "Predicting tsunami inundated area and evacuation road based on local condition using gis," *IOSR J Environ Sci Toxicol Food Technol*, 1 (*4*) 05–11 (2012). doi:10.9790/2402-0140511.
6) P. Tregoning, and A. Gorbatov, "Evidence for active subduction at the new guinea trench," *Geophys Res Lett*, 31 (*13*) n/a-n/a (2004). doi:10.1029/2004GL020190.
7) E. Basquin, A. El Baz, J. Sainte-Marie, A. Rabaute, M. Thomas, S. Lafuerza, A. El M'rini, D. Mercier, E. d'Acremont, M.-O. Bristeau, and A. Creach, "Evaluation of tsunami inundation in the plain of martil (north morocco): comparison of four inundation estimation methods," *Natural Hazards Research*, 3 (*3*) 494–507 (2023). doi:10.1016/j.nhres.2023.06.002.
8) W. Windupranata, N.R. Hanifa, C.A.D.S. Nusantara, G. Aristawati, and M.R. Arifianto, "Analysis of tsunami hazard in the southern coast of west java province - indonesia," *IOP Conf Ser Earth Environ Sci*, 618 (*1*) 012026 (2020). doi:10.1088/1755-1315/618/1/012026.
9) F. Usman, A.D. Wicaksono, and E. Setiawan, "Evaluation of the reduction of tsunami damages based on local wisdom contermeasures in indonesia," *Rev Eur Stud*, 8 (*1*) 157 (2016). doi:10.5539/res.v8n1p157.
10) F. Usman, J.K. Wardhani, I.C. Sari, and S. Chalim, "Assessing trauma healing methods for volcanic disaster evacuees in indonesia," *Journal Européen Des Systèmes Automatisés*, 56 (*6*) 1019–1025 (2023). doi:10.18280/jesa.560612.
11) F. Usman, S. Hariyani, E.B. Kurniawan, and I.C. Sari, "Measuring resilience of a tourism village against flash flood disaster," *Regional and Rural Studies*, 1 (*1*) 15–21 (2023). doi:10.21776/rrs.v1i1.4.
12) S. Surjono, Dhara K. Wardhani, A. Yudono, and Mujibur R.K. Muluk, "Residential preferences of post great disaster in palu city, indonesia," *Evergreen*, 8 (*4*) 706–716 (2021). doi:10.5109/4742114.
13) B. Shahriari, A. Hassanpoor, A. Navehebrahim, and S. Jafar, "Designing a green human resource management model at university environments: case of universities in tehran," *Evergreen*, 7 (*3*) 336–350 (2020). doi:10.5109/4068612.
14) Irma Alfie Yassin, R. Patrisina, and E. Amrina, "Location-allocation model for victims and health workers during post earthquake-tsunami health crisis in padang city," *Evergreen*, 9 (*1*) 234–245 (2022). doi:10.5109/4774244.
15) M.R. Pahlevi, D. Dinanti, A. Subagiyo, Y. Qomariyah, and J. Varo, "The relationship between community characteristics and urban sprawl in driyorejo sub-district, gresik regency, indonesia," *Regional and Rural Studies*, 1 (*1*) 22–31 (2023). doi:10.21776/rrs.v1i1.6.
16) J. Hallak, M. Koyuncu, and P. Miç, "Determining shelter locations in conflict areas by multiobjective modeling: a case study in northern syria," *International Journal of Disaster Risk Reduction*, 38 101202 (2019). doi:10.1016/j.ijdrr.2019.101202.
17) R.A. Ekaputra, C. Lee, S.-H. Kee, and J.-J. Yee, "Emergency shelter geospatial location optimization for flood disaster condition: a review," *Sustainability*, 14 (*19*) 12482 (2022). doi:10.3390/su141912482.
18) K. Rahman, D. Sisinggih, and R. Asmaranto,

"Application of sediment runoff model to the wlingi reservoir watershed, indonesia," *Civil and Environmental Science*, 003 (*01*) 010–017 (2020). doi:10.21776/ub.civense.2020.00301.2.
19) M. Muhadi, L. Limantara, and T. Prayogo, "Analysis of flood peak discharge based on watershed shape factors," *Civil and Environmental Science*, 005 (*01*) 008–016 (2022). doi:10.21776/ub.civense.2022.00501.2.
20) K. Ertugay, S. Argyroudis, and H.Ş. Düzgün, "Accessibility modeling in earthquake case considering road closure probabilities: a case study of health and shelter service accessibility in thessaloniki, greece," *International Journal of Disaster Risk Reduction*, 17 49–66 (2016). doi:10.1016/j.ijdrr.2016.03.005.
21) Y. Ikeda, and M. Inoue, "An evacuation route planning for safety route guidance system after natural disaster using multi-objective genetic algorithm," *Procedia Comput Sci*, 96 1323–1331 (2016). doi:10.1016/j.procs.2016.08.177.
22) M. Kako, M. Steenkamp, B. Ryan, P. Arbon, and Y. Takada, "Best practice for evacuation centres accommodating vulnerable populations: a literature review," *International Journal of Disaster Risk Reduction*, 46 101497 (2020). doi:10.1016/j.ijdrr.2020.101497.
23) S. S., and M. K., "Application of spatial and network analysis to evaluate shelter plan for tsunami evacuation," *Civil Engineering Dimension*, 17 (*2*) (2015). doi:10.9744/ced.17.2.88-94.
24) A.C.Y. Li, L. Nozick, N. Xu, and R. Davidson, "Shelter location and transportation planning under hurricane conditions," *Transp Res E Logist Transp Rev*, 48 (*4*) 715–729 (2012). doi:10.1016/j.tre.2011.12.004.
25) F. Lavigne, C. Gomez, M. Giffo, P. Wassmer, C. Hoebreck, D. Mardiatno, J. Prioyono, and R. Paris, "Field observations of the 17 july 2006 tsunami in java," *Natural Hazards and Earth System Sciences*, 7 (*1*) 177–183 (2007). doi:10.5194/nhess-7-177-2007.
26) B. Liang, D. Yang, X. Qin, and T. Tinta, "A risk-averse shelter location and evacuation routing assignment problem in an uncertain environment," *Int J Environ Res Public Health*, 16 (*20*) 4007 (2019). doi:10.3390/ijerph16204007.
27) G.J. Lim, S. Zangeneh, M. Reza Baharnemati, and T. Assavapokee, "A capacitated network flow optimization approach for short notice evacuation planning," *Eur J Oper Res*, 223 (*1*) 234–245 (2012). doi:10.1016/j.ejor.2012.06.004.
28) D.W. Edgington, "Planning for earthquakes and tsunamis: lessons from japan for british columbia, canada," *Prog Plann*, 163 100626 (2022). doi:10.1016/j.progress.2021.100626.
29) M.K. Lindell, A. Bostrom, J.D. Goltz, and C.S. Prater, "Evaluating hazard awareness brochures: assessing the textual, graphical, and numerical features of tsunami evacuation products," *International Journal of Disaster Risk Reduction*, 61 102361 (2021). doi:10.1016/j.ijdrr.2021.102361.
30) F. Makinoshima, Y. Oishi, and F. Imamura, "Mechanism of an evacuation cascade during the 2011 tohoku tsunami inferred from an evacuation simulation incorporating communications in social networks," *International Journal of Disaster Risk Reduction*, 71 102810 (2022). doi:10.1016/j.ijdrr.2022.102810.
31) E. Ozbay, Ö. Çavuş, and B.Y. Kara, "Shelter site location under multi-hazard scenarios," *Comput Oper Res*, 106 102–118 (2019). doi:10.1016/j.cor.2019.02.008.
32) A. Nugroho, A. Hasyim, and F. Usman, "Urban growth modelling of malang city using artificial neural network based on multi-temporal remote sensing," *Civil and Environmental Science*, 001 (*02*) 052–061 (2018). doi:10.21776/ub.civense.2018.00102.2.
33) W.P. Wijayanti, S.K. Machmud, and A. Subagiyo, "Linkage among two satellite cities: what makes people move? (case study: bogor regency and depok city)," *Regional and Rural Studies*, 1 (*1*) 1–5 (2023). doi:10.21776/rrs.v1i1.2.
34) U. Putri, and E. Ellisa, "Reclaiming residual spaces in urban life: the act of occupancy beneath pedestrian bridges in jakarta," *Evergreen*, 7 (*1*) 126–131 (2020). doi:10.5109/2740969.
35) J. Xu, X. Yin, D. Chen, J. An, and G. Nie, "Multi-criteria location model of earthquake evacuation shelters to aid in urban planning," *International Journal of Disaster Risk Reduction*, 20 51–62 (2016). doi:10.1016/j.ijdrr.2016.10.009.
36) A. Vecere, R. Monteiro, W.J. Ammann, S. Giovinazzi, and R.H. Melo Santos, "Predictive models for post disaster shelter needs assessment," *International Journal of Disaster Risk Reduction*, 21 44–62 (2017). doi:10.1016/j.ijdrr.2016.11.010.
37) Y. Shimura, and K. Yamamoto, "Method of searching for earthquake disaster evacuation routes using multi-objective ga and gis," *Journal of Geographic Information System*, 06 (*05*) 492–525 (2014). doi:10.4236/jgis.2014.65042.
38) F. Shoimah, F. Usman, and S. Hariyani, "Tsunami risk reduction in the new normal era based on community building in watulimo, indonesia," *IOP Conf Ser Earth Environ Sci*, 916 (*1*) 012033 (2021). doi:10.1088/1755-1315/916/1/012033.
39) F. Shoimah, F. Usman, and S. Hariyani, "Formulation of framework for evacuation of tsunami disaster after covid-19 pandemic on the south coast of watulimo, trenggalek," *TATALOKA*, 24 (*2*) 131–140 (2022). doi:10.14710/tataloka.24.2.131-140.