Evacuation route during a disaster with health protocol in the new normal era

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Abstract. The southern coast of Java Island, one of which is Sumbermanjing Wetan District, Malang Regency, is considered prone to the geological disaster tsunami. Sumbermanjing Wetan District is directly adjacent to the Indian Ocean, a seismic gap zone that produces geological processes and high-intensity seismic activity that can trigger tsunami waves. On June 13, 2021, the COVID-19 outbreak in Sumbermanjing Wetan District recorded 90 suspected cases (two were hospitalized and the other 88 were self-isolating at home), and 38 were confirmed positive for COVID-19 (34 recovered and 4 died). This research focuses on evacuation plans for coastal areas from the threat of a tsunami during the pandemic and the new normal era. The sub-variables for determining the shelters include building area, type of building, ease of access, building construction, and capacity. The sub-variables for determining the evacuation route include road class, pavement type, and road width. Meanwhile, the sub-variables for implementing health protocols in the new normal era are maintaining distance, wearing masks, washing hands, special treatment for symptomatic refugees, and implementing other health protocols. The implementation of health protocols in evacuation activities will bring an impact on the reduction of the available shelter’s capacity. The study results indicate the need for additional new shelters to implement health protocols in the new normal era. With this addition, it will impact the travel time from the residential areas at risk of tsunami impacts to the shelters. One of the reasons is that the closest shelter to the residential area is already full of refugees, so the refugees have to move and evacuate to the other shelters that can still accommodate them.

1. Introduction
The COVID-19 outbreak demands that all social classes, both the government and the community at the central and regional levels, remain vigilant and fully alert in dealing with worst-case scenarios related to natural disasters, such as earthquakes, tsunamis, and other natural disasters in the new normal era. When a natural disaster occurs, people tend to carry out normal activities, such as crowding and being close to one another because of the limited space in shelters or to feel safe and be comfortable. This is not easy in the new normal period, where people must maintain physical distance. If shelters become
overcrowded, the area will become a new epicenter and cluster of COVID-19 cases during a disaster [1].

It is essential to carry out a tsunami emergency response plan in the new normal era with the aforementioned conditions. This research aims to reduce the disaster’s impact on the community, while at the same time preventing the spread of COVID-19 in shelters. Therefore, it is necessary to pay attention to the evacuation efforts of earthquakes and tsunamis on the south coast of Malang Regency in the new normal era. This is due to the uncertainty of when the pandemic will end, which requires people to adapt to the new normal life [2].

Indonesia is located in one of the most active seismic zones in the world, the Ring of Fire [3]. Indonesia is geologically located at the confluence of three main active plates of the world, namely the Eurasian Plate in the north, the Indo-Australian Plate in the south, and the Pacific Plate in the east move and collide with each other [4]. These natural conditions cause Indonesia to have the potential of natural and mineral resources and natural disasters due to tectonic activities [5][6]. Around the location in which the plates meet, there is an accumulation of collision energy to a point where the earth's layers are no longer able to withstand the pile of energy, which then escapes in the form of a tectonic earthquake that can trigger a tsunami [7]. The probability of a tsunami in Indonesia with an inundation height of >3 m occurs once in 10~50 years [8]. Within two years, earthquake activity in Indonesia can cause one tsunami [9] [10]. Globally since the 19th century, 50% of tsunami disasters have occurred in Indonesia [11].

As an archipelagic country, Indonesia has ± 17,504 islands with a coastline that spans 99,093 km, making Indonesia one of the largest archipelagic countries in the world [12]. On the other hand, the protection of coastal areas against the threat of a tsunami disaster is sporadic. This is because the coastline of Indonesia, which is prone to tsunamis, is massive [13]. Forty-six percent of the coastline in Indonesia is prone to tsunamis—stretching from western Indonesia to eastern Indonesia—including Aceh, Nias, Bengkulu, Banten, Pangandaran, Pacitan, Trenggalek, Tulungagung, Blitar, Malang, Lumajang, Jember, Banyuwangi, to East Nusa Tenggara [3]. One hundred fifty of the 273 coastal cities in Indonesia have a high risk of a tsunami disaster [14].

In Indonesia, there have been more than 9 tsunamis in various intensities, including 54 destructive tsunamis with significant casualties and damage; more than nine tsunamis due to volcanic eruptions; more than three tsunamis caused by avalanches; and six tsunamis of unknown cause [9]. In the last few decades in Indonesia, a number of tsunami disasters occurred, which caused loss of life and property, such as Flores (1992), Banyuwangi (1994), Biak (1996), Maluku (1998), Banggai (2000), Aceh (2004), Nias (2005), Pangandaran (2006), Bengkulu (2007), Mentawai (2009), Palu (2018), and Banten (2018) [15].

The Ministry of Public Works stated that the south of Java Island is included in four areas with a high potential of tsunami-causing earthquakes [16]. In addition, areas along the southern coastline of East Java Province are prone to tsunami geological disasters. Therefore, eight districts on the south coast of East Java Province face the threat of tsunami disasters, which are Trenggalek, Banyuwangi, Jember, Pacitan, Malang, Blitar, Lumajang, and Tulungagung Regency [17].

Malang District ranks 31st out of 273 coastal cities in Indonesia with a 1/50–1/10 probability of a tsunami of more than 3 m (Figure 1). The maximum tsunami height on the coast with a 100-year return period is 4.7 m, the 500-year return period is 9.1 m, and the 2,500-year return period is 25.8 m [18]. The higher the tsunami wave, the longer the return period [15]. The tsunami-prone area covers the entire coast of the southern part of Malang Regency. The total area threatened by a tsunami in Malang Regency is 4.63%, covering six districts: Ampelgading, Bantur, Donomulyo, Gedangan, Sumbermanjing Wetan, and Tirtoyudo. The tsunami disasters in Malang Regency have a medium threat level, high loss rate, and medium capacity level, resulting in a high disaster risk level. Sumbermanjing Wetan District has the highest potentially-exposed population, which is around 9,302 people when compared to other districts in Malang Regency [19] [20].
On May 30, 2021, the development of the COVID-19 outbreak in Indonesia recorded 1,816,041 cumulative cases with 102,700 active cases, with 1,663,061 recoveries confirmed, and 50,280 confirmed deaths. Meanwhile, the COVID-19 outbreak in East Java Province recorded 154,781 positive cases with 2,100 active cases, 141,336 recoveries, and 11,345 deaths. Mapping of risk zoning for the COVID-19 outbreak shows that Malang Regency is at moderate risk, along with 25 other cities in East Java Province [21].

2. Methods

2.1. Study Area
Sumbermanjing Wetan District is one of the 33 Districts in Malang 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 sub-districts, 40 villages, 113 RW, and 514 RT [22].

In the middle, north, and east are valley areas, while in the south lies the Indian Ocean, beaches, and coral islands. The location of 11 sub-districts is on the slopes and 4 sub-districts are on the coast. The coastal villages of Sumbermanjing Wetan District are Sitiarjo, Tambakrejo, Tambaksari, and Sidoasri. The four villages are the priorities in this study because the residential areas located on the coast with an altitude of 1–50 meters above sea level will be directly affected when a tsunami occurs (Figure 2).

2.2. Analysis Method
Most of the tsunamis in Indonesia are local tsunamis caused by tectonic earthquakes. Thus, people in earthquake areas will receive natural warnings in advance, i.e., earthquakes with large shocks. If the community feels a strong shaking or an earthquake that swings weakly, but for a long time, the
community should immediately evacuate independently to a shelter without waiting for an early tsunami warning or an evacuation order from the authorities [1].

If there is an earthquake with the potential to create a tsunami in the new normal era, the evacuation of residents must be prioritized to save lives. In carrying out independent evacuations to shelters, the community should pay attention to health protocols, maintain cleanliness, and follow the policy of activity limitations in their respective areas. After the threat of disaster ends, the community can move to the final shelter under the direction and instructions of the authorities or to return to their home should circumstances allow. If people have to stay longer in the final shelters, the authorities must provide excellent and adequate medical facilities and support [1].

The use of GIS in various phases can be illustrated as planning, mitigation, preparedness, and emergency response activities. The use of GIS enables emergency management to cope with the occurrence of disasters. Therefore, data must be prepared and created to determine the size and space of emergency management allocations so that appropriate action can be taken in the event of a disaster [23]. Such emergency data include data related to shelters and evacuation routes. The spatial data will make it easier for the community to reach shelters [15]. All parameters in the analysis of shelters are mapped in a GIS because they have spatial components or location coordinates [24]. The role of GIS in evacuation analysis has been described in several studies [25].

**Figure 3** is a research flowchart related to tsunami evacuation plans in the new normal era. Parameters for determining shelters are building conditions, such as building type, building status, capacity, distance from roads, number of floors, etc. However, the new normal era parameters must also be an essential consideration.

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**Figure 3.** Research flowchart related to Tsunami evacuation plan in the new normal era
3. Result and Discussion

There were three analyses carried out in this study, namely: (1) shelter plan analysis, (2) access road analysis, and (3) new normal life analysis for the selected shelter. To analyze the feasibility of shelters, a weighting technique was carried out on buildings and places that can be used as shelters. The assessment variables for shelters include; the type of building, the distance from the beach, the number of floors, the capacity of the building, the type of building construction, the distance from the main road, the land around the building, and it must be ensured that the building is not in a disaster-prone zone. Figure 4 shows the buildings and places that have the potential to be used as shelters. Meanwhile, Table 1 is the result of the weighting of shelters in Tambakrejo Village, Sumbermanjing Wetan District, Malang Regency.

![Figure 4. Distribution of potential shelters](image)

**Table 1. Scoring of shelter in Tambakrejo Village**

| No | Name of Building / Place                      | Distance | Floor Level | Construction | Vulnerable | Capacity | Ground/Yard | Total Score |
|----|---------------------------------------------|----------|-------------|--------------|------------|----------|-------------|-------------|
| 1  | Masjid Al Falah                             | 5.00     | 1.00        | 3.00         | 1.00       | 4.00     | 3.00        | 17.00       |
| 2  | Masjid Miir                                 | 5.00     | 1.00        | 3.00         | 5.00       | 3.00     | 4.00        | 21.00       |
| 3  | Musholah Nurul Falah                        | 5.00     | 1.00        | 3.00         | 1.00       | 2.00     | 2.00        | 14.00       |
| 4  | GJKW Jamaat Sendangbiru                     | 5.00     | 1.00        | 3.00         | 3.00       | 2.00     | 2.00        | 16.00       |
| 5  | Rusunawa Sendangbiru                        | 3.00     | 5.00        | 5.00         | 5.00       | 5.00     | 5.00        | 26.00       |
| 6  | SMP TPN Sendangbiru                         | 5.00     | 2.00        | 3.00         | 1.00       | 2.00     | 2.00        | 15.00       |
| 7  | Puskesmas Sendangbiru                       | 5.00     | 1.00        | 3.00         | 1.00       | 2.00     | 2.00        | 14.00       |
| 8  | Field on the hill #1 (near intersection)     | 3.00     | 3.00        | 1.00         | 5.00       | 5.00     | 5.00        | 22.00       |
| 9  | Field on the hill #2 (near masjid miir)      | 3.00     | 3.00        | 1.00         | 5.00       | 5.00     | 5.00        | 22.00       |

Referring only to the weighting results for the shelters, Al Falah Mosque is included in the shelter group that can be used. However, judging on the location of the building, the building is in a tsunami inundation area (Figure 2). Thus, it can be concluded that the buildings and locations that can be used as shelters are only Miir Mosque, Sendangbiru Government Rental House (Simple Rental Flats – Rusunawa, in Indonesia), the public square near Miir Mosque, and the public square near the fork in the south causeway, with the farthest distance about 1.45 km from the beach.
To carry out weighting on the available road network, measurements of roads that pass through the residential areas to the available shelters were carried out. In order to weigh the road, the parameters taken into consideration consisted of road class, road quality, road width, and road material. By referring to the weighting results of the available road network, the Southern Cross Road is the road with the best condition because it is a national road with adequate road width and excellent material. Upper Pondokrejo and Lower Pondokrejo Road—though their road class is only a district road—have good quality and road materials with adequate road widths. While the tomb road, located in a residential area, has a road width of only 1.5 meters with road material in the form of a layer of stone sand, as shown in Figure 5.

Figure 5. The Condition of road network from and to shelters

Tambakrejo village has an area of 2,700 hectares with a residential area of 146 hectares. This village has a slope of 15 degrees, and the population in Tambakrejo Village is about 8,284 people or 1,791 families. The area potentially affected by the tsunami inundation is across the Sempu Island or around the Sendangbiru Beach area. The number of residents around the potentially affected area is around 3,000 people. If the 3,000 people are evacuated to the four shelters, then each shelter should accommodate about 750 people. However, the capacity of Miir Mosque is only about 100 people. Therefore, the distribution of refugees can be directed to the Sendangbiru Rusunawa, which has a capacity of about 2,000 people, and the public fields, each having a capacity of around 1,000 people.

Regarding the implementation of health protocols in the new normal era, several important considerations, including those related to social distancing and special treatment for refugees suspected of being exposed to COVID-19, will directly impact the available shelter capacity. With the implementation of health protocols, the capacity can shrink to only 30–50%. This is due to the implementation of physical distancing while in shelters. It is also necessary to prepare a place for self-isolation for refugees who present symptoms or are indicative of COVID-19.

4. Conclusion
Based on the research results on the Evacuation Route during Disaster with Health Protocol in New Normal Era, several essential findings can be drawn as conclusions. First, the impact of the pandemic has changed the social and cultural behavior of the community, especially regarding the implementation of health protocols in the new normal era.

Second, there are nine shelters, public buildings in places of worship (mosques and churches), schools, health centers, Government Rental Houses (Rusunawa), and public fields. Based on the results of the weighting of the nine shelters, only four locations are suitable for use, with the consideration that they are not in locations susceptible to tsunami waves, namely the Miir Mosque, Rusunawa, and two public fields that can be used as shelters.

Third, the weighting on the road network passed by the refugees from the residential areas to the shelters shows that there are several roads with inadequate quality. Therefore, it is necessary to improve the quality of the road network, either in the form of improving materials, road widths, and improving road conditions.
Fourth, the application of health protocols in the new normal era will undoubtedly reduce the capacity of shelters. As a result, it is necessary to add shelters that can accommodate around 3,000 residents in the Sendangbiru coastal settlement, an area potentially affected by the tsunami waves.

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