Characteristics of Potential Tsunami Evacuee and Evacuation Infrastructure in Pangandaran Beach, Indonesia

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Abstract. Pangandaran Regency is a strategic area that supports various economic and social activities. However, the existence of this strategic area is threatened by the potential of tsunami disaster, especially from the megathrust along the South Coast of Java Island. One of the efforts to enhance tsunami preparedness is to conduct evacuation plan and drill. Based on previous tsunami occurrence, it is known that success of evacuation during disaster is still limited by lack of community knowledge, preparedness, and limited infrastructure such as informative evacuation route maps, evacuation signs and proper evacuation sites. Therefore, the purpose of this study is to identify people's behavior in carrying out evacuations and actual condition of the current evacuation infrastructure which is later be used to obtain comprehensive information as the basis for evacuation plans preparation. This study aims to disseminate questionnaires to 174 respondents in Pangandaran Tourism Area and map tsunami evacuation infrastructure. This study shows a high awareness of tsunami hazards, in which 82% of respondents choose to evacuate after experiencing an earthquake or getting an early tsunami warning. In addition to the result, some respondents still do not know the route or evacuation site. Uninformed shelter destination and route choice result in potential congestion on the main roads, which slows evacuation by compromising survival rates. Three Pangandaran official TES can accommodate approximately 11,900 people, while the capacity of alternative TES if utilized 100% can accommodate 21,291 people. This indicates that the official TES and the new Alternative TEST can accommodate the villagers and some of tourists if the number of tourists reaches the maximum. Therefore, the existing building can be utilized as Temporary Evacuation Sites. Furthermore, there is a call to evacuation signs maintenance, in which some signs are currently in inappropriate condition such as damaged or show misleading information.

1. Introduction
Coastal area is an area that stores various of potential natural resources. These potentials include the potential of fisheries, mangrove forests, coral reefs, seaweed, transportation facilities and coastal tourism that can be a source of coastal community economy. However, another potential that coastal areas have is the potential for disasters such as tsunamis. Tsunami is a natural hazard that can cause detrimental impacts on coastal areas [1]. The impact caused by the tsunami can cause enormous losses to coastal areas such as damage to buildings and infrastructure [2] and if the community is not prepared
for the threat then it can cause many fatalities [3]. The main source of tsunami events in Indonesia is generally produced by shallow earthquakes in subduction zones or plate boundaries due to large energy releases that cause vertical shifts on the seabed [4].

The southern part of Java Island is directly facing the subduction zone so that it is one of the earthquake and tsunami hazard prone areas [5,6]. In addition, recent research conducted [7] shows that there is surface deformation of multi-GNSS receiver data that has the potential to cause earthquakes and tsunamis. One of the areas located on the South Coast of Java Island is Pangandaran Regency. Pangandaran Regency is one of the strategic areas that supports various social and economic activities. Pangandaran Regency is also a tourist area known by domestic and foreign tourists. However, the existence of this strategic area is threatened by the potential for tsunami disasters, especially from megathrusts along the South Coast of Java Island.

Based on the Sumatra earthquake in 2007, 2009, and 2010, it is known that evacuation during disasters is still limited by the lack of evacuation support infrastructure such as informative evacuation route maps, evacuation signs, and relevant evacuation sites [8,9]. In addition, based on the experience of the 2018 Palu Earthquake-Tsunami and 2018 Sunda Strait Tsunami, it is known that tsunami early warning systems in Indonesia are less effective. The lack of evacuation support infrastructure and ineffectiveness of this early warning system can increase the risk of disaster. However, the high risk of disaster can also be caused by the lack of public awareness of disasters, this can affect the community's decision to evacuate. Evacuation is an effective method to minimize the number of fatalities from tsunami disasters. Therefore, the lack of public awareness in evacuating can lead to an increase in fatalities due to disasters.

Therefore, in this study, identification of community behavior in carrying out evacuation and identification of the actual condition of the current evacuation support infrastructure aims to obtain comprehensive information as the basis for preparing evacuation plans and making better policy in disaster mitigation as an effort to reduce the risk of disasters, especially fatalities. In this study, data was acquired by distributing questionnaires to 174 residents around Pangandaran Tourism Area to determine tsunami evacuation behavior and map tsunami evacuation infrastructure such as tsunami evacuation sites and tsunami evacuation signs.

2. Methodology
To understand the characteristics of community behavior in conducting evacuation and the actual condition of evacuation infrastructure in Pangandaran Beach Tourism Area, the data and methods used are as follows:

2.1 Questionnaire Survey
Based on the earthquakes that caused tsunamis, it is known that evacuation during disasters is still limited by the lack of public awareness of disasters, where it can cause the onset of disaster risk, especially fatalities. Therefore, the identification of community characteristics in conducting disaster evacuation is done by distributing questionnaires to the community. The questionnaire survey was carried out in October 2020 and March 2021. This survey was conducted face-to-face with residents, but the questionnaires distributed were based on online forms, in this case, google forms. In the first questionnaire survey, questions were prepared to identify the source of information on potential tsunami disasters, as well as the knowledge of the community on tsunami evacuation. In this survey, 60 respondents were obtained. Subsequently, in the second survey, questions were arranged to explore information related to the behavior of community evacuation if a tsunami occurs, with questions related to factors that cause residents to decide to evacuate, the length of evacuation preparation time, evacuation objectives, evacuation methods, and the estimated travel time to the evacuation site. Respondents in this survey reached 174 residents.

2.2 Interview
In addition to distributing questionnaires to obtain information related to community behavior in evacuating, interviews were also conducted with officials of the Pangandaran regional disaster management agency, the government of Pananjung Village and Pangandaran Village, members of the disaster response community, and residents. Interviews with residents were carried out when they were filling out the questionnaire or after they finished filling it. Through this interview, more in-depth information could be obtained.

2.3 Identification and retrieval of information related to Temporary Evacuation Site (TES) location and location of evacuation signs.

Identification and geotagging activities were carried out simultaneously to determine and validate the location and condition of the evacuation supporting infrastructure, which are the Temporary Evacuation Site and evacuation signs. Before the survey, information concerning the TES location and evacuation signs in Pangandaran and Pananjung Village had been obtained. This information was acquired from the village government of Pananjung and Pangandaran Village, as well as BPBD (Regional Disaster Relief Agency) Pangandaran. The survey was conducted using the Avenza Maps app, where it helped to provide information on the location of evacuation signs based on data obtained for later verification. In this survey, documentation was also done as evidence or support in carrying out the identification.

2.4 Calculating the capacity of The Alternatif Temporary Evacuation Site (TES)

Budiarjo (2006) [10] explained the assumptions and formula to calculate the capacity for evacuation of some building functions which are potentially suitable for vertical evacuation as example for hotel. Space requirement for hotel design is 16 m² per person comprises: 12 m² per person for staying and 1.5 m² per person for circulation; 0.5m² per person for utilities; 1.5 m² per person for hall, lobby, and restaurant (public function); 0.3m² per person for employees’ room; and 0.2m² per person for office function. From this space requirement, the spaces that can be occupied for evacuation are the area (1.5/16= 9.4% area); public function area (1.5/16 = 9.4% area); and assumed 10% non-occupied rooms (0.1*12/16 = 7.5% area). Hence, the total available space for evacuation is 9.4%+9.4%+7.5% = 26.3% of the total building area.

3. Results

3.1. Questionnaire Survey and Interview

Based on the October 2020 survey, 60 respondents were obtained consisting of 37 Pangandaran Village residents, 12 Pananjung Village residents, and 11 Pangandaran Beach visitors or tourists. The age of the respondents was quite varied where the questionnaire was filled out by residents or visitors who were over the age of 13 years. Respondents consisted of 3.3% (n=2) aged 13-19 years, 10% (n=6) aged 20-29 years, 20% (n=12) aged 30-39 years, 30% of respondents (n=18) aged 40 to 49 years, 26.7% (n=16) were aged 50-60 years, and 3.3% (n=2) were over 60 years of age. Meanwhile, on the March 2021 survey, the number of 174 respondents show that for Pangandaran Village, the confidence interval is 90%, while for Pananjung Village, it is 75%. According to the data of the Pangandaran Village government, the population of the village is 11,209 people, while the population of Pananjung Village amounts to 9,493 people based on the data from the Pananjung Village Government. In this survey, interviews were conducted with citizens of various age groups and genders. Although the numbers were not exactly the same as the age profiles of the two villages, the results obtained were quite varied. The respondents consisted of 62.6% (n=109) male and 37.4% (n=65) female. As for age, 2.3% (n=4) aged 13-18 years, 10.3% (n=18) aged 19-25 years, 32.8% (n=57) aged 25-40 years, 39.1 % (n=68) aged 68, and 15.5% aged 55 – 65 years.
3.1.1. Knowledge of tsunami disaster. Based on the respondents' results, it is known that 66.7% have never attended disaster and tsunami preparedness training, 20% have done it once a year, 6.7% have done it 3 times or more in a year, and 3.3% have attended training 2 times a year (Figure 1). These results conclude that most of the residents have never participated in disaster preparedness training. Based on the results of interviews, residents are aware of what a tsunami is and what needs to be done if a tsunami occurs. The source of information on a potential tsunami that the citizens obtain varies, from internet or television media, neighbours or friends, information from BMKG, BASARNAS, BPBD or village governments and disaster preparedness communities.

![Pie chart showing participation in disaster preparedness training](image)

**Figure 1.** Participation in Disaster Preparedness Training

In addition, based on the questionnaire results, it is also known that 71.7% of respondents have never conducted a simulation, 18.3% of respondents have done it once, 5% of respondents have the simulation once every two years, and 5% of respondents have conducted an evacuation simulation every year. Evacuation simulation is one of the efforts to build community preparedness in tackling disasters, where citizens can have a picture of the actions that need to be taken if a tsunami occurs. Based on the interviews conducted with the officials of the Pangandaran regional disaster management agency and members of the Pangandaran disaster response community, it is known that to attract citizens into participating in training or simulations, they need to be promised a reward or some kind of compensation. However, currently, the Village Government, BPBD, and disaster response community are working on training and simulating more periodic evacuations. In addition, evacuation training and simulation are also implemented in schools as an effort to create disaster response schools.
3.1.2 Public awareness to conduct disaster evacuation. Based on the questionnaire results, it is known that 43.7% of residents will immediately evacuate after feeling an earthquake or seeing other signs of a tsunami; 39.1% evacuates after getting an early tsunami warning, and 17.2% evacuates if they see a wave coming. This shows that most of the residents have a fairly high awareness to evacuate, where the majority of residents choose to evacuate if they feel an earthquake or see signs of a tsunami and receive an early warning. However, there are still residents who will only evacuate if they see the waves coming, which is quite dangerous if they do not have enough time to reach the evacuation site.

3.1.3 Evacuation preparation time. Following the decision to evacuate, 77.6% (n=135) of the residents, in this case, will immediately and directly evacuate themselves. Therefore, it can be said that the time to prepare for an evacuation is equal to zero minutes. After the residents feel the earthquake or receive the tsunami warning, they choose to evacuate immediately to a safer place away from the beach. However, some residents also need time to prepare for evacuation; the time needed is, among others, 5 minutes for 8% of respondents (n=14), 10 minutes for 19.8% of respondents (n=17), 10 – 30 minutes for 1.7% of respondents (n=3), and more than 30 minutes for 2.9% of respondents (n=4), which can be

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**Figure 2.** Participation in Simulated a Tsunami Evacuation

**Figure 3.** Decision to Evacuation
seen in Figure 4. The evacuation preparation time is used by residents to prepare evacuation needs such as vehicles used to evacuate, carry valuables at home, or ensure the evacuation of other family members.

![Figure 4. Preparation Time before Evacuation]

### 3.1.4 Knowledge of evacuation destinations and routes.
The objectives of evacuating residents can be seen in Table 1 below, where there are still residents who do not know the purpose of their evacuation. The evacuation destination is selected based on the proximity level of the location where the residents reside with the purpose of evacuation. However, from the questionnaire results, it is known that residents choose to evacuate directly to the final evacuation site, which, in this case, is Mount Purbahayu. Residents feel safer if they go directly away from the beach or to a higher spot than to a temporary evacuation place or a hotel or a nearby high-rise building. Based on the results, it is also known that 4 residents who do not know the purpose of evacuation also do not know the evacuation route. Furthermore, the results of the questionnaire show that while 13 residents do not know the path to the evacuation site, the majority of the residents, 161 people, are aware of the evacuation route.

| Evacuation Destination      | Pananjung | Pangandaran |
|-----------------------------|-----------|-------------|
| Pangandaran Grand Mosque    | 8         | 21          |
| Cagar Alam                  | 1         | 8           |
| Shelter                     | 7         | 10          |
| Nearby Hotel or High Building | 12      | 11          |
| Pananjung Village Office    | 3         | 0           |
| Mountain                    | 42        | 46          |
| Don’t know                  | 1         | 3           |
| Wide Field                  | 1         | 0           |

### 3.1.5 Evacuation methods and estimated travel time for evacuation.
Based on the questionnaire results, it is known that the evacuation method chosen by 59.8% of the residents (n=104) is running, 30.4% (n=53) chooses to use motorcycles, 7.5% (n=13) opts for going on foot, while 2.3% (n=4) goes for cars. (Figure 5)
Most of the residents choose not to use the mode of transportation because they consider that the use of vehicles will delay the evacuation due to congestion. The estimated travel time to the evacuation site varies, depending on the destination and mode of transportation chosen.

3.2. Evacuation Infrastructure Conditions in Pangandaran.

3.2.1 Evacuation Sites. Pangandaran Tourism Area has three Temporary Evacuation Places (TES) and one final Evacuation Site (TEA). If compared with other subdistricts in Pangandaran, the number of TES in the Pangandaran subdistrict is the least. The Cimerak subdistrict has the highest number of TES with a total of 26 evacuation sites, and the Pangandaran sub-district has one TES. TES in the Pangandaran subdistrict includes:

a. Pangandaran Grand Mosque. Pangandaran Grand Mosque is located in a strategic location. It is a public facility with parking space and public bathrooms. During the 2006 tsunami, the mosque was also used as an evacuation site. Based on the questionnaire results, 16.667% of residents choose to evacuate to Pangandaran Grand Mosque.

b. Pangandaran Shelter. Pangandaran Shelter was built after the 2006 Pangandaran Tsunami. The shelter measures 60 x 50 meters and has three floors. According to the information provided by BPBD Pangandaran officials, the condition of the shelter at this time is somewhat neglected because it is not being used. Therefore, at the end of 2020, the PJS Pangandaran Regent, Dr. H. Dani Ramdan MT, suggested that the shelter will be used for various disaster activities and not just as TES. Based on the results of questionnaires and interviews, both residents of Pananjung and Pangandaran know the location and functionality of Pangandaran Shelter.

c. Cagar Alam. The location of TES in Cagar Alam is located near Goa Jepang, where the access to this location is quite uphill. In addition, the contours of this location are uneven and are still surrounded by large trees with no vacant land or fields. Based on the questionnaire results, only 5.172% of residents choose to evacuate to the nature reserve. According to the interviews, this choice is prompted by the dangerous condition of the nature reserve as it is located on the peninsula, at the end of which was flanked by the West Coast and the East Coast. However, if residents are near the nature reserve, they will choose to go there because it is a highland.
Meanwhile, TEA is located in Mount Purbahayu, more precisely in the Field of Purbahayu Village Office. However, in addition to the three main TES, BPBD Pangandaran and BMKG are currently working to turn several hotels into additional TES to reduce disasters risk.

3.2.2 Evacuation Capacity. In addition to accessibility, the capacity of evacuation sites is also important. The capacity of the evacuation site indicates the number of residents who can be accommodated in the event of a disaster. Based on an interview with one of the members of BPBD Pangandaran, it is known that the official TES in Pangandaran has a capacity of 11,900 people, which can be seen in Table 2.

Table 2. Capacity of main TES

| Name of TES               | Capacity   |
|--------------------------|------------|
| Masjid Agung Pangandaran | ± 500 people |
| Shelter                  | ± 5000 people |
| Cagar Alam               | ± 6400 people |
| Total                    | ± 11,900 people |

As for the alternative TES capacity, namely hotels, it is known that if 10% of the rooms in the hotel can be used by residents other than hotel visitors, the capacity is 5995 people. Meanwhile, if 100% of the hotel rooms can be used as evacuation sites, then the capacity is 21291 people. However, if the evacuation at the hotel can only be done on the top floor and does not take advantage of the rooms in the hotel, then the capacity is 7578 people, which can be seen in Table 4. In calculating the capacity of this hotel, it is assumed that the 1st and 2nd floors cannot be used as, in accordance to the tsunami scenario modeling, tsunami delays can reach more than 3 meters. Additionally, it is assumed that the usable area is 85%.

Table 3. Capacity of alternative TES

| No | Name of Hotel       | Number of floors | The capacity if 10% of the rooms in the hotel can be used | The capacity if 100% of the rooms can be used | The capacity if the evacuation can only be done on the top floor |
|----|---------------------|------------------|----------------------------------------------------------|-------------------------------------------------|---------------------------------------------------------------|
| 1  | Hotel Horison       | 4                | 528                                                      | 1884                                            | 1004                                                          |
| 2  | Hotel Laut Biru     | 6                | 1274                                                     | 4448                                            | 1185                                                          |
| 3  | Hotel d’BILZ       | 7                | 2545                                                     | 9077                                            | 1935                                                          |
| 4  | Hotel Pantai Indah  | 4                | 1078                                                     | 3846                                            | 2050                                                          |
| 5  | Hotel Fortuna       | 3                | 369                                                      | 1317                                            | 1404                                                          |
| 6  | Hotel Krisna Beach  | 3                | 201                                                      | 719                                             | 366                                                           |
|    | Total               | 5995             | 21291                                                    | 7578                                            |                                                               |

Based on the results of the tsunami modelling, with an earthquake scenario of 8.7, it is known that the total population affected in Pangandaran Tourism Area, namely Pangandaran Village and Pananjung Village, is 100%. The total population in both villages is 20,702. In addition, Pangandaran Area is a tourist destination that is regularly visited by tourists. Based on data from Pangandaran Tourism Office, it is known that in one day, the number of tourists visiting can reach 114,410 people. Therefore, it needs an evacuation site with a capacity of approximately 135,112 people. Three Pangandaran official TES can accommodate approximately 11,900 people, while the capacity of alternative TES if utilized 100% can accommodate 21,291 people. This indicates that the official TES and the new Alternative TEST can accommodate the villagers and 10% of tourists if the number of tourists reaches the maximum. However,
the calculation of this capacity is still an estimate, hence, it needs to be further reviewed to be applied in the field.

3.2.3 Evacuation Sign. Data on the location of evacuation signs were obtained from BPBD Pangandaran. The location data were then traced and identified. Prior to the field survey, the location points were plotted. From the plotting results, it is known that, in the data, there are still coordinate errors that can be caused by fallacies when entering coordinates or copying them to the survey sheet. Furthermore, according to the data, the number of evacuation signs in Pangandaran and Pananjung villages amounted to 109 signs. However, after the survey, the number of signs found was only 78, consisting of 45 appropriate signs between the BPBD data and surveys conducted and 23 uncharted signs, which can be pre-mapped but have coordinate errors. Meanwhile, the other 31 signs were not found in the field; this can be caused by missing signs or coordinates on the data that do not match in the field. The location of the evacuation sign can be seen in Figure 6.

![Image: The Location of The Evacuation Sign](image)

Figure 6. The Location of The Evacuation Sign

From the results of the survey, it is known that there are signs with damaged conditions, such as fading, invisible, and show misleading direction (Figure 7). The amount can be seen in Table 4.
Figure 7. Condition of evacuation sign. Misleading direction (a) invisible (b), and fading (c).

Table 4. The amount of evacuation signs with damaged conditions.

| Condition of Evacuation Sign | Amount |
|-----------------------------|--------|
| Misleading                  | 1      |
| Invisible                   | 3      |
| Demaged/Fading              | 7      |
| Total                       | 11     |

4. Conclusions

In this study, identification of community behavior in carrying out evacuation and identification of the actual condition of the current evacuation support infrastructure aims to obtain comprehensive information as the basis for preparing evacuation plans and making better policy in disaster mitigation as an effort to reduce the risk of disasters, especially fatalities. Based on the respondents' results, it is known most of the residents have never participated in disaster preparedness training and conducted a simulation of evacuation. This can lead to limited knowledge of citizens related to disasters and disaster evacuations as well as a lack of preparedness for tsunami disasters. The lack of community preparedness for disasters is also reflected in the decision to evacuate, where there are still residents who will evacuate if they see the waves coming. It is quite dangerous if the residents do not have enough time to reach the evacuation site or a safe place. In addition, to carry out evacuations, there are residents who need time to prepare. The evacuation preparation time is used by residents to prepare evacuation needs such as vehicles used to evacuate, carry valuables at home, or ensure the evacuation of other family members. The evacuation destination is selected based on the proximity level of the location where the residents reside with the purpose of evacuation. However, from the questionnaire results, it is known that residents choose to evacuate directly to the final evacuation site, which, in this case, is Mount Purbahayu. Residents feel safer if they go directly to a place that is far from the beach or higher than going to a temporary evacuation site or the nearest hotel or tall building. However, this can be dangerous, if residents do not have sufficient time to reach their evacuation goals. Most of the residents choose not to use the mode of transportation because they consider that the use of vehicles will delay the evacuation due to congestion. However, 30.4% of residents choose to use motorcycles and 2.3% use cars, so traffic jams or congestion can still occur.

TES in the Pangandaran subdistrict includes Pangandaran Grand Mosque, Pangandaran Shelter, and Cagar Alam. However, in addition to the three main TES, BPBD Pangandaran and BMKG are currently working to turn several hotels into additional TES to reduce disasters risk. Three Pangandaran official
TES can accommodate approximately 11,900 people, while the capacity of alternative TES if utilized 100% can accommodate 21,291 people. This indicates that the official TES and the new Alternative TES can accommodate the villagers and 10% of tourists if the number of tourists reaches the maximum. However, if the alternative TES is not 100% utilized, then the capacity will be less. As for the evacuation signs, based on the survey, the number of signs found was only 78, consisting of 45 appropriate signs between the BPBD data and surveys conducted and 23 uncharted signs, which can be pre-mapped but have coordinate errors. Meanwhile, the other 31 signs were not found in the field; this can be caused by missing signs or coordinates on the data that do not match in the field. From the results of the survey, it is known that there are signs with damaged conditions, such as fading, invisible, and show misleading direction.

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