Determining location of tsunami disaster temporary evacuation shelter (TES) utilizes network analysis in City of Makassar, South Sulawesi Province

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Abstract. The city of Makassar is a vulnerable area of the tsunami because it is located on the southwest coast of Sulawesi Island. The population is the highest number on Sulawesi Island. People will cause a lot of losses in the event of a tsunami in Makassar City. Therefore, preventive measures are needed as disaster mitigation. One of them is to determine the location of the Temporary Evacuation Place (TES) in the tsunami-affected area. The purpose of this study is to determine the location of TES on the coast of Makassar City. The variables used are DEM, land use, and travel time. TES locations are determined using GIS, the network analysis method with the tool service area. The analysis used was to sort out buildings in tsunami-affected regions based on the size and height of buildings according to the standards of the Federation Emergency Management Agency (FEMA). Based on the results of the research, there are 14 TES that are distributed in Makassar City. TES is in densely populated residential areas affected by the tsunami with an average height of 0-5 m above sea level. The TES in Makassar City is in the form of mosques, auditoriums, schools, and factories.

1. Introduction
According to the Intergovernmental Oceanographic Commission (IOC), the word 'Tsunami' originates from Japanese, which translates as 'harbor wave' [1]. The port waves have a meaning that is a series of travel waves produced by disturbances related to earthquakes that occur below or near the seabed, volcanic eruptions, underwater landslides, and coastal rock waterfalls [1]. Tsunamis can also be interpreted as high waves due to disturbances on the seabed or can be called seake. Seaquake is caused by tectonic activity in the form of collisions or shifts of plates [2].

The location of Indonesia, which is in three central plate meetings, namely the Eurasian plate, the Indo-Australian plate, and the Pacific plate, makes Indonesia an area prone to tectonic earthquakes. This collision implies that there are around six collisions of active plates that have the potential to trigger a strong earthquake. This makes Indonesia rich in active faults or active faults [3]. The faults have the potential to become an earthquake and even a tsunami.

One area in Indonesia that is prone to tsunamis is Sulawesi. The Eurasian plate, the Indo-Australian plate, and the Pacific plate are connected with faults in Sulawesi. In other words, this causes the area to be prone to tsunamis. In Table 1, it can be seen that Sulawesi experienced a tsunami 24 times in 1692-2000, but only seven tsunami data that can be taken and connected with earthquake events [4]. The table shows that the Makassar Strait is the area most frequently affected by earthquakes.

Makassar City is one of the cities prone to tsunamis because of its location, which is directly exposed to the Makassar Strait. In 2018, the population in Makassar was the largest, reaching 1.5 million [5]. Of the most significant number of people and the location of Makassar that is prone to tsunamis, this will
undoubtedly be detrimental if there is a tsunami that takes many lives. Therefore, preventive steps are needed to act when a tsunami occurs. One effort that can be done is to make a Temporary Evacuation Place (TES). The location of the proposed TES in the form of a vertical building that has a minimum TES floor height is the maximum tsunami run-up elevation at the TES location, plus 30%, plus 3 meters, and reduced the height of the land at the TES location [6].

| Location of the Earthquake | Date             | Depth | Magnitude (SR) | Run-up (m) |
|---------------------------|------------------|-------|----------------|------------|
| Makassar Strait           | 1st December 1927| Not recorded | 6.3          | 15         |
| Makassar Strait           | 11th April 1967  | 20    | 6.3            | 8          |
| Sulawesi Sea              | 14th August 1968 | 25    | 7.4            | 10         |
| Makassar Strait           | 23rd February 1969| 13    | 6.1            | 10         |
| Makassar Strait           | 8th January 1984 | 14.8  | 6.7            | Not recorded |
| Sulawesi Sea              | 1st January 1996 | 15    | 7.9            | 3.4        |
| Paleng Island             | 4th May 2000     | 18    | 7.5            | 6          |

Previous research that studied TES was in Pasir Nan Tigo Village, Koto Tangah District, Padang City using the Network Analysis method [7]. Network Analysis used is by comparing tools closest facilities, service area, and location-allocation. Nearest facilities are carried out by plotting as many as 16 points of tsunami-prone areas to reach TES, and the result is the fastest time to contact TES for 47 minutes while refugees must get to a safe place in less than 30 minutes. The service area is done by calculating the speed of refugees to reach the TES. Based on the results of the calculation that the travel time of the refugees to enter the TES in five minutes is equal to 300 seconds at a speed of 1.1 m / s so that the distance that can be taken for five minutes is 330 m. Even though the distance from the refugees to the TES is 1.98 km. Both methods are considered ineffective because of insufficient travel time for evacuation. Location - allocation method is carried out by adding three TES in the form of two mosque buildings and one school building so that the evacuation travel time becomes effective.

Other studies using similar methods [6] were carried out in Kota Pariaman, West Sumatra Province, by determining the location of new TES because existing TESs could not cover settlements in tsunami-prone areas. The method of determining the TES proposal is based on the boundary between inundation prone and safe zones so that the proposed TES is located at contours above 15 meters. The service area tools used refer to the Institute of Fire Safety and Disaster Preparation Japan to determine the scope of the TES area by making an area coverage of 541 m.

Therefore, the method of this research was carried out because previously there had been no research that determined the location of the TES based on the travel time of the refugees to the site of the TES and its area coverage. Besides, there has been no previous research regarding the determination of the location of TES conducted in Makassar City. The potential site of the TES is analyzed using Network Analysis with Service Area tools. The purpose of this study is to determine the location of proposals that can be used as TES. The results of the proposed TES location are expected to be a reference in evacuating refugees in the event of a tsunami in Makassar City.
2. Methodology

2.1. Study Area
The study was conducted in Makassar City, South Sulawesi Province. Geographically, Makassar City is located on the west coast of the southern part of South Sulawesi, with coordinates between 119 °, 18 '27.97" to 119 ° 32' 31.03" East Longitude and 5 ° 30' 18" - 5 ° 14' 49" South latitude. The height of this city varies between 0-25 meters above sea level. Makassar City has an area of 177.3 km² with a population in 2018 of 1.5 million.

2.2. Materials
This study uses DEM variables, land use, and travel time. DEM significantly increases the accuracy of tsunami inundation [8]. Besides, DEM is also essential for tsunami simulation and is very important in calculating tsunami inundation depth so that it can be used as tsunami mitigation such as tsunami inundation maps, determination of TES locations, and horizontal-vertical evacuation time maps [8]. The DEM used in this study was obtained from DEMNAS with Path 114 / Row 64. The use of residential land to find out the area that can be reached by TES so that it can be known if there are settlements that have not been contacted by TES. Also, road land use is needed as a unit of analysis in this study using the Network Analysis method [9]. The use of residential land used in this study was obtained from BIG with a scale of 1: 50,000 in 2018 [10]. Road use is derived from open-source data, namely Open Street Map. The best evacuation routes are not always short and straight roads. Various types of land use can have an impact on evacuation. For example, evacuation by road is significantly faster than crossing agricultural land [9]. Therefore, specific road data is needed by providing additional information such as speed on each road segment.

2.3. Method
Altitude data is processed from DEM and classified into two classes, namely 0 - 5 m above sea level and> 5 m above sea level. Areas with a surface height of 0 - 5 m above sea level were identified as tsunami inundated areas with 5-meter waves, while areas that had a surface height of more than 5 m above sea level were areas that were not flooded by the tsunami. Buildings that are recommended as disaster shelter are two-story, more than 12 meters high with dimensions of 10m x 15m [11]. Requirements for building rescuers or evacuation shelter, namely [11]:

- Concrete structure;
- Spacious and has a gathering place;
- Solid buildings;
- Multi-storey buildings;
- Has a minimum area of 150 m²;
- Designed to be earthquake resistant.

For this reason, the TES is determined from land-use data in the form of settlements selected from a building area of> 150 m² in the tsunami-affected area. Buildings from land use can be used as TES in the form of public facilities such as mosques, schools, and village offices.

After plotting the building > 150 m², it is necessary to look back on whether the building is under the requirements using Google Earth. If it is not appropriate, a search is carried out again to get the proper structure.

Then other land use data in the form of roads are given travel time information on each segment. Travel time is obtained from Google Maps to determine the time for residents to evacuate themselves. In addition, the determination of safe distance is determined to achieve the TES referring to the Institute of Fire Safety and Disaster Preparations Japan which states that [6]: Evacuation speed = 1 m / sec (walking speed for Older People); Evacuation process time = 12 minutes = 12 x 60 seconds = 720 seconds; Distance from TES ≤ 720 seconds x 1 m / sec = 540.72 m = 720 m [6]. Therefore, the travel time of residents to evacuate themselves is a maximum of 12 minutes on foot.
After getting the evacuation travel time, then analysis was carried out using Service Area tools. The service area is done to see the range of the area in the TES building with a travel time of 12 minutes. So that it can be seen in residential areas that can be reached by TES within 12 minutes.

3. Result and Discussion

3.1. Tsunami Affected Area

Tsunami affected areas are inundated due to tsunami wave run-up. The height of Makassar City, which tends to be flat (0-5 m asl) makes the tsunami-affected area in Makassar City covers a large area. In Figure 1, it can be seen that most area of Makassar City is a tsunami-affected area with a red indicator. The area affected by the tsunami is 112.10 km$^2$ while the area not affected by the tsunami is 65.14 km$^2$. Most of the areas affected by the tsunami in Makassar City were built areas dominated by densely populated settlements with a height of 0-5 m above sea level. The area is in the west of Makassar City until most are in the middle. Whereas for areas not affected by the tsunami are rice fields and shrubs with an average height of 8-10 m above sea level. The area not affected by the tsunami is to the east of Makassar City.

![Figure 1. Location of Temporary Evacuation Sites in Makassar City.](image)

3.2. Temporary Evacuation Site

In Figure 2, it can be seen that there are 14 TES in various sub-districts in Makassar City. The most TES is in Tamalate Subdistrict, which is three TES because the sub-district is a densely populated area. Fourteen of the TES indicated that the buildings were under the requirements described previously. The biggest TES among the other TES is the PT Eastern Pearl Flour Mills City Slide building located in Ujung Tanah District (Figure 2a & Figure 2b).
The amount of TES can also influence the distance of the TES to the beach so that there is a need for great and sturdy buildings to withstand tsunami waves. Table 2 is a list of names of buildings which are TES in Makassar City.

3.3. TES Service Area
Network analysis is a spatial analysis of the movement or movement of a resource from one location to another through human-made elements that form a network. One of the tools used in Network Analysis is the Service Area. The service area is defined as an area where refugees can reach evacuation facilities in a certain amount of time created using Network Analysis [12].

The service area of each TES is a residential area because the TES is expected to accommodate residents in certain regions. In Figure 2, it can be seen that all TESs can reach the built-up area, which is mostly residential. However, some areas that are not reachable by TES, but these areas are not affected by the tsunami.

**Figure 2a.** TES PT Eastern Pearl Flour Mills City Slide.  
**Figure 2b.** Road condition TES PT Eastern Pearl Flour Mills City Slide.
4. Conclusion
The location of 14 TES in Makassar City is spread in various sub-districts, the most TES is in Tamalate Sub-District, namely three TES because the sub-district is a densely populated area. The TES location follows the path with the speed of evacuation of residents within the TES area coverage for 0-12 minutes on foot. The location of the TES is in the tsunami affected area with an average surface height of 0-5 m above sea level, especially in densely populated areas.

Table 2. Temporary Evacuation Sites in Makassar City.

| Name of Building                             | Sub-district     | Coordinates         |
|---------------------------------------------|------------------|---------------------|
| Athirah Boarding School                     | Ujung Pandang    | -5.1351081, 119.4077229 |
| Poltekkes Audiotrium                        | Rappocini        | -5.1784193, 119.4448855 |
| Ujung Pandang IDF Indomaret                 | Tallo            | -5.1266292, 119.43624 |
| Mall of GTC                                 | Tamalate         | -5.1695232, 119.3885931 |
| Nurul Huda Mosque                           | Tamalate         | -5.1806406, 119.422137 |
| Makassar Polrestabes                        | Wajo             | -5.1322126, 119.4063568 |
| PT. Eastern Pearl Flour Mills City Side     | Ujung Tanah      | -5.1161291, 119.4087763 |
| Sekolah dan Harapan                         | Tamalate         | -5.1796012, 119.3949603 |
| Shop House Meteorologi Klimatologi dan Geofisika Hall | Panakkukang | -5.1428276, 119.450090 |
| UPTD AKPER ANGING MAMMIRI                   | Rappocini        | -5.159587, 119.4223093 |
| Al-Fatah Muhamadiyah Mosque                 | Mamajang         | -5.1739182, 119.4072652 |
| An Nur Mosque                               | Manggala         | -5.1718289, 119.4832136 |
| PT Malindo Makassar                         | Talamanrea       | -5.0898423, 119.4995023 |
| Al Muamalah Mosque                          | Talamanrea       | -5.1371674, 119.5038529 |
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