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Evacuation route and evacuation shelter planning for tsunami hazard in Pangandaran District

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The 2006 earthquake and tsunami which happened in Pangandaran caused the worst damage in the area. As we know, time and accessibility are very crucial in terms of evacuating people. There are several ways to reduce the impact of tsunami, such as evacuation direction map, evacuation route, evacuation shelter, and guide signs. The purpose of this research is to find out the potential location for the shelter evacuation and also the fastest evacuation route. Some variables used in this research are topography, accessibility, and travel time. This research also uses the GIS modeling using tools network analysis method in ArcGis to make the modeling for evacuation route and coverage area for evacuation shelter. Furthermore, this research also calculates capacity for evacuation shelter, the spatial data, the road condition, and the topography area. From the result, it can be concluded that the fastest evacuation route is slightly sloped, spacious enough, and approximately in a good condition. The location for tsunami evacuation shelter in Pangandaran is located in higher area and can be reached through the near settlement in the evacuation zone.

1. Introduction

Based on historical records, Indonesia is an area that often occurs earthquake and tsunami [1,2]. When the potential of earthquakes in Indonesia becomes higher, the potential for tsunamis in the region becomes higher too [3]. Based on records from the Directorate of Volcanology and Geological Hazard Mitigation (DVMBG) of the Department of Energy and Mineral Resources shows that there are 28 regions in Indonesia that are prone to earthquake and tsunami disaster [4]. Pangandaran bay, which is located in the south of West Java, is also an area through the active plate that is vulnerable to earthquakes. According to historical records, there was a tsunami disaster in Pangandaran in 2006 that caused 414 deaths [5].

In disaster reduction efforts, disaster management efforts are needed [6]. According to the Law of the Republic of Indonesia No. 24, 2007, disaster management is a dynamic, continuous and integrated process to improve the quality of measures related to disaster observation, analysis, prevention, mitigation, preparedness, early warning, emergency response, rehabilitation and disaster reconstruction [8]. Planning of the evacuation route and evacuation shelter is included in the tsunami disaster mitigation phase. Disaster mitigation is a series of efforts to reduce disaster risks through physical development as well as awareness and increased ability to deal with threats [8]. In the

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evacuation process, time and accessibility is very important. In disaster risk reduction there are several ways such as provision of evacuation route maps, evacuation shelters, and guidance signs [8].

2. Methodology

In this research, to make evacuation route needs some variables like topography, accessibility, and travel time. Network analyst method with tools new closest facility is the tools that can calculate fastest route and travel time, which in this research is used to make evacuation route. Furthermore, this research used evacuation shelter as the end of the evacuation route, travel from incident to facility and travel time component in each road segment. An incident that is used in this research is the settlement in the tsunami run-up zone. To calculate travel time using the formula (1).

$$t = S/V \tag{1}$$

Where t is Travel Time, S is Distance and V is Velocity.

The speed used in this research is the average walking speed of people during the evacuation. There are three speed assumptions according to people walking conditions during evacuation such as : (1) person with child, (2) an Independent elder person, and (3) adependent elderly person[7]. From three assumption, this research used the slowest walking speed of a dependent elderly person with speed 1,0 m/s. To determine potential shelter zone using provision from FEMA [9,10] as shown in table 1.

Table 1.Potential zone area location

No	Element	Indicator
1	Location	Over 200 m from the coastline and 100 m from the river
2	Population	Nearhigh population area
3	Accessibility	Less travel time fromthe tsunami to the coast Easy to access
4	Topography	At a height of more than wave to coast

To calculate the capacity for evacuation shelter using formulafor building capacity [8]. In this calculation, space for evacuation accommodation is 1m²/person with detail 0,8m²/personfor stay and 0,2m²/person for circulation. The calculation can be seen in formula (2) and capacity score of each building can be seen in table 2.

$$TEBC = \frac{(CS \times BA \times NrF)}{(SpP)} \tag{2}$$

Where TEBC is *Tsunami Evacuation Building Capacity*, CS is *Capacity Score (%)*, BA is *Building Area (m²)*, NrF is *Number of Floors*, and SpP is *Space needed for one person (m²)*

Table 2. Capacity Score

Building	Capacity Score
Worship Place	78%
School	30%
Office	23,6%
Shopping Center/Mall	23%
Hotel	26,3%
Hall and gallery	100%

3. Result and Discussion

3.1 Evacuation Shelter

The tsunami risk area in this study uses data from INARISK BNPB that provides disaster-related data throughout Indonesia. The extent of tsunami-affected areas belonging to BNPB uses calculations with the parameters of the tsunami wave heights in the coastline referring to the results of the BNPB study which is an annex of Perka No. 2 BNPB. In 2012, according to the Perka the maximum height that can occur in the area of PangandaranCiamis regency is 10 meters.

Shelter existingin Pangandaran area is spread in each district located in Pangandaran region. Pangandaran district has two existing Shelter, Sidamulih district has one existing shelter, Parigi district has three existing shelters, and Cijulang District has one existing shelter. Locations used as existing shelter in Pangandaran area ranges from public facilities such as mosques, fields, regent offices, and halls. In addition there is also an existing shelter deliberately built to become a shelter as it is located in the District of Pangandaran which has a tsunami shelter BNPB and Cijulang District that has Tanjakan Haras. Location data and shelter capacity can be seen in table 3.

Table 3. Existing Shelter

No	Existing Shelter	Districts	Capacity
1	Tsunami Shelter BNPB	Pangandaran	5100
2	Pangandaran Mosque	Pangandaran	682
3	Soccer Field	Sidamulih	-
4	Ciliang Village Meeting Hall	Parigi	126
5	Parigi Mosque	Parigi	292
6	Pangandaran Regent Office	Parigi	728
7	Conservation Area	Pangandaran	-
8	Tanjakan Haras	Cijulang	-

Figure 1 is a map of the potential areas of evacuation shelter located in the outer regions exposed to tsunamis. Areas with the widest potential are in Parigi Village, Cibenda Village, and Pananjung Village. Areas with the smallest potential shelters are located in Margacinta Village and Batukaras Village. Margacinta Village is the smallest potential area of shelters, because the village is quite far away and does not include the evacuation range within 30 minutes.

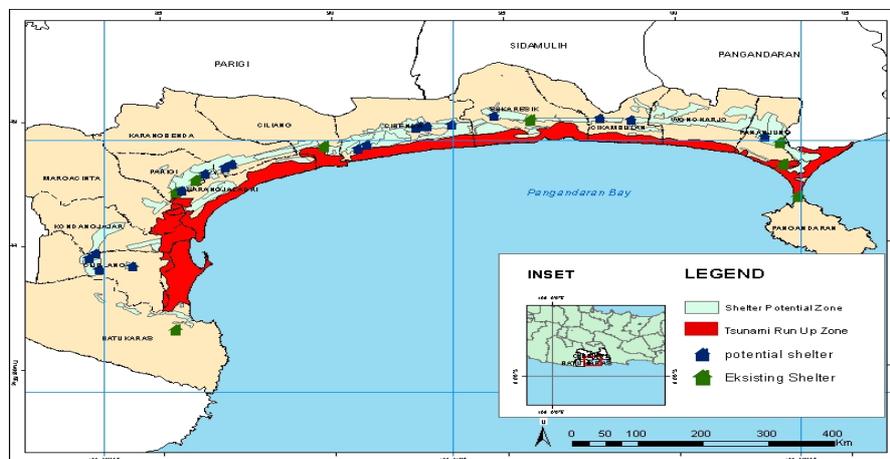


Figure 1. Shelter evacuation potential zone

The building that has the potential to become a temporary evacuation shelter in the coastal area of Pangandaran bay consists of various types of buildings ie mosques, schools, public health centers, government buildings, and shopping centers. The location of potential shelters are located at different altitudes that is between 9 - 18 mdpl. There are 16 buildings that have the potential to become temporary evacuation shelter . The location that has the lowest altitude is 9 mdpl SDN 1 Sukaresik building and the highest building location is SDN 1 Karangbenda building. Potential data of Pangandaran area shelter can be seen in table 4.

Based on the calculation of capacity building capacity of 16 potential shelter, it is known that the building that has the highest capacity is the building SMPN 1 Pangandaran with the number of 3,221 inhabitants. Building with the lowest capacity is Posyandu Dusun Patrol with a capacity of 11 residents.

Table 4. Shelter evacuation

No	Potential Shelter	Village	Districts	Elevation	Capacity
1	SMPN 1 Pangandaran	Pananjung	Pangandaran	11 m	3221
2	SMKN 1 Pangandaran	Pananjung	Pangandaran	11 m	2872
3	Al Falah Mosque	Cijulang	Cijulang	11 m	178
4	Al Islah Mosque	Cijulang	Cijulang	13 m	440
5	Al Istikmal Mosque	Cikembulan	Sidamulih	11 m	235
6	Ar Eiyadh Mosque	Karangbenda	Parigi	16 m	523
7	Hidayatul Falah Mosque	Cibenda	Parigi	17 m	138
8	MTS Bojong Cibenda	Cibenda	Parigi	16 m	396
9	Nuansa Bangunan	Cibenda	Parigi	16 m	155
10	Posyandu Dusun Patrol	Cibenda	Parigi	15 m	11
11	Puskesmas Cikembulan	Cikembulan	Sidamulih	12 m	725
12	SDN 3 Cibenda	Cibenda	Parigi	16 m	183
13	SDN 1 Karangbenda	Karangbenda	Parigi	18 m	263
14	SDN 1 Sukaresik	Sukaresik	Sidamulih	9 m	331
15	SDN 2 Cibenda	Cibenda	Parigi	16 m	241
16	Parigi Market	Parigi	Parigi	15 m	1482

3.2 Evacuation Route

In this method, the shelter is used as the end of evacuation route both the existing shelter and the potential building of the evacuation shelter and for the evacuation starting point is the point of settlement in the area exposed to the tsunami. There are four districts with a total of seven existing shelters and 16 existing potential shelter buildings. Pangandaran district has Nine routes leading to the four shelter (Figure 2). The nine routes are spread over three research villages located in Pangandaran district, two routes to potential shelter buildings of SMPN1 Pangandaran and SMKN 1 Pangandaran located within one area, one route to the shelter of Pangandaran Mosque, four routes to the BNPB Tsunami Shelter, and two lanes to the Conservation Area shelter. Sidamulih district has one shelter existing in the form of a soccer field and three potential evacuation shelter building that is mosque, Sidamulih health center, and SD Sukaresik (Figure 3).

Parigi district has the most number of existing shelters and has the most potential shelter building (Figure 4). It has 12 shelters with details of three existing shelters and Nine buildings that potentially become evacuation shelters. But, not all shelters become the end point of the evacuation routes,

because in modeling, it uses network analyst method to find the closest shelter from the starting point. The last district is Cijulang Subdistrict (Fig 5). In this area, there are two evacuation shelters, which is shelter Tanjung Harasand shelter Al Falah mosque.

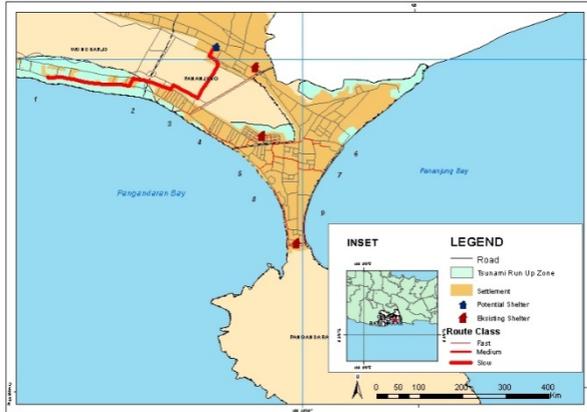


Figure 2. Evacuation Route Map of Pangandaran



Figure 3. Evacuation Route Map of Sidamulih

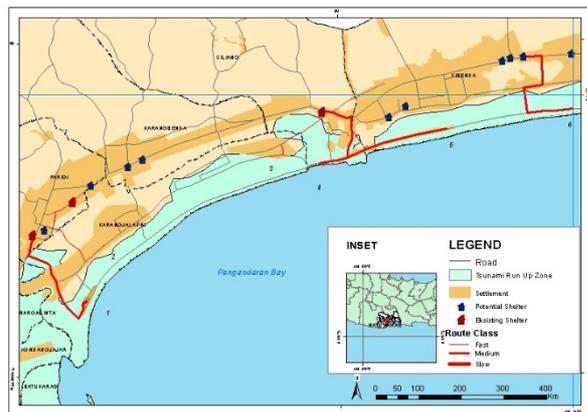


Figure 4. Evacuation Route of Parigi

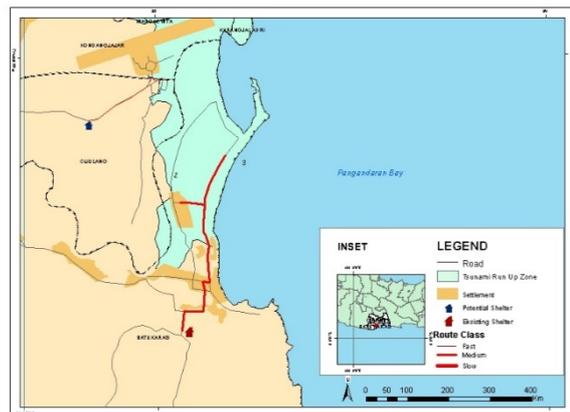


Figure 5. Evacuation Route Map of Cijulang

Table 5. Evacuation Path to Save Zone

District	Route	Travel Time (Minutes)	District	Route	Travel Time (Minutes)	
Pangandaran	1	30,89	Parigi	1	21,466	
	2	14,88		2	14,31	
	3	12,98		3	14,08	
	4	10,86		4	18,46	
	5	8,64		5	26,09	
	6	12,3		6	24,35	
	Cijulang	7	11,55	Sidamulih	1	10,5
		8	9,72		2	31,03
		9	8,52		3	11,74
	1	14,12		4	12,11	
	2	24,84		5	20,14	
	3	25,82				

Almost all routes can reach the evacuation shelter in the appropriate time set by BNPB which is 30 minutes (Table 5). There are two routes that must be taken within a longer time, which is Route 1 in Pangandaran district with travel time 30.89 minutes and Route 2 in Sidamulih district with a record time of 31.03 minutes. This is because there are no closer shelters to reach in less than 30 minutes. It can be seen from these results almost all of the routes have less than 30 minutes travel time according to the National Disaster Relief Agency stating that golden time of evacuation time is 30 minutes from the earthquake [8].

4. Conclusion

There are 16 potential evacuation shelters located in the potential shelter area. All shelters can be reached for 30 minutes from the beach. There are 23 new routes that reach all the way to the existing evacuation shelter and potential shelter building. With 23 routes and 16 new shelters, the evacuation path will start from the earthquake, the evacuation process uses 23 routes and leads to 15 shelters, both to existing shelters and to new potential buildings, until the arrival of PD-4 which means the threat of danger has been completed.

The modeling results in this research use network analysts which produce new paths that have already covered all tsunami affected areas. An addition of 16 buildings could potentially become temporary evacuation shelter and can accommodate a total of 11,394 people.

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