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The analysis of tsunami vertical shelter in Padang city

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Abstract

Padang is a coastal city, which is located opposite to the Indian Ocean. Just across Padang city there are areas of subduction, which can trigger a powerful earthquake and generate tsunami. Geologists have to say that the city of Padang is the area that is highly vulnerable to tsunamis in the near future.

Several studies have been conducted to prepare Padang city for tsunamis. Through the research, maps of tsunami inundation area has been successfully designed. So that the tsunami-prone areas, and tsunami safe area can be clearly identified.

According to Singh (2008), the time interval between the first powerful earthquake and tsunami to hit the coast of Padang is about 20-30 minutes. While residents have to walk 3-5 km to the safe area. It can be said that the time for tsunami evacuation in Padang city is very short. Therefore the choice of conducting vertical evacuation is urgent for the majority of the population rather than walking along the horizontal evacuation.

Padang city government with the aid of the international donors has built buildings for the shelter. Some of them are schools that have a strong structure, three storeys in which the roof are served as a tsunami evacuation. Data from the BPBDs office (Disaster Management Agency), stated that there are 13 tsunami evacuation buildings at this time with a total capacity of 30.550 people and the capacity for each building is varied between 1,000 - 3,000 people (BPBDs, 2013). This amount is very far from enough when compared to the potential loss of life as many as 400,000 people or more, or as only 7.64% of the total amount. And the location of the shelter buildings are not evenly distributed in tsunamis prone areas

Places for vertical tsunami evacuation in Padang are called TES (Temporary Evacuation Shelter). There have been 13 shelters established by the Government of Padang and BPBDs, and there is only one TES found in the study area. It really is not enough as it is seen in the range of services. Therefore the existing buildings and multi-storey structure is another alternate places to rescue in which they are expected to withstand earthquakes and tsunamis. This alternative building called Potential TES (P-TES)and there are 14 shelters for the study area.

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By using GIS analysis as well as buffer analysis method, a measurement against a range of services from 1 TES and 14 P-TES is conducted. Buffer radius service area in this analysis, are 450m, 900m, and 1350m. It means that the community who are in the circle will be able to reach shelter in time. As it is seen, the 15 shelters can accommodate refugees within a radius of 450m and 900m, and only few refuges can be accommodated within a radius of 1350m.

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Keywords: Tsunami; Evacuation Planning; Shelter; Community; GIS

1. Background

Padang is a coastal city, which is located opposite to the Indian Ocean. Just across Padang city there are areas of subduction, which can trigger a powerful earthquake and generate tsunami. Geologists have to say that the city of Padang is the area that is highly vulnerable to tsunamis in the near future. Padang is the third biggest city in Sumatra with a population of about 800,000. It is the capital city of the West Sumatra Province of Indonesia. It is situated directly on the coast of the Indian Ocean and is exposed to potential tsunamis in the future (see Fig. 1).

The potential tsunami hazard in Padang city has been studied by the International research community. Among them are (Borrero, Sieh, Chlieh, & Synolakis, 2006), (Taubenböck et al., 2009) and (McCloskey et al., 2008). They all have the same opinion that Padang is the region that is the most likely to be devastated by any huge tsunami that may occur in the near future.

The potential tsunami risk in Padang city exists as a high probability because there are many people who live and move in the coastal region. Most of the economic activity in Padang city, includes critical infrastructures, medical services, schools, public offices, and transportation networks, are also constructed parallel to the coastline; this results in a high exposure to potential tsunami waves.

It is estimated that about 50% of residents live in the lowland areas around the coast or in areas that are between 0 and 5 meters elevation above sea level. If a large tsunami occurs then they are indeed the communities that would need to be saved and/or rescued (BPS, 2011). Padang city is situated on very flat liquefiable ground. To reach an altitude of 5m from the coast, one has to walk more than 3 km. The population of the city is dense with 844.316 inhabitants (BPS, 2011), therefore it would be very difficult to evacuate about 400,000 people in a short time to a tsunami safe zone. There would not be enough time for people to reach a safe place or higher. Transportation facilities are far from sufficient and crowded vehicles with people who are panicking at the time would cause traffic jams.

The local government has constructed various efforts to develop local early warning systems and disaster management. These activities include preparing legislation (spatial planning, organization, Standard Operation Procedure, Early Warning System), preparing evacuation infrastructure (maps and evacuation routes as well as signposting), building shelters (vertical shelter), preparing resources for government officials, and in the community, and other support activities that must be done to anticipate the tsunami hazard. Therefore, this paper specifically researches on Shelter; both horizontal and vertical shelter.

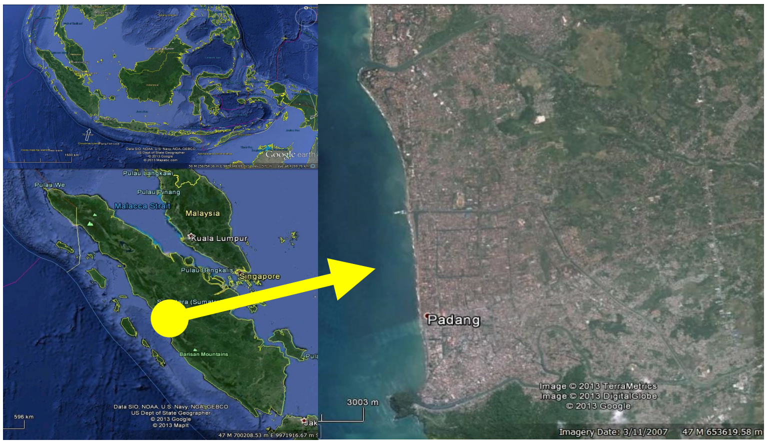

Fig. 1. Padang city
Source: Google Earth image

2. Characteristics of the tsunami in Padang

Disaster characteristics need to be identified and understood by the government and the community, especially those living in disaster-prone areas. This action is an attempt to "mitigate", against the disaster impact, which means actions are expected to reduce the impact of the disaster. Understanding of the hazards includes a thorough knowledge of the occurrence of such hazards; levels of possible disasters, the scale of disaster, destruction mechanism, sectors that will be affected by the disaster, as well as the impact of the damage.

The source event that could create a tsunami in Sumatra is the Sunda-arc subduction zones, both submarine features. When an earthquake occurs, the sea bed over the fracture zone may be catastrophically displaced, causing a collapse or an upheaval of the over-lying water mass. The Sunda-arc is one of the most active plate tectonic margins in the world (UNESCO-IOC, 2007).

Padang city is located in close to subduction zone with earthquakes that can cause tsunamis. Tsunami waves travel quickly and they reach the coast in very short period of time (GITEWS, 2008a). In that way, Tsunamis in Padang are called ‘local tsunamis’.

According to Singh (2008), the time interval between the first powerful earthquake and tsunami to hit the coast of Padang is about 20-30 minutes. While residents have to walk 3-5 km to the safe area. It can be said that the time for tsunami evacuation in Padang city is very short.

Several studies have been conducted to prepare Padang city for tsunamis. Through the research, maps of tsunami inundation area has been successfully designed. So that the tsunami-prone areas, and tsunami safe area can be clearly identified. Based on Padang Consensus on Official Tsunami Hazard Map-Protocol Nov 2008 (GITEWS, 2008b), has agreed an evacuation map for the city of Padang as shown below.

Fig. 2.Tsunami evacuation map Padang and study area
Source:http://www.gitews.org/tsunami-kit/id/id_tsunami_evacuation_map_padang.html

3. Characteristics of study area

In this paper, an analysis of the shelter just in the North region of Padang city. The study area (see Figure 2.) consists of 10 villages in 3 sub districts, with a total area around 47.35 Km2, region is split in two by the main road; the left region is densely populated residential area, and the area right there is an airport, was once for the commercial, now used by the military. Residential population in this region is not dense, and this is the side of the safe zone area. So for the residents who live on the right side, have a better chance to escape the tsunami.

In the northern region, has a very flat topography and very few multi-storey buildings. Unlike in the town centre which has many tall buildings as evacuation centres, and southern regions that have hills as a natural shelter. The study area has a high enough density of 439 to 34072 Person/km2, it can be seen in the table below.

Table 1. Villages in Study Area

No	Villages	Sub Districts	Area (km2)	Household	Pop_2011	Density
1	Koto Pulai	Koto Tangah	5.53	479	2430	439
2	Batang Kabung Ganting	Koto Tangah	3.32	2932	12488	3761
3	Bungo Pasang	Koto Tangah	3.32	2641	12107	3647
4	Koto Panjang Ikua Koto	Koto Tangah	8.18	2237	10627	1299
5	Dadok Tunggul Hitam	Koto Tangah	11.78	3626	16354	1388
6	Parupuk Tabing	Koto Tangah	9.41	4865	20797	2210
7	Air Tawar Barat	Padang Utara	1.53	4814	15597	10194
8	Air Tawar Timur	Padang Utara	1.39	1303	4013	2887
9	Kurao Pagang	Nanggalo	2.28	2509	11684	5125
10	Surau Gadang	Nanggalo	0.61	5144	20784	34072
			47.35	30550	126881	

Source: BPS (2011)

4. TSUNAMI EVACUATION METHOD

4.1. Horizontal evacuation

There are two methods of evacuation of the tsunami threat; horizontal and vertical. Horizontal Evacuation is evacuation by going away from the coast towards the tsunami safe area using the (recommended) on foot instead of driving.

This method requires evacuation pathways that utilize roads in the city, and several major roads in residential areas. In the event of a tsunami evacuation, and all residents moving by vehicles, there will be a traffic jam.

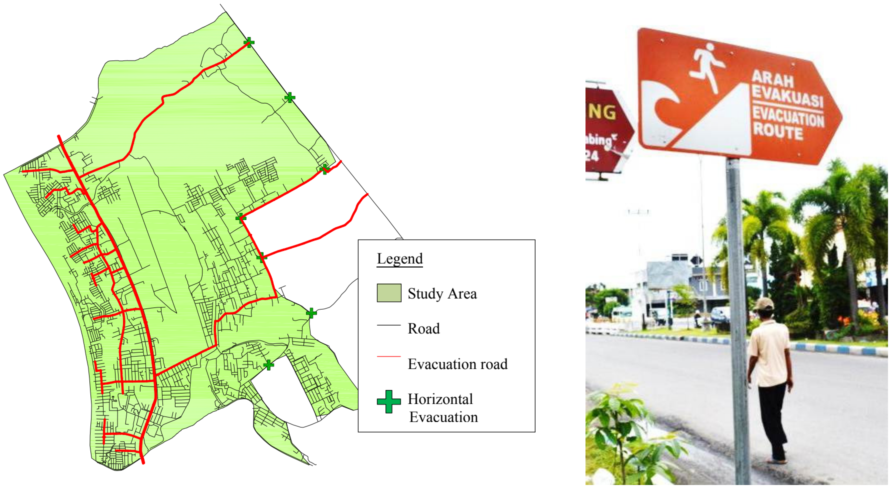

Fig. 3. (a) Horizontal Evacuation, (b) Signpost of Evacuation Route in Padang city

In order to reach safe zone, the speed of evacuees' movements in evacuation is the key factor before the tsunami strike. The Japan Institute for Fire Safety and Disaster Preparedness (1987, in (Amin, 2006)) gives an overview of the walking condition and average walking speed in disaster evacuation as shown in Table 2.

Table 2. Evacuee walking condition and average walking condition

Walking condition	Average walking speed
A person pushing a perambulator	1.07 m/s
A person with a child	1.02 m/s
An independent walking elderly person	0.948 m/s
A group of walking elderly people	0.751 m/s
(Institute for Fire Safety & Disaster Preparedness, 1987	

To analyse the mileage of refugees in the study area, using the lowest value from the table above, which is 0.751 m/s. According to (Singh et al., 2010), tsunami in Padang city came in 20-30 minutes, and is also expected, of refugees can save themselves as soon as possible within 10 minutes. Thus, there are three groups of speed; 10 minutes, 20 minutes, and 30 minutes, or 600 seconds, 1200 seconds and 1800 seconds. If multiplied by the speed of walking of refugees = 0.751 m/s the mileage for each group time is 450m, 900m, and 1350 meters. The third level of this range will be applied in the analysis.

Geographic Information System (GIS) is an information system that can analyse the data that is spatial or space. GIS has several tools for analysing spatial data, including Buffer Analysis, Overlay Analysis, and Network Analysis. By using Buffer Analysis, with the range/distance 450m-900m-1350m, which is applied at some point in the safe zone, it will show on the map (Figure 4), the level of service areas, from every point of the safe zone. There are many regions that are not affordable, or of refugees will not be able to reach the safe zone on time, especially residents who live in the region left of the main road.

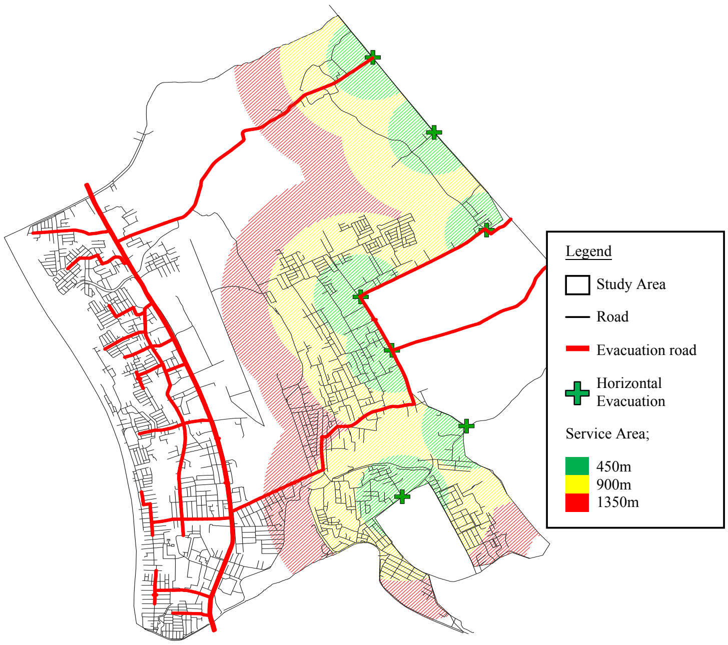

Figure 4. Service area of Safe Zone (450m, 900m, &1350m).

4.2. Vertical Evacuation

Vertical evacuation is the act of save themselves the way toward higher ground. Neither was a hill (natural shelter) or a multi-storey building. Because the study area, no hills at all, or very flat topography, then the option is used to build some of the more than three-story building, or utilizing the existing multi-storey buildings as vertical building.

There are several naming for vertical evacuation building, including; Tsunami Evacuation Buildings (TEBs) (Jay Raskin et al., 2009), Vertical Evacuation Structures (P646A, 2009). In Padang city called the TES or Temporary Evacuation Shelter. It said temporary, because it is expected to accommodate refugees, within 2-3 hours, before the refugees were evacuated to the tsunami evacuation centre in the safe zone. In addition to the standard equipment of vertical building shelters also are not available on the TES, except where standing refugees.

Padang city government with the aid of the international donors has built buildings shelter. Some of them are schools that have a strong structure, three storeys, and on the roof which served as a tsunami evacuation. Data from the office BPBDs (Disaster Management Agency), stating that there are 13 tsunami evacuation buildings at this time with a total capacity of 30.550 people and the capacity for each building is varied between 1,000 - 3,000 people (BPBDs, 2013). This amount is very far from enough when compared to the potential loss of life as many as 400,000 people or more or as only 7.64% of the total amount. And the location of the shelter buildings are not evenly distributed in tsunamis prone areas.

There is one of TES, in study area, namely a 3-storey mosque with a capacity of 1500 persons, who have been designated by the city government through BPBD (Disaster Agency) Padang city and the NGO Mercy Corps Indonesia. One of TES is not enough to accommodate all the refugees in this study area. Therefore, take some Potential Shelter or ‘P-TES’. TES and P-TES in the study area are represented in the map below.

Potential TES are existing multi-storey building, which is considered to be strong, which can accommodate the tsunami refugees for a while. It is still necessary to question the strength of the structure of the PTES. There are some buildings that are structurally new building and have been designed to withstand strong earthquakes and can also withstand the expected tsunami waves, and there are several other buildings that need to recalculate the strength of structure.

Table 3. Potential Vertical shelter in Padang City

No.	Name of Shelter	Address	Distance From Beach	Capacity (Person)
1	Escape Building Ktr Gubernur	Jl. Jend. Sudirman No. 51, Padang Barat	600	3500
2	Bappeda Prov. Sumbar	Jl. Khatib Sulaiman	700	2300
3	Mesjid Raya Sumbar	Jl. Khatib Sulaiman	750	4000
4	Mesjid Muhajirin	Komp.Pasir putih RT/RW; 3/5, Bungo pasang.	100	1500
5	Pasar Inpres	Pasar Raya	500	3750
6	SMA N 1 Padang	Jl. Belanti Raya No. 11 Padang	800	3000
7	SMK N 5 Padang	Jl. Beringin No. 4 Padang	400	2200
8	SMP N 4 Padang	Jl. Pulau Karam No. 82 Padang	700	1200
9	SMP N 7 Padang	Jl. S. Parman Lolong Padang	400	2500
10	SMP N 25 Padang	Jl. Beringin Belanti Timur, Padang	800	2300
11	SD N 15 Lolong	Belakang Taman Makam Pahlawan Padang	75	800
12	SD N 23 / 24 Ujung Gurun	Jl. Veteran No. 82 Padang	200	2500
13	Sekolah Al Azhar 32 Padang	Jl. Khatib Sulaiman	750	1000
			TOTAL	30,550

Source: Mercy Corps Indonesia (NGO-2014). Note; yellow = TES in study area.

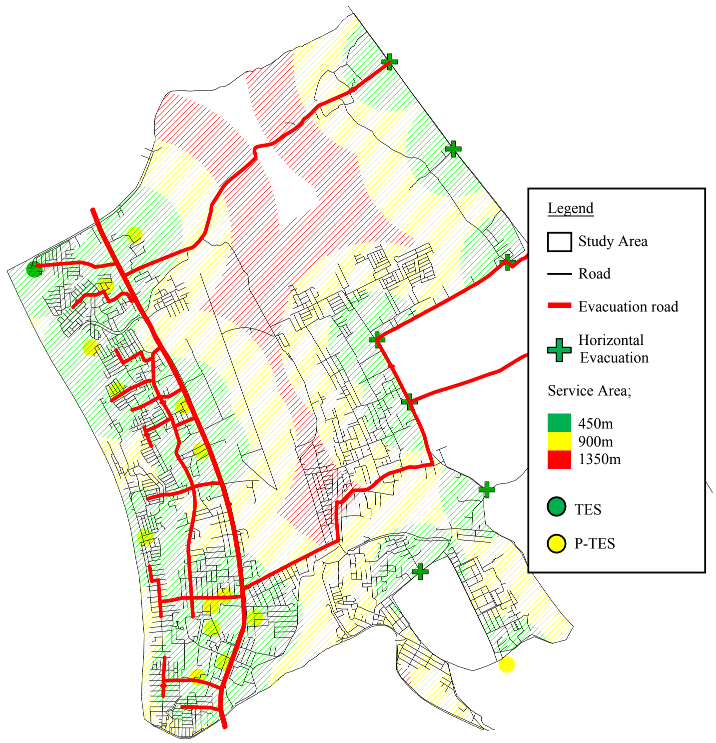

Fig. 5. Service area of TES, P-TES and Safe Zone (450m, 900m, &1350m).

Then by using Buffer Analysis, with the same range with the previous analysis (450m, 900m, and 1350m), the location points; TES and P-TES, analysed service area. Seen on the map below, that the distribution of TES, P-TES and Safe Zone points are able to serve most of the refugee's residents in the study area. While there are some spots that are not provided, but when viewed from the location, are still able to get close to the location of the safe zone.

5. Conclusion

Based on geographical location and condition of Padang city, the International Researcher stated that the city is dangerous and has a high level of vulnerability to tsunami hazard. The estimated time for the evacuation is 20-30 minutes respectively. It is believed for this study area that most of the refugees will not be able to reach a safe place in the right time if they rely merely on horizontal evacuation .Therefore the choice of conducting vertical evacuation is urgent for the majority of the population rather than walking along the horizontal evacuation.

Places for vertical tsunami evacuation in Padang are called TES (Temporary Evacuation Shelter). There have been 13 shelters established by the Government of Padang and BPBDs are, and there is only one TES found in the study area. It really is not enough as it is seen in the range of services on Figure 5. Therefore the existing buildings and multi-storey structure is another alternate places to rescue in which they are expected to withstand earthquakes and tsunamis. This alternative building called Potential TES (P-TES). There are 14 shelters for the study area.

By using GIS analysis as well as buffer analysis method, a measurement against a range of services from 1 TES and 14 P-TES is conducted. Buffer radius service area in this analysis, are 450m, 900m, and 1350m. It means that the community who are in the circle will be able to reach shelter in time. As it is seen in Figure 5, the 15 shelters can accommodate refugees within a radius of 450m and 900m, and only few refuges can be accommodated within a radius of 1350m.

Further research is to use network analysis as the substitution for buffer analysis. Refugees generally utilize the road network to run, while the buffer analysis methods tend to use the straight distance without a hitch. Therefore, further analysis is to determine the service area of any shelter to the road network or available evacuation route.

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