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Tsunami Evacuation Routes Using Network Analysis: A case study in Padang

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Abstract

The Village Pasir Nan Tigo located in the sub-district of Koto Tangah, Padang city. Geographically, the village located in the coastal area and some areas in this village are separated by a river. Topographically, this area is flat, and there are no hills that can be used as a natural shelter. The village located in the Tsunami Inundation Area, where the population in this district should be immediately evacuated to a safe area if there is a tsunami warning from the government or large tsunamigenic earthquakes.

However, due to the river that divides some areas, the refugees have to follow the main road in the village along the coastline before turning onto the highway of Padang and move towards a safe zone. The advice from the government is, they must run away from the seashore and get into the safe areas as quickly as possible. In other words, instead of moving towards the east of the city of Padang, the refugees must run to the south of the city. In this context, this study aims at assessing the evacuation route in this area by using Network Analysis. With the objective of reducing the number of fatalities in this village, the shortest path algorithm is applied to analyse the direction of movement, and the travel time communities need to get to a safe area of the tsunami. The results of closest facility analysis and service area analysis show that the horizontal evacuation method for Pasir Nan Tigo populations is ineffective or inaccurate, with the main reason; that the distance is very far. Therefore, the need for a vertical evacuation plan such as building a shelter is highlighted in this paper.

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Keywords: Tsunami; Evacuation Route; Network Analyst; Short Path Analyst; GIS

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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 a tsunami. Geologists have to say that the Padang city is the area that is highly vulnerable to tsunamis. Padang is the third biggest town in Sumatra with a population of about 800,000. It is the capital city of the West Sumatra Province of Indonesia. It is positioned directly on the coast of the Indian Ocean and is exposed to potential tsunamis in the future [1, 2, 10].

The potential tsunami hazard in Padang city has been studied by the International research community [1, 4, 13, 18, 21]. They all have the same opinion that Padang is the region that is most likely to be devastated by the massive tsunami that may occur shortly. The potential tsunami risk in Padang city exists as a high probability because many people live and move in the coastal region. The city often experiences large-scale earthquakes. In 2009, Padang city experienced an earthquake on a scale of 7.9. The earthquake, fortunately, did not generate the tsunami but there were 1000 casualties, and many houses or buildings were severely damaged. Some important infrastructure is also damaged, such as hospitals, some roads, bridges, water networks, and power grids [15, 16].

Based on Harisman [14] research, Pasir Nan Tigo village has a low level of mobility vulnerability, due to the location factor which is far from the safe tsunami zone. Pasir Nan Tigo village is the place of the study in this study. This study aims at assessing the evacuation route in this area by using Network Analysis. With the objective of reducing the number of fatalities in this village, the shortest path algorithm is applied to analyse the direction of movement, and the travel time communities need to get to a safe area of the tsunami.

2. Characteristic of the tsunami in Padang city

Padang city situates nearly to subduction zone with earthquakes that can cause tsunamis. Tsunami waves travel quickly, and they reach the coast in short period [11]. In that way, Tsunamis in Padang are called 'local tsunamis' or 'Near-Field Tsunami' [19, 22] and [7] [3] [21]. According to Singh, Hananto [20], the time interval between the first powerful earthquake and tsunami to hit the beach of Padang is about 20-30 minutes. Thus, it expected that residents could save themselves <30 minutes. In contrast to the actual condition, the residents have to walk 3-5 km to the safe area. The time interval for tsunami evacuation in Padang city is very short or extreme time. Through the research, maps of the tsunami inundation area have successfully designed. So that, the tsunami-prone areas, and safe tsunami area can be identified. Padang Consensus on Official Tsunami Hazard Map-Protocol Nov 2008 [12] [5], has agreed on an evacuation map for the city of Padang.

To reach the safe zone, the speed of evacuees' movements in evacuation is the key factor before the tsunami strikes the city [2]. 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 from 0.751 m/s to 1.07 m/s for several walking conditions. Also, the TCRP / NCHRP study recommended the speed of refugees walking in evacuation is 1.1 m/sec or 66 m/minutes [17]. To analyse the mileage of refugees in the study area using 1.1 m/s.

3. Research Methodology

Pasir Nan Tigo is one of 104 urban villages in Padang city, which is part of the district Koto Tangah. This village is located in the north, and on the coast of Padang city. Geographically, this village situated between 0°48'52"S - 0°51'57"S 100°17'26"E - 100°20'30"E elongating from north to south, and practically most of the area, is on the coast.

Based on the Tsunami Evacuation Map for Padang city, the entire village is in an inundation area or red zone. Thus, the entire population will have a high risk of tsunami threat. As Figure 1 shows, the position of Pasir Nan Tigo village located on the coast, and the city government of Padang has pointed out that the whole area is in the Tsunami Inundation Area.

The area of Pasir Nan Tigo is 14.57 km2, and the population in 2016 is 9435 inhabitants. The density of this village is 648 person/km2. The number of households is 2359. Therefore, the average of household members is four. The male population is 4787 people, and the female population is 4648, and the composition looks balanced [6]. Distribution of residential housing in this village can be seen in Figure 7(a).