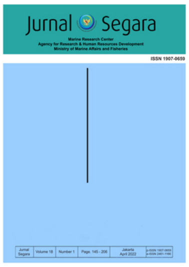

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DETERMINING THE CAPACITY OF TEMPORARY EVACUATION SHELTER IN CARITA AND LABUAN DISTRICT PANDEGLANG REGENCY

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ABSTRACT

A tsunami due to the GAK flank collapse occurred along the Sunda Strait Coast on December 22, 2018, with areas severely hit including Labuan and Carita Districts on the coast of Pandeglang Regency. The disaster resulted in the death of 431 people, more than 7200 injured and 46,646 people lost their homes. To anticipate the number of disaster casualties, disaster mitigation efforts are carried out using network analysis applications from GIS (Geographical Information Systems) software. The data used in the network analysis process is road data obtained from the Open Street Map in 2019 and supported by wave propagation and speed time to TES. This study used a walking speed of 0.751 m/second for elderly people. The results of the network analysis process showed the best route to the proposed Temporary Evacuation Shelter (TES). There are eight proposed TES in Carita District from which seven are located on Raya Anyer Sirih Street and another one is located on Perintis Kemerdekaan. The number of residents in each area segment in the proposed TES is between 179 and 2,677 people. Yet, there are four existing TES units in Carita District located on Perintis Kemerdekaan Street. In Labuan District, one TES unit is proposed, which has the capacity of up to 4,376 people. Meanwhile, its existing TES is in the form of a Tsunami Shelter Building with a capacity of 23,635 people.

Keywords: GAK Tsunami, NetWork Analysis, Temporary Evacuation Places, Segment Area Capacity.

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INTRODUCTION

The Sunda Strait and its surrounding areas are prone to tectonic and non-tectonic disasters. The tectonic disaster is caused by the megathrust process. The eruption of the Krakatau Volcano is another geological disaster in the form of non tectonic disaster (Prasetya, 1998; de Lange *et al*., 2001; Maeno & Imamura, 2007). It is recorded in the history that in 1883 a large tsunami occurred in the Sunda Strait which was triggered by the eruption of Krakatoa and resulted in the loss of more than 36,000 lives and damage to infrastructure (Self & Rampino, 1981; Simkin & Fiske, 1983; Sigurdsson *et al*., 1991). The same event occurred again in 1927 and triggered a small tsunami around the caldera of the 1883 Krakatau eruption. The tsunami was triggered by the emergence of the Anak Krakatau Volcano to the sea surface (Yudhicara & Budiono, 2008).

The tsunami disaster that occurred on December 22, 2018 was caused by the eruption of Anak Krakatau in the form of material flank collapse of steep Gunung Anak Krakatau as described by Walter *et al*. (2019) and Williams *et al*. (2019). The Sunda Strait tsunami on 22 December 2018 has caused the death of 431 people, more than 7200 injured and 46,646 people lost their homes (Ramadhan, 2018). The tsunami also caused damages to infrastructure on the coast of the Sunda Strait in both Banten and Lampung, with the most severe damage occurring in Pandeglang Regency, Banten Province.

In a book issued by the National Disaster Management Agency (2019), Banten Province has 1,551 villages, of which 22 villages are in the high hazard class for tsunamis and 77 villages have a medium hazard class spread over 5 districts/cities. (Pandeglang, Lebak, Tangerang, Serang dan Cilegon).

Regarding the number of fatalities in the event of a disaster, it is necessary to carry out emergency evacuation efforts as soon as possible. Emergency evacuation is a complex process that includes the speed and safety of evacuating residents to a safe location and as far away from disaster as possible (Ye M *et al*., 2012). According to Tammina & Chouinard (2012), the tsunami evacuation system is divided into five aspects, namely evacuation routes, evacuation locations, evacuation buildings, evacuation support facilities and community preparedness. For evacuation in urban areas; emergency shelter locations are in open locations such as city parks, green open spaces, stadiums, school playgrounds and other locations that can provide a safe place for disaster casualties or refugees. The safety of the lives of refugees is the main priority in the event of a disaster (Unal *et al*., 2016).

On December 22, 2018, there was a tsunami in South Lampung Regency. This tsunami was caused by the eruption of the Krakatoa volcano (GAK). This study used a network analysis process to get to the closest TES. The results of the analysis obtained an evacuation time of 22 minutes (BKL, 2018), and it was proposed that there were 13 TES spread across Katibung District, Sidomulyo District and Kalianda District. The distribution of the TES in each district was as follows: Katibung district 5 shelter, Sidomulyo district 2 shelter and Kalianda district 6 shelters. (Nugraha *et al*., 2020; http://repo.itera.ac.id).

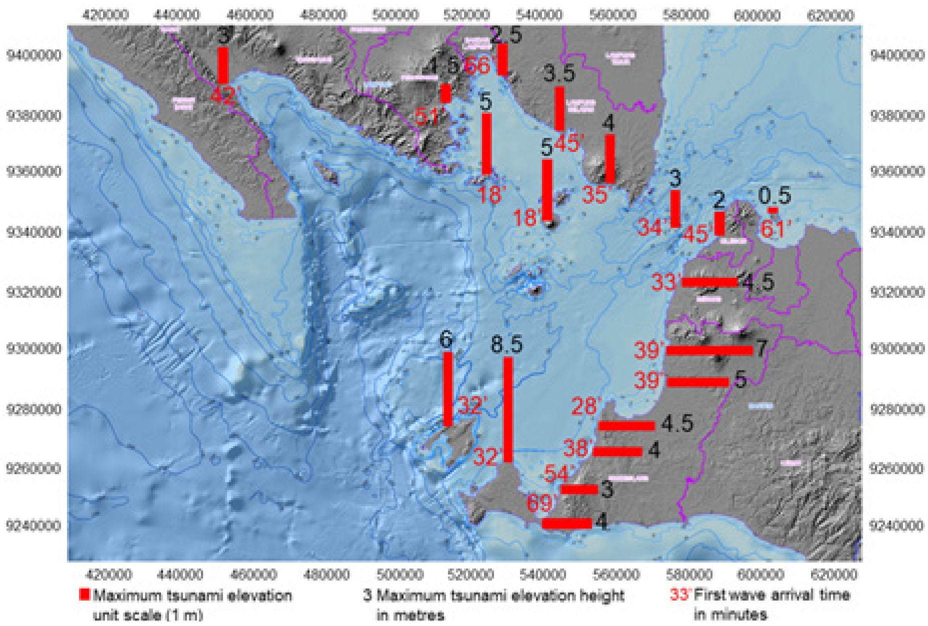

Figure 1. Time of propagation (red numbers) and maximum tsunami height in m (black numbers). Source: Annunziato *et al*., 2019

The tsunami wave propagation time hit Carita and Labuan Districts was 39 minutes with the wave heights were 7 m and 5 m respectively (Annunziato *et al*., 2019) (Figure 1). The maximum wave inundation occured in Labuan was 200 m from the shoreline (Borero *et al*., 2020).

To reach a safe area, the main factor was to get to the evacuation site as soon as possible before the tsunami hit the city (Ashar *et al*., 2014). Due to the tsunami disaster in Carita and Labuan districts, it was necessary to provide an evacuation route or route through the main road access to the Temporary Evacuation Shelter (TES) in a short time.

Residents in disaster-prone zones are expected to be able to immediately go to the available TES or to the proposed TES in a short time. The total capacity of the population residing in the location of the route area segment to TES needs to be known using the PIP (People in Pixel) approach. From the PIP it can be seen the number of residents in that segment of the area. Based on a study conducted by the BPBD of Pandeglang Regency, 253 TES were needed with various capacities. The prohibition on the construction and use of TES at a distance of 500 meters from the beach is also intended to provide additional safety guarantees for the community using TES (BPBD Pandeglang, 2019).

The tsunami in Carita District on 22 December 2018 reached an altitude of 2.58 meters and struck the surrounding coastal areas after the 40th minute (BMKG). Carita district is in a disaster-prone zone based on Inarisk Map from BNPB (2016).

Research on rapid evacuation is very important to minimize the number of casualties during the disaster (Takayama & Miwa, 2014). This paper discusses mitigation efforts towards Temporary Evacuation Shelter using the network analysis application in GIS toolkit software. The network analysis process used the elderly travel time. The aims of this research are: 1) Provide area segment or area route to Temporary Evacuation Shelter (TES) in a short time through the best route and main road network; 2) Proposed addition of TES in densely populated locations. While the research objectives are 1) Availability of area segment or area route to Temporary Evacuation Shelter (TES), 2) Proposed some TES are available in densely populated locations.

METHODOLOGY

Field Setting

Carita and Labuan district are located in Pandeglang Regency, on the west coast of Banten Province. Pandeglang Regency is known for tourism, as a number of hotels and resorts, located along the coast, are heavily occupied during the long holiday season (Syamsiddik *et al*., 2020). Carita District has an area of 41.87 km^2 while Labuan District has an area of 15.66 km^2 (BPS Kabupaten Pandeglang, 2017). These two districts are in the Sunda Strait and facing Mount Krakatau and the Indian Ocean. Carita district is the mainstay of beach tourism in Pandeglang Regency (Lesmana *et al*., 2020).

Labuan district has a PPI (Fish Landing Base) and Labuan Electric Steam Power Plant (PLTU), Labuan is an important area for the economy of Pandeglang Regency, Banten Province (Fahrezi *et al*., 2019). Labuan District is a low-lying area that is very vulnerable to disasters such as the tsunami disaster caused by the 2018 Krakatau Volcano eruption (GAK). Based on these conditions, it is necessary to do effective planning in disaster mitigation. Through observations from 2D, 3D visualization and sea-wall modeling, it can be seen that the coast of Labuan has a level of natural protection, especially low coastal vegetation in the north, residential areas that are relatively close to the shoreline further increase the vulnerability of this region. Therefore, it is necessary to build a sea wall that surrounds the coastline of Labuan District (Fahrezi *et al*., 2019).

Process of data collection

The research was carried out from March to October 2020. This study used secondary data including (Table 1).

Technique data analysis

The first step in carrying out the Network analysis process is to determine the location of the TES Determination of potential TES areas and TES proposals follow the provisions of Budiarjo (2006)

Table 1. Secondary data used in this research

No	Data	Sources	Year
1.	Administrative limits	Institution for Geospasial Information Scale 1:25,000	2018
2.	Tsunami Prone	Inarisk Map	2016
3.	Road Network	PT Infimap Geospasial System Scale 1:5,000	2019
4.	Beach Line	Pleiades Image	2018, 2020
5.	People In Pixel	PT Infimap Geospasial System	2018

Table 2. Requirements for TES Potential Areas based on Budiarjo (2006), modified

No.	Factor	Indicator
1.	Location	● Located at a distance of 100-200 m from the coastline ● Located at a distance of 100 m from the river
2.	Population	Located near high population concentration
3.	Accessibility	Travel time is less than the time the tsunami waves reach the coast
4.	Topography	Being in a tsunami hazard area
5.	Building Orientation	● Function as public facilities and private property ● Earthquake resistant construction

which have been modified according to real conditions (Table 2).

The second step is determination of travel time. Determination of travel time of movement of refugees in evacuation is a key factor because the people must have reached TES before the tsunami waves reach the coast. The Japan Institute for Fire Safety and Disaster Preparedness, (1987) provides an overview of walking conditions or average walking speed in an evacuation disasters as shown in Table 3.

Average walking speed in this study uses the lowest speed that is 0.751 m/s (Ashar *et al*., 2018). The reason for using the lowest speed is that it is necessary to propose some TES in several locations in disaster-prone areas. The process is carried out to determine the travel time of the movement of people to reach TES using the equation 1.

$$t = S/V \quad \text{......} \quad 1)$$

where,
t = Travel time
S = Distance (m)
V = Speed (m/s)

Additionally, distance determination in each road segment employed calculate geometry thus presented the distance component or road length in meters. Moreover, the Network Analysis processed by ArcGis software was used to get the best TES route (all road data is processed by generating a Network Dataset (ND) (ESRI, 2010). One of the tools from the Network Analysis extension that serves to determine the TES coverage area is the Service Area - used to find evacuation service areas, namely TES around disaster-prone locations on a road network. A service area is an area that includes all accessible roads, i.e. roads that lie within the specified impedance - in this study it is the lowest evacuation speed time. As in the evacuation service area the settlements are either within the coverage of TES and outside of TES because there is no main road access, so it is necessary to propose

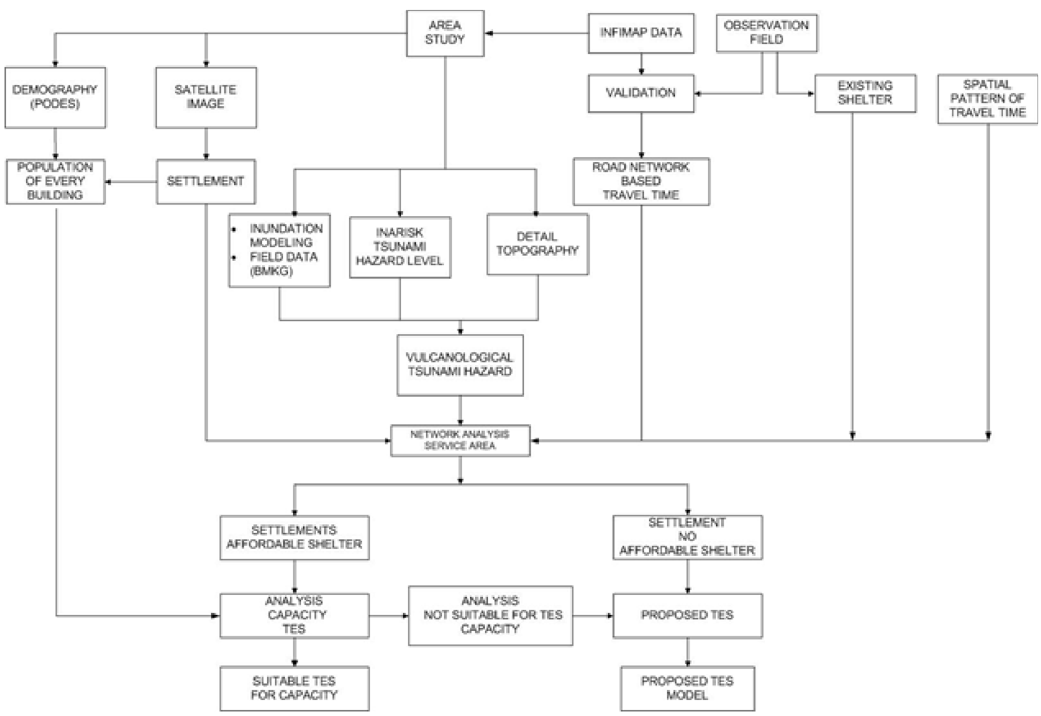

Figure 2. Workflow Scheme.

Table 3. 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
A group of walking elderly people	0.751 m/s
A independent walking elderly person	0.948 m/s

(Institute for Fire Safety & Disaster Preparedness, 1987)

TES. The physical existence of the proposed TES and access roads to TES were obtained from google earth. The TES used is multifunctional. In the workflow scheme (Figure 2), residents go to TES through routes is obtained from the process of network analysis. From the processed network analysis, area segmentations can be confirmed. After knowing the area segments in each district, the next stage is to determine the capacity of the population using PIP (People in Pixel), so that the total population in each segment is known.The third step is determination of PIP

PIP data is pixel-based population density data derived from the processing of building density from Landsat 8 satellite imagery. Each pixel measuring 30 x 30 meters from the density data (Ardiansyah *et al.*, 2019) is transformed into a population value using the proportion to data method BPS Village Potential (PODES). Hence, if all PIP pixels are totaled in one village, the number will be in accordance with BPS Podes data. This PIP data is demographic data that has a higher level of detail than Podes data, because in one village, it will show the distribution pattern of the population with a pixel base of 30 x 30 meters. For the accuracy of the data processing, this data can be used to measure the total population of an area whose boundaries are non-administrative (Batista e silva, 2013).

RESULTS AND DISCUSSION

In the coastal area of Carita District, there are three disaster-prone classes including high, moderate and low levels (Figure 3). The disaster-prone areas in Carita district is listed in Table 4.

The speed of tsunami wave propagation in Carita and Labuan districts is 39 minutes, that within such time residents are expected to immediately go to the nearest available TES - of two types, namely the proposed 8 TES units (Table 5) and the existing 4 TES units (Table 6) - through the provincial road in Carita district, i.e. Raya Anyer Sirih Street and Perintis Kemerdekaan Street. Furthermore, from the results of the GIS analysis, distributions of some TES are presented in Figure 4.

Furthermore, in the coastal area of Labuan District, there are three disaster-prone classes (Results of GIS analysis, 2021) including high, moderate and low levels (Figure 5). Labuan District of prone disaster areas is listed in Table 7.

Table 4. Disaster Prone Area

Number	Information	Area of Prone Disaster Km^2
1	High Level	49.9738
2	Moderate Level	1.0504
3	Low Level	0.8687

Table 5. Total Population in the Proposed TES in the segment area TES Carita district

Number	Information	Physical Building	Street	Number of Pepole In Pixel of TES area segmen
1	Proposed TES 1	House	Raya Anyer Sirih	689
2	Proposed TES 2	House	Raya Anyer Sirih	790
3	Proposed TES 3	Ponsel shop	Raya Anyer Sirih	471
4	Proposed TES 4	Restaurant	Raya Anyer Sirih	179
5	Proposed TES 5	Bare Land	Raya Anyer Sirih	887
6	Proposed TES 6	Bare Land	Raya Anyer Sirih	274
7	Proposed TES 7	Bare Land	No street name	1,219
8	Proposed TES 8	Alfa Mart	Perintis Kemerdekaan	2,677

Table 6. Total Population in Existing TES in TES area segment in Carita district

Number	Information	Street	Number of Pepole In Pixel of TES area segmen
1	Bali de Anyer Hotel	Perintis Kemerdekaan	575
2	Lippo Carita Condominium	Perintis Kemerdekaan	2,793
3	Al Barokah Mosque	Perintis Kemerdekaan	4,359
4	SMKN 3 Pandeglang	Perintis Kemerdekaan	3,325

Table 7. Labuan District of disaster-prone areas

Number	Information	Area of Prone Disaster (Km^2)
1	High Level	49.9989
2	Moderate Level	0.2513
3	Low Level	0.2962

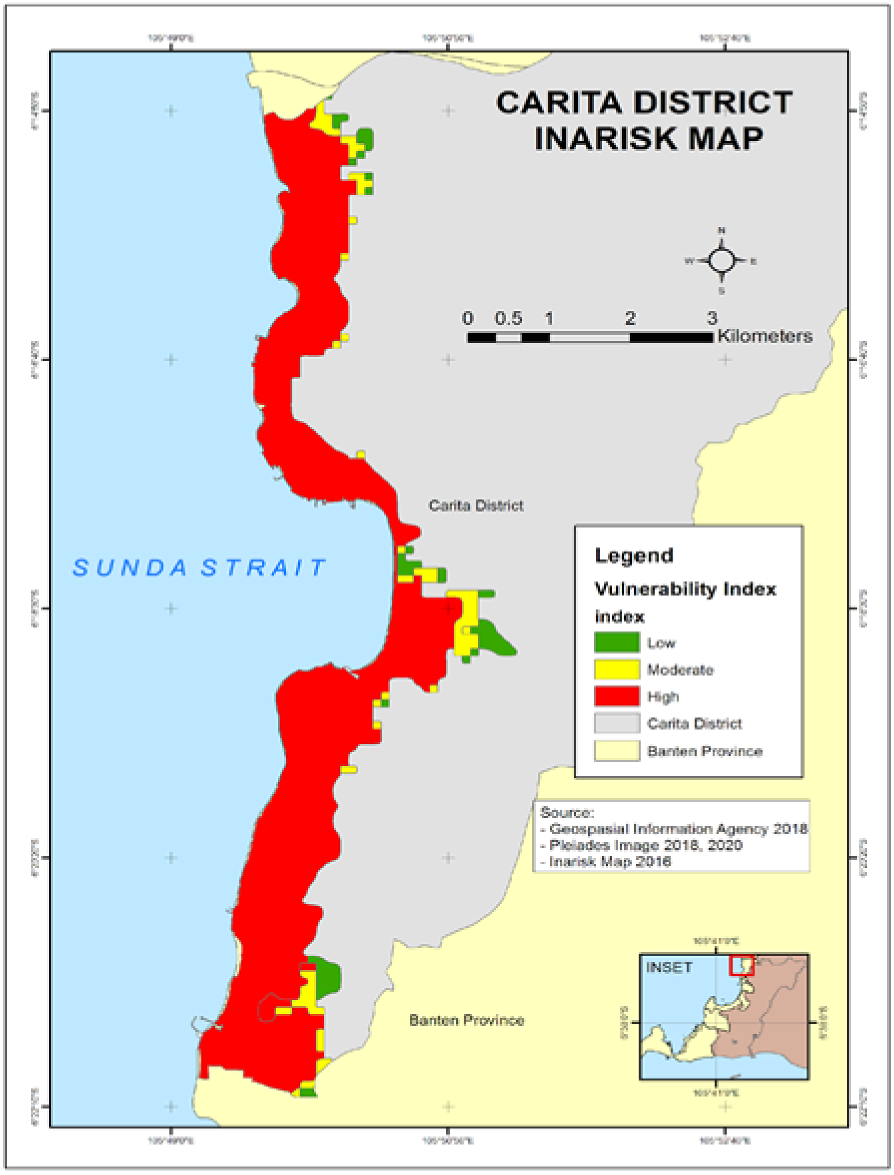

Figure 3. Carita District Inarisk Map (2016).

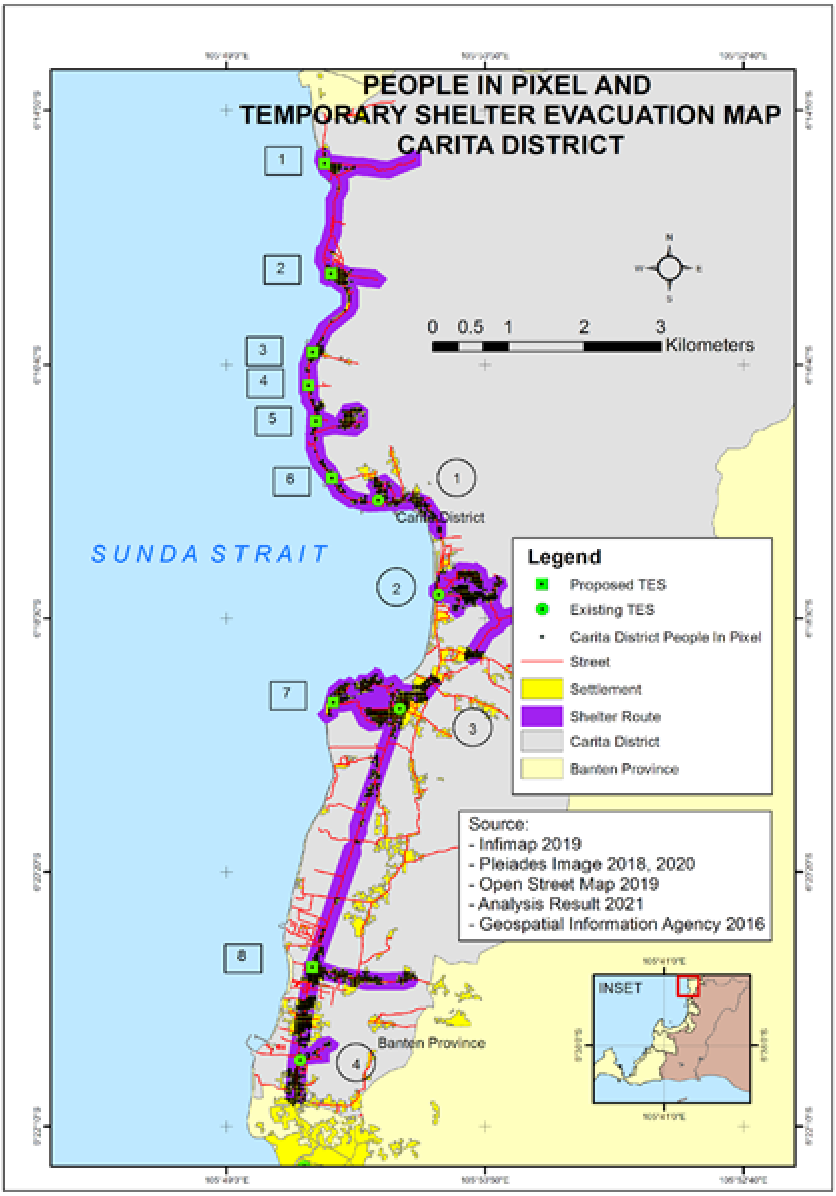

Figure 4. TES and PIP Map Carita District.

There are two types of TES in Labuan District, namely the existing TES and the proposed TES from GIS analysis (Figure 6). The existing TES Tsunami Shelter Building was built by Ministry of Public Works and Housing (Figure 7). The proposed TES is the building unit of Supplies Store Kurnia Foam Home in a densely populated location. Both the TES Shelter Building and the proposed TES are on the main road of Perintis Kemerdekaan that separated by a river. The total population in each segment area is shown in Table 8.

At the time of the incident in 2018, the residents of Labuan District did not know the availability of TES. The TES was built by the Ministry of Public Works and Housing. Due to the absence of socialization from

Table 8. Total Population in Existing TES in TES area segment in Labuan district

Number	Information	Street	Number of Pepole In Pixel of TES area segment
1	Shelter Tsunami Building	Perintis Kemerdekaan	23,635
2	TES Proposed (Supplies Store Kurnia Foam Home)	Perintis Kemerdekaan	4,376

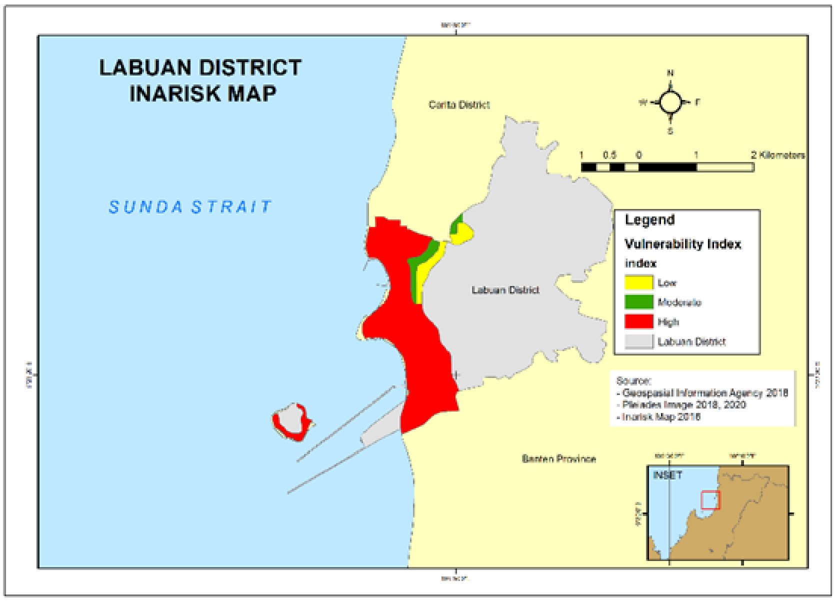

Figure 5. Labuan District Inarisk Map (2016).

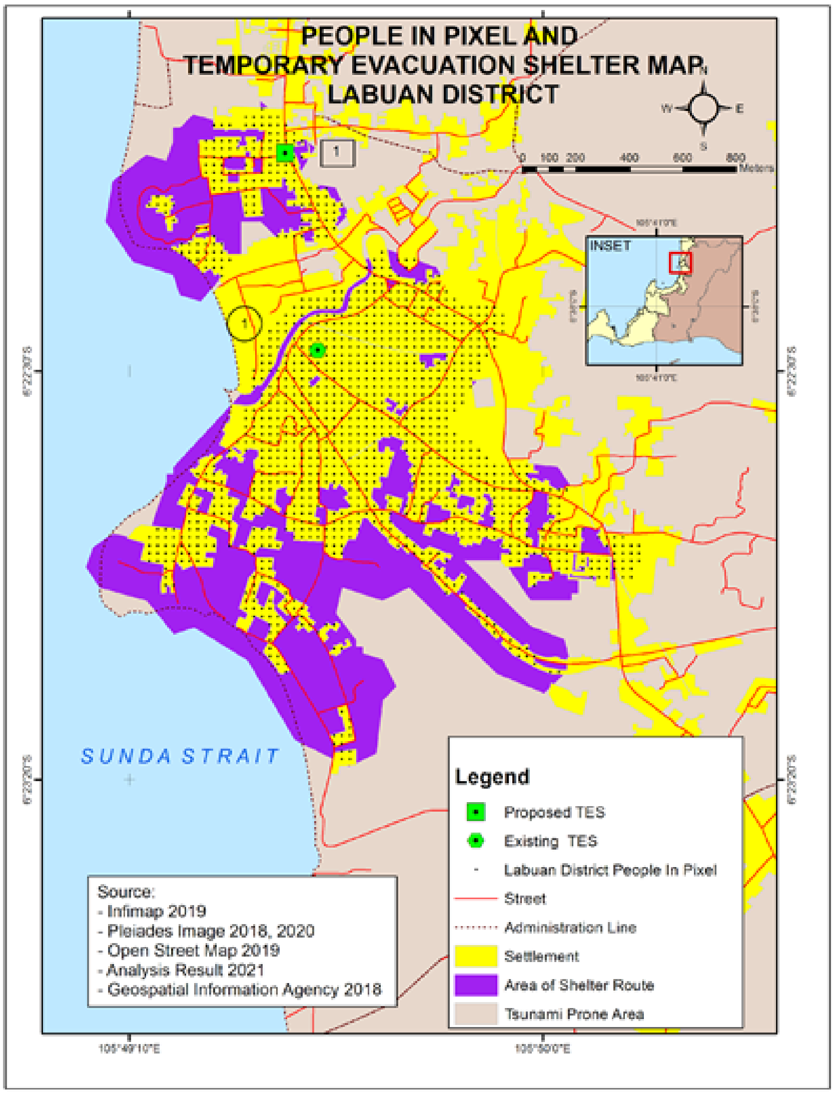

Figure 6. TES and PIP Map Labuan District.

Figure 7. Labuan Tsunami Shelter Building. (Source: Ismiati, 2019)

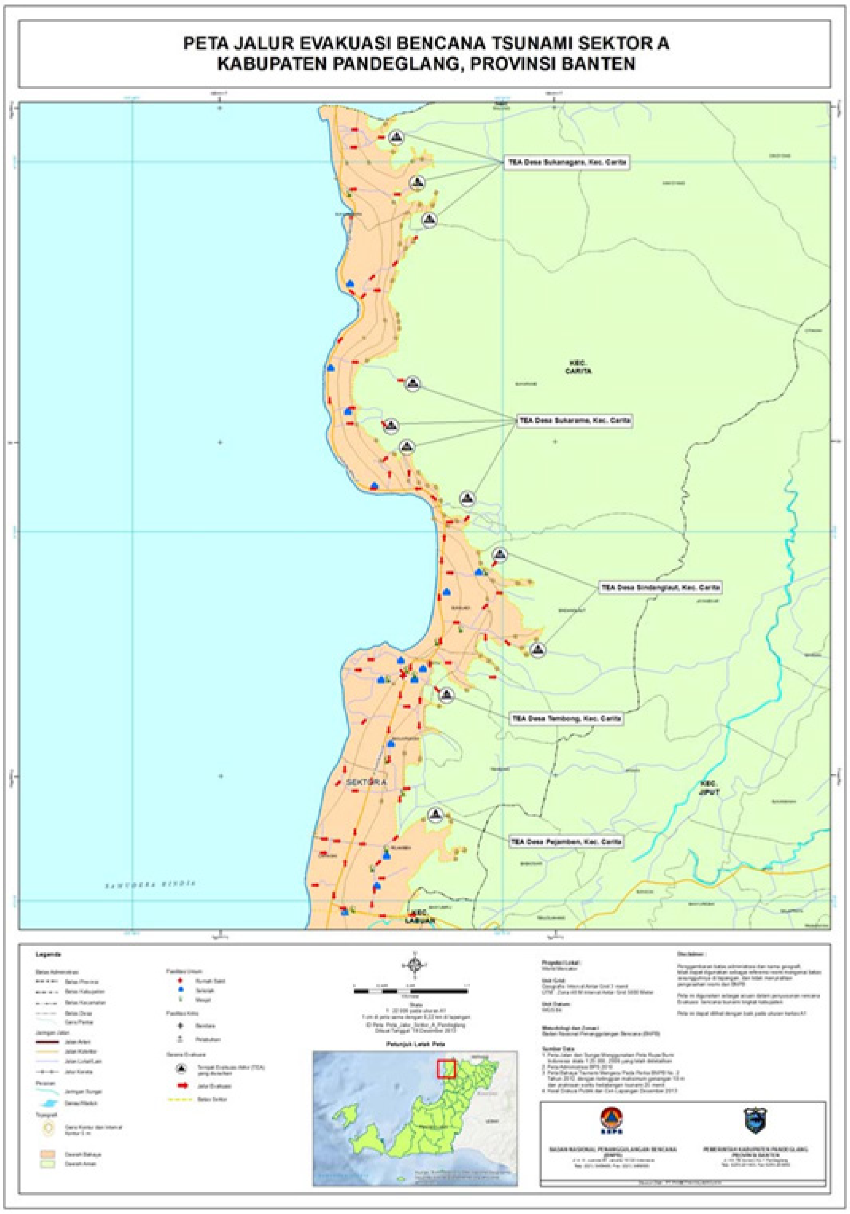

Figure 8. Sector A Tsunami Evacuation Route Map of Pandeglang Regency. (Source: BNPB, 2014)

the local government in socializing the availability of TES, currently, the Pandeglang Regency government is preparing temporary and permanent housing for victims of the 2018 tsunami disaster.

Similarities and Differences of Temporary Evacuation Shelters Between Carita District and Labuan District

The similarity of TES locations of both Carita Subdistrict and Labuan Subdistrict are on Perintis Kemerdekaan Street, the main road in Pandeglang Regency. The proposed TES locations in the two subdistricts are in accordance with the criteria in table 2. They are, e.g. the location is within 100-200 m from the coastline, it is located in a densely populated area with evacuation accessibility, it is easily accessible, the topography of the TES location is in a disaster-prone area, and building operations can be used as evacuation sites. The location to TES uses a Network analysis application which is processed using GIS software.

The difference between TES proposals in Carita District and Labuan District is in its quantity, as the number of TES proposals in Carita District are 8 TES units, while in Labuan District is 1 unit.The types of buildings proposed as TES in Carita District are houses, bare land, restaurants and shops, while in Labuan sub-district is a shop. The next differences are the number of buildings that can be used as TES. In Carita District, there are 4 buildings that can be used as TES. The types of buildings are hotels, schools and mosques. Meanwhile, in Labuan District, the TES shelter that can be used as a TES was established by PUPR (Pekerjaan Umum dan Perumahan Rakyat).

The results of the study from the BPBD of Pandeglang Regency have proposed TES (Temporary Evacuatian Shelter) and TEA (Final Evacuation Shelter) and the path to TES and TEA, the analysis process in 2013 (Figure 8). The analysis process carried out by BPBD did not use the network analysis method. Yet, this study use network analysis with a speed of 0.751 m/s (the speed of the elderly) to obtain the TES proposal and the total population capacity in each TES proposal using People in Pixel analysis.

CONCLUSION

In Pandeglang Regency includes Carita and Labuan Districts on December 22, 2018, a tsunami occurred due to flank collapse of the Krakatau Volcano (GAK), resulting in loss of life and property. Therefore, it was necessary to anticipate by proposing TES locations in the two districts. In obtaining the TES proposal using network analysis, the parameters used were the main road, located in a disaster-prone area and densely populated.

The results of the GIS analysis in Carita District presented a proposal of 8 TES units. The location of the 8 TES units were on Jalan Raya Anyer Sirih Street and Perintis Kemerdekaan Street, where both streets are also served as the best routes to TES in the shortest time. Jalan Anyer Sirih and Perintis Kemerdekaan are the best routes to TES in the shortest time. In addition to the proposed TES, there were four buildings that can be used as TES. They are: 1. Bali de Anyer Hotel, 2. Lippo Carita Condominium, 3. Al Barokah Mosque and 4. SMKN 3 Pandeglang. The existence of TES proposals and buildings that can be used as TES are located in densely populated areas. The total population in each segment of the proposed TES area was between 179 and 2,677 people. Meanwhile, the population in the four TES units had a capacity of between 575 and 4,359 people.

Furthermore, the results of the GIS analysis in Labuan District proposed 1 TES unit. The number of residents in this segment is 4,376 people, while the capacity in the existing TES Tsunami Shelter Building is of 23,635 people.

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