Massive earthquake countermeasures by establish muster point and migration path using network analysis in Matraman District, Jakarta, Indonesia

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Abstract. The issue of earthquake with magnitude 8 SR that threatens Jakarta has recently become a major concern due to the chance of catastrophic. This is closely related to the existence of a seismic gap located in Southern Java, Sunda Strait Megathrust. The seismic gap is a segment of an active fault known to produce a significant earthquake that shows no earthquake activities for an unusually long time. This situation implies that the moving crust is reserving potential energy which going to be release and resulting massive earthquake. The potential earthquake source located around 200 km from Jakarta which has densely populated and frequent annual disasters such as floods and fires. Matraman district is one of the densely populated areas in Jakarta with a population density of 319,291 per km². Through GIS, this research uses network analysis methods to create an evacuation route in the event of a disaster. This method works with a cluster system to obtain the most effective paths in predetermined zones. The evacuation route resulted from this analysis used 21 zones located in Matraman sub-district. Each zone has various evacuation time. The fastest time range between 1 to 3 minutes and the longest about 4 to 12 minutes. This evacuation route is also usable for SAR team and firefighter to reach the area of disaster.

1. Introduction

1.1. Background

Indonesia is an archipelagic country flanked by several subduction plate and subduction zones. Subduction zones in Indonesia are one of the causes of earthquakes in Indonesia. Geologically, Indonesia is located the meeting of 3 major world plates, the Eurasian Plate, the Indo-Australian Plate, and the Pacific Plate. The three plates move because of the convection currents becoming interconnected and causing a complex tectonic order. Sumatra and Java are places frequented by subduction zones. In January 2018 there was an earthquake in southwest Lebak, Banten Province, the disaster did not cause casualties but infrastructure damage occurred [1]. In the Sunda Strait Megathrust, which is located approximately 200 KM from Jakarta, there are indications of seismic gaps, according to predictions that the Jakarta earthquake is threatened by shocks on the Richter scale [2]. Matraman District which is a District located in East Jakarta, which has an area of 485 Ha with a population density of 193,700 people.
With the big earthquake, this area is one of the areas in Jakarta that can be severely affected by losses due to the disaster. Matraman is a District whose population is high and its settlements tend to be densely populated so that in the event of disasters such as earthquakes, floods, and fires, it can cause many fatalities and substantial material losses.

Based on seismic data from PUSGEN (Nasional Earthquake Study Center) five megathrust were found in South Sumatra and Java with magnitudes of 8.4-9.9 on the Richter scale ‘figure 1’. Mentawai-Pagai Megathrust, Enggano Megathrust, and West-Central Java Megathrust are megathrusts that have experienced earthquakes with magnitudes > 7.0 on the Richter scale. However, Sunda Strait and East Java Megathrust have not shown any seismicity with a magnitude of > 7.0 on the Richter scale. Those things that cause among researchers will be the potential for a large earthquake > 7.0 on the Richter scale in the future. Areas that are tectonic active but earthquakes that rarely occur for long duration are terms of seismic gap [2]. Subduction zones resulting from interactions between the Indo-Australian and Eurasian plates in the southern part of Sumatra and Java are active tectonic zones. But we must be aware of the area in order to indicate the presence of seismic gaps. Fedotov in 1965 and Mogi in 1969 were the first to introduce the term seismic gap through the mapping they conducted on Alaskan-Aleutian subduction [3].

**Figure 1.** Map of earthquake distribution in the southern region of Sumatra and Java indicated seismic gaps (modification from PUSGEN, 2018)

### 1.2. Objective

On Tuesday, January 22, there was a 6.4 magnitude earthquake centered in the south of Banten and the tremor was felt to reach Jakarta. In Jakarta thousands of people panicked out of office buildings, worried that the building would collapse. Even though Jakarta experienced relatively nothing compared to Banten which suffered severe damage and losses. The earthquake shook the capital, causing community activities to stop for a while, until traffic jams occurred on several roads.

Earthquake disasters are natural disasters that cannot be prevented and are difficult to overcome. The only handling is to prepare a good mitigation system and plan earthquake-resistant building structures. This can reduce the impact caused by earthquakes, namely casualties and damage to buildings. With the evacuation route, the evacuation plan can go well to the evacuation points that have
been set. To save the lives of residents and minimize them, there are several choices of effective evacuation routes and evacuation points that are eligible to connect the community when a disaster occurs [1]. Determining an effective evacuation route is easy. We use fit tools to detect spatially. Geographic Information System (GIS) has this ability and makes it easy to do mapping [4].

1.3. Contribution
In this paper, we write our research in determining an effective evacuation route to evacuation point. We can summarize this article:

- The evacuation route that we made can work for any traffic model as long as certain conditions are met.
- Our simulation is used to measure how much time is needed to reach the evacuation point. Usually people use evacuation sites to wait for the conditions of their settlement area to be conducive.
- We create data processing algorithms in the absence of pre-computing networks. The resulting route is realistic for a large area and short time.

2. Literature Review
There are four main discussions in this paper including criteria of evacuation points, network analysis, and area of study.

2.1. Network Analysis
Map network analysis begins with a basic map that some components will be included there are the map shp of the region, and data from the road network [5]. Then the speed is automatically obtained from ArcGIS 10.6, and to find out the travel time using the basic physics formula, namely:

\[
Time \ (s) = \frac{Distance \ (m)}{Velocity \ (\frac{m}{s})}
\]  (1)

Network analysis remains one of the most significant and persistent research areas in geographic information science usually call GIScience [5]. The shapefile is a non-topological data structure developed by Environmental Systems Research Institute (ESRI). It is possible to perform some network analysis and generally considered to be inefficient for network analysis [5]. Generally, network analysis is used for knowing the shortest route and the best route from one point to another point. There are some kind of network analysis, there are service area, closest facility, vehicle routing problem, location-allocation. Network analysis closest facility is using for this paper, because we want to know the closest route to get some facility (evacuation point) if major disaster occur [6].

2.2. Evacuation Routes
In making the evacuation route, a direct survey is needed to find out the condition of the area that will be made an evacuation route [7]. Evacuation routes should be based on careful considerations to facilitate a number of people in one area [8]. Determination of evacuation routes that are in accordance with the needs of the community for their preparedness that allows in minimizing losses and the number of casualties caused by disasters.

2.3. Criteria of Evacuation Points
Generally applied in determining the area to be an evacuation point. Referring to government regulation PU No. 20 / PRT / M / 2011 concerning disaster zone natural disasters, namely: [9]

- The absence of buildings that are at risk of being affected by a disaster is quite high (the building is not earthquake resistant).
• Not close to sources of disasters (high cliffs, sea, river, bank, volcano, and earthquake fault area).

3. Research Design
The research location was in Matraman District located in East Jakarta, and located between 601061.79 easting and 3318202.92 northing ‘figure 2’. The Basemap and the population map are shown in ‘figure 3’ and ‘figure 4’ respectively. We made the research design contained in the flowchart in ‘figure 5’. In this study we conduct a survey to obtain primary data, especially in terms of determining the right evacuation point and also to find out the traffic conditions in the study area. In its implementation the use of GPS (Global Positioning System) is needed to determine the points of latitude and longitude coordinates on the location of study area.

We have seen that conditions in the study area tend to be very smooth traffic, there are many small roads and alleys, often we find cars, motorbikes parked on roads and alleyways cause narrowing of the width of the road. Some points as shown on ‘figure 6’ and ‘figure 7’. We also collect secondary data from the literature to determine the extent to which potential disasters threaten the research area. Then we looked for population density data to determine the level of population density in each sub-district in Matraman District. In addition, aerial photography is used to check whether the plot of evacuation point is correct or not. A survey is conducted using local residents to find out the knowledge capacity of the population about disasters and what steps the population should take in the event of a disaster. After all data is collected from field observations and secondary data, analysis is carried out to determine the shortest evacuation route to the reference point with GIS analysis using ArcGIS 10.5.

Figure 2. Map of Matraman District Location
Figure 3. Basemap of Matraman District

Figure 4. Population Density Map

Figure 5. Research flowchart
Figure 6. The Situation of the Road in Matraman

Figure 7. Traffic Situation

4. Discuss and Result

4.1. Utan Kayu Utara Sub-district
Utan Kayu Utara Sub-district has a population density ranging from 25,120.83 to 36,121.73 population density per km². Based on the survey we have conducted, we found six evacuation points that could be used as evacuation sites when a disaster occurred. Six evacuation points are found in open land, RPTRA Utakara Beriman, Elementary School of 17 Utan Kayu, and parking lots that can be used for evacuation sites. Traffic conditions in this area are not crowded so it is expected that evacuation in this area is quite easy and smooth. Assuming an average pedestrian speed of 10 km / hour, the time for the farthest resident, the area going to the evacuation area, takes about 3 minutes 20 seconds to get to the evacuation point. And the fastest time for people with a short distance to the evacuation point takes around 60 seconds with the assumption that the road is smooth. Because Utan Kayu Utara area is quite extensive and the average evacuation point that we found was not too large, we increased the evacuation point. We found six evacuation points that we considered able to accommodate the community ‘figure 8’.

4.2. Utan Kayu Selatan Sub-district
Utan Kayu Selatan Sub-district has a population density ranging from 25,120.83 to 36,121.73 population density per km². Based on the survey we have conducted, we found four evacuation points that can accommodate the community ‘figure 9’. These four evacuation points are located in schools, precisely the school grounds can be used for evacuation sites, including Junior High School of 97 Jakarta, Senior High School of 31 Jakarta, Senior High School of 22 Jakarta, and UPBJJ-UT. Traffic conditions in this area are quite smooth, many roads are one way so as to minimize congestion that occurs so that evacuation is expected to run smoothly in this area. Assuming an average pedestrian speed of 10 km / hour, the time for residents who are farthest from the evacuation point takes about 7 minutes 10 seconds to reach the evacuation point. And the fastest time for people who are close to the evacuation point takes about 60 seconds.

4.3. Kayu Manis Sub-district
The Sub-district of Kayu Manis is one of the areas that have the densest population density ranging from 36,121.73 to 55,322.77 population density per km2. Based on the survey we have conducted from ‘figure 10’, we found three evacuation points that can be used as evacuation sites for people when a disaster occurs ‘figure 10’. These three evacuation points are found in the parking lot, Al Washliyiah Junior High School, Muhammadiyah Jakarta Vocational High School which can be used for evacuation sites. Traffic conditions in this area are quite dense but there are many roads that are one way so that they can prevent congestion. Usually congestion in this area occurs because of the large number of public transport stops and traders selling on the roadside Assuming an average
pedestrian speed of 10 km / hour, the time for the farthest residents is the area that goes to the evacuation takes about 5 minutes to get to the evacuation point. And the fastest time for people with a short distance to the evacuation point takes around 60 seconds with the assumption that the road is smooth.

4.4. Pisangan Baru Sub-district
Pisangan Baru Sub-district is one of the areas with the most densely populated population ranging from 36,121.73 to 55,322.77 population density per km2. It is quite difficult to determine the evacuation point in this place because this area is quite densely populated. Based on the survey we have conducted, we found three evacuation points that can accommodate the community ‘figure 11’. Three evacuation points are found in open fields that can be used for evacuation sites Vocational High School of 5 Jakarta, and Elementary School of 13 Pisangan Baru Morning. Traffic conditions in the area are quite dense because there are many markets and lots of public transport in this area. Assuming an average pedestrian speed of 10 km / hour, the time for the farthest resident, namely the area leading to the evacuation, takes about 8 minutes 10 seconds to get to the evacuation point. And the fastest time for people with a short distance to the evacuation point takes about 1 minute 35 seconds with the assumption of smooth traffic.

4.5. Palmeriam Sub-district
The Palmeriam Sub-district has a population density ranging from 25,120.83 to 36,121.73 population density per km2. Based on the survey we have conducted, we found three evacuation points that can accommodate the community ‘figure 12’. Three evacuation points are located in schools, precisely in the school grounds, market parking lots, and TNI fields which can be used for evacuation sites, including the Palmeriam market, DISLITBANG Field Army, and Elementary School of 02 Palmeriam Evening. The traffic situation in this area is very crowded, especially near the market, there are a lot of merchant, public transport, and people who make roads around the market jammed, plus the road condition are really narrow. However, the traffic conditions at the other two evacuation points, namely DISLITBANG TNI, are classified as smooth because they are on a big road as well as Elementary School of 02 Palmeriam Evening. Assuming an average pedestrian speed of 10 km / hour, the time for the farthest resident is the area leading to the Palmeriam market parking evacuation takes about 12 minutes to get to the evacuation point because the distance and roads are quite dense in the area. And the fastest time for people with a short distance to the evacuation point takes around 60 seconds with the assumption that the road is smooth.

4.6. Kebon Manggis Sub-district
The Sub-district of Kebon Manggis has the lowest population density among the areas in other Matraman sub-districts, ranging from 25,120.83 population density per km2. Based on the survey we have conducted, we found two evacuation points that can accommodate the community ‘figure 13’. Those two evacuation points are located on the TNI field which can be used for evacuation sites, Zeni Field and the Batalyon Zeni field. Traffic conditions in this area are not crowded so it is expected that evacuation in this area is quite easy and smooth. Assuming an average pedestrian speed of 10 km / hour, the time for the farthest resident, the area going to the evacuation area, takes about 4 minutes 40 seconds to get to the evacuation point. And the fastest time for people with a short distance to the evacuation point takes around 60 seconds with the assumption that the road is smooth. However, the problem is that we find the difficulty to find evacuation points in this area because there are rarely open land and dense houses so there are several road areas that do not have an evacuation point because it is very far to get to the two evacuation points that we have determined.
Figure 8. Utan Kayu Utara Urban Village Map

Figure 9. Utan Kayu Selatan Urban Village Map

Figure 10. Kayu Manis Urban Village Map

Figure 11. Pisangan Baru Urban Village Map
5. Conclusion

Based on this research we have conducted at least each of Matraman sub-district has minimum two evacuation points. The evacuation point is expected to accommodate the community when a disaster occurs. Network analysis method can easily choose the most effective route in determining the evacuation route. Each area has travel times to different evacuation points, the fastest is between 1 to 3 minutes and the longest is between 4 to 12 minutes it depends on the distance of the house to the evacuation point and also from the traffic condition.

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