Determine effective pedestrian paths as evacuation routes for landslide disaster (case study: manyaran and kembangarum villages)

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Abstract. Central Java is one of the provinces in Indonesia that is vulnerable to natural disasters, such as earthquakes, volcanic eruptions, and landslides. Landslide incidents in Central Java from 2011-2015 have the highest frequency compared to other disasters, i.e. 568 incidents. Primarily, for landslide, the data shows that the incidents in the city of Semarang have a high frequency. The previous study about the readiness index of several villages in the city of Semarang in facing the landslide disaster has been conducted and the result indicated that 2 out 19 surveyed villages belong to the category not ready for facing the landslides, namely Manyaram and Kembangarum. One of the causes of the lack of readiness is they don’t have an evacuation route. So, based on this condition, the purpose of this study is to determine an effective pedestrian path as evacuation routes for landslide disaster for Manyaram and Kembangarum Villages. In this case, the effective pedestrian path will be determined based on the shortest, fastest, and inexpensive route parameters. The method used in this study is Network Analysis with ArcGIS10.3 applications. The result of this study will display the route map and trip descriptions of the shortest, fastest, and inexpensive route.

1. Introduction
Central Java is one of the provinces in Indonesia that is vulnerable to natural disasters, such as earthquakes, volcanic eruptions, and landslides. Of the five disasters that most often occur during the last few years is a landslide disaster. Landslide incidents in Central Java from 2011-2015 have the highest frequency compared to other disasters, i.e. 568 incidents. Primarily, for landslide, the data shows that the incidents in the city of Semarang have a high frequency. According to [1] Semarang City has a high enough potential for landslides in almost all regions. Regions in the city of Semarang that have the potential for landslides are divided into three classes of vulnerability, namely: quite vulnerable, vulnerable, and very vulnerable found in the sub-districts [2]. The condition of the bare mountain slopes and the fragility of the rocks and the unstable soil conditions make these lands unable to hold water in times of heavy rainfall with a high level of the village. Besides being caused by high rainfall, the geological conditions which include the morphology of the area such as hills and slopes, the ~existence of geological structures (faults) that control, as well as the lithology/rock conditions that make up the area. Based on the results of research conducted by [3] the district of West Semarang is dominated by residential areas. Most of the settlements in disaster-prone areas are 63.8% of the total residential area or 45.82% of the total area of the District of West Semarang. This indicates that the risk of disasters in the West Semarang Sub-district is high because the extent of settlements in areas prone to disasters is greater than those that are not prone to disasters.

The previous study about the readiness index of several villages in the city of Semarang in facing the landslide disaster has been conducted and the result indicated that 2 out 19 surveyed villages belong to the category not ready for facing the landslides, namely Manyaram and Kembangarum [4]. This study also described several causes of the low index of preparedness of citizens against landslides in the
Kembang Arum and Manyaram villages which are basically the same. One of the causes of the lack of readiness is they don't have an evacuation route.

The query that requires to be resolved in this study is how to determine some alternative evacuation routes for the community through the pedestrian route in mitigating landslides and how to choose an effective evacuation route for the community through the pedestrian route in mitigating landslides. In this case, the effective pedestrian path will be determined based on the shortest, fastest, and inexpensive route parameters.

Efforts to mitigate the risk of natural disasters with various preventive measures to minimize the negative impacts of the disaster, one of them is by the existence of an effective and efficient evacuation route map based on several available variables so that the community can be helped in finding routes/paths to get to safe and fast evacuation sites via pedestrian evacuation routes. The approach used in determining the evacuation route in this study is the Network Analysis approach which has strong potential for solving pathway problems [5] in the application of Geographic Information Systems (GIS).

2. Methodology
The approach used in this study is a quantitative research approach with a descriptive approach that provides an overview of the object under study through data or samples that have been collected and processed. This research was conducted in Manyaran and Kembang Arum villages, which were conducted from February-March 2020. In this research, a method of data collection in the form of techniques and methods commonly used by researchers to collect data is needed, for example with field activities for primary data collection through interviews, and observations to determine the condition of the problem that is relevant to the purpose of the initial research.

Secondary data, it can be obtained by studying road data / official archives obtained from several agencies related to disaster management, such as the Semarang local government, in this case, BNPB for data related to disaster and regional monographs as well as several articles, journals from research studies with the same topic. The following are some secondary data needed in conducting this research, namely:

- Road data is an important factor in determining the route, in this case, a road network map in the Kembang Arum and Manyaram districts.
- Landslide Disaster Location Data of Kembang Arum and Manyaram villages from Semarang City BPBD which will be used as a reference in determining some shelters or temporary evacuation sites in the event of a natural disaster.
- Digital Map Data on Land Use 1: 25.000 from Bappeda Kota Semarang.
- Data on Land Transportation Map of Manyaram and KembangArum village
- Shelter Location Data is a temporary evacuation site for people affected by the landslide.

Data analysis techniques in this study using the Network Analysis method that will produce an effective evacuation route from several existing route alternatives, based on parameters by looking at the shortest route, the fastest route, the low-cost route, and also the pedestrian path with a path safest means that the evacuation paths formed later can also be used by pedestrian communities, as well as the qualitative descriptive analysis used to explain evacuation routes generated in the Geographic Information System application to determine these pathways. Map data that has been collected is then analyzed by scoring, overlapping, and description methods.

The scoring method is a way of analyzing data by giving a rating or score to each indicator in accordance with the parameters used. Furthermore, manual calculation with operation research tools precisely analyses the network with the Shortest Route Algorithm to see how far the comparison of numbers is generated. The results are said to be accurate if both results are close to or the same [6] Research methodology is shown in Figure 1.
3. Result and Discussion

3.1. Determination of Evacuation Paths

Evacuation means displacement or resettlement from dangerous areas, such as war hazards, flood hazards, landslides, volcanic eruptions, safe areas; it can also be interpreted as evacuating, moving away, evacuating people from the danger area. Evacuation Route is a special route that connects all areas to a safe area (Gathering Point). In a city, evacuation routes are very important to evacuate people to a safe place if something unexpected happens (in disaster). Therefore, evacuation route signs must be installed in all disaster-prone areas. Disaster evacuation routes are fundamental information needed in disaster-prone areas. Evacuation scenarios need to be supported by the readiness of the government and communities in flood-prone areas as noted in Law No. 24 About disaster management. Evacuation route planning is included in the preparedness stage before natural disasters occur. For the standard width of the evacuation route, there is actually no general provision, which must be considered whether this route can be traversed properly and quickly, and for the evacuation route, it should be able to load two vehicles so that if each other does not obstruct the evacuation process, there is a fixed gathering point with easy and wide access, away from sources of threats and the effects of threats. The determination of the evacuation route must at least consider a number of important things such as the Disaster Preparedness Training Handbook in [7] which has outlined some of the important things, namely:

- Evacuation route with the fastest and safest route for refugees to the refugee camp.
- There are alternative routes besides the main route.
- Suitability of the time needed to reach the shelter.
- Completeness of resources including the availability of vehicles that can be used in the evacuation process.
- It is also important to consider the position of the vehicle and the minimum amount of load if needed.
Evacuation maps are based on survey and design results that inform evacuation routes, places of refuge, and time to reach them, alternative routes, disaster safe locations, and the position of evacuation team standby posts.

As for some principles in regulating earthquake evacuation locations from the perspective of urban planning according [8] namely:

- Safety, means that potential evacuation sites must avoid potential risk areas such as fault lines, melting risks, and chemical warehouses.
- Land use control, means that prospective evacuation sites can only be selected from plots of land where the use rights are controlled by the government.
- Nearest evacuation, means that when an earthquake occurs, the shelter needs to be close to the residential area, and it must be easy for residents to find the earthquake evacuation shelter.
- Economy, for example, the cost of building a shelter from the government.
- Suitability of distance and time, means that evacuating must consider the distance and time to get to the shelter, and this can increase the likelihood of successful evacuation to the shelter.
- Maximum coverage, for example, a single shelter that has been determined must be with a standard of no more than 2 km.
- Population capacity, meaning that each shelter/evacuation place must have a population limit.

In the evacuation route and to get to an evacuation point very necessary for the role of GIS. The ability of GIS can be used in disaster management as a function of data displays, Land Information Storage and Retrieval, Zone and District Management, Site Selection, Hazard Impact Assessment, and Development / Land Suitability Modelling [9].

3.2. Route Determination with ArcGIS (Network Analysis)
In general, the definition of GIS is a component consisting of hardware, software, human resources, and data that work together effectively to enter, store, improve, update, manage, manipulate, integrate, analyze and display data in a geographically based information. GIS Component is shown in Figure 2.

![GIS Component](image)

**Figure 2.** GIS component.

Broadly speaking, a Geographic Information System consists of four main stages or four subsystems that need to be understood earlier by each user. GIS subsystem is shown in Figure 3.
A network is a collection of points called nodes, which are connected by arcs or branches. Figure 4. Show the link between start node and last node. In network analysis, there are several terms that are often used to describe a particular object such as events (events) and activities (activities). Activities are a work assignment, where the completion requires a certain period of time, costs, and facilities. Usually given the arrow symbol. Events are the beginning or end of an activity. Usually given a circle symbol. Many things can be presented with networks, communication systems, distribution systems, project planning, and others. Figure 5. and figure 6. explain the relationship between events and activities in a network system and a simple example of the relationship between the event and the activity above, it can be explained briefly.

The simple system that can be generated from this research is as follows, Land Transportation as the Network System, landslide disaster location as the initial node, the evacuation site/shelter as the final node and road/lane as arrows, types of currents in the form of vehicles, pedestrians. Or more clearly seen in table 1. below this:
Table 1. A simple overview of the system in this research.

| System Name     | Network System | First Node | Lastly Node | Arrows | Current Type            |
|-----------------|----------------|------------|-------------|--------|-------------------------|
| Evacuation Route| Land Transportation | Landslide Disaster Location | Evacuation Location | Rood lane/Route | Vehicle/On foot |

One of the tools that will be used in this research is network analysis or known as Network analyst which has been provided in the ArcMAP GIS application that aims to analyze the transportation network, where in analyzing the network Analyst network will find the path of the least impedance. The analysis of this toolbox can help users to find the shortest route between two or more locations, place a source right in the middle, or find the most efficient route connecting several locations. The location can be determined interactively by placing points on the layer, by entering addresses, or by using points in features that are in the class features. To analyze the Geographical Information System begins with image data as basic data. From the image data in the form of physical data, scanning is performed to obtain digital data. The layering process is the process of separating the layer categories that exist in digital data. The result of this layering is vector data that has been divided into several data layers according to their respective covers. For example, the Semarang city map data has been divided into sub-district boundary layers, road layers, river layers, and others. Each layer will get information from tabular data on the related process. The output of this process is a shape file (file with the extension shp), where this file is ready to be used to display geographically based information. Figure 7. Show the block analysis diagram model [10].

In this process, information can only be displayed to users. To get the analyzed display data, then from the view out of the view, a spatial analysis process is carried out by entering input categories called external parameters. The results of the spatial analysis process are data views that have been analyzed that can be used as a user reference in making choices, in this case, the route for selecting disaster evacuation routes [10]. The method of solving problems in finding effective pathways is divided into 4 parts, namely the shortest path, fastest path, cheapest path, safest path. The manual of the analysis model is as follows:
1) Determination of the Shortest Route.
To analyze the shortest path, the shortest path view is prepared. The external parameter used to find the shortest path is the distance/length parameter. Distance is denoted by L, which consists of several alternative roads (from start to finish) so that the notation is (L1, L2, L3 ... Lk). Segments are determined from each intersection. To determine the total cost field can be modeled as follows:
Cost Field (CF) = length
Total Cost Field = (D1+D2+D3+...+Dn) = ΣLk=1 L
where : D = Selected Path
N = Number of Alternatives

2) Determination of the Fastest Route.
The second problem is determining the fastest path, from a point/start point to the destination point (finish point). In determining the fastest path the external parameters that also determine the weighting (Cost Field) are the distance and the vehicle's rate. Distance is denoted by L, which consists of several alternative roads (from start to finish) so that the notation is (L1, L2, L3 ... Lk). Segments are determined from each intersection. Vehicle speed conditions are represented by speed V, each segment. So there are (V1, V2, V3, ..., VK). To determine the total cost field can be modeled as follows:
Fastest Cost Field (CF) = C = Speed / Distance, L/V
Total Cost Field = (E1+E2+E3+...+En) = ΣEkn=1 E
where: E = Chosen paths in the fastest analysis
N = Number of alternatives.
In the existing model Length is the distance based on the unit (not yet representing the original distance). To adjust the scaling, the length is multiplied by 60 units, this is intended to make the actual distance value. Length x 60 = meters. Because of the scale of 1: 60. Speed data is in km, so it needs to be adjusted. To find the cost field in meters, the formula is applied:
Fastest Cost Field (CF) = Minutes = (distance / speed * 1000) / 60
(3)
The results of this weight are used as the basic for the analysis.

3) Determination with Low Cost
For the analysis of determining the cheapest route, in this study using the transport route approach. This approach is used because this public transport model is able to trace every analysis road without recognizing road/route boundaries. For the analysis of the cost path, the cheapest route is determined by calculating the fare of the transport. With the distance, he traveled. The results of the multiplication are added with the first start rate. The modeling in this analysis is as follows, Distance is denoted by L, which consists of several alternative paths (from start to finish) so that the notation is (L1, L2, L3 ... Lk). Segments are determined from each intersection. To determine the total cost field can be modeled as follows :
Fastest Cost Field (CF) for D = Distance * Cost, /100
The unit used is the meter.
Total Cost Field = (D1+D2+D3+...+Dn) + Cost/ Starting Point = ΣLkn=1 L + Tsp
Where : D = Chosen Paths in the Fastest Analysis
N = Number of alternatives.
Tsp = first star rates
Of the three categories above, to determine the best path / the most appropriate path is to model the results of the analysis above to get an effective output in terms of time and cost. From the results of the three categories above displayed in a View, so the effective path can be determined by the user.

4) Determination of the safest path.
For the analysis of the determination of the path by considering the safest path will be done by looking at the environmental conditions around the landslide disaster site. The criteria used are
divided into 2 parts, namely the criteria for determining safe evacuations and the criteria for evacuation routes, shown in the following table 2:

**Table 2. Criteria of the safest path.**

| Evacuation Route | Evacuation Path                      |
|------------------|--------------------------------------|
| Retaining capacity | Included in the disaster affected zone |
| Availability of basic needs | Slope level                          |
| Toilet availability   | Road width / road section             |
|                     | Pedestrian Path                       |
|                     | Road Conditions                       |
|                     | The direction of the road             |

3.3. **Landslide Hazard Index**

Based on reports on the results of natural disaster studies in Indonesia in [11] the landslide hazard index is divided into three levels, namely low, medium and high, and the City of Semarang is high, which is equal to 184. Based on the results of research conducted by [3] the district of West Semarang is dominated by residential areas. Most of the settlements in disaster-prone areas are 63.8% of the total residential area or 45.82% of the total area of the District of West Semarang. This indicates that the risk of disasters in the District of West Semarang is high because the extent of settlements in areas prone to disasters is greater than those that are not prone to disasters. Landslide-prone location data shown in table 3.

**Table 3. Landslide prone location data.**

| Village        | Landslide Disaster Point |
|----------------|--------------------------|
| Kembang Arum  | RW 1, RW 7, RW 8, RW 9, RW 10, RW 11 |
| Manyaran       | RW 3, RW 4, RW 5, RW 6, RW 9, RW 10 |

Based on the landslide-prone location data [12],[13] the data collection and research carried out in the RT / RW that experienced the landslide, and the following are the location points that frequently occur in landslides in both villages. Map of landslide disaster point in kembang Arum village and Manyaran village can be shown in Figure 8. and Figure 9.
Figure 8. Map of landslide disaster point in Kembang Arum village.

Figure 9. Map of landslide disaster point in Manyaran village.
4. Conclusion
The use of algorithms in network analysis to determine the best evacuation routes produced will then be compared with manual calculations according to existing formulas so that the results of both calculations will be used to determine the best evacuation route points from several alternatives. It is expected that the evacuation route determination can help the local community in evacuating themselves when a landslide disaster comes. Evacuation Pathway Model is made by connecting the location of the evacuation space and the location of residential settlements that have a distance close enough to the location that is considered to have a high level of risk.

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