Assessing Evacuation Route Against Mount Merapi Hazard By Using Least Cost Path Method in Mriyan-Boyolali, Indonesia

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Abstract. This research aims to analyze the Least-Cost Path, an ArcGIS raster analysis, as a tool to find the evacuation route. The evacuation route of mount Merapi Eruption in Mriyan-Musuk of Boyolali regency in the scenario of sister village with Kiringan Village was selected as case study. There are 4 steps of analysis in this method such as; cost surface, cost distance cost backlink and cost path. This study analysis found 3 alternative routes which estimates 25-30 minute. These alternatives evacuation route are useful in distributing the flow of people when the eruption occurs.

Keywords: Evacuation route, GIS, Least cost path analysis

1. Introduction

Learning from the evacuation during Merapi volcano eruption 2010, fostering preparedness in for evacuation process in disaster management very needed [1]. Moreover, preparedness research to foster disaster resilience has been conducted and more interesting in Disaster management. It is not only for academic view side but for practical. However, in Indonesia, the study tends to focus on tsunami and earthquake. The topic mostly in general preparedness [2–4] and community preparedness [5–8]. The study concerning to the volcano eruption preparedness is still very limited [9,10]. With the high potential in volcano hazard, finding the optimum evacuation route for volcano victim not yet discussed [1].This study aims to fill the gap by exploring the alternative routes to foster volcano evacuation preparedness. The route will be explored to distribute the flow of people, vehicle and farm animals during evacuation. In addition, community surrounding needs a specific route and shelters for their farm animal.

The Least-Cost Path analysis is a raster analysis to find route from one point to another. Several research have been utilized this method for example utilize this method for assessing the corridor redundancy [11], routeing of power line [12], and greenway planning [13]. Different with the previous study, in this analysis variable of ‘road width’ will be proposed and examined due to it is not only for examined about fasting time, but also account of the number of people. Moreover, the variable of ‘road width’ also reflects the road capacity. As of the previous study, the time needs to evacuate is reflected in variable of ‘edge length’, ‘road damage’, and ‘surface type’.

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The goal of this study is to examine the accuracy of the Least Cost Path Analysis method to find alternative evacuation route. The specific parameter that will be examined is road capacity. Mriyan-Musuk of Boyolali regency in the scenario of sister village with Kiringan Village is selected as case study.

2. Method

This study utilized GIS approach that have been used on previous study in flood evacuation route in Bengawan Solo flood [14] and volcano mudflow evacuation [15]. The concept of this analysis is choosing the least-accumulated value of cells to go from one origin point to the destination point. To run the analysis, there are 4 steps to do [16,17]: (1) analyze the cost surface, (2) analyze the distance cost, (3) analyze the cost backlink, and (4) analyze the cost path. The first step was done by running the 'weighted-overlay' tool under the 'Overlay' toolset under the 'Spatial Analyst' toolbox. The cost surface was used as the base calculation. In this study, the variables were converted from polygon to raster with conversion tool. After that, the variable rasters were summed with weighted-overlay. The weight and score for the variables are described in the following table:

Table 1. Weight and Score of Variable

No.	Variables	Weight	Class	Score
1.	Road width	0.35	0.5 – 2.5 m (1 motorcycle)	80
			3 – 4 m (2 motorcycles or 1 car)	60
			4.5 – 5 m (1 car and more than 1 motor cycle; 2 cars)	40
			>5 - <= 6 meter (2 cars and more)	30
			>6 meter (more than 2 cars)	10
			not road	1000
2.	Road damage	0.3	0	10
			1 – 3	20
			4 – 6	30
			7 – 9	50
			10 – 12	70
			13 – 15	80
			not road	1000
3.	Edge length	0.25	<=100	10
			>=100 - <200	20
			>=200 - <300	30
			>=300 - <400	40
			>=400 - <500	50
			>=500 - <1000	60
			>=1000 - < 1500	70
			>1500	80
			not road	1000
4.	Surface type	0.1	Asphalt	20
			Concrete	30
			paving block	40
			asphalt/concrete with grass/soil	60
			unpaved (soil, grass, and gravel)	80
			not road	1000

Sister village policy is a community-based disaster risk management where people are encouraged to carry out their evacuation independently. Thus, most people prefer to use motorcycle and personal car to carry themselves and neighbours. Hence, the road capacity should be considered which is reflected in the use of width road variable. Manual Capacity of Indonesia Road [18] method is carried out to give the score of the road damage variable every 100 meter segment. The damage for roads having a less than 100 meter is calculated with the same method.

The second step of the analysis is calculating the distance cost. This was done by running the ‘Cost Distance’ tool under the ‘Distance’ toolset under the ‘Spatial Analyst’ toolbox. This tool calculated the total value (total cost) of each cell from the origin point. From here, the sum of value of cells is gained to determine the chosen cells to reach the destination from the origin point. The third step was calculating the cost backlink. This was done by running the ‘Cost Backlink’ tool under the same toolset and toolbox. The result of this step was a raster output showing the cells direction in 8 colours. This tool showed the direction from one cell to the next cell from an origin point until reach the destination point. The last step is calculating the ‘Cost Path’. This was done by running the ‘Cost Path’ tool under the same toolset and toolbox. The input of this tool is the output of ‘Cost Distance’ and ‘Cost Backlink’. The result of this step is a raster output showing the cells choose forming a route from the origin point to the destination.

3. Study Area

To explore the model within least cost path, Mriyan Village, Musuk District, having Kiringan village was as the pair selected as case study. Mriyan people understand and have learned the socialized evacuation process and capable to evacuate such as in 2010. In the previous event, people took turns in moving downward during five to seven days. When the activity of Merapi increases, kentongan (drum made from bamboo or wood) in mosques are sounded as early warning system. People then gather in the mosque to allocate the vehicle, then move to the assembly point. In here, people allocate the vehicle to carry the family and neighbors.

Mriyan village is separated by the cliff resulting two areas, the southern and the northern part. Each part has an assembly point and an evacuation route. The assembly point in the southern part is the Mriyan village Hall while the northern part is the Mriyan 2 Elementary School. The both evacuation routes come together in the node named Drajidan. From Drajidan, the both start to pass the same route to the destination. This study only takes the northern part for running the analysis. Figure 1 below shows the map of the study area.

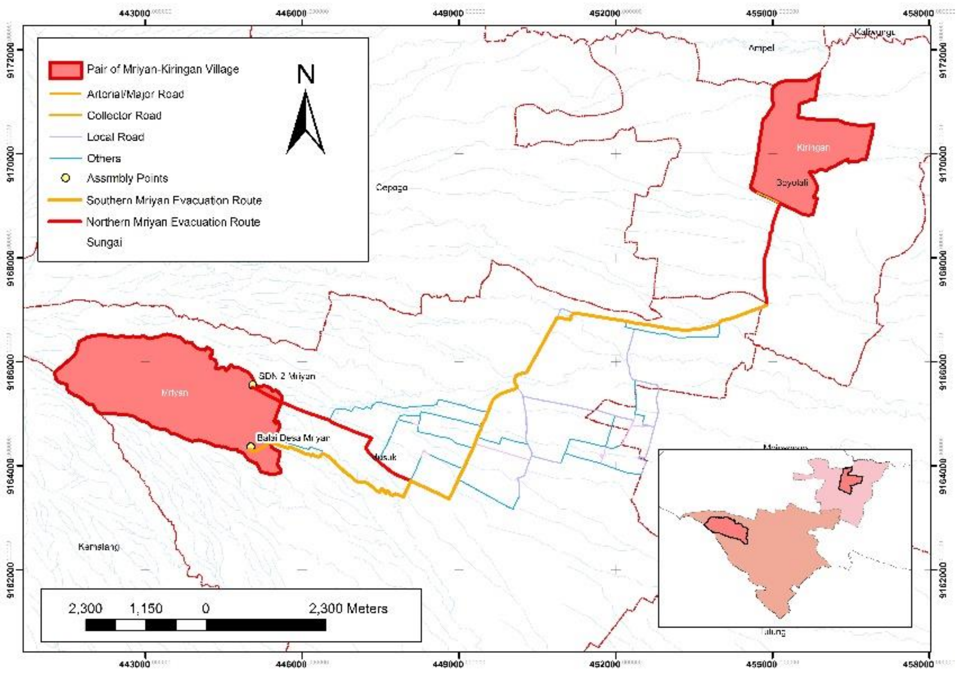


Figure 1. Study Area, Mriyan Assembly Point, and Mriyan Existing Evacuation Route (Interview with Village Chief, 2017).

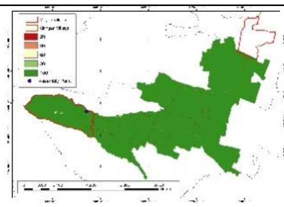
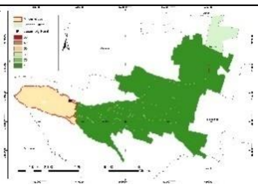
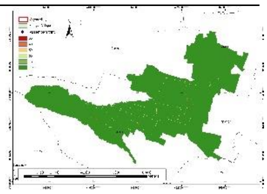
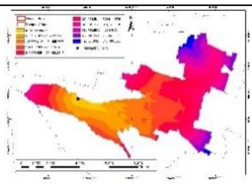
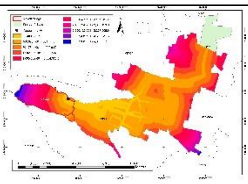
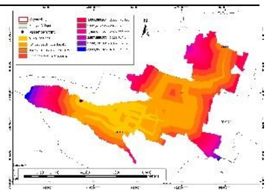
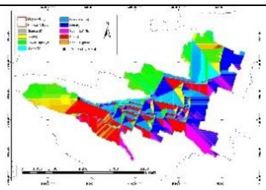
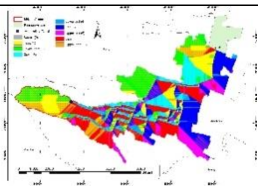
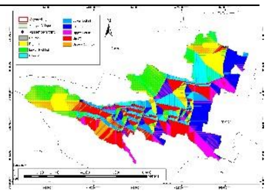
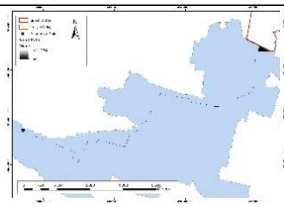
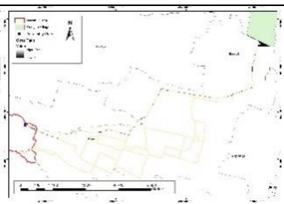
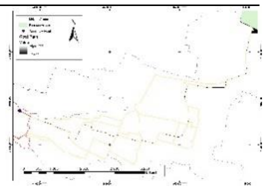
4. Data

The road data were obtained through field observation. Generally, roads from Mriyan village to the bottom village tend to be straight. There is not so much bent/turning. The most road pavements are asphalt and concrete. The roads in the upper part are mostly in good condition. The damages are cracking and some ravelling. The road with the worst condition is in Sruni. It is the only access to the Southern Mriyan. The local road condition from Drajidan to Kiringan to Musuk is mostly good enough, but there's a heavy damage in the form of potholes, collapsed, and cracking at once. Mostly, the road width is 3.5 – 4 meter, which is enough for a car and two motorcycles to pass the road side by side safely.

5. Analysis

The analysis started by filling the attribute table in the road polyline dataset. The polyline was then buffered, becoming polygon. To gain the 'not road' polygon, the administration polygon is cut in a hole with the dissolved buffer polygon. And then the two was merged. The 'not road' features were given score. After the attributes are complete, the polygon was then converted to raster with a 'Polygon to Raster' tool under the under the 'To Raster' toolset under the 'Conversion' toolbox. The output raster of the cost surface, cost distance, cost backlink, and cost path are shown in table 2.

Table 2. Route Evacuation Analysis by Using Least Cost Path Method

	Alternative 1	Alternative 2	Alternative 3
Cost surface			
Cost distance			
Cost backlink			
Cost path			

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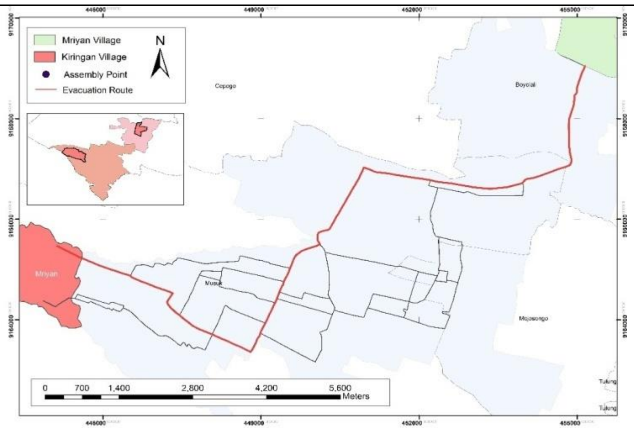
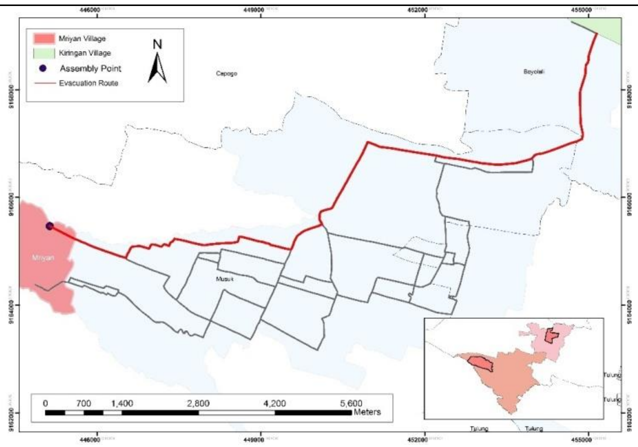
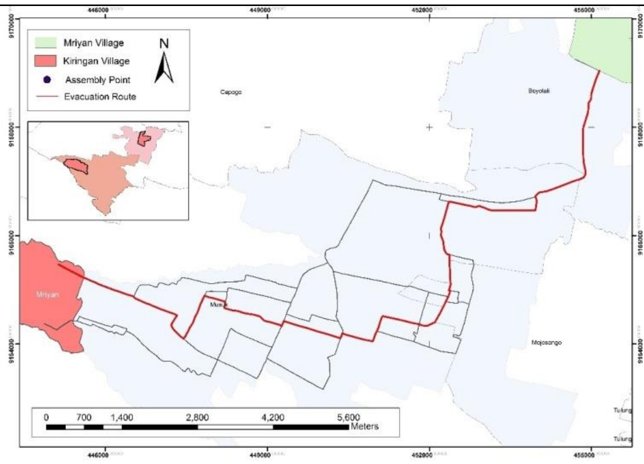
6. Result and Discussion

The first result (alternative 1) of the tool shows that the recommended evacuation route is similar with the existing. This shows that this analysis is effective to find evacuation route. The second result (alternative 2) is an unpaved moor road, the concrete-grass road, and concrete road. This result provides recommendation to construct the road. In normal situation, the road would help the villager when they're working. In disaster situation, the road would help the people to evacuate. The third result (alternative 3) is moor road. The moor roads are in good condition and already paved with concrete. The result could be seen in the Table 3 as follows :

Table 3. Evacuation Route Iteration and Result

Alternative	Cost Path
Alternative 1	
Alternative 2	
Alternative 3	

7. Conclusion

The Least-Cost Path is an analysis used to find evacuation routes. By using this method, 3 alternative route from Mriyan to Kiringan is founded as the best alternative route in sister village scenario. This study found analysis 3 alternative routes which estimates 25-30 minute.

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9. References

[1] Mei E T W, Lavigne F, Picquout A, De Bélizal E, Brunstein D, Grancher D, Sartohadi J, Cholik N and Vidal C 2013 Lessons learned from the 2010 evacuations at Merapi volcano *J. Volcanol. Geotherm. Res.* **261** 348–365

[2] James E 2008 Getting ahead of the next disaster: recent preparedness efforts in Indonesia *Dev. Pract.* **18** 424–429

[3] Esteban M, Tsimopoulou V, Mikami T, Yun N Y, Suppasri A and Shibayama T 2013 Recent tsunamis events and preparedness: Development of tsunami awareness in Indonesia, Chile and Japan *Int. J. Disaster Risk Reduct.* **5** 84–97

[4] Seng D S C 2013 Tsunami resilience: Multi-level institutional arrangements, architectures and system of governance for disaster risk preparedness in Indonesia *Environ. Sci. Policy* **29** 57–70

[5] Nakayama H, Shimaoka T and Others 2015 Identification of Factors Affecting Stakeholders' Intentions to Promote Preparedness in Disaster Waste Management: A Structural Equation Modeling Approach 九州大学工学紀要 **74** 79–98

[6] Hidayati D 2012 Striving to reduce disaster risk: vulnerable communities with low levels of preparedness in Indonesia *J. Disaster Res. Vol* **7** 75

[7] Marhaento H and Kurnia A N 2015 Refleksi 5 Tahun Paska Erupsi Gunung Merapi 2010: Menaksir Kerugian Ekologis Di Kawasan Taman Nasional Gunung Merapi *Geoplanning J. Geomatics Plan.* **2** 69–81

[8] Marhaento H 2016 GIS-Based Analysis for Assessing Landslide and Drought Hazard in The Corridor of Mt. Merapi and Mt. Merbabu National Park, Indonesia *Geoplanning J. Geomatics Plan.* **3** 15–22

[9] Peterson D W 1996 Mitigation measures and preparedness plans for volcanic emergencies *Monitoring and Mitigation of Volcano Hazards* (Springer) pp 701–718

[10] Sagala S, Okada N and Paton D 2009 Predictors of intention to prepare for volcanic risks in Mt Merapi, Indonesia *J. Pacific Rim Psychol.* **3** 47–54

[11] Pinto N and Keitt T H 2009 Beyond the least-cost path: evaluating corridor redundancy using a graph-theoretic approach *Landsc. Ecol.* **24** 253–266

[12] Bagli S, Geneletti D and Orsi F 2011 Routeing of power lines through least-cost path analysis and multicriteria evaluation to minimise environmental impacts *Environ. Impact Assess. Rev.* **31** 234–239

[13] Teng M, Wu C, Zhou Z, Lord E and Zheng Z 2011 Multipurpose greenway planning for changing cities: A framework integrating priorities and a least-cost path model *Landsc. Urban*

Plan. **103** 1–14
[14] Harsini S R I 2014 Luapan Sungai Bengawan Solo Di Kota
[15] Ardana D M S and Purwanto T H 2013 Penentuan Jalur Evakuasi dan Dampak Banjir Lahar Dingin Gunung Merapi Magelang, Jawa Tengah *J. Bumi Indones.* **2**
[16] Chang K-T 2006 *Geographic information system* (Wiley Online Library)
[17] Etherington T R and Holland E P 2013 Least-cost path length versus accumulated-cost as connectivity measures *Landsc. Ecol.* **28** 1223–1229
[18] Ministry of Public Works 1997 *Manual Indonesia Road Capacity*