Model of Pre-Positioning Warehouse Logistics for Disaster Eruption of Mount Merapi in Sleman Yogyakarta

by Naniek Utami Handayani

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Naniek Utami Handayani[1], Dyah Ika Rinawati[2], Yusuf Kurniawan Wiguna[3]
[1,2,3] Industrial Engineering Department, Faculty of Engineering, Diponegoro University
Semarang, Indonesia
naniekh@ft.undip.ac.id[1], dyah.ika@gmail.com[2], yusufkurniawan.wiguna@gmail.com[3]

***Abstract*— In generally, mitigation of natural disasters in Indonesia still be responsive and reactive to sudden disasters occur. It shows that disaster management system is not well coordinated and can't be quickly response to disaster mitigation. In this case, disaster management system need to be supported by manageable disaster logistics system. This study aims to identify the criteria for determining the location of a catastrophic disaster logistics warehouse in Sleman, Yogyakarta, and determine alternative logistics warehouse location. This research used AHP and Fuzzy-TOPSIS to select the criteria and sub criteria in determining the location of the warehouse logistics, while Fuzzy-TOPSIS used to rank the final location, so that the optimal location selected. The results showed that the most important criterion is the stability of the national, sub importantly, social circumstances and the location chosen for the logistics warehouse is Candibinangun.**

Keywords*— Merapi Eruption, Analytical Hierarchy Process, Fuzzy-TOPSIS, Warehouse, Distribution Logistics

I. INTRODUCTION

Yogyakarta is one of the provinces in Indonesia, located in areas prone to volcanic eruption. In Sleman, Yogyakarta, there is Mount Merapi, which is one of the most active volcanoes in Indonesia [1]. This conditions lead to high chances of natural disasters include volcanic eruptions and volcanic earthquakes. The frequency of volcanic eruptions is high at an average of 2-5 years in the last 100 years. Merapi's danger level is very high, due to the density of the population living around the slopes of Mount Merapi. This is shown in the data the victim died as a result of the eruption of Merapi in 2010 reached 353 people. According to the head section Hazard Mitigation BPBDs Sleman, Merapi eruption in 2010 resulted in an open lava dome leads to the East, so that in case of the eruption of Merapi lava predicted would lead to Gendol River located in Sleman.

Based on interviews with head section of disaster logistics BPBDs Sleman, the Merapi eruption in 2010, there has been no disaster logistics warehouse. The supply of relief goods is often delayed due to the considerable distance between the warehouse logistics with the location of disaster victims and the difficulty of access to the location. Based on interviews with the victim, the main complaint of the activity of the Merapi eruption disaster in 2010 was the delay in the delivery of relief goods as well as mismatches kind of relief goods. This indicates that existing logistics warehouse is less effective and efficient to support the emergency response to natural disasters.

Thus, Sleman need a disaster management system that capable to support emergency response quickly and efficiently. The unpredictability of natural disasters often leads to relief operations focusing more on response rather than preparedness, so systems are reactive rather than proactive and the structure of the supply chain will determine the effectiveness of the response [2].

Preparedness is a critical step that must be met in order to reduce the risk of disaster. Preparedness actions may include the provision of disaster logistics warehouses for storage of goods support, both pre- and post-disaster. The existence of warehouse logistics allow relief supplies stored properly and distributed quickly and accurately. The location of warehouse logistics should be optimal that the evaluation process for strategic decisions have to involves several aspects, such as the proximity to the disaster area, the value of the vulnerability of the area, and changes in the value of vulnerability over time. The proximity of logistics warehouse with disaster-prone areas will simplify and improve the performance of disaster management institutions [3].

The previous study [2] and [4] focused on developing criteria to select the optimal location in generally. The characteristics of natural disaster will differ depending on the type of disaster, for example earthquake will have different characteristic with volcanic eruption or flood. Specifically, volcanic disaster will have different impact depending on the condition of eruption. So, the mitigation for each volcanoes will be different. This research used criteria in [2] and [4] to evaluate all alternatives of disaster logistics warehouses location for volcanic eruption at Mount Merapi.

II. METHOGOLOGY

A. Determine of Criteria and Subcriteria to Selection Logistic Warehouse

Identification of the criteria to determine the location of disaster logistics warehouse refers to models of the research conducted by [2] and [4]. We try to combine the two models of the research. The determination of the location of the warehouse logistics of disaster can be seen from the aspect of location, national stability, cost, cooperation, and logistics [4].

Meanwhile, the criteria used in determining the location of disaster logistics warehouse is the distance, security, office facilities, warehouse facilities and comfort [2].

Selection of the criteria to determine the location of disaster logistics warehouse is done through brainstorming with experts in the Regional Disaster Management Agency (BPBD) in Sleman. The brainstorming results is used for model validation. Based on the results of brainstorming with Section Chief Logistics Management and Natural Disasters Refugees, Section Chief for Disaster Mitigation and Preparedness prevention field, and Section Chief of Rehabilitation and Reconstruction obtained the criteria for determining the location of the warehouse logistics. The criteria for determining the location of the warehouse logistics presented in Table 1.

TABLE 1 CRITERIA AND SUBCRITERIA

Criteria	Subcriteria
Location	Proximity to the evacuation site
	Located in the disaster-free areas
	Proximity to natural resources and human resources
	Accessibility
	Adequate land area
Cost	The land prices
	Maintenance
	Logistic
Access to logistics	Proximity to airport
	Proximity to highway
	Proximity to station
	Proximity to the other warehouse
National stability	Political situation
	Economic situation
	Social situation
Cooperation	Government
	Private organizations
	NGO's
	The neighboring countries
	Logistics agent
Safety	Safety of warehouse
	The distribution of relief goods
	Proximity to public safety facility
Warehouse facility	Appropriate infrastructure

B. Selection of Logistic Warehouse

Determining the location of disaster logistics warehouse using AHP and Fuzzy-TOPSIS. Furthermore, we present a brief explanation about the method.

Analytic Hierarchy Process (AHP) developed by Thomas L. Saaty in early 1970. The AHP is a pairwise comparisons method used for decision making in matters of Multi-Criteria Decision Making (MCDM). AHP approach is designed to help decision makers that use a combination of qualitative factors and quantitative factors in deciding a complex problem. The use of AHP in various fields increased significantly. This is due to AHP can provide solutions to a variety of conflicting factors. AHP is applied in agriculture, sociology, industrial and others. The AHP method to help solve complex problems by structuring a hierarchy of criteria, stakeholders, and alternative priorities [5, 6].

Before the 20th century, the theory of probability plays an important role in the settlement of the problem of uncertainty. In 1965, Lotfi A Zadeh introduced the fuzzy set theory, which indirectly implies that there are other theories that can be used to present the problem of uncertainty. Fuzzy logic is a mathematical framework used to present uncertainty, ambiguity, inaccuracy, lack of information and partial truth. In everyday life we are often faced with the problem of uncertainty and lack of information. Discussion of the uncertainty has been started since 1937 by Max Black [7].

TOPSIS was first introduced by Yoon and Hwang in 1981 as one of the methods in solving problems of multiple criteria. TOPSIS determine a solution of a number of possible alternatives by comparing each alternative with the best alternative and the worst alternative is between alternatives problems [7]. TOPSIS has been implemented in various fields, such as financial investments, comparison of the performance of some companies, the selection of operating systems, customer evaluation, and others.

In the early stages, by using AHP constructed a hierarchical structure determining the location of disaster logistics warehouse. Based on this structure can be known weights of criteria and alternatives are possible. Furthermore, determination of selected warehouses using Fuzzy-TOPSIS. Hierarchical structure determination disaster logistics warehouse shown in Figure 1.

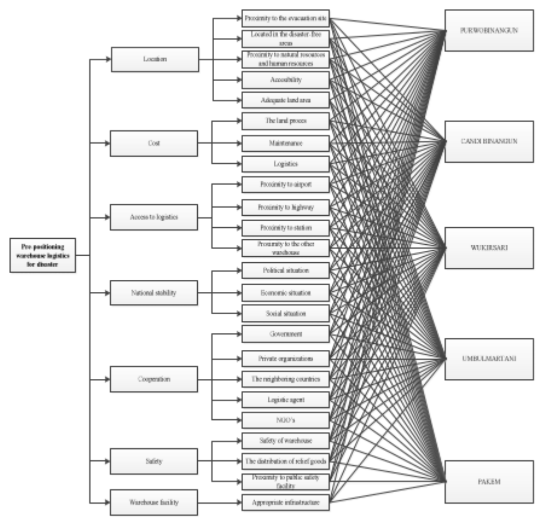

FIGURE 1 HIERARCICAL STRUCTURE FOR DETERMINATION LOCATION OF DISASTER LOGISTICS WAREHOUSE

III. RESULTS AND ANALYSIS

A. Specifies an alternative location

To determine the logistics warehouse location using the shortest distance from each barracks in Sleman. It is assumed that the delivery of relief goods logistics from the warehouse to the refugee camps dilakuakn one distribution day. Results of calculation of the distance to the warehouse each location can be seen in Table 2.

TABLE 2 THE RESULTS OF CALCULATION THE DISTANCE OF EACH ALTERNATIVE LOCATION

Alternative Location	Distance	Total
Wukirsari	220	440
Umbulmartani	225	450
Candibinangun	227	454
Purwobinangun	241	482
Pakem	246	492
Brayut	251	502
Umbulharjo	260	520
UII	260	520
Girikerto	298	596
Wonokerto	301	602
Hargobinangun	304	608
Gondanglegi	307	614
Bimomartani	307	614
Plosokerep	316	632
Pagerjurang	319	638
Gayam SD Banaran	319	638
Glagaharjo	324	648
Sindumartani	326	652
SD Jiwan	342	684
Merdikorejo	346	692
Lumbungrejo	367	734
Sumberejo	446	892
Banyurejo	467	934

B. *Calculation Using AHP Methods*

At this stage, the weighting for each criteria and sub-criteria by using AHP. Weighting was conducted to determine the level of interest criteria and sub-criteria. Weighting is done by using AHP where each criteria and sub-criteria compared using pairwise comparisons. Respondents in this stage is the party that is competent in Sleman BPBDs Mitigation Section Chief, Section Chief of Preparedness, Disaster Logistics Section Chief, Section Chief of the Rehabilitation and Reconstruction Section Head. Data processing is performed by using a software expert choice. Results of the weighting of criteria and sub-criteria can be seen in Table 3 and Table 4.

TABLE 3 THE RESULTS OF WEIGHTING CRITERIA

Criteria	Weight
Location	0,125
National stability	0,292
Cost	0,061
Cooperation	0,050
Access to logistics	0,200
Safety	0,209
Warehouse facility	0,064

Global weights are used to look at the most important sub-criteria overall. Subcriteria social conditions has the highest weight is 0.144. This suggests that social conditions is the most important factor in determining the location of the warehouse logistics. The second position is the security of the warehouse with a value of 0.141. This indicates that the security of the warehouse is an important factor in determining the location of the warehouse logistics. The third position is close to the highway subcriteria has a weight of 0,100. This is due to the ease of access to transport is essential so that assistance can be distributed quickly and precisely.

TABLE 4 THE RESULTS OF WEIGHTING SUBCRITERIA

Criteria	Subcriteria	Weights
Location	Proximity to the evacuation site	0,204
	Located in the disaster-free areas	0,246
	Proximity to natural resources and human resources	0,071
	Accessibility	0,391
	Adequate land area	0,088
Cost	The land prices	0,213
	Maintenance	0,293
	Logistic	0,494
Access to logistics	Proximity to airport	0,158
	Proximity to highway	0,184
	Proximity to station	0,302
	Proximity to the other warehouse	0,356
National stability	Political situation	0,599
	Economic situation	0,209
	Social situation	0,049
Cooperation	Government	0,143
	Private organizations	0,180
	NGO's	0,498
	The neighboring countries	0,063
	Logistics agent	0,260
Safety	Safety of warehouse	0,677
	The distribution of relief goods	0,133
	Proximity to public safety facility	0,190
Warehouse facility	Appropriate infrastructure	1,000

C. *Calculation using Fuzzy TOPSIS*

At this stage, the selection of alternative warehouse locations eruption of Merapi in Sleman using Fuzzy-TOPSIS. Based on the results of questionnaires to the five respondents, the next step is normalized fuzzy decision matrix based on the scale used very low-value 1 (0; 0.1; 0.25), low-value 2 (0.15; 0.30; 0.45), medium-value 3 (0.35; 0.5; 0.65), high-value 4 (0.55; 0.7; 0.85) and very high value-5 (0.75; 0.9; 1). Furthermore, the calculation of the normalized weighted matrix. The purpose of this calculation is to get the weight of each sub-criteria and alternative locations. Wj values for this calculation using the weights obtained from the calculation using AHP of each sub-criteria. Examples for the calculation of sub-criteria proximity to the evacuation site in Purwobinangun:

$$Vij \quad = (0,55 ; 0,7 ; 0,85) \times (0,026) = (0,014 ; 0,018 ; 0,022) \qquad (1)$$

The next stage is to calculate the minimum value and the greatest value. Positive ideal solution denoted by A *, while the negative ideal solution is denoted by A-. The value of FNIS (A-) and FPIS (A*) as shown in Table 5.

TABLE 5 THE VALUE OF FNIS (A-) AND FPIS (A*) FOR EEACH ALTERNATIVE LOCATIONS

Alternative Locations	FNIS A-	FPIS A*
Purwobinanngun	0,0009	0,1226
Candibinangun	0,0004	0,1226
Wukirsari	0,0004	0,1226
Umbulmartani	0,0004	0,1226
Pakem	0,0004	0,1226

The next step is to calculate the distance of each sub-criteria at each location. Here is an example of the calculation for the sub-criteria proximity to the evacuation site Purwobinangun:

$$d^* : \sqrt{\frac{1}{3}(0{,}014-0{,}1226)^2+(0{,}018-0{,}1226)^2+(0{,}022-0{,}1226)^2}$$
$$= 0{,}105$$
$$d^- : \sqrt{\frac{1}{3}(0{,}014-0{,}0009)^2+(0{,}018-0{,}0009)^2+(0{,}022-0{,}0009)^2}$$
$$= 0{,}017 \quad (2)$$

After getting the value of d * and d-then the next step is to calculate the value of D * and D by means of D * is the sum of the value of d * for each location while D- represent the number of d- values for each location , The following is the result of calculation D * and D for each sub-criteria and alternative locations.

TABLE 6 THE VALUE OF D* AND D- FOR EACH ALTERNATIVE LOCATIONS

Alternative location	*D**	*D-*
Purwobinangun	2,284	0,665
Candibinangun	2,282	0,680
Wukirsari	2,282	0,679
Umbulmartani	2,292	0,670
Pakem	2,292	0,670

The next step is to calculate the relative proximity of each sub-criteria and alternative locations to the positive ideal solution. Here is an example of the calculation for the sub-criteria proximity to the evacuation site in Purwobinangun. Table 7 is the result of value Cci after sorted.

$$Cci = \frac{0{,}665}{2{,}284+0{,}665}$$
$$= 0{,}22557 \quad (3)$$

TABLE 7 THE VALUE OF CCI

Alternative locations	*Cci*
Candibinangun	0,22952
Wukirsari	0,22923
Pakem	0,22607
Umbulmartani	0,22607
Purwobinangun	0,22557

To determine alternative location of disaster logistics warehouse using the shortest distance calculations. There are 23 dots the locations contained in Sleman. Of the 23 points location, the BPBDs Sleman recomemend 5 location to be an alternate location with the shortest distance. The locations are Wukirsari (440 km), Umbulmartani (450 km), Candibinangun (454 km), Purwobinangun (482 km), and Pakem (492 km).

After getting the criteria and sub-criteria, the next stage is the weighting of each criteria and sub-criteria by using AHP. The sequence of the criteria are national stability (0.292), security (0.209), access to logistics (0.200), location (0.125), warehouse facilities (0,064), expenses (0.061), and collaboration (0,050). Then, based on the global weight is known that subcriteria which has the highest weight is social conditions (0.144), safety of warehouse (0.141), and proximity to the highway (0,100).

Furthermore, the warehouse site selection of natural disasters eruption of Mount Merapi in Sleman. To obtain the location chosen for this study used a fuzzy TOPSIS method, in order to get the results of objective research. There are 5 alternative location that is Purwobinangun, Candibinangun, Wukirsari, Umbulmartani, and Pakem.

IV. CONCLUSION

Based on the analysis, from five locations of the disaster logistics warehouse, Candibinangun chosen as optimal location of the warehouse logistics natural disasters eruption of Mount Merapi in Sleman. Further research is to determine the shortest path in the distribution of relief goods for natural disaster eruption of Mount Merapi.

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