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# Integrating AHP, Cluster Analysis, and Fuzzy TOPSIS to Evaluate Emergency Warehouse Locations of Mount Merapi Eruption Victims

Diana Puspita Sari[a,1], Purnawan Adi Wicaksono[a,2], Naniek Utami Handayani[a,3], Yessica Efirani Siahaan[a,4]

[a]*Industrial Engineering Department, Diponegoro University, Semarang, 50275, Indonesia*
*E-mail: [1]dpsari.01@gmail.com; [2]nawanadi@gmail.com; [3]naniekh@gmail.com; [4]yessicasiahaan@gmail.com*

***Abstract*— This paper discusses using a multi-criteria decision model (MCDM) to determine a logistics warehouse location for humanitarian aid. This study concerns the volcanic disaster that occurred in Sleman Regency, Indonesia, in 2010. When this disaster occurred, the location for the logistics warehouse was still based on the closest distance with road access. Since it was located without considering several criteria, delivery to victims was not optimal and faced many obstacles. In this study, MCDM is applied using analytic hierarchy process (AHP) and Fuzzy TOPSIS (a technique for the order of preference by similarity to the ideal solution); AHP is used to generate selection criteria and sub-criteria based on expert opinion, while Fuzzy TOPSIS is used to identify the best option among potential locations based on these criteria and subcriteria. This study also uses cluster analysis to determine potential emergency warehouse locations in each operational area based on distance and the number of refugees. Seven criteria and 17 subcriteria were identified to determine the location of the emergency warehouse. In this case, the criteria and subcriteria with the highest weights were both delivery time. Based on the weight of the criteria and subcriteria and the cluster analysis, four potential warehouse locations were identified in the following priority order: Sukoharjo, Sidokerto, Tamanmartani, and Wedomartani.**

***Keywords*— logistics warehouse; volcanic disaster; cluster analysis; MCDM.**

## I. INTRODUCTION

Mount Merapi, located approximately 20 km from the central government of Sleman Regency, is the most active volcano in Indonesia. Its slope is densely populated and therefore has high disaster risk, comprising several areas in Sleman Regency: Cangkringan, Pakem, Turi, Tempel, and Ngemplak. Eruption by Mount Merapi may threaten people and property in this area through pyroclastic flow, stones, heavy ash, lava flows, and toxic gases, in addition to the secondary hazards of cold lava floods that can occur during the rainy season [1]. Based on data from the Operation Control Center (Pusdalops) of the National Disaster Management Agency (BNPB), the death toll in Sleman Regency in 2010 reached as high as 116 people, and 54,153 fled. The Merapi eruption also caused considerable losses in terms of residential property, infrastructure, social and economic aspects, and cross-sectoral value (BNPB, 2010).

Facing an eruption of Mount Merapi requires good disaster management, balanced among before, during, and after the disaster. One disaster-management activity is to distribute aid to refugees, which should be done quickly and accurately. This activity is also called logistics, which, in the sense of disaster management, is anything that can meet the needs of human life in the form of clothing, food, medicine, and other needs of daily living. Disaster logistics involve efficient planning, implementation, and control processes to control the flow of material and cost-effectively store goods to reduce victims' suffering. Disaster logistics also includes the gathering of related information from start to finish [3]. Good disaster logistics require preparation, including providing locations of logistics warehouses in areas close to the disaster to increase capacity, decrease response time, and reduce operating costs [4]. As a means of storing relief supplies, logistics warehouses are storage places created in case of disaster [5]. The Regional Disaster Management Agency (BPBD) Sleman is tasked as a government agency to perform disaster management in Sleman Regency. In 2010, at the time of the Merapi disaster, BPBD Sleman had not yet been established, so the implementation of logistics distribution was less systematic, and there was unclear coordination. Based on interviews with the Head of the Logistics Division of BPBD Sleman, the activities completed at that time were still responsive and not preventative, and the leading logistics warehouses were not operating. As a result, the delivery of logistics was not coordinated, and distribution was vulnerable to late delivery. Thus, the quality of disaster management still requires improvement by anticipating risks before a disaster occurs.

BPBD currently has one warehouse at the Operation Control Center (Pusdalops) in Pakem, built-in 2012 and operational since 2015. According to interviews with the Logistics Division Head, this warehouse is used for the nonemergency response. If a disaster occurs, a warehouse will be placed closer to the disaster. However, in the event of another Mount Merapi eruption, it has been established as a disaster emergency warehouse. In other words, there is no definite and strategic warehouse location to make logistics available. In [6], the issue of where to store logistics supplies for humanitarian aid is discussed, concluding warehouses must be placed in strategic, easy-to-reach locations where logistical support supplies can be immediately used when needed [7].

Several methods have been developed for determining such locations since this subject is a critical issue in supply chain management [8]. The basic methods used to determine location [9] include the following: factor rating, the center of gravity, cluster analysis, artificial neural network, and mathematical program method.

Regarding volcano disaster management, BPBD Sleman plans for an explosive Mount Merapi eruption scenario, in which magma is released from the volcano in the form of an explosion. Explosive eruptions generally occur when volcanoes are idle for long periods of time. BPBD Sleman plans for 7 km eruption impact, a 10 km eruption impact, and 15 km eruption impact. In an explosive scenario, five areas on the slopes of Mount Merapi face major impacts: Cangkringan, Pakem, Turi, Ngemplak, and Tempel. BPBD has designated as many as 27 barracks for residents in those areas (BNPB, 2012). The area affected by the eruption of Mount Merapi in Sleman Regency is shown in Figure 1.

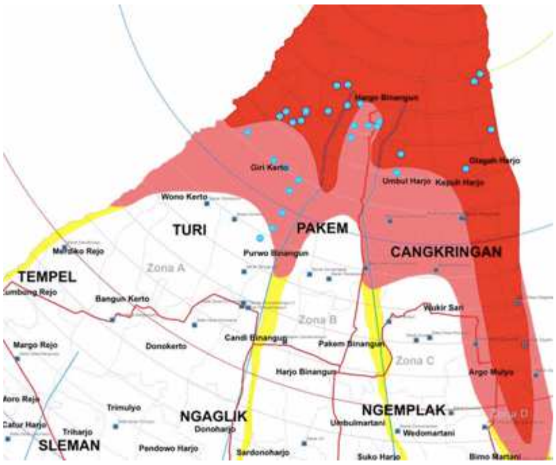


Fig. 1 The area affected by the eruption of Mount Merapi in Sleman Regency (Source: [10])

This research was conducted to propose to the Regional Disaster Management Agency (BPBD) a location for a new logistics warehouse around the evacuation areas in accordance with the planning scenario. The proposal includes the locations and number of logistics warehouses needed to serve potential disaster victims in Sleman Regency. The new strategic location is meant to meet all needs of displaced camps, resolving delays in logistics delivery, and minimizing losses that may be caused by the disaster. In this regard, we first determine the appropriate criteria and subcriteria for selecting locations for new logistics warehouses using weighted criteria and subcriteria selected by experts. The analytic hierarchy process (AHP) is used to select these criteria and subcriteria. Then, refugees are grouped by distance and number, and cluster analysis, with the concept of center of gravity, is used to find possible coordinate points of the new logistics warehouse based on a distance matrix calculated from each refugee point. The results are evaluated using the fuzzy technique for the order of preference by similarity to the ideal solution (Fuzzy TOPSIS), an approach to solving complex problems that involve comparing several alternatives. Fuzzy TOPSIS captures the human ambiguity involved when considering the complex, multi-criteria decisions [11]. In other words, Fuzzy TOPSIS can evaluate locations using subjective attributes that are usually difficult to explain, evaluating the solution while minimizing the uncertainty in human cognitive processes [12]. The final result after data processing is the optimal strategic location for a logistics warehouse.

## II. Materials and Methods

This research was conducted in Sleman, Yogyakarta. The first step was to conduct a preliminary literature and field study. The literature explains Multi-Criteria Decision Making (MCDM), cluster analysis, and the criteria and subcriteria that influence the determination of an appropriate logistics warehouse for disaster response. In the field study, interviews and questionnaires were administered. The second step was to identify the variables to be used. The research variables used in this study were the criteria and subcriteria [13], validated by providing questionnaires to respondents with relevant competence. The respondents were the Head of Emergency and Logistics and Staff of the Emergency and Logistics Section, Head of the Disaster Mitigation Section and the Staff of the Disaster Mitigation Section, and the Head of Preparedness and the Staff of Preparedness and Evacuation. For the AHP technique, respondents to the questionnaire on decision making should be experts [14], not in the sense that they are experts in a certain field of science but rather that they really understand and have competence in the relevant issues.

The criteria and subcriteria were selected by calculating the mean for each and choosing those with a mean value between 3 and 5, or between "Quite Important" and "Very Important" on the administered Likert scale. The criteria and subcriteria so selected were used to influence the determination of the location of the logistics warehouse in Sleman Regency, while those with a lower average value were ignored. Respondents could also offer additional criteria or subcriteria. After obtaining the selected criteria and subcriteria, we weighted each criterion and sub-criterion using AHP, one of the best MCDM approaches to solving complex, unstructured problems. AHP breaks such problems into components comprising hierarchies of criteria, interested parties, and experts, making decisions by identifying considerations to develop weight or priority [15]. At this step, a mathematical process begins to normalize and find the relative weights of each matrix, obtained by calculating the eigenvalues ($w$) corresponding to the largest eigenvalue ($\lambda_{max}$), as defined in eq. 1. After that, the evaluation is performed by calculating and checking the consistency ratio. If pairwise comparisons are consistent, then the matrix A has rank 1 and $\lambda_{max} = n$. Weights can be obtained by normalizing all rows and columns of matrix A.

AHP requires a condition that matrix A be consistent, defined as the relationship between A: $a_{ij}$ x $a_{jk}$ = $a_{ik}$. The formula of consistency index (CI) is shown in eq. 2. The consistency ratio (CR), used to determine whether the evaluation is sufficiently consistent, is derived from the ratio between CI and a random index (RI), as described in Table 2. The consistency of a random index for 1 to 10 criteria [16] is shown in eq. 3. If CR <0.1, the global weight is calculated, and the relative weight (*W*) of each element is aggregated to obtain a total rank for the alternatives formulated by eq. 4.

$$Aw = \lambda_{\max} w \tag{1}$$

$$CI = \frac{\lambda_{\max} - n}{n-1} \tag{2}$$

$$CR = \frac{CI}{RI} \tag{3}$$

$$W_i^s = \sum_{j=1}^{m} W_{ij}^s W_{ji}^{\alpha},\ i = 1,2,3,...,m \tag{4}$$

Where:

CI : Consistency index
λ : Eigen values
n : number of criteria

TABLE I
RANDOM INDEX VALUES

| n | RI | n | RI |
|---|---|---|---|
| 1 | 0 | 6 | 1.23 |
| 2 | 0 | 7 | 1.32 |
| 3 | 0.58 | 8 | 1.41 |
| 4 | 0.9 | 9 | 1.45 |
| 5 | 1.12 | 10 | 1.49 |

The second method used was cluster analysis, which classifies each point of demand based on proximity and the amount of demand by area. Cluster analysis uses the concept of center of gravity and is a statistical technique that classifies objects in a single unit. This analysis aims to group objects that have similarities in one shared basket and which have differences with other hoops where, in this case, the hoof must have homogeneous properties [17]. In this case, demand is the number of refugees. As each demand is at a known coordinate point, the next step is to calculate the distance matrix with eq. 7. Distance is calculated as Euclidean distance (the square root of the difference of the value of each variable in [18]). Furthermore, after all, distances are known, the two points of demand with the shortest distance are merged, with new coordinates obtained using eq. 5 and 6:

$$x = \frac{(x_1 d_1) + (x_2 d_2)}{d_1 + d_2} \tag{5}$$

$$y = \frac{(y_1 d_1) + (y_2 d_2)}{d_1 + d_2} \tag{6}$$

$$D = k\sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \tag{7}$$

Where:

$x_1$ = x coordinates of demand 1
$x_2$ = x coordinates of demand 2
$y_1$ = y coordinates of demand 1
$y_2$ = x coordinates of demand 2
$d_1$ = demand point 1
$d_2$ = demand point 2
D = distance of demand point 1 and demand point 2 location
k = scale used

The third step is to evaluate potential locations by using Fuzzy TOPSIS based on the concept that the best-chosen alternative. The criteria do not only have the shortest distance from the ideal solution but must also have the longest distance from the ideal negative solution but added to the fuzzy number [19]. The Fuzzy TOPSIS steps that we use are as below [20]:

- Aggregate the weight of criteria to get the aggregated fuzzy weight wj of criterion C*j* using eq. 8 and pool the decision-makers' ratings to get the aggregated fuzzy rating $x_{ij}$ of alternative $A_i$ under criterion $C_j$ using eq. 9.

$$w_{j1} = \min(w_{jk1}),\ w_{j2} = \frac{1}{K}\sum_{k=1}^{K} w_{jk2},\ w_{j3} = \max(w_{jk3}) \tag{8}$$

$$a_{ij} = \min k\left(a_{ij}^k\right),\ b_{ij} = \frac{1}{K}\sum_{k=1}^{K} b_{ij}^k,\ c_{ij} = \max k\left(c_{ij}^k\right) \tag{9}$$

- Construct the fuzzy decision matrix and the normalized fuzzy decision matrix using eq.10.

$$r_{ij} = mxn;\ i = 1,2,3,...,m\ ;\ j = 1,2,3,...,n \tag{10}$$

- Construct the weighted normalized fuzzy decision matrix using eq.11.

$$y_{ij} = w_{ij}\, x\, r_{ij} \tag{11}$$

- Determine FPIS and FNIS and calculate the distance of each alternative from FPIS and FNIS, using respectively eq.12, 13, 14 and 15.

$$A^+ = \{v_1^+, v_2^+, ..., y_m^+\} = \{(\max_j v_{ij} | i \in I'), (\min_j v_{ij} | i \in I'')\} \tag{12}$$

$$A^- = \{v_1^-, v_2^-, ..., y_m^-\} = \{(\max_j v_{ij} | i \in I'), (\min_j v_{ij} | i \in I'')\} \tag{13}$$

$$D_i^+ = \sqrt{\sum_{j=1}^{n}\left(v_{ij} - v_j^+\right)^2},\ i = 1,2,3,...,m \tag{14}$$

$$D_i^- = \sqrt{\sum_{j=1}^{n}\left(v_{ij} - v_j^-\right)^2},\ i = 1,2,3,...,m \tag{15}$$

A positive Ideal Solution ($A^+$) is obtained by finding the maximum value of the weighted normalization value ($y_{ij}$) if the attribute is a gain one and finding the minimal value of the weighted normalization value ($y_{ij}$) if the attribute is a cost one.

A negative Ideal Solution ($A^-$) is obtained by searching for a minimum value of the weighted normalization value ($v_{ij}$) if the attribute is a gain one and becomes the maximum value of the weighted normalization value ($v_j$) if the attribute is a cost one.

- Calculate the closeness coefficient of each alternative and rank the alternatives using eq.16

$$CC_i = \frac{D_i^-}{D_i^+ + D_i^-} \tag{16}$$

- Sorting based on $CC_i$ value from high to low.

The next stage is to perform the analysis to be able to discuss in more detail the data processing. At this stage, it is obtained the results of the discussion of the research thoroughly and answer the formulation of the problem is prepared.

## III. Results and Discussion

This research consists of four main stages: determining criteria and subcriteria of research, determining the importance of weight using AHP, determining potential location using cluster analysis, and potential location evaluation using fuzzy TOPSIS.

### *A. Criteria and Subcriteria in Determining Warehouse Location of Logistics Disaster*

The criteria and subcriteria used in this study are the criteria and subcriteria that have averages between the 3 and 5 on the Likert scale with the primary selection of this value because the meaning of number 3 on the Likert scale means quite essential and the number 5 has the meaning of very important. The seven criteria and 21 subcriteria were adapted from previous research [12]. After validation, seven criteria, and 17 subcriteria used as criteria and subcriteria that influence the determination of logistic warehouse location in Sleman regency. Table 2 shown the criteria and subcriteria after validation.

TABLE II
CRITERIA AND SUBCRITERIA

| Criteria | | Subcriteria | |
|---|---|---|---|
| A | Cost | A1 | Investment cost |
| | | A2 | Distribution cost |
| | | A3 | Operating costs |
| B | Delivery time | B1 | Delivery time for evacuation |
| C | Distance | C1 | Distance to disaster-prone areas |
| | | C2 | Distance to related NGO |
| | | C3 | Distance from supplier |
| D | Infrastructure | D1 | Land transportation availability |
| | | D2 | Availability of air transport |
| E | Climate conformity | E1 | Rainfall |
| | | E2 | Humidity |
| F | Socioeconomic aspects | F1 | Crime level |
| | | F2 | Employee availability |
| | | F3 | The convenience of communication (language) |
| G | Related aspects personal | G1 | Environmental health around the warehouse |
| | | G2 | Food diversity |
| | | G3 | Quality of life |

There are several subcriteria that have a value below 3, such are procurement cost, availability of sea lane transportation, temperature and socioeconomic aspects and the last is political stability. Thus, these four subcriteria are not taken into consideration in determining the location of the logistics warehouse in Sleman Regency

### *B. The Weighting of Criteria and Subcriteria using AHP Method*

AHP method in this research is used to determine the weight of each criterion and subcriteria that influence the selection of logistics warehouse locations in Sleman Regency. Input data used in data processing using AHP method is the result of pairwise comparison questionnaires, where each criterion or subcriteria on the same criteria is compared to each other. This method consists of four stages, namely: distributing paired questionnaires to the specified respondents, evaluating by checking the consistency ratio, estimating relative weights, and lastly, calculating the global weight.

After the results obtained questionnaire and inconsistent value valued at > 0.1, the next step is to calculate the relative weight and global weight using expert choice software. Table 3 is shown the result of weighting.

TABLE III
WEIGHT OF CRITERIA AND SUBCRITERIA

| Criteria | Weight of Criteria | subcriteria | Local Weight | Global Weight |
|---|---|---|---|---|
| A | 0.0489 | A1 | 0.1527 | 0.00747 |
| | | A2 | 0.4723 | 0.02310 |
| | | A3 | 0.3750 | 0.01834 |
| B | 0.4582 | B1 | 1.0000 | 0.45820 |
| C | 0.1991 | C1 | 0.0963 | 0.01917 |
| | | C2 | 0.5890 | 0.11727 |
| | | C3 | 0.3148 | 0.06268 |
| D | 0.1586 | D1 | 0.6661 | 0.10564 |
| | | D4 | 0.3339 | 0.05296 |
| E | 0.0503 | E1 | 0.5741 | 0.02888 |
| | | E2 | 0.4259 | 0.02142 |
| F | 0.0489 | F1 | 0.2259 | 0.01105 |
| | | F2 | 0.3353 | 0.01643 |
| | | F3 | 0.4388 | 0.02150 |
| G | 0.0360 | G1 | 0.5334 | 0.01920 |
| | | G2 | 0.1253 | 0.00451 |
| | | G3 | 0.3413 | 0.01229 |
| | | | Total | 1.00000 |

### *C. Determining Potential Locations using Cluster Analysis*

Cluster analysis is a grouping method that can classify each point of demand based on proximity distance and amount of demand (number of population) within a specific area with the concept of center of gravity. Calculation begins with identifying the coordinates of each point of demand. A coordinate point is known by using a map of the grid using google maps application. The purpose of grid delivery is as a benchmark for determining the distance and the combined location of the demand points. After each point of demand is known as the coordinates, the next step is to calculate the distance matrix using equation 7, using scale 1: 111 km, because the earth has a diameter of 12,756 km, and circumference ± 40.000 km. The earth's circumference of 3600 longitude means every 10 is ± 111 km. Every ten longitudes/latitude on the map represents a distance of 111 km, actually on the surface of the earth.

After all, distances are known, the distance between the two points of demand that have the shortest distance is done merging, eq.5 and six consequence can search the new coordinates of the merging of these two demand points. After the new coordinates are obtained, the distance calculation is done again continuously until no longer possible grouping because the point of demand is only one left or because of the maximum distance between the point of demand has been achieved. From the calculations that have been done, the obtained location of the logistics warehouse location is table 4.

TABLE IV
POTENTIAL LOCATION

| No. | Operation Area | Location | Coordinates |
|---|---|---|---|
| 1. | I | Sukoharjo | (7.69000 ; 110.43548) |
| 2. | II | Sidokerto | (7.75474 ; 110.45312) |
| 3. | III | Tirtomartani | (7.52750 ; 110.47070) |
| 4. | IV | Wedomartani | (7.73250 ; 110.43545) |

*D. Conducting Potential Location Evaluation using Fuzzy TOPSIS*

The Fuzzy TOPSIS Method in this research is used to evaluate the potential location of a logistics warehouse in Sleman Regency, which previously has been obtained from data processing by using the cluster analysis method. There are six steps in the calculation of volcanic logistics warehouse evaluation in the Sleman Regency. The first step is to make a decision-making matrix. The decision-making matrix used in this method is the matrix that contains the data to be processed, where the data describes the state of each alternative based on each subcriteria. The condition of each potential location of each subcriteria generates by questionary. The second step is to normalize the decision-making matrix. The purpose of normalizing the matrix is to obtain the same unit of each subcriteria of a potential location that previously still has a different scale. Normalization of decision making is done by using triangular numbers. The results of each questionnaire are converted into triangular numbers so that the decision-making matrix is between 0-1. The next step is to weight the normalized decision-making matrix. There is a multiplication of the matrix with the global weight obtained from AHP data processing to obtain the matrix weight. So we get the weight of the decision-making matrix.

After the matrix of normalization has been multiplied by the weight of importance, the next step is to determine the value of Fuzzy Positive Ideal Solution (F PISA+) and Negative Ideal Solution (F NISA-) using eq. 12 and 13 consequences. The next step after obtaining FPIS and FNIS is to calculate the distance from each alternative location with FPIS and FNIS using eq. 14 and 15. Distance from each alternative location is shown in table 6. After obtaining the d+ and d- values, then it is determined that the D+ and D- values using obtaining the D+ value at the Sukoharjo location are the sums of the d+ values for that location. Whereas to obtain the value of D- is the number of d- values at that location. Table 7 showing the value of D- is the number of D- values in each location.

TABLE V
F PISA AND F NISA VALUES

| Subcriteria | Goal | $A^+$ | $A^-$ |
|---|---|---|---|
| Investment Cost | Min | 0.0000 | 0.0075 |
| Distribution Cost | Min | 0.0000 | 0.0173 |
| Operating Costs | Min | 0.0046 | 0.0138 |
| Delivery Time to Evacuation | Min | 0.0000 | 0.4582 |
| Distance to disaster-prone areas | Min | 0.0000 | 0.0144 |
| Distance to Related NGO | Min | 0.0293 | 0.0880 |
| Distance from Supplier | Min | 0.0000 | 0.0470 |
| Land Transportation Availability | Max | 0.1056 | 0.0528 |
| Availability Air transport | Max | 0.0265 | 0.0000 |
| Rainfall | Min | 0.0000 | 0.0144 |
| Humidity | Min | 0.0054 | 0.0161 |
| Crime Level | Max | 0.0083 | 0.0028 |
| Employee Availability | Max | 0.0164 | 0.0041 |
| The convenience of Communication (language) | Max | 0.0215 | 0.0108 |
| Environmental Health Around Warehouse | Max | 0.0192 | 0.0048 |
| Food Diversity | Max | 0.0023 | 0.0001 |
| Quality of Life | Max | 0.0123 | 0.0031 |

TABLE VI
DISTANCE FROM EACH ALTERNATIVE LOCATION

| | Sukoharjo | | Sidokerto | | Tirto martani | | Wedo martani | |
|---|---|---|---|---|---|---|---|---|
| | $d^+$ | $d^-$ | $d^+$ | $d^-$ | $d^+$ | $d^-$ | $d^+$ | $d^-$ |
| A | 0.00 | 0.01 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.01 |
| B | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| C | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| D | 0.15 | 0.36 | 0.15 | 0.36 | 0.36 | 0.15 | 0.25 | 0.25 |
| E | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| F | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| G | 0.02 | 0.03 | 0.03 | 0.02 | 0.03 | 0.02 | 0.03 | 0.02 |
| H | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| I | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| J | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| K | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| L | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| M | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| N | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| O | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| P | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Q | 0.01 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 | 0.00 | 0.01 |
| ∑ | 0.33 | 0.56 | 0.33 | 0.54 | 0.56 | 0.32 | 0.44 | 0.44 |

TABLE VII
D+ VALUE AND D- VALUE IN EACH LOCATION

| Potential Location | $D^+$ | $D^-$ |
|---|---|---|
| Sukoharjo | 0.32783 | 0.56147 |
| Sidokerto | 0.34828 | 0.54093 |
| Tirtomartani | 0.56432 | 0.32488 |
| Wedomartani | 0.44416 | 0.43592 |

The next step is to calculate the value of CCI to determine the order of potential locations of the logistics warehouse in Sleman by using eq. 16. The final step in the calculation using the Fuzzy TOPSIS method is to sort the value of CCi from the largest to the smallest. The objective is to get the best possible emergency disaster storage location based on essential criteria and subcriteria. This study found that Sukoharjo is the best potential location. The following table 8 shows the sorting results:

TABLE VIII
RANK OF POTENTIAL LOCATION

| Rank | Potential Location | $CC_i$ |
|---|---|---|
| 1 | Sukoharjo | 0.63136 |
| 2 | Sidokerto | 0.60833 |
| 3 | Tirtomartani | 0.49486 |
| 4 | Wedomartani | 0.36536 |

The comparison between the old warehouse location and the new warehouse location is based on the map of refugee barracks in Sleman; the distance between the location of Mount Merapi and the Pakem area is on the eruption radius of 15 km where the distance is an insecure distance and too close. In 2010, the worst impact of the eruption on Merapi was on the impact of the eruption of 17 km; in other words, Pakem Regency, where the old logistics warehouse disaster is not safe to be a logistics warehouse. As for the location of a new warehouse in the village Sukoharjo, Ngaglik regency is at a distance of 20.4 km, which can be interpreted to have a reasonably safe distance from the worst impact eruption of Merapi. The problem of delivery time from the warehouse to the evacuation barracks in Pakem area logistics delivery time. Distribution of goods from Pakem warehouse to 27 barracks mostly has to pass the main river bridge accesses, namely the Boyong river, Kuning river, Opak river, and Gendol river. It will be more difficult if there is a cold lava flood after the eruption process, which will cause damage to bridge crossings commonly used for road access. In the village of Sukoharjo, there is no river flow and has access to the highway so that the logistics delivery process is faster than the other.

Based on data processing, Sukoharjo village is a potential location that can cover 27 evacuation barracks and is a location by applicable subcriteria. In addition to road access, the proximity to the airport also needs to be taken into account. The distance between Adisutjipto International Airport and Sukoharjo Village, Nganglik area, is much closer than the Pakem area. The time required to travel from Adi Sutjipto airport to Ngaglik area is 27 minutes while the greeting is 47 minutes. This distance is influential in the process of logistics delivery because the assistance obtained from outside the area of the country is sent through the airport. Proximity to public facilities such as airports can benefit and speed up the logistics delivery process. Warehouse logistics disaster formerly located in Pakem area is the center of controlling the operation of all BPBD activities and converted functioning into a logistics warehouse disaster when it occurs. It indicates all the main activities carried out in this warehouse, all equipment, and other needs are placed in Pakem area, obtained through the calculation of cluster analysis is the coordinate point in the rice field area. So, the difficulty is to determine another place that can be used as an alternative location. It is impossible to build an emergency warehouse in the area, by looking at some vacant land around the point of coordinates that can be used as an alternative to the construction of a logistics warehouse disaster.

## IV. CONCLUSION

There are seven criteria and 21 subcriteria chosen to be considered in determining the logistics warehouse of volcano disaster in Sleman Regency. These criteria are cost, delivery time, distance, infrastructure, climate, socioeconomic aspects, and related personal aspects. The selected subcriteria are investment cost, distribution cost, delivery time to the evacuation point, distance to disaster-prone areas, distance to related NGO, distance from supplier, availability of land transportation, availability of airway transportation, rainfall, humidity, crime rate, availability of employees, ease of communication, environmental health, food diversity, and quality of life. The location of the logistics warehouse by the criteria and subcriteria selected are Sukoharjo for the operational area I of Cangkringan, Sidokerto, for the operational area II Nganglik, Tamanmartani for the operational area III, Pakem and Wedomartani for the operation area III Turi-Tempel. The result of potential location determination is done by using the AHP method and cluster analysis and then evaluated the four potential locations by using TOPSIS fuzzy to obtain Sukoharjo as the best potential location.

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