

# Behavior Proportion According to Merapi Volcano Eruption Evacuations in 2010

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**Abstract –** This paper presents the need of contingency plan for evacuation of Merapi Volcanic eruption by considering the behavior proportion of people in the slopes of Mount Merapi when facing emergency response phase. The research had used exploratory retrospective view survey with face-to face interview. The questionnaire consists of two categories made based on literature studies. Both categories are respondent profile and behavior type. The sampling method used here is *multi stage stratified convenience sampling* ( $n = 100$ , *response rate* = 100%). Communities around the danger zone III and the danger zone II in Pakem and Cangkringan sub-districts are chosen to be the object of the study. This study shows that there are five types of people's behavior including the proportion and behavior mechanism in communities in slopes of Mount Merapi when facing emergency evacuation.

**Keywords –** Evacuation; Merapi eruption; Behavior; Risk Mitigation; 2010 volcanic crisis

## I. INTRODUCTION

Mount Merapi is located in the center of Java island, between the border of Central Java and Yogyakarta, at  $7^{\circ} 32.5'$  South latitude and  $110^{\circ} 26.5'$  East Longitude. The south side of Merapi is located in Sleman Regency, Yogyakarta Special Region Province and Central Java [1]. Any kind of accident or natural catastrophe from this Mountain can cause great damage to the environment and loss of people's lives.

Mount Merapi is classified into basaltic-andesitic strato volcano and lava dome [1, 2, 3, 4], it means that Mount Merapi is a conical volcano with a rough circular mound-shaped protrusion as result of slow extrusion of lava and may be destroyed by gravitational collapse or explosion, the collapse of lava dome can generate pyroclastic flows or *nuées ardentes* [5, 6]. Mount Merapi is the most active volcano in Indonesia [2] as well as one of the most active volcanoes in the world [7, 8, 9].

Mount Merapi's eruption in 2010 began with several tectonic earthquakes occurred, and big blasts at November 3<sup>rd</sup> and 5<sup>th</sup>. Eruption at November 3<sup>rd</sup> and 5<sup>th</sup> more

hazardous than October 26<sup>th</sup>, because *pyroclastic flows* launched over 15 km into south side of Mount Merapi [10]. *Pyroclastic flows* and volcanic materials damaged 3,307 buildings and resulted in 341 people died who were 242 people from Yogyakarta Special Region and 97 people from Central Java Province [10].

Many previous studies have shown that Merapi Volcanic eruption is a natural disaster causing high impact or high risk. Risk is closely related to the variation of the possible uncertain outcomes. Risk reflects the possible deviation of actual outcome from the expected value [12]. In the risk map, volcanic eruption can be classified into 'high impact-low probability' risk. One of the efforts in 'high impact-low probability' risk mitigation is by reducing its impact, reducing the impact can be done by assigning an evacuation policy and also by simulating the disaster evacuation system in ABM (Agent-Based Modeling). Agent-Based Modeling is computer simulation modeling used for simulating behavioral rules of people (agent) when facing the volcanic disaster. Agents are defined as decision-makers which have heterogeneous attributes and sets of rules or behaviors [13]. In this case, people living on the slope of Mount Merapi are considered as the agents according to the ABM framework to this study.

The purpose of this study is to determine the proportion of people's behavior during the 2010 eruption of Mount Merapi. The results of this study can be used as references in community-based evacuation behavior planning and can be recommended to the agencies and related organizations in an effort to recognize the concept of people's behavior and the proportion of each behavior when faced with an emergency evacuation of Mount Merapi eruption so that appropriate interventions can be formulated in an effort as a risk mitigation of Mount Merapi eruption.

## II. METHOD

The method of this study is exploratory retrospective view surveys and it is through face-to-face interview in which was done in Indonesian and Javanese language. Exploratory is one of the empirical methods capable of providing preliminary information for new research areas [14]. The obtained information in this study was information about behavior of the population since the improvement of the status of Merapi on October 20<sup>th</sup>, 2010 to October 26<sup>th</sup>, 2010.

The sampling technique used in this research is multi stages convenience sampling. This research stages consist of disaster vulnerability area that is, "danger zone III" and "danger zone II". Danger zone III is the most dangerous area with the position closest to the peak of Mount Merapi. Subsequently, the sub-districts covering both areas are Cangkringan and Pakem sub-districts, these sub-districts were selected by taking into consideration the greatest number of casualties in the areas affected by the Merapi Volcano Eruption.

There are three activities that the researcher can do in order to get the result of data by using the survey instrument survey. First, identifying relevant information to obtain by doing the literature reviews. Second, developing important questions. Third, testing the effectiveness of survey instruments by encouraging a pilot study in order to get the precise communication tool between researchers and respondents. Pilot study is done on two things: face validation and content validation. Face-to-face interviews were conducted to 100 respondents in West Kaliurang, Pelemsari, Pangukrejo, Gondang, and Petung Village. To increase the response rate, we gave presents for each respondent.

TABLE I. STRUCTURE OF QUESTION

| Stage | Objective  | Result   |
|-------|--|--|
| 1     | Clasified the type of respondent's behavior                                  | Five types of behavior based on Handayani et al., (2016) |
| 2     | Investigated the behavior of each type at three phase of evacuation decision | Behavior proportion                                      |

## III. RESULTS

### A. Respondents' Profile

The survey was undertaken among 100 respondents among five villages in "danger zone III" and "danger zone II". West Kaliurang, Pelemsari, Pangukrejo, Gondang, and Petung, the average age of respondents is 28.8 years. Most of the people of Merapi slopes work as farmers and cattle breeder. The people take care of cow on the land that they own. In livestock activities, the typical animals that the people breed are dairy cattle and beef cattle [15]. From the

research result, 20% of respondents work in the formal sector as government employees and private employees, 40% of respondents work as farmers and ranchers, and 40% respondents work in other sectors such as traders, housewives, students and others. The average number of family members who live in one house as many as 4 people. The average respondents live in this villages are for 27 years.

Contingency plan of 2010 Mount Merapi eruption disaster had considered vulnerable groups, it meant that they were the first group to be saved. According to Wolshon [16], in evacuation planning it is necessary to consider vulnerable community populations (children, parents, pregnant women, and disabled or people with special needs). While making evacuation decisions, vulnerable groups have a high dependence on the surrounding communities. From some disaster evacuation cases, as many as 20% of the total population, vulnerable groups are potentially in need of help [16]. From the results of the study, there are 30% of vulnerable groups (children, pregnant women, elderly, and disabled). Ninety four percent of them have been evacuated several days before the major eruption, 4% was evacuated during the eruption and shortly after the eruption, these factors were influenced by socio-cultural perception of Mount Merapi eruption, physical condition and mental health.

TABLE II. DEMOGRAPHIC INFORMATION OF RESPONDENT

|            | Demographic Information        | Percentage |
|------------|--------------------------------|------------|
| Gender     | Male                           | 51 %       |
|            | Female                         | 49 %       |
| Age        | Productive (15-64 year)        | 79 %       |
|            | Non-productive (< 15 and > 64) | 21 %       |
| Education  | Elementary school              | 43 %       |
|            | Junior high school             | 15 %       |
|            | Senior high school             | 25 %       |
|            | University graduate            | 5 %        |
|            | Non-formal education           | 12%        |
| Occupation | Farmers                        | 35 %       |
|            | Ranchers                       | 5 %        |
|            | Students                       | 16 %       |
|            | Housewives                     | 15 %       |
|            | Employees                      | 20 %       |
|            | Religious leaders              | 2 %        |
|            | Others                         | 7 %        |

### B. Cattle Ownership

Proulx [17] had found that after hearing the disaster warnings, respondents will be searching for their livestock. There are ample evidences to suggest that pet owners are reluctant to evacuate because refugee camps do not provide shelters for their pets [18]. There were 75% respondents from 100 claimed that they have 3 to 4 cows during eruption of Mount Merapi in 2010. While, the rest of them cared other cattle and pets, such as goats, poultries and rabbits.

At Mount Merapi, evacuations are organized at the municipality level. Although the municipality had made efforts to relocate to IDP (Internally Displaced Person) camps, community slopes of Mount Merapi have a tendency to go back to their house, the owners of livestock, especially cattle, which do not have shelter for their cattle. In the night, they stayed in the IDP camp, and in the morning, they would keep returning home to care for and feed their livestock. Cattle are something that is very valuable for the people of Mount Merapi slope, the cow has several functions, such as supporting their social status, being as form of investment, producing fertilizers, and plowing rice fields. [19, 20].

### C. Departure Time

Identifying departure times was a critical factor in evacuation planning. Several factors such as social factors might affect “go/stay” decisions [21]. Some studies have suggested that people will decide to evacuate after seeing or perceiving threats of danger or after obtaining information from others [22].

Villagers who inhabit in “danger zone III” are generally used to evacuate, because the position of their village which close to the danger area suggested them a lesson for the importance of evacuation. Our analysis of interviews and questionnaires also indicates that, 88% of respondents had made the first evacuation decision when CVGGM issued an increase of danger level from warning level III (prepared) to warning level IV (beware). There were 6% respondents from 100 claimed that they were evacuated when they received an appeal from the officers and volunteers, 1% after seeing the eruption, 4% after hearing a roar, and 1% of respondents refused to evacuate altogether, this was happened in Kaliurang village. Seven percent of respondents said they intentionally delayed the evacuation, from seven percent delaying the evacuation, five percent was caused by socio-cultural perception and beliefs that the pyroclastic flow or “lahars” would not pass through their residence which located on the south side of Mount Merapi, and two percent of respondents for preparing supplies at IDP camp, the average time to delay is 5 minutes. Generally, ninety nine percent of respondents had evacuated together with other people, either with family members or evacuating with their neighbors. The average time required from home to the IDP camp is 10 minutes.

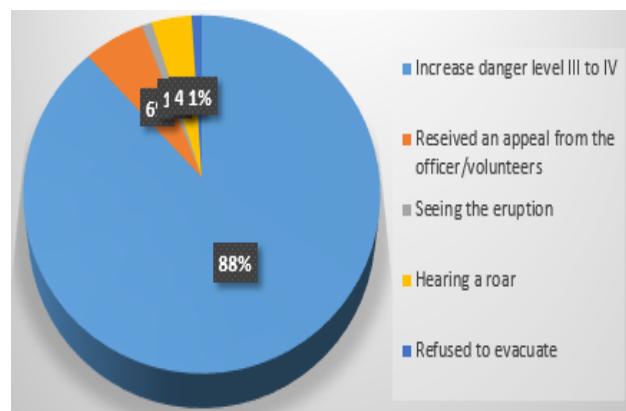


Fig. 1. Departure time

### D. Mode of Transportation

Vehicles which were used during the Mount Merapi eruption in 2010 were motor cycle, car, and truck, either what they owned or what they got from others (official transport) [11]. Based on interview, peoples who do not own vehicle will be given a ride by their relatives, neighbors, volunteers, army, police, and the Government and/or by the Non-Government Organizations (NGOs). People who did not receive a help pick up, they had to walk away from danger to the main road or a gathering point, then in the end, gradually picked up by team of volunteers or people who were ready to help.

From the research, 58% of respondents have a vehicle, 20% of respondents drive their own vehicles during the evacuation. 40% use motorcycles and 30% of respondents use trucks or mini-trucks. Emergencies cause vehicle capacity exceed the capacity of the vehicle in general. Based on the survey results, the capacity of vehicles such as mini-trucks can load as many as 20 people, 45 trucks, and motorcycles can carry up to 3 adults.

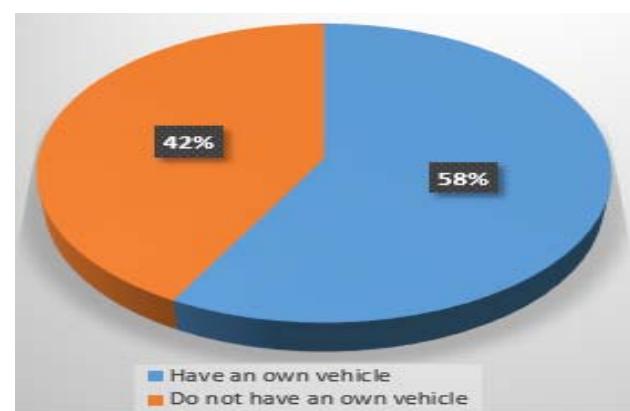


Fig.2. Vehicle ownership

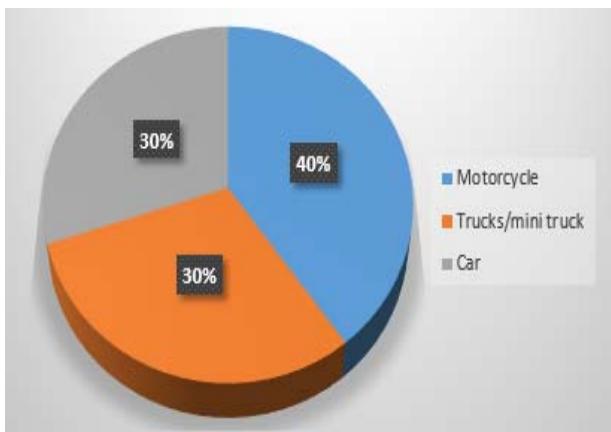


Fig. 3. Transportation mode

#### *E. Mechanism of Volunteers in Helping Others*

Fear of looting was one factor that causes resident reluctant to evacuate [11]. Many people still wanted to return home, although they were in dangerous conditions. The reasons were varied; such as fear of looting, caring and feeding of cattle, taking a shower, picking up supplies or checking the condition of their houses. At night, they stayed in the IDP camp, and went back every morning to their village. This daily migration was facilitated by the head of the village and the volunteers. Any citizen who wished to return home must obtain permission (approval) from the head of their village. After being granted permission, residents who wished to return home will receive a guide, the guidance for them usually by riding a truck, by one *Dukuh* (head of village) and about ten volunteers (male and female) or by riding their own motorcycle.

The supportive team was waiting in a rallying point, one person would guard and supervise visually the volcanic activity, while the communication between volunteers was facilitated by using a hand-held, portable, two-way radio transceiver such as walkie-talkie. In the event of danger then, the head of the supportive team fleet will provide cues signaling danger by sounding loudspeakers or "*kentongan*" for the peoples to immediately evacuate. There was a limit of time and circumstances set by the team, the average time was about 15 to 20 minutes by considering the list of participant names and hazard conditions.

#### *F. Evacuation Routes and Destination Choice*

In general, most people often look for routes which are familiar to them or look for roads normally used by people [21, 23]. The choice of destination may be related to the type and location of the accommodation. Commonly used accommodation types have generally been IDP camp (shelters), friends'/relatives' homes, hotels/motels [21, 24]. Based on previous research, of the selected accommodation types, average about 15% of refugees chose IDP camps (Sorensen, 2000). Factors affecting refugees in choosing evacuation sites are hazard severity, income levels, evacuation measures, emergencies,

evacuation, age, and ethnicity [25], education and livestock/pet ownership [26].

From this research, 95% respondents already know about the evacuation path from their house to the IDP camp or safer place. Most of the respondents stated that the path was commonly passed in their daily activities. Before the eruption occurred citizens have gained socialization of the destination, the nearest evacuation point is the village hall offices located in each village. Along with the increasing status of danger/warning level and also range of pyroclastic flow hazards, residents faced three displacement points of refuge (IDP). First, the Village Hall for the citizens of "danger zone III" and "danger zone II", second, the Wukir sari evacuation barracks, and third, the sports stadium in Maguwoharjo and several other community facilities. From the results of the study, 90% of residents chose to live in IDP camps with other residents, and 10% of respondents live in relatives' homes.

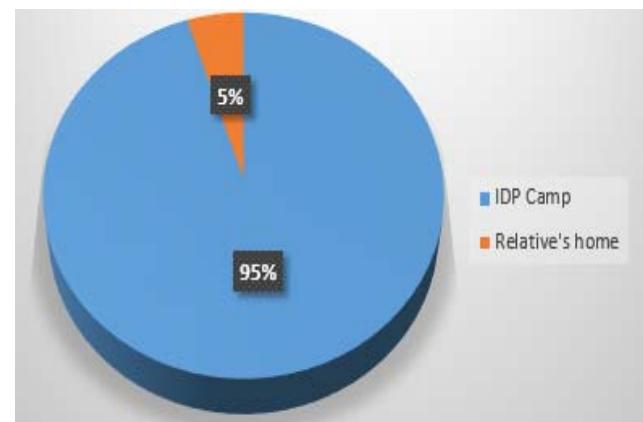


Fig. 4. Accommodation type

#### *G. Behavior Proportion*

During the evacuation period in the context of disaster in general, the refugees are always conflicted with three kinds of decision whether to evacuate or not, what mode of transportation to choose, and which evacuation route to take. However, the decision is based on the readiness of someone to evacuate during the disaster [15].

The first phase is go/stay decision, according to [10], there are two kinds of reaction from the society in the slope of Mount Merapi when facing eruption. They are (1) group of people who are ready, and (2) group of people who are not really ready. The unprepared group is influenced by several barriers such as lack of activity preparation, lack of education about disaster risk reduction and experience that may cause wrong perception about danger, discoordination, lack of knowledge about the evacuation route, confused, and a too long process of pre-evacuation due to gathering the family members and cattle.

Wrong perception about danger is influenced by socio-cultural factor, e.g., *Mbah Maridjan* and his followers'. *Mbah Maridjan* (*mbah* in javanese means grand father) was the caretaker of Mount Merapi during the

eruption in 2010. He and his followers refused to be evacuated because he was sure that the eruption of Mount Merapi will not flow to the southern side. He saw natural phenomenon using instinctual perspective based on his experience in observing the threat of Merapi eruption that almost never reach Kinahrejo Village, Cangkringan, Sleman where *Mbah Maridjan* resided at that time. The house is located just 4.5 km from the peak of Mount Merapi. This experience gave him a lesson that the natural environment in the southern side of Mount Merapi is the defense fortress for his people. The refusal to leave the danger zone has also been observed elsewhere. During the 1980 eruption of Mount St. Helens, a resident named Harry R. Truman refused to leave his home in the danger zone due to his attachment to the volcano and his belief that the volcano would not destroy his village [27]. Evacuation refusals at Merapi volcano and Mount St. Helens show us that even though local communities were prepared to face the eruption, in reality, not all members of the communities are prepared to evacuate.

According to Handayani et al., [15], during the evacuation, the community can be divided into five types. They are Official leader, (2) Cultural leader, (3) Vulnerability Groups, (4) Prepared-Community Members, dan (5) Unprepared-Community Members. Leader type is a type of community who can lead and direct others. The differences between an official leader and a cultural leader lies in their beliefs and sources of the information that he or she believes. Rationality comes from the beliefs and sources of information that they gained, confidence in irrationality can lead to false perceptions of the dangers of volcanic eruptions, which could hamper the success of the first phase of the evacuation process.

The second phase is the vehicle selection, a refugee who had prepared the vehicle will be better prepared to face the second phase from the whole evacuation process. Vehicle readiness is characterized by overall vehicle readiness, including preparing transportation modes to be used, fuel, or ready-to-go vehicle positions. A ready people in this second phase is not only meant for owners, but also for all family members who have prepared the vehicle for use during the evacuation process to a safer point for all members of their family.

The third phase is the decision to determine the path from their house to safer point. Readiness in this phase was characterized by an understanding of the path and the ability to overcome obstacles during the selection path. For refugees who drive a vehicle, the decision will be determined by his ability to choose the path to safer point and avoid obstacles. For refugees who do not ride their own vehicle, the decision of the path will be based on the rider.

Type official leader is members of the community who were authorized to lead a territory (Kepala Desa, Kepala Dusun), authorized to maintain security (army, police) and authorized to do the evacuation (government or NGO). The type of official leader is a member of the community who were ready for all of the phase of

evacuation decision-making, they are also able to lead and mobilize others, this type was characterized by the ability to lead and direct others, be rational, have well-prepared the vehicle, and understand the evacuation route to Safer point. From the research, 12% of respondents indicated as an official Leader type.

Type cultural leader is a member of community who was authorized by the palace of Yogyakarta to lead a region e.g., *Mbah Marijan* and somebody who has supernatural power that can bridge the communication between the spirits of ancestors with the society. The type of these leaders have an understanding and deep experience of the natural condition of Mount Merapi and supernatural belief. This type is unprepared at least in one decision-making phase. From the results of the study, only 1% of respondents indicate the type of cultural leader. Even though it is small, but this needs to be taken into consideration, because it can give a very big influence on the decision phase go/stay. People who believe will follow his instructions not to evacuate, but it is influenced also by the proximity and kin relationships.

The vulnerable group is the members of community who are pregnant, elderly, children, sick people, and people with disability. Vulnerability group is part of the population around the slope of Mount Merapi that should be prioritized in the evacuation planning and regulation decision-making. Based on the results of the study, most vulnerable groups have been evacuated several days before a major eruption occurred. At least, 30% of respondents are vulnerable.

The Prepared community member is the members of community who are prepared/ready for all of the phase of decision making process, and unprepared community member are the members of community who are unprepared/nor really ready at least in one phase of the decision making process. From this study, about 42% of respondents are prepared and about 15% are unprepared.

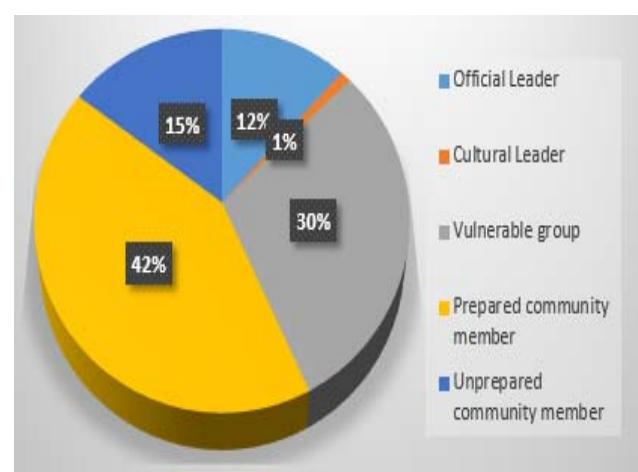


Fig. 5. Behavior type proportion

#### IV. DISCUSSION

Mount Merapi is the most active volcano in Indonesia and also worldwide. The volcano eruption is a type of risk that can be expected to occur because it presents itself gradually. Therefore, communities can prepare for anticipation of adverse possibilities. In the other hand, the volcanic eruption has a major impact on society and the environment. One of the problems is finding the best way to evacuate thousands of people in a region. To help solve the problem requires good planning. This evacuation plan can be done by designing a computer-based behavioral simulation.

This research is done through exploratory retrospective view survey and done through face-to face interview. This study has found patterns and mechanisms of community behavior along with their proportions and through face-to-face interviews, the result of the analysis behind the emergence of such behavior.

#### V. CONCLUSION

This paper discusses the need of contingency plan of Mount Merapi volcanic eruption by considering the behavior of surrounding communities. The results of this study are used as a reference in the planning of natural disaster evacuation as a recommendation to the relevant agencies and organizations in an effort to recognize the concept of behavior of the slopes of Merapi and the proportion of each behavior when facing an emergency evacuation of Mount Merapi eruption. Therefore, appropriate intervention in mitigation efforts can be formulated beforehand. Finally, the result of this study can be used as an evaluation material to observe the risk of Mount Merapi eruption disaster and how it might affect the community.

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