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A conceptual framework of volcanic evacuation simulation of Merapi using agent-based model and GIS

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Abstract

In volcanic crises, the ability of population to evacuate has important role to reduce the risk. Based on two experiences of crisis management of Merapi 2006 and 2010, it was reported that there are problems in this aspect that caused confusion of population during the crises which resulted in fatalities. Therefore, we propose a methodology to develop a simulation model to analyze population risk that can be used to highlight the probabilities of emerged problem during the evacuation. The methodology of this research will be highly relied on the GIS-ABM simulation. The simulation was developed from the relation of the volcano, surrounding population and stakeholder within the environmental system. Those elements are represented as agents with their attributes, roles, behaviour and properties. As an example of the application, we developed a simulation case study using Anylogic.

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Keywords: Volcanic risk management; evacuation modelling; agent-based modelling; GIS, Merapi.

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1. Introduction

The physical condition of Merapi environment that is suitable for farming and tourism attract people to stay in this area though it is prone to the volcanic disaster that result in problems when the eruption occur. It is identified that there are more than 50,000 people keep to live in the dangerous zone of Merapi although they experienced with several eruptions (Mei et al., 2013). Moreover, many people refuse the relocation policy although the volcanic eruption has damaged their settlements at 2010 (Ayuningtyas & Lele, 2013; Nuzulia & Sudibyakto, 2014).

During volcanic crises, the ability of population to evacuate has important role to reduce the risk, but problems are identified in this aspect. The expectation is that the populations at risk aware to make decision to evacuate themselves or to be evacuated during the crisis (Mei, Lavigne, Picquout, & Grancher, 2011). However, based on two experiences of crisis management of Merapi 2006 and 2010 (POSKO SET BAKORNAS PBP, 2006; Mei et al., 2013), populations confusion during the crises was still to be constraints on the evacuation processes which resulted in fatalities.

Evaluation of the evacuation plan based on the population behavior is necessary considering such previous problem to convince that it can be operated properly. As the goal of the plan is to save human lives from the volcanic impact, the effectiveness of the plan is measured from the ability to achieve the goal. However, currently, there is no enough method to measure this effectiveness until the plan is examined in the real disaster. As a consequence, it will be high speculation if in reality the plan is failed. In the critical time, it is potential to result fatalities.

Based on the explanation, it is important to develop simulations of the evacuation in the computer-based environment to identify the possible problems of the plan in various scenarios. This article is purposed to provide the conceptual framework of the development of simulation of volcanic evacuation using Agent-based Modeling and Geographic Information System (ABM-GIS). One of the advantages of using ABM for simulating real systems is that the real world can be experimented in-silico world without risks (van Dam, Nikolic, & Lukszo, 2012). To provide further explanation the rest of this article will provide the overview of related research, the conceptual framework followed by the application example using Anylogic and the conclusion.

2. Overview of Related Studies

As the most interesting volcano in Indonesia, Merapi has been explored in many researches from various point of views as well as the method/approach used. This research is ranged from physical aspect to social/human aspect. Physically, there are various studies that has been successfully explained the characteristic of hazard namely field study and hi-resolution imagery analysis (Charbonnier et al., 2013), field study and laboratory analysis (Damby et al., 2013), field study (de Bélizal et al., 2013), SAR (Bignami et al., 2013). Meanwhile, the existing research on social aspect are focusing on population responses, characteristics, perception or vulnerability (Christia, 2012; Donovan, 2010; Mei and Lavigne, 2012, Donovan, Suryanto, & Utami, 2012, Dove, 2008; Lavigne et al., 2008; Utami, 2008), influencing factor of evacuation decision (Sagala & Okada, 2009), evacuation management (Mei et al., 2013; Mei & Lavigne, 2013).

Based on many existing publications, there is no research that is focusing on evacuation modeling in Merapi, but there are plenty in the other geographic settings for various type of hazards. These studies can be categorized as macroscopic to microscopic models (Hamacher & Tjandra, 2001). Macroscopic models are mainly based on optimization approaches which does not consider the variability of the population in their decisions for selecting routes and destination (Hamacher & Tjandra, 2001). This model was applied for model development of evacuation GIS from flood (L. Yang, Liu, Yang, & Yu, 2015), volcanic eruption (Marrero, García, Llinares, Rodríguez-Losada, & Ortiz, 2010; Marrero et al., 2013), earthquake (Ye, Wang, Huang, Xu, & Chen, 2011). Meanwhile, microscopic models are based on simulation which is emphasized the individual parameters as well as the interactions between evacuees during evacuation operation (Hamacher & Tjandra, 2001). The example of this model is demonstrated using ABM for various hazard namely fire (Tan, Hu, & Lin, 2015), generic hazard (Nagarajan, 2014), tsunami (Mas, Suppasri, Imamura, & Koshimura, 2012), hurricane (Handford & Rogers, 2012), also using GIS for Generic hazard purpose (B. Yang, Ren, & Wu, 2012).

As explained, there are various techniques have been used to provide evacuation model of different type of hazards. However, the microscopic modeling for volcanic evacuation is not adequately explored. It is needed to be