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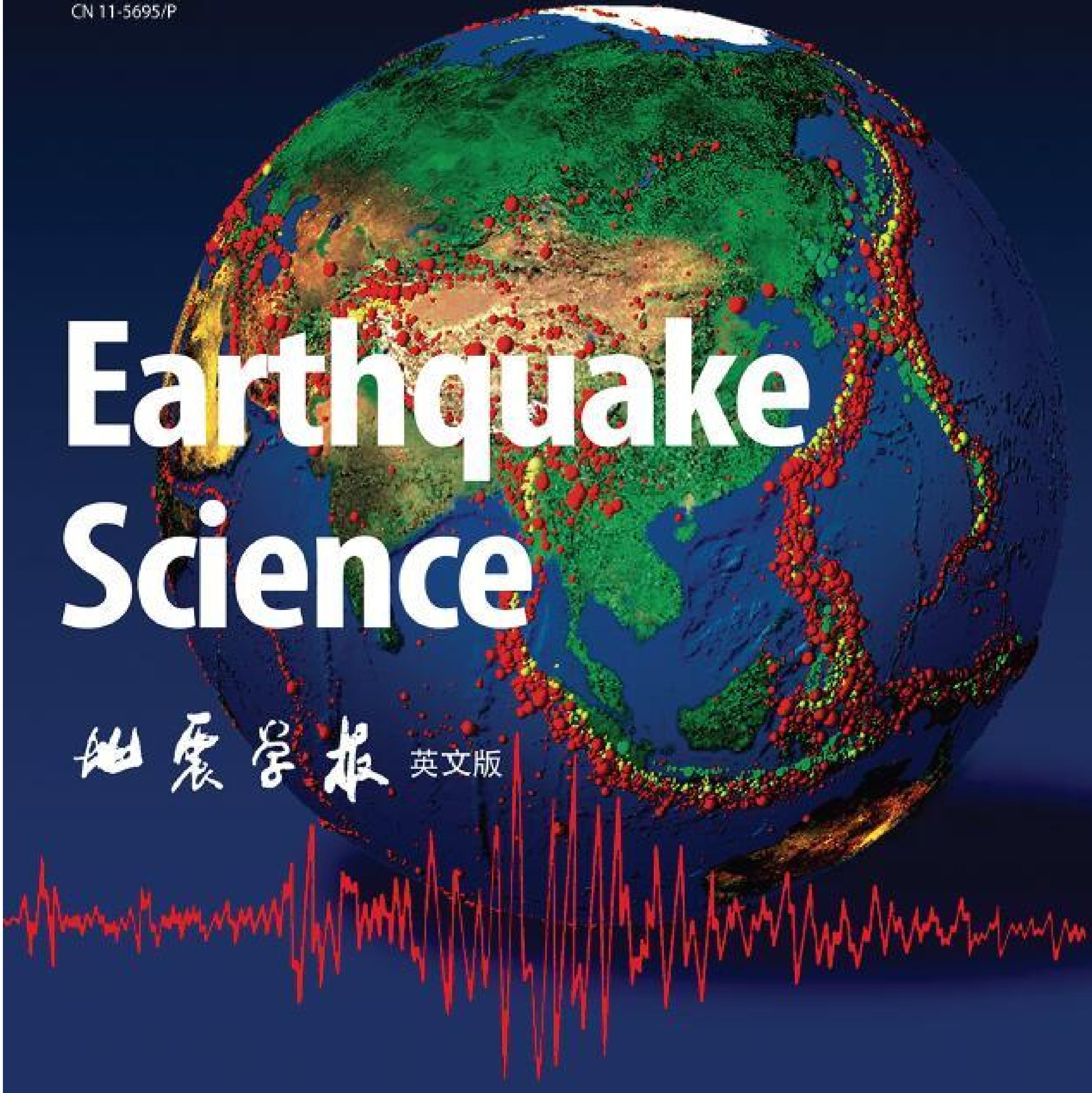

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Earthquake vulnerability disaster in the Lembang district of West Bandung Regency, Indonesia*

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Abstract This research is concerned with an analysis of the level of vulnerability for an earthquake disaster in Lembang district, an area in West Java that includes the Bandung basin and has a high potential for earthquake disaster. The Lembang district is close to the active Lembang fault whose movement can cause earthquakes of magnitude 7 on the Richter scale (Tempo Interaktif, May 11, 2010). The research method used to assess the level of vulnerability is essentially a descriptive approach. The data analysis is based on calculating an earthquake disaster risk index (EDRI), which is in turn based on assessment of the region's social, physical and economic vulnerabilities. The vulnerability level for earthquake disaster in the Lembang is ranked as medium category. The social vulnerability of the population is the major contributing factor given the high population density and growth rate for the region. The physical characteristics of the district, which includes mild temperatures and attractive scenery, make many people want to stay in and visit Lembang. The construction quality of buildings is so bad that they are not designed to withstand earthquakes, so improvement of building infrastructure is an alternative to reducing the various physical vulnerabilities.

Keywords: vulnerability; earthquake mitigation; west Bandung; Indonesia

1 Introduction

The Bandung basin, a region in West Java, Indonesia, has a high population density and a high level of economic activity. Most business sectors are represented in the region including the industrial, education, commerce and trade, and tourism sectors. The occurrence of a large earthquake in the region caused by subduction along the Lembang fault would be a disaster, its impact adversely affects all activities in the Bandung basin and beyond.

One specific area in the Bandung basin that has a high potential for disaster is the Lembang district, located in the West Bandung Regency. The region is very close to the Lembang fault, one of the most active fault lines in West Java. Unfortunately, the local population are not fully aware of the risks associated with living near an active fault despite the high level of seismic activity in Indonesia. To counter, there is a need to improve the overall awareness level of the risks associated with living in the Lembang region, so that the impact on the population when an earthquake occurs in the area can be lessened. Currently, the community in Lembang are not familiar with disaster prevention or preparedness, as can be seen in the case of the hotel industry, which in general has not issued evacuation plans in the event of an earthquake occurring. The lack of evacuation route signs can lead people to panic, and this would spread in the event of an earthquake, the evacuees being ignorant of what mitigation measures to take. Thus, evacuation schemes need to be put into place across all public and private sectors so that the public acquire a better level of awareness and preparedness with respect to earthquake risk and occurrence.

The population of Lembang district is 172,972 (Central Agency of Statistics, 2010) and is higher than the two other districts traversed by the Lembang fault, namely, Parongpong with 86,103 inhabitants and Cisarua with 63,891 inhabitants (Central Agency of Statistics, 2010). Based on the number of residents living in the respective areas, if an earthquake happens, the greatest number of casualties would be in Lembang district if proper disaster mitigation measures were not implemented.

The fault line in the Lembang area, which tracks in an east-west direction for 22 km, is not stable, the region have experienced earthquakes in 1834, 1879, 1910, 2003 and 2011. Although the magnitude of past earthquakes was less than 6 on the Richter scale, the impacts were quite destructive to the surrounding area. The last sizeable earth-

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quake occurred on August 28, 2011, in the Cisarua district. Some 301 homes were damaged and nine were badly damaged, despite the fact that the earthquake was only of magnitude 3.3 and lasted less than 3 s. The Lembang fault movement is monitored by seismographs, and the data have indicated that the fault movement is 2 to 4 mm/a. Given this fact, the people in Lembang should not be aware of the existence of the Lembang fault and understand the rationale for implementing earthquake risk mitigation strategies in their area.

Unfortunately, the population of Lembang, in general, are unaware of any procedures or policies put in place by the local government to mitigate against the risk of earthquakes. As mentioned, the population density of the region is high, and the area has an abundance of natural resources and is a tourist destination; hence, such a region should be equipped to respond to and deal with the consequences of an earthquake. At the present time, if an earthquake occurs there will be a severe impact on the resources and infrastructure of the region.

Measuring the earthquake vulnerability level for a region is closely related to the earthquake mitigation strategies that are in place and are designed to lessen the impacts of the earthquake on the region. Vulnerability describes the characteristics and circumstances of a community system or asset that make it susceptible to the damaging effects of a hazard. There are many aspects of vulnerability, arising from various physical, social, economic, and environmental factors. Based on the current situation in Lembang District, the authors are interested in highlighting and addressing deficiencies regarding earthquake vulnerability and disaster mitigation planning in the Lembang district of West Bandung Regency, Indonesia.

2 Method

The approach used in this research is a descriptive method. In essence, a descriptive method is directed at the disclosure of a problem that reveals which facts are real, although sometimes to undertake analysis, a survey methodis first required. A survey is a research method that aims to collect large amounts of data in the form of variables, units or individuals. For the present study, the aim was to collect the data needed to support an analysis of earthquake vulnerability data.

The study consisted of independent and dependent variables. The independent variables included the physical vulnerability (PV), the social vulnerability (SV) of the population, and the economic vulnerability (EV) of the Lembang district. In the case of PV there are three classes, namely, the built area, building quality and building density. The SV of the population also has three classes, namely, population density, population growth rate, and vulnerable groups, which consist of the female, elderly, and under-five population groups. The EV includes two classes, namely, income and livelihood. The dependent variable for this study is the vulnerability level for earthquake disaster in the Lembang region. An overview of the dependent and independent variables is given in Table 1 below.

Table 1 Research variable

Independent variable	Dependent variable
Physical vulnerability a. built area b. building quality c. building density	Level of vulnerability for earthquake disaster in Lembang district
Social vulnerability of population a. population density b. population growth rate c. vulnerable community groups: people >65 years old and <5 years old; the female population	
Economic vulnerability a. livelihood b. income	

The study involved all 16 villages in the Lembang subdistrict with a total population of 172,972 and comprising an area of 2,294,626.74 m^2. The sample area included the villages of Lembang, Kayuambon, Gudapanuripan, and Cikole. In the case of Lembang and Kayuambon, the population densities are both high and the commercial center for this region is Lembang; in the case of Gudangkahuripan, the village is very crowded and the topography is steep. Cikole village was chosen because it is very crowded and is located close to Tangkubanparahu Mount, and there are many tourist attractions. The population for each village was estimated using a stratified random sampling technique and was based on the responses of 78 participants.

The following materials and maps of Indonesia were consulted: map sheet 1209-313 Cimahi (1:25,000) and map sheet 1209-314 Lembang (1:25,000); geological map for Bandung (1:100,000), land map for Bandung (1:100,000), data on areas for buildings, density data for buildings, building quality data, data on population growth rates, data on population of vulnerable groups, data on income levels, rainfall data, data on Lembang, Gudangkahuripan, Kayuambon, and Cikole villages, and data on Lembang district for 2010.

For field investigation, visits were made to Lembang, Kayuambon, Gudangkahuripan, and Cikole villages. Next, planning and investigation regarding PV were undertaken.

The observations on PV included investigation of built-up areas, building density, and buildings with traditional construction. The equipment used in the field investigation included a global positioning system, a digital camera, and topographic maps of Indonesia (1:25,000), map sheet 1209-313 Cimahi (1:25,000), and map sheet 1209-314 Lembang (1:25,000). Data collected included specific location coordinates and PV data for selected sites throughout Lembang district.

Questionnaires were distributed to respondents in each village. The data collected include PV, SV for the population, EV, and respondent knowledge in connection with disaster prevention and mitigation. Scoring was done to assess the readiness level of each individual and household to an earthquake by summing all the scores for each dependent and independent factor, and then the summed score was divided by the number of questions in each parameter to calculate the average score for each factor, the value then was inputted into a formula for calculating the individual and household readiness score. Scoring was also done to determine the level of vulnerability that related to the level of PV, SV (household residence), EV, and vulnerability for earthquake disaster. The earthquake disaster risk index (EDRI) is a composite index that allows direct comparison of the relative overall earthquake disaster risk of cities worldwide, and describes the relative contributions of various factors to that overall risk.

Data analysis was based on analysis of the EDRI which in this case is taken as meaning only vulnerability. An EDRI analysis was used to determine the parameter of vulnerability value. Before analyzing the level of vulnerability for an earthquake disaster, let us consider first the indicator category that contributes most to determining the vulnerability of earthquake disaster in the Lembang district, namely, the SV factor. The SV factor consists of the following parameters (1) population density, (2) population growth rate, (3) the elderly and those under five years of age, and (4) the female population.

After the index is known for each parameter, the next index value is entered into the formula to obtain the total index for individuals and households. In the calculation of the total and individual indices, the final values are adjusted by weighting each parameter as described in Table 2 below.

After knowing the weighting for each parameter, the index value of individual communities and households can be calculated as follows (Unesco, 2006)

$$\text{Index value} = \frac{\text{weight } a}{100}\times a+\frac{\text{weight } b}{100}\times b+\frac{\text{weight } c}{100}\times c$$

where

a = index of disaster knowledge,

b = index of disaster readiness, and

c = index of resource mobilization

Table 2 The reference has been listed

Community	Parameter *a*	Parameter *b*	Parameter *c*	Total
Individuals and households	51	37	12	100

Sub indicator values are needed to calculate the vulnerability value of each indicator. The calculation of the standard value is based on data held by each village in Lembang district. The standard value is obtained from the following formula (Davidson, 1997):

$$X'_{ij}=\frac{X_{ij}-(X_1-2S_i)}{S_i} \tag{1}$$

where

X'_{ij} = standardized values for sub-indicator i in village j;

X_{ij} = unconverted value for sub indicator i in village j;

X_1 = average value for sub indicator i in Lembang district; and

S_i = standard deviation for sub indicators i.

The standard value of a vulnerability indicator is derived from the sum of the standard values of each sub-indicator divided by the number of sub-indicators. The standard value for regional vulnerability is derived from the sum of the standard values of each indicator divided by the number of indicators. The relevant formula is (Firmansyah, 1998)

$$V=\frac{X_1+X_2+X_3}{n} \tag{2}$$

where

V = vulnerability;

X_1 = the indicator raw value or sub-indicator X_1;

X_2 = the indicator raw value or sub-indicator X_2;

X_3 = the indicator raw value or sub-indicator X_3; and

n = number of indicators or sub-indicators

The vulnerability level was classified into three classes, namely, high, medium, and low (Table 3).

Table 3 Classification level for earthquake vulnerability

Default value	Classification
1.63–2.01	Low
2.02–2.39	Medium
2.40–2.77	High

3 Results and discussion

To find out the level of vulnerability for an earthquake disaster in Lembang district, an accumulation of the raw data for the vulnerability indicators is used. The indicator data are summarized in Table 4.

Overall, the results show that the vulnerability level for an earthquake disaster in Lembang is in the medium category. The SV of the population is the main problem because the population density and population growth rate are relatively high. Underlying factors for the area also are temperatures and natural beauty of the region, which encourage people to remain in Lembang. The construction standards of the buildings do not meet the criteria for earthquake resistance so there is an need to address this issue. Improving the construction quality of buildings may be one of a number of alternative strategies for reducing the number of PV. A large number of people live and work in buildings that are sub-standard with respect to earthquake resistance. Also, a number of low-income residents would benefit from a reduction in the level of EV, for example, through improvements in social programs including buildings infrastructure. A map that displays the different levels of vulnerability for an earthquake disaster in the region is presented in Figure 1.

Table 4 Overview of research results

Village	Physical vulnerability	Population vulnerability	Economic vulnerability	Default value	Classification
Lembang	3.80	2.49	1.98	2.77	High
Jayagiri	1.73	2.12	2.16	2.01	Low
Kayuambon	2.82	2.06	2.41	2.43	High
Wangunsari	1.90	2.18	1.97	2.07	Medium
Gudangkahuripan	2.49	2.50	1.99	2.33	Medium
Sukajaya	2.16	2.12	1.86	2.05	Medium
Cibogo	3.05	2.25	1.19	2.16	Medium
Cikole	1.72	1.94	1.91	1.86	Low
Cikahuripan	1.83	1.93	2.33	2.03	Medium
Cikidang	1.73	2.16	1.53	1.81	Low
Wangunharja	1.54	2.18	2.56	2.09	Low
Cibodas	1.04	2.31	2.00	1.78	Medium
Suntenjaya	1.23	1.56	2.11	1.63	Low
Mekarwangi	1.29	2.01	2.05	1.78	Low
Langensari	2.32	1.58	2.00	1.97	Low
Pagerwangi	1.59	1.94	1.99	1.84	Low
Average	**2.02**	**2.08**	**2.00**	**2.09**	**Medium**

Based on the findings of the present study, the factors that most determine the vulnerability for an earthquake disaster in Lembang are the social factors relating to the population, namely, the population density, the age demographics (i.e., the elderly and under fives), the female population, and the population growth rate. The population density in Lembang is very high and reaches 18,046 persons/km^2. This high population density is reflection of the relatively higher number of births compared to deaths. This high population density would correspond to a high number of estimated casualties (in the event of an earthquake). People aged less than 5 years and over 65 years of age fall into the low category with an index of 15.62%.

Knowledge of this index can assist the community to decide to evacuate first the elderly and the under-five population and hence reduce the number of victims. The female population in Lembang falls within the medium vulnerability category (Index 48.75%), thus implying that the male population should remain calm in the event of an earthquake and help to evacuate.

The rate of population growth falls in the high classification category (Index 5.7%). High population growth rates tend to be located in villages close to the center of Lembang, so there is a high probability that there will be more victims in the center compared to outlying villages.

The degree of earthquake vulnerability is associated with individual and household readiness given that such natural phenomena may be termed a disaster if casualties occur. Individual and household readiness levels fall into the less prepared vulnerability category, having an overall

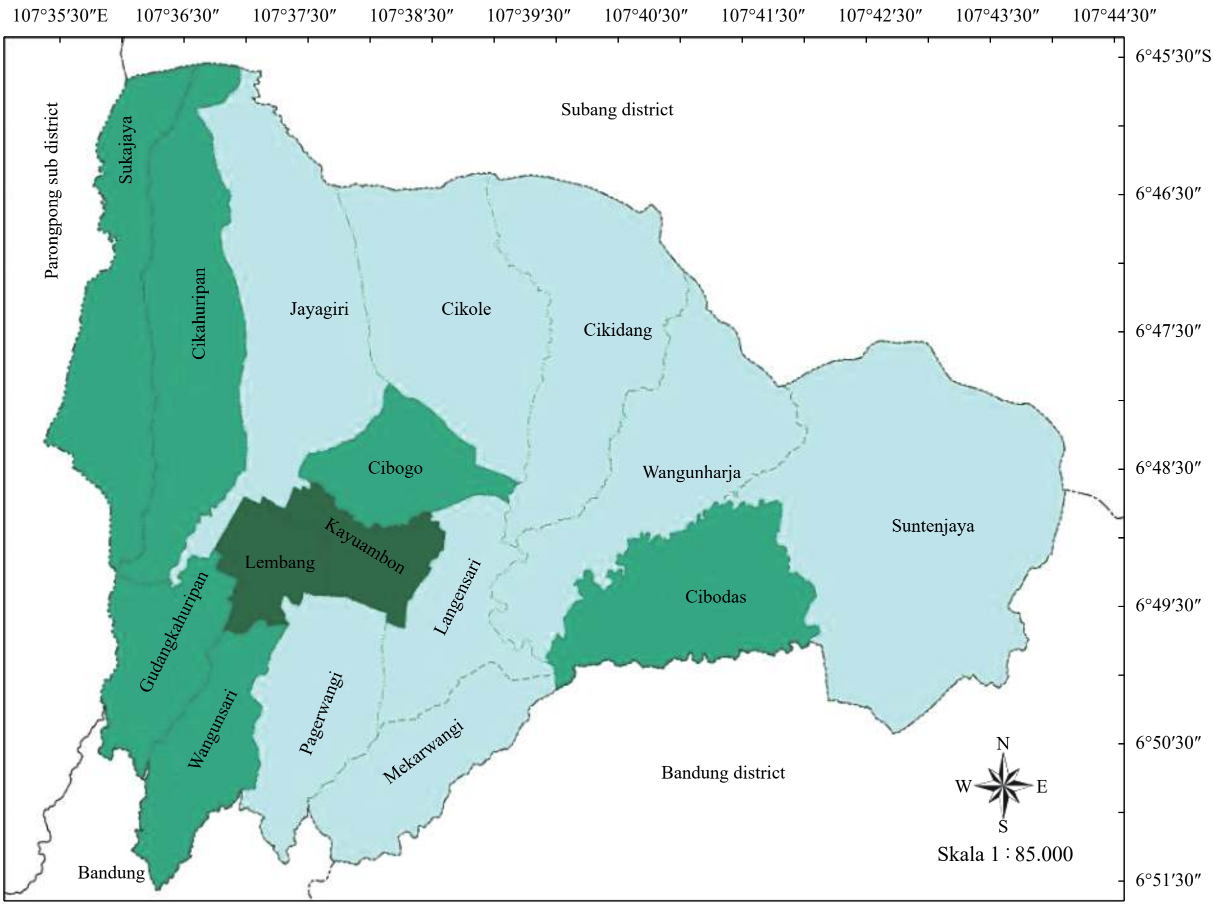

Figure 1 Map of vulnerability level for an earthquake disaster in Lembang

index of 50.96%. The low level of individual and household preparedness is due to the fact that there are still many residents who ignore the preparations that should be undertaken to mitigate the effects of an earthquake. Although the level of readiness is in the less prepared category, it should be remembered that the nature of readiness is not a fixed quantity, so over time the level of an individual's or household's readiness in Lembang can increase or decrease due to the socio-cultural, political, and economic conditions of the community.

Based on the research results, the PV level for an earthquake disaster in Lembang falls into the medium category, having a value of 2.02. Permanent buildings that do not meet the standards for earthquake resistant buildings are widely encountered. The condition of many buildings is such that they will be easily damaged if a sizeable earthquake occurs and will also threaten the lives of the inhabitants. The density of buildings in the center of Lembang is high so it will be difficult for residents to evacuate in the event of a disaster. Given that most of the day-to-day activities are located in the center of Lembang and that there is a lack of parks or open fields in the center, this is also an obstacle to safe evacuation.

The level of SV for the population in Lembang falls in the medium category with a value of 2.08. The dense populations in all villages means that the district has a high vulnerability for such density. The percentage of the elderly, the young and the female population (all together) must be high. This fact certainly facilitates the evacuation, but these vulnerable groups must be given priority when drawing up disaster evacuation plans. The rate of population growth in villages close to the center of Lembang is quite high, so the likelihood of a high number of casualties in these areas is also high.

The EV to an earthquake disaster in Lembang has been categorized as medium (value of 2.0). The percentage of people working in the non-agricultural sector is quite high, so the likelihood of high numbers of casualties for the non-agricultural sector is also likely to be high. The number of low-income residents in this cohort would be low, but prioritization and support for this cohort should be given because most of the population in this has not yet reached secondary.

The vulnerability level for an earthquake in Lembang has been classed as medium category (value 2.09). Physical vulnerability is a major problem for villages close to the centers of Lembang, Kayuambon, Cibogo, and Gudapanuripan villages. Building regulations should be enforced to reduce PV. The SV for the population is in the high classification for villages close to these village centers, given that the population density and growth rate are expected to increase rapidly. Economic vulnerability is the main problem for the bulk of the population whose livelihoods depend on non-agricultural activities, in contrast to that for low-income workers.

The above considerations are in accord with"vulnerability is a set of conditions that determine whether a hazard (both natural hazards and artificial hazards) will result in disasters" (United States Agency for International Development, 2009). As mentioned vulnerability may divided into PV, SV, and EV. Physical vulnerability includes infrastructure and the conditions of villages and small settlements located near the active fault while SV includes issues such as population density in these locations. This also reinforces the fact that the impact of vulnerabilities can compound disasters caused by natural events and is consistent with the statement of the UNDP (2004) that disasters can be caused by natural events or by man-made events.

APV is a vulnerability due to the possibility of a natural disaster occurring. The SV of a population is a vulnerability caused by human activities that trigger a disaster while the EV is associated with the income of the peoples. In general, it is assumed that the lower the income of the population, the more vulnerable the population is to earthquake disaster. These two quantities are closely related because the higher the SV of the population, the higher is the level of PV that threatens their lives and their livelihood.

Economical vulnerability is also related to PV and SV of the population. Economic vulnerability is a vulnerability associated with meeting the needs of the community. Livelihood and income are aspects that belong to EV. Livelihood, in this case, is seen to be closely linked to one's workplace. People who work indoors are considered more vulnerable to earthquake threats than people who work outdoors. Community income, in this case, is assessed according to level of personal income. High-income people will find it easier to access education, so their knowledge of disaster prevention will reduce their level of vulnerability to the threat of an earthquake. This is in accord with Mantra’s observation (1985) that "Population growth in an area is affected by the magnitude of births, deaths, and population migration." It is also in accord with the findings of Hosain et al. (2015) that the "People of Nepal had anticipated but never experienced such a devastating earthquake."This indicates that the vulnerability of the economy will affect the knowledge associated with an earthquake of high magnitude.

One of the aspects that determine vulnerability is the location of a community in terms of distance from the center of the threat such as in areas prone to volcanic eruptions and locations around volcanos. Such volcanic areas tend to be scenic with hot springs and fertile soil and are attractive for agriculture and tourists. The situation at Lembang is just such a situation, and people’s knowledge regarding vulnerability is described in the study of Birkman et al (2017): the understanding of different concepts of vulnerability is key when aiming to develop strategies for disaster risk management and adaptation to extreme events and natural disaster.

The contribution of various third parties is very important for increasing knowledge on disaster prevention. In accordance with United Nations International Strategy for Disaster Reduction (2008) that "exchange among knowledge and honesty in what different knowledge forms can and cannot achieve, disaster risk reduction can draw on the best wisdom that can be provided by those inside and outside the communities."

The role of government is very important in reducing disaster risk in Lembang. According to Joshi et al (2015), This is due to the government's ability to introduce policies quickly. The result is that the organizational style of each community prior to the disaster and the presence of a strong village leader are both crucial for the successful implementation of a recovery program. If the government does not put in place the right policy, then the community will suffer after a disaster. Thus, Stough et al. (2017). pointed out that the perceived quality of life diminished post-disaster due to the loss of social networks and belongingness, rather than to a diminishment in perceived instrumental support.

The physical location of Lembang is relevant to hypocentral theory. The hipocentrum is "the epicenter of earthquakes, where the occurrence of changes in layers of rock or dislocation in the Earth causes earthquakes" (Mulyo, 2004). The types of earthquakes based on their hypocenters consist of shallow earthquakes with focal depths less than 70 km, intermediate earthquakes with focal depths of 70–300 km, and deep earthquakes with focal depths of 300–700 km. The more shallow the focal depth of the earthquake, the greater will be the damage. On this basis, the area around Lembang is threatened by "hazardous conditions or seismic events that have the potential to harm, cause death and damage property, facilities, agriculture, and the environment" (Boli et al., 2004).

4 Conclusions

It can be concluded that the factors that most determine the vulnerability to an earthquake disaster in Lembang are the social factors of the population, namely, population density, female population, elderly population and population aged under five years old, and population growth rate. Population density in Lembang falls within the very dense classification, the female population belongs to the middle classification, the elderly and the under-fives are included in the lower classification, and the rate of population growth corresponds to a high classification.

The level of PV of earthquake disaster for the region is in the medium classification. The high number of permanent buildings that do not meet earthquake resistant building standards is a major issue that needs to be addressed. The level of SV of residences in Lembang falls within the medium classification. The high levels of population density and population growth rate should be given more attention because these high levels can lead to a high casualty rate, while vulnerable groups must be prioritized forin terms of being given assistance in disaster evacuation. The level of EV in Lembang is also in the medium classification. The high number of non-agricultural workers has a major impact on the final classification. The vulnerability level for earthquake disaster in the Lembang district is judged at the medium level, indicating that if a sizeable earthquake occurred, the impact would also be classified as medium level.

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