

# The Development of Health Capacity Index for a Semi-Quantitative Earthquake Hazards Risk Analysis with a Special Reference to the Lombok Earthquake Disaster 2018

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## ABSTRACT

Earthquakes often caused severe fatalities to human beings, as the case of Aceh earthquake 2004, and Lombok earthquake 2018. For the case of Lombok shallow earthquakes 2018, the earthquakes of a magnitude 7.0 have destroyed almost 800 thousand homes, and caused the death of more than 500 people. The main problem of such a case is that the time occurrence of an earthquake cannot be predicted. However, the risk due to earthquake should theoretically be able to predict, when parameters can be calculated in the quantitative risk index of  $R = H \times V / C$ . Particularly in this paper, health capacity is introduced using a rating system in order to measure the resistance of people occupying disastrous area to overcome difficulties during hard time emergency shelter and disaster relief. Two study cases were conducted which show that the capacity index, particularly people health index, could differentiate between low and medium-high casualties among cities ruined by Lombok earthquake 2018. The development of a quantitative risk index, particularly health risk indexes, is therefore important in hazard mitigation due to earthquakes, that it provides a simple quick apparatus of disaster assessment.

**Keywords:** Earthquake, Fatality, Health, Risk index, Health mitigation, Quick apparatus, Disaster assessment.

## 1. INTRODUCTION

Indonesia is the most active seismic region in the South East Asia [1]. This could be due to the tectonic setting of Indonesia, where the Indo-Australia ocean plate subducts beneath the Eurasia continental plate [2]; while, the Pacific plate moves to the west direction to compresses the Banda Arc then the Sunda Arc [3]. Notably, Aceh earthquake 2004, Yogyakarta earthquake 2006 caused severe casualties, and more recently Lombok and Palu earthquakes 2018 have ruined the area. In the case of Lombok earthquake in 5<sup>th</sup> August 2018, the shallow earthquake of a magnitude 7.0 has destroyed

almost 800 thousand homes, and caused the death of more than 500 people [4]. This case left behind traumatic conditions for people in Lombok Island, as it remains the events in the past, that a similar earthquake stroked the same place in North Lombok District [5].

In many cases where earthquakes stroke an area, mostly people are not well prepared. Moreover, the area is not designed for an earthquake, so high risks are faced by people to have severe fatalities. One important factor in reducing the risk is the capacity of the area including people capacity. Thus, the vulnerability and capacity of risk values are evaluated based on the case learnt from

Lombok earthquake 2018; then two cases were presented in this paper to show how the risk index works.

### 1.1 Risk Analysis Method

A rating system [6, 7] was adapted for analyzing hazard risks in Lombok Island due to earthquakes in 2018. The rating system was designed to estimate the potential risks of an area in a simple and easy way [7]. According to the updated the seismic conditions of Lombok and surrounding islands, the area were vulnerable to hazards due to earthquakes [4]. Hence, mitigation is an activity and measures should be conducted. The risk was the calculated from the following equation, which is the multiplication of hazard and vulnerability:

$$R = H \times V \quad (1)$$

R = risk of hazard

H = hazard potential

V = vulnerability

As can be seen in Equation (1), the parameter H is hazard potential that may be visible in the area observed, and the parameter V is the vulnerability of the area. However, the capacity of the area in resisting the hazard, including people occupy of the area, should therefore be introduced, so the hazard mitigation is included in Equation [8]:

$$R = H \times V / C \quad (2)$$

The parameter C in Equation (2) represents a reduction factor to the risk value; although, the parameter can be different from one to the other area for a similar hazard potential. In the case of the Lombok Island, hazard parameters were geological and seismic conditions. Both parameters were crucial, where Flores Fault is just located within a 50 km distance from the island.

The vulnerability parameters due to earthquakes may involve social, physical and economic values, which were then indexed using the following equation [8]:

$$V = 0.4 V_s + 0.3 V_p + 0.3 V_e \quad (3)$$

$V_s$  = social vulnerability

$V_p$  = physical vulnerability

$V_e$  = economic vulnerability

Detailed parameters are constructions, economic, culture and people assets [6]. These parameters certainly will be different among cities in Lombok Island, depending on the development of the cities. Therefore, the adaptation of Equation (3) to Equation (2) was conducted to gain the vulnerability index for Lombok Island.

### 1.2 Capacity Parameter

The capacity is a parameter that belongs to a city or area, including people occupying the city, in which the city has ability to overcome hazards caused by earthquakes. Based on the available data [8], the West Nusa Tenggara Province had a medium capacity index. This could involve seven variables: earthquake standard building, occupied area, evacuation access, public shelter, emergency facility, and people health condition.

For particular in this paper, the last variable was introduced. The health condition of people may represent the capacity of people within the area in overcoming the hazard in terms of the quality of life. According to the Health Office of West Nusa Tenggara Province [9], there may be two of three variables that could represent the capacity of the quality of life, which are life expectancy and morbidity. Life expectancy may represent nutrition and life behaviour; while morbidity refers to the consequences and complications (other than death) that result from a disease. The morbidity might represent the risk of fatalities carried by people within the hazard area. Thus, so with these two variables, people were hoped to be able to move quickly from the disaster area, and healthy enough to live in emergency conditions during the shelter time. Thus, these variables could reduce the vulnerability of the area, although, the hazard potential was high.

### 1.3 Rating System

Risk analysis applies a rating system that each parameter is valued from 1 to 5, from high to low, otherwise vice versa, depending on the contribution of each involving parameter 6. Total rating was calculated for all parameters causing risks, as can be seen in Table 1. The total applied rating was weighted by the total available rating. Thus, total weighted rating of hazard (H), vulnerability (V) and capacity (C), follows Equation (2).

For the sake of simplicity of using a spreadsheet package, for instance, let the values of zero (0) and one (1) to be used in this paper. The zero value (0) is used when the observed parameter does not exist, in contrarily for the value one (1). Then, the application of Equation (2) will result in a total risk, which was then classified in Table 2.

The minimum value obtained from Equation (2) would be less than 50 when no casualty is performed by a city or area, for which the hazard potential did not significantly influence the area (Table 2).

**Table 1.** Rating values for risk

| PARAMETER                              | TOTAL RATING |
|--|--------------|
| HAZARD                                 | 77           |
| Geological input                       |              |
| Seismic input                          |              |
| VULNERABILITY                          | 129          |
| Private/public buildings               |              |
| Economic assets                        |              |
| Culture assets                         |              |
| People assets                          |              |
| CAPACITY                               | 40           |
| Occupied area/total area               |              |
| Standard Building                      |              |
| Evacuation access/total area           |              |
| Public Shelters/total population       |              |
| Emergency facilities/total population  |              |
| Financial hazard supports/local budget |              |
| Health Condition/ total population     |              |

**Table 2.** Classification of Risk value

| R         | Risk Classification | Casualty           |
|-----------|---------------------|--------------------|
| <50       | No risk             | No casualty        |
| 50 - 100  | Low risk            | Low casualties     |
| 100 - 150 | Medium risk         | Medium casualties  |
| 150 - 200 | High risk           | High casualties    |
| >200      | Extreme risk        | Extreme casualties |

## 2. CASE REPORT

Case studies were conducted in two cities: Mataram and Tanjung in North Lombok. Data of hazard and vulnerability for both cities were obtained from [4, 6], while data of capacity were introduced in this paper, and other data for assessment justifications were available from [10].

### 2.1. City of Mataram

The City of Mataram is located at the west part of Lombok Islands. The distance from the earthquake epicentre of the 5<sup>th</sup> August 2018 was about 100 km, also about 150 km from the Flores Fault. Soils were dominated by loose coarse sand; while, rocks are far

below soil deposits, which were friable sandstone and massive volcanic breccias. Groundwater was on the surface. One seismic index was Modified Mercalli Intensity Index (MMI) which was V [4]. Hence, hazard potential was, as follows:

#### **Hazard potential H = 47**

- Soil = 9
- Rock = 10
- Fault = 7
- Groundwater = 4
- Seismic = 17

As the capital city of the West Nusa Tenggara Province, the city had medium vulnerability values [7], which were, as follows:

#### **Vulnerability V = 44.90**

- $V_s = 71$
- $V_p = 25$
- $V_e = 30$

#### **Capacity C = 29**

- Standard building = 4
- Occupied area = 3
- Evacuation access = 4
- Public shelter = 4
- Emergency facility = 4
- Financial support = 3
- Health condition: life expectancy = 4
- Health condition: morbidity = 3

Thus, the risk according to Equations (2) and (3) = 72.77

Risk classification : Low risk

Casualty : Low casualties

### 2.2. City of Tanjung

The City of Tanjung is located in the North Lombok District, where the epicentre of the 5<sup>th</sup> August 2018 earthquake was located. Most geological and seismic hazard potentials were available, including the shallow Flores Fault. According to the available data [4, 6], the hazard rating was, as follows:

#### **Hazard potential H = 64**

- Soil = 9
- Rock = 10
- Fault = 12
- Groundwater = 2
- Seismic = 31

Not all vulnerability indexes were applied in Tanjung, since the city has just developed for the last 5 years. Most constructions were traditional and ordinary buildings. In general, people of the city were educated just up to secondary school levels. Thus, the vulnerability values were, as follows:

#### **Vulnerability V = 34.20**

- $V_s = 57$

- $V_p = 20$
- $V_e = 18$

### **Capacity $C = 18$**

- Standard building = 1
- Occupied area = 4
- Evacuation access = 3
- Public shelter = 1
- Emergency facility = 3
- Financial support = 1
- Health condition: life expectancy = 2
- Health condition: morbidity = 3

Thus, the risk according to Equations (2) and (3) = 121.60

Risk classification : Medium risk

Casualty : Medium casualties

## **3. DISCUSSION**

Risk indexes have been developed in many forms, mostly based on hazard potential and vulnerability [11-15]. A semi-quantitative approach could be an easy and quick method for analysing hazard risks. A rating system, as applied by researchers [6, 7], is proposed for analysing risks due to earthquake hazards to measure potential, vulnerability and the capacity of an area and people to overcome difficulties during the disaster. Although, it is rather subjective, the rating system could quickly measure potential casualties that may be gained during the earthquake event. It is important for government, particularly the local government such the case of the West Nusa Tenggara Province in Indonesia, to estimate the capability of the government and its people in remedial measures [16-18].

Health capacity is introduced in the development of risk analysis, such that could be different one to other areas depending on health conditions. This could be important in reducing fatalities, since it could represent how people within the risk area could overcome difficulties during hard time in a disastrous event. A disaster relieve may take a long time, possibly more than five years, as Aceh earthquake, Yogyakarta earthquake, mud eruption in Sidoarjo, and the current disasters in Lombok and Palu in Indonesia [19, 20].

There are many parameters of community capacity [21], including health capacity [22], but, only two parameters are involved in the current analysis. Life expectancy and morbidity are significant parameters in representing health conditions [23, 24], and the West Nusa Tenggara Province is among the worst provinces in Indonesia in terms of health conditions [9, 25]. Two cases in current analysis show that the two parameters could differentiate the risk in hazards between low and medium casualties, although, other capacity parameters are also involved, such as public shelter [26], emergency facility

and financial support. These last parameters could be worse in other remote areas in Indonesia. Access to an emergency facility, such public health centre (PUSKESMAS) is even difficult at a remote area [27].

Thus, health conditions, health facilities and health budget are extremely important in reducing natural hazard risks [28], particularly earthquake risks where Indonesia is the most seismic active in South East Asia region<sup>1</sup>. Also, Indonesia is a huge archipelago country where may be almost 70% of the country are remote areas, and many are isolated area. A quick assessment method could be helpful accompanied by a geospatial analysis that a risk assessment could be quickly conducted [11, 29].

## **4. CONCLUSIONS**

A people capacity in terms of health quality has been introduced for the mitigation of earthquake hazards. A rating system has been applied to life expectancy and morbidity parameters to estimate the resistance of people in overcoming difficulties due to emergency conditions caused by earthquakes. Two cases learnt from the Lombok earthquake 2018 show that the capacity of people and area being influenced by earthquakes has been able to differentiate between low and medium to high casualties. Quick easy assessments could be important for a seismic active country, such as Indonesia, where inhabitants within remote area may have difficulties when natural hazards strike the area. Therefore, the proposed method may be applicable for hazard preparedness in other cities in Indonesia.

## **AUTHORS' CONTRIBUTIONS**

<sup>1</sup>WI conducted research in public health emergency cases during Lombok earthquake 2018, currently a Ph.D. candidate at the Hasanuddin University in Makassar.

<sup>2</sup>SA, MH, SS are the Promoter and Co-promoters of the first author at the Hasanuddin University in Makassar.

<sup>3</sup>FRA is lecturer at the Faculty of Medicine of University of Mataram, conducted research analysis.

<sup>4</sup>DSA conducted research in the earthquake mitigation of Lombok earthquake 2018.

## **ACKNOWLEDGMENTS**

The first author would like to acknowledge supports from Promoter and Co-promoters of the Faculty of Medicine, University of Hasanuddin, Makassar. Also, the help from Province of West Nusa Tenggara Government; the Research Centre for Earthquake and Disaster Mitigation, University of Mataram, Mataram, are appreciated. Authors also acknowledge supports from the Faculty of Medicine of University of Mataram.

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