Policy Implication For Economic Losses Reduction Due To Earthquake Disaster In Bantul City, Indonesia

M F N Aulady,1,2 and T Fujimi1

1Department of Architectural and Civil Engineering, Kumamoto University, Japan
2Department of Civil Engineering, Institut Teknologi Adhi Tama Surabaya, Indonesia

170d9410@st.kumamoto-u.ac.jp

Abstract. One of the worst earthquakes occurred in Indonesia is in Bantul city, Yogyakarta province in 2006. It suffered huge amount of economic losses and many casualties. This issue become more significant, because residential buildings in Bantul city is impoverished. Moreover, Bantul city has high density of population. Here, we estimate the economic losses due to the earthquake in the future based on the vulnerability of dwellings in Bantul area using risk curve. Furthermore, we simulate a hypothetical mitigation policy of risk reduction for future earthquakes. After policy implication with various subsidy scenario, the economic losses can be reduced up to 648,017.48 USD for 0.5 % probability of exceedance in 50 years. This study indicates that the government can reduce the risk of economics significantly as the beginning in reducing risk with various factors.

1. Introduction

Natural disaster is a disaster as a result of an event series that is caused by nature, such as: earthquake, tsunami, volcanic eruption, flood, drought, hurricane and landslide. Indonesia is one of the countries that is prone to natural disaster, especially earthquake. This is due to Indonesia is surrounded by three tectonic plates, the Indo-Australian plate, Eurasia, and the Pacific plate. Earthquakes are not directly related to climate change, but the risk of natural disasters is ever increasing because of population growth, increasing urbanization and continuous unregulated construction of buildings. More importantly, many existing buildings may not withstand future earthquakes. Due to continuous changes in seismic codes caused by increasing human knowledge and experience about earthquakes, seismic rehabilitation of existing structures and components is inevitable [1].

One of the worst earthquakes occurred in Indonesia is at Bantul Regency, Yogyakarta province in 2006. It suffered many casualties; the reported fatalities are 5,778 people dead [2]. National and local government attempted to recovery the Regency. Many developments have been done, but nescience about earthquake resistant building might make people experience the same event. Moreover, vulnerability in this Regency might increase.

Based on the experience of the natural disasters in the past, a building which has a fairly high vulnerability becomes a major cause of fatalities in an earthquake disaster. This is in accordance with the saying goes: "Earthquake does not kill people, but buildings do". Some earthquakes that occurred recently, such as the earthquake in Yogyakarta Special Region and in other areas have been many casualties and property losses, including the destruction of building houses, as well as damage to public facilities such as schools, hospitals and office buildings insufficiently established to anticipate the danger.
This issue becomes more significant, because residential buildings in Bantul Regency is impoverished [3]. Furthermore, Bantul Regency has high density of population [4]. According to areas occupied by residential dwellings and other facilities, it shows that urban development in Regency Bantul does not follow logical process, even the population growth has increased [5].

Due to the number of losses, lives as well as properties, it needs a proper strategy. Disaster management focuses on implementing strategies that may lead to eliminating the risk of disasters [6]. This research becomes important because by evaluating earthquake risk in Bantul Regency based on scientific data, the public will be aware of the importance of the earthquake impact and will be able to reduce the vulnerability of earthquakes.

A related research concerning to earthquake hazard analysis in Indonesia developed hazard curves for major cities of Indonesia including Yogyakarta Special Region for 10% probability of exceedance in 50 years [7]. Figure 1 shows Peak Ground Acceleration (PGA) of Indonesia at 2% probability of exceedance in 50 years. Seismic hazard map of Indonesia has been established by residential research and development center under Ministry of public works and residence [8]. As depicted in the figure, the color of Bantul city is peach or around 0.5-0.6g which is equivalent to intensity of VIII. Consequently, there would be a great shaking and heavy damage for unreinforced masonry buildings.

![Figure 1. Indonesia hazard map, ground motion for all modeled sources for peak ground acceleration at 2% probability of exceedance in 50 years](image)

The main objective of this research is to evaluate earthquake risk in terms of economic loss in Bantul, regarding current situation of Bantul by using risk curve. The risk curve is used to estimate the surviving casualties and fatalities that might be caused by a potential earthquake in the future. Furthermore, it applied the hypothetical policy to reduce the risk. Since, most developments in Bantul are incompatible with building code, homeowners usually provide home construction work directly to the foreman or workers without planning process by an expert. It is intended to given an illustration about simple home that resistant to earthquake. Furthermore, the survey about the ability of homeowner to retrofitting based on the building code shall be conducted. If the ability of homeowners for retrofitting is low, it is expected that the government will give subsidy by the applicable terms and conditions or give the consultation services to the public. Hence, both government and homeowners can participate in reducing the risk of earthquakes.
2. Target Area

2.1. Indonesia

Indonesia is an Archipelago country that covers a total area of 1.905 billion square kilometers. 4.85% of the Indonesia area is water territory. The population density is approximately 124.66/Km². It is administratively divided into 34 provinces. Each province which has a capital city is governed by a provincial governor and provincial council. Each province consists of some regencies headed by regional head. One of the densest islands in Indonesia as well as in the world is Java island. More than 50% of Indonesian population number is in Java island. The south area of Indonesia, especially in the middle and south of Java Island, is prone to earthquake disaster. It is due to subdural zone activity which is formed from collision between Indo-Australia plate and Eurasia plate in the south of Java.

\[\text{Figure 2. Correlation between Population density map of Java Island (a) [10] and Earthquake hazard map of Java Island (b) [11]}\]

Figure 2 how density map in Java island. From the figure, we can conclude that Yogyakarta is special province with population density is reach more than 500 people/Km², it has earthquake risk level that is approximately red color. It will increase the possibility of fatalities and economic loss due to earthquake significantly.

2.2. Yogyakarta Special Region

Located in south of Java, Yogyakarta is an area with long history. Yogyakarta become a special region due to that long history. It has free procedure in Yogyakarta regarding the head regional position, duties, governor and vice governor authorities, the local government institutions of YSR; culture; land; and layout. YSR has an area of 3,185.80 km² with a total population of more than 3 million people. YSR consists of 6 Regions which Bantul is one of region occupying the third position in population density which is reaching 1884 people/km².

\[\text{Figure 3. Yogyakarta Special Region (YSR) administration map [12]}\]
2.3. Bantul City

Bantul City which is a target area of this research is located on south YSR. The southern part of this district is a limestone mountain, the western tip of the Sewu Mountains. The large rivers flowing along Bantul city are Progo River (limiting this district to Kulon Progo Regency), Opak River, Tapus River and its tributaries. Bantul is directly adjacent to the Indian Ocean. It is divided into 17 sub-regions to ease administrative matters.

According to official website of Bantul government, the population of Bantul city in 2012 is 955,952 people, with an area of 506.85 km². The number of live able houses in 2013 reached 146,628 units or about 65.91% of the total houses in Bantul. There are several health and school facilities to support the population life. Most of the facilities including trade centers, hospitals and educational centers have been developed along the main road so that this situation has put the burden on households who live far from this main road for supplying their essential goods. Road conditions in Bantul district can also be categorized well from the total length of road 872,125 km, with 652,775 km is a paved road.

3. Methodology

3.1. Risk Curve

Risk curve is a two-dimensional plot of real or projected financial risk which shows a display of correlation between probabilities of exceedance represented in vertical axis versus real or projected financial reward (horizontal axis). The risk curves show how often the occurrence of an event such as earthquake may have consequences such as economic loss indicating level of loss with different return period. The area underneath the curve represent the expected losses in in a specific probability of exceedance in 50 years which calculated considering accident scenarios due to the earthquake.

3.2. Filed Survey

To determine the impact of the hazard, the first step is analyzing and reconstructing the environment that can be affected. In general, the data identify the different types of physical ground entities, including built assets, infrastructure, agricultural land and people. Based on the number of residential dwellings and population living in Bantul which were obtained through the literatures and public
statistics, a sampling in the target area and performing questionnaire survey distinguishes the percentage of various building typologies, the number of inhabitants in each type dwellings, cost value of the house, and other necessary data for loss estimation [14].

![Conceptual Risk Curve](image)

**Figure 5.** Conceptual Risk Curve

**Table 1.** Typology of Residential Building in Bantul city

| No | Building Type | Symbol | Description |
|----|---------------|--------|-------------|
| 1  | Unreinforced Masonry | UM | Constructed from brick, with no columns or beams, roofs made of tiles or asbestos |
| 2  | RC Low Rise Frame with Masonry infill walls | RCLRFM | The building has a frame (beams and columns) constructed from concrete. The frame is built first, then it is continued for the wall |
| 3  | Confined Masonry | CM | An improved version of MU, widely used by Indonesian people. The construction between walls and columns is done almost simultaneously |
| 4  | RC Medium Rise Frame with Masonry infill walls | RCMRFM | Constructed from frame concrete for buildings with medium height |
| 5  | Timber Frame with Structure infill | TFS | Building structure are from timber, and filled by rock wall and concrete |
| 6  | Unreinforced Masonry River Rock Walls | UMRRW | Building are not from concrete but using River rock wall |
| 7  | Timber Frame Residential | TFR | Constructed from timber and using for residential |
| 8  | Timber Frame Non-Residential | TFNR | Constructed from timber and not using for residential |
4. Result

Bantul is a small city with a strong heredity of culture and most of the population are farmers. As of it, more than 80% of buildings in Bantul City are residential, therefore most of the economic loss are related to these buildings. Figure 8 summarizes the result of risk calculation in terms of economic loss for residential buildings in Bantul City, respectively.

Figure 8 depicts risk curve in terms of economic loss for all residential buildings in Bantul city. The curve was obtained by calculating the selling price of buildings and its assets, followed by multiplying the damage ratio and the building number of each type. Then, the result is summed according to probability of exceedance in 50 years.

The building typologies unreinforced masonry, confined masonry, RC medium rise frame with masonry infill walls, timber frame with structure infill, unreinforced masonry river rock walls, timber frame residential and timber frame non-residential are assumed to be in category of masonry, RC low rise frame with masonry infill walls and RC medium rise frame with masonry infill walls are assumed to be in the category of timber for adjusting parameters.
5. Discussion
The estimation result of the loss exceedance probability (EP) curves in term of economic loss for each building typology is shown in Figure 8. The concaved-shaped curve observed in all curves describe that the smaller probability exceedance, the more increase of damage. Figure 8 indicates that 10% probability exceedance in 50 years is equal to 90% of risk value or 90% probability of damage value which is amounted to be 676,357.63 million USD for RCMRFM 2 Story. Namely, the minimum cost that need to be pay out by related organization for recovery RCMRFM 2 Story of 90% probability is 676,357.63 million USD. In the other hands, 10% probability exceedance in 50 years of UM building is approximately 128,854,77 million USD. The economic loss of 95% and 98% value at risk would be 234,736.47 and 346,736.476 million USD for UM residential building, respectively. And for RCMRFM 2 Story are 1,704,984.86 and 2,677,248.96 million USD.

The worst-case scenario of earthquake is at 0.5% probability of exceedance in 50 years which is equivalent to earthquake magnitude of M7.15. In this case, the economic loss for RCMRFM 2 Story and UM are at the highest value, which are approximately to 3,000 and 500 million USD. The economic loss for RCMRFM 3 Story is approximately to 276 million USD.

6. Policy Implication
In this section. We simulate a hypothetical mitigation policy of risk reduction for future earthquakes. As indicated in the previous section, the number of RCMRFM 2 story and UM plays a crucial role to increase the risk. It is because more than 90% house in target area is inadequate. In this section, the policy applied is to replace the UM building type with the standard building code. The policy applied is only for UM building because RCMRFM 2 story building is for capable family, so that they can apply the building code without government support. Based on budget plan (APBD) of Bantul regency data in 2014, the budget plan of Public Work Department is 14,021,886.46 USD and it is realized to 13,431,298.50 USD. This means that it is still 590,587.96 USD remaining in 2014. We assume that the remaining budget can be used to build concrete house with earthquake national standard. Then it will have 95 units new house that can be built.
Table 2. The number of concrete houses from various subsidy scenario

| Percentage Subsidy | Government | Home Owner | Government | Home Owner | Number of New House |
|--------------------|------------|------------|------------|------------|---------------------|
| 100%               | 0%         | $6,223.23  | -          | -          | 95                  |
| 90%                | 10%        | $5,600.91  | $622.32    | 105        |
| 80%                | 20%        | $4,978.58  | $1,244.65  | 119        |
| 70%                | 30%        | $4,356.26  | $1,866.97  | 136        |
| 60%                | 40%        | $3,733.94  | $2,489.29  | 158        |
| 50%                | 50%        | $3,111.62  | $3,111.62  | 190        |
| 40%                | 60%        | $2,489.29  | $3,733.94  | 237        |
| 30%                | 70%        | $1,866.97  | $4,356.26  | 316        |
| 20%                | 80%        | $1,244.65  | $4,978.58  | 475        |
| 10%                | 90%        | $622.32    | $5,600.91  | 949        |

It can be seen from Table 2 the number of concrete houses from various subsidy scenario, from the rest budget, the government can build up to 949 new houses with a subsidy of 10% per house, and it will then decrease the economic losses until $648,017.48 USD for 0.5% Probability of Exceedance in 50 years. Due to lack of data (Government website only publish the data on 2014). We assume that every year government has the same amount of remaining budget. So that, in three years government can subsidy up to 2,847 of concrete house. It will then reduce the economic losses for 0.5 Probability of Exceedance in 50 years up to $1,944,052.44 USD.

Figure 9. Calculation of risk in terms of economic loss after policy implication for UM residential building

7. Conclusion
The estimation of economic losses due to Bantul earthquake in 2006 has been done. The Residential building, especially UM building type is exposed highest value of economic losses, it is approximately to 500 million USD. After policy implication with various subsidy scenario, the economic losses can be reduced up to $648,017.48 USD for 0.5 % probability of exceedance in 50 years. Thus, the Bantul government can consider this policy properly. It can also reduce the vulnerability of Bantul city due to
earthquake disaster. Certainly, it still has many parameters to consider in this policy, such as the ability of homeowners to spend the costs, and other unexpected factors. However, this study indicates that the government can reduce the risk of economics significantly as the beginning in reducing risk with various factors.

8. References

[1] “National Disaster Prevention Plan 2015-2019,” The National Board for Disaster Countermeasure Abbreviated, Jakarta, Nov. 2014.

[2] S. Husein, S. Pramumijoyo, and D. Karnawati, “Micro Vulnerability Zone Mapping Vulnerability Province D.I. Yogyakarta,” presented at the Geology Symposium Yogyakarta, 2010, pp. 1–10.

[3] “Percentage of Poor People (Percent),” Statistic of D.I. Yogyakarta, 28-Feb-2018. [Online]. Available: https://yogyakarta.bps.go.id/dynamictable/2017/08/02/31/kepadatan-penduduk-menurut-kabupaten-kota-di-d-i-yogyakarta.html. [Accessed: 28-Feb-2018].

[4] “Population Density by Regency / City in D.I.Yogyakarta,” Statistic of D.I. Yogyakarta, 28-Feb-2018. [Online]. Available: https://yogyakarta.bps.go.id/dynamictable/2017/08/02/31/kepadatan-penduduk-menurut-kabupaten-kota-di-d-i-yogyakarta.html. [Accessed: 28-Feb-2018].

[5] R. Handayani, “Evaluation of Land Usage in Bantul District Based on Spatial Planning,” Universitas Gadjah Mada, Yogyakarta, 2013.

[6] N. Etinay, C. Egbu, and V. Murray, “Building Urban Resilience for Disaster Risk Management and Disaster Risk Reduction,” Procedia Eng., vol. 212, pp. 575–582, 2018.

[7] J. Nugraha, G. Pasau, B. Sunardi, and S. Widiyantoro, “Hazard Analysis of Earthquake and Isoseismal for Java-Bali-NTB Region,” J. Meteorol. Geophys., vol. 15, no. 1, pp. 1–11, 2014.

[8] “Source and Earthquake Hazard Map 2017,” Center of Research and Development of Housing and Settlements, 28-Feb-2018.

[9] “Source and Earthquake Hazard Map 2017,” Center of Research and Development of Housing and Settlements, 28-Feb-2018.

[10] J. K. Baird, “Asia-Pacific malaria is singular, pervasive, diverse and invisible,” Int. J. Parasitol., vol. 47, no. 7, pp. 371–377, Jun. 2017.

[11] “Earthquake Risk Map Indonesia 2011,” National Agency For Disaster Management, 16-Oct-2012.

[12] A. Wismadi, M. Brussel, M. Zuidegeest, H. Sutomo, L. E. Nugroho, and M. van Maarseveen, “Effect of neighbouring village conditions and infrastructure interdependency on economic opportunity: A case study of the Yogyakarta region, Indonesia,” Comput. Environ. Urban Syst., vol. 36, no. 5, pp. 371–385, Sep. 2012.

[13] “SIM Kewilayahan Berbasis WebGIS.” [Online]. Available: http://kewilayahan.bantulkab.go.id/rtrw.php?mod=1. [Accessed: 28-May-2018].

[14] I. . Sengara, M. Suarjana, D. Beetham, N. Corby, M. Edwards, and Wehner, “The 30th September 2009 West Sumatra earthquake: Padang Region damage survey,” Geoscience Australia, Canberra, 2010.