Earthquake Hazard Analysis Methods: A Review

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Abstract. One of natural disasters that have significantly impacted on risks and damage is an earthquake. World countries such as China, Japan, and Indonesia are countries located on the active movement of continental plates with more frequent earthquake occurrence compared to other countries. Several methods of earthquake hazard analysis have been done, for example by analyzing seismic zone and earthquake hazard micro-zonation, by using Neo-Deterministic Seismic Hazard Analysis (N-DSHA) method, and by using Remote Sensing. In its application, it is necessary to review the effectiveness of each technique in advance. Considering the efficiency of time and the accuracy of data, remote sensing is used as a reference to assess earthquake hazard accurately and quickly as it only takes a limited time required in the right decision-making shortly after the disaster. Exposed areas and possibly vulnerable areas due to earthquake hazards can be easily analyzed using remote sensing. Technological developments in remote sensing such as GeoEye-1 provide added value and excellence in the use of remote sensing as one of the methods in the assessment of earthquake risk and damage. Furthermore, the use of this technique is expected to be considered in designing policies for disaster management in particular and can reduce the risk of natural disasters such as earthquakes in Indonesia.

1. Introduction

An earthquake disaster risk is a function that consists of several variables namely disaster, exposure, and vulnerability. In UN / ISDR 2004 publication, it is mentioned that in the last 30 years counted from 2002, there was a continuous improvement in the implementation of disaster management, such as disaster mitigation and prevention, disaster risk management, disaster response, emergency management, and civil protection [1]. The application of disaster management is projected to reduce economic and human injuries caused by natural disasters in some countries, in general, which had suffered a massive material failure along with a lot of casualties among the community. Table 1 is describing economic losses and fatalities due to the significant disaster impact to every continent which experienced disasters in the first semester of 2017 [2].

2. Assessing Earthquake Hazard Methods

One of the efforts to reduce the earthquake disaster risk is by conducting an assessment of the earthquake hazard factors that exist in the specific region. Previous research on earthquake hazard assessment has been conducted, such as a research conducted by Ansal et al., against the seismic zone and micro-zonation that can be used to estimate the hazard of an earthquake. The purpose of seismic micro-zonation is to minimize the man-made environment damage. Thus, the zonation parameters were selected referring to this objective. Different zones were delineated to choose parameters in providing city recommendation with some guidelines, for examples, specifying population, building
density, and building characteristics. These analyses were considered in a probabilistic framework to account for possibilities due to various earthquake source mechanisms that are suitable to the aim [2].

The case study was located in two areas, which are Adapazari and Gölcük. Several parameters such as the local geological formations, classification of the site, shear wave velocity, the spectral acceleration, and site amplification to obtain seismic micro-zonation were analyzed.

**Table 1.** Economic losses and the number of casualties due to most significant disaster impact in the first semester of 2017.

| Continent   | Occurrence | No. Deaths | No. Total Affected | Damages (Million US$) |
|-------------|------------|------------|--------------------|-----------------------|
| Africa      | 38         | 635        | 50,966,253         | 2,489                 |
| Americas    | 32         | 654        | 7,639,426          | 8,700                 |
| Asia        | 60         | 1,657      | 21,952,969         | 18,609                |
| Europe      | 14         | 206        | 73,085             | 131                   |
| Oceania     | 5          | 10         | 9,907              | 2,422                 |

**Figure 1.** Microzonation of ground shaking compare with the geological formation of Gölcük.

The seismic micro-zonation analysis is showed in Figure 1. The micro-zonation mapping was accomplished by analyzing average spectral accelerations from site response analyses compared with the maximum value of spectral amplifications which are calculated using equivalent shear wave velocity [2]. Some grid points of the site amplifications were relatively high, while the other grid had a low peak ground accelerations, based on site response analyses. Here, the site response analysis was calculated using EERA or Shake program. As the results, spectral amplifications value varied on the deposit thickness, initial shear modulus estimation and also the input acceleration of time histories characteristics. Moreover, the spectral amplifications calculated using the equivalent shear wave velocities, V30, showed more realistic values when compared with the soil profiles [2].
The disadvantage of using the V30 method, which is considered one of the most effective approaches in considering soil amplification factors, is that, based on recent research, there is an error in estimating soil amplification [3].

An alternative method in the process of estimating the hazard of earthquakes is the probabilistic method of Neo-Deterministic Seismic Hazard Analysis (N-DSHA) [4]. This technique applies the attenuation equation and local site responses assumptions. Synthetic time series is also used to build earthquake scenario. The N-DSHA procedure generates ground motion parameters based on seismic wave propagation modeling at several different regional scales and several possible seismic sources as well as the availability of information data for structural modeling. N-DSHA is a statistical approach which can compute a large number of earthquakes possibilities, and it is also related to some detailed uncertainty and detailed data. The method employs physical-mathematical modeling formalized into the validation process. Also, N-DSHA can use information about the location of earthquake potential by entering the magnitude data [4].

Figure 2. The primary stage of (a) Deterministic Seismic Hazard Analysis (DSHA) and (b) Neo-Deterministic Seismic Hazard Analysis (N-DSHA).

The N-DSHA is supported by ground motion modeling in every location (i.e., the node from the regular grid), considering the scenario of events. It begins in the availability of information on earthquake sources and regional structural models seen in Figure 2. N-DSHA modeled the earth motion of the earthquake as a tensor between the earthquake source tensor and the Greens function for the medium (realistic synthetic seismograms at different source locations), and this avoided the incorrect scalar quantity applied to the approximate ground motion equation or attenuation relationship [4].

Another method is to use Remote Sensing [5]. The assessment of hazard and damage is evaluated using remote sensing before the disaster (pre-earthquake). Spatial analyzing of earthquake hazards uses remote sensing to describe microscale zonation and measurements of earth surface movement, and also to map exposure areas such as building density to assess risk [6]. Vulnerability to the community can be evaluated using indirect remote sensing correlation methods. Figure 3 shows the decreasing building density using remote sensing in Cologne, Germany. For post-earthquake events,
remote sensing can be applied in the analysis of hazard information shortly after the earthquake over a wide range of areas, assessment of risk and damage and monitoring of post-earthquake recovery.

In reviewing the risks and damage caused by earthquake disasters in Indonesia, there are several methodologies used such as a medium to high-resolution data like Landsat, Quickbird, and IKONOS. Moreover, there are free open-source and proprietary GIS softwares to process remote sensing image data such as ArcGIS, GrassGIS, and QuantumGIS.

Figure 3. 3-D Model of Cologne, Germany, highlighting the downtown area (brown color) and a decreasing building density to the peripheral urban areas.

3. Conclusions
In assessing the hazard caused by the earthquake, some approaches have been used, including the analysis of seismic zone and micro-zonation, Neo-Deterministic Seismic Hazard Analysis (N-DSHA), and using remote sensing. Each method has its advantages and limitations given. One of them is the micro-zonation method and the seismic zone. It is very time-consuming to do the soil investigation. It also needs high technology equipment to gain the accurate data of the soil. As a result, it takes the high demand for the cost of doing such soil investigation in several plotting areas. The site-specific studies are also needed to evaluate the effects of local soil conditions to gain more accurate detailed data.

In the Neo-Deterministic Seismic Hazard Analysis (N-DSHA) method, it takes a complexity of engineering calculation of the model input data quality and existing algorithms for diagnosis of times increased the probability. But it still requires considerable engineering judgment in analyzing this method.

Considering the use of data in real-time condition, it needs remote sensing method. It is supposed to meet the needs of the data, where the results obtained can be used accurately by the field conditions. More accurate data can be accessed easily and quickly. Thus, if an earthquake disaster occurs, the response time can be more considerably reduced, and countermeasures can be taken quicker. Some analyses used spatial data such as earthquake risk prediction, the area exposed by the earthquake disaster and the number of both physical and non-physical vulnerabilities occurring in the area.
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