Chapter I
Introduction

1.1 Background

After tsunami hazard predominantly damaged Nanggaroe Aceh Darussalam (NAD) Province in December 2004 and Earthquake in The Special Region of Yogyakarta in 2006, those cases increase the awareness impact of natural hazard for many stakeholders. Natural hazard have wide terms, but common case have been caused by geological hazards. Geological hazards are dangerous situation caused by geological processes (Noor, 2006). The kinds of geological hazards are landslide, mountain eruption, earthquake, flooding, erosion, salination, and drought (Noor, 2006).

Geological hazard caught avoided by hazard mitigation. The concept of hazard mitigation is decreasing risk from geological hazard with impacts on property damage and death toll (Noor, 2006). Spatial planning must consider about hazard mitigation, because it consists of land use arrangement; such as allocation of settlement area, industrial area, conservation area, etc. Analyzing land allocation in spatial planning based on geological hazard has objective to prevent from natural hazard damaging.

Spatial Planning Act No. 26 /2007 describes about how to hazard tackling with determine hazard vulnerability area. In article 42 verse 1: implementation and of spatial planning have been done to decrease hazard risk, which consist of applying spatial planning regulation, safety standard, and apply sanction for scofflaw.

To determine hazard vulnerability area in spatial planning is developed using many factors. Most of the factors are related to geological information map. Geological information map contains some information, which is related with the
stability of area from impact of geological hazard. Types of geological information are: structure and physical properties of rock, slope, earthquake intensity, and existing fault line. All those factors have close relation with stability of area, or describe underground condition. On the surface, existing land use, characteristic demographic of population and economic are the most factors affected in vulnerability from earthquake hazard.

Combination between susceptibility from (geological) hazard cause by earthquake and vulnerability is defined as a risk (Figure 1.1). Risk means the expected number of lives lost, persons injured, damage to property and disruption of economic activity due to a particular natural phenomenon, and consequently the product of specific risk and elements at risk (UNDRO, 1979) (Fournier, 1986) in Kjatsu, et al. (2005). Risk assessments in urban area have benefit to help and clarify decision making for disaster management and the development of mitigation strategies (Khatsu, et al. (2005).

**Figure 1.1** Risk concept; Function Hazard and Vulnerability

Two ways analysis have been done; first is hazard analysis, which measured from geological information (rock structure, slope, earthquake intensity, geological structure, and existing fault line), and second is vulnerability analysis which measured and compared all criteria’s (physical, demographic, and social), and produced rank of priority distribution vulnerability area.

It is difficult to make decision that involves many factors or information, and to solve the problem for decision making concept. Decision making is a process of choosing among alternative courses of action for the purpose of achieving a goal
or goals (Turban, 1995). SDSS can be defined as an interactive, computer-based system design to support a user or group of users in achieving a higher effectiveness of decision making while solving a semi structured spatial decision problem (Malczewski, 1999).

1.2 Statement of Research Problem
Earthquake is a deadly hazard in 20th millennium (UN, 2010), because it cannot be predicted when it come and what level of strength. BNPB (2007) recorded from 2002 to 2006 that earthquake and secondary impact of earthquake; tsunami, caused at least 120,000 death victims, and more than 600,000 houses were damaged in Indonesia. Those facts describe at least 90% total from other hazard like flood, drought, landslide, and etc.

![Figure 1.2 Number of death victim caused by natural hazard (BNPB, 2007).](image)

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Level of urbanization in Indonesia is still increasing; at least 119 inhabitants per square kilometer is the population density in Indonesia, and particularly in Jawa and Bali islands were 996 inhabitants per square kilometer (BNPB, 2007). The Population growth followed by the increase of built up areas, can increase vulnerability and risk level from natural hazard. As tool for development control, spatial/urban planning has strategic position in mitigation concept to avoid natural hazard.

One of the mitigation concepts to avoid high loss caused by earthquake is to develop spatial planning based on natural hazard potential and vulnerability factors. In facts, not all cities in Indonesia prepare spatial planning based on natural hazard potential and vulnerability factors. Existing locations in Indonesia are surrounded by tectonic and volcanic activities, which should be the priority review for urban planning.

The latest spatial planning guide in Bantul, which was revised in year 1999, has some refraction especially in determining for hazardous area. For example, in sub district Sewon, Kasihan, and Banguntapan were set to urban settlements area. In facts, in those area loss rates had reached high enough when earthquake occured in 2006. The loss rate was more than 4660 fatalities, and 2000 victims injured. For
structure, the level of damage reached more than 21000 houses damaged, and 15000 were totally destroyed. Those situations require arrangement based on earthquake hazard and vulnerability which aims to reduce lost in the future.

1.3 Aim of Research
This study has a purpose to define and describe about risk, which function of hazard and vulnerability area related to support urban planning process. Until now, there is not any clear term of risk, hazard, and vulnerability area noted in determine in spatial context. In this case, to determine risk has two combinations between hazard and vulnerability area.

1.4 Objective of Research
Objectives of this study are:
1. To determine hazard area based on geological information by using GIS spatial analysis.
2. To determine vulnerability area based on physical, demographic and social factors using multi-criteria analysis.
3. To determine level of risk area by combining hazard map and vulnerability map.

1.5 Research Questions
1. How to determine hazard, vulnerability, and risk area map based on geological information by using GIS spatial analysis?
2. Which location is potentially susceptible from earthquake hazard?
3. Which location is vulnerable when earthquake occurs? Vulnerability was observed from physical, demographic, and social factors.
4. How big is the risk probability degree in all area based on earthquake hazard, and related to the spatial planning guide.

1.6 General Research Methodology
It generally has been shown in schematic research methodology flow chart in the figure 1.4. The whole research work was divided into three major parts. First part
of methodology deals with review hazard and vulnerability literature particularly determined the criteria. The criteria should represent in spatial format data which will be used for spatial modeling.

The second part of methodology deals with multi-criteria analysis, which use pairwise comparison method (PCM) to assign criterion weighted. The third part of methodology deals with modeling with spatial analysis using GIS capability, which criteria weighted resulted from multi-criteria analysis is used to simulate in spatial analysis with weighted overlay method.

![Figure 1.4 Schematic diagram of research methodology](image)

### 1.7 Scope of Research

This research is focusing how to determine hazard, vulnerability, and risk area with simulation in GIS. GIS spatial analysis is used to simulate for hazard map model which represent geological information combination. The vulnerability map used was physical, demographic, and social aspects.

#### A. Hazard Analysis

Geological information is described in attribute and map (spatial data), and it was produced by Center of Vulcanology and Geological Hazard Mitigation, Ministry
of Mineral and Energy Resources. The geological information is classified into 5 (five) information:

1. Rock Structure and Physical Characteristic.
2. Geomorphology (Slope and Relief).
3. Existing fault line.
4. Earthquake Intensity.

B. Vulnerability Analysis

Vulnerability analysis consist of 3 (three) factors; physical, demographic (demographic of population), and social.

1. Physical Factor

Representative of physical aspects in urban risk analysis can be divided in three categories: density of built up area, number of structure, and type of structure.

2. Demographic Factor

The main factor of demographic vulnerability is described in characteristic demographic population that represents some data; 1) Total population, and 2) Density distribution, and 3) Population growth rates. Those criteria will transform into spatial data, which is sub-district administrative as a boundary unit.

3. Social Factor

Representative of physical aspects in urban risk analysis could be differentiated in three categories; 1) low income distribution, 2) Gender, and 3) Age structure (elderly and children).

C. Risk Analysis

Risk is the function of hazard and vulnerability, it means that the combination between hazard map and vulnerability map will produce risk map. Risk is multiplication between hazard and vulnerability function, which can be expressed in the following mathematical form:

\[
\text{Risk} = \text{Hazard} \times \text{Vulnerability} \quad (1)
\]
1.8 Location of Research

The research location was in the Bantul Regency, Yogyakarta Province. The coordinate geographic position was in latitude 07°44'04" S - 08°00'27" S, and longitude between 110°12'34" E - 110°31'08 E. The climate was influenced by sea in south (Indian Ocean), and the majority of land used for settlement and agriculture. Topographic conditions were steep in the west side, and flat in rest area such as coastal area.

The capital city of Bantul Regency located in District Bantul. Bantul regency consists of 17 districts. Bantul Regency has boundary with Yogyakarta and Sleman City in north, Gunung Kidul in east, Kulon Progo in west, and Indian Ocean in south. Some area were parts of expansion from Capital of Yogyakarta, where located in north Bantul (Subdistrict Kasihan, Sewon, and Banguntapan). It’s not surprising that the location is grouped into rapid development areas.
1.9 Research Output

The main output this study is;

1) Hazard area map based on geological information (ground stability), which is susceptible from earthquake.

2) Vulnerability area map based on multi-criteria analysis.

3) Risk map, which is the combination between hazard map and vulnerability map. Risk map is used to assess the spatial planning map that already exists.

1.10 Limitation of Study

This research is focus on hazard, vulnerability, and risk area from impact of earthquake hazard. Some limitation based on early investigated explain the limitation of this study are;

1. In the world, vulnerability concept is multi-interpretation; it wasn’t consensus to exactly define the meaning of vulnerability. That fact cause vulnerability analysis cannot use single solution problem, or as problems which possess multiple-solutions and contain uncertainty about the concepts, rules, and principles involved to reach these solutions (Rashed and Weeks, 2003) (Cutter, L.S., Boruff, J. B., and Shirley, L. W., 2003). So, in this research tried to generate the criteria related with hazard (earthquake) vulnerability, especially to determine the criteria. Widely examination of relevant literature was used to select the criteria.

2. Some of spatial data are not in the same basic scale or source, and it can decrease spatial accuracy. For example geological map has a scale of 1:100000 while administrative map has a scale of 1:25000.

3. To transform non-spatial data (in example; density of population) to spatial information used sub district administrative boundary as spatial analysis unit. The application theory to mapping statistical data was explained by Menno, Kraak J., and Ormeling F. (2009), which defined as choropleth map. Choropleth map a thematic map in which areas are shaded or patterned in proportion to the measurement of the statistical variable being displayed on the map, such as population density or per-capita income (Wikipedia, 2010).