CHAPTER IV
Risk Analysis in Urban Area Related Earthquake Hazard

4.1 Introduction
The number of casualities in earthquake hazard occurrence depend on the vulnerability condition and expected of hazard. When earthquake hits in dense area, it can cause high damage and injure many victims. That future concept interplay between hazard and vulnerability is defined as risk (Taubenbock et al. 2008). Risk is represent the measure level of damage, injured even death of victim. The measurement of risk can become an indicator for the safety an area when hazard occurs.

The concept of disaster risk in the concept of probability is directly affected by the devastating earthquake. The probability is highly dependent on the level of hazard and vulnerability levels, areas with high levels of hazard and vulnerability certainly have a risk (probability) a high damage as well, and vice versa. In regions with low levels of disaster does not mean not to be affected by the disaster, let alone have a high vulnerability structure, for the following risk factors increase the quality and quantity of the driving factors of vulnerability.

The result of risk study can be used to support spatial planning process, especially for land use planning. By the refer from risk map, land allocation process must suitable with risk area to avoid high impact by earthquake. The risk study also can be based for zoning regulation for planning control in the field.

4.2 Objective of Research
The objective of research is to determine level of risk area by combining hazard map and vulnerability map. Results of analysis of disaster risk maps are the basis of an
assessment of the distribution of settlements and judgments against the existing arrangement of space.

4.3 Literature Review

Risk is defining the probability (chance) of harm if someone or something (vulnerability) is exposed to hazard (Kentucky Geological Survey, 2009) or it can describe result from a future interplay of a hazard and various components defining vulnerability (Taubenbock et al. 2008). Risk is 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 of risk (UNDRO, 1979).

According to the UN (1991) and the UNDP (2004) in Taubenbock et al. (2008), risk is defining a conceptual superstructure as follows in equation 1. Risk formulas are multiply between hazard and vulnerability, in this research study hazard represent with earthquake occurrence and probability depend on geological structure. The vulnerability from earthquake hazard is representing with physical, demographic, and social factors.

4.4 Method of Research

The method of research risk mapping has been shown in figure 4.1. Determine degree of risk is combination among hazard and vulnerability, which refer to risk formula in equation 1. The source data for hazard and vulnerability from previous result in form of hazard and vulnerability map. The method to combine both map use spatial analysis by use map algebra feature in ArcGIS software.
4.4.1 The Risk Scenario

Risk assessment is combination between hazard and vulnerability will produce new information. The combination value is deriving from two combination scale value in hazard and vulnerability. In previous result show three (three) scale values for hazard and vulnerability. Both of the layers describe in high, medium, and low, but it has different order. For hazard; low values mean low stability or dangerous area when earthquake occur, conversely in vulnerability low value means low vulnerability or low damage impact for system (safety situation).

The new qualitative value was defined to give term degree of risk. Qualitative term (CASITA, 2004) in risk concept is such as low, very low, high, very high, etc. A new term was observed from logic situation; in example a certain area have the high stability area degree in hazard and it has low vulnerability means in that area the degree of risk is very low (very safety area). The detail qualitative term of risk is show in risk scenario matrix (Figure 4.4).

4.4.2 Data Preparation

The main data for risk analysis is hazard and total vulnerability map. The first step to data preparation is commensurate attribute value and scale classification. In previous explanation scale of hazard divided into three class; high, medium, and low,
meanwhile the vulnerability data still describe in value zero to one (high). Scale of vulnerability should commensurate until same with hazard data become three (three) class too (High, Medium, and Low), but there are contained different order. For vulnerability (Figure 3.23), the high status means high vulnerability or worst condition, meanwhile in hazard (Figure 2.18) high stability means high stability or resistance from earthquake impact (best condition) (Figure 4.2).

![Hazard and Vulnerability Scale](image)

**Figure 4.2** Hazard and Vulnerability Scale

### 4.4.3 GIS-Spatial Analysis

The concept risk spatial analysis based on map algebra using grid system (cell based modeling). Two spatial data from hazard and vulnerability map is become main source data. The main data was form on grid system with same grid size (30X30 meters). To combining two grid data was used map algebra method on ArcGIS software (Figure 4.3).

The simple map algebra concept explains which two grid value in two different layers are combine by simple mathematical operation. Before simulate by used map algebra method, it should re-define weight value for hazard and vulnerability, which is show in risk value matrix (Figure 4.4). Multiplication between hazard and vulnerability value was determine the risk value, which it classifies into six classes; very low risk, low risk, medium risk, high risk, very high risk, and extreme risk.

Each new class is generated from the process of spatial analysis is given a new value which is the multiplication of the disaster with vulnerability value. As an example of
high-value disaster multiplied by the high vulnerability will result in maximum risk values or the extreme value. So there are 9 (nine) new value that represents the value of disaster risk (Figure 4.4).

![GIS-Spatial Analysis Process for Risk Map](image)

**Figure 4.3** GIS-Spatial Analysis Process for Risk Map

<table>
<thead>
<tr>
<th>Vulnerability</th>
<th>X</th>
<th>Low (1)</th>
<th>Medium (2)</th>
<th>High (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hazard</td>
<td>High (1)</td>
<td>Very Low (1)</td>
<td>Low (2)</td>
<td>Medium (3)</td>
</tr>
<tr>
<td></td>
<td>Medium (2)</td>
<td>Low (2)</td>
<td>High (4)</td>
<td>Very High (6)</td>
</tr>
<tr>
<td></td>
<td>Low (3)</td>
<td>Medium (2)</td>
<td>Very High (6)</td>
<td>Extreme (9)</td>
</tr>
</tbody>
</table>

**Figure 4.4** Risk Value Matrix

4.4.4 Risk Assessment for Settlement Area

Impact of earthquake hazard is always endangering for place of human activity. Affected for human settlement can depend on ground condition (soil, rock structure), topography (slope), or type of structure. The important to assessment of risk level for human settlement is to get information about how damage probability in settlement
area. The benefit risk assessment in settlement area is use for local government to develop planning guidance and regulation for settlement. For the local people, it can use for settle plan guidance. The method to risk assessment for settlement area was used combination between risk map and settlement map, and it processed with GIS-spatial analysis, the final result show in risk assessment map in settlement area (Figure 4.5).

![Diagram](image)

**Figure 4.5 Method of Risk Assessment for Settlement Area**

### 4.5 Result and Discussion

Spatial analysis by using map algebra method (Figure 4.3) was produce risk spatial information. New information (and new value) was built as a new measurement which divided into six classes (Figure 4.4). The term of risk is related result from a future interplay of a hazard and various components defining vulnerability (Taubenbock et al. 2008). By defining in qualitative value (very low, low, medium, high, very high, and extreme), it’s clear to getting the picture how hazard and vulnerability has a role in earthquake occurrence.

The proportion of risk area is dominated by high risk class (Figure 4.6); it’s not far different from low and medium risk class. Percentage of high and very high risk area
should have more attention, because sum of both percentage areas reach 45% of total area (Table 3.8). It can say almost half of study area category in dangerous or risky area. The spatial distribution risk level is show in risk map (Figure 4.8), which has 6 level of risk. By manual interpretation, it can simple explanation where the risky area or the safety area. Level of hazard, especially low ground stability is most influence to risk determined.

In previous hazard explanation, stability factor was influenced by existing fault line. The area where passed by fault line would have extreme and very high risk class; in example Imogiri, Jetis, Bantul, Banguntapan, Pleret, and Pundong (Figure 4.7).

![Figure 4.6 Percentage Risk Area](image1)

![Figure 4.7 Risk Distributions in each Study Area](image2)
Imogiri have more than 80% extreme area and 39, 54% very high risk area from total risk area (Figure 4.7). The second hazardous area is located in sub district Jetis, which have 80,90 % extreme risk area, and 21,7% for very high risk area, followed by Banguntapan which has 19,91% extreme risk area.

Some area should have more attention such as Bantul, Piyungan, Pleret, Pundong which have very high and high risk area (Figure 4.8). Although, those areas haven’t extreme risk area, but it has at least 5% area were included very high risk class.

For the safety area or category in very low risk is located Dlingo and Pajangan. Those areas have majority in very low and low risk class, especially Pajangan although have more low ground stability area, but did not support with high vulnerability factor.
Another area is Sedayu, Pleret, Srandakan, Sanden, and Kretek, but isn’t absolute condition because it has other risk level such as medium or high risk area.

### 4.5.1 Risk Assessment for Settlement Area

By assigned value in settlement attribute which have quantity 10, and combined with risk attribute data. The attribute value in every settlement area was represent existing risk area, in example in extreme risk area the settlement value was 90, which represent multiplication value of settlement (10) and extreme risk area (9). Only 6, 42% and 18,91% settlement located in safety area or suitable for living places (Table 4.1). Those settlement areas are spread in several locations such as Sedayu, Pajangan, Pandak, and Bambanglipuro (Figure 4.9). For medium suitable settlement reach almost 30% from total settlement, and spread such as in Kasihan, Sewon, Banguntapan, and Jetis (Table 4.1).

#### Table 4.1 Distribution Level of Risk Settlement

<table>
<thead>
<tr>
<th>Score Value</th>
<th>Information</th>
<th>Total Area (m²)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Very Low Risk Settlement Area</td>
<td>7803</td>
<td>6.42</td>
</tr>
<tr>
<td>20</td>
<td>Low Risk Settlement Area</td>
<td>22970</td>
<td>18.91</td>
</tr>
<tr>
<td>30</td>
<td>Medium Risk Settlement Area</td>
<td>35133</td>
<td>28.92</td>
</tr>
<tr>
<td>40</td>
<td>High Risk Settlement Area</td>
<td>23957</td>
<td>19.72</td>
</tr>
<tr>
<td>50</td>
<td>Very High Risk Settlement Area</td>
<td>26274</td>
<td>21.63</td>
</tr>
<tr>
<td>60</td>
<td>Extreme Risk Settlement Area</td>
<td>5341</td>
<td>4.40</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>121478</strong></td>
<td><strong>100.00</strong></td>
</tr>
</tbody>
</table>

The risky settlement area divided into three classes; high risk, very high risk, and extreme risk. Almost 50% settlement was included in risky area (Table 4.1) where spread in such as Bantul, Jetis, Imogiri, and Dlingo (Figure 4.9). It is important to consider continuing living in those places, and it should going to do comprehensive structural and non structural mitigation.
4.5.2 Risk Assessment for Existing Local Spatial Planning

Measurement of risk analysis in urban area can support decision maker to allocate land and lifelines for the future. Based on risk analysis for earthquake impact and affected to area, it can avoid high damage when earthquake occur. For specific part of spatial planning, land use planning is an effective concept to avoid high loss and damage.

Review to spatial planning guidance in research study, it was contained some bias when confronting with risk analysis result. For example; Kasihan, Sewon, and Banguntapan were set in urban center and settlement area (Figure 4.10) located in risky area. Others bias such as Bantul and Jetis, which is set in industrial, settlement, urban area, agricultural, and urban areas can increase loss probability in the future. Some areas were appropriate with risk analysis result, for example Imogiri and
Dlingo which set in agricultural, protected area, and hazard vulnerable area (Figure 4.10).

![Spatial Planning Map of Bantul Regency](image)

**Figure 4.10 Spatial Planning Map of Bantul Regency**

### 4.5.3 Comparative Model of Risk with the Facts on The ground

The risk in earthquake disaster illustrates the probability of an area affected by the earthquake. As explained previously, if the risk the higher the probability the greater casualties and damage. In the case of the earthquake in Bantul regency, reviewed the risk factors of high or low number of fatalities and injuries. Districts with high levels of disaster risk through an extreme experience deaths and injuries greater than other regions. For example: located in district of Jetis, Imogiri, Piyungan, Pundong, Pandak, Bambanglipuro Pleret suffered substantial casualties as well as injured (4.11).

Areas that are not categorized as high or extreme disaster remains there are victims but the comparison is more dominated by the injured. They include district of
Kasihan, Sewon, Banguntapan, Displays, and Dlingo (Figure 4.11). The results are compared to map vulnerability and disaster maps show similar patterns of whole districts of Bantul are not free of fatalities and injuries.

The comparison shows that the district of Pajangan with the lowest risk level has a few casualties, while the district of Jetis with a very high level of risk is an area with a number of dead at most. While Imogiri with a number of areas with high risk of the most extensive number of victims is still under Jetis, this is related to physical vulnerability in the Imogiri is lower than Jetis (Figure 3.17). The data number of casualties in each district is shown in bar graph form, where the dark blue bar indicates the number of dead while the blue bars indicate the number of injuries. Explanation of statistical figures on the number of digits shown in every district, where the first number is the number of dead while the figures below are reported injured.

Figure 4.11 Comparative Risk Map and Distributed of Fatalities and Injured
The same results is shown on a comparison of risk maps and map the distribution of the destruction of buildings, which almost the entire area with a low risk category to experience extreme destruction and damage buildings (Figure 4.12). Some districts that experienced the destruction and damage to the building pretty much covers Jetis, Bantul, Imogiri, Bambanglipuro, Pundong, Pleret, and Pandak. These areas have a high risk level up to the extreme.

Some districts that experienced the destruction and damage to buildings is quite high but have low levels of risk include districts of Sewon, Kasihan, Banguntapan, Sedayu, Kretan, Sanden, and Srandakan. Inconsistency in the results of the comparison the number of casualties and damage to buildings with disaster risk map is possible because the level of detail maps that do not support, as well as on the vulnerability map and a map of the disaster.

Figure 4.12 Comparative Risk Map and Distributed of Damage and Shattered House
4.6 Conclusions and Recommendations

4.6.1 Conclusions

The conclusions are structured in line with the result and discussion of this research.

- Regional characteristics that have a high degree of risk and extreme almost entirely bypassed by the fault lines and areas with steep slopes.
- Most of the settlements in the study area into the region with high risk, so the probability of damage and casualties in the future will be very possible.
- Related to spatial planning in the study area do not pay attention to the allocation of land use aspects of disaster risk, there is need for evaluation at a later date there are adjustments to land use based on the risk of disaster.
- The comparison between the risk map with facts casualties and damage to buildings at some time after the earthquake there were some things that fit or not fit.
  1. Areas with a high risk to extreme high-rise building damage and casualties or injuries such as in sub Jetis, Bantul, Imogiri, Piyungan, and Banguntapan. This is consistent with the results of disaster risk analysis.
  2. Areas with low risk also affected by the casualties and damage to buildings, such as occurs in Kasihan, Sewon, and partly Banguntapan. The explanation is not in accordance with the logic of the risk of disaster in which low-risk areas should have a minimum number of victims and building damage.
  3. The difference results, with the reality on the ground is possible because of spatial data, especially related to hazard maps which less detailed, if available maps provide a more detailed scale of 1:25,000 will reduce hazard map generalization, which in turn affect the results of disaster risk map.

4.6.2 Recommendations

Some recommendations for further investigation are related to risk analysis:

1. Disaster risk map is a map derived from hazard maps and maps of disaster vulnerability, so the need for further investigation about the level of detail maps of disaster in particular.
2. Disaster risk assessment is closely connected with the prediction of the number of casualties and damage, it is necessary to further research on the relationship of risk with the amount of loss including economic loss.

3. Disaster risk maps can be used as the basis for spatial planning, it is necessary to further study the relationship between disaster risk and land-use management related spatial planning.