A Method of Economic Vulnerability Analysis on Flood Risk Assessment

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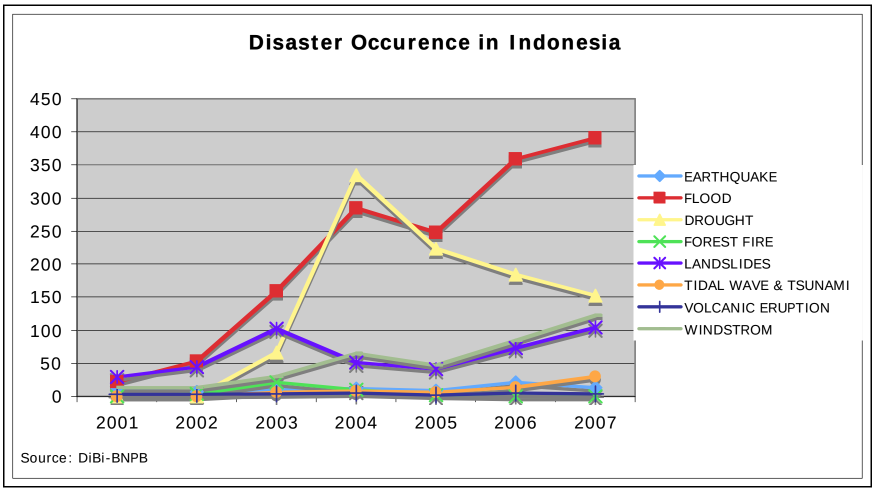
Abstract
This chapter is discussing background of research, research problem, research objectives, research questions and research significance and outline of reports. The research attempts to develop a model of economic vulnerability analysis using geo information technology as a part of spatial planning.

A. Background
In Indonesia more than 104 major floods occurred from 1980 to 2008 (Farid, 2010). The frequency of floods are highest than the others natural disasters. As stated in the final country report of Indonesia Government in 2007, from the total disaster, 70 percent of the total disaster is accounted for floods and windstorms and only 30 percent of the total disasters are accounted for by droughts, landslides, forest fires, heat waves and others. From 2003 to 2005, there were about 1,429 disaster incidences in Indonesia. 53.3 percent of the disaster was hydro-meteorological disasters (Bappenas and Bakornas PB, 2006). Of this figure in 2007, floods occur most often (400), followed by drought and windstorm at 150 and 140 respectively and the least are earthquakes, tsunami and volcanic eruptions. It is likely that global warming will lead to greater extremes of drying and heavy rainfall which will in turn lead to higher risk of climate hazards (Trenberth and Houghton, 1996; IPCC, 2007). Because of that, Indonesia is one of the vulnerable countries to climate related hazards.



Definition of flood is an overflow of an expanse of water that submerges land. The EU Floods directive defines a flood as a temporary covering by water of land not normally covered by water (www.wikipedia.com). In the term of "flowing water", the flood may also be applied to the inflow of the tide. Flooding may result from the volume of water within a body of water, such as a river or lake, which overflows or breaks levees, with the result that some of the water escapes its usual boundaries. Floods have effected on different parts of the earth as a result of increasing human's interference on global climate. In most cases, floods are caused by climatologically phenomena, which are out of human control. The scale and frequency of floods are likely to increase in the future as a result of climate change, inappropriate river management and construction in flood risk areas (Boer, 2010; Raharja, 2010; Wang, 2010). In addition, Sutardi (2006) said that there are three determinant conditions that heavily influence floods events those are: (1) the intensity and duration of rainfall, (2) the condition of river channels, and the existence of low land areas.

Since the increasing of disaster occurrence and urban development, there has been a marked increase in vulnerability due to the number of people and economic assets located in flood-prone areas. The cities located in flood-prone areas area vulnerable for disaster because the high concentration of people, buildings, infrastructure and socio-economic activities (Budiarjo, 2006). To deal with flood problems, recently, there is shifting paradigm from response management toward risk management with emphasis on disaster management. This management asked for more pro-active measures both structural and non-structural measures by implementing multidisciplinary approach and involving partnerships in the institutional framework. Disasters are no longer seen as extreme events, created entirely by natural forces, but as manifestations of unresolved problems of development. (ADB, 2001).

In damage evaluation, non-structural measures such as flood risk assessment that comprises hazards assessment and vulnerability assessment, is very important. In the frame of hazard assessment flood events are analyzed by means of recurrence intervals and spatio-temporal flood characteristics. Within vulnerability assessment flood prone utilizations are typically characterized by stage damage functions or risk curves. Neuhold (2010) notes if the assessment of flood risk considers three factors such as individual risk, economic risk and environmental risk yielding qualitative and quantitative statements which are typically subjected to substantial uncertainties. Furthermore, non-structural measure need new method for evaluating flood effects which are up to now rarely considered indirect loss (business interruption or economic effects) and intangible effects (environmental and social effects). So, a model of economic vulnerability analysis to measure indirect loss is needed. After that, flood risk assessment as a measure of the impact of flooding and likelihood that it will occur will be valuable input for disaster management plan.

For example, Bandung is one of the flood vulnerable cities in Indonesia. As an urban area, Bandung, is frequently exposed to flooding. The source of flooding is Citarum Rivers. In term of coverage areas caused by flood, the area of flood is 7450 hectare in 1986, but after the rehabilitation program, the area of flood is decreased to 5100 hectare. In 2001, there is also significantly decreased on flood area to 3200 hectare. The project seems will be succeed to reduce flooding areas, the area of flood is only 820 hectare, but unfortunately since 2005 the area of flood is increased to 1119 hectare. From 2006 to 2010, the flooding area and the total loss have been calculated yet (Kusuma, 2010 in Fuady, 2010).

There have been many studies conducted in Citarum watershed and its broader area but few studies focus on flood risk assessment. Subroto (2001) and Firdaus (2005) focus on land use in Citarik and Cirasea watershed. Shihab (2005) focus on study of landslide area control at Cirasea sub watershed. The latest studies conducted by Raharja, Boer, Sulandari (2010) focused on respectively watershed management, impact of land use and climate changes on stream flow and assessment of community participation to reduce impact of climate change at Citarum watershed. One of them, Sukiyah (2007) focused on the application of GIS for delineation of erosion and flood area in Citarum watershed.

Research Problems

Damage evaluation is crucial part of risk assessment. Economics activities, people at risk and environmental consequences are among the factors that determine the vulnerability. Prior to a flood, a loss estimation study needs to be done in order to estimate the human and economic loss and also intangible flood damages should be described for different possible flood scenarios. Regarding economics loss, it will be assessed by using I-O Model, one of economic methods that frequently selected for various economy analyses and developing some indicators for all elements at risk. Furthermore, the research on the evaluation of indirect damages and intangible flood damages is needed and urgent.

This research believes that economic vulnerability analysis is a key element to make appropriate disaster management plan: this research necessary to completely understand the effects of flooding on the complex economic production system.

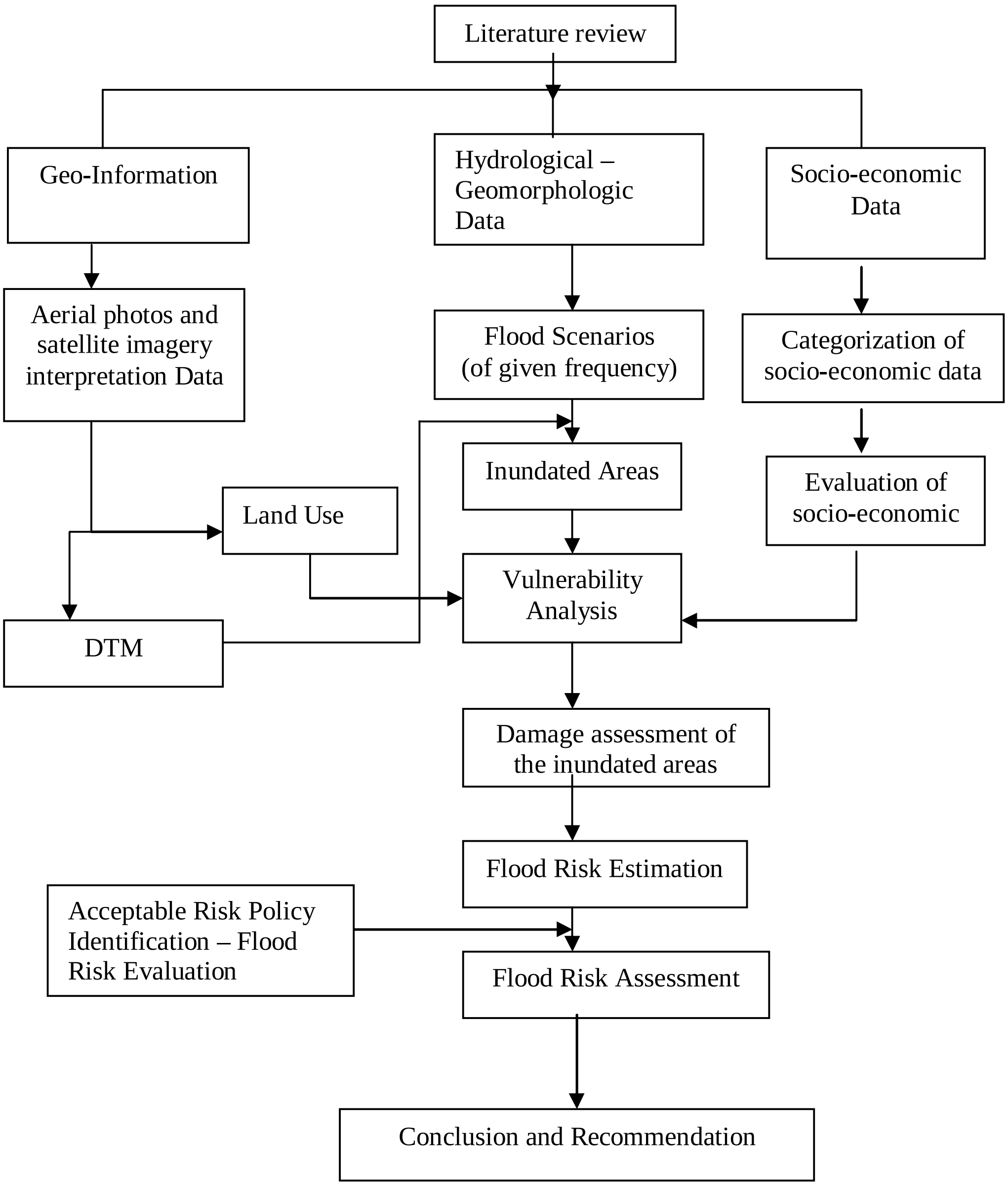
Research Objectives

The main objective of this study is to completely understand and to make a model the effects of flooding on the complex economic production system. The specific objectives are:

1. To identify the areas that could be potential hazard from flooding to human health, economic activity, the environment and cultural heritage
2. To understand the measure of vulnerability from a broad macro-economy perspective.
3. To analyze direct and indirect monetary damage during and after flood.
4. To create a model of economic vulnerability analysis for flood risk assessment.

This research is actually valuable as input for making decision in disaster risk management. It is important to understand that risk analysis — assessment, management, and communication — occurs throughout the planning process. Properly understood, risk analysis is an analytical approach to every decision.

Research Framework

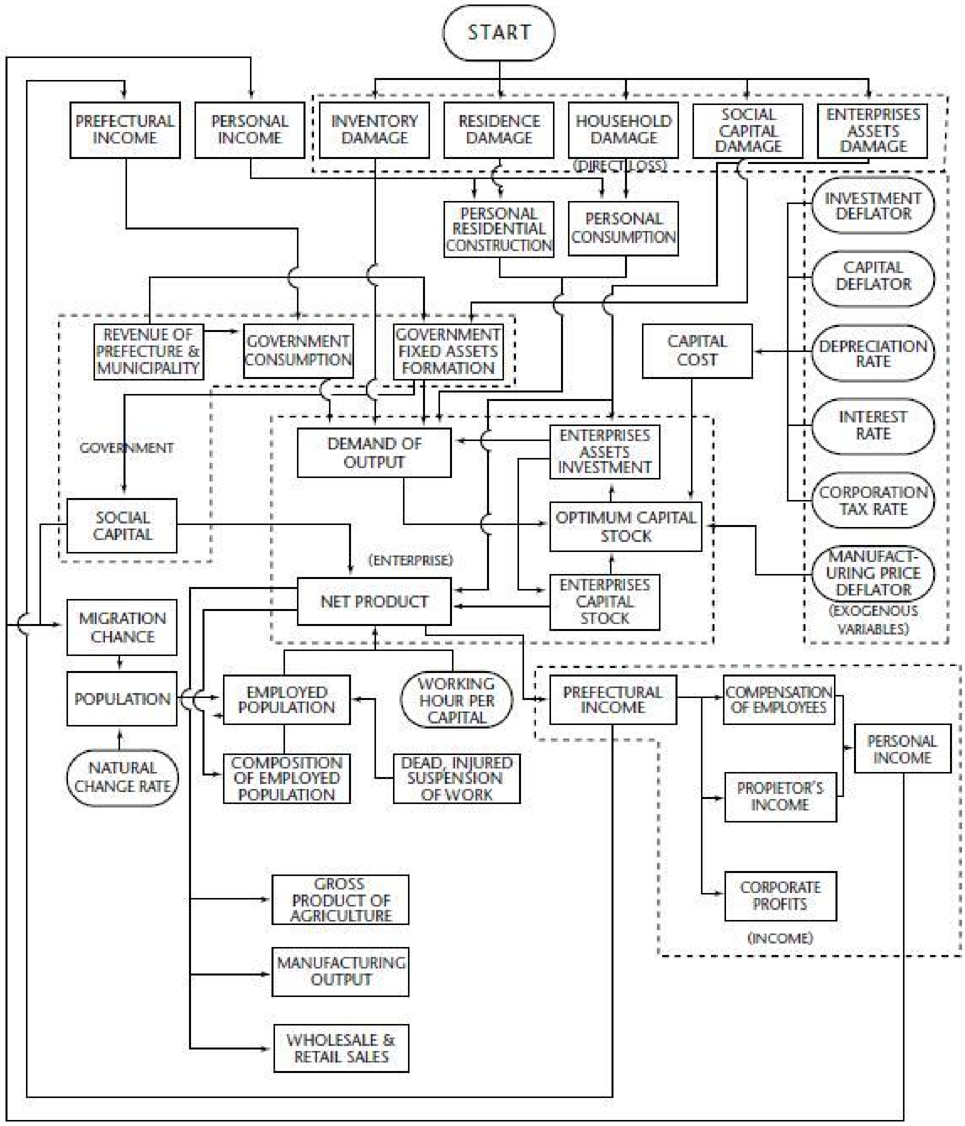


Data obtained will be analyzed using two kinds of analysis methods. The first is spatial data analysis using GIS method. This describes in detail of specific hazards known from data obtained from aerial photo, satellite imagery, maps, observations, and reviews of documents. This analysis is conducted to observe the first research objectives, namely to know the hazard effects and to know the problems faced of community capacity in achieving sustainable infrastructure. The second method is I-O analysis. This is quantitative analysis to know the economic effects of disaster. In this research, this analysis is emphasized to indirect damages (economic loss). And the end, both conclusion and recommendation will be presented.

B. FRAMEWORK OF ECONOMIC MODELLING

Economic Aspects of Vulnerability

United Nations Department of Humanitarian Affairs (UNDHA, 1992) defined vulnerability as the degree of loss (from 0 to 100 percent) resulting from a potentially damaging phenomenon. These losses may include lives lost, persons injured, property damage and disruption of economic activity. In the estimation of the actual or expected losses, two categories of damages (losses) are considered: direct and indirect. Kuribayashi et al., 1984 described a model of economic interaction that affect to indirect economic loss (damages).



Direct damages include property damage and its contents, infrastructures and loss of life, whereas indirect damages refer to the disruption of economic activity. According to WMO (2006) stated if many types of direct damage are difficult to express in terms that can easily be applied in public decision-making; these include loss of life, injuries, loss of cultural heritage, and disruption of families and dislocation of people. The vulnerability of a structure or land use is a quality of the structure or land use, irrespective to where it is built or located (UNDRO, 1991).

Direct Damages

Potential damage to structures and their contents are typically estimated through a combination of field surveys of structures in the area that would be affected by potentially damaging phenomena and information obtained from post-disaster surveys of damage. The USACE (1996) has developed a detailed procedure for estimating the potential damages to structures and their contents resulting from flooding. A similar procedure could be applied to determine potential damages from other types of natural disasters such as hurricanes, volcanoes, earthquakes, etc. The traditional USACE procedure for estimating a stage-damage function for residential structures involves the following steps.

(1) Identify and categorize each structure in the study area based upon its use and construction.
(2) Establish the first-floor elevation of each structure using topographic maps, aerial photographs, surveys, and (or) hand levels.
(3) Estimate the value of each structure using real-estate appraisals, recent sales prices, property tax assessments, replacement cost estimates or surveys.
(4) Estimate the value of the contents of each structure using an estimate of the ratio of contents value to structure value for each unique structure category.
(5) Estimate damage to each structure due to flooding to various water depths at the site of the structure using a depth-per cent damage function for the category of the structure along with the value from step 3.
(6) Estimate damage to the contents of each structure due to flooding to various water depths using a depth-per cent damage function for contents for the structure category along with the value calculated in step 4.
(7) Transform the depth-damage function for each structure to a stage-damage function at an index location for the flood plain using computed water-surface profiles for reference floods.
(8) Aggregate the estimated damages for all structures by category for common water depths.

Then, the aggregated stage-damage function is integrated with the stage-probability function, which is determined using hydrologic and hydraulic models, to determine the total flood damages or risk for various flood-mitigation scenarios. The USACE applies a "rational planner" model and the willingness-to-pay principle to compute the depreciated replacement value for a structure as per step 3. The three most common approaches to estimate the replacement value are use of the Marshall and Swift Valuation Service (MSVS), real-estate-assessment data and recent sales prices. Methods based on data derived from 4 and 5 are most commonly applied in the literature on public decision–making. Method 4 is commonly known as the human-capital approach. The current consensus in the field of economics is that the appropriate way to measure the value of reducing the risk of death is to determine what people are willing to pay (Lanoie *et al.*, 1995 in WMO, 2006).

Indirect Damages
Indirect damages are determined from the multiplier or ripple effect in the economy caused by damage to infrastructure resulting from a natural disaster (WMO, 2006). In particular, damage done to lifelines, such as the energy-distribution network, transportation facilities, water-supply systems and waste-management systems, can result in indirect financial losses greater than the direct financial damages to these systems and a long-term drain on the regional or national economy.

Wiggins (1994) described five problems affecting the determination of indirect economic losses (damages) as follows:
(*a*) Any aggregated loss data from previous natural disasters do not discern between how much of the loss to a particular economic sector resulted from disruption to lifelines, and how much resulted from direct damage.
(*b*) Available loss data, such as gathered by a questionnaire may be inaccurate, because many companies prefer not to disclose detailed financial loss data.
(*c*) The ripple effects of a changing local economy are difficult to measure and positively attribute to particular disruptions, such as telephone, electricity, direct damage, etc.
(*d*) It is difficult to determine if selected short-term losses are actually postponed rather than cancelled. That is, permanent losses result from economic activity — purchases, trips, use of services, etc. — that was cancelled because of a natural disaster, whereas other similar economic activity may be merely postponed to be “made up” at a later time.
(*e*) It is difficult to define the region of impact, and have economic data and models available for that region only. The determination of regions that experiencing indirect financial losses is not limited to the areas suffering physical damage, but also includes the normal delivery points of the affected industries.

Lee (1996) reports that analyses of the indirect damages resulting from earthquakes have been done with appropriate models of the regional economy that include: input-output (I-O) models, Social accounting matrix models, Computable general equilibrium models, and other macroeconomic models.

The input-output (I-O) model
I-O models are frequently selected for various economic analyses and are widely applied throughout the world (Lee, 1996). Wiggins (1994) notes that I-O models may be particularly well suited to estimation of indirect damages because it is thought that a properly applied I-O model can largely overcome the first four problems with the estimation of indirect economic losses listed previously. Lee (1996) presents how an I-O model could be applied to estimate the indirect damages resulting from an earthquake. Definition of the appropriate “region of impact” for indirect losses or damages remains a difficult problem for all macroeconomic models.

I-O model is a static general equilibrium model that describes the transactions between the various production sectors of an economy and the various final demand sectors that derived from observed economic data for a specific geographical region (nation, state, county, etc.). Input-output models constitute a substantially simplified method for analysing interdependency between sectors in the economy. It is necessary to understand the magnitude of the simplifications applied in I-O models, which include the following (Randall, 1981):

(*a*) the industrial sector, rather than the firm, is taken to be the unit of production;

(*b*) the production function for each sector is assumed to be of the constant-coefficient type;

(*c*) the question of the optimal level of production is not addressed;

(*d*) the system contains no utility functions; and

(*e*) consumer demands are treated as exogenous.

In the application of I-O models to estimation of indirect damages, a comparison is made between economic production with and without the occurrence of a natural disaster. Thus, because the goal is to estimate relative economic output and not exact economic output, the effects of some of the assumptions on the reliability of the estimated indirect damages are reduced. Furthermore, the constants in the I-O model are modified to reflect lost productivity in various sectors resulting from a natural disaster. So, I-O models are more reliable for estimating indirect damages than for estimating economic output because some of the problems listed above do not substantially affect estimation of indirect damages. In short, the approach to evaluating the indirect damages resulting from a natural disaster is to compare the post-disaster scenario with an estimate of what the economy would have looked like without the disaster.

C. CONCLUSION

In Indonesia, the frequency of floods are highest than the others natural disasters. UNDHA (1992) defined vulnerability as the degree of loss (from 0 to 100 percent) resulting from a potentially damaging phenomenon. A model is needed to calculate the economic impacts of direct and indirect losses from floods. Recently, I – O model is one of useful methods to make a model for economic impacts of floods.

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