Proceedings of International Conference: Issues, Management And Engineering In The Sustainable Development On Delta Areas
Semarang, Indonesia – February 20th, 2015
Paper No. XXX (The number assigned by the OpenConf System)

Indicators Identification For Developing Earthquake Risk Disaster Model For Roads

Mona ForalisaToyfur
Civil Engineering Doctoral Program,InstitutTeknologi Bandung
Jl. Ganeca 10, Bandung, Indonesia
monatoyfur@gmail.com

Abstract-Road network in Indonesia are exposed to various natural hazards, such as earthquakes, floods, landslides, volcanic eruptions etc. These disasters often cause damage to roads and bridges. Losses due to disasters caused by the damage of road infrastructures as well as socio-economic losses due to traffic disruption are compromising the development of the country. Risk assessment as one early stage of disaster risk management for road network are essential to the sustainability of the road network.. Risk assessment for roads are needed for analysis how to reduce potential damage and losses which may occur on future disaster. As resources are limited, priorities need to be identified in implementing risk reduction measure to the road infrastructure. This research limitation only risk assessment for road link. Risk assessment is needeed in order to provide adequate information for decision makers at the national and local level in prioritizing disaster mitigation works for road links. The risk assessment process is based on the determination of disaster risk index, calculated from a series of risk indicators, for each of road links within a road network.

***Keywords*: disaster, road link, model, risk assessment

1. Introduction

Indonesia is a country faced with many types of disasters [1]. The tsunami disaster in Aceh in 2004, the earthquake that occurred in Central Java and Yogyakarta in 2006, Pangandaran tsunami in 2006, floods in Jakarta in 2007-2014, the earthquake in West Sumatra in 2009, floods in Wasior 2010. Total losses suffered very large. Including most major disasters causing damage that tsunami and Nias (US $4.5 billion), the earthquake in Yogyakarta and Central Java (US $3.1 billion) and West Sumatra earthquake of US $2.8 billion (Bappenas, 2007). Estimates of the value of losses on roads and bridges caused by natural disasters can be seen in Figure 1.In Figure 1 shows very large losses in 2004 caused by major earthquake and tsunami Aceh.

Rural transportation systems and the communities and resources they access are often greatly impacted by natural disasters. Though most are low-volume roads, these routes may be the only access to large rural areas, isolated communities, crops, or natural resources. Closure or damage to these roads represents a major hardship to local populations, it can greatly hinder critical disaster-relief efforts, add to the cost of resource management, and result in costly road repairs. Many planning, location, design, and maintenance measures can be implemented to greatly reduce the risk and vulnerability of roads, particularly low-volume roads.

Seismic risk reduction for the intercity road systems, as the necessary tools for emergency response activities and reconstruction purposes in the aftermath of major earthquakes is of great importance, particularly for those countries which suffer form lack of widely spread reliable transportation networks.

Vulnerability to natural hazards can be defined as the extent to which people will be harmed and property will be damaged from that hazard. The greatest vulnerability occurs in areas with the greatest population, where the most infrastructure has been built, where road use is the highest, and where the local population is dependent on a single route. The greatest vulnerability results from possible prolonged delays for many people, high loss of infrastructure, and lack of alternative routes (OAS and USAID 1997).

Figure 1.Estimated Losses on Roads and Bridges
(Public Work Ministry &National Disaster Management Agency, 2012)

The road is an important factor in the movement of the area.According to Act no 38/2004 road as transport infrastructure has an important role in the economic, social, cultural, environmental, political, defense and security, as well as used for the greatest prosperity of the people. In addition, road infrastructure acts as the distribution of goods and services of the community, the nation, and the state.

2. Literature Review

2.1 Definition of Risk

Risk can be defined as: the combination of the likelihood of an occurrence of a hazardous event andthe severity of the consequences (human, social and economical losses) that can be caused by theevent.

2.2. Disaster Risk Management Process

In initial stage of risk management is the risk identification. After the risk identification, the next step is the risk analysis. Risk analysis is a process that combines information on the quantities (including probability) of a hazard with informationdescribes the level of vulnerability of the various elements that are threatened. The results of this risk analysis is a form of the estimated level of losses that may occur as a result of a disaster, as well as an overview of the degree of likelihood (risk). Risk analysis conducted by a review of hazard identification and analysis covering the hazard and vulnerability assessment that includes identification and vulnerability analysis.Risk disaster management cycle described on Figure 2.

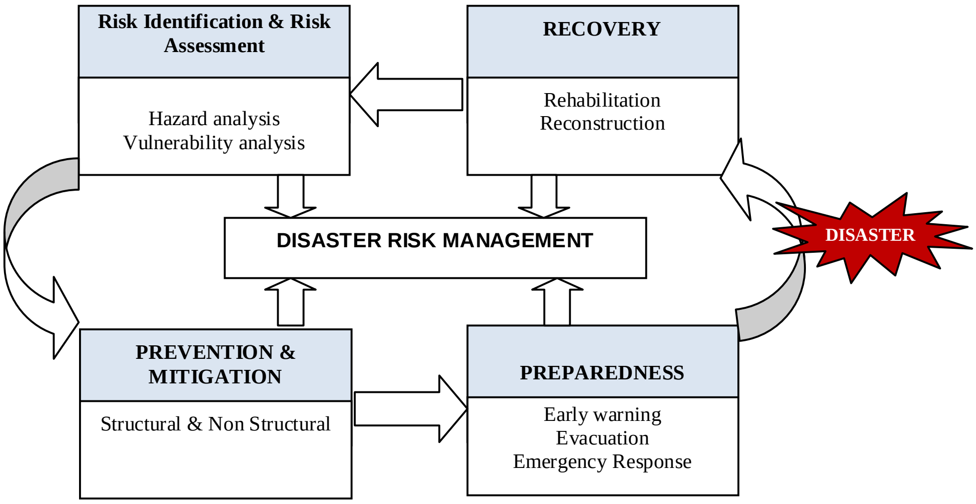

Figure 2. Disaster Risk Management Cycle
(UN/ISDR 2004)

Risk analysis can be carried out qualitative, semi-quantitative and quantitative. Qualitative risk analysis or semi-quantitative risk assessment is usually done for a quick (rapid risk analysis). Quantitative risk analysis carried out for in-depth risk analysis (in-depth risk analysis). Quantitative risk analysis performed by the analysis of hazard assessment, vulnerability and risk-depth with the application of science and technology sufficient to provide a picture of the extent of damage and losses that are quantitative in order to provide a more representative measure.

2.3. Risk Assessment Model for Road

Risk assessment aims to define a measure of the risk. Since risk management is subject tolarge costs and variable benefits, proper risk assessment and management are crucial tomake successful actions.

Therefore, if the measurement of uncertainty refers only to the probabilities of theevent occurrence, the measure of risk requires to carry out both the probability for outcomesand the related losses.Based on this definition, risk assessment of road network can be carried out as the productof three independent factors (Cafiso et al. 2005, Cafiso et al. 2008, Cafiso 2009) **exposure**, given by the number of people (and/or goods) that can be damaged by the event; **hazard**, linked to the probability that in a certain place there will be an event of a certainintensity with a given return time;**vulnerability**, which defines the propensity of an infrastructural element to undergodamage during the event.

In the context of vulnerability due to earthquake hazard on the road, vulnerability is defined as how likely it is an element of the road network were damaged, and collapse due to earthquakes. Vulnerability to earthquakes is a characteristic that accompanies any construction that does not depend on external factors. To define the physical vulnerability of road segments should be considered from a variety of components that bridge, embankment, tunnels, and others with characteristics different vulnerabilities and can not always be compared. Some elements of the network component of which is the bridge that assessed vulnerability is to assess whether the design criteria to consider earthquake load, type of construction being or not being, the foundation soil conditions, conditions of construction maintenance, alignment, and others.

Davidson (1997) has proposed an urban earthquake disaster risk index (EDRI), based on the concepts of hazard (H), exposure (E), vulnerability (V), external context factors (C) and response situation (R), as the main variables, and giving a weight to each of these, as:

$$EDRI= w_H H+ w_E E + w_V V+ w_C C+ w_R R \quad (1)$$

Hosseini and Yaghoobi (2006) have introduced some key issues on seismic risk evaluation of intercity road systems for road authorities:

1. The design of the network as a redundant system so that access can be maintained even if one or more links are cut. This redundancy may be in the form of a combined transportation, like road and railway, and/or road and airport or helipad especially for hazardous routes.
2. The establishment of design and construction standards, which consider risk concepts to provide a "robust" system which is not easily damaged. Risk concepts must consist:
    a. Complete and overall studies on two main parts of each road; road body such as pavement, embankment, trenches, etc. and structural components such as bridges, tunnels, culverts, etc.
    b. Definition of time- and user-dependent earthquake scenarios
    c. Evaluation of earthquake economic losses with the most possible precision. These losses include direct and indirect damages like short- and long-term economic consequences, death and injury losses of people. In this evaluation, people must be classified by their education, age, professions, cultural values, importance in emergency response activities, etc.
3. Preparing the zonation maps based on the faults not the political and geographical boundaries
4. Establishing an international non government organization for post-earthquake activities, whose members can do joint studies and communicate with each other without any limitations.

Hosseini and Yaghoobi (2008) developed implemented EDRI model for intercity road. This model is used for quick risk assessment. The parameters which are used in the risk calculation are of two kinds. One kind is related to seismic hazard and vulnerability, and the other is related to transportation service. The main parameters with regard to seismic hazard and vulnerability in each "service area" can be divided into following categories : the relative length of the road, the relative number of key structures of the road, the average number of key structures per kilometer, the relative length in high seismic hazard zone, the relative number of key structures of the road in high seismic hazard zone.

3. Methodology

This research, carried out with a literature review methodology. Conducted a literature review on the studies that have been done on disaster risk assessment model on roads and bridges.

A literature review on research related to the assessment risk model has been implemented in several other countries. The concept of the development of the model is done by using the risk index model with consideration of the availability of data and user models. Model risk index is used because this model using relative proportions and simple concept that allows users to perform analysis and make it easier for decision-making.

4. Analysis

The indicators used in this model is a combination of several indicators of the risk assessment models such as SRA (seismic risk analysis) and loss estimation. These models use extensive and quantitative data,so it is not suitable to be applied in Indonesia. Indicators that used are indicators that directly affect the value of disaster risk index. The selection of indicators is also based on the consideration of the possibility of the availability of data.

Indicators identified by the model EDRI who later developed for the road. In addition, the development of disaster risk assessment carried out by using a geographic information system, and Werner, et al (2004, 2008) developed the SRA which utilizes a road network database to assess the risk of earthquake disaster.

Based on developed models above, this research developed indicators for risk earthquake disaster assessment for road link in Indonesia. The factors, factor components and indicators that identified are defined in Table 1.

Table. 1. Factor, Factor Component and Indicator in Risk Index Model

FACTORS	FACTOR COMPONENTS	INDICATORS
HAZARDS	Groundshaking	Peak Ground Acceleration on road link
	Collateral Hazards	Percent length of link on high liquefaction susceptibility
		Percent length of link on landslide susceptibility zone
		Percent length of link on tsunami zone
EXPOSURE	Physical	Topography of road link
		Soil type
		Length of Road link
		Total length of road link
	Population (users)	Traffic volume
		Population
	Economic	Gross Domestic Regional Product on road area
VULNERABILITY	Physical	Number of bridges on road link
		Percent of long span bridges on road link
		Bridge existing condition
		Available of alternatives route/link
EXTERNAL CONTEXT	Economic	City function on economic development
	Politic	City function on politic
CAPACITY	Planning	Institution preparedness for emergency response & recovery
	Resources	Available of resources
		Gross Domestic Regional Product
	Access & Mobility	Access and mobility of resources

Because of limitation, this paper does not explain all of the indicator in this model. Below are few of justification of indicator selection.

Seismic hazard defines the probability of occurrence of a seismic event of certain intensity, in agiven area and in a given period of time. The evaluation of seismic hazard of an area is based onthe study of historic seismology and on the analysis of the geological seismologic andseismogenetic characteristics of the site.The historical studies are aimed at the definition of the principal geophysical characteristics(epicenter, magnitude, ground acceleration etc.) of seismic events that have struck in thepast the area under examination, in such a way as to predict the effects of earthquakesexpected for different return times in terms of horizontal force, acceleration, etc. (Cafiso, 2010).

Ground shaking is the most important componen of hazard because it is usually directly reponsible for the majority of damage suffered in an earthquake and because most other hazard types (i.e., liquefaction, landslide) require a sufficient level of ground shaking to trigger them (Davidson, 1997).

Liquefaction is a phenomenon in which soil changes from a firm material into a viscous semi-liquid material. If a saturated sand is subjected to ground vibrationa, it tends to decrease in volume, if drainage is unable to occur, the tendency in volume results in an increase in pore water pressure, and if pore water pressure builds up to the point at which it is equal to the overburden pressure, the effective stress become zero, the sand loses its strength completely, and it develops a liquid states (Seed and Idris, 1983).

Landslide can be triggered by the ground shaking associated with earthquakes. Like liquefaction, lanslide hazard is discussed in terms of susceptibility, opportunity and potential. Landslide susceptibility depends on soil cohesion, water level, and slope steepness. Landslide opportunity depends on ground shaking demand, precipitation, and distance to the earthquake source (Davidson, 1997).

Tsunamis are long period sea waves produced by uplifts or downdrops of the sea floor during an earthquake. When a tsunami runs up on land, everything in its path will be inundated with water, and often will be dragged out to the sea by the wave as it ebbs.

Seismic exposure represents the extension, the quantity and quality of the various anthropicelements that make up the territorial context (population, buildings, infrastructure, etc.) whoseconditions and operation could be damaged by a seismic event. The population is the maincategory at risk and the potential number of injured or dead people is considered as ameasure of exposure.The “direct exposure” can be related to the number of users present along the infrastructureduring the event or to the property value or to the mission of the element in thetransportation system. The expected vehicle density (vehicles per unit length of road) can beused as measure of exposure**.**

Seismic vulnerability is defined as the propensity of an element, simple or complex, to sufferdamage, collapse or modification during a seismic event. Seismic vulnerability is an intrinsiccharacteristic of each construction, that is independent from any kind of external factor. Forexample, the vulnerability of a bridge depends on the construction technologies adopted, onthe materials employed, on its structural configuration, on its age, on its state ofmaintenance, on the quality of the original project and so on. All these factors areindependent from the localization of the object and from the probability that a seismic eventcan take place there, which has been already evaluated in the study of seismic hazard.To define the vulnerability of a road segment, it should be considered that each stretchcould be composed by a series of components (bridges, embankments, trenches, tunnel, etc)with different vulnerability characteristics and evaluation models not always comparable.(Cafiso, 2010).If more than one vulnerable component is present on the same network link, to characterise with only one indicator of vulnerability a stretch of road between to nodes, many criteria of aggregation could be used, among which one of the simplest and of immediate applicationconsists in giving to the whole stretch the maximum value from among the indicators of structural vulnerability of the components that make it up.

5. Conclusion

Factors were identified based on the model of disaster risk index is the hazard, exposure, vulnerability, external context and capacity. Each of these risk factors assessed by the value of the index indicators contained in each of the factors and factor components. Each indicator index value is linier to the risk index values, except for capacity. Capacity indicators index is inversely proportional to the value of the risk index. In this model the value of the index indicators on the capacity factor is given in the form of a risk index values are inversely proportional to the value of the risk index on other factors. The bettervalue indexof capacity value, will be less risk of contributing to the risk index values.

References

Cafiso, Salvatore.(2010). Assessment of Seismic Risk and Reliability of Road Network.

Davidson, Rachel A. (1997). An Urban Earthquake Disaster Risk Index. The John A. Blume Earthquake Engineering Centre. California : Stanford University. Report no. 121

HosseiniMahmooddanVayeghan, FY (2008).A Risk Management Model for Inter-City Road Systems.The 14th World Conference on Earthquake Engineering. Beijing, China.

Seed, H. Bolton &Idriss, I.M. (1983). Ground motions and soil liquefaction during earthquake. Engineering Monographs on Earthquake Criteria, Structural Design, and Strong Motion Records, ed. Mihran S. Agbabian, vol. 5 Oakland, California: Earthquake Engineering Research Institue.

Sengara, I WayandanPribadi K.S (2009).KajianRisikountukPencegahandanMitigasiBecanaGempa di Indonesia.MengelolaRisikoBencana di Negara MaritimIndonesia ;UpayaMengurangiRisikoBencana. Buku 3.Bandung:InstitutTeknologi Bandung.

Triutomo, Sugeng. (2011).Indonesia : Improving Investment in Communities For Risk Reduction. Risk Returns. International Strategy for Disaster Reduction

Werner, dkk.(2004). New Developments in Seismic Risk Analysis of Highway Systems.13th World Conference on Earthquake Engineering.Paper No. 2189. August 1-6, 2004. Vancouver, B.C, Canada.

Werner, dkk.(2008). Analysis of Risk to Southern California Highway System. The ShakeOut Scenario, USGS Report 2008-1150. Oakland, CA.