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VULNERABILITY ASSESSMENT OF URBAN INFRASTRUCTURE TO CLIMATE CHANGE IMPACT: A FRAMEWORK AND CONCEPTUAL MODEL

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ABSTRACT: The majority of regions in Indonesia are considered to be vulnerable to potential impact of climate change, due to its geographical and socio-economic circumstance. In order to prioritize, design and implement intervention to adapt to climate change, it is essential to adopt a coherent set of approach, framework and method for examining vulnerability and adaptive capacity. To effectively formulate adaptation strategy at the local/cities (kabupaten-kota) level, it is proposed to apply "micro level-multi sectoral approach" which means assessing vulnerability at the micro-level but considering the multi sectoral impacts of climate change i.e. water and infrastructure sectoral. This study is present a framework and conceptual model to develop urban infrastructure vulnerability index.

Keywords: climate change, vulnerability, urban infrastructure, index

1. INTRODUCTION

Climate is a key factor determining different characteristics and distributions of natural and managed systems, including the cryosphere, hydrology and water resources, marine and freshwater biological systems, terrestrial biological systems, agriculture and forestry (IPCC 2007) [11].

Climate change is defined as long process and contain high complexity that very unpredictable, although using strictly mitigation. From Freeman, P., et.al,2001[9], climate change is forecasted to bring gradual changes in weather patterns, and changes in the variability of extreme events to broad geographic regions. Climate change may increase the risk of structural damage to buildings, especially damage resulting from strong wind, flood associated with more intense tropical cyclone and storms.

The current knowledge about climate change and forecasted impacts upon infrastructure are based on broad regional analysis. The IPCC has outlined representative examples of projected infrastructure impacts of extreme climate phenomena (IPCC 2001a) [10].

Identifying the impact of climate change on infrastructure as distinct from other influences on our need to maintain, repair, and replace infrastructure, benefits from explicit attention to a conceptual model for impact assessment.

Therefore, to effort adaptation for climate change have to do. For that reason, Vulnerability assessment and risk assessment will be necessary. Vulnerability assessment and climate change impact can used to sector that have potential impacts to climate change such as water resources, coastal area, agriculture, forestry, health and infrastructure.

An inevitable result of the increased damages to infrastructure from climate change will be dramatic increase in resources needed to restore infrastructure and assist the poor. If infrastructure vulnerability to climate-related events is currently a cause for concern, it will become even more so in the future. The section first examines the relationship

between changes in the magnitude of extreme events and losses to infrastructure (P. Freeman et al, 2001)[9].
Variability in climate extremes has contributed to the rising trend in total direct damage. The density of infrastructure, the sheer number of people living in riskier areas, and the increasing disparities in wealth and socioeconomic status increase the potential for greater human losses to hazard in the future (Mileti, 1999)[15].
In vulnerability urban infrastructure and water resource sector assessment, determination of vulnerability level based on type of infrastructure that directly deceived climate change impacts. The variable classified to based on the variability of infrastructure. Climate change impacts for urban infrastructure will occur to physically.
The majority of regions in Indonesia are considered to be vulnerable to potential impact of climate change, due to its geographical and socio-economic circumstance. In order to prioritize, design and implement intervention to adapt to climate change, it is essential to adopt a coherent set of approach, framework and method for examining vulnerability and adaptive capacity.
The purpose of this study is to develop local/cities (kabupaten-kota) level indicator of vulnerability and capacity to adapt to climate hazard. Published studies of local or region level vulnerability to date generally have been characterized by indicators chosen subjectively by the authors, based on assumption about the factor and processes leading to vulnerability (Brooks, N., et.al, 2005)[3].
This paper uses a conceptual model and frame work of vulnerability that incorporates water resources and infrastructure indicators to provide an all climate hazard assessment of vulnerability at the local/cities (kabupaten-kota) level. Based on better research at a local specific level, planning for the impact of climate change is essential for future infrastructure lending policy.

2. LITERATURE REVIEW

The understanding of vulnerability is very broad and current literature encompasses many different definitions, concepts and methods to systemize vulnerability (Birkmann, 2007[1]; Cutter, 2003[5]). Villagran de Leon (2006)[23] defines *vulnerability as the predisposition of an element or a system to be affected or susceptible to damage.* A very similar definition, but with particular focus on the social susceptibility, is given by Borden, et.al, (2007)[2].
Vulnerability is defined by IPCC TAR as: *The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes.* Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity. Levina, E. and D. Tirpak (2006)[13], found very different interpretations for vulnerability: one interpretation views vulnerability as a residual of climate change impacts minus adaptation, whilst another views vulnerability as a general characteristic or state generated by multiple factors and processes, but exacerbated by climate change. Five approaches to Climate Change Impact, Adaptation and Vulnerability (CCIAV) assessment have so far been classified. The Four are classified as conventional research approaches: impact assessment, adaptation assessment, vulnerability assessment and integrated assessment. The fifth approach is adopting risk assessment framework which can be considered as an emerging approach of CCIAV studies. The fifth approach has

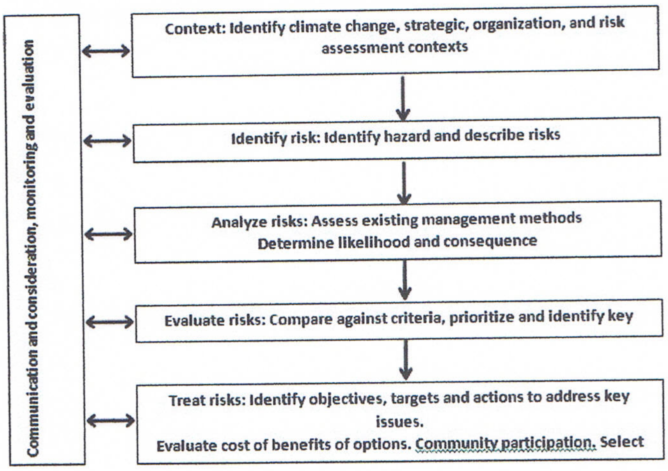
started to be applied in mainstreaming adaptation option into policy-making (IPCC, 2007)[11].
The regional approach in climate vulnerability studies is a useful approach because many practical adaptation strategies will be applied at a regional rather than sectoral scale and climate change impacts vary from region to region.
Many vulnerabilities studies while effective in making awareness to the possible effect of climate change, have limited effectiveness in providing local scale guidance in adaptation. Method and tools for supporting the process of building adaptive capacity at the local level are different from the ones used for assessing impacts, vulnerability and adaptation on national and global scales (see Table 1)

Table 1: Different Level of Vulnerability Studies

Scale Level	Data needs/analysis	Size of study region	Planning level	Accuracy	Expenditure per area
Macro	Qualitative	National	Adaptation policy	Low	Low
Meso	Combination of qualitative and quantitative	Regional	Adaptation Strategies	Middle	Middle
Micro	Quantitative	Local	Adaptation measures	High	High

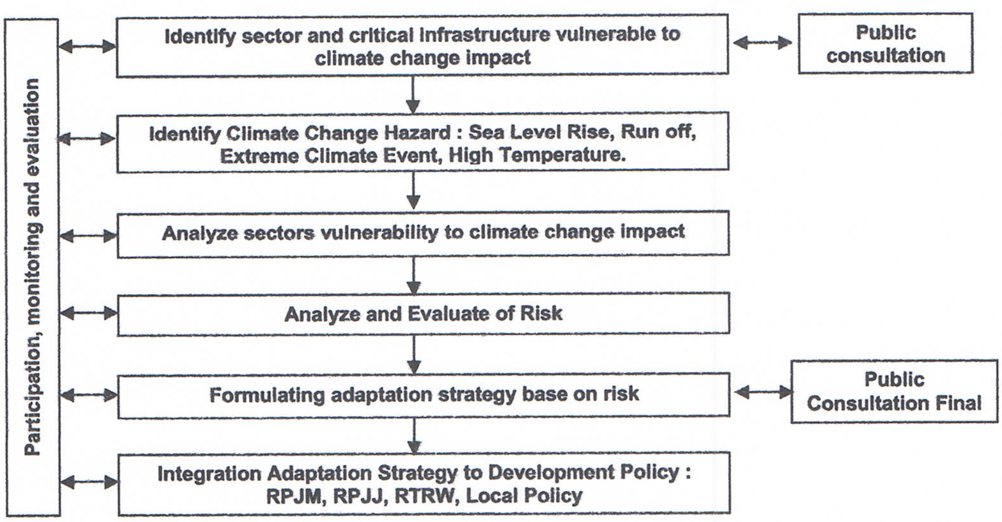
Source: modified from Messner, 2005[14].

Vulnerability variables were identified as many as 46 variables that representing generic vulnerability, representing economic well-being and inequality, health and nutritional status, education, physical infrastructure, governance, geographic and demographic factors, agriculture, ecosystems and technological capacity. Proxy data representing each variable were acquired from a variety of sources, including the World Bank, UNDP (Human Development Index), UNEP and CIESIN (N. Brooks et al. 2005)[3].
The methods and frameworks for assessing vulnerability must also address the determinants of adaptive capacity in order to examine the potential responses of a system to climate variability and change (IPCC,2007)[11].
Adaptive capacity is defined in the glossary of the IPCC (2001, p. 982)[10] TAR as ''The ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.'' Because adaptation does not occur instantaneously, the relationship between adaptive capacity and vulnerability depends crucially on the timescales and hazards with which we are concerned. The vulnerability, or potential vulnerability, of a system to climate change that is associated with anticipated hazards in the medium- to long-term will depend on that system's ability to adapt appropriately in anticipation of those hazards. However, vulnerability to hazards associated with climate variability that may occur in the immediate future will be related to a system's existing short-term coping capacity rather than its ability to pursue long-term adaptation strategies (N. Brooks et al. 2005)[3].
The Government of New Zealand [16], as an attempt to build adaptive capacity at Local Government Level, provides A Guidance Manual for Assessing Climate Change Impacts. The procedures used are Risk Assessment Framework (see Figure 1).



Source: New Zealand Climate Change Office, 2004
Figure1. Risk Assessment Framework

Adaptive capacity has been analyzed in various ways, including via thresholds and ''coping ranges'', defined by the conditions that a system can deal with, accommodate, adapt to, and recover from (de Loe and Kreutzwiser, 2000[7]; Jones, 2001[12]; Smit et al., 2000[19]; Smit and Pilifosova, 2001[20], 2003[21]). Some authors apply ''coping ability'' to shorter term capacity or the ability to just survive, and employ ''adaptive capacity'' for longer term or more sustainable adjustments (Vogel, 1998)[24]. Watts and Bohle (1993)[25] use ''adaptability'' for the shorter term coping and ''potentiality'' for the longer term capacity.
The Government of Indonesia [8] also provides A Guidance Vulnerability And Climate Change Impacts Assessment for local government (see Figure 2).



Source: Environmental Ministry Republic of Indonesia, 2009
Figure2. Vulnerability Assessment Framework (adopted from A Guidance Vulnerability and Climate Change Impacts Assessment for local government)

The risk assessment offers a framework for policy measures that focus on social aspects, including poverty alleviation reduction, diversification of food, protection of infrastructures and building of collective action.
The degree of risk also showed different types of infrastructure face notably different risk from changes in climate variability. It suggests that flooding and windstorms have the most widespread impacts on infrastructure such as buildings, bridges, roads, and water systems. Droughts appear to impact infrastructure to a milder degree, but have a heavy impact on agricultural sectors (P. Freeman et al, 2001) [9].
Small changes in climate variability correlate with large increases in infrastructure damage. Affeltranger, et al. (cited from D. Suroso,et.al.2009) [6] presents Risk Notation (see Figure 3). He defines Risk as an overlay between Hazards and Vulnerability.

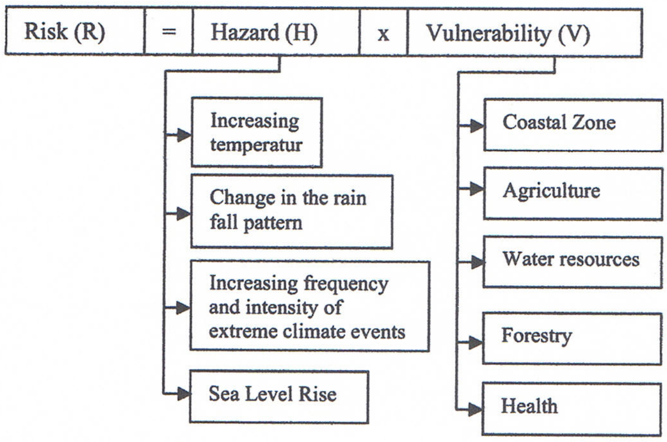


Figure3. Risk Notation

3. METHODOLOGY

The study of vulnerability assessment of infrastructure is a process initialization framework vulnerability assessment of infrastructure to determine vulnerability infrastructure index.
Following definition of risk and based on Risk Assessment Framework in Figure 2 and Figure 3, the process as follows.

a. Define sector and critical infrastructure vulnerable to climate change impact
Climate change impact affected many sector and infrastructure like socioeconomic, water resources, coastal area, agriculture, forestry, health and infrastructure (urban and rural) include utilities that are essential to community functioning. In this research will be focus to water resources sector and urban infrastructure.

b. Identify Climate Change Hazard
The type of climate change hazard that occurs based on characteristic location. It means hazard in tropic zone must be different with sub-tropic zone. Identification of character, magnitude and rate of hazards based on current and historical information, and projections of future climate change.

c. Identify Vulnerability
Vulnerability (V) is a function of Exposure (E), Sensitivity (S) and Adaptive Capacity (AC). Following definition of vulnerability,

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-the first phase in this step is to identify main indicator for exposure, sensitivity and adaptive capacity variable.
-Identify proxy for variable that have adaptive capacity indicator
-Collecting data based on proxy
-Analyzing data per sector that affected climate change.
-To get Infrastructure Vulnerability Index (IVI)

d. Analyze and Evaluate of Risk

Variable of risk related with vulnerability. Base on Risk assessment formula

R = H x V .... (1)

Determination level of risk using GIS tool that is overlay hazard map and vulnerability Index

e. Formulating adaptation strategy based on risk

Based on step a – d should be got information about level of risk and which area or zone that have risks. Then how to assess, these risks should be responded to, and treat the risk.

f. Integration Adaptation Strategy to Development Policy

The result of vulnerability and risk assessment should be used as guidance for sustainable local/cities (kabupaten – kota) development policy.

4. RESULT AND DISCUSSION

The main of this study is to define framework of vulnerability assessment and determine Infrastructure Vulnerability Index. The process of defining framework of vulnerability assessment has five main steps.

STEP1 Collecting data that influencing vulnerability due to climate change impacts and the study area (riverine area). Climate change impacts are hydrometeorology disasters, based on it's the collected data's are triggering data (run off, sea level rise), environment data (watershed, slope, topography, drainage), infrastructure data (type of infrastructure, wide, age, user and distance from riverine area). Also preparing attribute data for data spatial analyze like administrative map, topography map, land use map, infrastructure map, flood and sea level rise map, and watershed map.

STEP 2 Define hazard type and determination Infrastructure Vulnerability Index

The IPCC TAR (2001)[11] has reporting the impacts of climate change on human settlements that infrastructure of coastal/riverine areas has the largest impacts from flooding and sea level rise. And the most definite risk of urban infrastructure type is building infrastructure.

The step for determination infrastructure vulnerability index:

a. Collect variables of vulnerability to climate hazard :
   Exposure, sensitivity, adaptive capacity
b. Collect vulnerability indicators of urban infrastructure to climate hazard. The collecting data based on type of hazard and infrastructure.
c. Examine the resulting component on a) and b) how they influence Infrastructure Vulnerability Index (IVI).
d. Produce total score

IVI = IVI to hazard 1 + IVI to hazard 2 + ... + IVI to hazard n .... (2)

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STEP 3 Weighting of hazard and Infrastructure vulnerability index
The aim of this step is leveling degree of vulnerability. Based on it, scenario for vulnerability assessment can determine adaptation strategies (see Table 2)

Table 2: Scenario of Vulnerability Assessment

vulnerability level	IVI	Climate Change Variable				Building Infrastructure Variable					adaptation strategies
		sea level rise (cm)	duration flood (/year)	depth inundant (cm)	runoff (mm)	age (year)	type	total floor area (m2)	amount of user	distance from the coast/riverine area	
High	1.51 - 2	> 20	> 3	> 60	> 500	> 20	residential	>1000	>950	< 1 km	preventing development in areas near the coast/river
Moderate	0.76 - 1.5	10 ≤ x ≤ 20	2	30≤ x ≤60	200≤ x ≤500	15 ≤ x ≤ 20	Public building	600 ≤ x ≤ 1000	600 ≤x≤ 950	1 ≤ x ≤ 2	forestation modification of land use monitoring building development with standard building codes advance planning to avoid worst impact strict regulation of hazard zones hazard insurance
Low	0 – 0.75	< 10	1	<30	< 200	< 15	High building	< 600	< 600	> 2 km	Protecting the building with leeve or floodwalls repairing infrastructure drainage build tidal barriers and floodgate across riverside

Modified Bijlsma, et al, 1996 (cited from Ricard JT Klein, et.al. 1997) → no-18 ?

STEP 4 Data Spatial Analyze with GIS tool (ILWIS)

1. Before starting the actual analysis, it is important to have an idea of input data, such as administrative map, inundant/flood map, topographic map, infrastructure map, river/DAS map, SLR map.
2. Creating the weighting hazard map
   - assigning weight values to the classes of the parameter maps.
   - renumbering the parameter maps to weight maps.
   - combining the weight maps into one single hazard map.
   - classifying the combined weight map into a final hazard map.
3. Creating a vulnerability map
   A vulnerability classification can be carried out in the same way as the method used in the creation of the hazard map.
4. Creating The Risk Map
   Relation between hazard and vulnerability will make a qualitative risk map. The combination will be done using a two-dimensional table (hazard and vulnerability table). The 2-dimensional table will contain undefined values for all combinations,

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for example: when the hazard very low, it doesn't matter whether the vulnerability is low or high; the risk will be low in all cases. When the vulnerability is very low (meaning that the area doesn't contain any important elements at risk), the risk is always low.

5. Overlay the administrative map and risk map, and create a cross table.

STEP 5 The city map with the degree of risk
Output from data spatial analyze is a city map with the degree of risk. The result can determine adaptation strategies or technologies and use as a guidance policy makers in local/cities government.

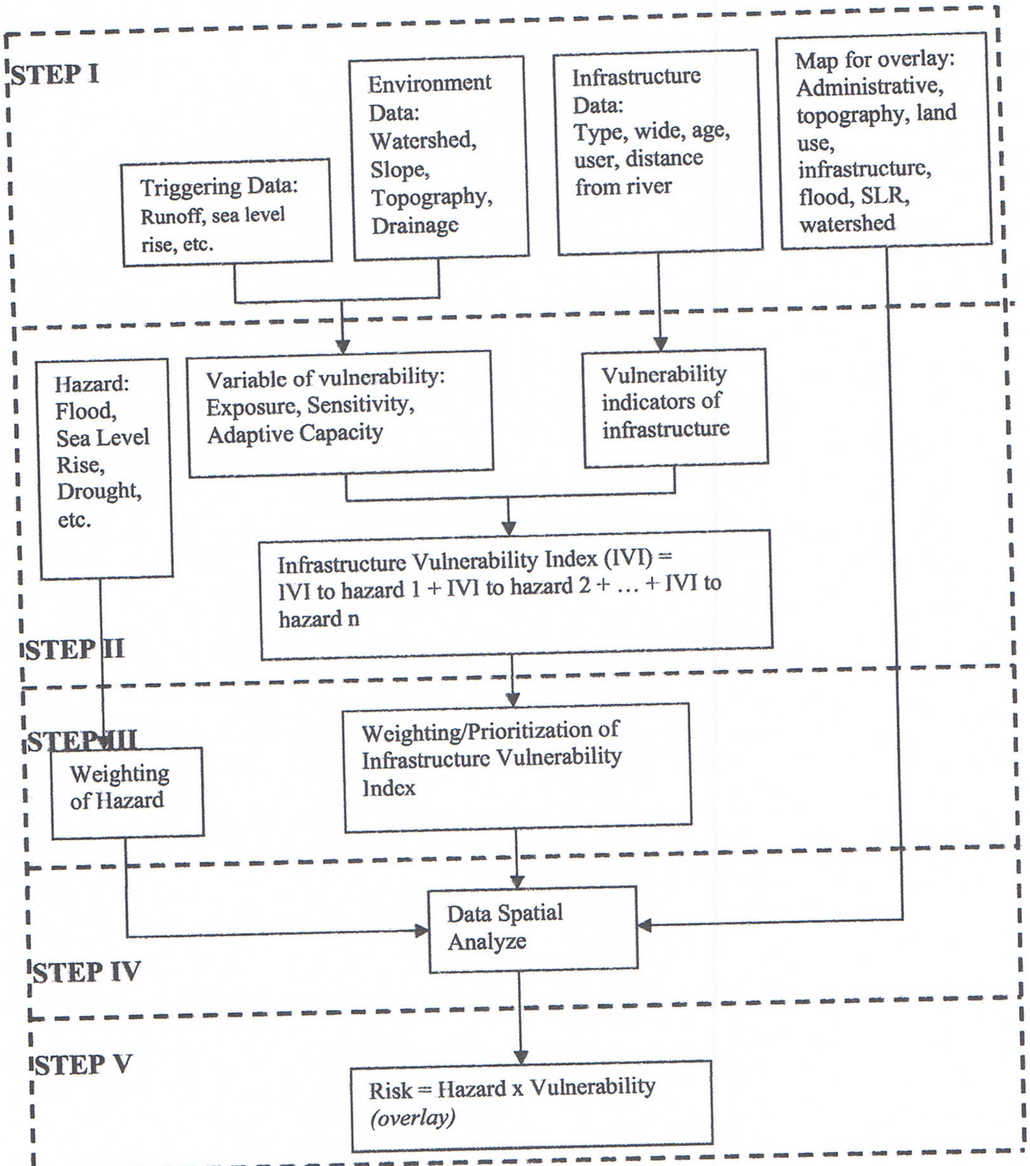

Figure4. Vulnerability assessment of urban infrastructure framework

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Island, Province of Nusa Tenggara Barat. Proceeding WOC Conference: Water and Coastal Sector, Manado.

7. De Loe, R.C., Kreutzwiser, R., 2000. *Climate variability, climate change and water resource management in the Great Lakes.* Climatic Change 45, 163--179.
8. Environmental Ministry Republic of Indonesia. 2009. *A Guidance Vulnerability And Climate Change Impacts Assessment for local government.* Editors: D. Suroso, T. Wahyuhadi, A. Sopyan, I. Sofian, H. Latief, B. Setiawan, Anggara Kasih.
9. Freeman, P., Warner, K. 2001. *Vulnerability of Infrastructure to Climate Variability: How Does This Affect Infrastructure Lending Policies?* Report Commissioned by the Disaster Management Facility of The World Bank and the Pro Vention Consortium,
10. IPCC, 2001. *Climate change 2001: Impacts, Adaptation and Vulnerability*, Summary for Policymakers, WMO.
11. IPCC. 2007. *Climate Change 2007: The Project Science Basis. Contribution of Working Group 1 to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.*
12. Jones, R., 2001. *An environmental risk assessment/management framework for climate change impact assessments.* Natural Hazards 23, 197--230.
13. Levina, E. and D. Tirpak (2006), *"Adaptation to Climate Change: Key Terms"*, OECD/IEACOM/ENV/EPOC/IEA/SLT(2006)1. May 2006.
14. Messner F., Meyer V. (2005), *Flood damage, vulnerability and risk perception – challenges for flood damage research.* UFZ Discussion Paper 13/2005, 24 p.
15. Mileti, D., ed. (1999). *Disasters by design: A Reassessment of natural hazards in the United States.* Washington, D.C.: Joseph Henry Press.
16. Ministry for the Environment of New Zealand. 2004. *Climate Change Effects and Impacts Assessment: A GuidanceManual for Local Government in New Zealand.* Wratt D, Mullan B, Salinger J, Allen S, Morgan T,Kenny G. with MfE. Ministry for the Environment, Wellington, 153 p.
17. OECD. 2009. *Integrating Climate Change Adaptation Into Development Co-operation : Policy Guidance.* Chapter 10 : Introduction to Local Level. ISBN-978-92-64-05476-9.
18. Richard, J.T. Klein, et.al., 1997. *Adaptation to Climate Change : Option and Technologies.* Framework Convention on Climate Change. Technical Paper.
19. Smit, B., Burton, I., Klein, R., Wandel, J., 2000. *An anatomy of adaptation to climate change and variability.* Climatic Change 45, 223--251.
20. Smit, B., Pilifosova, O., 2001. *Adaptation to Climate Change in the Context of Sustainable Development and Equity.* Chapter 18 in Climate Change 2001: Impacts, Adaptation, and Vulnerability—Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK.
21. Smit, B., Pilifosova, O., 2003. From adaptation to adaptive capacity and vulnerability reduction. In: Smith, J.B., Klein, R.J.T., Huq, S. (Eds.), *Climate Change, Adaptive Capacity and Development.* Imperial College Press, London.
22. Smith, B., Wandel, J., (2006). *Adaptation, adaptive Capacity and vulnerability.* Elsevier. Ltd.
23. Villagran de Leon, J.C. (2006). *Vulnerability - A Conceptual and Methodological Review*, SOURCE - Publication Series of UNU-EHS, United Nations University.
24. Vogel, C., 1998. *Vulnerability and global environmental change.* LUCC Newsletter 3, 15--19.
25. Watts, M.J., Bohle, H.G., 1993. *The space of vulnerability: the causal structure of hunger and famine.* Progress in Human Geography 17, 43–67.
26. CSIRO Marine and Atmospheric. 2007. *Infrastructure and Climate Change Risk Assessment for Victoria.* A Victoria Government Initiative. Australia.

Climate change is defined as a long process and high complexity that very unpredictable. This study is current vulnerability assessment because using existing data. It could be predicted the future of vulnerability by using the degree of current vulnerability and projection data. Then in the future can preventing adaptation to climate change impacts (see Table 3).

Table 3: Scenario Future Vulnerability

Current Vulnerability Level	Climate Variable	Type of Infrastructure	Future Vulnerability Level		
			2015	2035	2060
High	-Increase extreme daily rainfall -Increase sea level rise	Residential	Very High	Extreme	Extreme
Moderate		Public Building	High	Very High	Extreme
Low		High Building	Moderate	High	Very High

Modified from CSIRO Australia, 2006[26]

5. CONCLUSION

This study is a micro level vulnerability studies that developing from meso-level study in Lombok Island[6].The vulnerability study in local level has high accuracy. This is because using characteristic topography, climate and environment local. The process in vulnerability assessment as follows:

STEP 1 would be resulted the type of locally climate hazard and the most vulnerable of urban infrastructure (in this study is building infrastructure).

STEP 2 would be resulted Infrastructure Vulnerability Index

STEP 3 would be resulted the degree of Hazard and Vulnerability, then it could be to predict of adaptation strategies for current vulnerability.

STEP 4 would be resulted hazard, vulnerability and risk map.

STEP 5 would be resulted the degree of risk for the city level.

Based on those resulting, it could be explain that a framework of vulnerability assessment of urban infrastructure is usable for the local/cities.

REFERENCE

1. Birkmann, J. (2007). *Risk and Vulnerability indicators at different scales: Applicability, usefulness and policy implications*, Environmental Hazards, 7, 20-31.
2. Borden, K., Schmidtlein, M. C. Emrich, C. Piegorsch, W. P. and Cutter, S. L. (2007). *Vulnerability of US Cities to Environmental Hazards*, Journal of Homeland Security and Environmental Management, 4(2), Article 5, 1-21.
3. Brooks, N., Neil Adger, W., and Mick Kelly, P. (2005). *The Determinants of vulnerability and adaptive capacity at national level and the implications for adaptation.* Elsevier Ltd.
4. Brooks, N., 2003. *Vulnerability, risk and adaptation : A conceptual framework.* Tyndall Center. Working Paper No 38.
5. Cutter, S. L, Boruff, B. J. and Shirley, W. L. (2003). *Social Vulnerability to Environmental Hazards*, Social Science Quarterly, 84 (1), 242-261.
6. D. Suroso, T. Wahyudi, I. Sofian, H. Latief, O. Abdurahman, B. Setiawan. 2009. *Vulnerability of Small Islands to Climate Change in Indonesia : a case study of Lombok*