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Flood vulnerability index as a knowledge base for flood risk assessment in urban area

Hajar Nasiri[1] and Shahram Shahmohammadi-Kalalagh[2*]

1- Urban planning and design department, Design and Architecture Faculty, University Putra Malaysia
2- Department of Water Sciences and Engineering, East Azarbaijan Science and Research Branch,Islamic Azad University, Tabriz, Iran

Corresponding author: Shahram Shahmohammadi-Kalalagh

ABSTRACT: Climate change leads to increasing urban flooding hazard. Due to the extent of flooding impacts there is a need to improve methods in flood risk management. One of the most important sections of flood management is assessing flood vulnerability in urban scale. A lot of studies have been done on the flood hazard, including flood vulnerability assessment because understanding of vulnerability is not only vital for the existence of the exposed societies to extreme floods, but also for their adaptation to climate change. For achieving this goal one approach is developing a Flood Vulnerability Index (FVI).Vulnerability index, will determine which areas are most vulnerable to flooding those should be considered in the future redevelopments. That means FVI produces a relationship between the theoretical perceptions of flood vulnerability and the daily management process. This study is mainly based on the literature on flooding vulnerability.

***Keywords*:** Climate change, Flood management, Flood risk assessment, FVI, Urban area.

INTRODUCTION

Floods, the most prevalent of natural risks, are anticipated to happen more strictly and regularly in the future because of climate change. This means that many urban areas across the globe are likely to be under serious threat of floods, the adverse impacts of which are already believed only next to that of earthquakes (Balaban, 2009) Unplanned rapid urbanization, change in land use and poor watershed management mainly in flood plains become important issues for consideration as the flood causes (Adelekan, 2011). Identification of all kinds of natural threats for decreasing their impacts involves different evaluations about both hazard and vulnerability. Regard to UN guidelines, vulnerability can be evaluated as a percentage of the assumed losses caused by threats which are include two groups: Direct damages which are happening during the hazard and Indirect damages which are results of direct damages, so reduce the vulnerability is vital for all of the communities include urban environments (Dall'Osso, 2010). High frequency and effects of flooding, have made the efficient urban flood management planning necessary. Risk assessment is a vital component of flood management and reducing the vulnerability and is becoming more important with population increasing (Ahmad and Simonovic, 2012). So there is a need for a method to calculate flood vulnerability.

Floods in Malaysia

Malaysian cities have a good chance to not be exposed to some disaster like earthquake, but severe floods occur frequently in this country. Flash flood and Monsoon flood are two main Types of flood which take place in this country. The monsoon floods occur generally from Northeast Monsoon which be happening during November to March with heavy rains to the southern part of Sarawak ,east coast states of the Peninsula and northern part of Sabah. Some of the verified flood incidences in the country were in 1926, 1931, 1947, 1954, 1957, 1963, 1965, 1967, 1969, 1971, 1973, 1983, 1988, 1993, 1998, 2001, 2006, 2007, 2010, 2012 and 2013. Report from DID (Department of Irrigation and Drainage) uttered that around 29,000 sq.km or 9% of total land area of country and more than 4.82 million people (22%) is involved by flooding every year. Flood annual also leads to around RM915 million loses in Malaysia. While monsoon flood is rule by long period and heavy precipitation, more local flooding which covers a big district has been reported in current times for instance 2th -6th October flood in 2003 that influenced a large part of northwestern of the Peninsula include states of Kedah, Penang and Northern Perak or two occasions happen in April 2002 and October in Kuala Lumpur which has been identified because of uncontrolled development and activities within the catchment and flood plain (Abd Jalil Hassan, 2006). So the necessity of comprehensive measures for managing and mitigating flood risk in Malaysia is obvious. Except structural measures such as the construction of dams, levees or the SMART Tunnel, flood risk management in Malaysia also includes non-structural measures special flood forecasts and early warning system. But flood management relies seriously on the support of flood risk assessment in spatial planning. This can be achieved through the flood risk maps or flood vulnerability assessment methods. At present, the development of these methods is insufficient to be used for analysis in Malaysia (Ho, 2009).

Flood vulnerability

Flood vulnerability is the key element in flood risk assessment and damage evaluation. Researchers have developed many methods to assess flood vulnerability. There is a need to develop our understanding of the vulnerability because nowadays it is understood that vulnerability is the root cause of disasters. However, despite increased knowledge about the vulnerability, flood risk is still very widespread. This leads to questions being raised about the efficiency of vulnerability assessments and their effect on flood mitigation and adaptation (Khan, 2012). United Nations described flood vulnerability as the degree of damage to a given items at risk caused by flood with determined amount and was expressed as a scale from 0-1 (no damage to total damage) (United nations, 1982). As the flood vulnerability in an area depends on some environmental, economic, social and even political factors it is difficult to measure vulnerability (Jixi Gao, 2007). That means vulnerability is influenced by several factors including human settlements conditions, infrastructure, authorities policy and abilities, social imbalances, economic patterns, etc. So flood vulnerability is different for people in different condition (Pandey et al., 2010).

Regards to previous works vulnerability assessment methods can be divided in three groups(Dapeng Huang, 2012):

- Vulnerability index system
- Vulnerability curve method
- Disaster loss data

Each of these groups of method has some strength and weakness that is mentioned in Table 1.

Table 1. Vulnerability assessment methods (Dapeng Huang, 2012)

Methods for assessing vulnerability	Vulnerability index system	Vulnerability curve method	Disaster loss data
Characteristics	• Widely used in flood vulnerability studies • Depends on complicated indices and weighting of their subjective	• Is based on actual damage survey • Should be relatively accurate • Takes a lot of time and resource • Not applicable for other regions	• Simple • Because of inaccurate and unevenly recorded data ,result should be treated caution

Flood Vulnerability Index system

The FVI system can be used as an instrument to link a multidisciplinary subject with a large number of components in a straight way and also can provide a good review of vulnerability in three scales include: River basin, sub-catchment and urban area. This system helps decision makers to control the possible damages and distinguish the precise measures for implementing before flooding (Balica and Wright, 2010). The Flood Vulnerability Index can be used in action plans to manage flooding and can improve local decision-making practices with appropriate measures to reduce vulnerability in different spatial levels (Balica et al., 2009) . Parameters and indices should be designed to produce information for specific target areas.

Development Flood Vulnerability Index methodology in urban area

Urban areas are densely populated, which makes them vulnerable to flood impacts. These areas are vulnerable to floods because of three important reasons: exposure, susceptibility and resilience. That means the vulnerability of each area is reflective of the exposure and susceptibility and the resilience of that area to acclimate from the effects of those conditions (Meulen, 2012). Exposure is the scope that human Settlements and people lives are positioned in flood risk area (UNDP/BCPR, 2004). Susceptibility is exposed factors in the system, which effect the probabilities of being harmed during floods (UNESCO-IHE, 2013). Resilience is adaptation capacity of each community to changes in hazardous area by modifying itself to achieve an acceptable structural and functional level (Galderisi, 2005). With these indicators, additional information can be provided for vulnerability reduction. Table 2 illustrates the appropriate indicators in urban scale but it is an important matter that selection of vulnerability indicators is directly relevant to the local study context.

Table 2. FVI system components (Balica, 2012; UNESCO-IHE, 2013)

Factors	Indicators					
	Exposure	Acronym	susceptibility	Acronym	resilience	Acronym
	Population density	P_D	Child morality	C_M	Warning system	W_S
	Disable people	% disable			Evacuation on roads	E_R
Social	Cultural heritage	C_H			Emergency services	E_S
	Population Growth	P_G			Shelters	S
					Past experience	P_E
					Awareness &Preparedness	A/P
	Closeness to river	C_R	Unemployment	U_M	Amount of investment	Am_{Inv}
Economic	Industries	I_{ND}	Urban growth	U_G	Flood insurance	F_I
	River discharge	R_D	Human development index	H_{DI}	Dams storage capacity	$D-S_C$
	Rainfall	$R_{ainfall}$	Urban Growth	U_G		
	Evaporate Rate	E_V				
Environmental	Land Use	L_U				
	Contact with River	C_R			Storage over yearly runoff	$^{S_C}/_{V\ year}$
	Topography	T			Dikes-Levees	D-L
	Evaporate RateRain fall	E_V				
physical		$R_{ainfall}$				

The interaction between vulnerability factors and the vulnerability components in different spatial scales include river basin, sub catchment and urban area serves as the base of this methodology (Balica, 2007). Although there are some other grouping for component and indicators of this system. For instance, Dapeng Huang et al., 2012) suggests multidimensional vulnerability with four component include population vulnerability, death vulnerability, agriculture and economic vulnerability. But regard to urban scale, FVI system is mentioned by (Balica, 2012) is more relevant for urban areas. The general formula for FVI is calculated by classifying the component in three groups of indicators: exposure (E), susceptibility (S) and resilience (R) (Balica et al., 2012).

$$\mathrm{FVI} = \frac{\mathrm{E}*\mathrm{S}}{\mathrm{R}} \quad (1)$$

With regard to urban indicators this equation is become to following ones (Balica, 2012).

$$FVIsocial = \left[\frac{P_D*C_H*P_G*\%disables*C_M}{P_E*{}^{A}/_{P}*S*W_S*E_R*E_S}\right] \quad (2)$$

$$FVI_{Economic} = \left[\frac{I_{ND}*C_R*U_M*U_G*HDI*R_D}{F_I*AmInv*D-S_C*D}\right] \quad (3)$$

$$FVI_{Environmental} = \left[\frac{U_G*R_{ain\ fall}}{E_V*L_U}\right] \quad (4)$$

$$FVI_{Phisycal} = \left[\frac{C_R*T}{{}^{E_V}/_{R_{ain\ fall}}*{}^{S_C}/_{V_{Year}}*D-L}\right] \quad (5)$$

Total FVI of each urban area is average of these four FVI (Eq. 2-5). This index value is as follows (Table 3):

Table 3. Flood vulnerability interpretation (Balica, 2012)

Index value	Description
< 0.01	Very small vulnerability to floods
0.01-0.25	Small vulnerability to floods
0.25-0.50	Vulnerable to floods
0.50-0.75	High vulnerability to floods
0.75-1	Very high vulnerability to floods

The index gives a number from 0 to 1, signifying low or high urban flood vulnerability and shows which urban areas need detailed investigation for selecting more effective measures. This method shows that FVI provides a reliable source for broad overview of flood vulnerability to take appropriate strategies.

CONCULSION

This study provides a review of assessing flood vulnerability approaches as part of flood risk management and concerning on FVI methodology. This methodology recognizes different characteristics for different spatial scales, allowing a more in- depth analysis and interpretation of local indicators .the whole concept of FVI is that we have a hazard, in this case flood event which is effecting the system (river basin, sub-catchment or urban area) in four of its main components (social, economic, environmental and physical). The FVI can be used in combination with other decision making tools and specifically include participatory methods with the people of areas as identified as vulnerable.

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