UNIVERSITI PUTRA MALAYSIA

FLOOD VULNERABILITY ASSESSMENT IN URBAN AREAS IN KUALA LUMPUR, MALAYSIA

HAJAR NASIRI

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UNIVERSITI PUTRA MALAYSIA

BERILMU BERBAKTI

FLOOD VULNERABILITY ASSESSMENT IN URBAN AREAS IN KUALA LUMPUR, MALAYSIA

By

HAJAR NASIRI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Doctor of Philosophy

September 2018

DEDICATION

To my Parents
Mohammad Ali and Masoomeh
For their boundless support, in everything
And for my family as well as all those encouraged me in this journey

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

FLOOD VULNERABILITY ASSESSMENT IN URBAN AREAS IN KUALA LUMPUR, MALAYSIA

By

HAJAR NASIRI

September 2018

Chairman : Mohd Johari Mohd Yusof, PhD
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The District Flood Vulnerability Index (DFVI) is a composite index that allows direct comparison of the relative overall flood vulnerability of urban districts worldwide, and describes the relative contributions of various factors to that overall risk.

The methodology involves two concepts. First, vulnerability, which covers three related conceptions named factors of vulnerability: exposure, susceptibility and resilience. The other conception concerns the actual flooding; considerate which elements of a system are suffering from this natural disaster. Four main components of a system are recognized which are affected by flooding: social, physical, environmental and economic components. The interaction among the vulnerability factors and the components attends as the base of the recommended methodology. The development of the DFVI brings together a body of knowledge about flood risk vulnerability from a wide range of Disciplines to offer three principal benefits.

First, the direct comparison of general flood vulnerability provides a useful tool for inter-city allocation of mitigation resources and effort. Most previous work in flood risk assessment has focused on a single component of the risk, and/or on a single region. The DFVI provides a systematic way to directly compare the overall flood risk vulnerability across a large number of districts or urban regions. Second, the disaggregated DFVI will increase awareness of the wide range of factors on which a district' vulnerability depends, from the expected runoff amount, to the number of inhabitants, to a district's existing economic condition.

A comprehensive DFVI will highlight the fact that even in urban regions with low vulnerability, a flood may occur, and if it does, the other characteristics of the area could turn that single event into a major disaster. Third, by reassessing the index periodically, the DFVI may be used to monitor trends in flood vulnerability over time.

The DFVI has been developed using the following six-step procedure: (1) create a conceptual framework of all the factors that contribute to flood vulnerability—social, physical, environmental and economic factors; (2) identify simple, measurable indicators to represent each of the factors in the framework (e.g., population, dominant land use of each district, precipitation, percentage of the green and open space); (3) combine the indicators Mathematically into the composite DFVI; (4) gather data and evaluate the DFVI for each of the Kuala Lumpur major districts, (5) perform a sensitivity analysis to determine the robustness of the results, (6) interpret the numerical findings to assess their reasonableness and implications, and present the results in a variety of easily understandable graphical forms. A six sample analysis was conducted to explore the challenges associated with this process, and to illustrate its feasibility.

Regards to findings of this research In the Kuala Lumpur districts, Wangsa Maju is the most socially vulnerable to floods, followed by the City Centre, and Damansara is determined the least vulnerable zone. The high social vulnerability of Wangsa Maju is mainly due to its maximum population density relative to all the Kuala Lumpur zones.

In considering physical vulnerability, it was revealed that the high physical vulnerability index of the City Centre zone is the consequence of high number of low cost and old buildings in this area, Damansara has the least vulnerability in terms of physical vulnerability. Comparing the results of environmental DFVI, it can be seen that Wangsa Maju has a higher environmental vulnerability and the smallest value of environmental vulnerability index belongs to Bandar Tun Razak,

It is apparent from the results of economic vulnerability index comparison between Kuala Lumpur zones that Sentul has the highest economic vulnerability index where Damansara has the lowest economic vulnerability index.

Combining the four main components vulnerability results in overall DFVI values shows all districts of Kuala Lumpur place in vulnerable districts category special Wangsa Maju and city center zones have high vulnerability to flood.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENILAIAN BENCANA BANJIR DI SEBAHAGIAN KECIL KAWASAN PERBANDARAN KUALA LUMPUR, MALAYSIA

Oleh

HAJAR NASIRI

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Pengerusi : Mohd Johari Mohd Yusof, PhD
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Indeks Bencana Banjir Kawasan Perbandaran (*The District Flood Vulnerability Index*) ringkasnya DFVI merupakan indeks komposit yang boleh dijadikan perbandingan langsung yang relatif terhadap berlakunya bencana banjir bagi kawasan bandar di seluruh dunia, dan menjelaskan hubungkait berbagai faktor yang menyumbang kepada resiko bencana tersebut.

Metodologi ini melibatkan dua konsep. Pertama, bencana alam, yang merangkumi tiga konsep yang berkaitan dengan faktor bencana : pendedahan, rentanan dan ketahanan. Konsep lain yang berkaitan dengan berlakunya banjir ; mengambilkira elemen-elemen sistem yang menyebabkan penderitaan akibat bencana alam. Empat komponen utama sistem dikenal pasti yang terjejas akibat banjir: komponen sosial, fizikal, alam sekitar dan ekonomi. Interaksi di antara faktor-faktor kelemahan dan komponen merupakan asas kepada metodologi yang dicadangkan. Perkembangan DFVI serta pengetahuan tentang kelemahan risiko banjir daripada pelbagai disiplin untuk menawarkan tiga manfaat utama.

Pertama, perbandingan secara langsung terhadap kelemahan penyediaan alat yang berguna untuk menghadapi bencana banjir, peruntukan yang disediakan bagi perbandaran terhadap sumber dan usaha pengurangan musibah. Kebanyakan kerja terdahulu dalam penilaian risiko banjir hanya tertumpu pada satu komponen risiko, dan/atau di satu kawasan. DFVI menyediakan cara yang sistematik untuk membandingkan secara langsung kelemahan risiko banjir di sebilangan besar daerah atau kawasan bandar. Kedua, DFVI yang terpilah akan meningkatkan kesedaran tentang pelbagai faktor berdasarkan kerentanan daerah, dari jumlah limpasan (*runoff*)

yang dijangkakan, kepada jumlah penduduk, kepada keadaan ekonomi di kawasan dan daerah yang terlibat.

DFVI komprehensif pula akan menyerlahkan fakta yang menjelaskan walaupun di kawasan bandar yang mempunyai kelemahan yang rendah, banjir mungkin berlaku, dan jika ia berlaku, ciri-ciri lain di kawasan itu boleh menjadikan satu-satunya peristiwa berlakunya bencana besar. Ketiga, dengan menilai semula indeks secara berkala, DFVI dapat digunakan untuk memantau kecenderungan kerentanan banjir berterusan dari masa ke semasa.

Pembentukan dan perkembangan DFVI menggunakan enam langkah prosedur seperti berikut: (1) mewujudkan kerangka konseptual (*conceptual framework*) bagi semua faktor yang menyumbang kepada faktor-faktor sosial, fizikal, persekitaran dan ekonomi yang terjejas oleh musibah banjir; (2) Mengalpasti petunjuk mudah (*simple indicator*) yang boleh diukur untuk mewakili setiap faktor dalam rangka kerja (misalnya populasi, penggunaan tanah dominan bagi setiap daerah, hujan, peratusan ruang hijau dan terbuka); (3) menggabungkan petunjuk Matematik ke dalam DFVI komposit; (4) mengumpul data dan menilai DFVI bagi setiap Daerah utama Kuala Lumpur, (5) melakukan analisis kepekaan (*sensitivity analysis*) untuk menentukan ketekalan kajian, (6) mentafsir penemuan (*numerical findings)* untuk menilai kemunasabahan dan implikasinya, dan membentangkan hasil dalam pelbagai bentuk grafik yang mudah difahami. Menganalisis enam sampel telah dijalankan untuk meneroka cabaran yang berkaitan dengan proses ini, dan untuk menggambarkan kebolehlaksanaannya.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

AHP	Analytic Hierarchy Process
ANP	Analytic Network Process
BAP	Budget Allocation Processes
C.I.	Consistency Index
C.R.	Consistency Ratio
CA	Conjoint Analysis
CPI	Consumer Price Index
CVI	Climate Vulnerability Index
DBKL	Kuala Lumpur City Hall (Malay: Dewan Bandaraya Kuala Lumpur)
DFVI	District flood vulnerability index
DID	Department of Irrigation and Drainage of Malaysia
EC	Expert Choice
EVI	Environmental Vulnerability Index
FDS	Flood Detection System
FVI	Flood Vulnerability Index
FVI_E	Environmental flood vulnerability index
FVI_{EC}	Economic Flood vulnerability index
FVI_{PH}	Physical Flood vulnerability index
FVIs	Social flood vulnerability index
GIS	Geographic information system
GWP	Global Water Partnership

HFA	Hyogo Framework for Action
HVI	Human Vulnerability Index
IAH	International Association of Hydro geologists
ICID	International Commission on Irrigation and Drainage
IDNDR	International Decade of Natural Disaster Reduction
IPCC	International Panel of Climate Change
ISDR	International Strategy for Disaster Reduction
IWA	International Water Association
KGPA	Civil Service Golf Club
KL	Kuala Lumpur
KLGCC	Kuala Lumpur Golf and Country Club
MATLAB	MATrix LABoratory
MCDA	Multi Criteria Decision Analysis
MMD	Malaysian meteorological department
MSMA	Urban Storm water Management Manual (Malay: Manual Saliran Mesra Alam)
PCA	Principle Component Analysis
PCM	Pairwise Comparison Method
R.I.	Random Index
SIWI	Stockholm International Water Institute
SMART	Storm Water Management and Road Tunnel
SOPAC	South Pacific Applied Geoscience Commission
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution

UN	United Nation
UNDESA	UN Department of Economic and Social Affairs
UNDP	UN Development Program
UNECE	UN Economic Commission for Europe
UNEP	UN Environment Program
UNESCAP	UN Economic and Social Commission for Asia and the Pacific
UNESCO	UN Educational, Scientific and Cultural Organization
UNESCO-IHP	UNESCO -International Hydrological Program
UNICEF	UN Children's Fund
UNISDR	United Nations Office for Disaster Risk Reduction
UNSD	UN Statistics Division
UNSGAB	UN Advisory Board on Water and Sanitation
UNU	UN-HABITAT United Nations University
WBCSD	World Business Council for Sustainable Development
WHO	World Health Organization
WPI	Water poverty index
WWC	World Water Council

CHAPTER 1

INTRODUCTION

1.1 Introduction

Floods are expected to occur more severely and frequently in the future due to climate change. This shows that many urban regions across the world are expected to be under severe threat of floods, the adversative effects of which are at present supposed only next to that of earthquakes (Balaban, 2009). Unplanned quick urbanization, change in land use arrangement, fragile watershed management, decrease recharge of groundwater by extension of impermeable surfaces in urban areas lead to increasing amount of people are exposed to flood adverse effects. Information from DID (Department of Irrigation and Drainage of Malaysia) declared that around 29,000 km^2 or 9% of total land area of Malaysia and more than 4.82 million people (22%) is involved by flooding every year. Flood annual also leads to around RM915 million loses in this country, so flood is a major source of a hardship in this country (Adelekan, 2011; Department of Irrigation and Drainage Malaysia, 2013). In fact high regularity and effects of flooding has made the efficient urban flood management necessary.

This research argues flood vulnerability assessment as an essential part of the urban flood management. This chapter presents the introduction to the research. It is divided into six parts. The first part describes the research background. The second part clarifies problems that generate the research. Third part refers to the aim, objectives and the questions produced from the identified issues. The forth part presents the importance of the research to the development of knowledge. Subsequently the general framework of the thesis and the brief conclusion are come.

For the duration of the International Decade of Natural Disaster Reduction (IDNDR) from 1990 to 1999, it was appreciated that the earlier paradigm of “flood protection” was unsuitable (UNISDR, 2009). Complete protection is both inaccessible and unsustainable, because of high prices and inherent uncertainties. As an alternative, flood management has been suggested as being more appropriate and this paradigm is now receiving increasing attention within flood research. Flood risk management deals with a wide group of subjects and tasks extending from the forecasting of flood, over their social consequences to measures and tools for risk reduction and reduction economic costs and human loss to adequate level. Avoiding decrease or shifting the effects of flood over procedures for mitigation and adaptation is flood risk management‘s core aim (UNISDR, 2009).

So two attitudes for facing with flood and flood management exist: structural (flood protection) and non-structural:

Structural measures or protection measures consist of infrastructure expansion like levees, dams or river dike that modifies the river flow (Faisal, Kabir, 1999). The basic principles consist of storing, diverting and confinement of floods (See Figure 1.1).

Figure 1.1 : Structural measures in flood protection
(Source: Department of Irrigation and Drainage Malaysia, 2013)

Non-structural measures contain of numerous mitigation actions not modifying the river flow. They contain training, flood insurance, assessing methods, emergency services, land use planning, building codes, warning and forecasting, health and social measures and public attendance (See Figure 1.2). The goal is to reduce loss of life and properties. Considering flood management as a social issue rather than engineering measures (structural measures) is the best attitude in flood mitigation. In fact, even structural measures could have useful consequences for specific period; they also lead to the potential threat as well, because they rebuild natural process and do not follow natural rules (Gao, Nickum, & Pan, 2007).

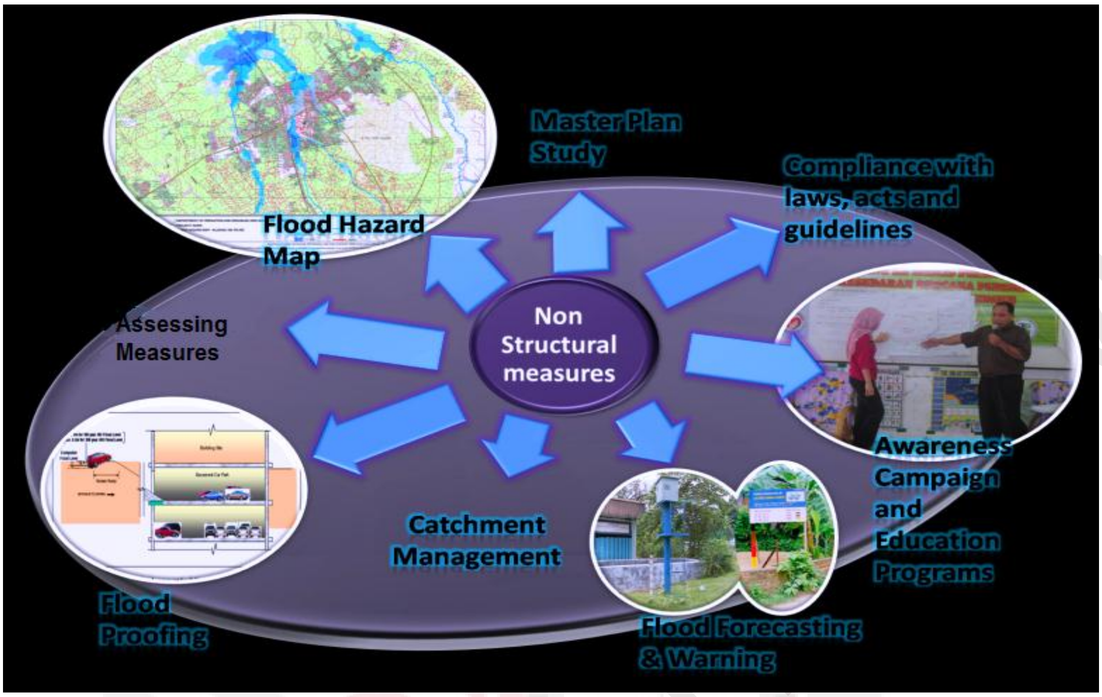

Figure 1.2 : Non-structural measures in flood management
(Source: Department of Irrigation and Drainage Malaysia, 2013)

In flood risk management, flood risk is generally based on three factors: hazard, exposure, and vulnerability. Hazard is the extreme natural event including its frequency, exposure refers to the people, their environment and properties influenced by flood; and vulnerability mentions to the susceptibility of people and properties and the coping capacity to deal with flood impact (Kron, 2009).

In this regard, for decreasing impacts of flood according to flood management definition, evaluations flood risk constituents is inevitable. Floods are increasingly being examined through the lens of vulnerability which examines how environmental, social and other factors lead some portions of population to extremely suffer adverse impacts when a flood hazard strikes. Also, vulnerability in diverse places is different due to human activities, environmental characteristics, and the culture of society in face of hazards. Moreover, evaluation of vulnerability is an important element of flood management and decreasing vulnerability is becoming more significant section of this kind of planning with population increasing in urban areas (Ahmad & Simonovic, 2013). In flood management, it is imperative to trace the risk and analyses how it might change because of future developments or the possible execution of a measure. To achieve this aim vulnerability assessment methods are very appropriate (De Moel, Asselman, & Aerts, 2012).

In city context, whereas researchers in the natural science have developed important technologies and physical tools to reduce flood impacts and social science researches has concentrated on the social, economic, political and behaviour issues from flooding. Urban planners has expanded management measures to tackling these impacts by simplifying decision making process and helping city authorities (Kang, 2009). Honestly, enhancement of management actions is related with the need to advance decision making procedure. For instance, investments inside the city can be assigned in the best manner. To achieve this aim, introducing indices for evaluate vulnerability and identifying more vulnerable zones and comparing them, can be useful. The index is a quantitative variable that would allow comparing the disaster risk and its impacts between varied areas exposed to flood (Birkmann, 2007). Every index is conducted first by identifying the most suitable type of data to counting vulnerability and second recognizing available data at the spatial scale of study (Mclaughlin & Cooper, 2010). The indicators let us to identify aims and provide strategies guidance to reduce vulnerability. The vulnerability indicators let us to set more precise and quantitative targets for vulnerability decrease (Balica, 2007).

The Flood Vulnerability Index (FVI) is a method to assess flood vulnerability on three scales: river basin, sub–catchment and urban area by categorizing different components those affect the susceptibility of the people who live in flood prone areas. The current flood vulnerability index consists of four main components. Social, economic, environmental and physical components which are specified by some indicators in Balica's (2007) study and meteorological, hydrogeological, socio-Economic and countermeasure components in Connor and Hiroki's (2005) research.

1.2 Problem statement

Floods are natural phenomena which cannot be prevented. But, some factors like climate change and human activities (such as urban development, economic possessions in flood plains or decrease of the natural water preservation by land use) lead to increase in the probability and impacts of flood events. They have the potential to be a reason for life loose, people movement, environmental, economic and cultural damages. So that regard to flood frequency across the world it is desirable to reduce the adverse consequences of this event. Table 1.1 presents flood incidence in the world in the last decade.

Table 1.1 : The number of flood events in the world, 2006-2015

Continent	Kind of flood	No.Events	Killed	Total Affected	Damage (000 US$)
Africa	Unspecified	15	172	177994	107256
	Flash flood	47	1235	1294482	429981
	General flood	353	5548	26935350	2755631
	Storm surge/coastal flood	2	19	33000	-
		417	6974	28440826	3292868
Americas	Unspecified	7	22	14033	-
	Flash flood	17	196	334307	330330
	General flood	288	9320	36966337	40763803
	Storm surge/coastal flood	2	-	59690	-
		314	9538	37374367	41094133
Asia	Unspecified	15	367	2310511	2000
	Flash flood	147	7837	44952072	14684534
	General flood	515	35109	784788728	159513893
	Storm surge/coastal flood	8	230	7825150	757520
		685	43543	839876461	174957947
Europe	Unspecified	5	5	13400	-
	Flash flood	21	254	78616	4338560
	General flood	169	610	2979082	26435262
		195	869	3071098	30773822
Oceania	Flash flood	8	18	17386	1627000
	General flood	34	121	542622	10512247
	Storm surge/coastal Flood	5	-	75985	-
					-
		47	139	635993	12139247

(Source: Guha-Sapir, Below, & Hoyois, 2015)

As it is observed, flood disasters in Asia are more than other continents in terms of event number and also costs and human lives which affected by it. Also, because of climate change there has been a growth in flood occurrence during the time. Table 1.2 presents the increasing trend in flood frequency in southeast region of Asia based on 55 years datasets (1960-2015).

Table 1.2 : Flood events number, deaths, estimated damage cost in Southeast Asia

Time period	Number of event	Death	Estimate damage (US $,000)
1960-69	16	1206	95011
1970-79	39	2191	734142
1980-89	61	3173	773672
1990-99	105	5337	5104482
2000-2009	219	6954	5440685
2015 (includes Pacific)	63	1863	11500000

(Source: Sharma, 2012; ESCAP, 2015)

223 million people are affected by the most awful flood in China in 1998, respects to information, 3,004 people were dead, 15 million became homeless and the economic damage was more than US$ 23 billion. Due to severe flooding in Cambodia and Vietnam in 2000, 428 people were dead and the economic loss evaluated more than S$250 million (Pelling *et al.*, 2004). For the last 10 years for high amount of flood, thousands of people have been influenced in Indonesia, Bangladesh, Malaysia, Pakistan, Korea and India by ruining their agricultural grounds, housing and food. Table 1.3 shows the number of floods in West Asia, in the same period.

Table 1.3 : Flood events number, deaths, damage cost in west-Asia

Time period	Occurrence	No of death	Total damage (‘000US$)
1960-2014	34	1363	3,292,900

(Source: Guha-Sapir, Below, & Hoyois, 2014)

Malaysian cities are in a good condition because they are not exposed to some hazards like earthquake. However, intensive floods happen regularly in this country. Flash flood and Monsoon flood are two kinds of flood which happen in Malaysia. All prior main floods occurred for the reason of heavy monsoon rains in long period, since 1993, no major monsoon flood excluding in year 1998. That means there are two kinds of rainfall cause to flooding in Malaysia (Abustan, 2006):

(i) long period rainfall in a wide area with moderate amount
(ii) Short period local rainfall with high intensity

The monsoon floods take place typically from Northeast monsoon which be occurring November to March with heavy rains to the southern Sarawak, east coast states of the Peninsula and northern Sabah. Some of the confirmed flood events in the country were in 1926, 1931, 1947, 1957, 1963, 1967, 1969, 1971, 1973, 1983, 1988, 1993, 1998, 2001, 2006, 2007, 2010, 2012, 2013, 2014 , 2015,2016 and 2017 (DID Malaysia, 2009; Nasir, 2015; Estrada MA, Koutronas E, & Tahir M, 2017)

Regards to DID (Department of Irrigation and Drainage of Malaysia) around 29,000 km^2 or 9% of country’s territory and more than 4.82 million people (22%) are influenced by flooding each year. In addition, annual flood cause to nearby RM915 million loses in Malaysia. Although monsoon flood is ruled by long period and heavy rainfall, more local flooding which contains a vast district has been described in recent times. For example, 2^{th}-6^{th} October flood in 2003 that effected a huge area of north-western Peninsula cover states of Penang, Kedah and Northern Perak or two occasions happened in April and October 2002 in Kuala Lumpur which have been assessed due to unbounded urban growth and operations in the catchment and flood plain (Hassan, Ghani, & Abdullah, 2006). The principal reasons of flooding in Malaysia are like this:

i. Loss of flood storage as a result of urban growth into and taking over flood plains and drainage routes
ii. Intensive overflow amount as a result of urbanization
iii. Insufficient drainage routes or fail of localized drainage development workings, raised inadequately downstream
iv. Restriction at bridges and channels that are also small or partially blocked by debris build-up or from other causes
v. Siltation in stream channels from unselective land clearance processes
vi. Localized continuous heavy rain
vii. Tidal backwater consequence
viii. Inadequate waterway capacity

Table 1.4 displays highest flood events in Malaysia between 1950 to 2015 which shows numbers of affected people and economic losses.

Table 1.4 : Most important floods in Malaysia

Date	No total affected	Cost of damage (000.US$)	Location
Jan 1967	140000	25600	Kelantan
26.12.1970	243000	37000	Kuala Lumpur
28.11.1986	250000	11500	Kelantan
2003	-	Unknown	Kedah , Kuala Lumpur
2006-2007	176533	990000	Johor, Malacca, Pahang, Negeri Sembilan, Shah Alam , Kuala Lumpur
28.12.2008	6000	21000	Johor, Terengganu,
3.11.2010	50000	8000	Kedah, Perlis,
28.1.2011	20000	Unknown	Kajang , Kuala Lumpur (Jalan Tun Razak)
5.12.2013	37000	Unknown	Pahang , Terengganu, Johor
15 Dec 2014- 3 January 2015	More than 200,000	9.42 billion	Johor, Kedah, Kelantan, Pahang, Perak, Perlis, Sabah, Sarawak, Selangor and Terengganu
7 Feb-March 2016	More than100000	550000	(Kuching, Bau, Samarahan and Serian in Sarawak), (Tangkak, Ledang and Segamat in Johor) and (Alor Gajah, Central Malacca and Jasin in Malacca) and parts of Negeri Sembilan.
7 Nov 2017	7 Dead, 10,000 Displaced	Unknown	Kelantan, Perlis, Kedah and Penang

(Source: (ADRC, 2011;Guha-Sapir *et al.*, 2014; Chan, 2012; Abustan & Wahid, 2008; Nasir, 2015; Estrada MA *et al.*, 2017)

The capital of Malaysia, Kuala Lumpur (KL), was constructed at the end of 19th century as a tin Mining habitation at the mud-covered conflux of Klang River and Gombak River. After a century it has developed the nation's main city and the heart of business and urbanization in Malaysia. The KL revolution into the extreme-modern metropolitan area as it is today has not been without its challenges, and the fast expansion of the last thirty years, involved it with urban overcrowding, traffic congestion and overwhelming struggle of flash flooding. KL is located in the middle upper of the 120 kilometre extended Klang River which drains a catchment of some 1,288 km^2. The river source is in the Selangor state, streams in the Federal Territory of KL before re-inflowing Selangor somewhere it gently meanders through rolling lands and flat coastal plains and lastly evacuates into the Malacca Straits. Kuala Lumpur is exposed to number of severe floods with the most awful recorded in 1971, because it is situated in a flood plain. Nevertheless, just after the catastrophic flood of 1971, efforts were begun to solve the problem.

Over the past years, occurrences of major flooding in Kuala Lumpur where quick urbanization is happen were very regular (Table 1.5). Some researches stated that the main reasons of Kuala Lumpur flash floods are: uncontrolled urbanization, drainage paths blocking, surface runoff rising, weak drainage maintenance and insufficient drainage system (Nasir, 2015).

Table 1.5 : Flooding incidences in Kuala Lumpur

Period	Year	Total affected	Cost of damages US $	Comments
Before 1950	1926			
1970s	1971	180'000	34 millions	The worst catastrophic flood in Malaysia
1980s	1982,1986,1988	Unknown	Unknown	
1990s	1993,1995,1996,1997	Unknown	Unknown	
2000s	2000,2001,2002, 2003, 2006, 2007	Unknown	Unknown	
2010-2013	2013	Unknown	Unknown	Jalan Pinang
2014-2017	2016 (May), 2017(Sep/Oct)	Unknown	Unknown	Jalan Tuanku Abdul Halim & Jalan Lingkungan Budi& Jalan Kuching

(Source: Merriman, Browitt, 1993; Althuwaynee, Pradhan, & Ahmad, 2015; Hani Shamira Shahrudin, 2017)

After the terrible 1971 Kuala Lumpur flood, Malaysian government took some helpful steps to face with the flood issue. Some of them are:

- Formation the Permanent Flood Control Commission
- Formation flood disaster recovery mechanism
- Structural measures operation
- Development warning systems and flood anticipating
- Implementation river basin studies and provision drainage master plans for major towns
- Setting up of a national system of hydrological and flood data gathering stations

Honestly, as well as structural measures like dams or levees construction or the SMART Tunnel, flood risk management contains non-structural actions, particularly, flood forecasts and early warning system have hired in Malaysia. Nonetheless, flood management trusts extremely on the provision of flood risk evaluation in spatial planning. This can be attained over the flood risk maps or flood vulnerability assessment approaches. At this time, in Malaysia, the improvement of these approaches is inadequate to be used for analysis (Ho, 2009).

As one of the main sections in flood management process, flood vulnerability can be evaluated by different methods. Nowadays across the world different approaches have been used for vulnerability assessment regards to flood events characteristics and the circumstance which flood happen. Among these methods, index method is very common because of covering more aspects of vulnerable society which is simple for using by decision makers in municipalities and city authorities. On the other side vulnerability assessment is a requirement of the European flood directive 2007/60/EC (Parliament & Committee, 2007) for reducing natural hazard risks. In Kyoto in 2005, governments across the world were obligated to reduce disaster risk, through the approval of a guideline to decrease vulnerabilities to natural hazards, called the Hyogo Framework for Action (HFA). A guideline mentioned indicator-based approaches to different scales for observing disaster risk and vulnerability to raise the capability of countries to manage risks (United Nations, 2005). As a result, the indicators through the index can be a guide to understanding the current and future state of an area in facing natural hazards.

One of the most important goals of assessing flood vulnerability with index method (FVI), is to create an understandable link between the theoretical concepts of flood vulnerability and the day-to-day decision-making process and to summarize this link in an easily accessible tool.

The FVI (Flood Vulnerability Index) methodology has already been used for assessing cities but never been tested in Malaysia. Also, regards to previous studies it can be determined that indexes of vulnerability to environmental hazards cannot hope to be meaningful when applied to large-scale systems like a large city. So that there must be emphasis on smaller scales of analysis as one of the chief problem of this method is homogeneity of large regions, in spite of profound social and physical differences which can lead to unrealistic results and leads to unnecessary measures and investments across the city. This research is a new one that trying to decrease the scale of FVI from large city to the district inner the city. The purpose of this research is to assess the current method of calculating the flood vulnerability index to adjust it for city district scale. Different scales have different indicators which makes them vulnerable to floods and to orient future urban growth away from risk areas and to promote resilience of neighbourhood concept we need to recognize the most vulnerable areas of each city. The current FVI focuses on large scale like the river basin, sub catchment and whole the city, neglecting some of the factors which change the vulnerability of smaller spatial scales like urban districts. So this study will develop FVI with significant local factors and more in depth interpretation of them for district scale.

Research Question: How can flood vulnerability index (FVI) be applied in urban district scale for flood management in Malaysian cities?

Therefore the thesis research objectives are:

1.3 Research aim and objectives

Research aim:

To develop FVI method in urban district scale as a practical model in accordance with European flood directive 2007/60/EC for reducing natural hazard risks by index method assessment.

This model can contribute to the development of the current knowledge based on flood risk assessment methods and provides a more precise tool for this aim. It is based on a synthesis of the literature on vulnerability and helps as a framework to illustrate the different sides of flood vulnerability. It specifies different characteristics of human and environmental systems that interact to produce vulnerability. The model distinguishes between different components of vulnerability, particularly exposure, susceptibility and resilience, and highlights the interactions between these components and the human-environment system. While the specific objectives are:

Research objectives

(1) To identify the flood vulnerability components (physical, economic, environmental and social) and their indicators for Kuala Lumpur city.
(2) To determine the most significant indicators which appropriate for the district scale through expert elicitation and regulate weight of selected indicators to define the index.
(3) To construct the district flood vulnerability index (DFVI) and examine it in Kuala Lumpur districts.

1.4 Scope and method of research

With respect to vulnerability assessment methods, earlier studies often focused on wide regions and set of indicators for large scales in the vulnerability assessment. While, this research will examine vulnerability in a smaller district scale, which is related to different factors in the flood vulnerability. The main reasons to study the FVI in different scales are:

- Vulnerability is socially and geographically differentiated.
- Spatial heterogeneity consequences in more precise picture of reality
- Administrative and Political separation can simplify the accessibility of Data, according to specific scale

So the geographical focus of this research will be on the districts of capital of Malaysia (Kuala Lumpur) which has a long history of flooding.

1.5 Thesis framework

The following research introduces a new tool for determining how much a district of a city is vulnerable to flood in Kuala Lumpur city context. This dissertation is organized as follow (Figure 1.3):

Chapter one: Introduction	Research problem, research objectives
Chapter two: Literature review	Background of study, Creating Theoretical frame for the
Chapter three: Research methodology	Description of applied methods, scope of research and case study selection
Chapter four: Analysis of data	Index construction; examine the index in case studies, Robustness analysis of index
Chapter five: Discussion,	Summary of findings and analysis, Recommendations (Guidelines and further works)

Figure 1.3 : Research structure

Chapter one (current chapter) includes an introduction to flood management, problem statement and objectives of the research. This chapter also gives a brief history of flood hazard in Malaysia.

Chapter two provides a review of the appropriate literature, including conceptual frameworks of flood vulnerability index and its related indicators for assessing flood vulnerability.

Chapter three presents FVI methodology and its implementation in city district scale.

Chapter four analyses achieved data to identify and select the relevant indicators for district scale with Delphi Fuzzy method and deals weights assigning process to selected indicators by AHP (analytic hierarchy process) in Expert Choice software. Furthermore, it gives a comprehensive analysis of the data collected in Kuala Lumpur related to theoretical frameworks introduced in chapter Three.

In chapter five, overall conclusion, FVI comparison in Kuala Lumpur districts recommended strategies for reducing flood vulnerability index in most vulnerable area and ideas for further studies are discussed.

1.6 Significance of study

This study provides one of the first attempts to introduce an index for flood vulnerability assessment in Malaysian city. The main motivation of conducting this study is that Malaysia being of the more vulnerable countries among the flood prone countries in Asia.

Moreover, it has been understood that as a result of quick urban development and climate change era, flood vulnerability has been rising extensively in this country. This study was driven by this concept that it would be worthwhile to the municipalities and decision makers in city affairs to allocate flood mitigation measures and investments assigning in more necessitous districts of city and distinguish the vulnerable areas to conduct the future development of city to less vulnerable area.

This research is also expected to contribute for providing valuable knowledge which is desirable for urban planners and policymakers to meet the challenge of disregarding social and economic factors in flood vulnerability assessment. Also, to simplify the method for comparing flood vulnerability in different areas, instead of using software which need more time to learn.

REFERENCES

Abd Jalil Hassan, Aminuddin Ab.Ghani, R. A. (2006). Development of Flood Risk Map using GIS for Sg. Selangor Basin. In *6th International Conf. on ASIA GIS*.

Abustan, N. A. W. (2006). Monsoon flood in Malaysia. Monsoon Flood caused greatest damage Shah Alam, Selangor.

Abustan, & Wahid, N. A. (2008). The Vulnerability of Malaysia in Facing Flood Experiences.

Adelekan, I. O. (2011). Vulnerability assessment of an urban flood in Nigeria: Abeokuta flood 2007. *Natural Hazards*, *56*(1), 215–231. https://doi.org/10.1007/s11069-010-9564-z

Adger, W. N. (2006). Vulnerability. *Global Environmental Change*, *16*(3), 268–281. https://doi.org/10.1016/j.gloenvcha.2006.02.006

Adger, W. N., Brooks, N., Bentham, G., & Agnew, M. (2004). New indicators of vulnerability and adaptive capacity. *Change*, *5*(January), 128. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.112.2300&rep=rep1&type=pdf

Adler, Michael, and E. Z. (1996). *Gazing into the oracle: The Delphi method and its application to social policy and public health*. Jessica Kingsley Publishers.

ADRC. (2011). *Country Report of MALAYSIA 2011*.

Ahmad, S. S., & Simonovic, S. P. (2013). Spatial and temporal analysis of urban flood risk assessment. *Urban Water Journal*, *10*(1), 26–49. https://doi.org/10.1080/1573062X.2012.690437

Alexander, D. E. (2002). *Principles of emergency planning and management*. Oxford University Press on Demand.

Althuwaynee, O. F., Pradhan, B., & Ahmad, N. (2015). Estimation of rainfall threshold and its use in landslide hazard mapping of Kuala Lumpur metropolitan and surrounding areas. *Landslides*, *12*(5), 861–875. https://doi.org/10.1007/s10346-014-0512-y

Babbie, E. R. (1973). *Survey research methods*.

Balaban, M. S. (2009). Risk Society and Planning, the case of flood disaster management in turkisch cities. *Voorbeeld Thesis*, (March).

Balica, S. (2007). Development and Application of Flood Vulnerability Indices for Various Spatial Scales. *M.Sc Thesis*, (April). Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Development+and+Application+of+Flood+Vulnerability+Indices+for+Various+Spatial+Scales#2

Balica, S. F. (2012). *Applying the flood vulnerAbility index As A knowledge bAse for flood risk Assessment*.

Balica, S. F., Popescu, I., Beevers, L., & Wright, N. G. (2013). Parametric and physically based modelling techniques for flood risk and vulnerability assessment: A comparison. *Environmental Modelling and Software*, *41*, 84–92. https://doi.org/10.1016/j.envsoft.2012.11.002

Balica, S. F., Wright, N. G., & van der Meulen, F. (2012). *A flood vulnerability index for coastal cities and its use in assessing climate change impacts*. *Natural Hazards* (Vol. 64). https://doi.org/10.1007/s11069-012-0234-1

Balica, S., & Wright, N. G. (2010). Reducing the complexity of the flood vulnerability index. *Environmental Hazards*, *9*(4), 321–339. https://doi.org/10.3763/ehaz.2010.0043

Batty, M. (2008). The size, scale, and shape of cities. *Science*, *319*(5864), 769–771.

Bhuiyan, M. J. A. N., & Dutta, D. (2012). Analysis of flood vulnerability and assessment of the impacts in coastal zones of Bangladesh due to potential sea-level rise. *Natural Hazards*, *61*(2), 729–743. https://doi.org/10.1007/s11069-011-0059-3

Birkmann, J. (2007). Risk and vulnerability indicators at different scales:. Applicability, usefulness and policy implications. *Environmental Hazards*, *7*(1), 20–31. https://doi.org/10.1016/j.envhaz.2007.04.002

Blaikie, P. (1994). *At risk : natural hazards, people's vulnerability, and disasters*. Routledge.

Blaikie, P., Terry, C., Ian, D., & Ben, W. (1996). *At Risk: Natural Hazards, People's Vulnerability, and Disasters*. *Human Ecology* (Vol. 24). https://doi.org/10.4324/9780203428764

Böhringer, C., & Jochem, P. (2007). Measuring the immeasurable—A survey of sustainability indices Impact 1-measuring... *Ecological Economics*, *63*(1), 1–8. Retrieved from /citations?view_op=view_citation&continue=/scholar?hl=en&start=10&as_sdt=0,36&scilib=1&citilm=1&citation_for_view=mgNa2J0AAAAJ:2osOgNQ5qMEC&hl=en&oi=p

Booysen, F. (2002). AN OVERVIEW AND EVALUATION OF COMPOSITE INDICES OF DEVELOPMENT The search for alternative indicators of development has witnessed the development of a variety of composite indices . These indices represent macro-level valuations of development insofar as. *Social Indicators Research*, *59*, 115–151. https://doi.org/10.1023/A:1016275505152

Borden, K. A., Schmidtlein, M. C., Emrich, C. T., Piegorsch, W. W., & Cutter, S. L. (2007). Vulnerability of U.S. Cities to Environmental Hazards. *Journal of Homeland Security and Emergency Management*, *4*(2), 1–23. https://doi.org/10.2202/1547-7355.1279

Brace, I. (2005). *Questionnaire design: How to plan, structure and write survey material for effective market research*. Kogan Page Publishers.

Buckley, J. J., Feuring, T., & Hayashi, Y. (2001). Fuzzy hierarchical analysis revisted. *European Journal of Operational Research*, *129*(3), 48–64.

Burton, C. G. (2012). The Development of Metrics for Community Resilience to Natural Disasters, 198. https://doi.org/10.1007/s13398-014-0173-7.2

C. A Sullivan, J. . M. & T. . F. (2010). Centre for Ecology and Hydrology: Software-PC-IHACRES, *49*(0), 3116243.

Cannon, T. (1994). Vulnerability Analysis and the Explanation of "Natural" Disasters. *Disasters, Development and Environment*. Retrieved from http://leeclarke.com/courses/disasters/cannon_vulnerability_analysis.pdf

Cardona, O. D., van Aalst, M. K., Birkmann, J., Fordham, M., McGregor, G., Perez, R., … Sinh, B. T. (2012). Determinants of Risk : Exposure and Vulnerability Coordinating. In *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (pp. 65–108). https://doi.org/10.1017/CBO9781139177245.005

Cendrero A, F. D. (1997). A Procedure for Assessing the Environmental Quality of Coastal Areas for Planning and Management. *Journal of Costal Research*, *13*(3), 732–744.

Chan, N. W. (2012). Impacts of disasters and disasters risk management in Malaysia: The case of floods. *Economic and Welfare Impacts of Disasters in East Asia and Policy Responses.*, (December), 503–551. https://doi.org/10.1007/978-4-431-55022-8

Change, O. (2001). Intergovernmental Panel on Climate Change. *United Nations*. https://doi.org/10.1007/BF02986817

Clayton, M. J. (1997). Delphi: A technique to harness expert opinion for critical decision-making tasks in education. *Educational Psychology*, *17*(4), 373–386. https://doi.org/10.1080/0144341970170401

Coninx, I., & Bachus, K. (2007). Integrating Social Vulnerability to Floods in a Climate Change Context. *Proc. Int. Conf. on Adaptive and Integrated Water Management, Coping with Complexity and Uncertainty,* 30.

Coyle, T. R. (2013). 2013 survey of expert opinion on intelligence, 1–32.

Creswell, J. W. (2013). *Research design: Qualitative, quantitative, and mixed methods approaches.* Sage publications.

Cross, J. A. (2001). Megacities and small towns: Different perspectives on hazard vulnerability. *Environmental Hazards*, *3*(2), 63–80. https://doi.org/10.1016/S1464-2867(01)00020-1

Cutter, S. L. (1996). Vulnerability to environmental hazards. *Progress in Human Geography*. https://doi.org/10.1177/030913259602000407

Cutter, S. L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E., & Webb, J. (2008). A place-based model for understanding community resilience to natural disasters. *Global Environmental Change*, *18*(4), 598–606. https://doi.org/10.1016/j.gloenvcha.2008.07.013

Cutter, S. L., Boruff, B. J., & Shirley, W. L. (2003). Social Vulnerability to Environmental Hazards. *Social. Sci. 84*(2), 242–261.

Dalkey, N. C., & Helmer, O. (1963). An experimental application of the Delphi method to the use of experts. *Management Science, 9*(3), 458–467.

David de Vaus. (2002). *Analyzing Social Science Data: 50 Key Problems in Data Analysis*. Sage.

DBKL. (2004). *kl structure plan 2020. DBKL.*

De Moel, H., Asselman, N. E. M., & H. Aerts, J. C. J. (2012). Uncertainty and sensitivity analysis of coastal flood damage estimates in the west of the Netherlands. *Natural Hazards and Earth System Science*, *12*(4), 1045–1058. https://doi.org/10.5194/nhess-12-1045-2012

Delbecq, Andre L., Andrew H. Van de Ven, and D. H. G. (1975). *Group techniques for program planning: A guide to nominal group and Delphi processes*. Glenview, IL: Scott, Foresman.

Department of Irrigation and Drainage Malaysia. (2013). Flood Management - Programme and Activities - Flood Management in Malaysia, (December). Retrieved from http://www.water.gov.my/our-services-mainmenu-252/flood-mitigation-mainmenu-323/programme-aamp-activities-mainmenu-199?lang=en&start=1

DID. (2004). *M. S. M. A. Urban storm water management manual for Malaysia.*

DID Malaysia. (2009). *DID Manual (Volume 1 – Flood Management). Department of Irrigation and Drainage, Malaysia* (Vol. 1).

Dilley, M. (2005). *Natural disaster hotspots: a global risk analysis*. *World Bank Publications* (Vol. 5). https://doi.org/10.1080/01944360902967228

Dingman, S. L. (2002). Water in soils: infiltration and redistribution. *Physical Hydrology*, 222–242.

Dinh, Q., Balica, S., Popescu, I., & Jonoski, A. (2012). Climate change impact on flood hazard, vulnerability and risk of the Long Xuyen Quadrangle in the Mekong Delta. *International Journal of River Basin Management*, *10*(1), 103–120. https://doi.org/10.1080/15715124.2012.663383

Dixit, A. (2003). Floods and vulnerability: Need to rethink flood management. *Natural Hazards*, *28*(1), 155–179. https://doi.org/10.1023/A:1021134218121

Dutta, D., Herath, S., & Musiake, K. (2003). A mathematical model for flood loss estimation. *Journal of Hydrology*, *277*(1–2), 24–49. https://doi.org/10.1016/S0022-1694(03)00084-2

El-Gafy, I. K. E. D. (2015). The water poverty index as an assistant tool for drawing strategies of the Egyptian water sector. *Ain Shams Engineering Journal*. Faculty of Engineering, Ain Shams University. https://doi.org/10.1016/j.asej.2015.09.008

ESCAP. (2015). *Disasters in Asia and the Pacific: 2015 Year in Review*.

Estrada MA, Koutronas E, Tahir M, M. N. (2017). Hydrological hazard assessment: THE 2014-15 Malaysia floods. *International Journal of Disaster Risk Reduction*.

Faisal, I. M., M. R. Kabir, and A. N. (1999). "Non-structural flood mitigation measures for Dhaka City. *Urban Water*, *1.2*, 145–153.

Farrell, Alex, and M. H. (1998). What does sustainability really mean?: The search for useful indicators. *Environment: Science and Policy for Sustainable Development*, *40*(9), 4–31.

Fricke, T. J., & Lewis, K. V. (1976). FLOOD ESTIMATION FOR URBAN AREAS IN PENINSULAR MALAYSIA, (16).

Füssel, H.-M. (2010). Review and quantitative analysis of indices of climate change exposure, adaptive capacity, sensitivity, and impacts. *World Development Report*, 34. https://doi.org/10.1016/j.gloenvcha.2010.07.009

G.J.Klir, & Folger, T. A. (1988). *Fuzzy sets, uncertainty, and information*.

Gall, M. (2007). Indices of Social Vulnerability to Natural Hazards: A Comparative Evaluation, 231. Retrieved from http://books.google.com/books?id=exg4Tf4VX6sC&pgis=1

Gao, J., Nickum, J. E., & Pan, Y. (2007). An assessment of flood hazard vulnerability in the Dongting Lake Region of China. *Lakes and Reservoirs: Research and Management*, *12*(1), 27–34. https://doi.org/10.1111/j.1440-1770.2007.00318.x

Gervacio, R., & Liong, M. T. S. (2014). Combined Literature Review: Health, Social and Economic Impacts of Extreme Events, 557.

Gheorghe, A. V. (2005). *Integrated Risk and Vulnerability Management Assisted by Decision Support Systems: Relevance and Impact on Governance*. Springer Science & Business Media.

Ginsburg, N., James, O., & Grant, B. (1986). *Geographic perspectives on the wealth of nations*. *Chicago : University of Chicago,Dept. of Geography, 1986*. University of Chicago. Retrieved from http://encore.lib.cuhk.edu.hk/iii/encore/record/C|Rb1054265|Sgeographic+perspectives+on+the+wealth+of+nations|Orightresult|X5?lang=eng&suite=def

Gordon, T. J. (2009). The Delphi Method. *Futures Research Methodology v3.0 [CD-ROM]*, 1–29.

Green, C. (2010). Towards sustainable flood risk management. *International Journal of Disaster Risk Science*, *1*(1), 33–43. https://doi.org/10.3974/j.issn.2095-0055.2010.01.006

Guha-Sapir, D., Below, R., & Hoyois, P. (2014). "EM-DAT: International disaster database. Retrieved from www. em-dat. net

Habibi, A., Jahantigh, F. F., & Sarafrazi, A. (2015). Fuzzy Delphi Technique for Forecasting and Screening Items. *Asian Journal of Research in Business Economics and Management*, *5*(2), 130–143. https://doi.org/10.1007/BF00027519s

Han, W. J., & Tsay, W. D. (1998). Formulation of quality strategy using analytic hierarchy process. In *Twenty Seven Annual Meeting of the Western Decision Science Institute* (pp. 580–583). University of Northern Colorado, USA.

Hani Shamira Shahrudin. (2017, September 2). Evening downpour brings traffic to a stop as flash flood hits Jalan Kuching. *New Straits Times*.

Hashim, N. (2011). The Planning & Implementation of Urban Agglomeration. *Bengkel Inisiatif 22 : Memacu Pertumbuhan Melalui Aglomerasi Bandar*, (April).

Häussler, Peter, and L. H. (2000). A curricular frame for physics education: Development, comparison with students' interests, and impact on students' achievement and self-concept. *Science Education*, *84*(6), 689–705.

Hewitt.K. (1983). On the poverty of theory: natural hazards research in context. In *Interpretations of Calamity from the Viewpoint of Human Ecology* (pp. 231–262).

Hinkel, J. (2011). " Indicators of vulnerability and adaptive capacity": Towards a clarification of the science-policy interface. *Global Environmental Change*, *21*(1), 198–208. https://doi.org/10.1016/j.gloenvcha.2010.08.002

Ho, Y. F., and H. L. C. (2007). Healthy housing rating system. *Journal of Architecture*, *60*, 115–136.

Ho, J. C. (2009). CoMEM Coastal flood risk assessment and coastal zone management case study of Seberang Perai and Kuantan Pekan in Malaysia Jiann Chyuan Ho July 2009, (July).

Ho, Y., & Wang, H. (2008). Applying fuzzy Delphi method to select the variables of a sustainable urban system dynamics model. ... *Conference of the System Dynamics ...*, 1–21. Retrieved from http://www.systemsmodelbook.org/uploadedfile/1376_272c89b6-32c7-4a9d-8a77-b7c613d7a0d2_HO311.pdf

Hogarth, R. M. (1978). A note on aggregating opinions. *Organizational Behavior and Human Performance*, *21*(1), 40–46. https://doi.org/10.1016/0030-5073(78)90037-5

Hsu, Y., Lee, C., & Kreng, V. B. (2010). The application of Fuzzy Delphi Method and Fuzzy AHP in lubricant regenerative technology selection. *Expert Systems with Applications*, *37*(1), 419–425. https://doi.org/10.1016/j.eswa.2009.05.068

Huang, D., Zhang, R., Huo, Z., Mao, F., E, Y., & Zheng, W. (2012). An assessment of multidimensional flood vulnerability at the provincial scale in China based on the DEA method. *Natural Hazards*, *64*(2), 1575–1586. https://doi.org/10.1007/s11069-012-0323-1

IPCC. (2001). *Climate change 2001: impacts, adaptation, and vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Published for the Intergovernmental Panel on Climate Change*. Retrieved from http://treconservice.com/onep/wp-content/uploads/2015/01/Impacts-Adaptation-and-Vulnerability.pdf

Ishikawa, A. (1993). The Max-Min Delphi method and fuzzy Delphi method via fuzzy integration *, *55*, 241–253.

Joannet, K. (2012). *Vulnerability and resilience in developing countries facing natural disasters -Focus on Dhaka flooding disaster by integrating a hydrodynamic model in the Flood Vulnerability Index (FVI)*. Leeds.

Jones, B., & Andrey, J. (2007). Vulnerability index construction: methodological choices and their influence on identifying vulnerable neighbourhoods. *International Journal of Emergency Management*, *4*(2), 269. https://doi.org/10.1504/IJEM.2007.013994

Jones, H., & Twiss, B. C. (1978). *Forecasting technology for planning decision*. PBI.

Kaly, U., Briguglio, L., Mcleod, H., Schmall, S., Pratt, C., & Pal, R. (1999). *Environmental Vulnerability Index (EVI) to summarise national environmental vulnerability profiles*.

Kang, J. E. (2009). *Mitigating flood loss through local comprehensive planning in Florida*. *ProQuest Dissertations and Theses*. Retrieved from https://pallas2.tcl.sc.edu/login?url=http://search.proquest.com/docview/305118255?accountid=13965\nhttp://www.tdnet.com/uscc/resolver/default.asp?genre=article&issn=&volume=&issue=&title=Mitigating+flood+loss+through+local+comprehensive+planning+in+Florid

Kates, R. W. (1985). The Interaction of Climate and Society. In *Climate Impact Assessment: Studies of the interaction of Climate and Society (SCOPE Series)* (pp. 3–36). Retrieved from http://rwkates.org/pdfs/a1985.01.pdf

Keeney, S., Hasson, F., & McKenna, H. (2006). Consulting the oracle: Ten lessons from using the Delphi technique in nursing research. *Journal of Advanced Nursing*, *53*(2), 205–212. https://doi.org/10.1111/j.1365-2648.2006.03716.x

Khan, F. A., & Salman, A. (2012). A simple human vulnerability index to climate change hazards for Pakistan. *International Journal of Disaster Risk Science*, *3*(3), 163–176. https://doi.org/10.1007/s13753-012-0017-z

Khan, S. (2012). Vulnerability assessments and their planning implications: A case study of the Hutt Valley, New Zealand. *Natural Hazards*, *64*(2), 1587–1607. https://doi.org/10.1007/s11069-012-0327-x

Kron, W. (2009). Flood insurance: From clients to global financial markets. *Journal of Flood Risk Management*, *2*(1), 68–75. https://doi.org/10.1111/j.1753-318X.2008.01015.x

Kumpulainen, S. (2006). Vulnerability concepts in hazard and risk assessment. *Special Paper of the Geological Survey of Finland*, (42), 65–74.

Kundzewicz, Z. W., & Menzel, L. (2005). Natural flood reduction strategies – a challenge. *International Journal of River Basin Management*, *3*(2), 125–131. https://doi.org/10.1080/15715124.2005.9635252

Leary, R. A. O., Choy, S. L., Murray, J. V, Kynn, M., Denham, R., Martin, T. G., & Mengersen, K. (2009). Comparison of three expert elicitation methods for logistic regression on predicting the presence of the threatened brush-tailed rock-wallaby Petrogale penicillata, (October 2007), 379–398. https://doi.org/10.1002/env

Lee, G., Jun, K. S., & Chung, E. S. (2013). Integrated multi-criteria flood vulnerability approach using fuzzy TOPSIS and Delphi technique. *Natural Hazards and Earth System Science*, *13*(5), 1293–1312. https://doi.org/10.5194/nhess-13-1293-2013

Lee, H.-S. L. H.-S. (2001). Aggregation of fuzzy opinions under group decision making\nenvironment. *10th IEEE International Conference on Fuzzy Systems. (Cat. No.01CH37297)*, *1*, 279–285. https://doi.org/10.1109/FUZZ.2001.1007275

Leedy, P. D., & Ellis, J. O. (2001). *Practical research planning and design*.

Lein, James K., and L. E. A. (2010). Hazard vulnerability assessment: How well does nature follow our rules? *Environmental Hazards*, *9*(2), 147–166.

Linstone, Harold A., and M. T. (2002). The Delphi Method. *Techniques and Applications*.

Linstone, H. A., & Turoff, M. (2002). The Delphi Method - Techniques and applications. *The Delphi Method - Techniques and Applications*, 1–616. https://doi.org/10.2307/1268751

Liu, A. M., & Fellows, R. (2008). Behaviour of quantity surveyors as organizational citizens. *Construction Management and Economics*, *26*(12), 1271–1282.

Marsalek, J., Rochfort, Q., Brownlee, B., Mayer, T., & Servos, M. (1999). An exploratory study of urban runoff toxicity. *Water Science and Technology*, *39*(12), 33–39.

Mclaughlin, S., & Cooper, J. A. G. (2010). A multi-scale coastal vulnerability index: A tool for coastal managers? *Environmental Hazards*, *9*(3), 233–248. https://doi.org/10.3763/ehaz.2010.0052

Menoni, Scira, and F. P. (1996). An attempt to link risk assessment with land use planning: a recent experience in Italy." : An International Journal 5.1 (1996): 6-21. *Disaster Prevention and Management*, *5*(1), 5–6.

Merriman, P. A.,; Browitt, C. W. A. (1993). *Natural disasters: protecting vulnerable communities*.

Michela Nardo, Michaela Saisana, A. S. & S. T. (2005). *Tools for Composite Indicators Building Prepared*. *European Communities*. https://doi.org/10.1038/nrm1524

Mileti, D. (1999). *Disasters by Design: A Reassessment of Natural Hazards in the United States*. Joseph Henry Press.

Ministry of Natural Resources and Environment. (2007). Flood and Drought Management in Malaysia. Putra Jaya.

Morse, S. (2013). *Indices and Indicators in Development: An Unhealthy Obsession with Numbers?* https://doi.org/10.4324/9781849771719

Muller, A., Reiter, J., & Weiland, U. (2011). Assessment of urban vulnerability towards floods using an indicator-based approach-a case study for Santiago de Chile. *Natural Hazards and Earth System Sciences*, *11*(8), 2107–2123. https://doi.org/10.5194/nhess-11-2107-2011

Murray, Thomas J., Leo L. Pipino, and J. P. van G. (1985). A pilot study of fuzzy set modification of Delphi. *Human Systems Management*, *5*(1), 76–80.

Murry, J., & James, H. (1995). Delphi: A Versatile Methodology for Conducting Qualitative Research. *The Review of Higher Education*, *18*(4), 423–436.

Mustafa, D., Ahmed, S., Saroch, E., & Bell, H. (2011). Pinning down vulnerability from narratives to numbers. *Disasters*, *35*(1), 62–86.

Næss, L. O., Norland, I. T., Lafferty, W. M., & Aall, C. (2006). Data and processes linking vulnerability assessment to adaptation decision-making on climate change in Norway. *Global Environmental Change*, *16*(2), 221–233. https://doi.org/10.1016/j.gloenvcha.2006.01.007

Nardo, M., Saisana, M., Saltelli, A., Tarantola, S., Hoffman, A., & Giovannini, E. (2008). Handbook on Constructing Composite Indicators: Methodology and User Guide. *Methodology*, *3*, 162. https://doi.org/10.1787/9789264043466-en

Nasir, S. R. M. (2015). Perspective of Stakeholders on Flash Flood in Kuala Lumpur. *Springer Singapore*, 51–63.

Nasiri, H., Mohd Yusof, M. J., & Mohammad Ali, T. A. (2016). An overview to flood vulnerability assessment methods. *Sustainable Water Resources Management*. https://doi.org/10.1007/s40899-016-0051-x

Nasiri, H., & Shahmohammadi-kalalagh, S. (2013). Flood vulnerability index as a knowledge base for flood risk assessment in urban area. *Journal of Novel Applied Sciences*, *2*(8), 269–272.

Niemeijer, D. (2002). Developing indicators for environmental policy: Data-driven and theory-driven approaches examined by example. *Environmental Science and Policy*, *5*(2), 91–103. https://doi.org/10.1016/S1462-9011(02)00026-6

Nyeko, M. (2012). GIS and multi-criteria decision analysis. *CAB AbstractsJournal of Geographic Information System; 2012*, *4*(4), 341–348.

O’Keefe, P., Westgate, K., & Wisner, B. (1976). Taking the naturalness out of natural disasters.le. *Nature*, (260), 566–567.

Osborne, J., Collins, S., Ratcliffe, M., Millar, R., & Duschl, R. (2003). What “ideas-about-science” should be taught in school science? A delphi study of the expert community. *Journal of Research in Science Teaching*, *40*(7), 692–720. https://doi.org/10.1002/tea.10105

Pandey, A. C., Singh, S. K., & Nathawat, M. S. (2010). Waterlogging and flood hazards vulnerability and risk assessment in Indo Gangetic plain. *Natural Hazards*, *55*(2), 273–289. https://doi.org/10.1007/s11069-010-9525-6

Parliament, E., & Committee, S. (2007). DIRECTIVE 2007/60/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL. *Official Journal of the European Union*, (2455), 27–34.

Parris, T. M., & Kates, R. W. (2003). Characterizing and measuring sustainable development. *Annual Review of Environment and Resources*, *28*(1), 559–586.

Parris, T.M., Kates, R. W. (2003). Characterizing and measuring sustainable development. Annu. Rev. Environ. Resour., 28, 559. *Annual Review of Environment and Resources*, *28*(1), 559–586.

Patro, S. G. K., & Sahu, K. K. (2015). Normalization: A Preprocessing Stage, 4. Retrieved from http://arxiv.org/abs/1503.06462

Peduzzi, P., Dao, H., Herold, C., Mouton, F., & Rochette, D. (2001). *Feasibility Study Report On Global Risk And Vulnerability Index Trends per Year (GRAVITY)*. Geneva, Switzerland.

Pelling, M. (2012). *The vulnerability of cities: natural disasters and social resilience*. Earthscan.

Pelling et al., M. (2004). *Reducing Disaster Risk A Challenge For Development*. *United Nations Development Programme - Bureau for Crisis Prevention and Recovery*. https://doi.org/10.1007/s003450050172

Plate, E. J. (2002). Flood risk and flood management. *Journal of Hydrology*, *267*(1–2), 2–11. https://doi.org/10.1016/S0022-1694(02)00135-X

Queste, A. and Lauwe, P. (2006). User needs: Why we need indicators. In *Measuring Vulnerability to Natural Hazards: towards disaster resilient societies* (pp. 103–114).

R.F.Connor;K.Hiroki. (2005). Development of a Method for Assessing. *Water Science and Technology*, *5*(August), 61–67.

Rashed, T., & Weeks, J. (2003). Assessing vulnerability to earthquake hazards through spatial multicriteria analysis of urban areas. *International Journal of Geographical Information Science*, *17*(6), 547–576. https://doi.org/10.1080/1365881031000114071

Renkema, T. J. W., & Berghout, E. W. (2002). Guidelines for Reducing Flood Losses. *Development*, *39*, 79. Retrieved from http://www.unisdr.org/eng/library/isdr-publication/flood-guidelines/Guidelines-for-reducing-floods-losses.pdf

Rosenthal, U., & T'Hart, P. (2012). *Flood response and crisis management in Western Europe: a comparative analysis*. Springer Science & Business Media. Retrieved from http://books.google.co.uk/books?hl=en&lr=&id=KVABCAAAQBAJ&oi=fnd&pg=PT8&dq=personal+crisis+management&ots=PNvJ2f0LlX&sig=UbbKAIxA7LpQQnLsrllSQn18IrY

Rowe, G., & Wright, G. (1999). The Delphi technique as a forecasting tool: issues and analysis. *International Journal of Forecasting*, *15*, 353–375. https://doi.org/10.1016/S0169-2070(99)00018-7

Rowe, G., & Wright, G. (2001). Expert opinions in forecasting: The role of the Delphi technique. *International Series in Operations Research & Management Science*. https://doi.org/10.1016/j.accreview.2004.12.084

Saaty, T. L. (2013). The analytic network process. *Decision Making with the Analytic Network Process*, *195*, 1–40. https://doi.org/10.1007/978-1-4614-7279-7_1

Saisana, M., Saltelli, A., & Tarantola, S. (2005). Uncertainty and sensitivity analysis techniques as tools for the quality assessment of composite, 307–323.

Saisana, M., Tarantola, S., & Saltelli, A. (2005). Uncertainty and sensitivity analysis techniques as tools for the quality assessment of composite indicators. *Journal of the Royal Statistic Society*, *168*(2), 307–323.

Salant, P., Dillman, I., & Don, A. (1994). *How to conduct your own survey*.

Samuels, P. (2006). A European perspective on current challenges in the analzsis of inland flood risks, (March 2000), 21–34. Retrieved from http://dx.doi.org/10.1007/978-1-4020-4598-1_2

Schanze, J., Zeman, E., & Marsalek, J. (Eds. . (2007). *Flood risk management: hazards, vulnerability and mitigation measures*. Springer Science & Business Media.

Schanze, J. (2006). Flood Risk Management – a Basic Framework. *Flood Risk Management: Hazards, Vulnerability and Mitigation Measures*, *67*, 1–20. https://doi.org/10.1007/978-1-4020-4598-1_1

Sharma, B.A.V., Prasad, D. R. & S. P. (1984). *Research methods in Social Sciences* (First Edit). New Delhi: Sterling Publishers Private Limited.

Sharma, D. (2012). Situation analysis of flood disaster in South and Southeast Asia-A need of integrated approach. *Int J Sci Environ Techno*, *1*, 167–173.

Shuid, S. (2004). Low Medium Cost Housing in Malaysia: Issues and Challenges. , *International Islamic University Malaysia. Cost-Housing*, 1–13. Retrieved from http://www.frejaprogram.org/www1/Malaysia_low cost housing.pdf

Smit, B., & Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Global Environmental Change*, *16*(3), 282–292. https://doi.org/10.1016/j.gloenvcha.2006.03.008

Smith, K. (2013). *Environmental hazards: assessing risk and reducing disaster*. Routledge.

Somerville, J. A. (2008). Delphi Characteristics, (2007), 1–11.

Steenbergen, M. R., & Marks, G. (2007). Evaluating expert judgments, *2006*, 347–366. https://doi.org/10.1111/j.1475-6765.2006.00694.x

Strauss, Harlan J., and L. H. Z. (1975). The Delphi Technique and Its Uses In Social Science Research. *The Journal of Creative Behavior*, *9*(4), 253–259.

Sullivan, C. (2002). Calculating a Water Poverty Index. *World Development*, *30*(7), 1195–1210. https://doi.org/10.1016/S0305-750X(02)00035-9

Sullivan, C. a, Meigh, J. R., Giacomello, a M., Fediw, T., Lawrence, P., Samad, M., … Steyl, I. (2003). The water poverty index: Development and application at the community scale. *Natural Resources Forum*, *27*, 189–199. https://doi.org/10.1111/1477-8947.00054

Sullivan, C., & Meigh, J. (2005). Targeting attention on local vulnerabilities using an integrated index approach: The example of the climate vulnerability index. *Water Science and Technology*, *51*(5), 69–78.

Sullivan, C., Meigh, J., & Lawrence, P. (2006). Application of the Water Poverty Index at Different Scales: A Cautionary Tale. *Water International*, *31*(3), 412–426. https://doi.org/10.1080/02508060608691942

Takemoto, S. (2011). Moving towards climate-smart flood management in bangkok and tokyo.

Tapsell, S. M., Penning-Rowsell, E. C., Tunstall, S. M., & Wilson, T. L. (2002). Vulnerability to flooding : health and social dimensions. *Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences*, *360*(1796), 1511–1525. https://doi.org/10.1098/rsta.2002.1013

Timmerman, P. (1981). Timmerman1981.pdf. In *Vulnerability, resilience and the collapse ofsociety. A ReviewofModels and Possible Climatic Appli-cations.* Toronto: Institute for Environmental Studies, University of Toronto.

Tingsanchali, T. (2012). Urban flood disaster management. In *Procedia Engineering* (Vol. 32, pp. 25–37). https://doi.org/10.1016/j.proeng.2012.01.1233

Turner, B. L., Kasperson, R. E., Matson, P. A., McCarthy, J. J., Corell, R. W., Christensen, L., … Schiller, A. (2003). A framework for vulnerability analysis in sustainability science. *Proceedings of the National Academy of Sciences of the United States of America*, *100*(14), 8074–8079. https://doi.org/10.1073/pnas.1231335100

Tyshenko, M. G., ElSaadany, S., Oraby, T., Darshan, S., Aspinall, W., Cooke, R., … Krewski, D. (2011). Expert elicitation for the judgment of prion disease risk uncertainties. *Journal of Toxicology and Environmental Health - Part A: Current Issues*, *74*(2–4), 261–285. https://doi.org/10.1080/15287394.2011.529783

UNISDR. (2009). UNISDR Terminoology on Disaster Risk Reduction. *International Stratergy for Disaster Reduction (ISDR)*, 1–30. Retrieved from www.unisdr.org/publications

UNISDR. (2015). *Sendai Framework for Disaster Risk Reduction 2015 - 2030*.

United nations. (1982). *Proceedings of the Seminars on Flood Vulnerability Analysis and on the Principles of Floodplain Management for Flood Loss Prevention*. Bangkok.

United Nations. (2005). International Strategy for Disaster Reduction Hyogo Framework for Action 2005-2015: Building the Resilience of Nations. *World Conference on Disaster Reduction (A/CONF.206/6)*, 25.

Van Der Veen, A., & Logtmeijer, C. (2005). Economic hotspots: Visualizing vulnerability to flooding. *Natural Hazards*, *36*(1–2), 65–80. https://doi.org/10.1007/s11069-004-4542-y

Villagrán De León, J. C. (2006). *Vulnerability: A conceptual and methodological review*. *SOURCE "Studies of the University: Research,Counsel,Education" Publication Series of UNU-EHS*. Tokyo, Japan.: United Nations University—EHS,. Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Vulnerability:+A+conceptual+and+methodological+review#0

Vincent, K. (2004). Creating an index of social vulnerability to climate change for Africa. *Change*, *56*(August), 41. Retrieved from http://www.tyndall.ac.uk/publications/working_papers/wp56.pdf

Whitman, N. I. (1990). The Committee Meeting Alternative; Using the Delphi Technique. *Journal of Nursing Administration*, *20*(7–8), 30–36.

Whitman, N. I. (1990). The Committee Meeting Alternative Using the Delphi Technique. *JONA*, (20), 30–36.

Wikipedia. (2013). Expert elicitation. *SUmmer SCHOOL*, *74*(July 2012), 1–16. Retrieved from http://en.wikipedia.org/wiki/Expert_elicitation

Wind, Y., & Saaty, T. L. (1980). Marketing Applications of the Analytic Hierarchy Process. *Management Science*. https://doi.org/10.1287/mnsc.26.7.641

Wong, I. F. T. (1970). Reconnaissance Soil Survey of Selangor.

Wu, K. Y. (2011). Applying the fuzzy Delphi method to analyze the sustainable neighborhood unit evaluation factors (pp. 23–28).

Wu, S. Y., Yarnal, B., & Fisher, A. (2002). Vulnerability of coastal communities to sealevel rise: a case study of Cape May county, New Jersey, USA. *Climate Research*, *22*(Ipcc 1996), 255–270. Retrieved from http://www.ccpo.odu.edu/~atkinson/ODUResearch/papers/wu_et_al\n__2002_New_Jersey1.pdf

Xu, C., & Gertner, G. Z. (2008). A general first-order global sensitivity analysis method. *Reliability Engineering & System Safety*, *93*(7), 1060–1071. https://doi.org/10.1016/j.ress.2007.04.001

Zahran, S., Brody, S. D., Peacock, W. G., Vedlitz, A., & Grover, H. (2008). Social vulnerability and the naturaland built environment: a model offlood casualties in Texas. *Overseas Development Institute, USA*, *32*(4), 537–560. https://doi.org/10.1111/j.0361-3666.2008.01054.x

Zhang, H., Li, H., & Tam, C. M. (2004). Fuzzy discrete event simulation for modeling uncertain activity duration. *Engineering, Construction and Architectural Management*, *11*(6), 426–437. https://doi.org/10.1108/09699980410570184

Zhou, H., & Al, E. (2010). Resilience to Natural HAzards: A Gegraphic Perspective. *Natural Hazards*, *53*(1), 21–41.