DEVELOPMENT OF COMMERCIAL FLOOD DEPTH-DAMAGE CURVE FOR KUANTAN, PAHANG

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ABSTRAK

Banjir mendatangkan konsekuensi yang buruk kepada komuniti dan individu. Seperti yang sedia maklum, kesan langsung banjir termasuk kehilangan nyawa, kerosakan harta benda, kemusnahan tanaman, kehilangan ternakan, dan kemerosotan kesihatan akibat penyakit air. Impak banjir biasanya dinilai melalui penilaian kerentanan akibat banjir. Walaubagaimanapun, di Malaysia kajian kerentanan akibat banjir adalah terhad terutama dari aspek anggaran kerosakan banjir. Oleh itu, tujuan utama kajian ini adalah untuk menganggar kerosakan banjir yang dialami pada tahun 2013 di Kuantan. Tinjauan temubual telah dijalankan untuk mengumpul maklumat kerosakan. Analisis regresi telah dijalankan bagi mengenalpasti faktor-faktor yang mempengaruhi tahap kerosakan dan satu lengkung kedalaman-kerosakan banjir telah dihasilkan bagi menggambarkan hubungan di antara tahap kerosakan (dalam peratusan) melawan tinggi air banjir. Peratusan kerosakan dikira dengan membahagikan kerosakan sebenar dengan anggaran kerosakan. Keputusan menunjukkan kerosakan isi premis adalah lebih tinggi berbanding kerosakan struktur. Purata kerosakan isi premis bagi premis dua tingkat ialah RM42,971 berbanding RM5,609 kerosakan struktur. Manakala kerosakan premis satu tingkat adalah lebih rendah iaitu RM23,103 (isi premis) dan RM4,161 (struktur). Berdasarkan jenis perniagaan, kerosakan isi premis bagi perniagaan barangan dan servis adalah lebih tinggi (RM35,974) berbanding perniagaan makanan dan minuman (RM11,813). Kerosakan struktur bagi kedua-dua kategori perniagaan adalah lebih rendah iaitu masing-masing adalah RM5,063 dan RM5,609. Dari analisis regresi didapati pendapatan perniagaan dan jenis perniagaan mempengaruhi kadar kerosakan isi premis, manakala kerosakan struktur hanya dipengauhi oleh aras premis. R^2 yang diperolehi bagi lengkung kerosakan-kedalaman banjir yang dihasilkan adalah baik iaitu 0.91 dan 0.86 masing-masing bagi kerosakan isi premis dan kerosakan struktur dan boleh digunakan untuk kajian penilaian risiko banjir di kawasan kajian pada masa depan.

ABSTRACT

Floods caused great consequences to communities and individuals. As most people are well aware, the immediate impacts of flooding include loss of life, damage to property, destruction of crops, loss of livestock, and deterioration of health conditions owing to waterborne diseases. The consequences of flooding are normally assessed by flood vulnerability assessment. However, in Malaysia, the studies on flood vulnerability are limited especially on flood damage. Therefore, the main purpose of this study is to assess flood damage during the 2013 Kuantan flood. Interview survey was conducted to collect the damage information. The regression analysis was performed to determine the factors that effects the level of flood damage and a depth-damage curve was developed to show the relationship between the damage in percentage and flood depth. The percentage of damage was obtained by dividing the actual damage with estimated damage. The result shows that content damage is higher than structural damage. The average content damage for two level premises is RM42,971, compared to RM5,609 for structural damage. While content damage for single level premises is lower which is RM23,103 (content) and RM4,161 (structural). According to the type of business, good & services content damage is higher (RM35,974) compared to food and beverages (RM11,813). The structural damage for both business category is lower which is RM5,063 and RM5,609 respectively. Regression analysis shows that business income and type of business are the variables that effects the level of content damage, while the structural damage was influenced only by the level of building. The R^2 for flood depth-damage curve is good enough which are 0.91 and 0.86 for content and structural damage respectively and can be used for future studies on flood risk assessment at the study area.

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LIST OF SYMBOLS

%	Percentage

LIST OF ABBREVIATIONS

TRMM	Tropical Rainfall Measuring Mission
JAXA	The Japan Aerospace Exploration Agency
RF	Random Forest
AHP	Analytic hierarchy process
SPA	Set pair analysis
FCE	Fuzzy comprehensive evaluation
RM	Ringgit Malaysia
PRB	Pahang River Basin
Sig.	Significant
KRB	Kuantan River Basin
IWUMD	Irrigation and Water Utilization Management Department

CHAPTER 1

INTRODUCTION

1.1 Introduction

Flooding is natural hazard that happen without exception. Natural hazards vary in magnitude and intensity in time and space (Tsakiris, 2014). Flood catastrophe widely gives huge impact towards life and property (Balica et al., 2013). The heavy rainfall, ice melting, high tide and blocked drain can cause the arise of water from river, lake and drainage systems (Fallis, 2013). There are few types of flood which are coastal flooding, river flooding, flash flood, groundwater flood and drainage and sewer flood (Dachalan, 2014).

The flood share common nature i.e. the potential to wreak havoc (Dachalan, 2014). This flood cause enormous economic damages and human suffering (A. K. Pistrika & Jonkman, 2010) and also leads to loss of life (Miller et al., 2015). However, according to Fallis (2013), flood gives few benefits towards agricultures and earth. Flood can nourish the soils where agriculture can take place and natural plants can growth (Fallis, 2013).

According to D/iya et al. (2014) there are two types of flood happen in Malaysia which are flash flood and monsoon flood. This types of flood distinguish by the time to recede to the normal level (D/iya et al., 2014). In Malaysia there are a few flood prone areas according to Dachalan (2014). East coast peninsular of Malaysia experienced the northeast monsoon that occurs between October and March (D/iya et al., 2014). According to Lang (2019), heavy rain lasting on the order of a few days are common during the northeast monsoon.

Many flood mitigation options have been adopted to mitigate the impact of flooding. Nowadays, the non-structural flood mitigation measures such as flood modelling, flood warning system and flood risk assessment have been given more attention compared to structural works (Romali et al., 2018). In Malaysia, the risk of flooding is normally presented in term of its hazard e.g. flood inundation and flood extend map. The risk of flooding in terms of flood consequences is rarely assessed. Hence, the assessment of flood vulnerability is compelling to mitigate the impacts of flooding. The lack of study in vulnerability assessment gives minimum information about flood damage. In fact, flood damage estimation is the important element in the assessment of flood vulnerability.

1.2 Problem Statement

Kuantan River Basin (KRB) is one of the flood prone area in Pahang. Pahang was severely hit by the 2013 flood where almost 6000 household were affected (Star, 2013). According to Sean (2019) the worst hit district was Kuantan with 4,148 victims. Many flood hazard assessment works had been done at KRB, however, to date no flood vulnerability assessment is available.

Flood damage is essential in flood vulnerability assessment where it is needed in the development of flood risk mapping, risk analysis comparison and financial appraisals. However, conducting flood damage assessment in developing countries is challenging due to the limitation of data. The historical data is not available and collecting flood damage data is hard due to the lack of cooperation from respondent during the interview especially among commercial sector. It is difficult to meet personally with the owner of the building/shop as the shops are normally attended by the shop attendant but the information about the flood event was known by the business's owner.

As the assessment of flood damage within the commercial sector has not gained much attention so far, hence the main aim of this study is to assist in the commercial flood vulnerability assessment at Kuantan River Basin. The damage experienced by the commercial sector during the 2013 flood was assessed and the factors that effects the level of damages at the study area was identified. A commercial flood depth-damage curve was developed. The information of flood damages obtained in this study may be useful to assist engineer and local authorities in the further flood risk management works in minimizing the risk of damages caused by flood.

1.3 Objectives:

The objective of this study are:

1. To assess the commercial flood damages of 2013 Kuantan flood.
2. To study the relationship between flood damages and socio-economic/property characteristics of the study area.
3. To establish a commercial flood depth-damage curve for Kuantan.

1.4 Scope and limitation of study

The study was conducted in Kuantan, Pahang. Kuantan was being chosen as the study area due to its potential as the future hub of trade centres in Pahang. The commercial properties along the Kuantan's river was selected as the sampling area for interview survey during the data collection. The damage category assessed in this study is direct tangible damage, selected due to the limitation of damage data. This study focuses on the structural and content damage of properties, for commercial categories only.

1.5 Significance of study

The assessment of flood damages through interview survey is important in flood risk assessment to obtain the real picture of the damage that experienced by the commercial properties during the 2013 Kuantan flood. The identification of factors that influenced the level of flood damages is essential to study the effect of local condition of the study area to the flood damage. The flood depth-damage curve shows the relationship between the flood damage and the flood depth is needed in the modelling of flood damage.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Flood management is essential to minimize the damage towards human and economic loss. The management of flood does not abolish the flood, only for mitigate (Tingsanchali, 2012). To implement the flood risk management, there are few steps mention by PLANMalaysia dan Majlis Perbandaran Kuantan (2017) on affected areas. Therefore, it is important to understand the effectiveness of the flood reduction measures before any structures being builds. Flood mitigation is distinguished into two groups; structural and non-structural.

Structural mitigation where the physical structure constructed to minimize the damages towards flooding areas and stagnant water. In order to construct the structure, it is important to understand the individual measure in terms of flood mitigation. The examples of structural flood defences are dikes, dams and flood control reservoirs, diversions, and flood ways (Merz et al., 2010). All of them are the most used structural flood mitigation all over the world.

Non-structural flood mitigation is also considered as a set of mitigation in small scale to minimize the impact of flood without effecting the current flood event. This method is an adaptation to mitigate flood to enhance the efficiency of flood mitigation. It is consist of flood management measures such as flood modelling, flood assessments, zoning source control, and flood awareness (Menzel & Kundzewicz, 2015). Therefore, non-structural measures are considered as important as structural measures in flood mitigation.

2.2 Classification of flood in Malaysia

Flood is define as the overflow of water that influences the natural or artificial banks in any parts of the river systems (D/iya et al., 2014). Chinh et al. (2017) mentioned that flood exposure and susceptibility increase due to population growth, rapid socio-economic development, and urbanization. Flood risk also happen cause by uncontrolled urbanization and a low capacity of the drainage infrastructure (Chinh et al., 2017).

According to D/iya et al. (2014) there are 189 river basins throughout Malaysia included Sabah and Sarawak. Unfortunately, 89 of them are prone to experience flood. There are approximately 29,800 km² or 9% of the total Malaysia area, and is affecting almost 4.82 million people which is around 22% of the total population of the country are vulnerable to flood disaster (D/iya et al., 2014).

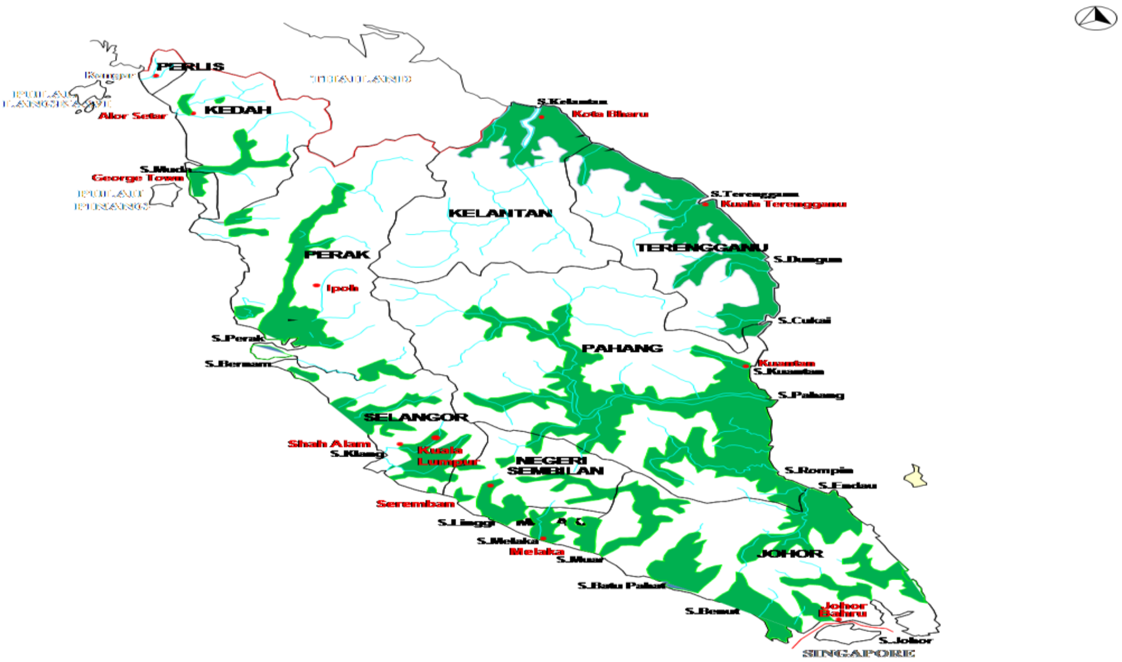

Figure 2.1 Flood prone areas in Peninsular Malaysia

Source: Fallis (2013)

Flood is the most destructive natural hazard that happen in Malaysia. Flood event gives awful burden towards people as it disrupts their day to day activities and the burdens can last for a week in the coming years, climate change is likely to make the situation even more challenging. In this country, the flood is distinguish into two groups: flash flood and monsoon floods (D/iya et al., 2014).

Figure 2.1 shows flood prone areas in Peninsular Malaysia while Figure 2.2 shows flood prone areas in Sabah and Sarawak. Pahang is the most devastated state during the 2013 flood where Kuantan was hit the most with 4,148 victims, followed by Rompin (3,615), Pekan(2,716), Maran (1,179) and Jerantut (63) (Sean, 2013)

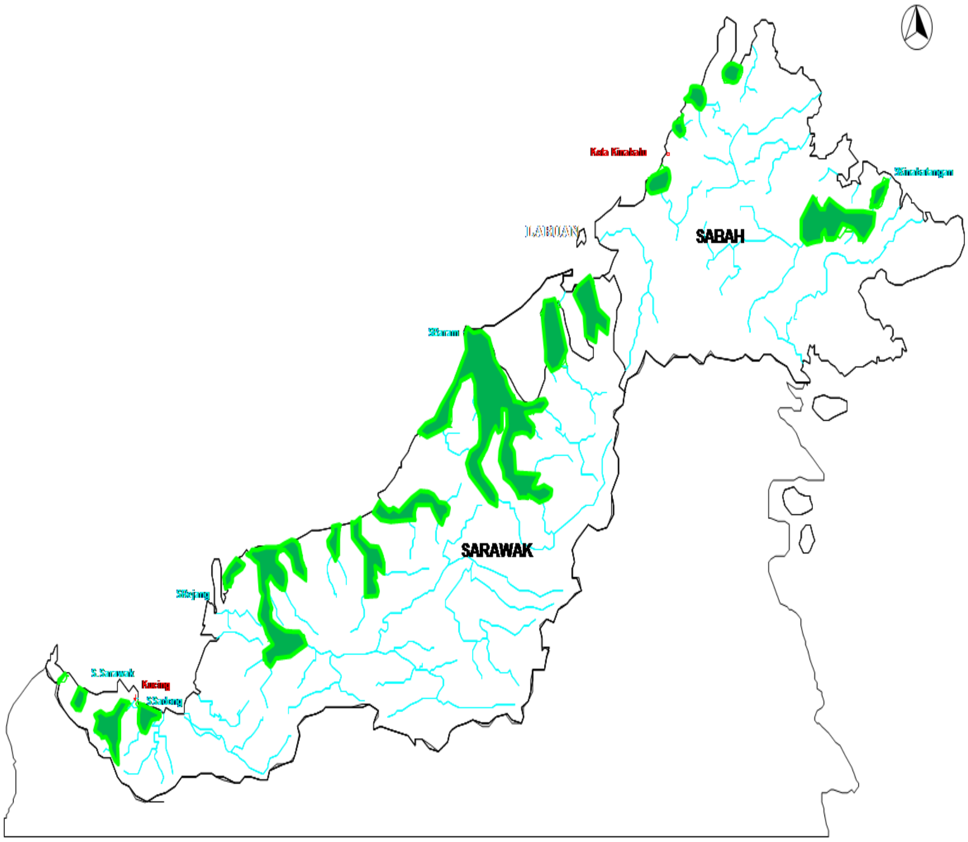

Figure 2.2 Flood prone areas in Sabah and Sarawak

Source: Fallis (2013)

2.2.1 Flash flood

Flash flood is defined as the sudden rise in water level due to malfunction of drainage systems. This flood normally happened in urban areas. According to D/iya et al. (2014), the climate changes is the factor of flash flood. Flash flood always happen in cities such as Klang Valley where rapid development take place due to the incompetent urban drainage system. The increases of land use also increases the risk and exposure of flood damages towards urban residents.

The low-income residents in the flood-plain area severely affected due to low-income and with minimal income they only afford small scale of flood mitigation to reduce the impact (D/iya et al., 2014). This heavy rain caused by the wind that flow through South China Sea bringing in plentiful moisture (Lang, 2019). Figure 2.3 shows TRMM image by NASA and the Japanese space agency JAXA.Source.

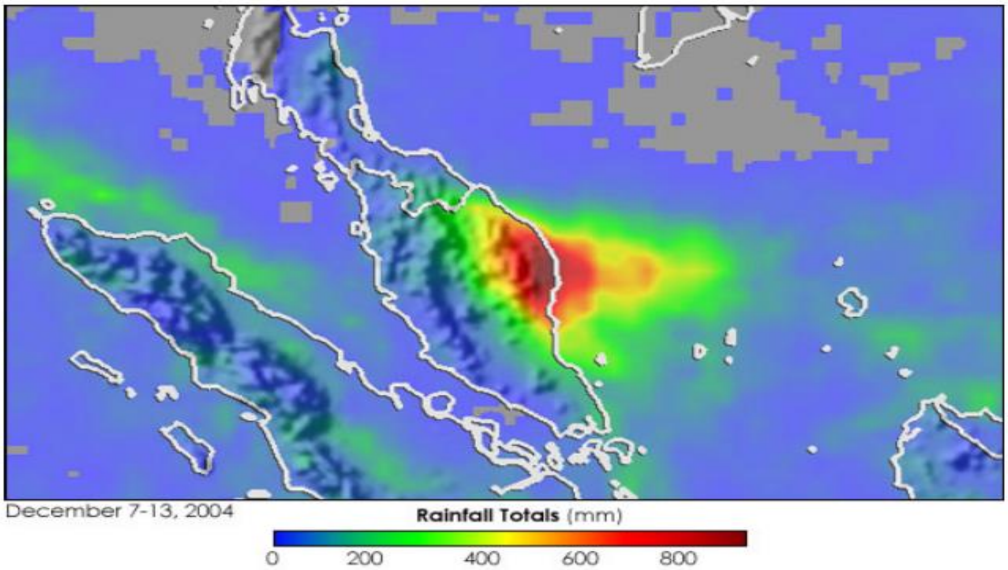

Figure 2.3 TRMM image by NASA and the Japanese space agency JAXA

Source: Lang (2019)

2.2.2 Monsoon flood

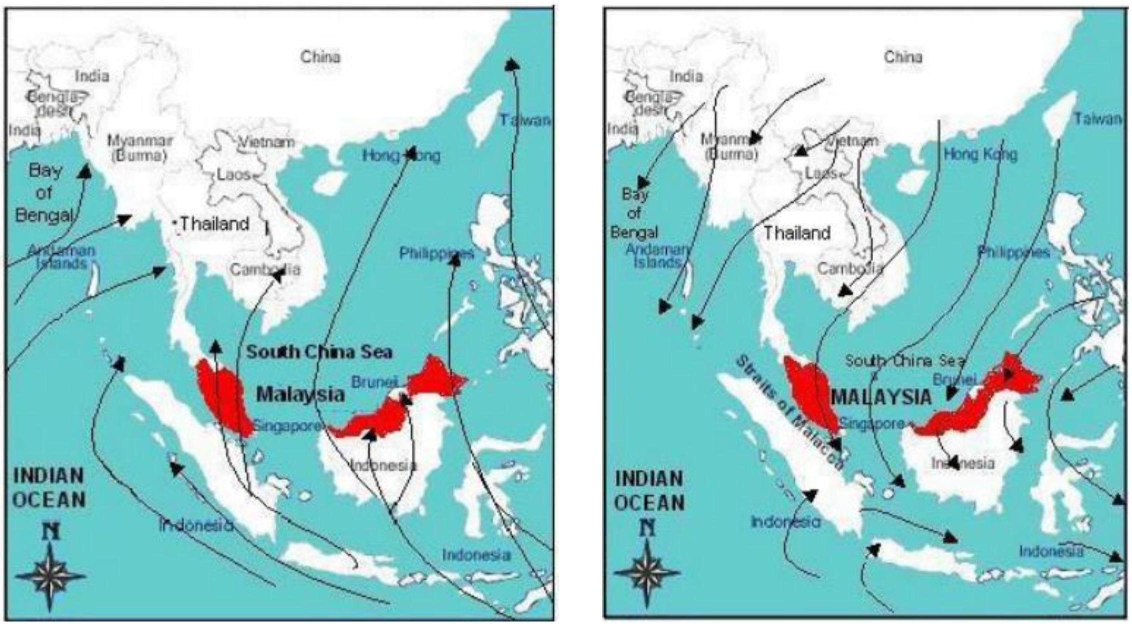

Figure 2.4 Southwest and Northeast Monsoon

Source: D/iya et al. (2014)

Malaysia rainfall influenced by this two groups of monsoon: the South west and the North east Monsoons (D/iya et al., 2014). Figure 2.4 show the southwest monsoon and the northeast monsoon. North east monsoon happen between October and March. Monsoon flood is caused by the heavy rain event that pour for a few days (Lang, 2019). Due to northeast monsoon the east coast of Malaysia such as Terengganu always experience flood event especially during November and December (D/iya et al., 2014)

2.3 Flood risk assessment

Risk can be related to probability and consequence (Balica et al., 2013), as shown in Equation (2.1):

$$Risk = Probability \ x \ Consequences \qquad (2.1)$$

This concept of flood risk mainly focused on probability a high flow event of a given magnitude occurs, that results in consequences which span environmental, economic and social losses effected by the event. Flood risk consist of the identification, quantification and evaluation of risk (Miller et al., 2015).

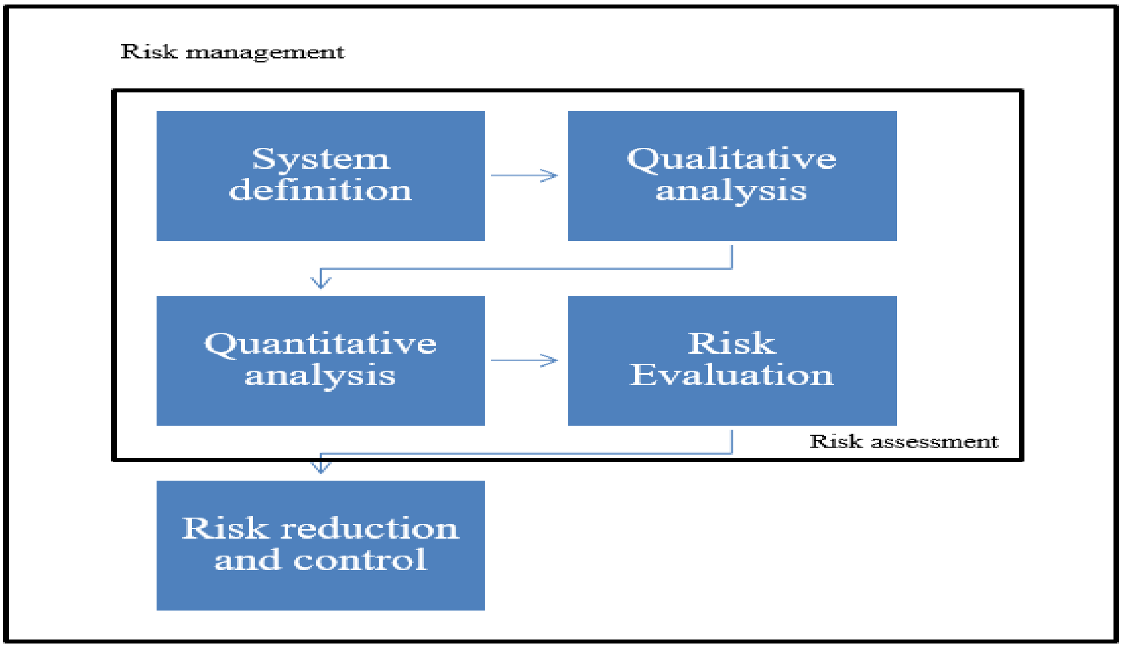

Figure 2.5 A framework to assess the flood risk
Source: Miller et al. (2015)

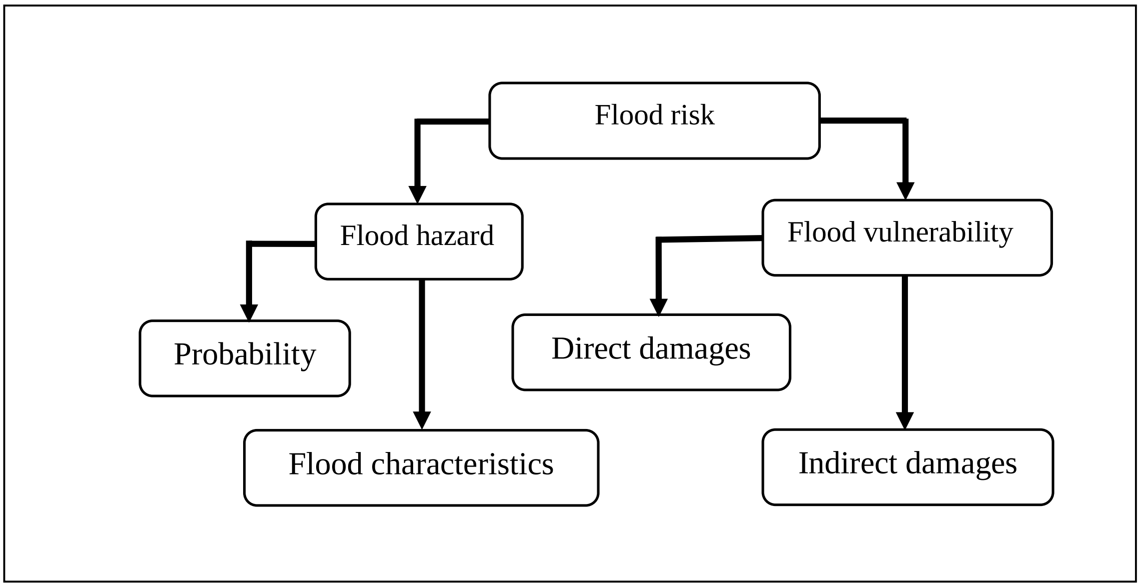

Figure 2.6 Framework to access flood risk

Source: Olesen et al. (2017)

Risk analysis gives a rational basis for flood management (Hall et al., 2009). Flood risk assessment can provide information at national-scale as well as regional and local to support the development of flood management policy (Hall et al., 2009). Flood risk assessment is flood management in flood mitigation parts. It can be distinguished into two parts: hazard and vulnerability (Romali et al., 2018). In assessing hazards, the extension of flood and magnitude commonly being used, whereas in the vulnerability part the future outcomes of the flooding to the unprotected element such as properties, human being, goods and environment.

In order to lessen the impact of the flood, flood risk management approach is essential to support flood mitigation. Recent action taken was risk-based mitigation where focus on non-structural approach (Romali et al., 2018). The flood risk assessment is a method to estimate the possible outcomes of the flood. Flood risk is distinguished into two groups: hazard and damage (Zhou et al., 2012). A framework to assess the flood risk has been proposed by Olesen et al. (2017) and Miller et al. (2015), presented in the Figure 2.5 and Figure 2.6 respectively.

2.3.1 Flood hazard assessment

Flood hazard is distinguish as the measure of total, range, and areas of flooding contemplate to happen with a specific return period (Olesen et al., 2017). The purpose of flood hazard is to obtain accurate risk levels (Wang et al., 2015). Hazard assessment interpreted to deliver flood extend and damages outcome (Vorogushyn et al., 2010). Flood hazard risk assessment is significance to ensure the health and sustainability of human society (Wang et al., 2015).

Disaster-inducing factor and hazard-inducing environment are the influences combine in hazard assessment (Wang et al., 2015). However, the difficulty happens if the multi-variable and non-linear relationship between indices and risk level (Wang et al., 2015). Therefore, few methods being adopt to solve the problems, which are analytic hierarchy process (AHP), set pair analysis (SPA), and fuzzy comprehensive evaluation (FCE) (Wang et al., 2015). Figure 2.7 show the example of flood hazard risk assessment map (eleven indices) based on Random Forest.

Vorogushyn et al. (2010) in their Inundation Hazard Assessment Model (IHAM) shown in Figure 2.8 defined a hybrid probabilistic deterministic model with the involvement of three models coupled in dynamic ways i.e. 1D, 2D and 3D. IHAM was inserted in Monte Carlo simulation to descript the natural variability of the input hydrograph form and the randomness of dike failures (Vorogushyn et al., 2010).

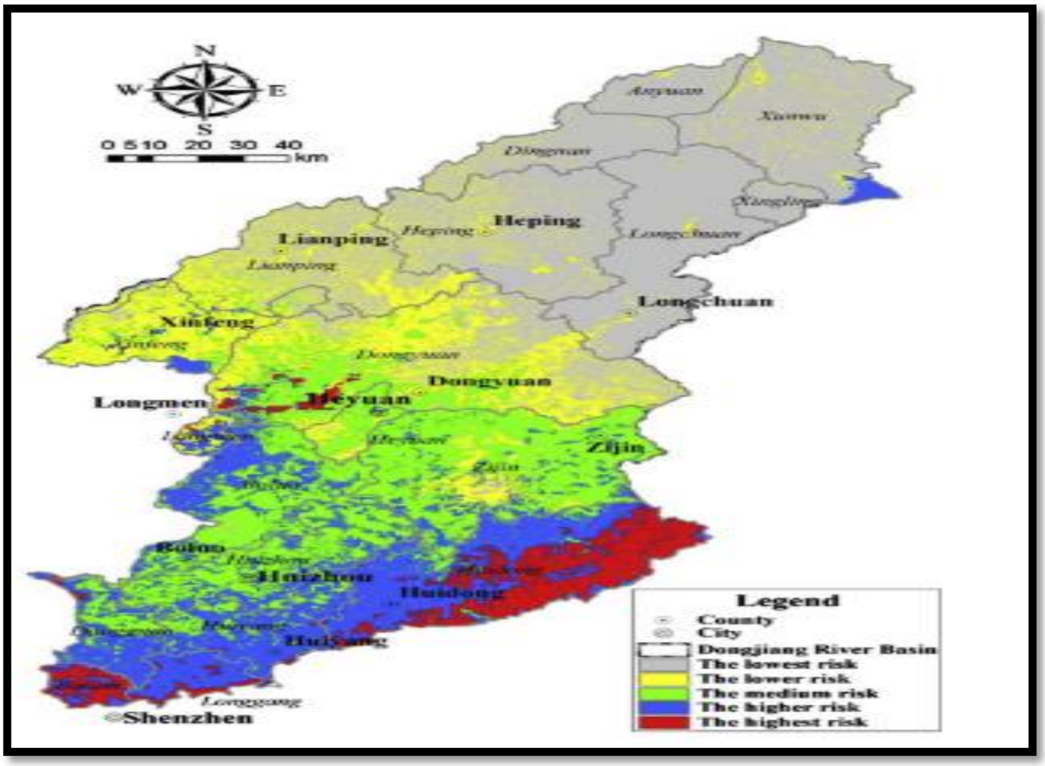

Figure 2.7 Flood hazard risk assessment map (eleven indices) based on RF
Source: Wang et al. (2015)

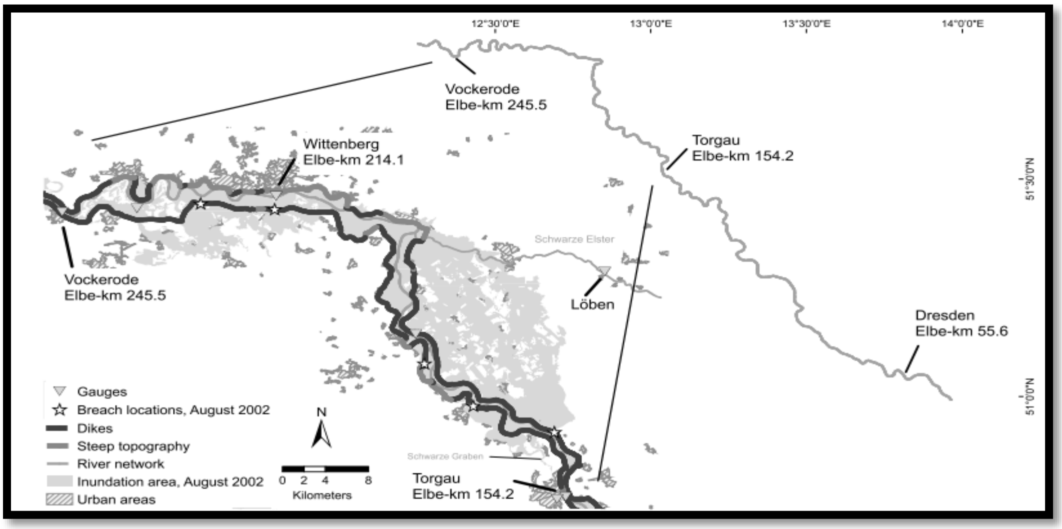

Figure 2.8 Inundation Hazard Assessment Model (IHAM)
Source: Vorogushyn et al. (2010)

Jonkman et al. (2008) assessing flood risk for case study at South Holland using three main steps i.e. determination of flood probability, simulation of flood characteristic and assessment of flood consequences. Figure 2.9 and Figure 2.10 shows the result of flood hazard for neighbourhood and individual fatalities based on Hydrodynamic model (Sobek 1D2D) simulation.

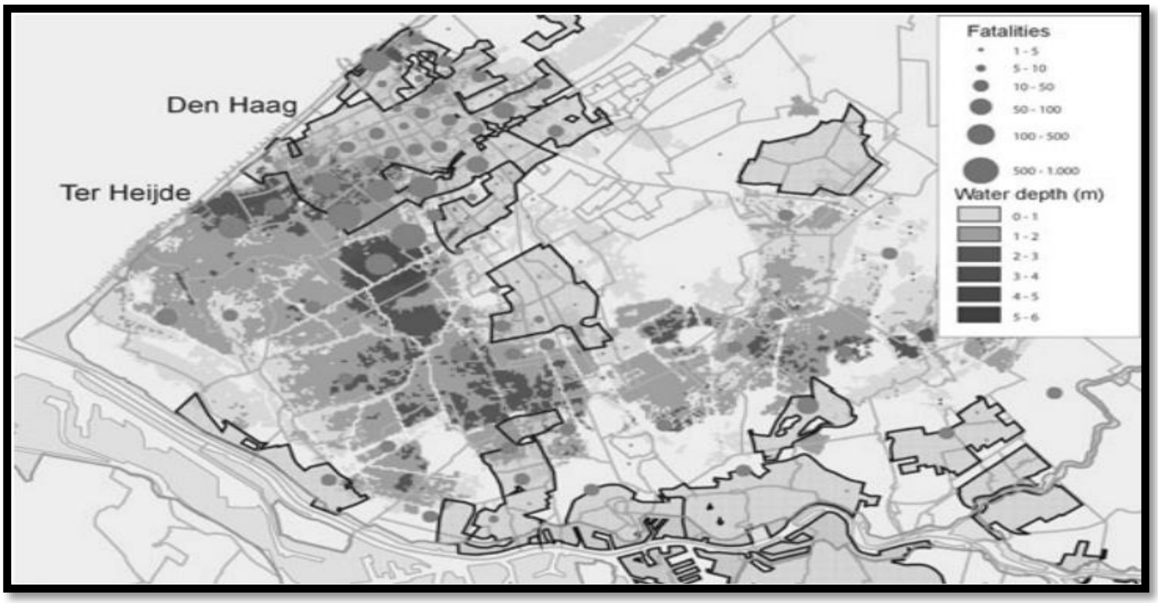

Figure 2.9 Fatalities by neighbourhood
Source: Jonkman et al. (2008)

Figure 2.10 Fatalities by individual

Source: Jonkman et al. (2008)

2.3.2 Flood vulnerability assessment

Vulnerability can be defined by the characteristics of a system that describe its potential to be harmed. It can be expressed in terms of functional relationships between expected damages regarding all elements at risk and the susceptibility and exposure characteristics of the affected system, referring to the whole range of possible flood hazards (Scheuer et al., 2011). Flood vulnerability depends on the number and value of elements at risk and their susceptibility.

Flood vulnerability assessment can assist in decision making to reduce damage and fatalities (Balica et al., 2013). This assessment were useful in the development of risk mapping, evaluation of financial appraisals for insurance and loss compensation (Olesen et al., 2017). Vulnerability also related to the expression of the flood severity and probability, also the risk of hazard that expose to the elements (Scheuer et al., 2011).

2.4 Flood damage assessment

Flood damage assessment is to determine the vulnerability of flooding areas (Olesen et al., 2017). Risk mapping and financial appraisals for insurance and loss compensation can be conducted as assessments of flood damage (Olesen et al., 2017). Flood risk assessment is a part of mitigation strategies. A risk is defined as the potential and probability of flood impacts to the community and assets (Romali et al., 2018; Olesen et al., 2017) .

Therefore, flood hazard and flood vulnerability are the main components of flood risk (Olesen et al., 2017). Assessment of flood vulnerability is define as the cost of damage assessment (Olesen et al., 2017). These initiatives reinforced the flood mitigation in the future.

2.4.1 Types of flood damages

Flood damages can be measured in two ways: tangible and intangible. Tangible damages can be calculated in monetary terms. Intangible damages cannot be transform into monetary terms such as damages to ecosystem functions where it difficult to convert into monetary terms (Romali et al., 2018)

Direct damages means the direct contact by floodwaters to property (Win et al., 2018). Direct damages for structural damages can be classified into two groups: (1) the inundation damage that allowed for reimbursement only for repairing the building structure and (2) the major structural damage/total destruction that allowed for reimbursement for reconstructing the building structure (Pistrika, 2010).

In the other hand, indirect damages is the consequences effects from disturbance of physical and economic systems, and as well as economic depletion due to business downtime (Win et al., 2018). Damages happen after the actual event take account as indirect damages (Thieken et al., 2008). Table 2.1 shows the summary of types of flood damages.

Table 2.1 Summary of types of flood damages

	Measurement		
Form of damages		**Tangible**	**Intangible**
	Direct	Physical damage to property such as buildings, contents and infrastructure	Loss of life, health effects, and loss of ecological goods
	Indirect	Loss of industrial production, traffic disruption and emergency costs	Inconvenience of post-flood recovery and increased vulnerability of survivors

Furthermore, flood damage can be distinguish into three class i.e. micro-scale, meso-scale and macro-scale (Romali et al., 2018). Macro-scale where the assessment is conducted on nation-scale (Olesen et al., 2017). Damage for individual household is define as micro-scale (Olesen et al., 2017). As local community can be define as meso-scale (Olesen et al., 2017). Table 2.2 shows the summary of flood damages.

Table 2.2 Summary of flood damages.

Type of damages	**Description**
Macro-scale	Nation
Meso-scale	Community
Micro-scale	Individual

Source: Romali et al. (2018)

2.4.2 Method to assess flood damage

The assessment of flood damages can be done in two ways; either directly from existing database of by using modelling approach (Romali et al., 2018).

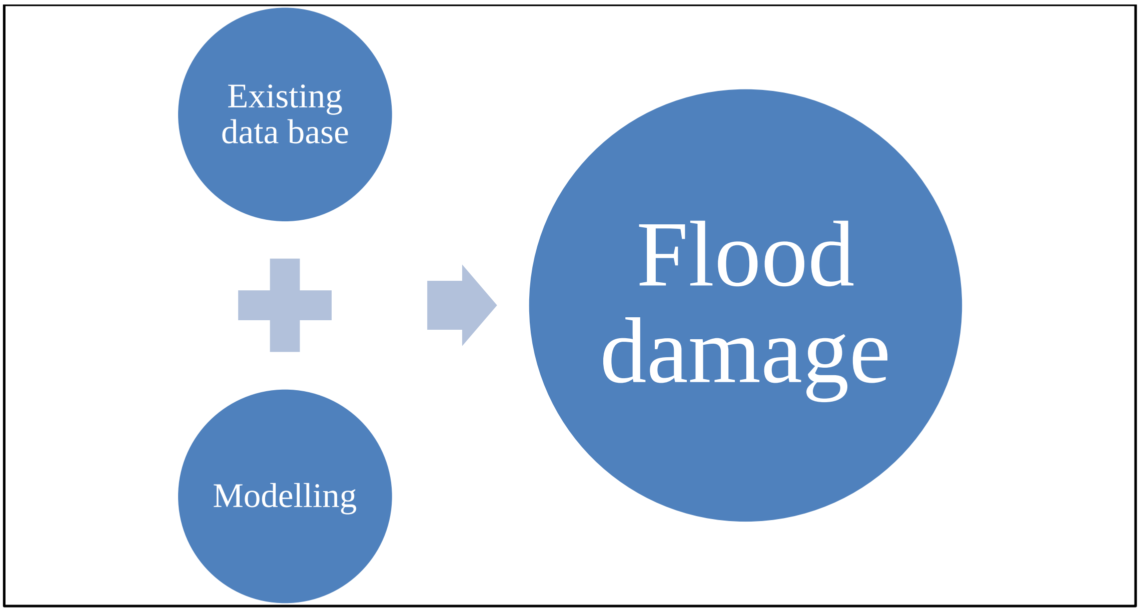

Figure 2.11 Ways to access flood damage
Source: Romali et al. (2018)

2.4.2.1 Existing data base

Flood damage data is appraised from past flood event, collected from interview survey or secondary respondent such as local authorities, newspaper and internet (Romali et al., 2018). Interview survey is described into three types which are focus on capturing lived experiences: direct observation; participant observation; and qualitative interviews. This data can be collect through questionnaire (Win et al., 2018).

Normally questionnaire survey consists of questions regarding to flood damage data/information and demographic data (Win et al., 2018). In flood damage section the depth and duration of water, income loss, other expenditures, and agriculture damage was asked. As demographic part the questions that being collected are age, gender, education, occupation, income of each household member and expenditure, building typology. Figure 2.8 shows the sections in the questionnaire used by (Win et al., 2018).

Win et al. (2018) mention that the selection of flooding areas is based on inundation flood map released by Irrigation and Water Utilization Management Department (IWUMD) for Bago city, Myammar. Then randomly select the residential needed for the data.

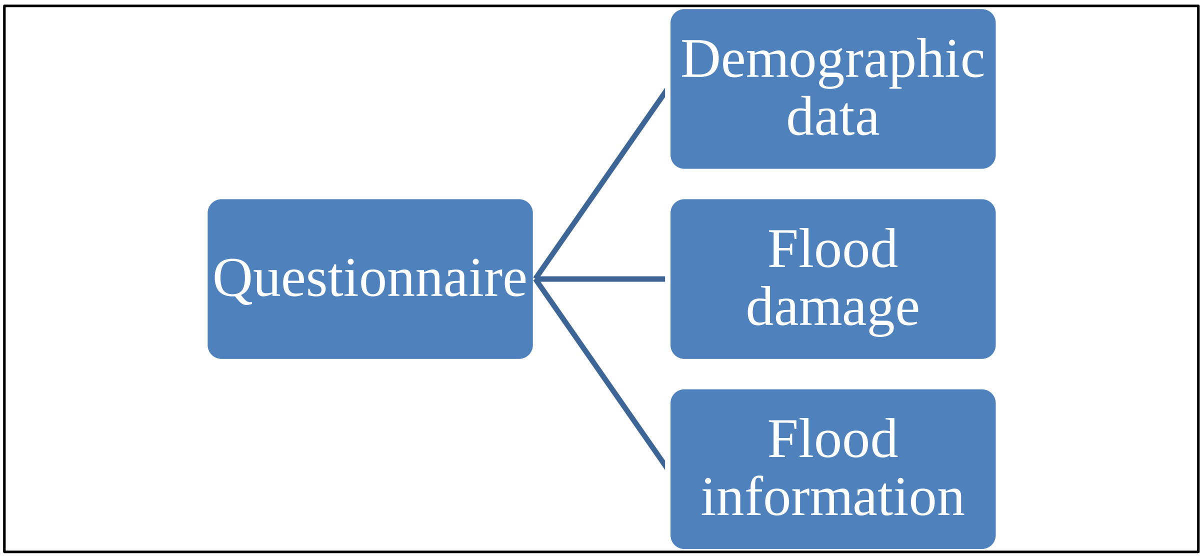

Figure 2.12 Summary of section in questionnaire

Source: Win et al. (2018)

2.4.2.2 Modelling approach

Modelling approach relates flood damages with other related factors such as economic, the nature of damage, and flood variables. The used of software GIS to estimate the flood damages were used by past researchers to generate the flood damages. Ahamad et al. (2009) used the combination of GIS database land cover/land use information and ground roughness values to estimate flood damage of Muda river basin, Kedah.

Infoworks RS and HEC-RAS generates vector-base layers from spatial and non-spatial data derived from field survey measurements, previous reports and remote sensing image analysis (Ahamad et al., 2009). Steady and unsteady flow water surface calculations is able to perform by this systems (Ahamad et al., 2009). GIS function and database storage can perform one dimensional hydraulic modelling for a full network, provide input and output information in tabular and graphical formats with present of Infoworks RS which is a combine 1D hydrodynamic ISIS Flow simulation engine (Ahamad et al., 2009).

Most of the past researchers using GIS-Based model that being developed by the Centre for the assessment of Natural Hazards and Proactive Planning of National Technical University of Athens under the auspices of the EU Programme INTERREG IIIC-Sud Initiative and the Regional Operation Framework of NOÉ Programme - subproject DISMA and for hydraulic and hydrology part ware executed by Hec-Ras (A Pistrika, 2010).

2.5 Flood damage curve

Flood damage curve can be distinguished as absolute or relative cost (Olesen et al., 2017). Absolute damage curve where produce the absolute damage cost for the exact damage type (Olesen et al., 2017). A certain object only being choose the part of it to be potentially damage for inundation depth is define as relative damage curves (Olesen et al., 2017). Both damages can be produce either empirically or synthetically (Olesen et al., 2017).

Synthetic damage where the curve function is developing based on damage data of historical floods or from hypothetical analysis. Synthetic method can build used two types of data; either based on the existing historical databases or by using data based on interview surveys.

Empirical damage is where the data of damages and depth is applied to fit a parameterized function and stratified by building classifications to compute depth-damage estimates (Lehman and Hasanzadeh Nafari, 2016). Foundation height, ground elevation, percent damages below ground, number of stories, height of stories, maximum damage as a percent, and the beginning elevation for damage includes in the parameters for empirical (Lehman and Hasanzadeh Nafari, 2016). Figure 2.13 shows the overview of flood damage curve adopt from Olesen et al. (2017).

Flood damage curve is related by flood damage and flood parameters in flood damage assessment which give damages towards the buildings. Flood parameters is often directly contact with building structures (Pistrika, 2010). This is graphical presentation of flood loss due to flood event where resulted from physical contact from flood parameters towards building and contents affect from depth of flood water. Figure 2.14 below show examples of flood damage curve. This curve shows the relationship between flood damages and flood parameters that affected the level of flood damages.

Observation of flood damages is the requirement data for empirical construction of flood damage function (Olesen et al., 2017). Synthetic damage curve where depends on synthetic data from the expert and without damage observation (Olesen et al., 2017). An example of synthetic damage is multi- coloured manual (MCM) applied in the UK (Olesen et al., 2017).

After further classification of damage, past researcher Olesen et al. (2017), mention groups of flood damage curves: residential, commercial and industrial, and road. The structure and content damages are separately calculate (Shawcross et al., 2017). Curve damage need to classify accordingly to the respective groups. Olesen et al. (2017) classified commercial into seven groups: business, industrial, public land, CA, special use, common and hiatus. In Australia, Melbourne Water flood Mitigation Prioritization Tool was applied to provide an absolute stage-depth damage curve (Olesen et al., 2017).

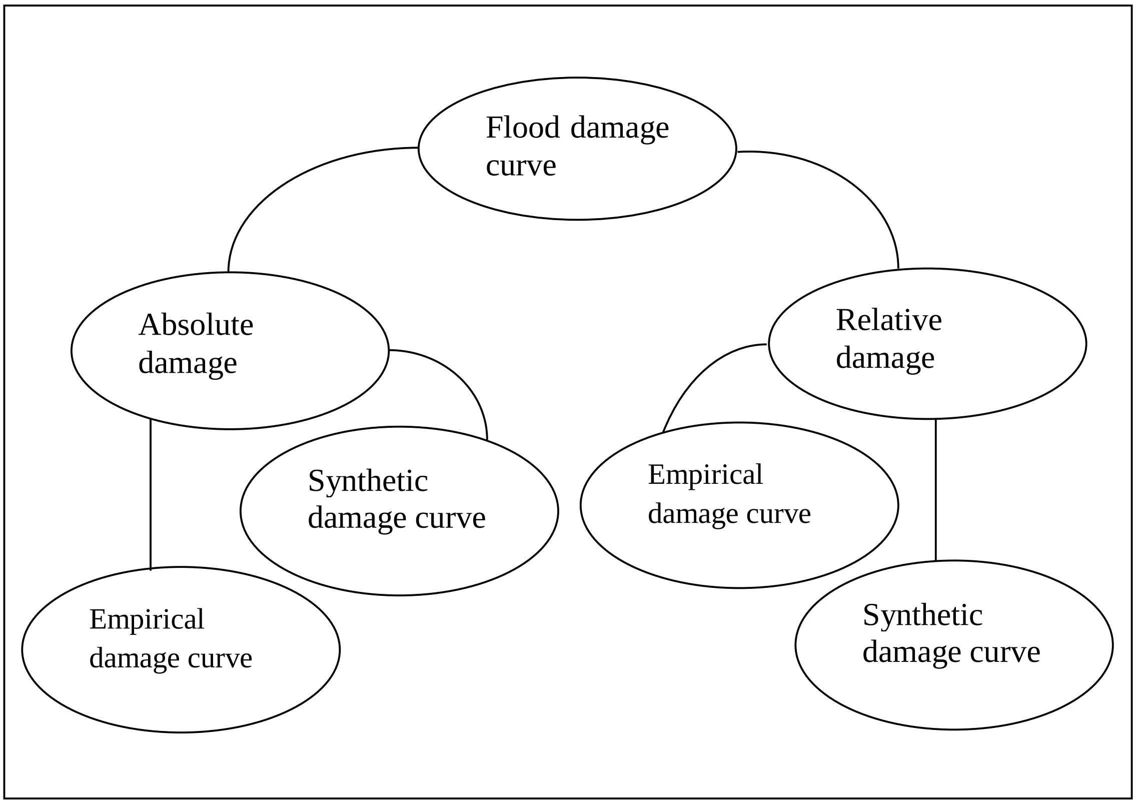

Figure 2.13 The overview of flood damage curve

Source: Olesen et al. (2017)

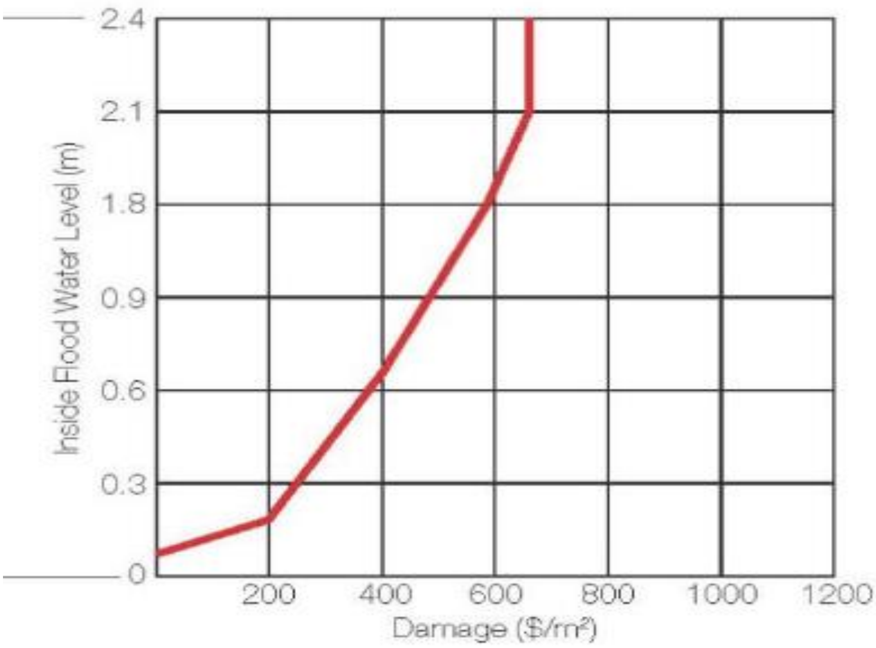

Figure 2.14 Examples of flood damage curve

Source: Shawcross et al. (2017)

2.5.1 Flood parameters

There are a few flood parameters that have been used in the development of flood damage curve from past studies which are flow velocity, flood duration, sediment concentration, lead time and information content of flood warning, and the quality of external response in a flood situation (Pistrika and Jonkman, 2010). Table 2.4 summarized the damage influencing factors considered in different flood damage assessments.

This parameters may significantly affect the flood damage, however past researchers mostly used water depth as flood damage parameter (Win et al., 2018). As mention by Pistrika and Jonkman (2010) for case study at the Lower 9th Ward, New Orleans, US, they take flow velocity into account as parameter.

Table 2.3 Summary of damage influencing factors

Researcher	Parameter	Descriptions
Win et al. (2018), Thieken et al. (2008), Pistrika et al. (2014)	Water depth	The deeper the water depth, the greater the damaged towards buildings and its content
Kreibich et al. (2009), Pistrika and Jonkman (2009),	Flow velocity	The higher the velocity of the flood waters, the greater the impact towards buildings structure due to lateral pressure.
Kreibich and Thieken (2008), Thieken et al. (2008a)	The quality of external response in a flood situation	There are various precautionary measures, which are able to reduce flood damage significantly. Examples are constructural measures such as elevated building configuration, use of suitable building material or flood adapted interior fitting. Measures like flood secure configuration of oil tanks or secure storage of chemical can prevent contamination

2.5.2 Flood damage curve development method

United Kingdom use MCM (Multi-Coloured-Manual) with present absolute stage-depth damage curves. This manual is based on synthetic data that generate through the "what if" questions and expert knowledge. Direct tangible damage is the only type that can be produce with this manual. MCM also include intangible in the manual (Olesen et al., 2017).

In Australia, Olesen et al. (2017) states that ANUFLOOD and RAM are the main model use in flood damage estimation. ANUFLOOD applies synthetic stage-damage curve to residential and commercial (Olesen et al., 2017). 15% of the direct residential damages and 55% of the direct commercial damages are take into account as indirect damages in ANUFLOOD.

RAM is define as an empirical-synthetic model, with an absolute unit loss for micro scale damage assessment (Olesen et al., 2017). Damage to building structures and contents are included in RAM with different size of building whether smaller or larger than 1000 m^2.The method calculate 30% of direct damage as indirect damage (Olesen et al., 2017).

Pistrika et al. (2014) compare several generalized depth-damage functions that being built by US Army Corporation with “Moschato step function”. Those depth-damage function were applicable to all communities as the generalized a regional level. The use of curve fitting toolbox software in MatLab to produce mathematical function (Pistrika et al., 2014).

2.6 Conclusion

Flood damage assessment is one of the important element in the flood risk assessment to support flood mitigation to minimize the impact of the flood towards people and properties. There is limited study about flood vulnerability especially towards commercial damage because the damage data is difficult to obtain. Therefore, the study on flood damage is compelling for future flood mitigation measures.

In Malaysia the study on flood vulnerability is scarce compare to flood hazard. The vulnerability study is important in flood damage estimation works in future that can help to reduce the impact towards people and properties especially towards commercial sectors. The empirical method, ex-post flood damages evaluation, and collection of damage data during site survey after the flood event is the most common method used to produce the flood depth-damage curve. The depth-damage curve is important in presenting the relationship between flood depth and damage.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter presents the methodology used in this study. Figure 3.1 shows the flow of the study which involves a few steps to develop the flood damage curve. The first step is to develop the questionnaire survey based on the information from previous studies. Then the questionnaire was used to gather the information regarding the flood damage. The data was then analysed using the statistical and regression analysis. The flood damage versus flood depth curve then was established using Microsoft excel.

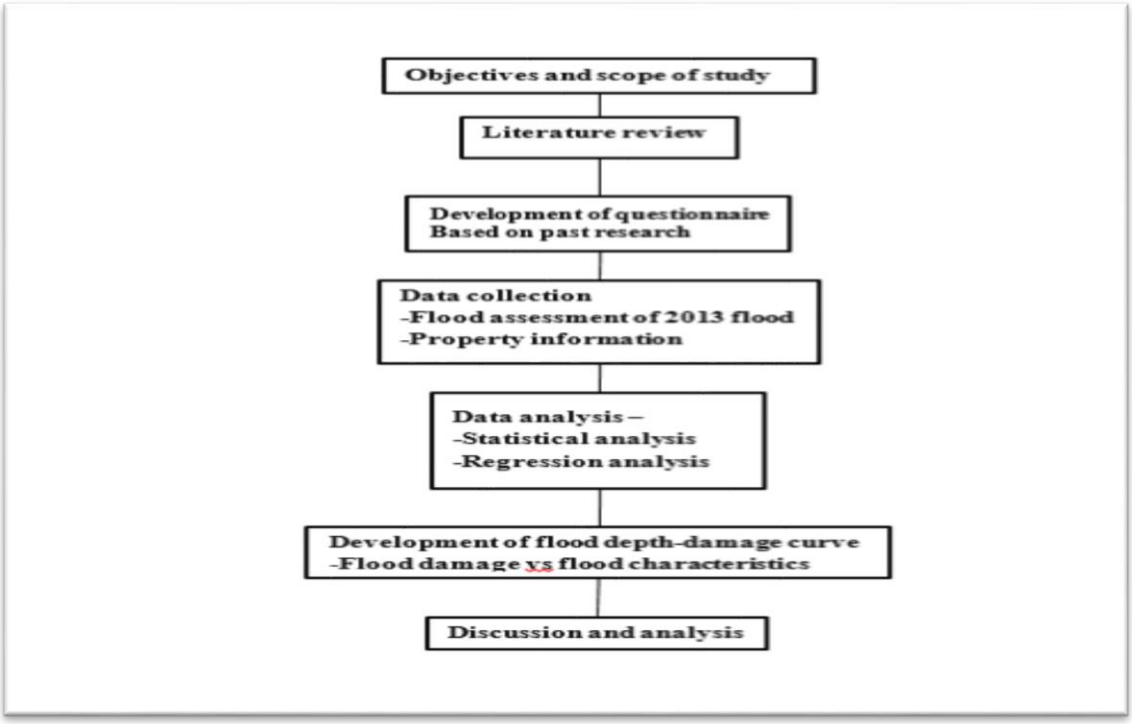

Figure 3.1 The flow of methodology

3.2 Description of study area

This study was carried out at Bandar Kuantan, Pahang. During 2013 flood, this place hits the worst then other district in Pahang. This district was being chosen because due to its potential to become a future hub trader in Pahang. The selected places would be decided through the range of depth gives by JPS, Pahang. Figure 3.2 shows the map of Kuantan, Pahang. The places that involve are Sg. Isap, Bukit Rangin, Permatang Badak, Bukit Setongkol and Jalan Tanah Putih. This places is nearby to the Pahang river which is the source of the flooding.

Figure 3.2 Map of Kuantan, Pahang

Source: Google Map

3.3 Questionnaire design

The questionnaires were distributed to the commercial respondents that are effected by the flood in 2013 around the Kuantan. The survey consists of social class, the buildings, the contents (inventory items), and the damages cause direct by the flood event.

The type of questionnaire that being used for this study is closed-ended question. Respondents need to choose one or two answers for each question. This questionnaire was distinguished into two categories and each category has two sections. 100 respondents are needed to complete this study in order to develop damage curve.

In ownership category, there are a few questions about owner detail such as name, education, income and age. The section two of ownership category contain of question about buildings such as price of building, year of buy and numbers of building level. This section also asked about the insurance that cover the buildings.

The damage category for first section contain of content in the building and percentage the damage content. In section two will asked about the structural damage and a few cost such as cleaning cost, cost for repairing vehicle. Table 3.1 below show the section contain in the questionnaire.

It is observed that more survey needed in order to obtain accurate data and reliable damage curves. The completed questionnaires collected from the commercials will be keep and update because it will be meaningful to damages curves in the future.

Table 3.1 The section contain in the questionnaire

Category	**Section 1**	**Section 2**
Ownership Survey	Personal detail	Buildings information
Damage Survey	Content damage	Structural damage

3.4 Data collection

In data collection, the face to face interview technique is used. During the collection of the data, the observation also being made towards the buildings to observe the proof of previous flood event. This method being choose, so personally meet with the victims during the session. During the sessions, the places that being choose is refer to the data from JPS that have the historical depth of flood water.

The data was collected at Bukit Setongkol, Sg. Isap, Bukit Rangin and Permatang Badak as the areas were severely affected during 2013 flood. Face to face interview is essential in order to observe the damages toward the structure of the buildings if there any left. The interviewer can know the impressions about the tragedy happen.

3.5 Regression Analysis

In regression analysis, the STATA was used to obtain the factors that affect the level of flood damage. STATA is a general-purpose statistical software that operate in the fields of economics, sociology, political science, biomedicine and epidemiology that enables users to analyse, manage, and produce graphical visualizations of data. This software produce a linear regression analysis that can be generalised into the linear equation stated as Eq. (3.1).

$$Y_i = ß_0 + ß_1 X_i + \varepsilon_i \quad (3.1)$$

Y_i = Dependent variable
$ß_0$ = Population Y intercept
$ß_1$ = Population slope population
X_i = Independent variable
ε_i = Random error term

3.6 Flood damage curve

The chosen parameter is water depth because gives the most damage to structures. Lehman and Hasanzadeh Nafari (2016) mention that majority of the variance of the damages when the structures are stratified by construction and use is depth. For a given construction practice (wood construction, concrete block construction, or steel frame construction), and a given use (residential, or commercial) there could be great variance between the contents of the structures.

In commercial most of the content is on the first floor and for second floor normally for store to keep the stock for refill later. Therefore, the commercial tend to get more damages. The damages also depend on the contents of the building according types of business such as restaurants, grocery store, hardware and etc.

The flood damage curve in this study was established by plotting the flood damage (in percentage) versus flood parameters using the collected damage data. Pistrika et al. (2014) has follow Eq. (3.1) and Eq. (3.2) to calculate the percentage of the damage for each category.

$$Structures\ Damage\ rate = \frac{Building\ damage\ value(RM)}{Averagebuilding\ value(RM)} \tag{3.1}$$

$$Content\ DamageRate = \frac{In{-}building\ DamageValue(RM)}{Average\ In{-}building\ Value(RM)} \tag{3.2}$$

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

The main aim of the study is to develop depth-damage curve based on damage data collected from questionnaire survey. This questionnaire is to obtain information regarding to flood depth, flood damage and past experience from flood event.

During the survey, the data of socio-demographic of respondent about business income, race, age, and gender were collected. The lowest business income is RM 1,000 while the highest income is at RM 10,000. The information of races are groups into four; Malay, Chinese, Indian and others. Figure 4.1 shows the distribution of races of the respondents. Most of the respondents are Malay races with more than 50%.

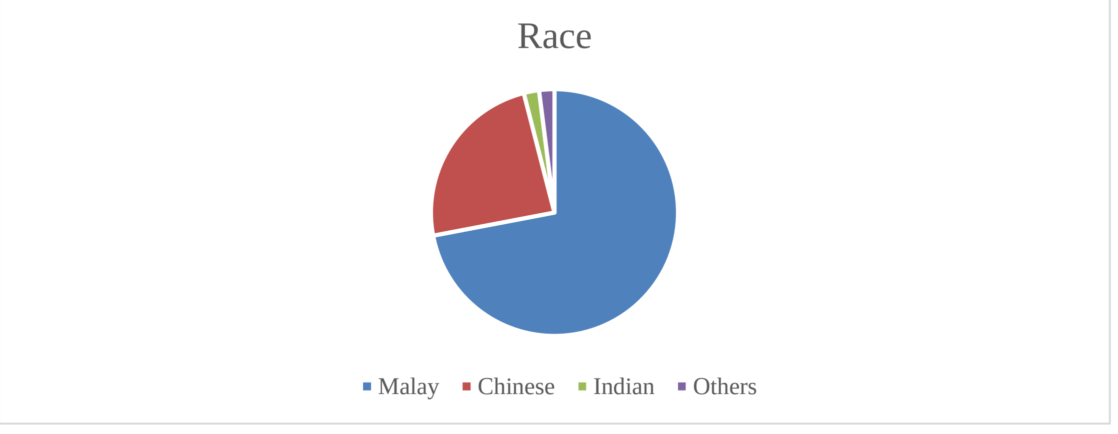

Figure 4.1 The races distribution of the respondents

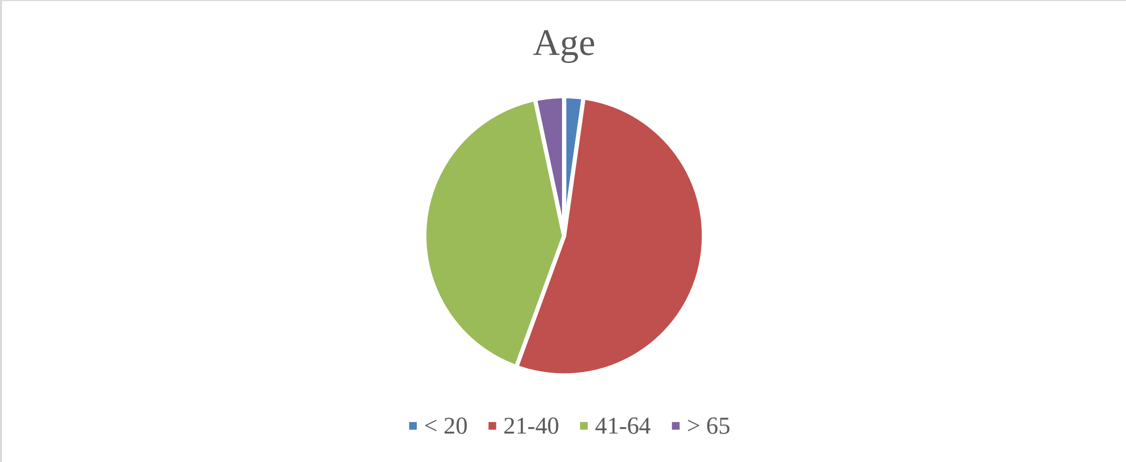

Figure 4.2 The distribution of respondents' ages

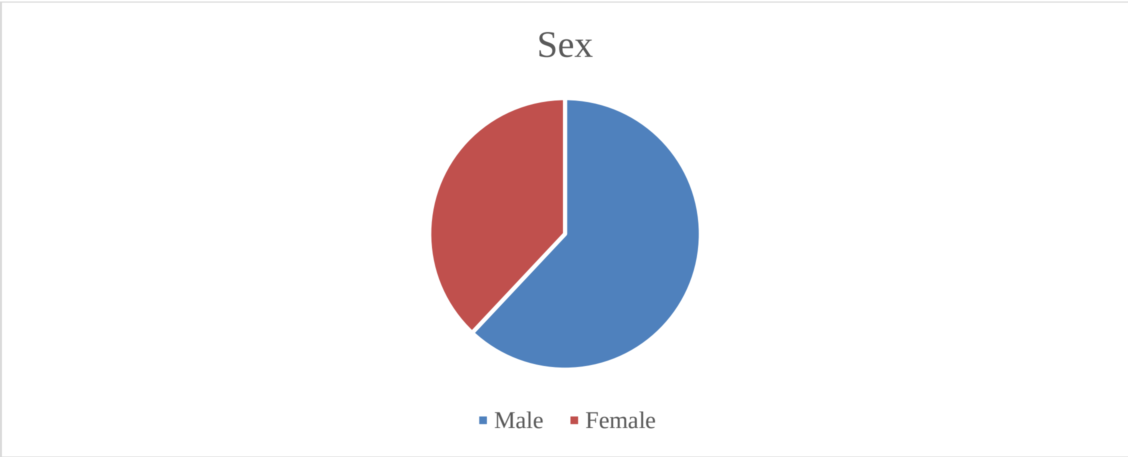

Figure 4.3 The distribution of respondent's gender

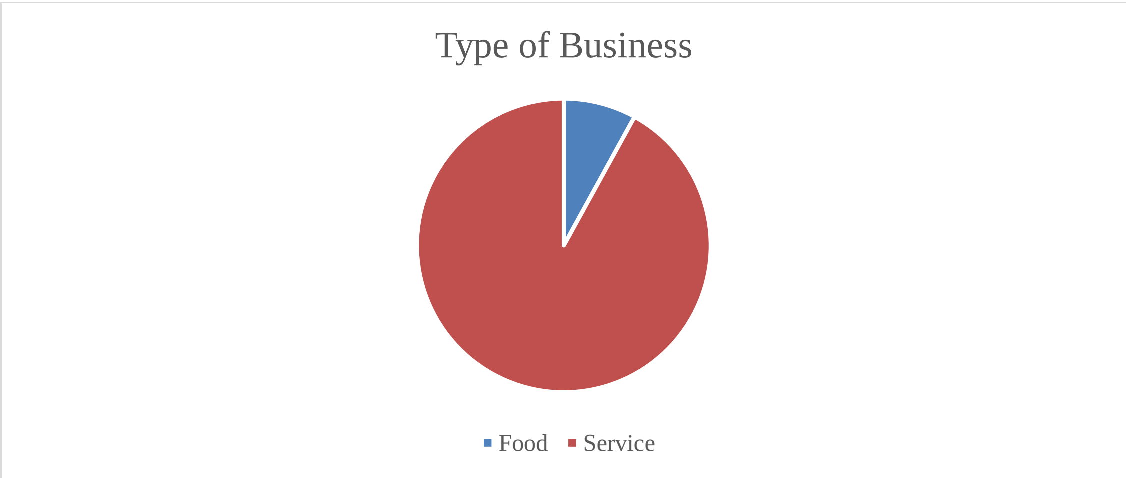

Figure 4.4 The distribution of business types

Figure 4.2 and Figure 4.3 shows that the most ages of the respondents are from 21-40 years old with more than half of the respondent and the majority respondent comes from male. Figure 4.4 shows that the type of business is 92% from good & services type and 8% from food and beverages type of business.

The building of commercial is whether one level building or two level buildings where 65% is one level building and 35% is two level building. This level of building mostly come from same places such as one level building come from Bukit Setongkol 9, Sg Isap 5, Permatang Badak, Tanah Putih Baru and Sg Isap 7. Figure 4.5 and Figure 4.6 shows the one level building, whereas Figure 4.7 shows the two level building.

Figure 4.5 One level building

Figure 4.6 One level building

Figure 4.7 Two level building

Table 4.1 shows the summary of average damage and standard deviation for content and structural damage. In the table consists of two criteria that being observed which are level of building and type of business. Average content damage for one level building is RM 23,103 which is higher than structural (RM 4,161). Two level of building has higher average content damage which is RM 42,971 compare to one level building.

The content damage tends to has higher damage because content in the building or commercial easy to destroy if exposed to water compare to structural part. If the structural of the building exposed to water the parts is rarely fully damaged. The two level building tend to has higher damage because the owner of the building tends to put the content at level one and used level two only as the store to keep the stocks, so from the actions the commercial tend to experiences more damage compare to one level buildings.

The good & services type of business has higher respondent which is 77% compare to 23% for the food & beverages business. The average content damage for good & services is higher which is RM 35,974, whereas only RM 11,813 for food & beverages. The average structural damage for food & beverages is lower than good & services which is RM 3,656 and RM 5,063 respectively.

The good & services business experienced higher content damage because that type of business holds varieties of stocks and easily to destroy if exposed to water compare to food business type where it only exposed their equipment towards water and the equipment not totally damaged because a few equipment can be used back. For the structural part, most of the food type business used mozac to their wall and floor, therefore there is no need repair for that parts and the repair only for door part.

Table 4.1 Summary of average of damage and standard deviation for content and structural damage

Criteria	Number of buildings	Content Damage(RM)		Structural Damage(RM)	
		Average Damage (RM)	Standard Deviation (RM)	Average Damage (RM)	Standard Deviation (RM)
Number of level					
1	65	23,103	23,341	4,161	2,883
2	35	42,971	28,352	5,609	2,579
Types of commercial					
Food	23	11,813	8,450	3,565	3,479
Service	77	35,974	27,902	5,063	2,525

Table 4.2 Summary distance from the Kuantan's river

Distance	Frequency	Percentage (%)	Valid percentage (%)	Cumulative percentage (%)
100	1	0.01	0.01	0.01
300	1	0.01	0.01	0.02
400	8	0.08	0.08	0.10
500	27	0.27	0.27	0.37
600	5	0.05	0.05	0.42
700	1	0.01	0.01	0.43
1000	31	0.31	0.31	0.74
1100	1	0.01	0.01	0.75
1500	1	0.01	0.01	0.76
2000	1	0.01	0.01	0.77
2500	19	0.19	0.19	0.96
3000	1	0.01	0.01	0.97
4000	3	0.03	0.03	100
Total	100	100	100	

4.2 Simple Regression Analysis

The socio-economic and property characteristics variables was being tested and the suitable value of P which is less than 0.05 was selected. This value could give and produce more reliable flood damage function relationships. Business income and business type give effect to content damage as dependent variables, whereas level of building give effect to structural damage.

Based on the result in Table 4.3 and Table 4.4, the simple regression model for content damage and structural damage is presented in Eq. (4.1) and Eq. (4.2) respectively.

$$ContentDamage(RM) = 9550 + 4.5BusinessIncome - 12525Food\ \&\ Beverage \tag{4.1}$$

$$StructuralDamage(RM) = 2713 + 1448LevelofPremises \tag{4.2}$$

BusinessIncome = Business income (RM)
Food&Beverage = Type of business
LevelofPremises = Level of premises

Table 4.3 Simple regression for content damage

Model	Unstandardized Coefficient		t	Sig.
	B	Standard Error		
Constant	9549	5571	1.71	0.09
Business Income	4.5	0.9	5.23	0
Food and beverages	-12515	5690	-2.2	0.03

Table 4.4 Simple regression for structural damage

Model	Unstandardized Coefficient		t	Sig.
	B	Standard Error		
Level of building	1448	584	2.48	0.015
Constant	2712	835	3.25	0.002

As shown in Table 4.4 for content damage, the simple regression shows that the flood damage due to content was influenced by business income and type of business (food & beverages). This show the larger the scale of the business give the higher level of damage. The type of business also contributes to the level of damage because for the food & beverages type of business, the equipment tends to exposed to water especially the electric equipment such as refrigerator, gas tank and etc.

In Table 4.4, the regression analysis shows that the variable that influences the structural damage is the level of building. This shows that the higher the buildings give greater structural damage. This happen because the two level building tends to decorate their building, therefore the repair cost is higher. This finding can be applied to the future flood damage estimation works and contribute to flood risk reduction scenarios to determine the efficient solutions.

4.3 Flood depth damage curve

Figure 4.8 shows the commercial flood depth-damage curve for Kuantan. The curve is plotted using the logarithmic trend line. Flood depth is the important element that being observed during the survey and the damage percentages were determine by using Eq.(3.1) and Eq. (3.2). This curve shows the relationships between flood depth and flood damage, and explanation and prediction in mathematically to economic damage during flooding.

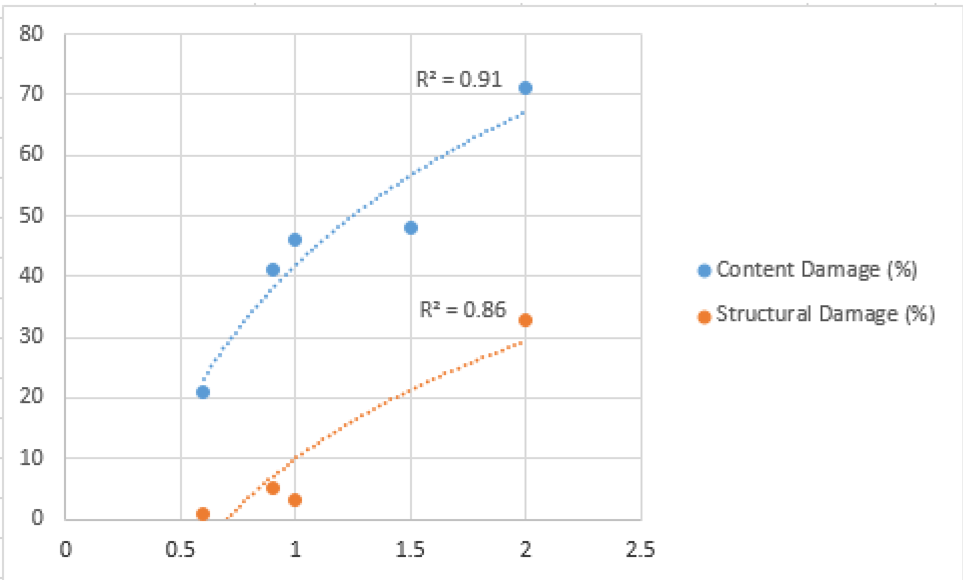

Figure 4.8 The depth-damage curve for content and structural damage

Figure 4.8 shows that the R^2 are 0.91 and 0.86 for content damage and structural damage respectively. The level of flood damage increase as the water depth increases. The percentages of content damage are higher than structural damage. From the observation during the interview survey, the owner of the business left their business properties in order to save their house and their life. Therefore, the content damage gives more effect in damage compare to structural. Also the replacement of the commercial content (eg. goods and furnitures) is more than to repair the structural of the building (eg. paint of wall and door).

CHAPTER 5

CONCLUSION

5.1 Introduction

Direct assessment of flood damage was carried out using interview survey and a commercial flood depth-damage curve for Kuantan was developed using the collected damage data. As for the improvement of future flood damage assessment studies, the flood damage influencing factors was identified through this study.

5.2 Conclusion

The conclusion of this study in relation to the study objectives are as follows:

1. Flood damages experienced by the commercial sector during the 2013 Kuantan flood was assessed through interview survey. The content damage was found to be higher than the structural damage. The content damage for one level building and two level building was RM 23,103 and RM 42,971 respectively. The structural damage is lower which is RM 4,161 and RM 5,609 for one and two level building respectively. According to the types of business, the content damage experienced by the good & services business (RM 35,974) is higher than the food & beverages (RM 11,813). The same trend is observed for structural damage where the damage value is lower, i.e. RM 3,479 for food & beverages and RM 2,525 for good & services.

2. The rate of content damage was influenced by the business income (RM) and type of the business (food & beverages) variables while structural damage was only influenced by the level of building. These variables should be given priority in the future flood damage assessment works

3. The commercial flood depth-damage curve obtained in this study is reasonable with R^2 of 0.81 and 0.88 for content damage and structural damage respectively

5.3 Recommendations

A few recommendations for future flood risk assessment studies in Kuantan areas are suggested:

1. Instead of face to face interview technique, interviews using telephone are suggested as it is sometimes difficult to meet personally with the owner of the building/shop as the shops are normally attended by the shop attendant

2. Future studies at the study area should include other categories such as residential and industrial. Furthermore, other flood parameters such as flood duration is worthwhile to be considered in the development of the flood damage curve.

3. Inclusion of other types of damages such as indirect and intangible damage is suggested to produce a more details damage estimates

REFERENCES

Ahamad, M. S. S., Ali, R., Zakaria, N. A., Ghani, A. A. and Chang, C. K. (2009). Flood loss asssessment of the 2003 Muda River flood. *3rd International Conference on Managing Rivers in the 21st Century*, 601–606.

Balica, S. F., Popescu, I., Beevers, L., and 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

Chinh, D. T., Dung, N. V., Gain, A. K. and Kreibich, H. (2017). Flood loss models and risk analysis for private households in can Tho City, Vietnam. *Water (Switzerland), 9*(5). https://doi.org/10.3390/w9050313

D/iya, S. G., BarzaniGasim, M., EkhwanToriman, M. and Abdullahi, M. G. (2014). Floods in Malaysia-760. *International Journal of Interdisciplinary Research and Innovations*, *2*(4), 59–65. https://doi.org/10.5897/AJBx10.009

Dachalan. (2014). What are the Different Types of Floods? Retrieved from Environmental Technology website: https://www.envirotech-online.com/news/water-wastewater/9/breaking-news/what-are-the-different-types-of-floods/31906

Fallis, A. . (2013). Pengurusan Banjir. *JPS Malaysia*, *53*(9), 1689–1699. https://doi.org/10.1017/CBO9781107415324.004

Hall, J. W., Dawson, R. J., Sayers, P. B., Rosu, C., Chatterton, J. B. and Deakin, R. (2009). A methodology for national-scale flood risk assessment. *Proceedings of the Institution of Civil Engineers - Water and Maritime Engineering*, *156*(3), 235–247. https://doi.org/10.1680/wame.2003.156.3.235

Jonkman, S. N., Kok, M. and Vrijling, J. K. (2008). Flood risk assessment in the Netherlands: A case study for dike ring South Holland. *Risk Analysis*, *28*(5), 1357–1373. https://doi.org/10.1111/j.1539-6924.2008.01103.x

Lang, S. (2019). Monsoon Rains Flood Malaysia. Retrieved from NASA and the Japanese space agency JAXA website: https://earthobservatory.nasa.gov/images/14367/monsoon-rains-flood-malaysia

Lehman, W. and Hasanzadeh Nafari, R. (2016). An Empirical, Functional approach to Depth Damages. *E3S Web of Conferences*, *7*, 05002. https://doi.org/10.1051/e3sconf/20160705002

Menzel, L. and Kundzewicz, Z. W. (2015). Non structural flood protection - a challenge. *International Conference 'Towards Natural Flood Reduction Strategies,'* (January 2003). Retrieved from https://www.researchgate.net/publication/254887487%0ANON

Merz, B., Kreibich, H., Schwarze, R. and Thieken, A. (2010). Review article "Assessment of economic flood damage." *Natural Hazards and Earth System Science*. https://doi.org/10.5194/nhess-10-1697-2010

Miller, A., Jonkman, S. N. and Van Ledden, M. (2015). Risk to life due to flooding in post-Katrina New Orleans. *Natural Hazards and Earth System Sciences*, *15*(1), 59–73. https://doi.org/10.5194/nhess-15-59-2015

Olesen, L., Löwe, R. and Arnbjerg-Nielsen, K. (2017). Flood Damage Assessment Literature review and recommended procedure. In *Cooperative Research Centre for Water Sensitive Cities* (Vol. 4). Melbourne: Cooperative Research Centre for Water Sensitive Cities.

Pistrika, A. K. and Jonkman, S. N. (2010). Damage to residential buildings due to flooding of New Orleans after hurricane Katrina. *Natural Hazards*, *54*(2), 413–434. https://doi.org/10.1007/s11069-009-9476-y

Pistrika, A. (2010). Flood damage estimation based on flood simulation scenarios and a GIS platform. *European Water*, *30*, 3–11.

Pistrika, Aimilia, Tsakiris, G. and Nalbantis, I. (2014). Flood Depth-Damage Functions for Built Environment. *Environmental Processes*, *1*(4), 553–572. https://doi.org/10.1007/s40710-014-0038-2

PLANMalaysia and Majlis Perbandaran Kuantan (2017). *DRAF RENCANGAN TEMPATAN DAERAH Kuantan 2035 (PENGGANTIAN)* (1st ed., Vol. 1; Majlis Perbandaran Kuantan, Ed.). Kuantan, Pahang, Malaysia: Perpustakaan Negara Malaysia.

Romali, N. S., Yusop, Z., Sulaiman, M. and Ismail, Z. (2018). Flood risk assessment: A review of flood damage estimation model for Malaysia. *Jurnal Teknologi*, *80*(3), 145–153. https://doi.org/10.11113/jt.v80.11189

Scheuer, S., Haase, D. and Meyer, V. (2011). Exploring multicriteria flood vulnerability by integrating economic, social and ecological dimensions of flood risk and coping capacity: From a starting point view towards an end point view of vulnerability. *Natural Hazards*, *58*(2), 731–751. https://doi.org/10.1007/s11069-010-9666-7

Sean, O. H. (2013, December). Floods: No let-up in Pahang, blackout in Kuantan as waters rise. *The Star Online*, p. 1. Retrieved from https://www.thestar.com.my/news/nation/2013/12/04/floods-pahang-kuantan-blackout/

Sean, O. H. (2019, March 7). Kuantan is set to be a major trade centre in the east coast. *The Star Online*, pp. 5–8. Retrieved from https://www.thestar.com.my/news/community/2013/03/07/kuantan-is-set-to-be-a-major-trade-centre-in-the-east-coast/

Shawcross, S. W., Sol, D. and Stante, A. (2017). Canadian guidelines and database of flood vulnerability functions. In *Government of Canada*. Canada.

Star, T. (2013, January). 6,000 households affected in Kuantan. *The Star Online*, p. 10894. Retrieved from https://www.thestar.com.my/news/nation/2013/01/09/6000-households-affected-in-kuantan/#uFvFuDQL5ivoUKxI.99

Thieken, A. H., Schwarze, R., Ackermann, V., Kreibich, H., Kuhlmann, B., Kunert, U., and Seifert, J. (2008). Method For The Evaluation Of Direct and Indirect Flood Losses. *4th International Symposium on Flood Defence*, (May). Institute for Catastrophic Loss Reduction.

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

Tsakiris, G. (2014). Flood risk assessment: Concepts, modelling, applications. *Natural Hazards and Earth System Sciences*, *14*(5), 1361–1369. https://doi.org/10.5194/nhess-14-1361-2014

Vorogushyn, S., Merz, B., Lindenschmidt, K. E. and Apel, H. (2010). A new methodology for flood hazard assessment considering dike breaches. *Water Resources Research*, *46*(8), 1–17. https://doi.org/10.1029/2009WR008475

Wang, Z., Lai, C., Chen, X., Yang, B., Zhao, S. and Bai, X. (2015). Flood hazard risk assessment model based on random forest. *Journal of Hydrology*, *527*, 1130–1141. https://doi.org/10.1016/j.jhydrol.2015.06.008

Win, S., Zin, W. W., Kawasaki, A. and San, Z. M. L. T. (2018). Establishment of flood damage function models: A case study in the Bago River Basin, Myanmar. *International Journal of Disaster Risk Reduction*, *28*(November 2017), 688–700. https://doi.org/10.1016/j.ijdrr.2018.01.030

Zhou, Q., Mikkelsen, P. S., Halsnæs, K. and Arnbjerg-Nielsen, K. (2012). Framework for economic pluvial flood risk assessment considering climate change effects and adaptation benefits. *Journal of Hydrology*, *414–415*, 539–549. https://doi.org/10.1016/j.jhydrol.2011.11.031

APPENDIX A
SAMPLE APPENDIX 1

Measuring flood depth

Taman Bukit Rangin, Lorong Permatang
Badak baru 2

Perkg. Sg. Isap Aman Batu 3

Lorong Sg. Isap Jaya 2

Lorong Sg. Isap Jaya 1, Sg. Isap Jaya,
Jalan Gambang,

Interview survey

Jalan Sg Isap 4, Perumahan Sg isap 2,

Perkg. Sg. Isap Aman Batu 3

Perkg. Sg. Isap Aman Batu 3

Taman Bukit Rangin, Lorong Permatang
Badak baru 2