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

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Thesis submitted in fulfillment of the requirements
for the award of the
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Specially dedicated to

my beloved late brother,

Mohd Hanis bin Mohd Razaki

who have died from

car accident during my first

year degree journey (2015).

This is for you, Brother.

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ABSTRAK

Dalam tahun kebelakangan ini, banjir sering berlaku dan meninggalkan kesan yang teruk di kawasan banjir. Oleh itu, ia merupakan satu isu penting bagi setiap negara untuk mencegah dan mengurangkan kadar kerosakan banjir. Tujuan kajian ini adalah untuk menilai kerosakan banjir secara langsung yang telah dialami oleh mangsa banjir pada tahun 2013 di Kuantan dan mengenal pasti faktor-faktor yang mempengaruhi tahap kerosakan banjir. Kadar kedalaman banjir di kediaman dibangunkan berdasarkan data kerosakan yang dikumpulkan semasa tinjauan temu bual. Peratusan kerosakan dikira dengan membahagikan kerosakan struktur atau kandungan anggaran dengan nilai kerosakan sebenar. Mengikut jenis bahan binaan, kerosakan struktur secara purata adalah RM2642, RM2250 dan RM2120 masing-masing untuk bata, kayu dan bata dan rumah kayu. Kerosakan kandungan isi rumah untuk semua jenis bahan adalah lebih tinggi antara RM 4104 hingga RM 4556 bagi setiap harta benda. Kebanyakan rumah adalah satu rumah teres dengan purata kerosakan sebanyak RM 2250 bagi setiap harta tanah. Daripada analisis SPSS, kadar kerosakan dipengaruhi oleh harga rumah, bahan binaan dan pendapatan isi rumah. Dengan nilai R^2 dari 0.98 dan 0.82 untuk kandungan dan kerosakan struktur masing-masing, lengkung kerosakan kedalaman banjir yang diperolehi dalam kajian ini adalah cukup baik dan boleh digunakan untuk kajian masa depan mengenai penilaian risiko banjir di kawasan kajian.

ABSTRACT

In recent years floods occur frequently and cause severe impacts to the flooded areas. It is consequently an important issue of many countries to prevent and mitigate flood damage. The aim of this study is to assess the direct tangible flood damage experienced by the victims of 2013 Kuantan flood and to identify the factors that influence the level of flood damage. A residential flood depth-damage curve is developed based on the damage data collected during interview survey. The percentage of damage is calculated by dividing the estimated structural/content damage with the actual damage value. According to the types of construction materials, the average structural damage is RM2642, RM2250 and RM2120 for brick, wood and brick and wood house respectively. The content damage for all types of materials is higher which is between RM 4104 to RM 4556 per property. Most of the houses are one storey terrace house with average value of damage is RM 2250 per property. From the SPSS analysis, the rate of damage was influenced by house's price, construction materials and household income. With R^2 of 0.98 and 0.82 for content and structural damage respectively, the flood depth-damage curves obtained in this study is good enough and can be used for future studies on flood risk assessment of the study area.

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LIST OF SYMBOLS

R^2	Coefficient of determination

LIST OF ABBREVIATIONS

MOLAND	Monitoring Land Use/ Cover Dynamics
1D	1 Dimensional
2D	2 Dimensional
3D	3 Dimensional
GIS	Geographical Information System
SPSS	Statistical Package for the Social Sciences

CHAPTER 1

INTRODUCTION

1.1 Introduction

Floods are naturally occurring phenomena that can and do happen almost anywhere. In its most basic form, a flood is an accumulation of water over normally dry areas. Floods become hazardous to people and property when they inundate an area where development has occurred, causing losses. Mild flood may have some impact on people or property, such as damage to the landscape or resulting in undesirable debris. While, severe flooding can often destroy buildings, crops, and can also cause severe injury or maybe death (FEMA, 2008).

Flood risk assessment is the systematic approach to identify how flooding impacts the environment. In hazard mitigation planning, flood risk assessments are the basis for mitigation strategies and actions by defining the hazard and enabling informed decision making. The danger of flooding can't be basically distinguished by knowing where the flood happens. The most well-known strategy for deciding flood risk are hazard and vulnerability assessment (FEMA, 2008).

Flood damage assessment is a basic segment of flood risk mitigation. To assess measures that can be taken to moderate the harms from flooding, evaluation of harms must be led utilizing direct assessment or modelling approach. Without clear and reproducible flood damage assessment, analysis is extremely troublesome, and the administration of hazard is less dependable (FEMA, 2008).

The estimation of damages caused by floods usually focus on the flood depths. That is why the flood depth-damage curves have been used in several locations around the world as the most commonly used method for assessing the impact of floods (Merz et al., 2010). The flood depth-damage curves can also be classified as absolute or relative, depending if the cost is given in economic terms or as a percentage of the total value of the asset that has been affected. There are two factors influencing the damage that are the impact parameters and the resistance parameters. The impact parameter reflects the specific characteristics of a flood event (such as water depth, flow velocity, etc.) and for the resistance parameters represent the properties of the affected assets (such as building type or materials, emergency measures used, etc.) (Merz et al., 2010). It has been concluded that, with the exception of flood depth, most of the influencing factors that have been affected have been neglected in the modelling of the damage (Merz et al., 2010).

A flood risk approach seems to have significant potential in reducing flood impacts. However, the implementation of this method is still new and lack of available literatures regarding to it, especially on the derivation of flood damage function curve. Hence, with the aim to assist in the assessment of flood risk in Malaysia, it is compelling to carry out a study on the development of site-specific damage curve that reflects the local condition of the study area.

1.2 Problem Statement

Floods often cause significant losses to people and properties. The expected losses in residential area are lower than commercial or industrial area, hence the damage estimation is often neglected or only accounted for by using simple approaches and rough estimates (Merz et al., 2010). However, due to the higher concentration of population and asset nowadays, the vulnerability of residential area is increased, thus needed a detail damage assessment that can also be used to predict future flood effects (Diakakis et al., 2017).

Many previous researchers such as Herath (2003) and Chinh (2017) used modelling approach to estimate flood damage compared to direct assessment. Assessing damage using direct method is time-consuming and costly. Furthermore, the assessment was based on the respective flood event only. In contrast, the modelling approach can be used for any flood event as the depth-damage curve is expressed in percentage (Oliveri and Sontoro, 2000). Using our own damage curve is appropriate to reflect the effect of local condition to damage estimates. Hence, an attempt has been made to conduct a study on flood damage assessment in an urban area where a site-specific flood depth-damage curve was produced.

1.3 Objective of the Study

The objective of this study are:

i. To assess the direct residential flood damage of 2013 Kuantan flood and identify the factors that influenced the level of flood damage.

ii. To develop a residential flood depth-damage curve for Kuantan based on 2013 flood event.

1.4 Scope and Limitation of Study

In order to conduct this research study, the data from the interview survey was collected from residential area of Kuantan, Pahang. Kuantan is one of the big flooded city that has been affected during 2013. The focus of this research is to get the estimation of direct tangible damage which included the damage caused by direct contact with water, and contains most of the insurable losses. Flood depth-damage curve is the plot of flood damage versus corresponding flood parameters. This study only considers flood depth as the flood parameter.

1.5 Significant of Study

Flood depth-damage curve is the important element in the assessing of flood damage. The depth-damage curve is used as the input in flood damage modelling. The developed damage curve may be applied to the further flood damage estimation works of Kuantan. The identification of socio-demographic or other related factors that influenced the level of flood damage is useful for future planning of damage assessment studies in Kuantan.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Flood risk assessment is an important tool in assessing the possibility of floods. Risk analysis can be used as part of flood management, but can also be used in cost-benefit analysis, when comparing different adaptation strategies. Therefore, this analysis is important when assessing the choice of flood disaster reduction and optimizing the economy from possible measures (Apel et al., 2008).

The flood hazard is characterized as the measurement of the number, degree and area of flood anticipated that would happen with the span of return gave. This implies the conveyance of waterproof space computed as an arrival period capacity can be utilized to outline the risk of flood. Vulnerability is the weakness of the zone that has been flooded. The best approach to express the vulnerability is to evaluate the cost of damage (FEMA, 2008). Figure 2.1 shows a framework to assess the flood risk that has been proposed by Zhou (2012).

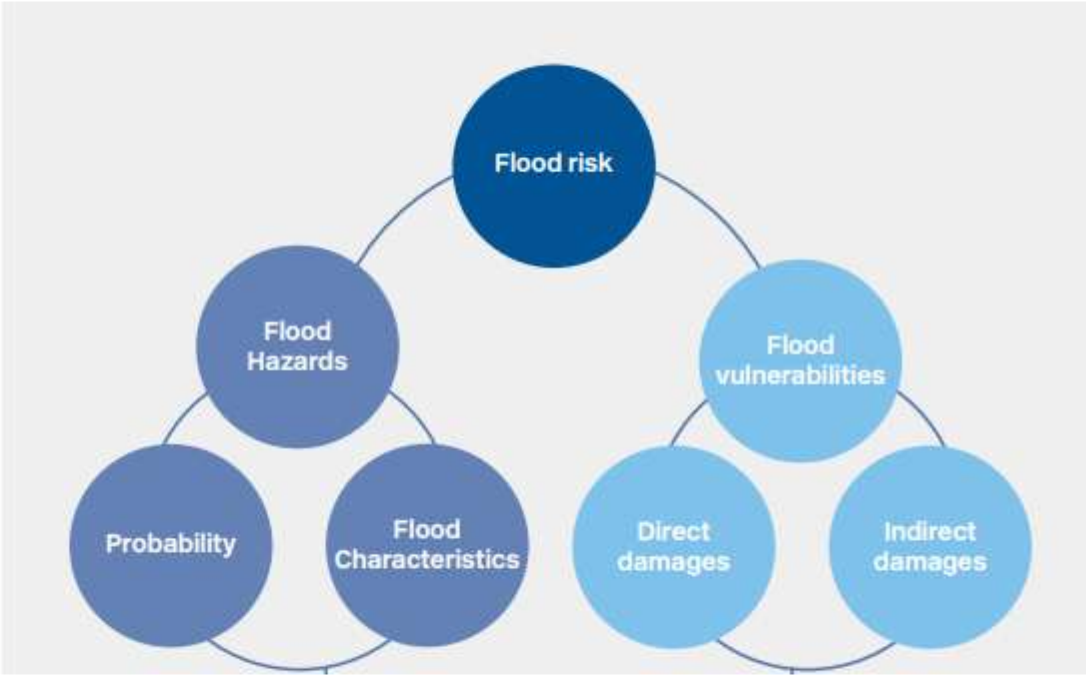

Figure 2.1: A framework for flood risk

Source: Zhou et al. (2012)

2.2 Flood

A flood occurs when water overflows the normally dry land. Floods can be grouped into several types as follows: groundwater, fluvial, pluvial and coastal.

2.2.1 Groundwater

Rising groundwater will mostly lead to basements being flooded with non-polluted water and cause common flood. Occurs when the water table rises above normally expected and anticipated levels and intersects with the surface, this is usually after long periods of sustained rainfall. This dataset is a susceptibility indication which identified areas where geological conditions may result in flooding and where groundwater may come close to the surface.

2.2.2 Fluvial

Fluvial floods are caused by streams. The level of contamination in the water from the waterway relies upon a few catchment includes for instance; it can be influenced by the nearness of industrial areas in the upstream zone. Fluvial flood include the high water level and velocity. High velocity water may likewise contain pieces, which can represent a hazard to the population and structure (Olesen et al., 2017)

2.2.3 Pluvial

Pluvial flood are flood that have been caused by the load of the recovering framework during the rain occasions. Extreme load might be resulting to the crack of mists or prolonged rain occasions. Accordingly, while evaluating the effect of pluvial flood, it is imperative to assess the hazard that individuals bear irresistible sicknesses, particularly if the joined sewer system is introduced in an appealing zone (Olesen et al., 2017).

2.2.4 Coastal

Beach floods are caused by rising ocean levels, caused by waves and tidal surges. Also, as fluvial floods, floods on the beach include the danger of high water levels and solid streams. The danger of irresistible sicknesses isn't so high. In any case, there is a general danger of higher auxiliary harm and harm to electrical segments, since saltwater is more destructive (Olesen et al., 2017).

Flooding may happen as a flood of water from water bodies, for example, a stream, lake, or sea, in which the water overtops or breaks levees, bringing about a portion of that water getting away from its standard limits, or it might happen because of an amassing of water on soaked ground in a flood zone. While the extent of a lake or other waterway will fluctuate with regular changes in precipitation and snow dissolve, these adjustments in measure are probably not going to be viewed as noteworthy unless they surge property or suffocate residential creatures (Olesen et al., 2017).

Floods can likewise happen in streams when the stream rate surpasses the limit of the waterway channel, especially at curves or wanders in the conduit. Floods frequently cause damage to houses and organizations on the off chance that they are in the normal flood of rivers. While riverine flood damage can be disposed of by moving far from river, individuals have generally lived and worked by streams on the grounds that the land is typically level and prolific and in light of the fact that streams give simple travel and access to trade and industry. Some flood grows gradually, while others, for example, flash flood, can create in only a couple of minutes and without noticeable indications of rain. Furthermore, flood can be local, affecting an area or network, or extensive, influencing whole river basin (Olesen et al., 2017).

Flood mitigation includes the administration and control of flood water development, for example, diverting flood run-off using flood walls and flood gates, as opposed to anticipate flood inside and out. It additionally includes the administration of individuals, through measures, for example, departure and dry/wet sealing properties. The prevention and mitigation of flooding can be contemplated on three levels: on individual properties, small communities, and entire towns or urban communities. The expenses of insurance ascend as more individuals and property are ensured (Olesen et al,. 2017).

When considering structural solutions, it's important to comprehend the viability of individual measures in terms of flood mitigation impact. For instance, a few works may reduce flooding to an expansive region by centimetres which giving a negligible advantage to an extensive number of homeowners that are minimum influenced by flooding and no advantage to those property holders that are most exceedingly terrible influenced. Flooding can occur in developed urban zones because of an expansion in the rate of tempest water overflow or towns and rural areas worked inside floodplains. Poor storm water management can likewise cause limited flooding (Zhou, 2014).

Depending on locality and the nature of the flooding, a number of structural (infrastructure) and non-structural (flood resilience) mitigation measures may be available. However, flood mitigation measures may only lessen the impact of flooding. No amount of intervention can stop heavy rain or high tides. The community, local businesses, emergency services, local council and government need to work together to reduce the impact of flood waters. The Northern Territory Government is committed to assisting residents in flood-prone areas through a range of flood mitigation options (Box et al., 2013)

Structural flood mitigation is where physical structures are constructed or modified to reduce the impact of flooding on individual properties or whole catchments and include infrastructure, including dams, levees, bridges and culverts. When considering structural solutions, it's important to understand the effectiveness of individual measures in terms of flood mitigation impact. For example, some works may reduce flooding to a large area by centimetres which provides minimal benefit to a large number of homeowners that are least affected by flooding and almost no benefit to those homeowners that are worst affected (Box et al., 2013).

Non-structural flood mitigation is proven method and technique for reducing flood risk and flood damages incurred within floodplains. Thousands of structures across the nation are subject to reduced risk and damages or no risk and no damage due to implementation of non-structural measures. Besides being very effective for both short and long term flood risk and flood damage reduction, non-structural measures can be very cost effective when compared to structural measures. A particular advantage of non-structural measures when compared to structural measures is the ability of non-structural measures to be sustainable over the long term with minimal costs for operation, maintenance, repair, rehabilitation, and replacement. The examples of non-structural measure are flood modelling, flood forecasting and flood risk assessment.

2.3 Flood Risk Assessment

Flood risk assessment is related to two elements, hazard and vulnerability. Any floodplain management program must be established on a sound technical and scientific basis in order to be effective, whether for flood loss reduction or to manage natural resources, or both. For management purposes, nature of the flood hazard and the degree of flood risk for a specific site often has to be determined.

2.3.1 Hazard Assessment

Water depth is identified as the main element in the flood hazard assessment. Moreover, the simulation of flood characteristics, for example, peak discharge and flood inundation, is obtained through computer and numerical models, which can be assembled into one-dimensional (1D), two-dimensional (2D), and three-dimensional (3D) models (Teng et al., 2017). These models are broadly connected in urban regions as they can contribute to the representation and the simulation of the physical situation that can occur during floods.

In any case, time of simulation, which relies upon cell estimate, computer framework productivity, size of modelling region, level (scope) of study, and a few different parameters, ought to be additionally considered while characterizing the cell size of the flood inundation simulation (Mallak and Ishak, 2012).

2.3.2 Vulnerability Assessment

Vulnerability is the measure of the capacity to climate, resist, or recover from the effects of hazard in the long term as well as the short term. Vulnerability relies on numerous variables, for example, land use, type of development, content and use, the nature of populations (mobility, age, health), and warning of a looming hazardous events and eagerness and capacity to take responsive activities. This implies inside a identified flood hazard area there might be a similar exposure or danger of flooding, however an extensive variety of vulnerability to the hazard. Floodplain managers and projects need to perceive and represent scopes of vulnerability to flood hazards (FEMA, 2008).

The vulnerability of the flood area is generally calculated using a flood damage assessment. Such assessment might be utilized, for obscure future occasions as risk mapping and after the occasions observed in financial assessment for insurance and compensation losses (Merz et al., 2011).

Economists have identified two key valuation methods to estimate the cost of damage to natural hazards, which is the assessment of economic losses and the assessment of financial losses. Thus analysts have analysed the country as a whole, and therefore consider the economic impact of the country needed and instead focus only on the area used. If the budget is done on a national scale (or many other scales greater than the potentially flooded area), it is referred as a macro scale assessment. In economic analysis, the real opportunity opportunities for specific losses are used, and need to be exempted from tax.

Financial analysis considers losses to individual households, called micro-scale assessment. However, financial analysis can be used on a meso-scale, in this case it covers the local community (Merz et al., 2011). The difference between economic and financial assessment is shown in Table 2.1.

2.4 Flood Damage Assessment

The most well-known and globally accepted technique for estimation of urban flood damage is using the depth-damage function. Structure and content damage resulting from flood hazard are impacted by numerous variable, typically only building use and inundation depth are considered as damage-causing factors and included into the formulation of depth-damage functions. The building age, type of foundation, and height of the main floor can be included as factors which contribute to the estimated damage of a structure, which are external to the depth-damage functions (Pistrika et al., 2014).

Table 2.1 : The difference between economic and financial damage assessment. Adapted from Hammond et al. (2015).

	Economic	Financial
Geographic restraint	Nation-wide: Macro scale	Individual catchments, municipalities and/or households: Micro/meso scale
Economic appraisal	Real opportunity cost Depreciated asset values Tax excluded	Replacement cost Replacement asset values Tax included
Indirect losses	All production and sale losses for business is excluded, unless business is being relocated outside of the nation	All business losses are included

2.4.1 Flood Damage Classes

The cost of damage can be assessed comprehensively with the utilization of socioeconomic analysis. In this analysis, material damage was evaluated, as well as related with flood, and expenses related with the loss of welfare for the affected population (Hammond et al., 2015). This is a thorough analysis, and there are numerous variable to consider for the cost of damage related with floods. Accordingly, cost organization and appraisal restrictions are difficult to determine. To reduce the estimation of damage in socioeconomic analysis, the losses are divided into four classes, listed in Table 2.2 along with the sample of loss type.

The classes have been defined from the concept of direct and indirect losses, and whether the losses are significant or not. Direct losses are defined as losses incurred as a result of direct contact with water, while indirect losses are only due to floods. Direct losses are directly attributable to the duration of a flood, while indirect losses can affect the time scale of the month and year (Merz et al., 2011). In addition, the loss is divided into tangible and intangible losses. Unlike significant losses, significant losses are objectively quantitative losses, i.e. losses can be accounted for in direct monetary value, which can be determined based on whether or not the market is out of the asset in question (Hammond et al., 2015). Each of these four classes of damage is presented in Table 2.2.

Table 2.2 : Damage Classes. Adopted from Hammond et al. (2014)

	Direct loss	**Indirect loss**
Tangible	Structural damage Cars Infrastructure Livestock Crops Evacuation and rescue operations Clean up costs	Disruption to transport Business interruption Temporary housing of evacuees Loss of industrial production
Intangible	Lives and injuries Diseases Loss of memorabilia and pets Damage to cultural or heritage sites Ecological damage Inconvenience	Stress and anxiety (PTSD) Disruption of living Loss of community Reduced land values Undermined trust in public authorities

2.4.1.1 Direct and Indirect Damages

This class of damage is included in most material damage caused by direct contact with water, and contains most of the insurable losses. Therefore, this class of damage is partially or wholly always included in the damage assessment. This observation is however partly based on the fact that this class is always included in damages costs, and is mostly the only one included. Moreover, is it the best understood damage class (Hammond et al., 2015). Three leading methods for the quantification of direct tangible damages were recognized in the majority of previous studies are damage assessments through insurance data, the unit cost (or average) method and stage-depth damage curves.

Insurance data from previous flood events has often been applied in studies where intangible and indirect damages have been neglected. The insurance pay-out is used as an indicator of the physical damage that the flooding has created. This cost represents the replacement cost. Therefore it can be necessary to depreciate the insurance pay-outs to obtain a more correct damage loss. Insurance data is also applied in ex-ante assessments, where it can be used as empirical data and thereby help to estimate the expected loss in the future (Olesen et al., 2017). When using insurance data in the loss assessment, the following points need to be considered;

i. Not all inflicted stakeholders hold insurance, and their loss is therefore not included in the insurance data. This can concern private households as well as government owned buildings and structures.

ii. Not all inflicted stakeholders are economic realistically insured; some might be under or over insured.

The total estimated cost of a flood event can strongly increase if indirect damages are considered in the assessment (Djordjević, 2014). Many case studies have applied a percentage of direct damage as representative of the indirect damage. This method therefore assumes that the indirect tangible damages are directly correlated to the direct tangible damages, which is a rather coarse assumption. Consequently, the method is primarily used as a simplification, when other data is not available. A more precise method is the unit cost method, where a sector specific loss unit is applied. Since the indirect damages are mostly disruptions, the damage cost is given as a cost per hour or day. Hereafter it is necessary to estimate how many people and businesses will be disrupted by the different types of damages and the length of these disruptions. A method to estimate the cost of the disruptions to people, e.g. caused by traffic jams, is to set the duration of the disruption in relation to the average wage. The estimation of business loss is more difficult, but can mostly be described by interruptions of production due to flooding. For businesses previous studies have used the gross margin per day and multiplied it with the number of days the flood has caused disruption (Dutta et al., 2003). The length of the disruptions can however be challenging to estimate, and is the factor that causes the highest uncertainty in this damage class.

2.4.1.2 Tangible and Intangible Damages

Intangible damages are often associated with the health and welfare of the citizens. The direct intangible losses in this damage class can include irreversible losses, like loss of human life and cultural heritage. Indirect intangible damages mostly involve an interruption in the citizens everyday lives, and can span from health issues to annoyances like power and water cut offs, to difficulties in getting to work. Direct intangible damages are often most significant in developing countries, since high rates of loss of life as a consequence of flooding have been observed here. In developed countries, risk of life is mostly related to coastal flooding, flood defence failure and flash floods. Here, the combination of high velocity, high water depths and debris in the water causes loss of stability in the water and puts people in the risk of drowning. Moreover, high density cities with bad drainage systems can experience a high risk of infectious diseases spreading. Risks to life and health can be reduced by the implementation of warning systems that allow for an evacuation of the people at risk (Olesen et al., 2017).

Indirect intangible damages are hard to quantify in general. Often, attempts are made to provide estimates based on the damage estimates for the other damage classes. However, it can be difficult to identify meaningful relations between the damage estimates for different classes. An example is the flooding of traffic infrastructure. In this case an indirect intangible damage are annoyances caused to citizens, but these are hard to set in relation to the material damage or the delay in traffic. Another example is the quantification of damages resulting from supply interruptions of water or electricity depending on the direct damages to a water treatment plant or a transformer station.

Both intangible damage classes have been neglected in the majority of previous damage cost assessments that can be found in the international literature. The most common reason for this, is that the intangible damages are hard to quantify (Meyer et al., 2009). In particular intangible impacts where excluded in studies, where the common metric of money has been used for e.g. risk mapping (Meyer et al., 2009).

The fact that intangible damages can be irreversible makes them especially hard to quantify. Therefore, intangible losses are sometimes not monetized, but included in the damage assessment in a qualitative manner by applying, for example, multi-criteria risk assessments. A multi-criteria analysis can be performed by adding monetary values to tangible damages, but also using a scoring or weighing factor either attached to areas of specific importance or vulnerable hotspots (Halsnæs et al., 2014).

In several case studies survey based cost estimation has been performed after major floods. Here, it is not only possible to include the tangible damages, but also the intangible costs. The primarily used methods to assess the intangible damages have been the concepts of "willingness to pay" and "willingness to accept", or the so-called contingent valuation (Meyer et al., 2013). However, these concepts rely on the expressed or stated preference methods, which have been widely criticised (Handmer et al., 2002). Another method for the value of recreational resources has been the so-called travel cost method. Here, the appraisal is based on valuation of the total cost the visitors have held to visit the place, which included, for example, monetizing both the actual travelling cost and the time spent on travelling (Penning-Rowsell et al., 2013).

2.4.2 Estimation Approaches

Estimation of flood damage in urban areas is very important as a quick estimate of economic damage after a disaster can be very useful in allocating resources for recovery and reconstruction. Usually, estimation of potential flood damage is needed in long-term flood control planning and emergency management. While the potential flood hazard reduces with improved flood mitigation schemes, flood damage potential increases with the accumulation of wealth and urban expansion. A prior estimate of flood damage potential thus helps in crisis management after a large scale urban flood disaster (Herath et al., 2003).

Unit loss models and model applications are the two common flood damage estimation approaches. These models are based on depth-damage relationships for typical property types. They aggregate the estimated flood damage for individual properties, employing detailed surveys of land-use units. While, the second approach employs models which estimate the linkage effects or inter-sector relationships of flood (Herath et al., 2003).

2.4.2.1 Direct Estimation

The principal advantage of the unit loss model is its ability sensitively to estimate primary impacts and the potentially large damage differences generated by relatively small increases in flood levels. But, the unit loss approaches are less suitable for modeling the impact of extensive floods, although unit loss data have been used as the basis for more generalized flood loss data incorporated by researchers.

The flooding throughout Europe in 2002 constituted one of the most severe flood events in more than a century. During this event, the Vltava river exceeded the water level of the major 1890 Prague floods. In order to evaluate flood losses, a methodology for assessing direct flood damage potential using the Monitoring Land Use / Cover Dynamics (MOLAND) database combined with a flood extent map, hazard map (and connected flood depth) and economic asset data (Kasanko et al., 2003).

Subsequently to the 2002 floods, a new methodology was introduced, where constructing ‘synthetic’ stage-damage curves and these are based on hypothetical analysis. Quality of damage assessment depends on the quality of the classification. The classification offered by the MOLAND database signifies a high level of detail. The concept of damage function is used when calculating flood damage. In order to assess flood damage correctly, impact parameters need to be incorporated within a method. The results provide an average estimate and should not be considered a detailed cost assessment of the damage, since they strongly depend upon the quality of damage functions and availability of detailed datasets (Genovese, 2006).

2.4.2.2 Modeling Approaches

After the potential flood hazard is identified for the given region, the most important is to understand and identify the characteristics of hazard. For this issue the newly developed modelling approach can be used. Output parameters from modelling should give users the correct characterizations of the flood processes and not only the flood extend (like in traditional methodology for flood hazard mapping), but also for flood depth, water flow velocity, warning time, duration (Alkema, 2007). Flood modelling for hazard and risk assessment became the popular tool on different stages of flood management (Plate, 2002) it is necessary to choose the proper approach to simulate flood processes among available tools and software. Nowadays 1D and 2D modelling approaches are wide used for modelling of river flow. The Saint Venant equation is widely used for 1D flow modelling (Brunner et al., 2015).

There are many issues involved in an adequate flood loss estimation model due to the nature of the flood damages. The flood parameters are flow velocity, duration, depth and few others. Based on the questionnaire survey, historical flood damage information, laboratory experiences, the stage-damage function will represent the relationship between flood damage and the parameters damage function (Brunner et al., 2015).

The flood loss estimation modelling approach based on Geographical Information Systems (GIS) was developed by the Ministry of Construction of Japan in order to carry out damage estimations once the extent of the flood has already been calculated (Brunner et al., 2015). The approach utilizes a distributed flood inundation model created through the use of GIS consisting of property information and stage-damage functions, and describes damage to each property category for a given flood depth and duration. This methodology can be used to estimate damage potential under various flooding scenarios and, by being coupled with flood simulation applications, can serve as a tool for rapid economic appraisal of flood control project benefits as well as for assessing relative merits of different flood control options.

By combining a flood inundation simulation model with a loss estimation model in order to account for direct flood damage, the GIS-based modelling approach is an expansion of existing methodology. In the loss estimation modelling, direct flood damages are categorized into three main groups: urban, rural and infrastructure damages. In this approach, GIS plays an integral role in pre- and post-processing of spatial input and outputs. The model also integrates a physically-based distributed hydrologic model and a flood damage estimation model. It considers all the physical processes in a river basin for flood inundation simulation and utilizes stage-damage relations for different land cover features in order to estimate the economic losses caused by floods. The results of application in the Japanese river basin show that the model can simulate flood inundation parameters well (Dutta and Herath, 2003).

2.5 Flood Depth-Damage Curve

In Malaysia, flood damage curve has not been widely used and still lack of damage curve for damage assessment model (Romali et al., 2015). Damage curves are graphical representations of the losses expected to result at a specified depth of flood water. Such curves are typically used for housing and other structures, where stage or depth refers to depth of water inside a building and damage refers to the damage expected as a result of that depth of water (Emergency Management Australia, 2002).

2.5.1 Approaches and Methods

Smith (1994) distinguishes basically two approaches for the development of these curves. The first approach actual damage survey is based on gathering of data from actual flood events and their use as a guide to future events. But the extrapolation of these curves from place to place has presented some difficulties due to differences in warning times, building types and contents. A different approach was required and a new method was developed. It is based on synthetic stage-damage curves, which do not rely on information from an actual flood event but are based on hypothetical analysis.

Synthetic stage-damage curves are of two types. These are based on existing databases and on valuation surveys. Both require the elements at risk to be subdivided into a number of classes.

2.5.1.1 Existing Databases and Valuation Survey

All the elements at risk are included within a cadastral database. They are classified in different categories and subcategories and stage-damage curves are developed for each of these groups. Usually, the estimates of the damages to building fabric are obtained using existing information on the possible effects of flooding on building materials. The losses to content are based mainly upon ownership rates obtained from marketing manuals, relating ownership to social class. This method makes the assumption that properties in flood-prone areas are comparable within a whole country. The limitation of this approach is that all this information on itemized flood damage to building structure, the market and consumer ownership statistics and the data on social class are not always available in all the countries (Coto, 2002).

In order to evaluate flood losses in Prague during 2002 flood, a methodology for assessing direct flood damage potential using the existing database combined with a flood extent map, hazard map (and connected flood depth) and economic asset data (Kasanko et al., 2003). The study area includes the central part of the city of Prague that was flooded in 2002. Combined with existing information on land use and flood depth, maps of the flooded areas provide information that can be used for flood damage assessment, urban and rural planning and validating flood simulation models.

The alternative approach to the inventory method is to undertake surveys of the different types of dwellings at risk in the flood-prone study areas. There is no reason to doubt the validity of this assumption; but the valuation survey method is normally limited to dwellings in a particular region.

An example for this valuation approach is the method developed specifically for the damage assessment in Las Juntas de Abangares, Costa Rica, by Leandro (1993). In this case, the elements at risk were divided into damage sectors, which include groups of elements with common features related to the social or economical activity they perform. Three main damage sectors were defined:

i. Buildings: subdivided using the building material (concrete blocks, prefabricated concrete or wood) as first parameter and the use (residential, commercial and industrial) as second parameter. Inside the commercial activities, grocery stores, bars, churches, hotels and shops are also differentiated. The curves for each building type show the percentage of damage to structure and content, in relation to floodwater depth.

ii. Transportation lines: this sector includes all the roads, power and telephone lines and bridges that, in case of flooding, would be used during the implementation of the strategies of emergency. The damage curve refers only to the fact that the element is available or not during the emergency.

iii. Crops: include agricultural and cattle raising activities. The damage refers to the amount of money (presented as percentage of the total production value) necessary to recover the original production. Two types of floods were considered: passive and active. The damages caused by passive flooding are related only to physical contact between floodwater and the element, with almost no structural damage for buildings. On the other hand, during an active flooding, structural damages can occur. Therefore, different damage curves were developed to assess both cases (Leandro, 1993).

2.5.1.2 Synthetic Method

This approach is to collect synthetic data on damages for the area under investigation. These are damages, which would occur for a potential flood with predefined parameters. These data are assessed either by experienced damage assessors or questionnaires: "How much damage would result for this element from a flood with the following parameters?" These data can be collected for single buildings or a representative object from a certain class or sector and can be used to derive damage functions (Bubeck, 2007).

2.6 Conclusion

Flood damage assessment is a critical component of flood risk mitigation. To evaluate measures that can be taken to mitigate the damages from flooding, assessment of damages must be conducted. Without clear and reproducible flood damage assessment, analysis is very difficult and the management of risk is less reliable.

The flood depth-damage curve is based on empirical data of actual, ex-post flood damages, collected during site survey immediately after the flood event. The curve represents the relationship between flood depth and damage. Hence, it is important for flood damage analysis to focus on the development of damage curve.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter discussed about the methodology applied to carry out the survey and analysis to produce the flood depth damage curve. The survey was carried out around Kuantan city that has been affected during 2013 flood such as Kg Sg Isap, Sg Soi and Kg Permatang Badak as shown in Figure 3.1.

Figure 3.1: Study area

3.2 Flow Chart of Methodology Study

The Figure 3.2 shows the flow chart of the survey. This survey involved with a few steps to produce the flood depth damage curve. The parameters involved are depth and damage that occurred after the flood. The survey was conducted and the data collected was analysed to produce the curve.

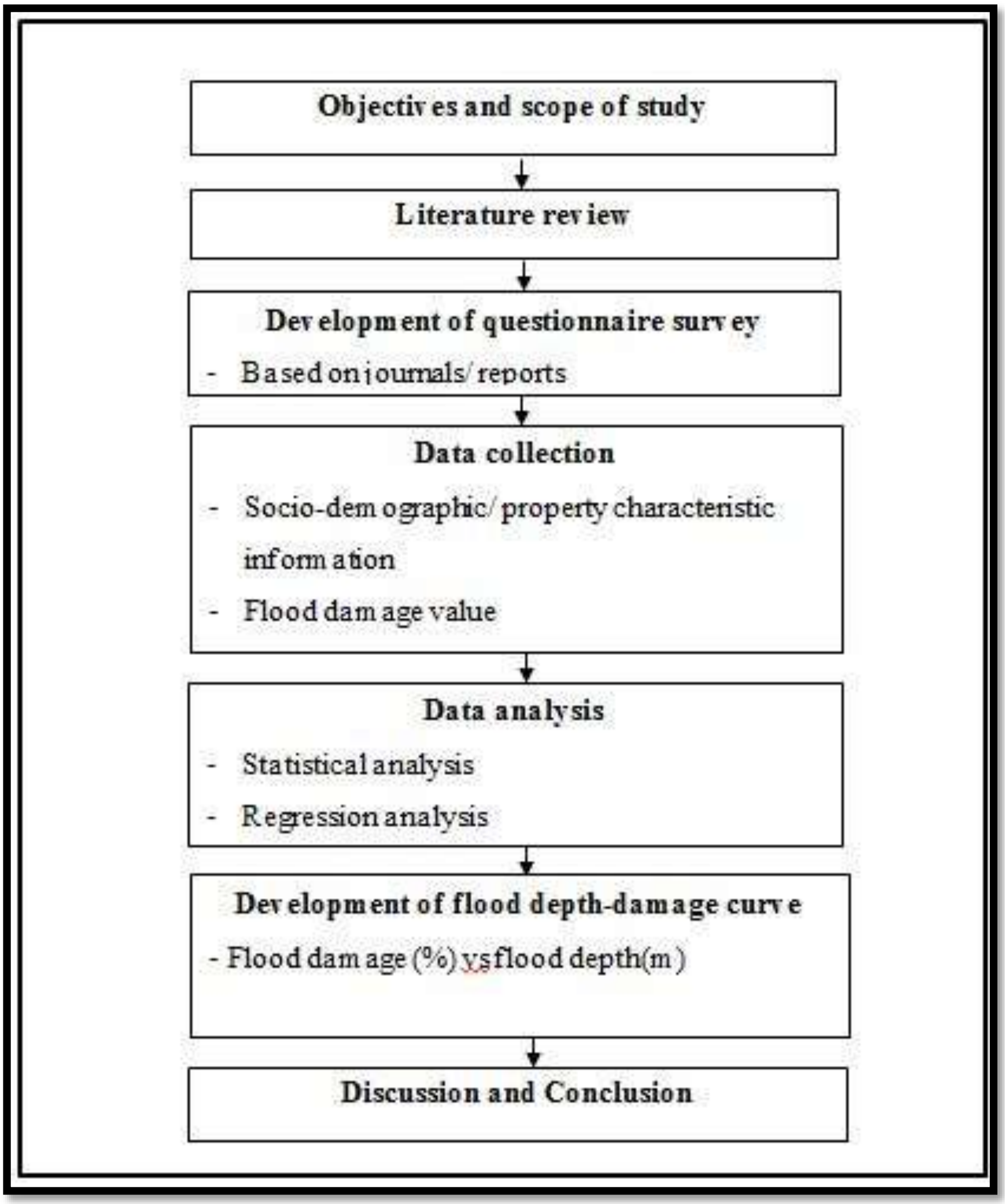

Figure 3.2: Flow Chart of Methodology Study

3.3 Questionnaire Design

The questionnaire forms were sent out to the respondents that are the residents. The survey consisted in interviewing residents in Kuantan flood prone urban area in order to develop a data base characterizing the social class, the houses, the contents (inventory items) and the damages caused to dwellings by a reference flood event.

About 100 questionnaires were distributed to respective respondents, and all the questionnaires were collected and processed. It is recognized that more questionnaires would be required in order to obtain more accurate and statistically reliable damage curves. Feedback from the questionnaires completed by the residents has been available to others, who are asked to answer the same questionnaire, expressing their own opinion as well. Thus, the questionnaire-based loss database, will be frequently updated, and more accurate and statistically more meaningful damage curves will be published in the near future.

The closed-ended type questionnaire consists of two sections; residential property survey and residential damage survey as shown in Table 3.1. For section 1, the socio-demographic information (such as age, sex, household income, and education level) and the property characteristics (such as types of property, type of construction materials, numbers of storeys and distance from river) were asked. The respondents also have to estimate the total value of in-house belongings. For section 2, respondents were asked to estimate the damage depth/duration and damage value of the flood events i.e. the value of content, structural and vehicle damage. In order to obtain the statistical characteristics of flood damage and to study the influence of the socio-economic and property characteristic variables to the level of flood damage, an analysis using SPSS was conducted.

Table 3.1: Parts of questionnaire survey

Category	**Section 1**	**Section 2**
Residential Property Survey	Personal Details	House Information
Residential Damage Survey	Content Damage	Structural Damage

3.4 Data Collection

Questionnaires were distributed to the respondents at residential area of Kuantan. The related information was gained through interview survey. Sg Soi, Sg Isap and Permatang Badak was selected as the study area based on previous massive flood event. The aim is to develop a data base characterizing the social class, the houses, the contents (inventory items) and the damages caused to dwellings by a reference flood event which is 2013 flood.

The data was collected by face to face interviews with the residents of Kg Permatang Badak, Kg Sg Isap and Kg Sg Soi as shown in Figure 3.3 and Figure 3.4. The survey was conducted from 25 March 2018 to 8 April 2018.

Figure 3.3: Interview survey carried out among the residents

Figure 3.4: Measuring the height of the flood

3.5 Development of Flood Depth-Damage Curve

Damages to structures in the floodplain are strongly related to the water depths due to the flooding. There are many other important parameters, but depth describes the majority of the variance of damages when the structures are stratified by construction and use (Lehman et al., 2016). 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. Additionally, there may be considerable differences in the components of the structure and their elevation relative to the ground. For instance, some two story residential structures may have the laundry room on the first floor, while others may have the laundry room on the second floor. Since the laundry probably would have either gas or high voltage electrical, different components within the structures may get damaged at different depths relative to the first floor or ground level of the structure. This implies that there is considerable uncertainty in the damage for a give elevation even when use and construction type are held constant (Lehman et al,. 2016).

Flood depth-damage curve in this study was developed using the collected damage data by plotting the flood damage (in percentages) versus flood parameters.

The following Eq. (3.1) and Eq. (3.2) based on the study by Win et al. (2018) were used to calculate the percentages of damage for each damage type:

Content Damage Rate:

$$\frac{\text{Estimated Content Damage Value (RM)}}{\text{Actual Content Value (RM)}} \tag{3.1}$$

Structural Damage Rate:

$$\frac{\text{Estimated Structural Damage Value (RM)}}{\text{Actual Structural Value (RM)}} \tag{3.2}$$

3.6 Development of Depth-Damage Regression Equation

A few variables that may be influenced the level of flood damage were entered into the SPSS software to investigate the relationship between damage and other factors. Depth-damage regression equations were built by using regression analysis methods. Through the comparative analysis of the correlation coefficient of the regression equation, linear regression model has been generated.

The model performance is reasonable, when the significant values (P) for the variables was observed to be less than 0.05. Independent variables, such as house's price, construction materials and house income were considered for explaining the structural and content damage rate. The multiple regression model revealed which factor that affected the damage rate the most.

In this study, a multiple regression model was used to analyse the flood damage and its socio-demographic and property characteristics variables, which is specified in Eq. (3.3).

$$Y = Xb + e \tag{3.3}$$

where Y is flood damage, X are the determinants of flood damage, and b is a parameter (variables).

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This study conducts questionnaire survey in Kuantan flood prone area and a questionnaire form was used to gain information on the extent of disaster (flood depth), loss value and past flooding experience.

According to the survey data, we investigated about the job and income of every member of the household. In this situation, we checked the main job category and income of the household head and other household members in order to classify them into groups as follows: (1) government servants, (2) private servants, (3) own business and as for income, there are 3 categories that are low income (1) <1000, normal income (2) 1000-3000, and high income (3) >3000.

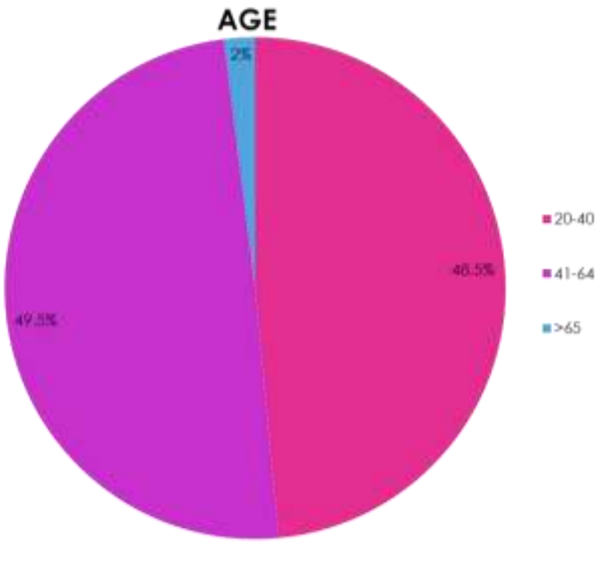

Figure 4.1: Age distribution of the respondents

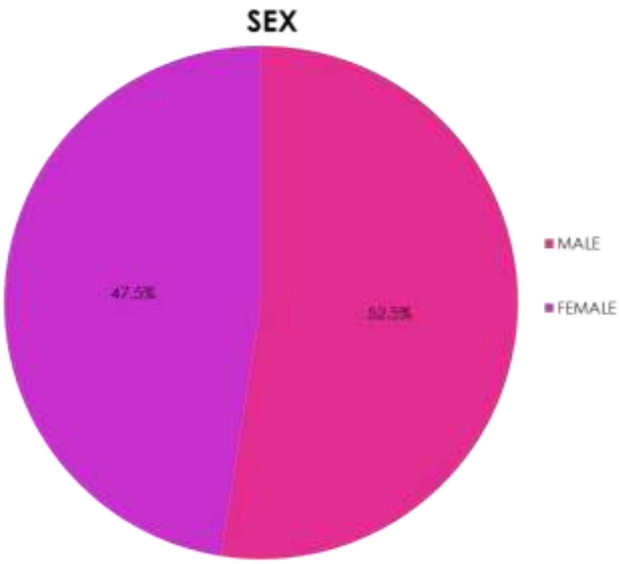

Figure 4.2: Sex distribution of the respondents

From the Figure 4.1 and Figure 4.2, almost 50% of the respondents are from the age of 41 to 64 and 52.5% are male. All respondents are Malay as the study areas are an old Malay residential.

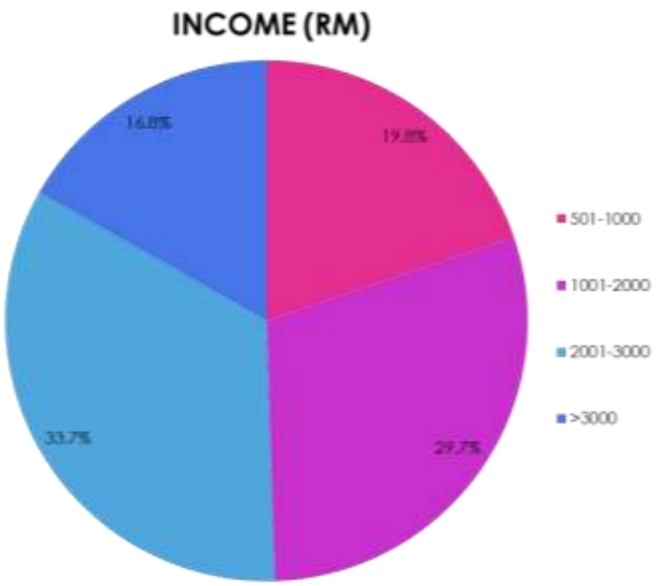

Figure 4.3: Income distribution of the respondents

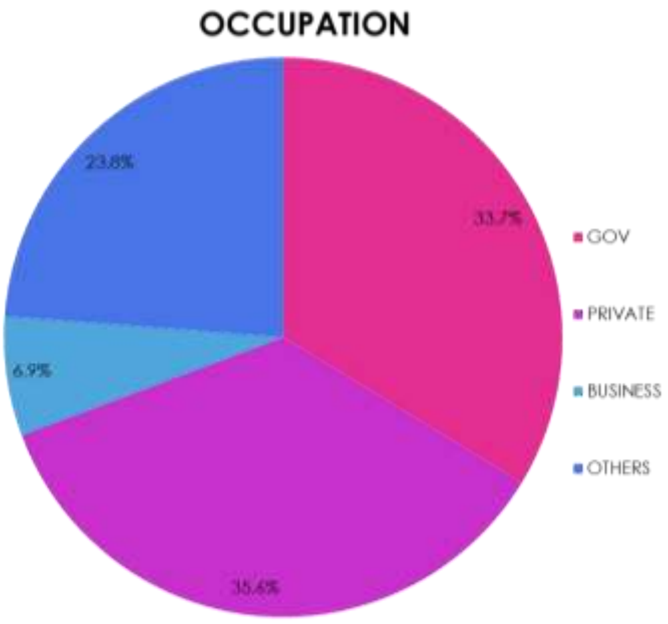

Figure 4.4: Occupation distribution of the respondents

The average house income is between RM 2001 to RM 3000 where 36% of the respondents working in private sector. The construction materials type that is mostly observed is brick which is 65.3%. 24.8% of the houses are combination of brick and wood, whereas wood houses are observed to be only 9.9%. Most of the houses at the survey area i.e. Sg. Soi, Sg. Isap, and Permatang Badak are one storey terrace house as shown in Figure 4.5, Figure 4.6 and Figure 4.7 respectively.

Figure 4.5: Single storey terrace house at Kg Sg Soi

Figure 4.6: Single storey terrace house at Kg Sg Isap

Figure 4.7: Single storey terrace house at Kg Permatang Badak

The distribution of flood damage according to construction materials are shown in Table 4.1. The average damage of brick houses is the highest, which is RM2642. The average structural damage for wood and brick and wood house is RM2250 and RM2120 respectively. The average content damage is between RM4104 to RM4556 for all types of construction materials. The average value for one storey terrace house is RM 2250 per property. A large amount of damage was usually caused by high water level due to the closer distance from river as shown in Table 4.2.

Table 4.1: Distribution of damage according to construction materials.

Type of house	Structural Damage			Content Damage		
	Number of building	Average value of damage (RM)	Standard deviation of damage (RM)	Number of building	Average value of damage (RM)	Standard deviation of damage (RM)
Brick	66	2642.42	1664.29	66	4556.06	2726.91
Wood	10	2250	824.958	10	4550	1535.69
Brick and Wood	25	2120	960.469	25	4104	1946.04

Table 4.2: Distribution of distance from river

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	400	20	19.8	19.8	19.8
	500	3	3.0	3.0	22.8
	700	39	38.6	38.6	61.4
	800	11	10.9	10.9	72.3
	1000	13	12.9	12.9	85.1
	1200	9	8.9	8.9	94.1
	2000	2	2.0	2.0	96.0
	5000	4	4.0	4.0	100.0
	Total	101	100.0	100.0	

Depth-damage relationships can be computed by a regression equation with the percent-damage to structure or percent-damage to content as the dependent variable. Flood level is the most important, and can be the only independent variable, in the regression. Water height accounts for the greatest variation in the percent damage-equation. Other variables that may be important in the regression are type of construction material, structure, age and condition of the building. However, except for structure type, these variables have seldom been isolated for any flood damage analysis. Sometimes structural and content-damage are computed as a combined total.

4.2 Multiple Regression Analysis

The rate of flood damages is influenced by a number of variables. If variables are tested and found to be significant, they can be used to compute more reliable flood damage function relationships. Other important variables directly affecting structure damage include construction material, age and condition of the buildings. These are variables that have received little attention for this research. However, Penning-Rowsell and Chatterton (1979) have isolated some of these factors and built them into separate depth-damage functions at least for residential property.

Based on the results in Table 4.3, the multi regression model in Eq. (4.1) is obtained:

$$Y=0.662\boldsymbol{a}-2.773\boldsymbol{b}+1.723\boldsymbol{c}+21.719 \quad (4.1)$$

Where;
"a" represents house's price,
"b" represents construction materials
"c" represents the household income.

Table 4.3: Results of multiple regression analysis

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	21.719	10.148	1.992	2.456	.027
House Income	1.723	1.080	.197	1.511	.034
Construction Materials	-2.773	.915	-.167	-1.742	.036
House's price	.0662	.722	-.387	-4.108	.021

This multi regression model shows that the level of flood damage is influenced by the house's price, types of construction materials, and the household income. We attribute the small contribution made by socio-demographic factor to the total damage to the vast experience of the local residents of the Kuantan. Flooding is essentially an annual problem, so the local people have learned how to deal with it, and how to minimize the damage to their personal possessions, regardless of their house type. Knowing the relationship between flooding and its damaging factors, these finding can be easily applied to a flood damage estimation works and contribute to different flood risk reduction scenarios to identify more effective counter-measures.

4.3 Flood Depth-Damage Curves

The depth-damage curve, which is the plot of damage in percentages versus water depth was constructed using power function. Water depth is observed during interview survey while damage percentages were calculated using Eq. (3.1) and Eq. (3.2). This study focused on the relationship between flood damage and water depth, and how they can mathematically explain and predict the economic damage from flooding.

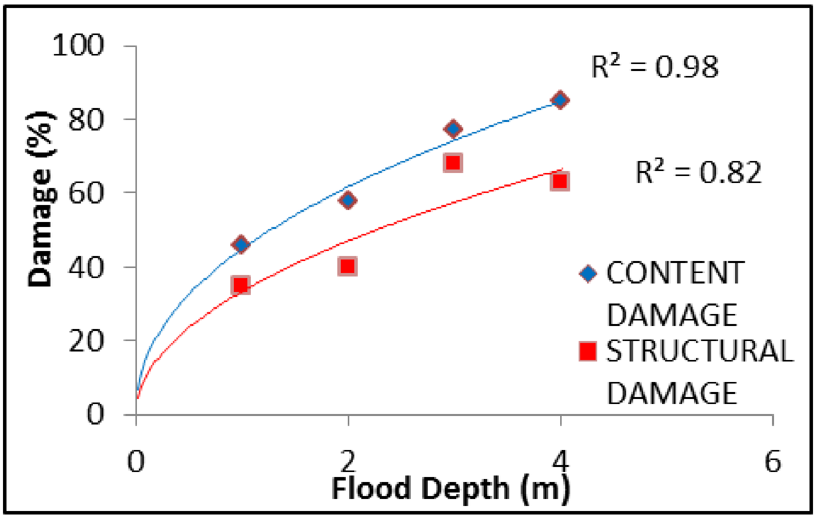

Figure 4.8: Flood depth-damage curve for residential area for Kuantan

From Figure 4.8, it can be seen that the R^2 is 0.98 and 0.82 for content damage and structural damage respectively. The damages increase as the flood depth increases. The percentage of content damage is up to 85% which is higher than the structural damage (up to 65%). As observed from the interview survey, most of the flood victims left their belongings and furniture and could not save any of them. This explained why the content damage is higher than structural damage. Furthermore, the cost of repair or to replace the house content (e.g. furniture and kitchen cabinet) is higher than the cost to repair the structural damage (e.g. wall repainting and tiles replacement).

CHAPTER 5

CONCLUSION

5.1 Introduction

In this study, flood damage assessment was performed for a residential category of Kuantan, Pahang that has been affected. Flood damage was assessed using direct assessment and a flood depth-damage curve was developed using the collected survey data. The factors influenced the level of damages was identified using SPSS for future damage assessment works.

5.2 Conclusion

The results of this study in relation to the research objectives are as follows;

i. Interview survey was conducted to collect damage data and to assess the residential direct tangible damage experienced by the victims of 2013 Kuantan flood. The distribution of structural damage according to the construction materials are RM2642, RM2250 and RM2120 for brick, wood and brick and wood house respectively. The average content damage is between RM4104 to RM4556 for all types of construction materials. Most of the houses are one storey terrace house with average value of damage is RM 2250 per property.

ii. From the regression analysis, the flood damage is found to be influenced by the house's price, construction materials and house income variables. This finding is useful in the future flood damage assessment works where the design of the questionnaires can be focused on the more influenced variables.

iii. The flood depth-damage curve obtained in this study is reasonable as the R^2 is 0.98 and 0.82 for content damage and structural damage respectively. The damage is contributed more by the content damage where the damage percentages (85%) is higher than the structural damage (65%).

Finally, we conclude that these findings are very useful for the application of future flood damage estimation works in support for flood disaster risk reduction efforts in Malaysia.

5.3 Recommendations

The results of this study allow us to make a number of recommendations for improving flood damage prevention in the Kuantan area.

i. For any residential areas, we recommend the establishment of early warning systems and adaptation measures, such as construction of high plinth levels for houses located in flood-prone areas. These steps should decrease the value of damages respectively.

ii. By using flood depth-damage curve it is able to contribute to flood loss estimation models for the entire flood area. This facilitates public officials as they conduct cost-benefit analysis of different potential solutions and remediation approaches. A comprehensive flood loss estimation model should be the focus of future research.

iii. Research and development should be extended to consider additional direct damage such as damage of public infrastructure and indirect damage such as interference in transportation facility in future research.

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APPENDIX A
PHOTOGRAPH DURING SITE SURVEY

Measuring the flood level

Interview session

House contents and vehicle damage