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Establishment of flood damage function model for urban area in Kuantan: A preliminary study

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Establishment of flood damage function model for urban area in Kuantan: A preliminary study

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Abstract. Previous studies on flood damage assessment mostly discussed the relationship between flood damages and hydrological impacts parameters such as flood depth and flood duration. The influence of resistance parameters on flood damages is rarely investigated. Hence, an attempt has been made to establish a flood damage function model based on the relationships between flood damages and the variables of socio-economic and property characteristics for an urban area in Kuantan. Using a face to face interview technique, a field survey was conducted to gather damage data and related information from the 2013 Kuantan flood. Damages to residential structures were found to be influenced by household income, type of construction materials, and house level. On the other hand, household income, house type, and occupation were identified as the most significant variables that influenced the damages of residential content. For the commercial category, only the areas of the premises were significantly affected by the various structural damages, whereas the content damages depended mostly on the type of business, the surrounding areas, and the premises' number of floors. The relationship between flood damages and their influencing factors is important and should be further tested before proceeding with any application on a wider scale.

1. Introduction

Network and properties are tremendously affected by floods, which also can degrade environmental quality, trigger infrastructural interruptions, and jeopardise living comfort. The magnitude of flood effects relies on the type of activities in the population, the regularity of flooding occurrences, and the degree of flooding and its potency [1]. If there is inadequate enactment to sustain flood management strategies, the intensity of flood damages will become higher, which will affect human safety and socio-economic routines. Currently, a risk-based options for mitigating flood is being emphasised more in comparison to the prevailing methods of controlling flood. In recent years, the non-structural flood mitigation measures, such as flood modelling, flood warning system, and flood risk assessment have been given more attention in flood mitigation compared to structural works. A critical component in managing flood risks is through assessing the numerous destructions resulting from flooding.

In developing nations, the challenge of evaluating flood damages is resultant of insufficient data. In Malaysia, the risk of flooding is normally presented in terms of its hazard, e.g. flood inundation and flood extent map. The risk of flooding in terms of its consequences is rarely assessed. Studies on flooding vulnerability are scarce where only few studies have investigated the approximation of damages. Additionally, the impact of resistance parameters (i.e. the characteristics of the assets involved, which include building category or type of materials) on flood damages is seldom examined. The majority of flood damage evaluation reports deliberated on the correlation between flood damages and parameters of hydrological effects, such as the depth and duration of floods. In reality, flood risk evaluation ought to include all scopes of damages to acquire wide-ranging details of damages caused by flood [2]. In addition, an exploration of flood damages associated with other flood influencing factors, instead of the flood parameters, may prove to be better in understanding the impact on socio-economic conditions of one particular region, as well as the property characteristics, which may affect the extent of flood damages. The notion of social vulnerability in the context of managing disasters was presented in the 1970s upon researchers' acknowledgement that vulnerability also encompasses socio-economic determinants, which influence the resilience of communities [3]. Social vulnerability refers to the socio-economic and demographic determinants which influence a community's resilience. Thus, for the purpose of assisting flood vulnerability evaluation of an urban area in Malaysia, a study was undertaken to investigate the impacts of resistance parameters to the extent of damages caused by flood. Also ascertained, was a function model of flood damages, which indicates the correlation between flood damages and the study area's socio-economic/property characteristics.

2. Study area

The district of Kuantan in Pahang was selected as the study area. Located 250 km east from Kuala Lumpur, the Kuantan district covers an area of 2453 km^2. The Kuantan River Basin (KRB) is a significant watershed of Kuantan city [4]. The area of KRB has been estimated around 1638 km^2 with a length of 93.44 km. The basin begins from Sungai Lembing, passing through Kuantan and terminates at Perkampungan Tanjung Lumpur, before flowing out to the South China Sea. Figure 1 illustrates the KRB map, showing the area, primary river, secondary tributaries, and the streamflow station. Several major floods have occurred along the Kuantan river, caused by the high amount of precipitation collected by the basin throughout the north-eastern monsoon seasons [4]. For the past several decades, the Kuantan river have faced serious flooding in 2001/02, 2011/12, and the latest in 2013. Major damages affected properties, infrastructure, and traffic; approximately 14,044 people were evacuated in the 2013 flood. Nevertheless, thus far, a flood vulnerability evaluation has not been considered for the river basin. Therefore, Kuantan has been chosen as the study area, since the assessment of flood damages is imperative in evaluating the effects of flood to properties and communities in Kuantan.

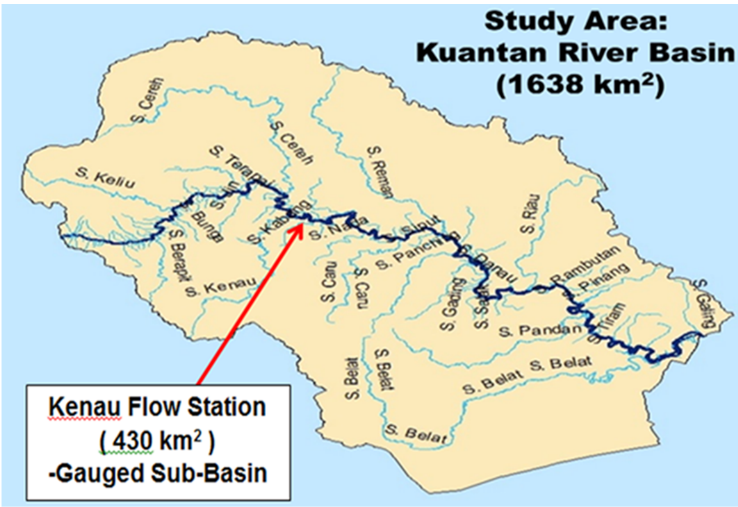

Figure 1. Map of Kuantan River Basin (adopted from [5])

3. Methods

3.1. Questionnaire survey

Questionnaire survey for flood damage data collection was developed based on previous literature, manuals, and reports [6–8]. The questionnaire was used to gather data or information on the flood features, damages incurred, and losses encountered by the victims of the chosen flood event.

Two separate sets of questionnaires were prepared for the residential and commercial categories. Each set consists of two main sections: Section A and Section B, as shown in Table 1. The questionnaire was designed based on three scopes: demographic data, information on residential properties, and damage data. Section A pertains to demographic details, while Section B relates to information on residential properties and damages experienced by residents in the 2013 flood. The demographic details include multiple aspects, such as gender, age, race, education level, occupation, and household income. Section B is divided into two subsections, i.e. Part 1 and Part 2. The property survey in Part 1 acquired information on the price of the house, year of purchase, ownership status, house type, number of storeys, house construction material, house insurance, and the estimated value of the house content (furniture, appliances, gate, etc.). Part 2 gained information on damages, the depth and duration of flooding, the cost of damages to fabric/structure, the cost of cleaning, content damage, vehicle damage, and the loss in wages or income.

Table 1. Outline of questionnaire survey for residential and commercial categories

<table>
<tr><th rowspan="2">Category</th><th rowspan="2">SECTION A:
General information</th><th colspan="2">SECTION B</th></tr>
<tr><th>PART 1:
Property survey</th><th>PART 2:
Property damage survey</th></tr>
<tr><td>Residential</td><td>Address, gender, age group, race, education level, occupation, and the household income</td><td rowspan="2">Price of properties, year of purchase, rental rate, types, no. of storeys, building materials, insurance status, and value of content, or value of stocks (for commercial only)</td><td rowspan="2">Year of flooding, flood water level, duration of flooding, frequency of flooding, problems faced due to flooding;
Information of property damage, structural and content damage, vehicle damage, cleaning cost, and daily wages/trading/sales loss (for commercial only)</td></tr>
<tr><td>Commercial</td><td>Address, type of business</td></tr>
</table>

3.2. Data collection

This study surveyed a total of 203 residential houses and 134 commercial premises to gain a clearer picture of the 2013 flood event. Interviews were conducted using questionnaires developed for the residential and commercial categories. The data collection was carried out around the residential and commercial areas of KRB that were affected by the 2013 flood. Potential sampling areas were selected based on the previous information of massive flood events provided by the Department of Drainage and Irrigation (JPS) Pahang, newspapers, internet sources, and field visits. The data collection areas involved Sg. Isap, Bukit Rangin, Permatang Badak, Bukit Setongkol, Sungai Soi, and Jalan Tanah Putih. These places are located along the Kuantan river and have been frequently flooded in the past. During the survey, a global positioning system (GPS) was used to determine the exact location of the surveyed properties. Respondents from the respective categories were selected at random to create a database as a future reference to the 2013 flood event, and characterised the social class, the types of house, the household content (inventory items), and the damages to residences.

3.3. Flood damage model

This study used a multiple regression model to ascertain the correlation between floods and numerous variables that influence damages caused by floods. This technique had been implemented by some researchers to analyse flood damages and their factors. In this current study, every independent variable value (flood influence factor, x) is linked to the dependent variable value (flood damages, $Flood_D$). The dependent variable signifies the extent of property damages, which include structural and content damages. The independent variables are gender, age, race, education background, occupation, and household income, while the property variables are ownership, price of property, property type, number of storeys, building materials, and flood insurance status. Equation (1) shows the general regression equation used in this study:

$$lnFlood_{Di} = \beta_0 + \beta_1 lnx_{i1} + \beta_2 x_{i2} + \beta_3 x_{i3} + \cdots + \beta_p x_{ip} + \varepsilon_i \quad (1)$$

where $i = 1, 2, 3, \ldots\ldots n,$ while p and ε signify the numbers of independent variables and the error term, respectively. The analysis examined the coefficient of determination value (R^2), and the p-value (significance level), with a 5% level of significance ($p < 0.05$).

4. Results and discussions

4.1. Socio-economic and property characteristics

For the residential category, the respondents' personal information such as gender, age, race, years of education, and occupation is shown in Table 2. Female respondents make up 52% of the total sample. Most respondents (55%) are in the age range of 41–64 years old, with a mean age of 44 years old. Most of the respondents (99%) are Malay, while others are only 1%.

Table 2. Background of the respondents for the residential category

Category	Class/class interval	Frequency	Percentage (%)
Gender	Male	98	48
	Female	105	52
Age	18–19	1	1
	20–40	79	39
	41–64	111	55
	65–100	12	5
Race	Malay	202	99
	Chinese	-	-
	Indian	-	-
	Others	1	1
Years of Education	7	7	3
	12	115	57
	Over 12	76	37
	Others	5	2
Occupation	Government sector	60	30
	Private sector	65	32
	Business	23	11
	Others	55	27

Years of education was used as proxy for respondents' education level. The majority of the respondents (57%) had completed 12 years education until the secondary level, while 2% did not provide their education background, and was marked as 'others'. Only 37% of the respondents graduated the higher-level education, and work mostly with private sectors, as shown in Table 3. On the other hand, Table 4 shows the distribution of household income for the residential respondents. The average household income is RM2809. Amongst the 203 respondents, only 10% earn more than RM5000 per month, while 3% earn less than RM1000 per month. Most (72%) respondents fall under the low-income category (RM1000 – RM3000).

Table 3. Sample size by educational background and occupation

Years of education (years)	Occupation			
	Government sector	Private sector	Business	Others
7	0	1	3	3
12	32	28	15	40
Over 19	28	35	4	9
Others	0	2	0	3

Table 4. Distribution of residential respondents by household income

Class interval (RM/month)	Frequency	Percentage (%)	Cum Percentage (%)
<1000	7	3	-
1000-3000	146	72	75
3001-5000	30	15	90
>5000	20	10	100

Table 5. Property characteristics of the residential category

Category	Class/class interval	Frequency	Percentage (%)
Ownership status	Yes	175	86
	No	28	14
Price of property	LPH	173	85
	MPH	29	13
	HPH	1	1
Type of Property	Terrace	141	69
	Semi-detached	12	6
	Bungalow	18	9
	Others	32	16
Number of storeys	One-storey	196	97
	Two-storeys	7	3
Building materials	Concrete	126	62
	Concrete and timber	59	29
	Timber	18	9
Flood insurance	Yes	76	37
	No	127	63

Table 5 shows the characteristics of the residential property, i.e. ownership status, price and type of property, number of storeys, building materials, and flood insurance status. Most of the respondents (86%) own their house, while the rest are tenants. The properties are divided into three classes according to their price: low-priced house (LPH), medium-priced house (MPH), and high-priced house (HPH). This study surveyed a total of 173 LPH (priced less than RM80,000), 29 MPH (priced between RM80,000 and RM300,000), and 1 HPH (priced more than RM300,000). The majority of the houses are in the low class, with property values less than RM80,000. Most of the surveyed houses are terrace (69%), one-storey type (97%), with concrete as the building material (62%); whereas, 37% of the respondents have property insurance, suggesting that awareness toward the necessity for flood insurance still remains low.

The property characteristics of the commercial category are shown in Table 6. The impact of flood damages can only be observed through the variables of property characteristics, as most respondents are not the owner of the premises; hence, such information may be insignificant. The interview was conducted on 54 premises of goods and services, and 80 premises of food and beverages. Only 28% of the premises are owned by the respondents, while the remaining 72% are rented. The premises' values range from RM100,000 to RM300,000, with only 33% being over RM300,000. Most of the premises are one-storey type (72%), with built-up area of more than 100 m^2. Again, awareness toward the necessity for flood insurance still remains low, since only 3% of the business premises have been insured.

Table 6. Property characteristics of the commercial category

Category	Class/class interval	Frequency	Percentage (%)
Type of business	Good & services	54	40
	Food & beverages	80	60
Ownership status	Yes	38	28
	No	96	72
Price of property (RM)	100,000 – 200,000	84	63
	200,001 – 300,000	6	4
	> 300,000	44	33
Area (m^2)	< 100	49	37
	>100	85	63
Number of storeys	One-storey	96	72
	Two-storeys	38	28
Flood insurance	Yes	4	3
	No	130	97

4.2. Flood damage function model

4.2.1 Residential. The rate of flood damages was influenced by several variables. If the variables were tested and found to be significant, they could be used to compute more reliable relationships of flood damage function. This study's findings indicated that residential structural damages were influenced by the household income, type of construction materials, and house level (Table 7). Equation (2) provides the correlation between residential structural damages and the variables of socio-economic and property.

$$Flood_{RS} = -107.38 + 828.43EDU + 1167.03lnINC + 1186.88MAT - 603.07OCCU1 - 1050.14OCCU2 - 7154.61LEVEL1 - 8897.64LEVEL2 + \varepsilon_i \quad (2)$$

where ε is the error term and $Flood_{RS}$ is the residential structural damages caused by flood (RM); the affecting determinants are shown in Table 7.

The R^2 obtained for this relationship is 0.12. When raw data is used, a low R^2 is normal, yet the value attained in this study is lower in comparison to the result obtained by Poussin et al. [9], in a study amongst French households on the behaviour of mitigating damages caused by flood (R^2 from 0.19 to 0.31). The demographic and socio-economic characteristics of the community did not significantly influence the damages on residential structures. Among the variables, only household income showed a significant influence. The damages on residential structures correlated positively with the household income and building materials. This is consistent with the findings by Win et al. [10], stating that the rate of flood damages is usually linked to the variables of number in a household, household income, and building materials. Additionally, Safiah Yusmah et al. [4] discovered that gender showed no significance in influencing the proneness to flood, because this extent was determined by income. Assuming that the remaining variables did not change, an increase in an income unit would also increase in the value of structural damages. This result describes high-income respondents' affordability in purchasing more costly houses, wall furnishing, gates, etc., hence, the higher value of damages. Meanwhile, the structural damage was negatively related to the house level.

Table 7. Results of socio-economic and property characteristics impact on residential structural damages (RM)

Variable	Coefficient	Std. Error	t-Stat
EDU_secondary	828.43	497.98	1.66
lnINC[a]	1167.03	415.52	2.81
MAT_concrete[a]	1186.88	492.21	2.41
OCCU_government	-603.07	618.50	-0.98
OCCU_private	-1050.14	584.77	-1.80
LEVEL_1[a]	-7154.61	3354.83	-2.13
LEVEL_2[a]	-8897.64	3608.25	-2.47
Constant	-107.38	4611.59	-0.02

[a] is significant at 5%. EDU_secondary is the dummy education level for the secondary level, lnINC is ln house income; MAT_concrete is the dummy construction material for concrete, OCCU_government is the dummy occupation for the government sector; OCCU_private is the dummy occupation for the private sector; LEVEL_1 is the dummy house level for a one-storey house; and LEVEL_2 is the dummy house level for a two-storey house.

Table 8. Results of the socio-economic and property characteristics impact on residential content damages (RM)

Variable	Coefficient	Std. Error	t-Stat
OCCU_government	-1679.25	1081.79	-1.55
lnINC[b]	2132.66	738.26	2.89
TYPE_terrace[b]	-3304.65	946.89	-3.49
OCCU_private[b]	-2771.02	996.54	-2.78
LEVEL_1	-1872.70	2266.49	-0.83
MAT_concrete	197.17	895.24	0.22
Constant	-4755.54	6194.38	-0.77

[b] is significant at 5%. OCCU_government is the dummy occupation for the government sector; lnINC is ln house income; TYPE_terrace is the dummy house type for a terrace house: OCCU_private is the dummy occupation for the private sector; LEVEL_1 is the dummy house level for a one-storey house; and MAT_concrete is the dummy construction material for concrete.

The damage function model for the residential content is shown in equation (3). As presented in Table 8, the residential content damage is influenced by the household income, type of house, and occupation.

$$Flood_{RC} = -4755.54 - 1679.25OCCU1 + 2132.66lnINC - 3304.65TYPE - 2771.02OCCU2 - 1872.70LEVEL1 + 197.17LEVEL2 + \varepsilon_i \quad (3)$$

where ε is the error term and $Flood_{RC}$ is the residential content damages caused by flood (RM); the affecting determinants are shown in Table 8.

Similarly, the R^2 obtained for this relationship is low (0.15). The content damage increased for every unit increase in the household income when other variables did not change. In contrast, the content damages decreased for terrace houses among respondents working in the private sector. This can be justified by the cheaper content of terrace houses (furniture, appliances, etc.) compared to the content of semi-detached houses or bungalows; thus, the lower value of damages. Based on Table 3, most respondents with higher education work in the private sector. Those with higher education are more knowledgeable, and are more inclined to be mindful and ready for a natural disaster. Correspondingly, those with better occupation are more inclined to be aware and well-prepared with early mitigation decisions. The finding is similar to the result by Romali et al. [5], which discovered that the residential content damages were influenced by the respondents' occupation.

4.2.2. Commercial. Table 9 and Table 10 show that only the areas of the premises had significant effects from the various structural damages, whereas the damages to content depended mostly on the type of business, the surrounding area, and level of the premises. For primary data, performance of the model is deemed good with an R^2 value of 0.19 for the commercial structure, and a value of 0.24 for its content. The result is consistent with the study by Poussin et al. [9], as mentioned earlier.

Table 9. Results of the socio-economic and property characteristics impact on commercial structural damages (RM)

Variable	Coefficient	Std. Error	t-Stat
RACE_malay	111.20	576.80	0.19
EDU_primary	-165.58	680.28	-0.24
Ln_area[c]	1883.05	525.18	3.59
TYPE_F&B	776.01	657.91	1.18
LEVEL_1	-802.27	599.11	-1.34
Constant	-4278.66	2602.08	-1.64

[c] is significant at 5%. RACE_Malay is the dummy race for Malay; lnINC is ln house income; EDU_primary is the dummy education level for the primary level: Ln_area is ln area of the premises; TYPE_F&B is the dummy type of business for food and beverages; and LEVEL_1 is the dummy level for a one-storey premises.

By assuming that other variables did not change, a unit increase in the ln area of the premises would result in an increase in the structural and content damages of commercial properties. Meanwhile, a significant relationship was observed between the content damage and the commercial property's type of business. This finding can be justified by the fact that the average content damage of food and beverages business was higher compared to that of goods and services business. The supplies and equipment in food and beverages premises would have been more exposed to flooding and difficult to be relocated during flood events compared to those in goods and services premises. In addition, the content damage was negatively related with the premises' number of floors.

Table 10. Results of the socio-economic and property characteristics impact on commercial content damages (RM)

Variable	Coefficient	Std. Error	t-Stat
Type_G&S[d]	-14451.26	6093.45	-2.37
Ln_price	1463.26	2953.36	0.50
Ln_area[d]	9418.32	4654.76	2.02
LEVEL_1[d]	-11589.52	5772.73	-2.01
Constant	-21054.61	45415.78	-0.46

[d]is significant at 5%. TYPE_G&S is the dummy type of business for goods and services premises; Ln_price is ln price of the premises; Ln_area is ln area of premises; and LEVEL_1 is the dummy level for a one-storey premises.

The structural and content damages model for commercial properties are shown in equation (4) and equation (5), respectively:

$$Flood_{CS} = -4278.66 + 111.2RACE - 165.58EDU + 1883.05lnAREA + 776.01TYPE - 802.27LEVEL + \varepsilon_i \quad (4)$$

where ε is the error term and $Flood_{CS}$ is the commercial structural damages caused by flood (RM); the affecting determinants are shown in Table 8.

$$Flood_{CC} = -21054.61 - 14451.26TYPE + 1463.26lnPRICE + 9418.32lnAREA - 11589.52LEVEL + \varepsilon_i \quad (5)$$

where ε is the error term and $Flood_{CC}$ is the commercial content damages caused by flood (RM; the affecting determinants are shown in Table 8.

5. Conclusions

The main findings from this study are as follows:

i) The residential property's structural damages caused by flood were influenced by the household income, the type of construction materials, and the house level. On the contrary, the household income, the type of house, and occupation are the most substantial variables that determined the residential property's content damages.
ii) For the commercial category, only the built-up area had a significant effect on the various structural damages caused by flood, whereas the content damages significantly correlated with the type of business, the built-up area, and the premises' number of floors.

In conclusion, the less significant effects of the socio-economic factors to the flood damages are attributed to the experience of the local residents in dealing with recurring flood events. Only household income and occupation have significant effects on residential property damages. On the other hand, the type of business plays an important role to the various commercial property damages. The correlation between flooding and its destructive determinants can be utilised to assess damages caused by flood; whereas flood risks can be minimised by implementing more efficient countermeasures.

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