Assessment of multiple variables predicting the psychological effects of flooding: Case study in Peninsular Malaysia

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ABSTRACT

Floods are among the most disastrous environmental hazards, causing devastating tangible and intangible impacts. The psychological impact, which can be classified as intangible damage, is a crucial part of well-being assessment. The psychological impact of flooding has begun to receive attention in recent years; however, the complexity of measuring it makes it less attractive to be considered in damage empirical assessment and risk studies. The present study seeks to evaluate willingness to pay for the psychological impact of flooding experienced by households and business premises, and the different factors that could be determining variables of the psychological impact. A total of 217 respondents have participated in the empirical face-to-face survey conducted in different vulnerable places in Peninsular Malaysia. Through the willingness to pay (WTP) method, only 107 and 34 respondents from residential and business premises, respectively, expressed their agreement to spend on flood management efforts. The study found that flood durations and family sizes are statistically significant contributors to psychological impact for households, reflecting the intangible damages to the residential sector. The results suggest a greater investment to support affected people's welfare by improving communities' resilience and consolidated management during flood events from different authorities. These will enhance flood risk reduction efforts and reduce the psychological impacts on people at risk of flooding. The findings also revealed a key challenge of inferring intangible flood damages for business sectors through empirical evidence.

Keywords: Intangible damage, Flood characteristics, Flood psychological effect, Socioeconomic variables, Willingness-to-pay.

1 Introduction

Flooding remains one of the greatest threats, with its unprecedented impact to the society. A comparison of flood events across different return periods reveals that the impact of flooding on both residential properties and business premises can be extremely severe (Merz et al., 2010). A post-flood survey by DOSM (2021) of the 2021 flood in Malaysia has reported that flood damages on residential buildings (living quarter loss) amount to US$395 million, while US$123 million in damages from business premises (DOSM, 2021). Numerous studies have attempted to quantify tangible flood damages on residential and business properties (Van Ootegem et al., 2015; Kabirzad et al., 2024), given their importance for the community's well-being and economy. Studies that attempt to provide the correlation of the socio-economic and building characteristics to flood damages often apply regression-based modelling, given the multi-faceted nature of flood consequences (Foudi et al., 2017; Hudson et al., 2017; Sulong & Romali, 2022).

Over the past decade, analysis of flood consequences has evolved beyond conventional tangible economic damages to intangible impacts, such as psychological effects, as a critical subset of adverse flood consequences (Stanke et al., 2012; Yoda et al., 2017). Psychological effects can be defined as the emotional and mental responses individuals experience due to disruptions in daily life, such as anxiety, depression, and stress, exacerbated by isolation and changes in routine (Veale, 1987). The psychological impact of flooding stemmed from people's experience during or after the devastating event, which may involve losing possessions, physical health, livelihoods, or even worse, the lives of loved ones (Law et al., 2025). During the disastrous flooding in 2014 and 2021 in Malaysia, severe psychological effects on individuals and the community have been reported (Ridzuan et al., 2022).

Current scholarly consensus has emphasized that the psychological effects of flooding is important to be integrated in flood management decision-making (Ti et al., 2016; Nawi et al., 2021; Sulong & Romali, 2022). In fact, addressing the psychological impacts of flooding and establishing ways to enhance emotional support systems during periods of high disaster risk can bolster community resilience. For instance, robust social networks and organized shelter systems have been shown to significantly reduce anxiety and stress during post-flood recovery (Zahari & Hashim, 2018; Akhir et al., 2021). Some studies have even found that intangible flood damages could be more severe than tangible losses (Nga et al., 2018; Han et al., 2023; Joseph et al., 2015).

Among the critical factors that influence the intangible damages of flooding are the socio-economic characteristics, specifically the income levels (e.g., Fatemi et al., 2020), and the spatial elements, such as proximity to riverine systems (e.g., Yang et al., 2020). The intangible damage could also increase with flood depth and duration (Lekuthai & Vongvisessomjai, 2001). In addition to flood characteristics, flood experience and building height could improve the accuracy of flood intangible damage assessment (Darnkachatarn & Kajitani, 2025). Limited studies have attempted to investigate the relation of these factors in terms of how they influence psychological effects. To include the psychological effects as part of the integral component of flood damage using the econometrics methods remains a challenge due to the ethical and social complexities (Frongia et al., 2016; Nafari & Mendis, 2018; Babcicky et al., 2021). The subjectivity of the valuation and the difficulty in obtaining coherence in determining the psychological effects of flooding further contribute to the complexity. The aforementioned has resulted in higher potential dismissal of psychological effects of flooding integration into the cost-benefit analysis (CBA) framework alongside the tangible economic losses, which could lead to malinvestment in flood risk mitigation efforts. Even if investments were allocated for reducing mental burden, justifications were difficult to make in terms of how much public spending a case would require. Moreover, allocations to reduce psychological effects are usually prompted reactively.

One of the approaches used in the valuation of non-marketable intangible flood damages is the willingness-to-pay (WTP) through the contingent valuation method (CVM). In the CVM, the monetary amount that is willing to be provided for a particular good or service that can alleviate flooding is considered (e.g., Foudi & Osés-Eraso, 2022; Rodríguez Castro et al., 2025). The method is particularly useful for valuing flood risk mitigation, as it estimates the economic value of non-market assets or services by determining the maximum amount an individual is willing to pay for them (Entorf & Jensen, 2020). Since the late 20th century, studies have employed CVM, though their initial application to disaster economics was controversial. After years of refinement and evaluation, the method is acknowledged as one viable way to measure non-market value. However, the application of non-market valuation in flood damage assessment, particularly for informing decision-making agencies in damage management, is infrequently used and remains relatively new (Rogers et al., 2019).

The present study aims to assess intangible flood damage represented by the psychological effects of flooding experienced by households and businesses in Peninsular Malaysia. Current studies in Malaysia on the two elements at risk in the context of psychological losses, alongside other flood damage factors, are absent. The ability to understand their influence on flood damages through an empirical lens and to be able to identify key drivers would provide evidence to support the refinement of flood damage modelling and flood management options. The present study elicited the monetary value of psychological impact from respondents through empirical surveys at affected locations to better understand and address future flood impacts. Based on respondents' flooding experiences and their recollection of its effects on their well-being, the study attempts to incorporate the subjective experiences of people exposed to flooding in the risk-based flood investment decision-making.

There are two mechanisms for the information of WTP can be acquired: through stated or revealed preference approach. The first one is elicited by directly asking the respondent on the amount, whilst the second is by observing the behaviour (Foudi & Osés-Eraso, 2022; Tomoi et al., 2024). WTP can also be elicited by adding a portion of expenses to bills to cover the WTP to improve the quality of life, and shows that the socio-economic factors could contribute to determining the WTP, particularly the income and education, to reduce respondents' health risk (Jianjun et al., 2016).

2 Study Areas and Surveys

The study aims for in-person interviews with individuals from residential and business premises with prior flood experience and still living in the flood-prone areas. The study areas were first identified through a desk study and secondary information review by focusing on the regions in Peninsular Malaysia that are often flooded, one from the northeast, and another from the southwest of Peninsular Malaysia. Within the two specific regions, identification is then made on viable territory and states for the ground survey to be made, which led to Kuala Lumpur Federal Territory, Selangor state, and Kelantan state being selected for further review. A description of what is the damage generation process that the study would want to focus on led to specifying only cases of fluvial flooding. Common flood cases due to extreme storms in Peninsular Malaysia that lead to devastating damage can be distinguished between those that are ultimately caused by water that exceeds a riverbank and those that are mainly caused by attenuation of runoff exacerbated by impermeable surfaces and exhaustion of existing storage spaces. The former is sometimes referred to as a fluvial flood, whilst the latter is referred to as a pluvial flood. Flooded areas to be surveyed were set to be those that are located adjacent to rivers within a radius of 1.3 km, such that the distance from the river can be incorporated as part of the possible decisive factors to psychological intangible damage.

Demarcations of areas were made to limit samples only from areas where fluvial floods are the primary cause of the damage generation process. This is assisted by rigorous reviews of authorized documents and reports related to floods at the territory and state levels, such as those published by the Department of Irrigation and Drainage (2012), Kuala Lumpur City Hall (2015), and the National Statistics Department. Grey literature and open-source websites were also consulted to verify and confirm the suitability of areas. Finally, exact villages or towns affected by fluvial floods for face-to-face interviews were identified. In-person interviews were conducted between July and September 2020. Within the selected locations, each respondent was approached individually at their residential or business premises. To ensure relatively recent experiences with flood damage, only individuals who had experienced at least one flood event in the past 10 years preceding 2020 were included. Descriptions of intangible losses were provided in length to respondents during the interview prior to the other specific questions.

Figure 1 illustrates the study area, highlights of Kota Bharu in Kelantan, Kuala Lumpur Federal Territory, and Dengkil and Kajang districts in Selangor, where the ground surveys were conducted. Frequent flooding and large-scale evacuations have been reported in these locations. For instance, in the 2013 flood event, as many as 2000 residents evacuated from the area (Khairi et al., 2013). These reports are consistent with information obtained from interviews with the Kuala Lumpur City Hall (DBKL) in 2020. Kajang and Dengkil in Selangor were selected as sample locations because they have experienced multiple flood events, some of which resulted in large-scale evacuations. Both Kajang and Dengkil are situated within the Langat River basin. Flood reports indicate that approximately 200 people were evacuated in Kajang, and nearly 500 residents were relocated to public shelters from various inundated areas in Dengkil during the 2020 flood event. In Kota Bharu city, Kelantan experienced particularly devastating floods in 2014, which led to the evacuation of 20,000 residents (Abdullah, 2014).

Historical evidence has shown that Kelantan faces higher flood risks than Selangor and the Kuala Lumpur study area. During the site visits, respondents in Kelantan often exhibit strong religious beliefs, perceiving flooding as predetermined and beyond human control. This belief may reduce reported distress and lower engagement in the WTP initiative. In addition, some respondents displayed a lack of interest in interviews, possibly due to diminished trust following repeated flood events across Peninsular Malaysia. In contrast, respondents in Kuala Lumpur showed stronger interest and support for WTP based on flood risk reduction initiatives. Several families express a willingness to allocate part of their monthly income to mitigate flooding risks, often driven by distress and fear resulting from repeated flood experiences between 2010 and 2020. This suggests that the WTP values may be influenced by emotional response to past events. Emotion-driven valuations may bias stated preference estimates and were therefore excluded from the final analysis, consistent with previous methodological recommendations (Joseph et al, 2015).

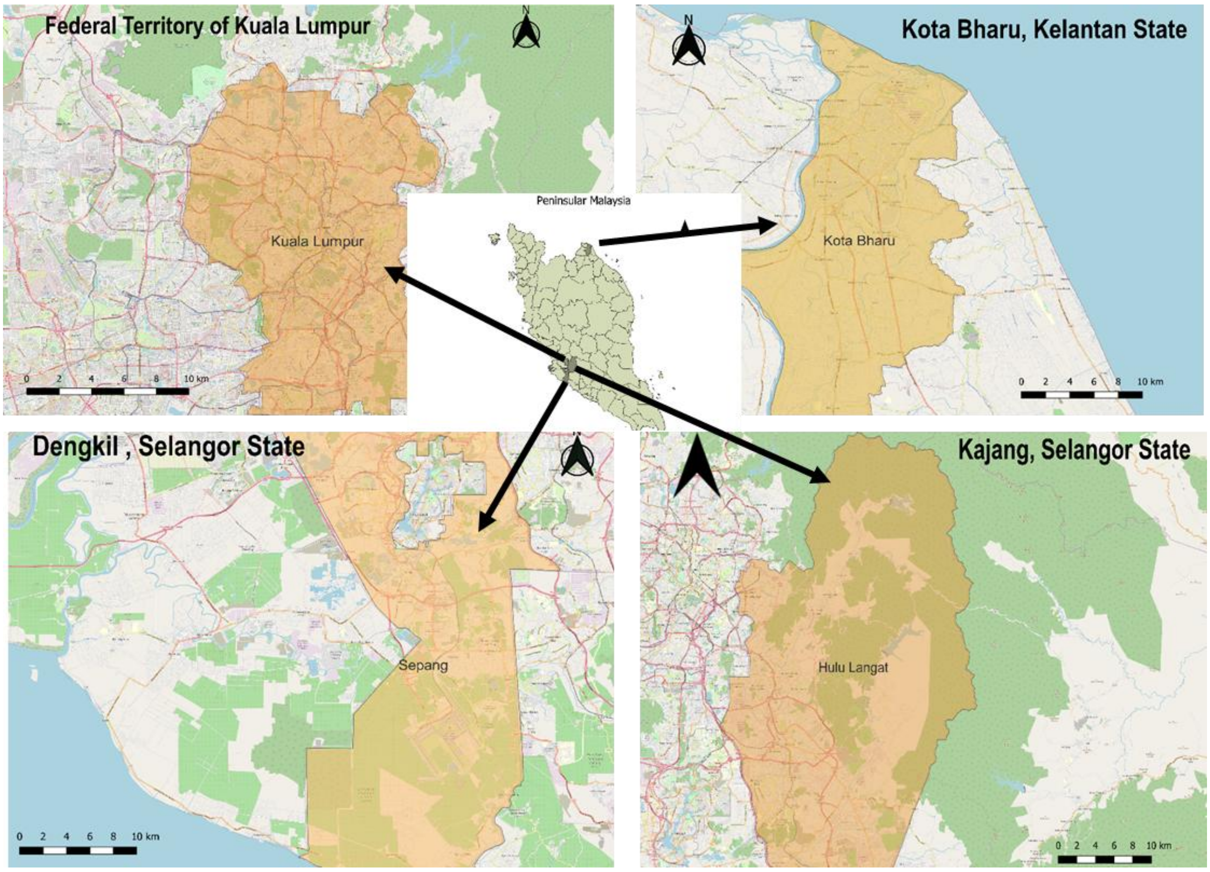


Figure 1. The map was created using OpenStreetMap and the Malaysian district and territory boundaries file. Areas where surveys were conducted in Peninsular Malaysia, and the yellow area is the district or territory boundaries. Top left: Kuala Lumpur Federal Territory; Top right: Kota Bharu district, Kelantan; Bottom left: Dengkil, Sepang district.

3 Data and Methods

This section explains the data and methods applied for the analysis. Variables considered for the establishment of the decisive factors to intangible damage are explained in Section 3.1. Section 3.2 continues to describe the method of WTP, continued by Section 3.3 on data pre-processing, and lastly Section 3.4 on regression and model specification.

3.1 Variables for intangible flood damage analysis

A range of variables, identified based on expert knowledge and literature review, are considered important for estimating intangible flood damage. The variables are grouped by flood characteristics, building factors, and socio-economic characteristics. Figure 2 shows the eleven independent variables: flood depth, flood duration, building type, proximity to water bodies, business type, household size, years of living (residential) or years of operation duration (business), ownership, income, the presence of elderly individuals, and the presence of children. Despite the number of possible exogenous variables that could have influenced the psychological effects of flooding, we limit to only eleven subset variables to take advantage of the contact time with respondents and the quality of responses. All of the explanatory variables were used to assess their correlation with the intangible damage. Whilst some of the respondents shared their recovery experiences of post-flooding during the interview, the recovery rates were not being considered explicitly as one of the variables in the multivariate analysis.

The survey questionnaire was designed to allow for separate analysis of residential and business. Residential buildings were classified as village-type, terraced, or bungalow, while businesses were categorized as micro, small-to-medium, or large businesses, similar to that proposed in KTA (2003). These classifications represent the primary building structure types prevalent in Malaysia. The categorization of business premises type was based on the total number of workers, as specified by SME Corporation Malaysia (2022). Businesses were categorized into micro and small businesses based on the number of full-time permanent employees. Micro businesses were defined as having fewer than five employees, while small to medium businesses included those with five to thirty employees (SME Corporation Malaysia, 2022).

As for the socio-economic characteristics, three classifications were used for the demarcation of the residential sector income levels following the national standard and the parent study (i.e., Kabirzad et al., 2024) (Department of Statistics Malaysia, 2020). The classification is B40 (bottom 40%), M40 (middle 40%), and T20 (top 20%). The B40 group included those earning less than US$ 1130 per month, the M40 group covered incomes between US$ 1130 and US$ 2553.45 per month, and the T20 group consisted of households earning more than US$ 2553.45 per month. For business, micro business income is between US$ 73,367- US$3,668,380, and small-medium income is US$ 3,668,380 - US$ 7,333,170 (SME Corporation Malaysia, 2022).

As the dependent variable, the intangible suffering due to the psychological effects of flooding was valued using the WTP approach. The monetary values that the respondents are willing to pay to alleviate flood damages were taken as a proxy. The absolute value of WTP originally in Malaysian Ringgit (MYR) was converted to US Dollars (US$). The study aimed to assess damage using multiple variables and understand the multiple variables' contributions. The process in which the survey was made in person, and then the data was screened for missing values and duplication, is shown in Figure 3. Further explanation of the process is discussed in the next sub-sections. Ultimately, a multivariate regression analysis was undertaken to identify the contributing factors of intangible damage to residential buildings and business premises.

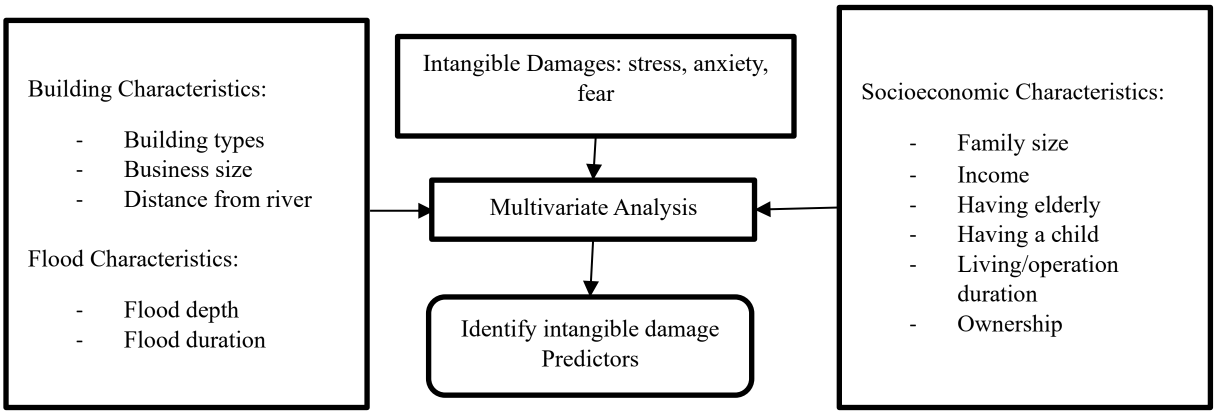
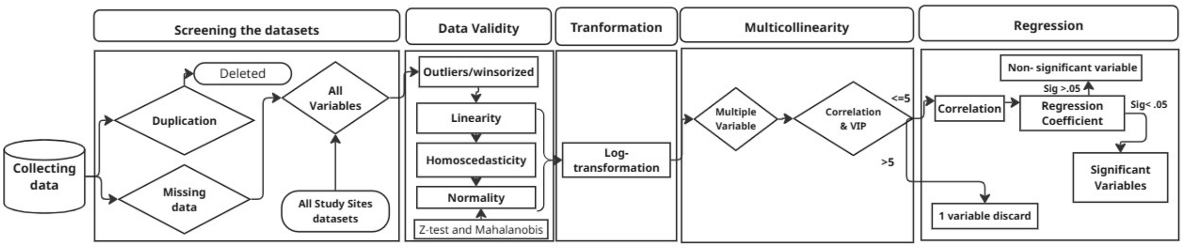


Figure 2. The intangible damage assessment and the independent variables used in the multivariate analysis for the damage model.



* Winsorization, Empirical rule,Z-test (Normality) and Mahalanobis distance

Figure 3. The data process and analysis flowchart

3.2 Intangible losses by the contingent valuation method

Intangible damages of flooding for households primarily involved diminished well-being, stress, anxiety, and sleep disturbances linked to the difficulty in managing possessions and to recovery. For businesses, the intangible damages centre on employee well-being and the subsequent disruption of operations and recovery (Lekuthai and Vongvisessomjai, 2001). To quantify the non-market values for alleviating psychological health resulting from flooding, the present study adopts the contingent valuation method (CVM) to estimate the WTP of people who have experienced flooding and could experience flooding again, similar to the work by Foudi & Osés-Eraso (2022).

During the in-person engagement, conversations with household heads, business managers or owners in flood-exposed areas were conducted in Malay, as many residents felt more comfortable speaking their native language. The conversations were informal at first but shifted to a more formal tone once participants were willing to engage further. The engagement was conducted cautiously to ensure interviewees received sufficient information about the study's purpose before delving deeper into the willingness-to-pay (WTP) questions. A sequential information-sharing process was applied to ensure that respondents received sufficient information and were gradually brought into the topic and questions regarding WTP. Respondents can be emotionally affected by their past devastating flood experiences

(Joseph et al., 2015), and this can be addressed by validating respondents' psychological experiences prior to questions being asked.

After listening to and validating their stories, they were briefed on the effects of stress and anxiety. Additionally, they were informed about the challenges of monetizing intangible flood damage, which requires the adoption of the contingent valuation method (Markantonis et al., 2012; Semrau et al., 2016;Joseph et al., 2015). To avoid confusing intangible losses with tangible losses (as seen in Kabirzad et al., 2024), and to focus willingness-to-pay (WTP) responses solely on psychological and mental health effects, the distinction between the two was explained to the interviewees. They were advised not to include financial or asset losses in their WTP values (e.g., Foudi et al., 2022). Respondents were then presented with a dichotomous choice question on their willingness to pay for flood mitigation that could reduce the intangible damage of flooding that they experienced before. Respondents who answered "yes" were then asked an open-ended question on how much they are willing to pay. Those who stated “no” were asked for their reasons. Interviews for open-ended questions were only continued for respondents who answered ‘yes’. From the face-to-face conversations, those who refused to pay were influenced by their strong views about the payment vehicle that should be part of the government's responsibility. Such a protest bid is common in similar social studies, and exclusions of the protest bids are necessary to reduce bias in the analysis.

Meanwhile, a number of questions were adopted to guide responses on WTP values associated with alleviating psychological burden. For instance, some of the interviewees have built concrete barriers at the opening of their house to protect from flood intrusion. Such a real case was used as a surrogate to the WTP value, but with emphasis on alleviating their psychological burden. Example questions are: (1) how much they are willing to allocate to reduce their stress and anxiety if the same flood event were to occur?, (2) if the same event as the worst that they had experience is to happen in the future and they were not at home, will the property-level protection barriers that they have constructed able to ease their psychological burden of not be able to save possessions while they are not there? If yes, then the costs for the barriers were asked, or (3) if the respondents do not yet have property-level barriers, they will be asked if they are willing to spend on one, and by how much to alleviate the same psychological burden as they have experienced during the worst flood experienced before. The price of WTP is adjusted for the inflation rate using the Malaysian Consumer Price Index calculator to maintain consistency and comparability across different periods (Malaysia CPI Inflation Calculator, 2021). Furthermore, the results were presented as an absolute value in US dollars (US$) for a flood event. Information on the selected variables for the multivariate analysis, such as building types, income level, etc., of the respondents was then collected. All information was stored using an online standard form, including the coordinates of the building’s location where the interview took place.

The collected information of the WTP represents the anxiety and stress at their personal level related to the businesses that they are managing, and the stress and anxiety stemming from impacts on productivity and disruption of sales, etc., manifested from the condition of flood events that they are in. Whilst the description is not exhaustive and pathways of intangible damages on individuals and businesses that they own or work in may overlap, the present study does not express a distinction. It is perceived that the intangible damages can be of any disturbance to the running of the businesses that cannot be monetised, whether it stems from a personal level of the business owner/worker related to the businesses, or from more specific losses to the business, such as loss of opportunity that they are stressed and anxious about. Moreover, the WTP does not consider economic losses that can be monetised indirectly, for example, due to business downtime, and this was made clear during the interview (e.g., Darnkachatarn & Kajitani, 2025).

3.3 Data Pre-processing

The data that has been collected was filtered to identify duplicates and missing information for all variables. The data pre-processing was conducted for both types in preparation for the correlation and regression analysis. Missing information was imputed with values having similar characteristics to the ones recorded (e.g., Rodríguez Castro et al., 2025). All datasets of the same type of variable from different areas were combined into a single database. Building type, business size, the presence of elderly or children, and ownership status were treated as binary variables, whilst others were treated as continuous variables. Outliers in all continuous variables were identified and treated using winsorization, the z-test or three standard deviation cut-off, and the Mahalanobis distance method. After completing this process, the normality, linearity, and homoscedasticity were assessed. Subsequently, a multicollinearity assessment between the variables to identify highly correlated independent variables was undertaken. The regression analysis on intangible damage for residential types of buildings indicated multicollinearity between two independent factors, which are flood duration and distance from the river. Therefore, the distance from the river was excluded to improve the accuracy and reliability of the regression, which leaves only nine independent variables.

For the normality test, some datasets were first transformed to accommodate the variables in normality using the log or log-log transformation (Svenningsen et al., 2020). For residential buildings, the datasets were log-log transformed except for independent variables, such as building type, presence of elderly, presence of children, and ownership status. Meanwhile, for commercial buildings, the datasets remained untransformed except for income data, which was log-transformed. Linearity was checked to ensure that the dependent variable is linearly related to each independent variable. Violations can reduce model accuracy, though slight deviations may be acceptable depending on context. In this case, residual plots confirmed a generally linear relationship, but some continuous variables did not meet the assumption.

Another assumption is that the residuals exhibit constant variance, ensuring the absence of heteroscedasticity (unequal variance), Heteroscedasticity can bias regression estimates and reduce predictive accuracy. Therefore, statistical transformation, such as logarithmic adjustment or other methods, is applied.

3.4 Regression Analysis and Model Specification

After the pre-processing of datasets was completed, multivariate regressions were performed to explore the relationship between intangible flood impacts in terms of victims' psychological burdens and the considered factors. These models enabled the identification of key factors contributing to damage severity related to the three groups of factors: flood characteristics, building types, and socio-economic conditions (Lee, 2020). The regression analyses for this study considered three significance thresholds, such as 10%, 5%, and 1% (e.g., Lamond et al., 2015). Table 1 presents the detailed descriptions of explanatory variables considered. The goal of the analysis is to identify predictors that statistically influenced the psychological burden of respondents due to flood events. Meanwhile, standardized coefficients β were utilized to determine the relative significance of each predicting variable (x), allowing for comparison of their effects on intangible damages (Y). The final models include error terms that address unexplained variations. These models were expressed as a general equation 1, encompassing all essential variables to ensure reproducibility for future research investigating flood impacts in comparable settings (Svenningsen et al., 2020).

$$Damage(Y) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k + \epsilon \ldots . Eq. 1$$

Table 1. The independent variables were used in the multiple regression assessment.

Explanatory Variables	Description	Multivariate analysis
Flood characteristics		
Flood depth	Water depth inside the building from the ground floor, range residential (0.3-2m), business (0.3-1.6m)	Continuous variable
Flood duration	Water duration stays around the house during the day, ranging (1-14 days)	Continuous variable
Building or business characteristics		
Building type (low-cost type, Terrace, Bungalow)	Low-cost, terrace or bungalow	Dummy variable (Low-cost house = 0, Terrace & bungalow =1)
Business size	The micro or small-medium business premise	Dummy variable (Micro = 0, Small to medium = 1)

Distance from River	Distance of building from the fluvial flood stream, residential(15-1307m) and business(5-1250m)	Continuous variable (meter)
Socioeconomic conditions		
Family Size	Number of members in the household or family (1- 12 persons)	Continuous variable
Ownership	Tenant or owner	Dummy variable (Tenant = 0, Owner=1)
Income (family/Business)	Average monthly income per household or revenue per premise; residential (from US$122 and more than US$2,554) and commercial (Micro up to US$ 73,307-Small-medium US$ 7,333,170)	Continuous variable
Year of living or business operation duration	Number of years the respondent has lived in the area or operated a business in the area (1-64Yrs).	Continuous variable
Having children	With children or not.	Dummy variable (Without children under 14 years old = 0, with =1)
Having elderlies	Households with the elderly.	Dummy variable (Without elderly above 65 years old = 0, with =1)

The model's performance was evaluated using the coefficient of determination (R^2), which indicates the proportion of variance in the damage explained by the independent variables (e.g., Poussin et al., 2015). However, R^2 is not always recommended as a sole indicator of model accuracy, as it can be artificially inflated by adding more independent variables (Jarantow et al., 2023). Furthermore, a low R^2 does not necessarily indicate a weak relationship, as statistically it is heavily influenced by the variation in the independent variables (Hamilton et al., 2015). Therefore, its interpretation must always be contextualized within the specific research scope (Hair et al., 2018).

4 Results

The results are presented in three stages; first, Section 4.1 elaborates on respondents' characteristics and general feedback from the face-to-face interviews. Second, Section 4.2 examines variations in intangible damages across key determinant variables. Lastly, Section 4.3 presents a multiple regression analysis to identify decisive factors of intangible damage.

4.1 Respondents' characteristics and responses

A total of 380 respondents were approached, of whom 217 provided valid responses. Eliciting monetary valuations for psychological impacts proved challenging, particularly when respondents were asked about their willingness to pay (WTP) to reduce flood-related psychological distress. Despite the use of a sequential and tailored interview approach to build respondents' trust, some participants expressed disagreement when asked about their willingness to make monetary contributions to safeguard themselves from the psychological effects of flooding.

Of the valid respondents, only 141 responses (107 residential and 34 businesses) expressed willingness to pay for disaster risk reduction measures, while 76 respondents (35%) stated zero WTP or refused to contribute. Common reasons included limited income, the belief that flood mitigation is the government's responsibility, lack of trust, and the perceptions that flood impacts were not severe or were primarily emotional. Such "protest zero" responses are common in contingent valuation studies for flood reduction measures (e.g., Brouwer et al., 2009; Jones et al., 2015), and are typically excluded to reduce bias (Foudi et al, 2022). In this study, zero WTP responses were excluded to focus on identifying the drivers for the non-zero range of WTP. Furthermore, WTP was used as a proxy for the intangible damage, which is unlikely to be zero in the context of damaging flood events.

Most respondents were from residential buildings, reflecting limited commercial activity in the study areas. Local information indicated that several flood-affected businesses had permanently relocated to safer locations. Time constraints and demanding schedules also limited participation among business owners, resulting in excessively long waiting times and limited interviews. Consequently, the dataset is dominated by residential respondents. Given the difficulty of collecting socio-economic and psychological data, data validity relied partly on expert judgment.

Table 2 summarises the number of residential and business respondents. Forty-four percent (44%) of residential respondents and sixty-seven percent (67%) of business respondents were only from the Kota Bharu (Kelantan) study area, where terrace buildings accounted for nearly 40% of all buildings, followed by low-cost housing. Respondents from the Segambut district of Kuala Lumpur were few, and primarily resided in terrae and low-cost houses. In Kajang and Dengkil areas of Selangor, most respondents also lived in terrace houses, while Kota Bharu district respondents were more evenly distributed across building types.

Among business respondents, the predominant type of business is micro-sized enterprises (76%), followed by small to medium businesses. The small-to-medium businesses (SMEs) represented 24% of the study sample. Kota Bharu recorded the highest flood depths for both residential and business premises, largely attributed to the major flood event in 2014. Although the case study sites experienced flooding in different years, all locations have been severely affected by flooding over the past decade.

Table 2. Summary of the respondents in residential and business premises categories across the study sites

Study Site	Respondents' flood-year experiences	Residential building type				Business Type		
		Bungalow	Terrace	low-cost	Total	Micro	Small-medium	Total
Segambut	2010-2020	2	8	17	27	2	2	4
Kajang & Dengkil	2020	5	21	9	35	6	1	7
Kota Bharu	2014	16	14	15	45	18	5	23
Total respondents (%)	Sample size	23 (21%)	43 (40%)	41 (38%)	107 (100)	26(76%)	8(24%)	34 (100)

Variations in intangible damage across residential households and businesses were analysed in terms of income groups, business size, and the distance from the river using both total and average WTP values. Total values refer to the cumulative WTP within each category. Meanwhile, the average values represent the mean WTP. Comparisons across income groups are presented in Figures 4 and 5.

4.2 Variations in Intangible Damages Across Determinant Variables

Bar charts were used to examine patterns of flood exposure and intangible damage across income groups and business sizes. The analysis focused on whether lower-income households and micro businesses experienced greater exposure and demonstrated higher WTP to reduce psychological impact. Intangible damage was assessed using both total and average WTP across income groups, business size, and buildings' distance from the river. categories.

Figure 4 presents that most residential respondents belonged to the bottom 40% (B40) income group, followed by the middle 40% (M40) income group, while the top 20% (T20) group had the fewest respondents. Given that the interviewed people are randomly approached based on the criteria of their building's proximity to rivers, this distribution highlights the disproportionate exposure of lower-income households to flooding. Only 13 and 5 respondents belonged to the M40 and T20 groups, respectively, compared with 86 respondents from the B40 group. Average WTP value ranged from US$46.6 to US$186.4 across all income groups. While the B40 group recorded the highest total losses due to its larger sample size, median WTP values per household were comparable across all income groups.

Figure 5 presents results for the business premises. Micro businesses were more exposed to flooding than small to medium businesses, reflected in a larger sample size (24 versus 7). Micro businesses also showed a higher total WTP value, largely due to their greater representation. However, the median WTP value was similar across business sizes, consistent with the findings for residential households. This suggests that lower income or smaller business size does not necessarily imply significantly lower WTP.

Residential households reported higher intangible losses than businesses, reflecting their greater perceived need for interventions to reduce psychological and mental effects associated with flooding. However, comparable median WTP values across income and business size categories indicate that income alone cannot be identified as a decisive factor based on single-variable analysis. These findings may change with a larger sample size, highlighting the challenges of collecting data from flood-affected populations. While descriptive analysis provides useful insights, multivariate analysis is required to identify key determinants of intangible flood damage.

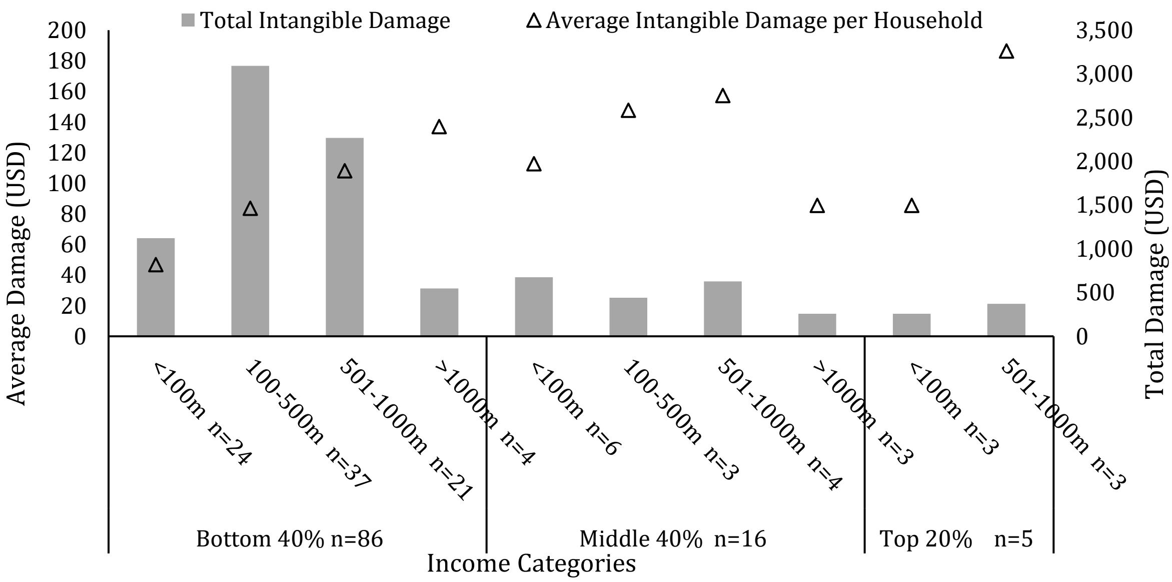


Figure 4. A comparison of the total and average values of intangible damages was conducted across income groups, distance from the river categories, and the number of samples (n).

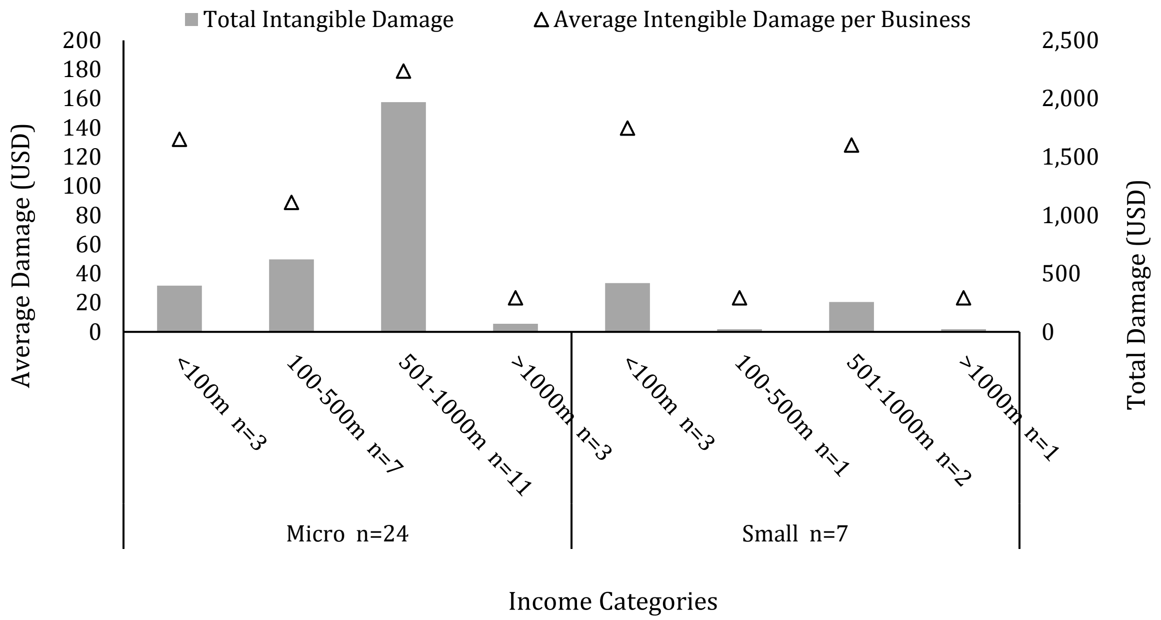


Figure 5. Intangible damage assessment of business premises considering income categories, distance from the river, and the number of samples (n)

4.3 Multiple Regression Analysis of Intangible Damages

This section presents results of multivariate regression for residential and business sectors, examining building characteristics, socio-economic factors, and flood attributes influencing WTP. The objective is to identify the relative strength and significance of intangible damage drivers.

4.3.1 Residential Building Intangible Damage

Table 3 presents the correlation matrix between intangible damage and explanatory factors. Most variables show a positive association with intangible damage at varying levels of significance. Flood durations, family sizes, and building types are positively correlated with intangible damage at a significance level at 5% or 10%. The relationships are intuitive; longer flood duration increases distress. A similar result was found in a previous study that flood duration has a positive contribution to flood loss (Czajkowski & Cunha, 2020). Similarly, the larger the number of family members, the greater the anxiety level and therefore the positive relationship with WTP. Large families do contribute to greater anxiety during floods, according to Babcicky et al. (2021), where there will be greater responsibilities that they have to bear.

Flood depth and proximity to rivers are not found to be statistically significant in explaining the WTP for the reduction of intangible damage. However, previous studies have found that flood depth and residence in proximity to rivers can be statistically significant explanatory variables for intangible flood damage (Lamond et al., 2015; Babcicky et al.,2021). Moreover, previous studies in Peninsular Malaysia have used flood depth as a key indicator to evaluate tangible flood damage (Rehan & Yiwen, 2023;

Kabirzad et al., 2024; Fadhil et al., 2025). Another counterintuitive finding from the present study is that families are willing to pay for psychological health, but not defined by their income level. The findings of income level as an insignificant variable to explain the WTP are quite similar to some studies. For example, Ghanbarpour et al.(2014) and Yusmah et al.(2020) show that the middle-income households are more willing to contribute to flood prevention measures, whilst higher-income households are less responsive. Results from the present correlation matrix also indicate that other socio-economic characteristics are not statistically significant in explaining the WTP. This is in contrast with what has been found in Foudi & Osés-Eraso (2022), where older individuals have a lower demand for protection despite being financially vulnerable.

Table 3. Correlation matrix of flood intangible damages to households with damage predictors.

	IntD	FD	FDu	BT	DfR	HC	HE	Ow	FS	Inc
Intangible damage, IntD	1									
Characteristics of flood										
Log (Flood depth), FD	.131	1								
Log (Flood duration), FDu [a]	.291***	.171*	1							
Characteristics of Building										
Building Type BT	.163*	.013	.128	1						
Log (Distance from River) DfR [a]	.123	.172*	.667***	.257***	1					
Socioeconomic characteristics										
Having children, HC	.075	.023	-.230**	-.102	-.340***	1				
Having elderly, HE	-.029	.121	.089	.021	.102	-.172	1			
Ownership, Ow	-.037	.100	.071	.018	.023	-.013	.159	1		
Log (Family size), FS	.262***	-.071	-.004	-.082	-.114	.383***	-.031	-.260	1	
Log (Income), Inc	.151	-.108	-.168*	.304***	-.072	.138	.044	.038	.114	1
Log (Living duration), LDu	-.049	.059	.057	-.321***	-.104	.094	.173	.403***	.214**	-.152

Note: *. Correlation is significant at the 0.1
**. Correlation is significant at the 0.05
***. Correlation is significant at the 0.01
[a] Distance from the river and flood duration variables have multicollinearity issues

Table 4 presents the multivariate linear regression results after addressing multicollinearity and statistically significant considerations. Among the components examined, only two variables, flood duration and family size, are significant explanatory variables for intangible damage at 1% significance level. The results indicate that a 1% increase in flood duration leads to a 1.12% increase in WTP, while a 1% increase in family size is associated with a proportional rise of 1.5% in intangible damage. For example, adding an individual to a household can lead to a relative increase in intangible damage of approximately 12.5%. In other multiple regression studies, flood duration has been identified as statistically significant to intangible damage of residences (e.g., Czajkowski & Cunha.,2020). But family size is not (Joseph et al., 2015).

Table 4. Intangible damage multiple regression results for the residential sector.

Residential Sector				
	Intangible damage (R-squared = 0.231)			
Explanatory variables	Unstandardized Coefficient, B	Standard Error	p-value	Standardized Coefficient, β
Characteristics of flood				
Log (Flood duration)	0.486 1.12 [a]	0.156	0.002	0.299
Socioeconomic characteristics				
Log (Family size)	0.65 1.50 [a]	0.222	0.004	.301

[a] The value represents the percentage increase resulting from a 1% rise.

The regression model for intangible damage yielded a coefficient of determination (R^2) of 0.23, indicating that the dependent variable (i.e., the intangible damage) is explained by other variables at 23% of its variance. Although the value of R^2 is modest, it is considered acceptable in studies of intangible flood impact (Hair et al., 2018) because R^2 values in such contexts are often constrained by limited variability in explanatory variables (Hamilton et al., 2015). In some research fields, an R^2 of 0.10 or lower is acceptable, as it is entirely context-dependent on the research scope (Hair et al., 2018).

4.3.2 Business Premises Intangible Damages

Table 5 presents a correlation matrix of business premises, where seven variables are considered and the other variables —such as family size, having children, and/or elderly members—were not included as they are considered only for the residential building regression analysis. The results show that variables are correlated to intangible damage at varying significance levels. Income is positively correlated, while years of business operation are negatively correlated with the intangible damage. It is argued that experienced businesses may better cope with shocks and therefore suffer much less compared to those with less experience (Abdullah et al., 2019). Meanwhile, analysis of a multiple regression model for business premises shows that the considered variables do not adequately explain intangible damage in the business sector, with a p-value above 0.1, suggesting a failure to reject the null hypothesis. Previous studies supported that these variables are not a significant to intangible damage in business premises (Czajkowski and Cunha, 2020)

Table 5. Correlation matrix of flood intangible damages to business with damage predictors

	IntD	FD	FDu	BS	DfR	Ow	YBO	Inc
Intangible damage (IntD)	1							
Characteristics of flood								
Flood depth (FD)	-.038	1						
Flood duration (FDu [a])	-.052	.404***	1					
Characteristics of Building								
Business size (BS)	.068	-.150	-.231	1				
Distance from river (DfR)	-.238	.322**	.424***	-.231	1			
Socio-economic Characteristics								
Ownership (Ow)	.117	.082	.007	-.028	.137	1		
Years of Business Operations (YBO)	-.320*	.348*	.530***	-.171	.350**	.201	1	
Income (Inc)	.370**	-0.152	-.171	.067	.053	.014	-.114	1

Note: *. Significant at the 0.1 level
**. Significant at the 0.05 level
***. Significantly at the 0.01 level,
[a] variable was removed due to multicollinearity between the independent variables

The regression analysis for business premises did not yield statistically significant results, indicating that the proposed model could not reliably predict intangible damage in the business sector. A review of the literature reveals limited empirical evidence on intangible flood damage models for business, reflecting the complexity of capturing non-market losses in the context. Data collection proved particularly challenging, as few business owners were willing to disclose information on psychological or emotional impacts. The small sample size may introduce bias and reduce the accuracy of the damage model in the business sector. On the other hand, comparing intangible damage assessments between households and businesses is difficult, as each context presents distinct forms of evidence for evaluating impact. Intangible damages for businesses primarily relate to employee well-being, operational disruptions, asset management, revenue losses, and recovery challenges.

4.4 Effects of Sample Size

Despite the insights obtained, the analysis suggests that the current sample size may be insufficient to fully model intangible impacts across both sectors. A primary limitation is the lack of statistically significant associations in the business sector, which is largely attributable to small sample sizes. In the residential sector, while flood duration and family size were significant predictors, the distribution of the sample may result in bias and the statistical insignificance of the other variables. Specifically, smaller sample sizes for the middle income (M40) and high income (T20) than the B40 income group may limit the accuracy of the residential findings related to income level. Therefore, increased sample sizes from diverse flood-prone regions are necessary to improve model prediction and account for the heterogeneous nature of these sectors. Nonetheless, this requires laborious efforts and resources to target both the quality and quantity of sample sizes.

5 Conclusion

This study assesses the psychological health impact of flooding — conceptualised as intangible damage—on residences and businesses. By applying a non-market willingness-to-pay approach, the present study estimates the monetary value of stress, distress, and worry associated with flood events through face-to-face surveys at selected flood-prone locations. The aim is to highlight a critical need to strengthen social resilience by identifying key variables. The analysis hypothetically suggested that building characteristics, socio-economic conditions, and flood characteristics are vital contributions to intangible damage. The findings show that for the residential sector, family size contributes to shaping psychological impacts, as larger households tend to receive greater intangible losses. Moreover, flood duration emerged as a key contributor to intangible damage, suggesting for well-planned and effective response mechanisms in residential communities. In addition, the waiting time of victims in flooded areas and in evacuation centres should be reduced with an effective response and consolidated management from different authorities. In the business sector, while all variables considered did not yield statistically significant results, larger companies appear better able to cope with flood-related psychological impacts, suggesting that experience and adaptive capacity can reduce intangible damages.

To reduce psychological vulnerability and strengthen social resilience, policy measures such as improved early warning systems, enhanced public awareness, and better land-use planning are essential. Timely evacuation planning and targeted protection of the vulnerable are necessary to mitigate the impacts of flood duration. These findings emphasize the value of integrating social characteristics into flood resilience planning through active community engagement and the development of context-specific awareness guidelines. Strengthening resilience also requires improved flood forecasting and the integration of social characteristics into planning at multiple spatial scales.

As one of the few studies attempting to quantify intangible flood damages for both residential and business sectors, this research contributes preliminary evidence to an emerging field. However, several avenues for future research remain to advance the understanding of flood risk management. Future work could incorporate a broader range of indicators alongside physical and economic variables in multivariate analyses that would better explain variations in intangible damage. Future studies could also detail specific determinants in the business sector—such as job titles, service types, and the nature of business models—to further discern the classification and magnitude of intangible losses. However, getting participation from people through face-to-face interviews could be challenging. This emphasizes the need for coordinated efforts in managing flood damage-related data for effective proactive interventions and strategic policy decisions.

Authors Contribution:

Authors Name	Contribution
S.A.K	Writing (original draft preparation, review, editing), Conceptualization, Data Curation, Formal Analysis, Investigation and Methodology, Software, Validation, Visualization
B.M.R	Writing (review and editing), Conceptualization, Supervision, Methodology, Funding Acquisitions, Validation, Visualization
Z.Z	Conceptualization, Supervision, Methodology,
B.Y	Conceptualization, Supervision, and Methodology
B.H	Conceptualization, Supervision, and Methodology
M.E.T	Project administration, Conceptualization, and Validation
E.C.P	Review

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