SOUTHEAST ASIA REVIEW OF ECONOMICS AND BUSINESS
ISSN: 2472-9299 (Print) and 2472-9302(Online) Volume I, Issue 1, 2017, pp. 92-105
http://sareb-journal.org

HOUSEHOLD ECONOMIC LOSSES OF URBAN FLOODING: CASE STUDY OF CAN THO CITY, VIETNAM

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Abstract: *This article examines the economic losses caused by urban flooding in Can Tho City, Vietnam. Opportunity-cost and household co.0sts are emphasized. Household interviews showed that annual economic losses due to flooding were 11 % of household annual income. Furthermore, the study reveals that there are differences in cost structure at different stages of flooding. An estimated regression model suggests that household location and education status were significant factors affecting economic losses. The empirical results further indicated that the before flooding cost used as proxy measure for prevention activities significantly reduced the economic cost of urban flooding in Can Tho City.*

Keywords: *Urban flooding, Economic costs, regression analysis, Can Tho City, Vietnam.*

I. INTRODUCTION

Urban flooding impacts the quality of life of many urban residents, and causes losses as both direct and indirect costs which can occur before, during, and after flooding. Direct costs are monetary expenses incurred when preparing for or coping with floods. These costs include labor and materials. Indirect flooding costs are expressed as opportunity costs, including for example missed work, reduced revenue (for vendors and owners of retail shops), increased travel time, and health care. To prevent flooding, loss, people may adjust their daily travel activities, move their belongings to higher ground. Subsequent costs included those for coping with or mitigating flood damage. Some coping measures may also be seen as forms of adaptation. Flooding costs are increasingly becoming a large part of a household's total annual expenditure.

Low-income populations in large cities in low altitude countries are the most likely to be negatively affected by climate change-related factors such as flooding. According to the Intergovernmental Panel on Climate Change (2007), Vietnam is among the five countries most seriously affected by sea-level rise. If sea level rises 0.2 to 0.6 meters, it is said that up to 200 thousand hectares of Vietnam's plains would be submerged. A one-meter rise would submerge 0.4 million hectares of the Red River Delta and 90 % of the Mekong Delta. According to the Ministry of Natural Resources and Environment (2009), such a rise would submerge thirteen provinces.

Flooding in Can Tho City is caused by upstream flooding and high tides from the East Sea. As reported by Huong and Pathirana (2013), floods inundated approximately 30–50 % of the city. In 2008, of the 81 main streets, 21 were inundated by high tides and rain (MONRE, 2009). Additionally, hundreds of blind alleys were flooded. The peak of the flood of October 2011 inundated almost the whole city (Can Tho's People Committee, 2011). The most serious urban flooding happens from September to November. A high tide usually happens at the start and middle of the lunar month, causing urban flooding twice a month. At these times, even though the water levels in the rivers are not high, high tides can flood the city. Rain is also a major factor causing of flooding. In the middle of the rainy season, flooding usually occurs right after the rain. Can Tho City is on average one meter higher than sea level. In the worst-case scenario, the maximum inundation depth may rise up to 1.51 meter.

Flood protection infrastructure in Can Tho City is inadequate. A water discharge system has not been completely installed. There is no river dike. According to ACCCRN (2009), the capacity of the rain water and sewage discharge systems are less than 50 % of demand. Furthermore, urbanization has reduced the natural adjustment of surface water and has decreased the natural reservoir inside the city. Table 1 presents the results of flood survey in 2009 by the Can Tho People's Committee. Results show that rain and high tides were main causes of urban flooding in Can Tho City.

Table 1. Results of the 2009 Flood Survey in Can Tho City

No	District	Reasons for flooding	Number of sites flooded	Percentage (%)
1	Ninh Kieu	Rain	12	20
		Rain and high tide	38	62
		Rain, high tide and upstream flood	11	18
2	Binh Thuy	Rain	5	29
		Rain and high tide	8	47
		Rain, high tide and upstream flood	4	24
3	Cai Rang	Rain	2	13
		Rain, high tide and upstream flood	13	87
	Total	Rain	19	20
		Rain and high tide	46	49
		Rain, high tide and upstream flood	28	31

Source: Can Tho's People Committee (2011).

As far as it can be ascertained, there are no prior studies of household flooding costs in Vietnamese cities. The objective of study is to fill this important gap in the literature. This article categorizes the extensive economic losses caused by flooding in Can Tho City, Vietnam, before during and after flooding. It also makes policy recommendations for reducing these losses. The remainder of this investigation is organized as follows.

First is a literature review. Then the methodology used and the empirical model are presented. The next section describes the survey data collected and the characteristics of respondents. The following section categorizes the costs of urban flooding. After that, an alternate flood cost calculation method is presented. The next section reports the results of an econometric analysis using survey data. The final section provides concluding remarks and policy recommendations.

II. LITERATURE REVIEW

To assess the impacts of natural disasters such as typhoons and floods, some studies have used a loss and damage framework (Huq, et al., 2013). Loss was characterized as the permanent negative impacts of climate change and damage as those impacts that can be reversed. A distinction was made between avoidable and unavoidable loss and damage. In many empirical studies, loss and damage are reported as having incurred when the costs of adaptation are not recuperated; or when adaptation efforts are either impossible, ineffective, or maladaptive in the long term. Residual losses were said to occur even if mitigation and adaptation efforts are successful (Huq et al., 2013.).

Bubeck *et al.* (2012) assessed public flood-risk perceptions in a flood-prone province in central Vietnam. Three hundred people responded to a survey which had the following four sections: (i) personal and household characteristics; (ii) risk perception; (iii) expectations about climate change; and (iv) experience with natural disasters. Regression results showed that flood-risk perceptions were only weak predictors of precautionary behavior.

Huraera *et al.* (2010) assessed household and community disaster coping strategies in poor urban areas in Bangladesh. The study examined how households use physical, economic, and social means to reduce risk, reduce losses, facilitate recovery from flooding and high temperatures; and how grassroots adaptation differs according to flood risk. Using a before-during-after framework, the study surveyed 35 households, and identified experiences of climatic variability, hazards and coping strategies. Results found that before a disaster, most households took few preventative actions, but that impact minimizing actions were practiced regularly. After a disaster, most households made changes while rebuilding their structures, including changing building and plinth materials, and increasing plinth levels.

Orapan *et al.* (2012) used a before-during-after framework to measure the direct and indirect costs that 600 households experienced in Thailand's historical 2011 flood. It explored the actions that people took before the flood, financial costs incurred during and after the flood, and health-related costs. Housing damage was the largest cost component but differed significantly among households. Costs associated with lost wages were greatest in lower-income households.

III. METHODOLOGY AND MODEL SPECIFICATION

3.1. Research Questions

The key questions to be answered by this study include:

(1) What are the components of economic urban flooding losses?

(2) Which research methods are appropriate for measuring the costs of urban flood economic losses?

(3) How does flood-warning impact households' losses?

(4) What public policy options could reduce urban flood losses?

3.2. Analytical Method

Our study follows the before-during-after approach used by Orapan *et al.* (2012). Both direct costs and indirect costs in each period were considered. In each period, either an ex-post or ex-ante approach was assigned to identify and measure the flood-related cost. Preventative costs including each household's contribution to the community-costs. These were estimated rather than calculated. Figure 1 presents the conceptual framework of the flood-related total economic losses.

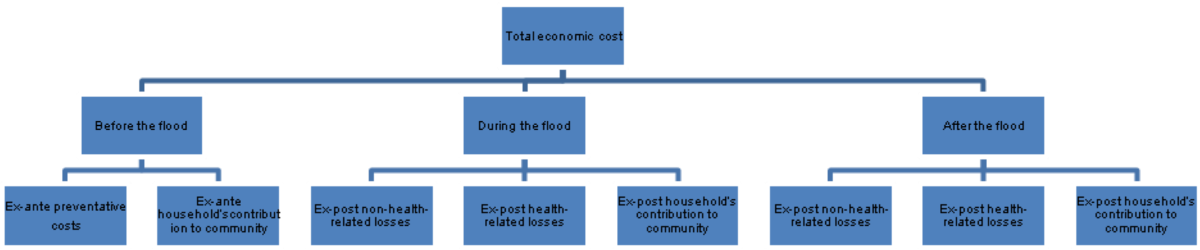

Figure 1. Measurements of total economic cost concept used in the urban flooding study

The direct costs include labor and materials to prepare for, cope with, and recover from the flood. Direct costs also include preventative actions such moving belongings to higher places, building concrete blocks, installing sandbags outside the house, pumping water, and other similar measures.

Indirect costs include opportunity costs such as losing work, increased travel time, and care for sick household members. The opportunity costs were the product of monetary values of lost productivity and days of work missed. The value of lost productivity was estimated based on the respondent's income and the assumption of a minimum daily wage rate for values of lost time. This was calculated at a minimum unskilled worker's wage of VN$ 150,000 per day (approximately US$7). Vendors and retail store-worker earnings or revenues lost due to the flood were considered as an opportunity cost.

A sum of cost drivers was derived including direct costs and indirect costs estimated with either ex-ante or ex-post values. Ex-ante values were estimated based on income opportunity costs due to flooding. The household's economic losses due to urban flooding depend on exogenous and endogenous factors. Exogenous factors include gender, head of household's education status and age, household income and location.

Endogenous factors include flood-warning information exchange, concerns about flooding, and the likelihood of moving to another place.

3.3. Empirical Model Specification

To econometrically identify factors that contributed to the household economic losses and assess the effectiveness of the prevention activities by the household before the flood, the following causality regression model (1) was used:

$$Flood\_Cost_i = \beta_0 + \beta_1 Inf\_Exgn_i + \beta_2 Con\_Levl_i + \beta_3 Gen_i + \beta_4 Edu\_Levl_i + \beta_5 Age_i + \beta_6 Inc_i + \beta_7 Mov_i + \beta_8 Pos_i + \beta_9 Prevent_i + e_i \quad (1)$$

where: $Flood\_Cost_i$: total economic losses due to the flood (1000 VN$); Inf_Exgn_i: dummy variable of flood-information exchange within neighborhood (1: yes; 0: otherwise); Con_Levl_i: dummy variable of concern level regarding flooding (1: yes; 0: otherwise); Gen_i: dummy variable of gender of household head (1: male; 0: otherwise); Edu_Levl_i: education status of household head (years of schooling); Age_i: age of household head (in years); Inc_i: household income (1000 VN$); Mov_i: dummy variable of moving to another place within the next five years (1: yes; 0: otherwise); Pos_i: dummy variable of location (1:main street; 0: otherwise); $Prevent_i$: prevention activities by the household before flooding; e_i: error term.

IV. THE DATA AND CHARACTERISTICS OF RESPONDENTS

4.1. Data

To collect data for this investigation, 250 household interview candidates were selected via random sampling with clustering. Clusters included households living on main street, alleys with limited vehicle access, or in some residential estates in the central part of the city. These areas were the most vulnerable to flooding in recent years. Determination of the flooded areas was based on the flood map and field survey. The particular households selected for interview depended on the total number of households living on the street. The selection of the first respondent was done randomly. If the next household was not willing to participate in the interview, a subsequent household was selected. Table 2 presents a distribution of households by location. Interviews were based on a questionnaire. A 16 household pilot survey tested the questionnaire beforehand. Survey results reveal that 82% of respondents were heads of households, and 57% were female. 250 households were interviewed. All respondents had experienced flooding.

Table 2. Distribution of Households by Location

Location	Frequency	Percentage (%)
Main street	105	42.0
Blind alley	116	46.4
Residential estate	29	11.6
Total	**250**	**100.0**

4.2. Contextual Information on Respondents

The average number of years living in the flooded areas was 20. The size of house, on average, was about 94m^2, of which 32% were less than 50m^2 and 45 % were 50–100m^2. In general, the education status of the typical respondent was high. Many had a bachelor degree or were educated in high school, secondary or primary schools. The mean age of respondents was 51. The mean annual household income was VN$ 122 million (US$ 5,800). The mean size of household was 4.66 people. Families with 1–5 members represented 55.6% of the respondents. In terms of age, 52% had family members of under 15 years of age and 40% of households had members who were over 60. Nearly half of respondents were private business owners, with 41% working as grocery store owners. Another 29% of respondents are workers such as carpenters and bricklayers. Salary earners and pensioners are also included, accounting for nearly 12% each. Also, 80% of respondents own their own houses privately. The remainder rent their house for business purposes. One story houses account for nearly 76% of the sample. A large proportion of houses were newly built in recent years. Additionally, 11% of respondents reported that they would consider relocating to another place to live and/or work. This demonstrates that the floods could cause major changes in their lives. Survey results show that during times of flood, private sector respondents such as business owners and grocers incurred the most income losses. Meanwhile, salary or wage earners were relatively unaffected.

Flooding in Can Tho City usually happens between August and November. The number of days of inundation and number of households affected by flooding were highest in October. During the floods, 48% of houses had water inside the house. The level of inundation depended on the area and time of flood. The most extensive inundation happened when heavy rains happen at high tide. 77% of respondents thought that urban flooding had become very serious during the last five years. Additionally, 57% thought that urban flooding would remain a serious problem over the next ten years. Additionally, 65% of households had a plan to cope with urban flooding before it happened: 22% planned to raise their house; 20% planned to protect it with a concrete barrier; 19% planned to move their furniture to a higher place; 15% planned to place sandbags outside the house; 6% planned to repair their sewage discharge system; and 4% were preparing to install a pumping machine in preparation for the floods.

The Chi squared statistics (χ^2s) reveal that there was statistically significant relationship between inundation status, flood concern levels, and schedule of flood resistance. The more serious the flood predictions were, the higher the probability of preparedness was. Additionally, χ^2s indicated that the relationship between education levels and concern levels about urban flooding is statistically significant at any conventional level. The higher the education level, the more concern a respondent had.

Moreover, 38% of respondents said that family members had become ill during floods. Among those, 43% and 35% suffered from skin diseases or influenza respectively. Health problems were usually caused by a polluted environment and poor hygiene behavior. Skin disease, influenza and petechial fever were indirect effects on health while accidents due to working in a flooded environment were direct effects. Additionally, the study found negative mental health impacts caused by flooding, with 20% of respondents saying they had felt unwell during times of flood.

4.3. Prevention and Damage

The survey results suggest that few respondents had ample warning, but were familiar with flood risks. Approximately 21% knew about the floods via media such as weather forecasts and news. These results suggest that a flood-warning information exchange could be a useful way for people to prepare to cope with impending floods. Exchanging early flood-warning information could also help in recommending appropriate measures they should take in advance. It should be noted here that this survey does not consider the impact of urban flooding on public infrastructure, focusing instead on assessing the impact on livelihoods.

Table 3 shows measures used immediately after early flood-warning information was released. Over half of the households surveyed applied emergency measures such as moving furniture to higher places for safety, cleaning sewage discharge systems, installing sandbags around the house and elevating the base of the house. Damages to equipment or durable assets were estimated based on their time of use. In this study, based on accounting rules, rates of depreciation at 5% (over a timeline of 20 years) and 20% (over a timeline of 5 years) were applied to calculate the costs of fixed assets and durable assets respectively. Indirect costs refer to losses that households have incurred indirectly due to flooding. Identifying and calculating the indirect costs were based on the concept of opportunity costs. An opportunity cost represents the change in net income or value due to flooding, such as the loss of revenue by grocery stores or lost wages due to the floods. To calculate the value of opportunity costs for lost income, a daily wage rate of VN$ 150,000 (approximately US$ 7) was used in this study. Both direct and indirect costs were defined within the timeframe of before-during-after the flood, and both were also classified into fixed costs and variable costs in calculations. A combination of both direct and indirect costs was considered as economic costs or economic losses.

Table 3. Measures Taken After Flood-warning Information Released

Measure used to cope with and adapt to the flood	Frequency	Proportion (%)
Installing sandbags	24	8.7
Elevating base of house	18	6.5
Building a wall/barrier	33	12.0
Moving furniture to higher places	42	16.8
Cleaning sewage discharge system	8	3.0
Buying a water-pumping machine	7	2.5
Other	20	7.2
Doing nothing	124	44.9
Total	**276**	**100.0**

V. ECONOMIC LOSSES CAUSED BY FLOODING IN CAN THO CITY

5.1. Direct Costs

Table 4 presents the direct costs calculations. In the after-flood period, all direct costs were variable cleaning costs. The average annual direct costs per household were VN$ 1,339,000 (approximately US$ 64), of which VN$ 601,000 (approximately US $29) were before-flood costs; VN$ 393,000 (approximately US$ 19) were during-flood costs, and VN$ 345,000 (approximately US$ 16) were after-flood costs.

Table 4. Total Economic Costs of Flooding: Direct Costs.

	Per event(1000 VN$)			Per year(1000 VN$)		
	Total cost	**Fixed cost**	**Variable cost**	**Total cost***	**Fixed cost**	**Variable cost**
1. Before flooding						
Fixed assets (depreciation@20 years)	375	375	0	375	375	0
Durable assets (depr. at 5 years)	59	59	0	59	59	0
Materials	28	0	28	167	0	167
Subtotal	*462*	*434*	*28*	601	*434*	*167*
2. During flooding						
Duration assets (depr. at 5 years)	14	14	0	14	14	0
Vehicle damage	9	0	9	56	0	56
Materials	32	0	32	191	0	191
Other	22	0	22	132	0	132
Subtotal	*77*	*14*	*63*	393	*14*	*379*
3. After flooding						
Cleaning costs	58	0	58	345	0	345
Subtotal	*58*	*0*	*58*	345	*0*	*345*
Total direct costs	**597**	**506**	**91**	**1,339**	**793**	**546**

**The calculation of total costs per year is based on the observation that there are three months of flooding (October, November and December) during a year with two floods per month. The variable costs are calculated on the per event basis while the fixed costs are calculated on the per year basis.*

Cost components in the before-flood period included investments and materials to mitigate or prevent flood damage, such as elevating the base of the house or buying a water-pumping machine. Fixed costs accounted for 72% of before-flood costs. In contrast, in the during-flood period, variable costs comprised 96%. This was because during the floods people did not invest much to prevent flood damage. Instead, they used materials to repair damage or to cope with the flood, depending on its severity.

5.2 Indirect Costs

In the after-flood period, all the indirect costs were labor costs, of which approximately 82% was derived from house cleaning and repairs. Table 5 presents the results of the indirect costs calculations. A large proportion of indirect costs were respondent's labor, accounting for 59 %. The remainder were lost income. All indirect cost components were variable costs. Total annual indirect costs per household were VN$ 12,150,000 (approximately US$ 578), comprising of VN$ 405,000 (approximately US$ 19) before-flood costs; VN$ 9,270,000 (approximately US$ 440) during-flood costs, and VN$ 2,475,000 (approximately US$ 118) after-flood costs. Before flooding occurs, people spend time preparing for the flood, such as moving assets and furniture to higher places, repairing the outside of the house and installing sandbags around the house.

Table 5. Total Economic Costs Due to Urban Flooding: Indirect Costs

	Per event(1000 VN$)			Per year(1000 VN$)		
	Total cost	**Fixed cost**	**Variable cost**	**Total cost**	**Fixed cost**	**Variable cost**
1. Before flooding						
Own labor: moving assets to safer places	26	0	26	153	0	153
Own labor: outside repairs	3	0	3	18	0	18
Own labor: installing sandbags	9	0	9	54	0	54
Own labor: cleaning sewage discharge system	2	0	2	9	0	9
Own labor: others	29	0	29	171	0	171
Subtotal	*68*	*0*	*68*	*405*	*0*	*405*
2. During flooding						
Missed work	180	0	180	1080	0	1080
Revenue loss	472	0	472	2830	0	2830
Other losses	468	0	468	2808	0	2808
Health cost	362	0	362	2174	0	2174
Own labor: pumping water	42	0	42	252	0	252
Own labor: moving assets to safer places	6	0	6	36	0	36
Own labor: outside repairs	8	0	8	45	0	45
Own labor: installing sandbags	2	0	2	9	0	9
Own labor: other	6	0	6	36	0	36
Subtotal	*1545*	*0*	*1545*	9270	*0*	*9270*
3. After flooding						
Own labor: outside repairs	338	0	338	2025	0	2025
Own labor: cleaning sewage discharge system	75	0	75	450	0	450
Subtotal	*413*	*0*	*413*	2475	*0*	*2475*
Total indirect costs	**2025**	**0**	**2025**	**12,150**	**0**	**12,150**

During the floods, lost income accounts for the largest proportion at 42%, while health costs and other variable costs account for 23 and 30% respectively. Labor costs account for just 5% of the total during-flood indirect costs and it was dominated by pumping water.

5.3. Economic Costs

In summary, the direct costs of the before-flood period account for the largest proportion of costs at 45%. Direct costs during and flooding were approximately the same. Most before-flood costs were for investment. Many such investments could be considered forms of adaptation. Meanwhile, the indirect costs incurred in the during-flood period comprised the largest proportion at 76%, while the before-flood costs were 3%. Much of the cost during and after flooding were for labor or lost income. Table 6 shows the cost components of total economic losses and the comparison of total direct costs and total indirect costs in the total annual economic losses per household.

Table 6. Cost Categories

	Per event(1000 VN$)			Per year(1000 VN$)		
	Total cost	**Fixed cost**	**Variable cost**	**Total cost**	**Fixed cost**	**Variable cost**
Total economic costs, in which:	2622	*506*	*2116*	*13,489*	*793*	*12,696*
Total direct costs	*597*	*506*	*91*	*1339*	*793*	*546*
Total indirect costs	*2025*	*0*	*2025*	*12,150*	*0*	*12,150*
Indirect costs/total costs (%)				90.1		
Total variable costs/total economic losses (%)				94.1		
Income per year				121,638		
Economic losses/income per year (%)				11.1		

The total annual economic loss caused by flooding was VN$ 13,489,000 (approximately US$ 642) per household. With a mean annual income of VN$ 121,638,000 (approximately US$ 5792), the percentage of economic losses due to flooding in a household's income was approximately 11 % per year. 90% of total economic costs were indirect. Additionally, nearly 95% of economic costs were variable costs

5.4. Flooding Costs Before, During, and After Floods

Table 7 presents economic losses in the before-flood period. Total annual before-flood costs were VN$ 1,006,000 (approximately US$ 48), of which direct costs were VN$ 601,000 (approximately US$ 29) and indirect costs were VN$ 405,000 (approximately US$ 19). All direct costs were actual costs and included investments such as elevating the base of the house. 72% of direct costs were fixed. All indirect costs were derived from the time spent preparing for the flood, such as moving assets or furniture to higher places. All of the before flood indirect costs were variable.

Table 7. Total Economic Costs before Flooding

	Per event(1000 VN$)			Per year(1000 VN$)		
	Total cost	**Fixed cost**	**Variable cost**	**Total cost**	**Fixed cost**	**Variable cost**
1. Direct costs						
Fixed assets (depreciation@20 years)	375	375	0	375	375	0
Durable assets (depreciation@5 years)	59	59	0	59	59	0
Materials	28	0	28	167	0	167
Subtotal	*462*	*434*	*28*	601	*434*	*167*
2. Indirect costs						
Own labor: moving assets to safer places	26	0	26	153	0	153
Own labor: outside repairs	3	0	3	18	0	18
Own labor: installing sandbags	9	0	9	54	0	54
Own labor: cleaning sewage discharge system	2	0	2	9	0	9
Own labor: other	29	0	29	171	0	171
Subtotal	*68*	*0*	*68*	405	*0*	*405*
Total before-flood costs	**529**	**434**	**95**	**1006**	**434**	**572**

Table 8 presents economic losses in the during-flood period. Total annual during-flood costs were VN$ 9,663,000 (approximately US$ 460), of which direct costs were VN$ 393,000 (approximately US$ 19) and indirect costs were VN$ 9,270,000 (approximately US$ 441). All of the direct costs were for materials and repairs to damaged facilities and vehicles.

Table 8. Total Economic Costs during Flooding

	Per event (1000 VN$)			**Per year (1000 VN$)**		
	Total cost	**Fixed cost**	**Variable cost**	**Total cost**	**Fixed cost**	**Variable cost**
1. Direct costs						
Durable assets (depreciation @ 5 years)	14	14	0	14	14	0
Vehicle damage	9	0	9	56	0	56
Materials	32	0	32	191	0	191
Other	22	0	22	132	0	132
Subtotal	*77*	*14*	*63*	393	*14*	*379*
2. Indirect costs						
Missed work	180	0	180	1080	0	1080
Revenue loss	472	0	472	2830	0	2830
Other losses	468	0	468	2808	0	2808
Health cost	362	0	362	2174	0	2174
Own labor: pumping water	42	0	42	252	0	252
Own labor: moving assets to safer places	6	0	6	36	0	36
Own labor: outside repairs	8	0	8	45	0	45
Own labor: installing sandbags	2	0	2	9	0	9
Own labor: other	6	0	6	36	0	36
Subtotal	*1545*	*0*	*1545*	9270	*0*	*9270*
Total during-flood costs	**1622**	**14**	**1608**	**9663**	**14**	**9649**

Table 9 presents economic losses in the after-flood period. Total annual after-flood costs were VN$ 2,820,000 (approximately US$ 134), of which direct costs were VN$ 345,000 (approximately US$ 16) and indirect costs were VN$ 2,475,000 (approximately US$ 118).

Direct costs were actual costs, consisting of cleaning costs. Indirect costs consisted of labor costs. All the direct and indirect costs were variable costs. Losses were higher in the after-flood period than the before-flood period. Table 10 shows the comparison of economic losses in the before-flood, during-flood and after-flood periods.

During flooding, nearly half of respondents' houses were inundated heavily at 20–50 cm. More than three-quarters of respondents thought that urban flooding had become a very serious issue over the last five years, and half of respondents thought it would continue to be so for the next ten years. Many households had plans to prepare for urban floods before they occurred. There was statistical evidence to show significant relationships among inundation status, concern levels about the floods and plans for coping with the flood. The more serious the flood forecast and the more concerned people were about the flood, the higher the probability of preparedness. Similarly, the higher the education level, the more concerned a respondent was.

Table 9. Total Economic Costs After Flooding

	Per event (1000 VN$)			**Per year (1000 VN$)**		
	Total cost	**Fixed cost**	**Variable cost**	**Total cost**	**Fixed cost**	**Variable cost**
1. Direct costs						
Cleaning costs	58	0	58	345	0	345
Subtotal	*58*	0	*58*	345	0	*345*
2. Indirect costs						0
Own labor: outside repairs	338	0	338	2025	0	2025
Own labor: cleaning sewage discharge system	75	0	75	450	0	450
Subtotal	*413*	*0*	*413*	2475	*0*	*2475*
Total after-flood costs	**470**	**0**	**470**	**2820**	**0**	**2820**

Finally, people's knowledge of floods came from several sources, either from their own past experience or the media. Exchanging flood-warning information early on also gave residents more time to prepare which have synergic effect via prevention activities.

Table 10. Cost Classification in the Before-During-After Flooding Framework

	Per event (1000 VN$)			**Per year (1000 VN$)**		
	Total cost	**Fixed cost**	**Variable cost**	**Total cost**	**Fixed cost**	**Variable cost**
Total costs, in which:	2622	*448*	*2174*	*13,490*	*448*	*13,042*
• *Total before-flood costs*	*529*	*434*	*95*	*1006*	*434*	*572*
• *Total during-flood costs*	*1622*	*14*	*1608*	*9663*	*14*	*9649*
• *Total after-flood costs*	*470*	*0*	*470*	*2820*	*0*	*2820*
Total variable costs/total economic losses (%)	82.9			96.7		
Income per year				121,638		
Loss/income per year (%)				11.1		
Before-flood cost/total economic losses (%)				20		
During-flood cost/total economic losses (%)				62		
After-flood cost/total economic losses (%)				18		

VI. AN ECONOMETRIC ANALYSIS

To econometrically identify factors that affect the economic costs of urban flooding in the City of Can Tho to recommend policy measures to minimize these costs of the facts life that urban floods have become more and more serious in large cities in low altitude countries. The empirical model specified by equation (1) is estimated using the data from the survey. The estimation results are summarized in Table 11. The Natural logarithmic value of the cost of before flood is used as a proxy measure for the prevention activities by the households in the flooded area.

An analysis of the overall estimation results reveals that, the coefficient of determination, R^2, is expected to be low for regressions using cross-sectional data, R^2 for this estimation is 0.226. The F-statistic is 27.302 indicating that the model fits the data very well.

Table 11. Regression Results of Economic Losses Due to Urban Flooding

Variable	**Coefficient**
Constant	2.1154^{***}
	(3.7687)
Flood information exchange with neighbors	0.1934^{ns}
(Yes = 1, No = 0)	(0.2435)
Level of concern regarding flooding	-0.4678^{**}
(Concerned = 1, Not concerned = 0)	(-1.7874)
Gender	-0.3165^{ns}
(Male = 1, Female = 0)	(-0.4452)
Education level	-0.0858^{***}
(Schooling year)	(-2.4351)
Age	0.0076^{ns}
(Year)	(0.1454)
Income	$-8.54E\text{-}07^{ns}$
(1000 VN$)	(-0.6783)
Uncertainty	0.4558^{***}
(Relocating to another place within next 5 years = 1, Not relocating = 0)	(2.9865)
Location	0.3574^{***}
(Main street =1, Blind alley = 0)	(2.8977)
Log(Cost before flooding)	-0.102^{***}
	(-2.3740)
$R^2 = 0.226$	*F*-statistic= 27.302^{***}

Notes: $^{*, **, ***}$ significant level at 10%, 5% and 1% respectively. Numbers in parentheses are t-values.

Bases the strength of the t-statistics, the level of concern regarding flooding, educational level of the responders, intention to relocate to another place in the next 5 years, locations of the households are statistically significant, indicating that these factors affect the economic costs of Flooding in Can Tho. More interestingly and possibly more useful information for policy makers is the significance of the logarithmic value of the cost before flooding, used as a proxy measure for prevention activities, i.e., preventions pay off!

VII. CONCLUDING REMARKS AND POLICY RECOMMENDATIONS

Urban floods in Can Tho City have become more serious in recent decades. They damage the city's infrastructure, and affect residents' livelihoods. Floods occur in the city for a number of reasons: The Mekong

River upstream flooding coinciding with a high tide regime in the East Sea; the timing and scale of rains; the poor flood-prevention infrastructure system in the city; and urbanization. Urbanization has reduced the natural adjustment of the surface, increasing surface runoff, and decreasing the city's natural reservoir. This study ought to assess the costs borne by local residents when faced with these floods.

Survey results show that public awareness of flooding, education levels, household location, and probability of relocating homes to avoid floods were factors statistically affecting the economic losses due to floods. Public awareness and education levels reduced economic loss, while the probability of relocating to another place was correlated with increased economic loss. Those living on a main street incurred higher losses than those living in a blind alley or residential cluster. This due to relatively more business damage or revenue losses.

The survey results also reveal that total annual household's economic losses were $US 642 which accounted for 11% of annual household income. Indirect (opportunity) costs accounted for 90% of total economic losses. These costs included labor, missed work and lost business revenue. This study shows that the during-flood period incurred the largest portion of economic losses.

Statistically, the estimation results provide evidence that, if each household paid more attention and spent more on preparation for floods before they happened, damages and losses would be reduced. This implies that, if appropriate adaptation measures were implemented before flooding, the costs incurred during and after flooding would fall. Investing in adaptation measures would increase households' resilience to urban flooding.

To reduce losses due to flooding, the following measures are recommended:

- First, the city should prepare a short-term coping strategy and a longer-term plan for adapting to urban flooding in order to minimize the impacts on individual households. In the short term, partial flood-prevention systems in vulnerable areas should be temporarily established. In the long term, the city's flood prevention needs to be integrated into the master plan for upgrading the city's infrastructure. When building new residential clusters, sewage discharge systems should be connected with the city's main discharge systems.

- Second, the city needs to build an early-warning system: the regression analyses show that if preparedness is ensured at the beginning of a flood event, losses caused by urban flooding are reduced. Many of these preparedness actions are permanent measures, such as elevating houses or surrounding them with concrete walls. Other strategies such as cleaning drains should be considered a coping strategy.

- Third, the city should establish an urban flooding-mitigation unit, which could launch permanent activities to enhance public awareness about urban flooding. Results of the regression analyses show that losses could be reduced if people were more aware of flood consequences. If investment was made prior to the floods, losses and due to flooding could be prevented or reduced. As households would incur fewer damages or losses, this could be regarded as a contribution to their longer-term resilience to climate change.

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