Analysis of Flood Vulnerability of Urban Buildings and Population in Hanoi, Vietnam

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1. Introduction

Vulnerability is a set of conditions and processes, resulted from physical and other factors, that increases the susceptibility of an object or a community to the effects of hazards. The reduction of natural disasters can not be achieved unless there is as good as an understanding of what or who are vulnerable to the impact of hazards and why. There can be different types of vulnerability according to the different hazards that might affect a given place. Assessment of vulnerability of social and economic sectors is essential for risk analysis.

South-east Asia is one of the most frequently affected regions by floods. Many of cities located in this region are vulnerable to floods due to their geographic locations in floodplains of large rivers (Dutta and Herath, 2004). Hanoi, the capital of Vietnam, is one of the such cities, which is located in the Red Rive delta and highly vulnerable to floods. Due to high economic growth and increase of population, the city is expanding rapid in recent years. It has become very important analyze the vulnerability of various economic and social sectors of the city towards flood risk reduction.

The objective of this research was to analyze and assess vulnerability of residential and non-residential building and population in the Hanoi city for urban flood disaster risk management.

2. Study Area

The study area is Hanoi, the capital of Vietnam, which is located in the Red River delta with an area of 921 km^2 and population of 3.6 million (in 2000) with an average density of 2,999km^{-2}. The Hanoi province is divided into 12 administrative districts. The urban area is made up of 7 inner districts, namely Hoan Kiem, Ba Dinh, Hai Ba Trung, Dong Da, Tay Ho, Thanh Xuan and Cau Giay as shown in Figure 1. Rest of the 5 peri-urban districts are around urban center i.e. Tu Liem in the west, Thanh Tri in the south, Dong Anh and Soc Son in the north and Gia Lam in the east. The average altitude of Hanoi city is 6m from mean sea level, which is below the lowest water level of the Red river recorded near the city. The highest recorded water level in the Red river near the city was 14.6m in 1971. The city area is protected by two series of dykes, preventing the area from floods from the Red river system. The dyke system has a total length of 2,700 km. The dyke system is considered as the lifeline of the Hanoi as it protects the city from floods of Red river. At present, the system can stand for flood level of 13.5m (Figure 2). The dyke system was built through a period of many years and at many locations the material and building technology were not reliable, many sections of the system are poorly repaired, and during the wet season, sand erodes and leaks appear and the system is not robust enough to be absolutely relied on for any kinds of floods, especially, for long return period floods exceeding flood heights of 13.5m, there is high possibility of breaching the system and that can be a cause of catastrophic disaster for the city. Although due to many structural measures installed in the upstream of the Red river system including several reservoirs, risk of catastrophic disaster due to extreme rainfall can be ignored and there is a definite need of analyzing impacts of flood disaster resulted from failure of the dyke system.

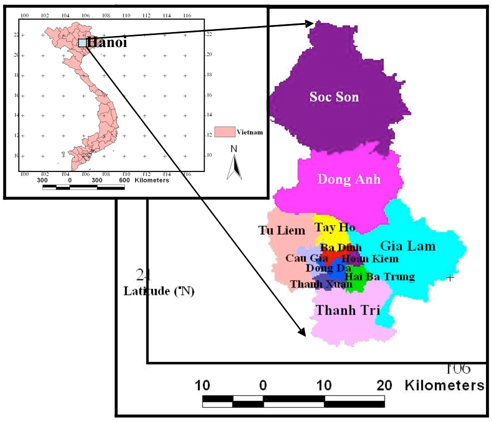


Figure 1: Location of Hanoi City with the district boundaries

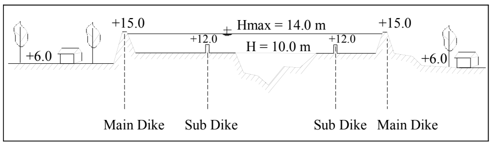


Figure 2: Schematic diagram of cross-section of Red River near Hanoi

3. Methodology

3.1 Questionnaire Survey

Statistical analyses were carried out to understand the vulnerability of economic and social sectors based on experiences of past flood damage to buildings and population. In absence of readily available past records, an extensive questionnaire survey was designed to gather data and information on impacts of floods to residential and non-residential buildings and people in different districts of Hanoi in past several years. The survey locations covered four of the most frequently flood affected districts of Hanoi namely: Dong Anh, Gia Lam, Tay Ho, and Dong Da. A total of 604 samples within these four districts were surveyed for three categories of buildings: residential, commercial and industrial buildings. The questionnaire survey was focused on damage by floods to various types of buildings and people living/working there due to the recent floods of 1996, 2000, 2001, 2002 and 2003, assuming that respondents still had memory of these events and their impacts. As floods in the past years affected only a limited number of non-residential buildings in the selected four locations, the sample size of the non-residential buildings are much smaller compared to the residential buildings. The distributions of surveyed buildings are shown in Figure 3.

3.2 Data Processing

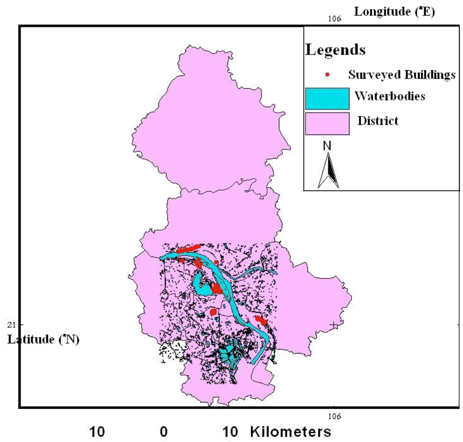


Figure 3: Locations of Surveyed samples in Hanoi

A wide range of questions related economic and social factors (termed as “variable” in analysis) were included in the questionnaires. Collected data and information through questionnaire survey were both qualitative and quantitative nature. Table 1 shows the quantitative variables, their units and range of their magnitude within the surveyed samples. The qualitative data are quantified (i.e. ranked in numerical value) before entering into spreadsheet with logical sequential references for statistical analysis. The quantification of the social aspects involves two steps, establishing criterion and standardizing the variables. Establishing criterion is to provide a score for a qualitative variable. In this study the following standard methodology of quantification is adopted (Tanhueco *et al.*, 2003).

$$X_i = (R_i - R_{min}) / (R_{max} - R_{min})$$

Where, R= raw score, X = standardized score

The scoring involves a numeric range from “0” to “5”. Table 2 shows the scoring process of qualitative variables. The standardized range for variables to combine in loss function equation is from 0 to 1. For the variables which are in ordinal scale, the responses from survey are coded first. Then the variables are standardized using the standardizing equation. The qualitative variables for which there was single type of response, they were eliminated from the analysis. For example, response for "Availability of basement floor" and "Flood insurance for buildings" response were 100% "No" and thus, they were not considered in statistical analysis. Table 2 shows the quantifying process of qualitative variables. Column 2 shows assigning code to responses from survey and column 3 shows scoring of the coded responses.

Table 1: Units and validity range of qualitative variables

Variables	Units	Range covered
Age	year	1-80
Floor area (residential)	sq. m	10-605
Floor area (commercial)	sq. m	10-1400
Outside area (residential)	sq. m	0-1800
Outside area (commercial)	sq. m	0- 600
Total area (residential)	sq. m	10- 2000
Total area (commercial)	sq. m	10- 2000
Plinth level	m	0-2
Height of 1st Floor	m	5-2
Flood height	m	0-3
Flood duration	day	0- 120
Available flood warning time	hrs	0-168
Water supply interruption	hrs	0- 840
Electric supply interruption	hrs	0- 720
Time to get back normal condition	day	0-90
Living period in that locality	Year	1-80
Average family income	VND/ month	3,000-35,000,000
No of family members	no/family	1-20
Family members (younger than 8 years)	no/family	0-6
Family members (older than 60 years)	no/family	0-5
No of school going children	no/family	0-15
No of earning person	no/family	1-8
No of workers	no/(commercial or industrial facility)	1-300

3.3 Statistical Analysis:

Using the quantitative and standardized qualitative variables, multiple regression analyses (MRA) were carried out to develop relationships between flood damage for different categories of residential and non-residential buildings and different variables considering damage to different categories of buildings as dependent variable and economic and social factors as independent variables.

Table 2: Quantification of qualitative variables

Variable	Coding	Scoring
Construction Material	Wood Structure: 3 Mix Structure: 2 Concrete Structure: 1	Wood Structure: 3 Mix Structure: 2 Concrete Structure: 1
Availability of second floor	YES: 1 NO: 0	YES: 1 NO: 0
Experience of flood	Never: 0 One time: 1 Two times: 2 Three times: 3 Four times: 4 More than four times: 5	Never: 0 One time: 1 Two times: 2 Three times: 3 Four times: 4 More than four times: 5
Flood insurance (for building, contents, storage goods, person)	YES: 1 NO: 0	YES: 1 NO: 0
Weather forecast	Hourly or several times through the day: 4 Daily: 3 Weekly: 2 Rare: 1 Never: 0	Hourly or several times through the day: 4 Daily: 3 Weekly: 2 Rare: 1 Never: 0
Availability of savings to address flood expense	YES: 1 NO: 0	YES: 1 NO: 0
Outbreak of waterborne diseases	YES: 1 NO: 0	YES: 1 NO: 0
Feel of isolation	YES: 1 NO: 0	YES: 1 NO: 0
Get charity service	YES: 1 NO: 0	YES: 1 NO: 0

For example, in case of 'Experience of flood", if response is "Four times" then the row score would be "4". The standardized range (of 0 to 1) would be (4-0) / (5-0) = 0.8.

All the possible independent variables that may contribute to damage of various categories are initially incorporated in the analysis and correlation matrix for independent variables were developed by computing coefficients of correlations between all pair of independent variables. For the pairs which have showed high correlations, one of the variables of those pairs were eliminated from the analysis.

Economic Aspect:

For economic factors, the total property damage to residential and non-residential buildings is considered. While estimating the value of an estate, several economic aspects can be considered: the market value, the replacement value, the substitution value, the transformation value and the complementary value. In this study for estimating total value of a building, combined present replacement value of building structure, contents and outside property is taken. Total damage due to flood for both residential and non-residential buildings are calculated as:

Total property damage = Structural damage + Content damage + Outside property damage + Cost for flood prevention measures + Cleanup cost

For residential buildings the selected independent variables are: *Building age, Building floor area, Building outside area, Building total area, Plinth level, Construction Material, Height of 1st Floor, Availability of second floor, Availability of Basement floor, Flood height, Flood duration, Flood insurance for building, Flood insurance for contents, Number of family members, Average income of family, Experience of flood, Weather forecast, Available flood warning time and Availability of savings to address flood expense*. Percent of total property damage for building is calculated as,

*Y = (Total Damage/ Present replacement value of total building property) *100*

For non-residential buildings, the selected independent variable are: *Building age, Building floor area, Building outside area, Building total area, Plinth level, Construction Material, Height of 1st Floor, Availability of second floor, Availability of Basement floor, Flood height, Flood duration, Flood insurance for building, Flood insurance for contents, Experience of flood, Weather forecast, Available flood warning time, Availability of savings to address flood expense, Flood insurance for storage goods and No of workers.*

Socio-economic Aspect:

Social risk indicates those impacts which relate to human sufferings (Alkema, 2003; Lekuthai, 2003). Socio-economic damage is related to mostly peoples, their livelihood style and their feel of isolation, anxiety or discomfort (Parker and Cannon, 2002). In this study, damage on social sector is considered as the total indirect damage resulted from the following expenses as obtained from the questionnaire survey:

- Expenses related to flood protection
- Post-flood cleaning and maintenance costs
- Additional expenses for food
- Additional expenses for transportation
- Additional expenses for repair access roads, parking areas
- Additional expenses related to health
- Loss of income during flood

Total socio-economic damage due to floods for a family is estimated as follows:

Damage = Flood Prevention measure cost + Cleanup cost + Additional expenses due to flood + Expenses due to waterborne diseases

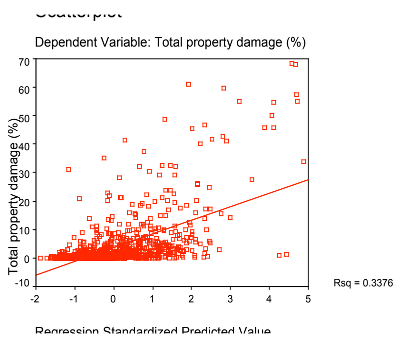
Percent of total damage is calculated as,

*Y = ((Total Damage/Family income) *100)/Total number of family members*

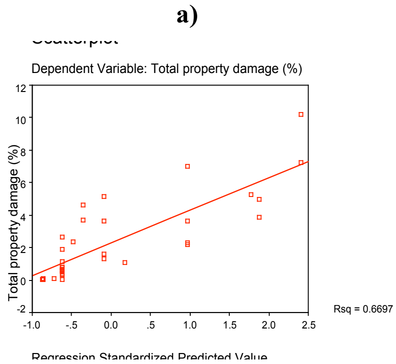
The following independent variables are considered for socio-economic impact analysis: *Family members (younger than 8 years), Family members(older than 60 years), No of school going children, No of earning person, Flood* *height, Flood duration, Water supply interruption, Electric supply interruption, Time to get back normal condition, Flood insurance for person, Experience of flood, Weather forecast, Available flood warning time, Availability of savings to address flood expense, Staying time in that locality, Outbreak of waterborne diseases, Feel of isolation and Get charity service.*

4. Results and Discussion

Figure 4 shows the scatter plots and the best fitted linear multiple regression lines for the total damage to residential and non-residential buildings and Table 3 shows the linear regression models for the respective categories. It shows that in addition to flood parameters, several other factors contribute to damage to residential and non-residential buildings in Hanoi. The relationship for non-residential buildings show high R^2 value compared to residential buildings. From the Table 4, it can be seen that availability of second floor, experience of past floods, weather forecast and flood warning time help in reduction of damage.



a)



b)

Figure 4: Scatter plots and best fitted linear multi-regression line damage categories: a) Residential buildings, b) Industrial buildings

Table 3: Factors affecting the total property damage to residential and non-residential buildings

Category (Sample size)	R^2	Best fit linear multi-regression model
Residential (1086)	0.34	$Y = 10.105 + 0.003\ X_4 - 1.528\ X_8 + 3.405\ X_{10} + 0.182\ X_{11} - 10.335\ X_{16} - 0.07\ X_{18} - 2.947\ X_{19}$
Industrial (36)	0.67	$Y = -8.143 + 0.533\ X_{11} - 11.528\ X_{17}$
Variables used	Y=Regression standardized predicted damage (percentage of damage/sample) X_4 = Building total area (m^2) X_8 = Availability of second floor X_{10} = Flood height (m); X_{11} = Flood duration (day) X_{16} = Experience of flood; X_{17} = Weather forecast X_{18} = Available flood warning time (hr) X_{19} = Availability of savings to address flood expense	

The scatter plot and the best fitted linear multiple regression line for socio-economic damage for family is shown in Figure 5. Table 4 shows the linear multi-regression model for the socio-economic damage. It shows that in addition to flood parameters, several other factors contribute to socio-economic damage, one of the main factors is the availability of earning people in a family that help reducing the damage. The charity service also helps people positively during the flood period. More the number of days to get to normal condition, the higher is the socio-economic impact.

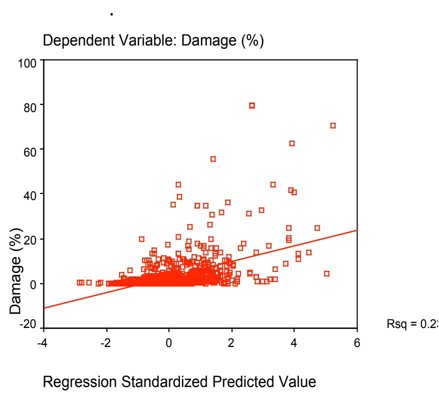


Figure 5: Established loss functions on socio-economic for a family

Table 4: Factors affecting the total property damage to urban family

Category (Sample size)	R^2	Best fit linear multi-regression model
Residential building (1134)	0.27	$Y = 13.526 - 1.116\ X_4 + 2.153\ X_5 + 0.107\ X_6 + 0.032\ X_9 - 5.954\ X_{18}$
Variables used	Y=Regression standardized predicted damage (percentage of damage/sample) X_4 = No of earning persons; X_5 = Flood height (m) X_6 = Flood duration (day) X_9 = Time to get back normal condition (day) X_{18} = Get charity service	

5. Conclusions:

This study was an attempt to analyze the vulnerability of buildings and population covering economic and social sectors for urban floods in Hanoi City, Vietnam. The analysis was carried out based on the data and information collected through questionnaire surveys conducted in different locations of the Hanoi city focusing on residential and non-residential buildings. Statistical analyses were carried out to develop relationships between different economic and social factors and flood damages. The results show that total economic flood damage to residential and non-residential damage are governed by several other factors in addition to flood parameters such as availability of second floor, experience of past floods, weather forecast and flood warning, which help in reduction of damage. Similarly, for socio-economic damage is governed by number of earning people in a family, availability of charity services, duration of floods and time that takes to return to normal condition. The results can be useful for decision makers for reduction of vulnerability of urban buildings and population. Due to limited number of sample with large heterogeneity, the outcomes of the analyze may not be best representative analysis for the Hanoi city, however, it gives a general understanding and the further analysis can be carried out with higher number of surveyed samples.

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