

**ENVIRONMENTAL AMENITIES AND DISAMENITIES, AND  
HOUSING PRICES; USING GIS TECHNIQUES**

A Dissertation

by

SEONG-NAM HWANG

Submitted to the Office of Graduate Studies of  
Texas A&M University  
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

August 2003

Major Subject: Urban and Regional Science

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Major Subject: Urban and Regional Science

## ABSTRACT

Environmental Amenities and Disamenities, and Housing Prices; Using GIS Techniques.

(August 2003)

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This research investigated the effects of Scientifically Estimated Environmental Risks (SEERs) and perceived risks of floods, hurricanes, and hazardous material releases, and hazard mitigation measures with other locational and neighborhood amenities on housing prices. This study also tested the relationship between demographic characteristics and SEERs as well as demographic characteristics and environmental risk perceptions.

The relationships among these different types of variables were examined by means of statistical analyses such as correlational analyses, ANOVA, MANOVA, and hedonic price regression analyses.

Major findings of this research are as follows:

- There were no statistically significant relationships between most of the demographic characteristics (age, sex, household size, marital status, tenure at the present home) and SEERs of the two natural hazards (a flood and a

hurricane). By contrast, SEER of hazardous materials was correlated with all demographic characteristics.

- There were little differences in risk perceptions of natural and technological hazards across demographic groups. Specifically, the respondents' risk perceptions of both natural and technological hazards did not differ by age, household size, and marital status. By contrast, educational level, gender (male =1), and median household income were negatively related to perceived risk of the natural hazards, whereas educational attainment and gender were negatively related to perceived risk of hazardous material releases.
- SEERs of floods and hurricanes were positively related to respondents' perception of property damage, but not related to injury or health problems from those natural hazards. SEER of hazardous materials was related to all three categories of risk perception of a hazardous material release.
- Neither the SEERs of natural hazards nor risk perceptions of these hazards had impacts on housing prices. However, the SEER of hazardous material releases and risk perceptions of this hazard were significant housing price determinants.
- None of the variables representing household hazard mitigation measures contributed to the explanation of housing prices.

## **DEDICATION**

To Min-Hi Seo, who has always given me her endless prayer, love and encouragement

for my academic success,

To Tae-Sik, Yae-Seong and Yae-Joon who made sure I never gave up,

To my mother in heaven, father, parents-in-law, brothers, brother-in-law, sisters

to whom I owe what I am.

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# CHAPTER I

## INTRODUCTION

### 1.1. Problem Statement

Housing can be viewed as “a complex package of goods and services that extends beyond the shelter provided by the dwelling itself” (Orford, 1999). Namely, housing is regarded as a combined demand for personal security, autonomy, comfort, well-being, and status with access to various services such as educational, medical, financial, and recreational facilities (Knox, 1995). Many studies of housing prices have attempted to quantify the value of amenities and disamenities. Generally, housing price is a function of a dwelling’s structural characteristics (e.g., number of bedrooms, living area, and age), neighborhood characteristics (e.g., the number of white persons and schools), proximity to locational amenities (e.g., distance to Central Business Districts, parks, and open space, etc.); (Can, 1990; Grether & Mieszkowski, 1974), and other environmental, social, economic, and political factors (Grether & Mieszkowski, 1974).

Additionally, housing price can be affected by various environmental disamenities such as risk from natural and technological hazards (Clark & Neives, 1994; Folland & Hough, 1991; Brookshire et al., 1985; Nelson, 1981; McClelland et al., 1990). The effects of hazard-related variables on housing prices are important because environmental hazards present conflicting market signals. On the one hand, the loss of

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This dissertation follows the style and format of *Journal of the American Planning Association*.

life from natural and technological disasters has been falling in the United States because of improved systems for forecasting, warning, and evacuation in hazard-prone areas (Mileti, 1999; Burby, 1998). On the other hand, there has been rapid growth in the number of people and structures especially in hazard prone areas. Thus, property loss from natural and technological disasters has been rising (Mileti, 1999). The FEMA (1997) concludes that 9.6 million U.S. households and property valued at \$390 billion are currently at risk from a 1% annual chance of flooding in such locations. Along the Atlantic and Gulf coasts, about \$3 trillion in infrastructure adjacent to the shoreline is vulnerable to erosion resulting from floods and hurricanes (FEMA, 1997).

This increased vulnerability raises questions about people's risk perceptions and, especially, about the impact of these variables on housing prices. In particular, it is important to assess the degree to which housing prices reflect scientifically estimated risks arising from environmental hazards. If risk perceptions are accurate, then housing prices in hazardous areas are likely to be discounted below the levels that would be expected on the basis of their other structural, neighborhood, and locational characteristics. A study of the effects of hazard vulnerability on house prices should explore the effects of multiple hazards because many structures are vulnerable to multiple hazards (such as floods, hurricanes, and chemical accidents), not just a single hazard. A major limitation of existing housing price research associated with hazards is that it has dealt with only the effect of a single natural or technological hazard on housing prices (Damianos & Shabman, 1979). Thus, research is needed to analyze



whether or not there is a relationship between vulnerability to multiple hazards and housing prices.

A second limitation of prior research in examining the relationship between environment disamenities and housing prices is that existing research has mostly neglected the potential difference between scientifically estimated risks and perceived risks, in some cases even using the estimated risk (i.e., distance from a hazardous facility to sampled houses) as a proxy for public risk perceptions (Clark et al., 1997). This will be misleading if, as is likely, the estimated risk is not related to perceived risk. Indeed, little research has considered the relationship between scientifically estimated risks and public risk perceptions to see if these are significantly related. As a complementary study, this research will also investigate how the scientifically estimated environmental risk and perceived risk are related to social, economic, and demographic characteristics.

A third limitation of existing research is that it has failed to determine whether individual hazard mitigation is related to residential property value (Babcock & Mitchell, 1980). It is commonly assumed that a housing unit with individual hazard mitigation measures or under the protection of collective mitigation works has a higher potential price than comparable houses since the protected unit has a lower probability of property damage and casualties. However, few tests of this assumption could be found in the research literature.

These limitations in the research literature will be addressed in this study by examining the relationships of scientific estimates of flood, hurricane and chemical

hazards, and risk perceptions of these hazards with housing prices, and also by studying the relationship of individual hazard mitigation measures with housing prices.

## **1.2. Research Objectives**

This study will investigate the effects of both scientifically estimated environmental risks and public risk perceptions of the three multiple hazards (floods, hurricanes, and hazardous material releases) on the housing prices of single-family housing units in year 2002 within Harris County, Texas.

The study objectives are:

- To test whether scientifically estimated risk and perceived risk of multiple hazards are related to residents' household characteristics,
- To test whether scientifically estimated risk of multiple hazards is related to residents' perceived risk of those hazards,
- To simultaneously test the effects of scientifically estimated risk of multiple hazards on property values,
- To simultaneously test the effects of residents' perceived risk of multiple hazards on property values, and
- To test the effects of household hazard mitigation measures on property values.

### **1.3. Anticipated Benefits of the Research**

Research results from this study are expected to contribute to the scientific understanding of environmental hazard management and housing prices. Considering that little research has investigated how multiple hazards and hazard mitigation measures are related to housing values, this research will help to determine the extent to which multiple hazards and hazard mitigation measures influence property values. In particular, this study is expected to identify the degree to which each hazard agent and mitigation measure would contribute to the housing price. Additionally, the existing research has not considered both the perceived risk and the scientifically estimated risk of environmental hazards as determinants of housing prices. Therefore, analyzing the scientifically estimated risk and the perceived risk of multiple hazards simultaneously will help improve our understanding of how these two independent variables can be related to housing prices.

In addition to its scientific contributions, this study will provide practical benefits to governments, insurance companies, housing purchasers, and real estate agents. Specifically, this research will make local governments aware of their residents' beliefs about environmental risk, and how they plan to protect their homes and family members from potential hazard impacts. Also, it will help disaster insurance companies to more accurately reflect the environmental risk level of each dwelling unit in estimating its insurance premium. Finally, it will provide prospective homebuyers and real estate agents with hazard-related information so that they know the extent to which houses differ in their vulnerability to damage from environmental hazards.

#### **1.4. Organization Of The Dissertation**

Chapter II delves into the literature related to this research. First, this chapter looks into the concept and attributes of housing, and determinants of housing prices. It also describes the general concepts of environmental hazards and public risk perception. Finally, it discusses previous research findings on environmental hazards, risk perceptions, hazard mitigation measures, and housing prices.

Chapter III introduces the theories and models applied to this research, and also develops research hypotheses from the literature review. More specifically, this chapter discusses existing models and theories (such as the psychometric model of risk perception, the hedonic price model, and self-insurance theory), the research rationales and six hypotheses, and a conceptual house price model based upon the hypotheses.

Chapter IV describes the study design, study area, study population and unit of analysis, and sampling process. Furthermore, this chapter introduces study variables and measurements including property values, and household, structural, locational, neighborhood and environmental risk characteristics (estimated and perceived), and hazard mitigation variables. The chapter finishes with the description of research methods including survey procedures, geographic information systems techniques, and statistical analyses.

Chapters V through VIII show how the six hypotheses were tested by statistical analyses such as bivariate correlations, Analysis of Variance (ANOVA), Multivariate Analysis of Variance (MANOVA), and hedonic price regression analysis. Chapter V shows analyses and findings testing the first hypothesis that the scientifically estimated

environmental risks (SEERs) of a flood, a hurricane, and a hazardous material release are related to household characteristics. Chapter VI shows analyses and findings testing the second hypothesis that perceived risks of these hazards are related to household characteristics. Chapter VII shows analyses and findings testing the third hypothesis that SEERs are related to public risk perceptions of the hazards. Lastly, Chapter VIII presents the hedonic price regression analyses and findings testing hypotheses 4 through 6 that SEERs of floods, hurricanes and hazardous material releases, risk perceptions related to those hazards, and household hazard mitigation measures are related housing prices.

Chapter IX provides conclusions, with major research findings of this study, contributions, implications, recommendations for future study, and study limitations.

## **CHAPTER II**

### **LITERATURE REVIEW**

#### **2.1. Introduction**

This chapter reviews five areas of the research literature. The first part of the chapter discusses the concept and attributes of housing, and determinants of housing prices. The second section covers the concept, definition, and classification of three environmental hazards (a flood, a hurricane, and a hazardous material release), as well as the concept and some measurement issues related to public risk perception. The third section describes previous research findings regarding the relationship of environmental hazard vulnerability to housing prices. The fourth part presents previous study results on the relationships of risk perception and housing prices. The last section addresses the definition of hazard mitigation and its relationship to housing prices.

#### **2.2. Concept of Housing**

##### ***2.2.1. What Is Housing?***

Housing covers the largest portion of urban land use. As of year 2000, there were 115,904,641 housing units in the United States (U.S. Census Bureau, 2000). In a general sense, housing can be defined as “the stock of houses, apartments, and other shelters that provide the usual residences of persons, families, and households” (Adams, 1984, p.515). Bourne (1981, p.14) lists several common definitions of housing based upon the literature. He defines housing as a physical facility, an economic good, a social or

collective good, a package of services, and a sector of the economy. As a physical facility, housing provides shelter and requires services (i.e., water, sewer, electricity) supplied by governments. As an economic commodity, the cost of housing is a major fraction of income, and housing is exchanged in a market. As a social or collective good, housing is one of the critical components (i.e., education, food, and health care) in the social system in which everyone participates. As a package of services, housing is related to locational (i.e., proximity to some amenities and disamenities) and neighborhood attributes (i.e., quality of natural and physical environment, and historical, social and demographic elements). As a sector of the economy, housing is a fixed capital stock and one means of producing benefit and utility.

### ***2.2.2. Attributes of Housing***

Housing has several attributes. According to Bourne (1981), housing has such attributes as fixed location, long life span, slowness in responding to changing demands, complexity and diversity of the housing stock, exogenous influences (i.e., the number of housing units is influenced by natural population growth and migration), policy overlay (i.e., influence of governmental regulations), and spatial externalities (i.e., interdependence or mutual influences of housing units). Bogart (1998) distinguishes housing from other goods and services by five themes: heterogeneity (i.e., no two houses are same in terms of cost, space, location, and neighborhood), immobility, durability, large expense in relation to income, and high adjustment costs (e.g., moving expenses and transportation cost). Even though other goods and services contain some of those

characteristics, none has all of them (Bogart, 1998). Housing also confers status, social position, wealth, power, aspirations, and personal identity (Adams, 1984). A housing property consists of land and improvements, with the latter including a building, structure, fixture, or fence, bedrooms, bathrooms, garages, fireplaces, roof, and pools. A housing property has three main elements: the housing unit's location, the physical environment of its surroundings, and its social setting (Adams, 1984).

### ***2.2.3. Determinants of Housing Price***

Research on property values has attempted to explain housing prices by using a multitude of variables. Stull (1975) developed four categories to classify the housing attributes, and examples of these are shown in Table 2-1.

First, *structural characteristics* include all attributes relating to the physical structure of a house itself and its lot. Structural characteristics of a house and its land are the primary contributors to its economic value, because they provide the greatest utility to the owners (Bajic, 1984). It is expected that housing price increases with the number of bedrooms, the number of stories and the size of the lot, and decreases with the age of a house. Furthermore, structural attributes are thought to be more tangible and precisely evaluated than other housing characteristics (Orford, 1999). For instance, the lot or dwelling area of a house is much easier to measure accurately than distance to transport routes, which means that structural characteristics are sure to be reflected in the housing price. With the selection and importance of structural characteristics, Grether and Mieszkowski's (1974) study of the physical attributes of a house found that the living and



lot area of the house, the house age, the number of bathrooms, and the number of garages were the most critical factors in determining residential housing price.

Second, *locational or accessibility characteristics* measure the distance or the travel time from a housing unit to locations of special concern, even though these attributes as locational externalities are unmarketed and, thus, are paid for indirectly through housing purchase (Pinch, 1985; Orford, 1999). For instance, a house's property value can be positively affected by its location near a quality park equipped with good recreation facilities or negatively affected due to its location near a hazardous material facility. That is, accessibility increases property value by decreasing transportation costs which, in turn, bring benefit or utility to the household (Forrest, Glen, & Ward, 1996). Conversely, accessibility removes locational advantages when there is noise, air pollution, and congestion in nearby transport routes or higher crime rates in nearby parks and recreation areas (Sanchez, 1993).

Third, *environmental or neighborhood characteristics* involve the space surrounding the house, and refer to the social and physical features of the neighborhood (Stull, 1975). Although locational characteristics focus upon access to those features, environmental characteristics focus upon the spatial aspects of the neighborhood (e.g., size and form of open spaces) and their quality. Several researchers have studied a number of variables related to environmental amenities (that add to property values) and disamenities (that detract from property values). The amenity effects included the quality, scenic view, number and area of parks, forests, and water bodies within specific distances of houses. Many of previous studies found that open spaces and forests located

within a specific radius of houses positively influenced housing prices (Bolitzer & Netusil, 2000; Geoghegan, 2002; Luttik, 2000; Lutzenhiser & Netusil, 2001; Smith, Poulos, & Kim, 2001). The disamenity effects include air/water pollution, earthquakes, flood, and extreme hazardous material facilities. Since the present study is interested in environmental hazards as determinants of the value of residential property, a specific literature review of environmental hazards follows in the next section.

Finally, *public service characteristics* involve the real property tax rate, and the number and quality of public services. Unfortunately, there has been little research that has delved into such variables. One possible explanation for this paucity of research is that many of these variables (e.g., water, sewer, public library, tax rates, and museums) tend to be uniform within a community so that there is no observable effect of those variables when a study examines property values only in a single city.

**Table 2-1. Determinants of housing prices and their examples**

Determinants	Examples
Structural	Lot size, dwelling size, number of rooms, house age, garage, pool, etc.
Locational or Accessibility	Distance to the Central Business District, major highways, airports, park, recreation area, forest, and water bodies, etc.
Environmental or Neighborhood	Income, race, education, crime rate, subdivision, land use, quality of amenities (i.e., park, water bodies, and forest), environmental pollution, and environmental risk, etc.
Public Service	Property tax rates, number, or quality of public services, etc.

## **2.3. Environmental Hazards and Public Risk Perception**

### ***2.3.1. What Is a Hazard?***

A hazard is viewed as a threat to humans and to things they consider valuable (Kates & Kasperson, 1983). Similarly, Deyle et al. (1998) define a hazard as an extreme event that poses risk to human settlements. According to Alexander (1993), a hazard is regarded as the exposure to some risk of disaster in the pre-disaster situation, due to the presence of human population in hazard-prone areas. Burton and Kates (1964, p. 413) refer to natural hazards as “elements in the physical environment, harmful to man and caused by forces extraneous to him”. According to Deyle et al. (1998), consequences of harmful impacts of hazards include direct effects (injuries, deaths, health problems, and damage to personal property, public facilities, equipment, and infrastructure), and indirect effects (loss of jobs, business earnings and tax revenues, losses caused by business and production interruption, and the public costs of all phases of hazard adjustment).

### ***2.3.2. Classifying Hazards***

Researchers attempted to differentiate natural and technological hazards to better understand distinguishing characteristics of various hazards. Conventionally, hazards have been categorized depending upon the hazard agent source, such as earthquakes, floods, hurricanes, tornadoes, and hazardous material accidents (Quarantelli, 1988a). Two major categories, natural and technological hazards, have been developed according to the original source of the extreme events (Quarantelli, 1988b). Natural and

technological hazards are ones that can lead to disasters by interacting with humans and the built environment. In general, natural hazards can be classified into climatic and geologic hazards. Climatic hazards include storms, hurricanes, severe wind, tornadoes, drought, floods, and natural fires. Geologic hazards include earthquakes, subsidence, erosion, volcanic eruptions, landslides, and mudslides.

Technological hazards have been classified in different ways. Starr (1969) divided them into voluntary and involuntary exposures. Lowrance (1976) categorized them into acute or chronic effects. Perrow (1984) used low-probability/high-consequences and high-probability/low consequences to classify technological hazards. Slovic (1987) classified various technological risks based upon dread/unknown and common/known. Hohenemser, Kates, and Slovic (1983) classified technological hazards in terms of 12 characteristics that could be described by two factors – whether they were dreaded and whether they were well known to those exposed. These characteristics and their measurements are as follows (Hohenemser, Kates, & Slovic, 1983, p.379):

- *Intentionality of harmfulness. Measures the degree to which technology is intended to harm.*
- *Spatial extent of impact. Measures the maximum distance over which a single event has significant impact.*
- *Concentration. Measure the concentration of released materials relative to natural background.*
- *Persistence. Measures the time over which a release remains a significant threat to humans.*
- *Recurrence. Measures the mean time interval between releases above a minimum significant level.*

- *Population at risk. Measures the number of people in the United States potentially exposed to the hazard.*
- *Delay. Measures the delay time between exposure to the hazard release and the occurrence of consequences.*
- *Annual human mortality. Measures average annual deaths in the United States due to the hazard.*
- *Maximum human mortality. Measures average annual deaths in the United States due to a single event.*
- *Transgenerational effect. Measure the number of future generations at risk from the hazard.*
- *Potential nonhuman mortality. Measures the maximum potential nonhuman mortality.*
- *Experienced nonhuman mortality. Measures nonhuman mortality that has actually been experienced.*

Hohenemser, Kates, and Slovic (1983) divided technological hazards into three classes: ‘Multiple extreme hazards’, ‘extreme hazards’, and ‘hazards’. *Multiple extreme hazards* includes nuclear war, radiation, and nerve gas. *Extreme hazards* includes antibiotics, vaccines, uranium mining, asbestosis, LNG explosions, car and airplane accidents, ozone depletion, AIDS, and global warming. *Hazards* includes food additives and appliances.

Barton (1969) defined four main attributes by which different hazards could be classified: namely, scope of impact, speed of onset, duration of impact, and social preparedness. Anderson (1969) added secondary impacts to those classes. Lindell and Perry (1992) assembled lists of distinguishing characteristics for classifying different

hazard agents through existing literature, which include scope of impact, speed of onset, duration of impact, health threat, property threat, secondary threat, and predictability. Table 2-2 shows how the classification works by comparing three hazard agents (i.e., riverine flood, volcanic eruption, and nuclear power plant).

**Table 2-2. Hazard agent classification**

Defining Characteristic	Riverline Flood	Volcanic Eruption	Nuclear Power Plant Accident
Scope of impact	Highly variable, long and narrow	Highly variable, broad area	Highly variable, broad area
Speed of onset	Rapid: flash flood Slow: main stem	Rapid	Variable
Duration of impact	Short	Long	Long
Health threat	Water inhalation	Blast, burns, ash inhalation	Ingestion, inhalation, direct radiation
Property threat	Destruction	Destruction	Contamination
Secondary threat	Public health danger from water/sewer	Forest fires, glacial snowmelt	Secondary contamination
Predictability	High	Poor	Variable ability to predict releases after accident onset

Source: Lindell and Perry (1992, p. 23).

### ***2.3.3. Environmental Hazards Studied in This Research***

This study considers three main hazards (i.e., floods, hurricanes, and hazardous materials) to examine relationships between environmental hazards (estimated and perceived) and household characteristics, between scientifically estimated environmental risks and risk perceptions, and between environmental hazards and housing prices.

#### **A. Floods**

Flooding is a prominent natural hazard that has continually caused many deaths and enormous economic losses. Furthermore, many urban areas of the United States are

intensively developing flood prone areas, causing the human and property vulnerability to flood hazards to rise. In fact, floodplains are occupied and utilized due to the economic advantages of level ground for transportation, fertile soils for agriculture, and available water supplies (Texas Division of Emergency Management, 2000).

Flooding results from the overflow of major rivers and streams, melting snow, ice jams, dam and levee failure, heavy rains, storm surge from hurricanes, or inadequate local drainage. Two critical factors contributing to flooding are rainfall intensity and duration. Intensity is the rate of rainfall, and duration indicates how long the rain lasts. Topography, soil conditions, and ground cover are also closely related to flooding.

There are three types of floods: flash floods, riparian floods, and coastal floods. Flash floods result from severe rainfall and rapid surface runoff in a relatively limited drainage area, resulting in peak runoff within six hours. Urban areas composed of roads and buildings are so impervious that flash floods are more likely to happen with much lower rainfall (Bryant, 1991). Flash floods are a major concern in areas when the terrain is steep, runoff rates are high, streams flow in narrow canyons and gullies, or extreme thunderstorms stall over an area (Texas Division of Emergency Management, 2000). Flash floods are a threat to a human safety because they usually happen without any warning. Riparian floods happen along streams and rivers due to precipitation that last for periods ranging from a few hours to many days. Riparian floods take place in large river systems that cover many independent river basins. Variations in the intensity, amount, and distribution of precipitation play a major role in riparian floods (Texas Division of Emergency Management, 2000). Coastal floods result from storm surge and

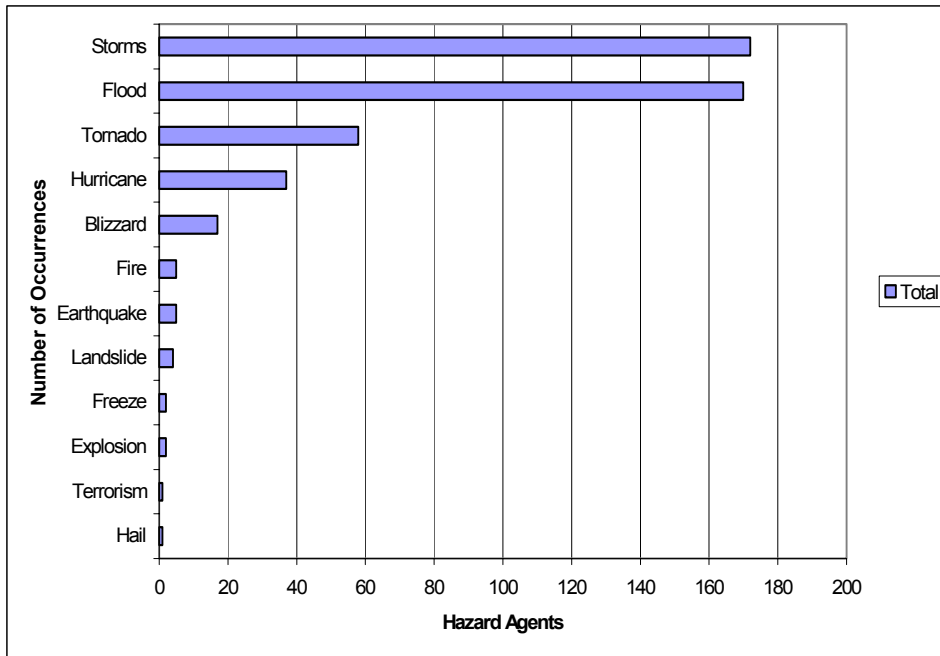
waves caused by the high winds of tropical hurricanes. These floods are among the most widespread, destructive natural hazards in the United States. For instance, in June 2001, Tropical Storm Allison devastated major areas of Harris County and neighboring communities, claiming 22 lives, and damaging 20,000 homes and 5,000 other buildings at an estimated cost of 20 billion dollars.

White (1975) estimates that about 17,000 of the 20,000 urban communities in the United States experience flood problems. Flooding can have critical impacts on an estimated 7 % of the land area (White, 1975). Today less than 15 % of the U.S. communities have structural flood protection, and only 20 to 30 % of buildings at risk of flooding are covered by national flood insurance (FEMA, 1997). According to FEMA, 9.6 million U.S. households and property valued at \$390 billion are currently at risk from at least a 1% annual chance of flooding. Floods are the costliest and deadliest natural hazard in the U.S., causing over 1,600 deaths and annual property losses of \$19.6 billion to \$196 billion from 1975 to 1994 (National Weather Service's National Climate Data Center: <http://www.ncdc.noaa.gov/oa/ncdc.html>). Meanwhile, urban development in floodplain areas continues to increase by 1.5% to 2.5% per year. In addition, rapid population migration to coastal counties is occurring. Along the East and Gulf coasts, about \$3 trillion in infrastructure adjacent to the shoreline is vulnerable to erosion from flooding and other natural hazards (FEMA, 1997). Annual flood damages in the U.S. average over \$4 billion (emergency assistance costs plus property losses), and flood-related loss of life during the past ten years averaged about 99 deaths per year (U.S. Army Corps of Engineers, 1999). In addition to the economic and life losses resulting



from floods, significant indirect social costs include stress from evacuations and life in temporary emergency shelters, as well as the destruction of homes, schools, and workplaces.

During the period from 1992 to 1999, the federal government declared a total of 354 major disasters in the 50 states and the District of Columbia. The 354 declarations resulted from 474 incidents, arising from 12 kinds of hazard agents: blizzards, earthquakes, explosions, fires, floods, freezes, hail, hurricanes, landslides, storms, terrorism, and tornadoes. Of the 354 presidential disaster declarations, storms (172) – including snowstorms, coastal storms and winter storms – ranked first (see Figure 2-1). This was followed by floods (170), tornadoes (58), hurricanes (37), blizzards (17), fires (5), earthquakes (5), landslides (4), freezes (2) and explosion (2), hail (1), and terrorism (1). One significant fact is that, considering that most of the storms and hurricanes were accompanied by flooding, more than half of the disaster declarations were related to floods.



**Figure 2-1. Hazard agents that caused major disaster declaration and their frequencies. January, 1992 to September, 1999**

Source: FEMA (<http://www.fema.gov/library/drcys.shtm>)

## B. Hurricanes

A hurricane is a cyclone that originates in tropical oceans, accompanied by thunderstorms and circulating winds over tropical waters. Tropical cyclones are classified in Table 2-3.

**Table 2-3. Types of tropical cyclones**

Types	Description
Tropical Depression	An organized system of clouds and thunderstorms with a defined surface circulation and maximum sustained winds <sup>a</sup> of 38 mph (33 kt <sup>b</sup> ) or less.
Tropical Storm	An organized system of strong thunderstorms with a defined surface circulation and maximum sustained winds of 39-73 mph (34-63 kt).
Hurricane	An intense tropical weather system of strong thunderstorms with a well-defined surface circulation and maximum sustained winds of 74 mph (64 kt) or higher

<sup>a</sup>Sustained winds are defined as a 1-minute average wind measured at about 33 ft (10 meters) above the surface. <sup>b</sup>1 knot = 1 nautical mile per hour or 1.15 statute miles per hour. Abbreviated as "kt".

Source: National Hurricane Center ([http://hurricanes.noaa.gov/prepare/title\\_basics.htm](http://hurricanes.noaa.gov/prepare/title_basics.htm)).

Tropical storms occur approximately ten times per year between June 1 and November 30 over the Atlantic Ocean, Caribbean Sea, and Gulf of Mexico, and six of these storms usually become hurricanes that pose serious risk to the Atlantic or Gulf coast. During the period from 1900-1996, the U.S. mainland experienced a total of 158 hurricanes (see Table 2-4). Florida experienced the most hurricanes, accounting for 23%, followed by Texas (23%), and Louisiana, and North Carolina (16%, each).

**Table 2-4. U.S. mainland hurricane strikes by state, 1900-1996**

Area	Category Number					All 1,2,3,4,5	Major 3,4,5
	1	2	3	4	5		
U.S. (Texas to Maine)	58	36	47	15	2	158	64
Texas	12	9	9	6	0	36	15
Louisiana	8	5	8	3	1	25	12
Mississippi	1	1	5	0	1	8	6
Alabama	4	1	5	0	0	10	5
Florida	17	16	17	6	1	57	24
Georgia	1	4	0	0	0	5	0
South Carolina	6	4	2	2	0	14	4
North Carolina	10	4	10	1	0	25	11
Virginia	2	1	1	0	0	4	1
Maryland	0	1	0	0	0	1	0
Delaware	0	0	0	0	0	0	0
New Jersey	1	0	0	0	0	1	0
New York	3	1	5	0	0	9	5
Connecticut	2	3	3	0	0	8	3
Rhode Island	0	2	3	0	0	5	3
Massachusetts	2	2	2	0	0	6	2
New Hampshire	1	1	0	0	0	2	0
Maine	5	0	0	0	0	5	0

Source: National Hurricane Center (<http://www.nhc.noaa.gov/paststate.html>).

Hurricanes can produce high wind, tornadoes, coastal flooding from storm surge, and inland flooding from heavy rain (Lindell et al., 2001). Hurricane winds can destroy buildings, and the flying debris that high winds carry is a great threat to life. A hurricane is classified based upon the strength of its winds using the Saffir-Simpson scale (see Table 2-5). The extreme winds make a landfall before the hurricane eye does. Hurricanes can also spawn tornadoes some distance from the center of the storm. There were 23 tornadoes related to Hurricane Alicia that hit Galveston in 1983 (Lindell et al., 2001). Another hazard associated with hurricanes is storm surge. A storm surge refers to a large

dome of water, 50 to 100 miles wide and as much as 18 feet or more in height. When a hurricane strikes, the storm surge sweeps across the coastline, leading to damaging coastal flooding. Finally, hurricanes can lead to widespread torrential rainfall. Floods resulting from the heavy rainfall can threaten inland areas.

**Table 2-5. Saffir-Simpson hurricane scale**

Saffir/Simpson Category	Wind Speed (mph) <sup>a</sup>	Wind Velocity Pressure (psf)	Expected Surge (ft)	Expected Damage
One	74–95	19.0	4–5	<ul style="list-style-type: none"> <li>• Vegetation: some damage to foliage.</li> <li>• Street signs: minimal damage.</li> <li>• Mobile homes: some damage to unanchored structures.</li> <li>• Other buildings: little or no damage.</li> </ul>
Two	96–110	30.6	6–8	<ul style="list-style-type: none"> <li>• Vegetation: much damage to foliage; some trees blown down.</li> <li>• Street signs: extensive damage to poorly constructed signs.</li> <li>• Mobile homes: major damage to unanchored structures.</li> <li>• Other buildings: some damage to roof materials, doors, and windows.</li> </ul>
Three	111–130	41.0	9–12	<ul style="list-style-type: none"> <li>• Vegetation: major damage to foliage; large trees blown down.</li> <li>• Street signs: almost all poorly constructed signs blown away.</li> <li>• Mobile homes: destroyed.</li> <li>• Other buildings: some structural damage to small buildings.</li> </ul>
Four	131–155	57.2	13–18	<ul style="list-style-type: none"> <li>• Vegetation: major damage to foliage; large trees blown down.</li> <li>• Street signs: all down.</li> <li>• Mobile homes: destroyed.</li> <li>• Other buildings: extensive damage to roof materials, doors, and windows; many residential roof failures.</li> </ul>
Five	>155	81.3	>18	<ul style="list-style-type: none"> <li>• Vegetation: major damage to foliage; large trees blown down.</li> <li>• Street signs: all down.</li> <li>• Mobile homes: destroyed.</li> <li>• Other buildings: some complete building failures.</li> </ul>

<sup>a</sup> Wind gusts can exceed the maximum sustained wind speed by 25% or more.

Source: Lindell et al. (2001).

As of 2000, 53% of the total U.S. population (namely, 148.3 million residents out of a total of 281.4 million U.S. population) lived in coastal counties, even though the land area of these counties covered only 25.1 % of the nation. Table 2-6 indicates that the coastal areas with far greater population densities were more vulnerable to hurricanes. Moreover, transients including tourists have increased the coastal population substantially (Lindell et al., 2001). Rapid population growth in the coastal areas has not only raised the risk of property loss from hurricanes and coastal storms, but also compounded evacuation problems because highway capacity has frequently failed to catch up with population growth (Lindell et al., 2001). Although the hurricane forecasting system has been improved, it is near the limits of its capability, yet evacuation lead times continue to increase by an hour per year in major metropolitan areas (Griffith, 1985). This increased evacuation time has the potential for causing a large number of fatalities if an evacuation is delayed, or a hurricane changes direction unexpectedly – Currently, Galveston County, Texas needs an evacuation lead time of 33 hours for Category 5 storm (Lindell, Prater, & Wu, 2002).

**Table 2-6. Population in coastal counties: 1970-2000**

	Total (U.S.)	Coastal Region			Balance of U.S.	
		Atlantic	Gulf of Mexico	Great Lakes Pacific		
<b>Land area</b>						
1,000 sq. miles	3,536	148	114	115	510	2,649
Percent	100	4.2	3.2	3.3	14.4	74.9
<b>Population</b>						
1970 (mil. <sup>a</sup> )	203.3	51.1	10.0	26.0	22.8	93.3
1980 (mil.)	226.5	53.7	13.1	26.0	27.0	106.7
1990 (mil.)	262.8	61.0	16.5	25.9	33.2	115.3
2000 (mil.)	272.7	65.2	18.0	27.3	37.8	133.1
1970 (percent)	100	25	5	13	11	46
1980 (percent)	100	24	6	11	12	47
1990 (percent)	100	24	6	10	13	46
2000 (percent)	100	23	6	10	13	47

<sup>a</sup> The measurement unit is million.

Note: These coastal areas defined by U.S. National Oceanic and Atmospheric Agency, 1992 include 673 counties and equivalent areas with at least 15 percent of their land area either in a coastal watershed (drainage area) or in a coastal cataloging unit (a coastal area between watersheds).

Source: U.S. Census Bureau (2000).

In September, 1900 a major hurricane that hit Galveston Island, Texas in the Gulf of Mexico resulted in the death of over eight thousand people. In 1992 Hurricane Andrew (a Category 4 hurricane on the Saffir/Simpson Hurricane Scale), which struck south Florida and Louisiana with fierce wind and storm surges, led to an unprecedented property loss in U.S. natural disaster events (estimated \$ 30 billion). Additionally, Andrew claimed 15 lives, and left nearly one-quarter million people temporarily homeless. Tables 2-7 and 2-8 list the 24 deadliest hurricanes and 25 costliest hurricanes, respectively, which have struck the Atlantic and Gulf coasts. These lists come from data obtained from the National Hurricane Center's web site, and the storms are listed in descending order of death and damage costs. It is noteworthy that Hurricane Diane, though defined as a Category 1 hurricane, ranked thirteenth deadliest, killing 184 persons. Hurricane Agnes (1972), also a Category 1 hurricane, was fifth costliest with damage estimated at 6.9 billion. These figures tell us that the effect of a hurricane may depend not only upon storm intensity, but also upon its impact areas (e.g., urban center), arrival time (e.g., day or night), and other factors (e.g., hurricane duration, indirect impacts, emergency preparedness, disaster responses, and hazard mitigation measures at the collective and individual levels).



**Table 2-7. The deadliest hurricanes in the United States 1900-1996**

Ranking	Hurricane	Year	Category	Deaths
1.	TX (Galveston)	1900	4	8000 <sup>a</sup>
2.	FL (Lake Okeechobee)	1928	4	1836
3.	FL (Keys)/S. TX	1919	4	600 <sup>b</sup>
4.	NEW ENGLAND	1938	3	600
5.	FL (Keys)	1935	5	408
6.	AUDREY (SW LA/N TX)	1957	4	390
7.	NE U.S.	1944	3	390 <sup>c</sup>
8.	LA (Grand Isle)	1909	4	350
9.	LA (New Orleans)	1915	4	275
10.	TX (Galveston)	1915	4	275
11.	CAMILLE (MS/LA)	1969	5	256
12.	FL (Miami)/MS/AL/Pensacola	1926	4	243
13.	DIANE (NE U.S.)	1955	1	184
14.	SE FL	1906	2	164
15.	MS/AL/Pensacola	1906	3	134
16.	AGNES (NE U.S.)	1972	1	122
17.	HAZEL (SC/NC)	1954	4	95
18.	BETSY (SE FL/SE LA)	1965	3	75
19.	CAROL (NE U.S.)	1954	3	60
20.	SE FL/LA/MS	1947	4	51
21.	DONNA (FL/Eastern U.S.)	1960	4	50
22.	GA/SC/NC	1940	2	50
23.	CARLA (TX)	1961	4	46
24.	TX (Velasco)	1909	3	41
25.	TX (Freeport)	1932	4	40
26.	S TX	1933	3	40
27.	HILDA (LA)	1964	3	38
28.	SW LA	1918	3	34
29.	SW FL	1910	3	30

<sup>a</sup>May actually be as high as 10,000 to 12,000. <sup>b</sup> Over 500 of these lost on ships at sea; 600-900 estimated deaths. <sup>c</sup> Some 344 of these lost on ships at sea.

Source: National Hurricane Center (<http://www.nhc.noaa.gov/pastdead.html>)

**Table 2-8. 25 costliest hurricanes striking U. S. coast**

Ranking	Hurricane	Year	Category	Damage (U.S.)
1	Andrew (SE FL/SE LA)	1992	4	\$26,500,000,000
2	Hugo (SC)	1989	4	\$7,000,000,000
3	Fran (NC)	1996	3	\$3,200,000,000
4	Opal (NW FL)	1995	3	\$3,000,000,000
5	Frederic (AL/MS)	1979	3	\$2,300,000,000
6	Agnes (NE U.S.)	1972	1	\$2,100,000,000
7	Alicia (N TX)	1983	3	\$2,000,000,000
8	Bob (NC and NE U.S.)	1991	2	\$1,500,000,000
8	Juan (LA)	1985	1	\$1,500,000,000
10	Camille (MS/AL)	1969	5	\$1,420,700,000
11	Betsy (FL/LA)	1965	3	\$1,420,500,000
12	Elena (MS/AL/NW FL)	1985	3	\$1,250,000,000
13	Gloria (E U.S.)	1985	3	\$900,000,000
14	Diane (NE U.S.)	1955	1	\$831,700,000
15	Erin (C & NW FL/SW AI)	1995	2	\$700,000,000
16	Eloise (NW FL)	1975	3	\$490,000,000
17	Carol (NE U.S.)	1954	3	\$461,000,000
18	Celia (S TX)	1970	3	\$453,000,000
19	Carla (TX)	1961	4	\$408,000,000
20	Donna (FL/Eastern U.S.)	1960	4	\$387,000,000
21	David (FL/Eastern US)	1979	2	\$320,000,000
22	New England	1938	3	\$306,000,000
23	Kate (FL Keys/NW FL)	1985	2	\$300,000,000
24	Allen (S TX)	1980	3	\$300,000,000
25	Hazel (SC/NC)	1954	4	\$281,000,000

Source: National Hurricane Center (<http://www.nhc.noaa.gov/pastcost.html>).

### C. Technological Hazards

Technological hazards can be defined as “the origins of incidents that can arise from human activities such as the manufacture, transportation, storage, and use of hazardous materials” (FEMA, 2002), and that can arise from fire, and failure of structures and infrastructure. According to Cutter (1993), technological hazards can be referred to as the interaction between technology, society, and the environment. Technological hazards, unlike natural hazards, were once believed to have little or no potential for causing catastrophic levels of death and property damage (Quarantelli,

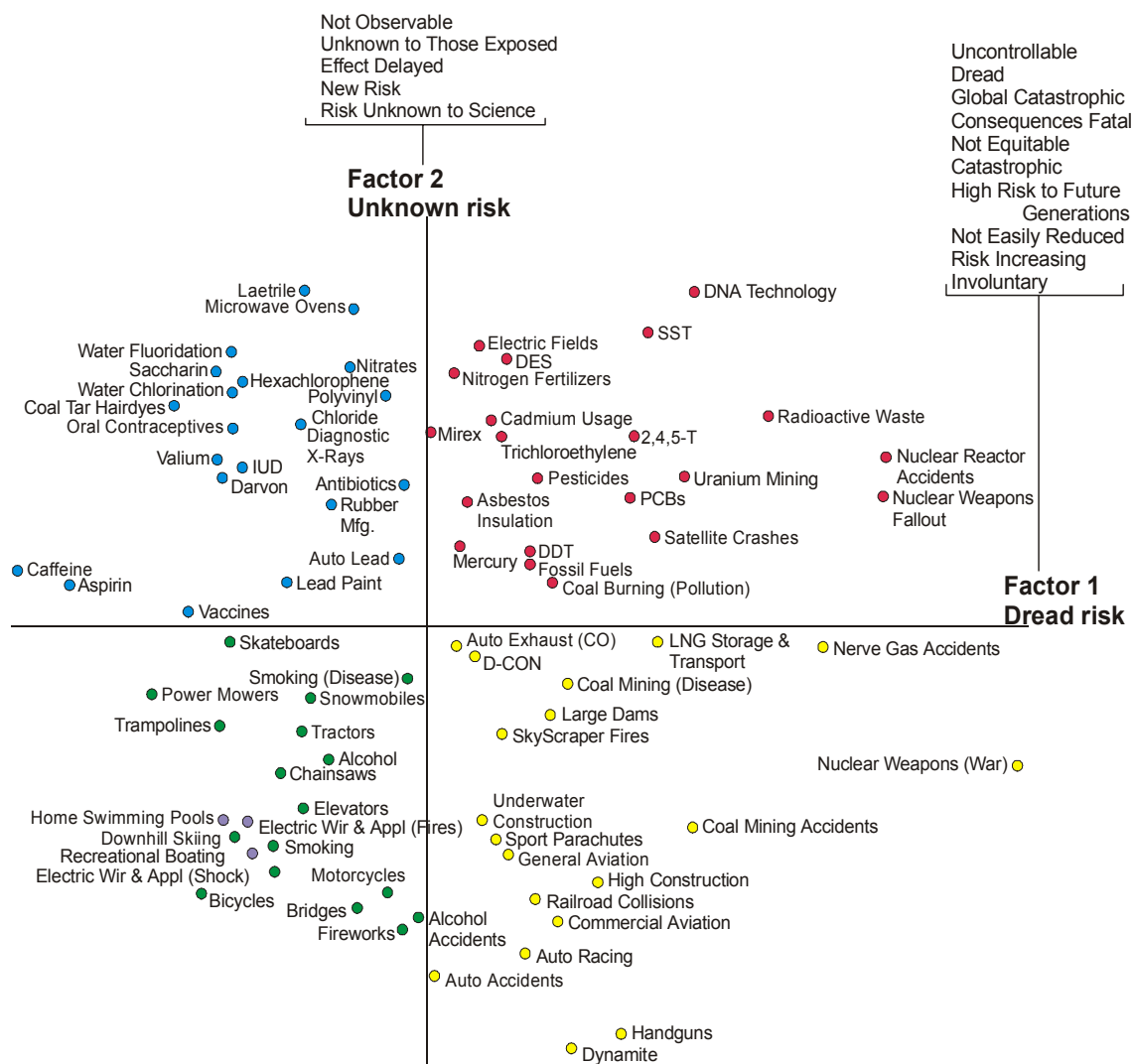
1984). However, during recent decades, the growth of chemical and nuclear technologies has been accompanied by the possibility of catastrophic and long-term harm or damage to people, and property (Slovic, 1987). During recent decades, high-profile hazardous material accidents stimulating environmental concern and research activity have included the 1984 Bhopal, India toxic chemical release; The 1979 Three Mile Island, Pennsylvania nuclear power plant accident; the 1986 Chernobyl, Soviet Union nuclear power plant accident; and the 1989 Exxon Valdez oil spill, Alaska (Baum et al., 1983; Maser & Solomon, 1990; Picou & Gill, 1996).

Compared to natural hazards, technological hazards have several distinctive attributes. First, technological hazards are different from natural hazards, wars, and terrorism because they result from human error or mismanagement of technology. Technological hazards are products of our society that result from failures in technological systems as well as failures in the political, social, and economic systems that manage the use of those technological systems (Cutter, 1993). Technological hazards are interwoven with the elements of complexity, surprise, and interdependence. Therefore, technological hazards should be understood in terms of political, economic, social, and historical contexts within which they occur (Cutter, 1993). Second, some technological hazards can lead to insidious diseases that may not become evident until many years later (Hoetmer, 1991). For example, Hoetmer (1991) mentions that high toxic radioactive leaks that occurred from 1944 to 1947 at the Hanford Nuclear Reservation, Washington are now being regarded as the cause of high incidences of cancer and heart problems among residents of the area. Third, many technological

hazards are highly related to certain geographical areas. Geography helps us identify which areas are subject to the potential impacts of technological hazards, and who bears the risk of technological hazards (Cutter, 1993). Fourth, unlike most natural hazards, technological hazards such as invisible leaks and releases of hazardous materials can be preceded by little or no warning (Hoetmer, 1991). Finally, technological hazards are induced by industry and the widespread use of science (Beck, 1992; Cutter, 1993). The occurrence of technological events is increasing, as the creation of hundreds of new substances each year causes more chances for human error (Hoetmer, 1991).

Since the Industrial Revolution, there has been an exponential increase in new risks of technological hazards, the most common of which include fires, explosions, transportation accidents, structural failures, and hazardous material releases (Hoetmer, 1991). Slovic (1987) identified 81 hazard agents related to technologies, based upon two main components: dread and unknown, which include 15 risk characteristics. 'Unknown risk' contains those that are 'unobservable', 'unknown to those exposed', 'delayed effects', 'new risks', and 'risks unknown to science'. 'Dread risk' contains 'uncontrollability', 'dread', 'global catastrophe', 'fatal consequences', 'inequity', 'high risk to future generations', 'not easily reduced', 'risk increasing', and 'involuntary'. The upper left quadrant in Figure 2-2 includes unknown/common risks such as Laetrile, water chlorination, and saccharin, while the upper right includes unknown/dread risks such as radioactive waste, nuclear reactor accidents, and satellite crashes. Smoking, power mowers, and all examples in the lower left quadrant are known/common risks,

while nerve gas accidents, large dams, and nuclear war in the lower right quadrant are known/dread risks.

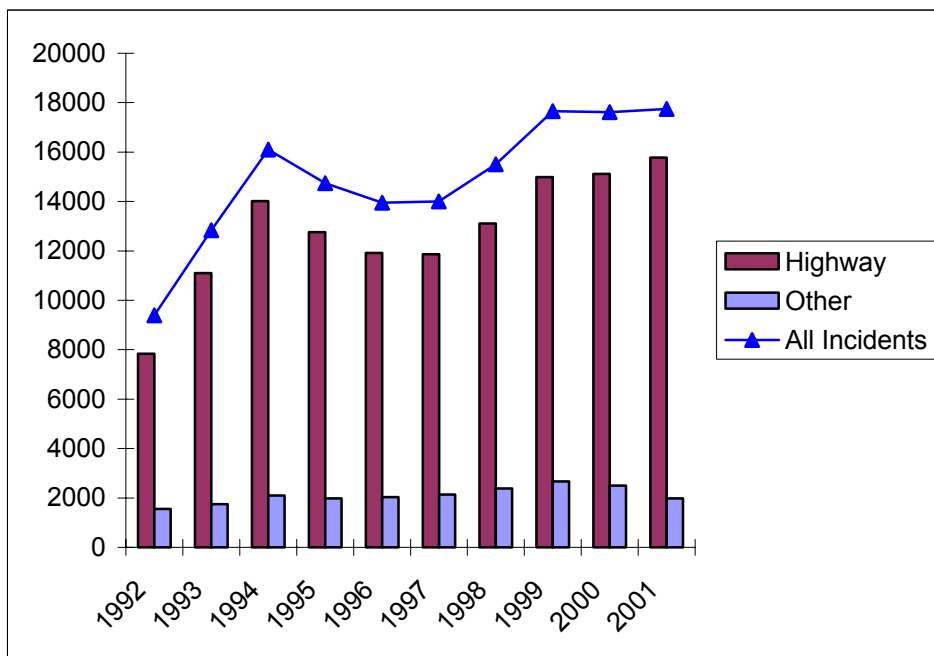


**Figure 2-2. Location of 81 hazards related to risky technologies and activities, location of 81 hazards on factors 1 and 2 derived from the interrelationship among 15 risk characteristics**

Note: Each factor is made up of a combination of characteristics, as indicated by the diagram.

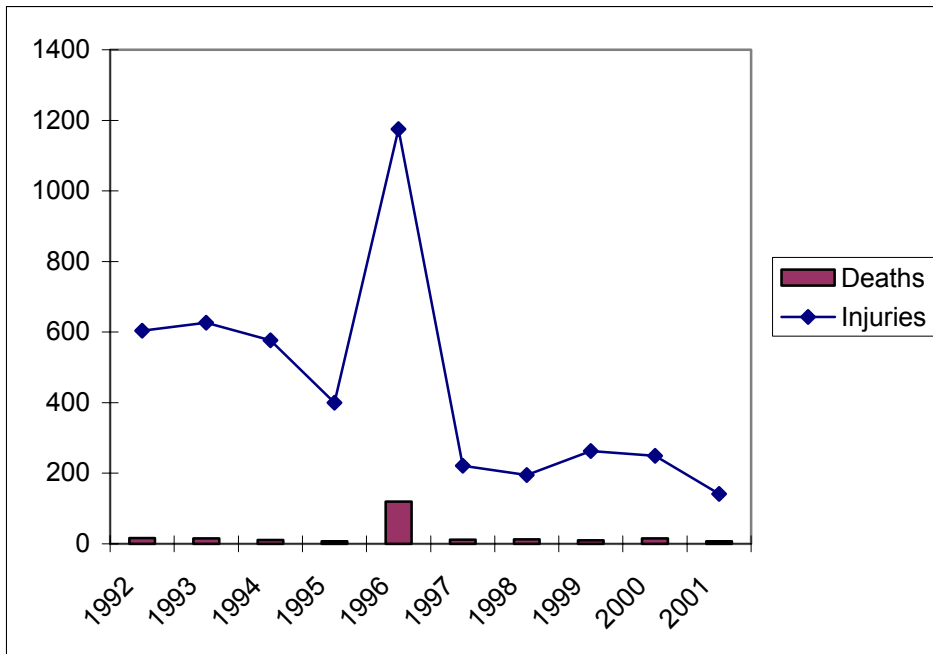
Source: Slovic, P. (1987). Perception of risk. Science, 236, 280-285.

Vulnerability from technological disasters is increasing. Each year two billion tons of over 2,400 toxic chemicals are transported, and 266 tons of hazardous wastes are created (Scanlon, 1987). In fact, according to the U.S. Department of Transportation (2002), hazardous material incidents by transportation modes including air, highway, railway, and water increased from 9393 occurrences in 1992 to 17,749 occurrences in 2001 (see Figure 2-3). During the same period, there appeared to be a trend showing a gradual decrease in terms of the number of deaths and injuries, although there was a sharp spike in 1996 (see Figure 2-4). Moreover, dollar losses generally increased during the period (see Figure 2-5).



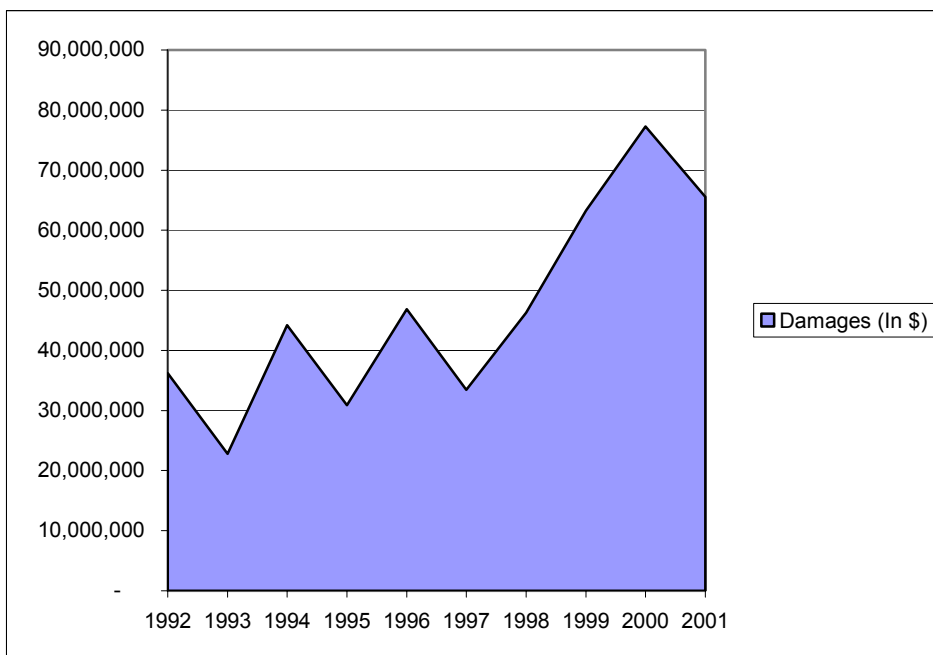
**Figure 2-3. Number of hazardous material transportation accidents**

Source: U.S. Department of Transportation (2002).



**Figure 2-4. Deaths and injuries by hazardous material transportation accidents**

Source: U.S. Department of Transportation (2002).



**Figure 2-5. Dollar losses of hazardous material transportation accidents**

Source: U.S. Department of Transportation (2002).

Unfortunately, there is no available database on deaths, injuries, and monetary losses derived from disasters at fixed-site facilities. The Environmental Protection Agency's Toxics Release Inventory (TRI) contains only information reported annually by industry groups and federal facilities on the locations and quantities of chemicals stored on-site, and releases and transfers of certain toxic chemicals from industrial facilities.

#### ***2.3.4. Environmental Risk and Risk Perception***

Individuals' perceived risk plays a major role in determining how they respond to environmental hazards by interpreting warning messages or taking protective actions against hazard events (Lindell & Perry, 1992; Burn, 1999). Slovic (1987) argues that individuals build upon risk perception to estimate dangerous situations during emergencies. There are various definitions of risk because risk is a fuzzy word with many different meanings. Regarding risk, Slovic and Weber (2002) provide the most common definitions of risk and their examples (p.4):

- *Risk as a hazard. Example: "Which risks should we rank?"*
- *Risk as probability. Example: "What is the risk of getting AIDS from an infected needle?"*
- *Risk as consequence. Example: "What is the risk of letting your parking meter expire" (answer: "Getting a ticket")*
- *Risk as potential adversity or threat. Example: "How great is the risk of riding a motorcycle?"*



By combining the second and third definitions mentioned above, Kates and Kasperson (1983), and Cutter (1993) more specifically define risk as measuring the probability of the occurrence of natural and technological hazards leading to certain adverse consequences. In the present study, environmental risk associated with floods, hurricanes, and chemical hazards will be scientifically estimated, based upon location of a house within an area that is expected to be affected by an extreme event with a specified recurrence interval or intensity. For example, being located within the 100-year flood plain means that the property has a chance of getting flooded once per 100 years. This will be regarded as the highest flood risk area, a 500-year flood as the second highest, and the other areas as essentially flood risk free areas. Similarly, the risk of a hazardous material release is measured by the likelihood of a major release; the nearer to a hazardous material facility, the higher likelihood of an event severe enough to threaten the residents' health and safety. Finally, the risk of a hurricane is measured by being located in an area that is vulnerable to one of the five different categories of hurricane intensity. That is, hurricane risk is defined directly in terms of intensity rather than recurrence interval. To examine the spatial distribution of the three risks, the risk area for each of the hazards will be defined and described in detail in Chapter 4.

Environmental risk perception has been defined in slightly different ways by several disaster experts. According to Mileti, Drabek and Haas (1975), risk perception is referred to as the individual's understanding of the character and relevance of a hazard. Sorensen and White (1980) similarly define risk perception as an individual's understanding of the temporal nature, probability, and the potential consequences of the

disaster caused by a hazard. In the context of this study, environmental risk perception is defined as one's beliefs about individual hazards that are caused or induced by nature and humans.

Risk perceptions have been measured or assessed in several ways. Jackson (1977) measured respondents' risk perception by using free-response methods. Jackson and Mukerjee (1974) asked respondents about potential troubles of their city in association with earthquakes to assess their risk perceptions. Dooley, Catalano, Mishra and Serxner (1992) evaluated respondents' risk perceptions by asking them about their level of concern about the hazard. Through previous studies, Lindell (1994, p. 305), as shown in Table 2-9, identified four components of perceived risk characteristics: characteristics of the hazard agent, characteristics of the impact, perceived personal consequences, and affective reactions to the hazard. This study will measure individuals' risk perceptions by asking them to rate their perceived consequences such as property damage to their home, injury or health problems to themselves or members of their household, which may result from a flood, a hurricane, or a hazardous material release.

**Table 2-9. Components of perceived risk characteristics**

Perceived Risk Characteristics	Examples
Hazard agent characteristics (Mulilis & Lippa, 1990)	Likelihood of a dangerous event Ease of reducing risk Preventability of a release
Impact characteristics	Speed of onset Scope of impact Duration of impact Existence of environmental cues
Perceived personal consequences (Kunreuther et al., 1978; Palm et al., 1990; Showalter, 1993)	Health and safety impacts Property loss Interference with work Social disruption
Affective reactions to the hazard	Ratings of dread Frequency of thought about the hazard Frequency of discussions about the hazards with others

Source: Lindell (1994, p.305).

Individuals have their own view of risk and make judgments based upon it. There are many factors influencing individuals' risk perceptions (Cutter, 1993, p.24):

- a. Experience: There are a large number of research findings on how past experience with environmental hazards affects one's perception. Persons with more past experience (Burton & Kates, 1964), and those with recent and intense impact by the hazard (Kates, 1971) tend to have more accurate hazard perceptions. Burton, Kates, and White (1978) claim that in some countries, natural hazards like floods are so common that the population has experienced disasters quite often, resulting in what is called a disaster subculture. In this subculture, the risk from the specific natural hazard tends to be neglected because the people know what to do, and have developed coping responses to handle the hazardous events they have repeatedly experienced (Cutter, 1993; Weller &

Wenger, 1972). Conversely, lack of experience with hazards tends to increase the level of perceived risks until people have adapted to them (Cutter, 1993)

- b. Culture: Several papers tried to confirm cross-cultural factors that might make a difference in risk perceptions (Vlek & Stallen, 1981; Keown, 1989; Kleinhesselink & Rosa, 1991). However, they found few differences in perceived risk among people from different nations.
- c. Race, gender, and socioeconomic status: Whether these variables explain variations in risk perception has produced inconclusive results. Mohai (1990) and Cutter (1981) found that blacks had higher levels of concerns than whites about pollution. Some empirical studies found gender differences in the perception of hazards, especially nuclear war (Silverman & Kumka, 1987), industrial hazards and health (Stallen & Thomas, 1988). However, Cutter et al. (1992) found no evidence to differentiate gender characteristics. Finally, the relationship between socioeconomic status and risk perceptions has remained low.
- d. Distance: Distance is strongly related to the objective risks which populations are subject to during and/or immediately after an extreme event (Cutter, 1993). Estimated distance serves as a heuristic anchor for judging risks (Lindell & Earle, 1983), impacting our perception of hazards (Cutter, 1993).
- e. Tangible effect: For example, public perception of air pollution is influenced by tangible or observable features such as smoke, dirt, warning signs about chemical facilities, and the increased proportion of population who worry about or are aware of air pollution (Liu, 1996).

#### **2.4. Environmental Hazards and Housing Price**

A body of research conducted since the late 1960s has addressed the influences of environmental amenities and disamenities on property values. A great deal of research examined the hypothesis that environmental hazards are capitalized negatively into property values, but the status of this hypothesis remains inconclusive and controversial.

Tobin and Montz (1995), in a study of four communities in California and Illinois, reported that flood risk contributed to the reduction of property values. This finding is consistent with data collected by Shilling et al. (1985) in Baton Rouge, Louisiana, by Damianos and Shabman (1976) in three Virginia communities, by Donnelly (1989) in La Crosse, Wisconsin, and by Shultz and Fridgen (2001) in Fargo, North Dakota and Moorhead, Minnesota. Additionally, Brookshire et al. (1985) reported a statistically significant negative relationship between property values and earthquake risk. Finally, Beron et al. (1997) compared housing price before and after the Loma Prieta Earthquake and found that housing prices in affected areas declined after the earthquake.

However, Babcock and Mitchell (1980) reported that in a small community near Toronto, there were no statistically significant effects of estimated and perceived flood risk on property values. This finding is supported by several other empirical studies that found no relationship between home values and flood risk (Muckeston, 1983; Schaefer, 1990; Zimmerman, 1979).

Regarding environmental pollution, Nelson (1978) and Harrison, and Rubinfeld (1978) demonstrated that property values would contain the marginal value of clean air,

while Leggett and Bockstael (2000) showed a statistically significant effect of water quality on property values around the Chesapeake Bay. With regard to technological hazards, Folland and Hough (1991) addressed the issue of noxious facilities in an analysis of agricultural land markets in 500 counties in the U.S., finding that the prices of agricultural land in the vicinity of noxious facilities were significantly lower than for comparable land elsewhere. Clark and Neives (1994) also concluded that land rent was lower in regions with nuclear power plants. Consistent with this result, a study of the Dallas housing market showed that property values close to a lead smelter increased after the plant was closed and cleaned up (Dale et al., 1999). As well, Gawande and Jenkins-Smith (2001) found that property values along spent nuclear waste shipment routes in South Carolina were diminished due to the perceived risks from highly publicized shipments of used-up nuclear fuel to a storage site. McClelland et al. (1990), and McCluskey and Rausser (2001) also found a negative relationship between housing prices and proximity to noxious facilities.

Contrary to these findings, Gamble et al. (1978) found selling prices were not related to potential risk of the Three Mile Island (TMI) nuclear plant. Also, Gamble and Downing (1982), and Nelson (1981) found that the TMI accident created no statistically noteworthy difference in housing sale prices. Finally, Metz and Clark (1997), who studied two nuclear power facilities in California, asserted that there was no evidence to show that nuclear power plant risks influenced the value of properties located around the plants.

## **2.5. Environmental Risk Perceptions and Housing Prices**

Despite much research on environmental hazards, relatively little research has been conducted on the relationship between risk perceptions and housing prices (Babcock & Mitchell, 1980). A fundamental hypothesis in house price research is that perceived risk leads to lower bids on houses at risk from natural and technological hazards, compared to houses located elsewhere, and that people act on these perceptions in negotiating housing prices.

Prior research has examined whether prospective homeowners' risk perceptions are related to race (Vaughan & Nordenstam, 1991), gender (Greenberg & Schneider, 1995; Lindell & Perry, 2000), occupation (Lamson, 1983), age (Hodge et al., 1979), hazard experience (Lindell & Prater, 2000; Burton, et al., 1978; Perry & Lindell, 1990; Burn, 1999), hazard-related information (Montz 1993; Mileti & Darlington, 1995), social and cultural factors (Slovic, 1987), material wealth (Laska, 1990) and personality traits (White, 1974; Wilson, 1990). Kunreuther et al. (1978) and Palm et al. (1990) concluded that insurance purchase was significantly related to public perceptions of the probability of an earthquake and expected property damage from such an earthquake. White (1974) found that the magnitude and frequency of flooding, personal experience with past floods, and personality characteristics were associated with people's risk perceptions. The general conclusion of this research is that if prospective home purchasers' perceived risk of a specific hazard in a community is salient, they will offer less for properties vulnerable to hazards in order to reduce any potential future loss. As for chemical risk, areas in proximity to hazardous facilities, such as nuclear power plants,

landfills, incinerators, brown fields, and other Locally Unwanted Land Uses (LULUs) have direct and long-term adverse effects including health problems (Adeola, 1995; Novotny, 1998) and community disruption (Brown & Mikkelsen, 1989; Maser & Solomion, 1990). This will also cause the value of property located around such dangerous facilities to decrease. In fact, in a survey of residents in communities hosting a variety of LULUs - including abandoned or active land fills, incinerators, and petrochemical processing facilities - Adeola (2000) found that residents living in communities listed in the Environmental Protection Agency's National Priority List (NPL) felt more concerned about environmental problems than did residents of non-NPL communities. He also showed that the NPL residents felt more concerned not only about their health due to chemical risk, but also about property devaluation due to contamination and stigma.

Conversely, some researchers have asserted that there are many reasons why people are apt to underrate or even ignore the risk of environmental hazards. First, people often do not have enough hazard-related knowledge and information to increase their level of perceived risk (Covello, 1983). Several studies reported that the majority of the flood risk area residents believed the area where they live was a nice residential area that was not at risk of flooding (White, 1974; Smith & Tobin, 1979). Surprisingly, Turner et al. (1979) documented that when asked to list the three major issues facing Southern California, only two percent of the respondents listed earthquakes. These findings show that a lack of hazard knowledge and information could lead people to fail to personalize risk. Second, people can feel either apathetic or optimistic about their risk



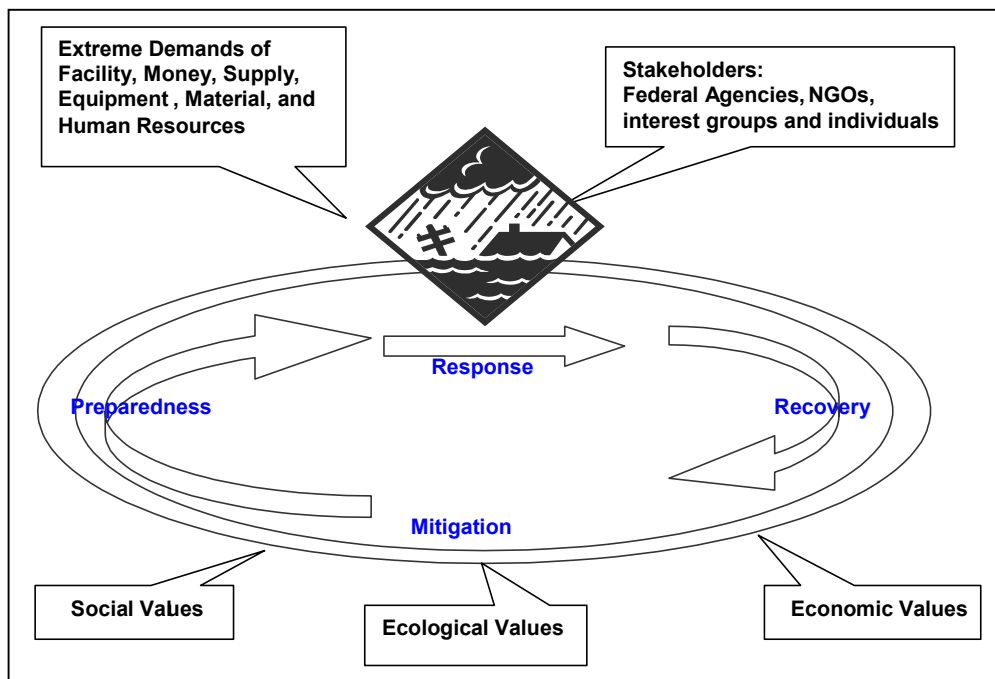
of death, injury, or property damage due to environmental hazards. Also, according to Lindell et al. (1997), people tend to act as if a very low probability of an extreme event is zero, simply believing that it will not harm them or their property. Moreover, Mileti and Darlington (1995), and Lindell and Prater (2000) found that risk perception was not significantly related to seismic hazard adjustments. Third, environmental risk is often ignored because people place a higher priority on dealing with daily issues of living (Drabek, 1986). Fourth, people tend to expect that they can be protected by a variety of structural mitigation measures and may overestimate the efficacy of community protection works (Parker & Harding, 1979). Fifth, people expect that they will be provided with disaster relief from governments and nonprofit organizations in case of disasters (Burby, 1998; Jackson, 1977). Finally, people often prefer to live in houses that are located near valleys, streams, rivers, and seas because these provide a scenic view, even though they are vulnerable to various natural hazards. Because of these factors, housing prices might not reflect marginal prices associated with risk perception.

## **2.6. Hazard Mitigation Actions and Housing Prices**

Burton et al. (1978) noted that the hazard vulnerability of a community to environmental hazards such as flooding and earthquake results from the interaction of three components: 1) the physical environment; 2) the human environment; and 3) the hazard mitigation measures conducted to reduce or prevent the impact of natural and technological disasters. According to Lindell and Perry (1992), hazard mitigation can be defined as the following:

*Hazard mitigation actions such as reducing the occupancy of vulnerable areas or strengthening structures are directed toward eliminating the causes of a disaster, reducing the likelihood of its occurrence, or limiting the magnitude of its impact if it does occur.*

Figure 2-6 shows where the mitigation stage belongs in the four phases of emergency management activities including preparedness, response, and disaster recovery. This conceptual model shows that hazard mitigation activities continue throughout the whole process of emergency management system (see Table 2-10) until another impact comes.



**Figure 2-6. Hazard mitigation within the cycle of emergency management**

Source: Schwab et al. (1998).

**Table 2-10. Four phases of emergency management and examples**

Phase	Definition	Illustrative Activities
Mitigation	Actions undertaken all year around to reduce the vulnerability of life and property to natural and technological hazards.	Hazard identification and vulnerability analysis Land use management Disaster insurance Building codes Structural mitigations Public education (Adjustment) Regulations of hazard-prone areas
Preparedness	Actions directed toward developing operational systems for effective and efficient disaster response.	Emergency management planning Warning systems Stockpiling food and medical supplies Training Public education (Self-help)
Response	Activities conducted to reduce disaster impacts from the time of the event until the time situation is stabilized.	Evacuation Protective actions Mobilization of emergency personnel and resources Search and rescue Emergency shelter Mass feeding Medical care Security within impact area Damage assessment and control
Recovery	Activities conducted to return lifeline services to normal condition (short-term recovery), and restore the community to its original condition after disaster (long-term recovery)	Temporary housing Clean-up, repair and reconstruction Redevelopment loans Legal assistance and liability assessment Victim counseling Community planning

Source: Lindell & Perry (1992), and Drabek (1991).

There are two main types of mitigation activities: structural and nonstructural mitigation. The potential human impact of hazards can be altered by modifying either the natural event system (structural mitigation) or the human use system (nonstructural mitigation) or both. For example, the probability of loss of life or property can be reduced by community protection works such as dams, by land use practices that control the number of people and the amount of property in the floodplain, and by building

construction practices that reduce the vulnerability of individual structures (Lindell and Perry, 1992). Table 2-11 shows one typology of the types and characteristics of hazard mitigation measures.

**Table 2-11. Hazard mitigation measures**

Type	Definitions And Examples
Structural Measure	<ul style="list-style-type: none"> <li>• Definition: Means modifying the natural event system.</li> <li>• Designed by engineers and managed or maintained by public works staff.</li> <li>• Examples:               <ul style="list-style-type: none"> <li>○ Storage reservoirs</li> <li>○ Detention basins</li> <li>○ Levees/floodwalls/seawalls</li> <li>○ Channel modifications</li> <li>○ Land treatment for increasing infiltration</li> <li>○ Emergency flood fighting including use of sandbags</li> <li>○ Storm water management including drains and storm sewers</li> </ul> </li> </ul>
Nonstructural Measure	<ol style="list-style-type: none"> <li>1. Land Use Management:           <ul style="list-style-type: none"> <li>• Definition: Means modifying the human use system as preventive activities</li> <li>• Administered by building, zoning, planning, and/or code enforcement officials.</li> <li>• Examples:               <ul style="list-style-type: none"> <li>○ Policies and plans for development in hazard prone areas</li> <li>○ Zoning and subdivision regulations</li> <li>○ Open space preservation</li> <li>○ Building code development and enforcement</li> <li>○ Relocation</li> <li>○ Acquisition</li> </ul> </li> </ul> </li> <li>2. Property protection:           <ul style="list-style-type: none"> <li>• Undertaken by property owners on a building-by-building or parcel basis.</li> <li>• Examples:               <ul style="list-style-type: none"> <li>○ Retrofitting and elevating structures</li> <li>○ Flood insurance</li> </ul> </li> </ul> </li> </ol>

**Table 2-11. (continued)**

Type	Definitions And Examples
Nonstructural Measure	<p>3. Natural resource protection:</p> <ul style="list-style-type: none"> <li>• Protect or restores the natural ecosystem and watersheds.</li> <li>• Implemented by parks, recreation, or conservation agencies.</li> <li>• Examples: <ul style="list-style-type: none"> <li>○ Wetlands protection</li> <li>○ Best management practices</li> <li>○ Erosion and sediment control</li> <li>○ Coastal barrier protection</li> </ul> </li> </ul> <hr/> <p>4. Public information</p> <ul style="list-style-type: none"> <li>• Inform residents and visitors in flood prone areas of the flood hazards as well as ways to protect people and property from them.</li> <li>• Implemented by a public information office.</li> <li>• Examples: <ul style="list-style-type: none"> <li>○ Hazard identification and vulnerability maps and data</li> <li>○ Library resources</li> <li>○ Outreach projects</li> <li>○ Technical assistance</li> <li>○ Real estate disclosure information</li> <li>○ Environmental education programs</li> </ul> </li> </ul>

Source: Wetmore & Jamieson (1999)

There have been a small number of research findings about the impact of collective hazard mitigation measures on property values. Soule and Vaughan (1973) examined the effect of the Lake Cumberland reservoir completion in Kentucky on housing prices. Their analysis demonstrated that housing prices were positively related to flood protection by the reservoir. They added that this property value increase was due to the previous decrease in property values caused by yearly flooding. Damianos and Shabman (1976) investigated the effects of a structural measure (dam), and a nonstructural measure (zoning) on residential property values in three communities in Virginia. They found that the area with structural adjustments experienced an increase in property values, but that there was no statistically significant relationship between

floodplain zoning and land values. In five counties in western Oregon, Muckleston (1983) conducted research hypothesizing that land values of property within regulated floodplains would be significantly lower than those of property not so regulated. This research tested the allegation of real estate and development interests that floodplain regulations play a major role in reducing property values. However, he found that there was no statistically significant difference in residential land values between the regulated and unregulated lots in the study areas. Shilling et al. (1985) showed that the sale prices of houses located in a flood risk area were higher than those of houses elsewhere because a certain portion of flood insurance costs was capitalized into the sale price of houses vulnerable to flood.

## **CHAPTER III**

### **THEORIES, MODELS, AND HYPOTHESES**

#### **3.1. Introduction**

This chapter describes theories and models applied to this research, and also develops research hypotheses that were derived from the literature review. More specifically, the first part of the chapter discusses the psychometric model, hedonic price model, and self-insurance theory. The second part states the research rationales, followed by the six research hypotheses. The last part introduces a conceptual model that identifies the attributes affecting housing prices directly and indirectly.

#### **3.2. Psychometric Model of Risk Perception**

Slovic (1987) defines public risk perception as the intuitive judgments people make in evaluating environmental risks. The psychometric paradigm of public risk perception studies uses an experimental approach and quantitative methods to create cognitive maps of public risk perception (Liu, 1996). The psychometric model maintains that public risk perception is a function of various risk attributes, such as voluntary and involuntary risk (Starr, 1969), new and old risk (Sjoberg, 2002), dread risk and common risk, and known and unknown risk (Slovic, 1987). As such, people's perceived risks are closely linked to the location of a hazard within the two dimensional space (Liu, 1996). Recent research has examined how risk perception varies across social, economic, and demographic groups (Slovic, 1992; Liu, 1996).

### **3.3. Hedonic Price Model**

Empirical studies of housing prices have attracted economists, real estate practitioners, geographers, planners, and policy makers in recent decades because a dynamic housing market is directly or indirectly linked to urban growth, reflecting transformation of the urban landscape (Ding et al., 1999).

The hedonic price method was developed by Court (1939) and theoretically explicated by Rosen (1974) to estimate the values of the individual characteristics (called the hedonic prices) of a complex product whose components are not separately marketed (Donnelly, 1989). This model, at first, was utilized mainly to examine the prices of non-spatial composite goods, such as automobiles, tires, refrigerators, and personal computers (Griliches, 1971). Later, this model has been extensively used in house price research to value environmental characteristics such as water pollution (Harrison & Rubinfeld, 1978; Leggett & Bockstael, 2000), accessibility to parks and forests (Tvrainen & Miettinen, 2000; Tvrainen, 2001), and social infrastructure (Cummings et al., 1978). It also has been used to value the risk of natural and technological hazards including earthquakes (Brookshire et al., 1985; Tvrainen, 2001), floods (Donnelly, 1989; Holway & Burby, 1990; Folland & Hough, 1991), hazardous materials (McCluskey & Rausser, 2001; McClelland, Schulze & Hurd, 1990), and nuclear power plants, (Clark & Neives, 1994; Nelson, 1979). In general, the housing market is influenced by positive or negative externalities that increase or decrease home values, respectively (Ding et al., 2000). The hedonic price model is the market clearing function created by the interplay between bid functions of buyers and offer functions of



sellers (Rosen, 1974). According to Rosen (1974), the bid function reflects buyers' willingness to pay for an attribute of interest, subject to their income and tastes. The offer function reflects sellers' acceptable minimum unit prices for forsaking a bundle of housing attributes (Rosen, 1974; Shultz, 1993).

The model simply equates the observed property values to the housing attributes and reveals the marginal prices of the attributes (Can, 1990). In the context of the model, a house is treated as a heterogeneous good, defined by a bundle of attributes such as structure, locations, amenities, and disamenities. The formal relation between the property value and housing attributes can be written as follows (Can, 1990).

$$P(A) = P(A_1, A_2, A_3, \dots, A_i),$$

where  $P(A)$  is the observed value of the property and  $A = (A_1, A_2, A_3, \dots, A_i)$  is a bundle of housing attributes, with  $A_i$  measuring the amount of the  $i^{\text{th}}$  housing attribute. In other words, the property value is defined by a hedonic price function, which is a mathematical relationship between the housing prices and the quantities or qualities of attributes (Wallace, 1996). Hedonic prices are referred to as "the implicit prices of attributes and are revealed to economic agents from observed prices of houses and the specific amounts of characteristics associated with them" (Rosen, 1974, p.34). Basically, the marginal implicit price represents consumers' willingness to pay the market premium to consume one more level of an attribute.

From the equation above, the marginal implicit price (MIP) of any attribute is deduced as follows:

$$MIP (A_i) = \Delta P / \Delta A,$$

where  $P$  is implicit price function and  $A_i$  is  $i^{\text{th}}$  amenity being valued. The marginal implicit price estimates are usually obtained by using the mean values of the quantity of the attribute, the quantities of other attributes, and the property value (Shultz, 1993). By estimating and comparing the marginal implicit prices of different housing attributes, we will be able to determine the effect of each environmental amenity and disamenity.

For any housing attribute, the hedonic marginal price for an attribute (e.g., air quality) is an estimate of both the marginal bid for the air quality attribute by the household purchasing all housing attributes and the marginal offer for the air quality attribute by the firm (or seller) producing all of the attributes (Bartik, 1987). Therefore, the marginal implicit price of a housing attribute, such as proximity to a lake or a floodplain, represents an economic benefit or loss for a small change in that attribute (Freeman, 1993). In practice, the implicit prices for different house attributes can be estimated by regressing the selling price of a house onto the attributes (Rosen, 1974). Thus, the hedonic price model can be specifically defined as follows:

$$P = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + e,$$

where  $P$  is a vector of observed property values,  $\alpha$  is the regression intercept, the  $\beta_i$  are regression coefficients,  $X_1$  is a vector of structural attributes,  $X_2$  is a vector of

neighborhood attributes,  $X_3$  is a vector of locational attributes, and  $e$  is a vector of random errors.

The functional forms most commonly utilized in the hedonic price model are linear, semi-log, and double log forms, but there are no theoretical guidelines that generally suggest a certain functional form for the price estimations (Orford, 1999). The semi-log functional form (i.e., taking the natural logarithm of the dependent variable) is recommended for three reasons (Wooldridge, 1999):

- The semi-log model usually reduces the likelihood of heteroskedasticity, which means that the variance of the unobservable error (conditional on the independent variable) is not homogeneous. For instance, strictly positive variables such as housing prices can lead to such problems as heteroskedasticity or skewedness. Taking the log of the dependent variable can reduce the problems that such conditional distributions can have.
- A model that has the dependent variable in logarithmic form narrows the range of the dependent variable by a significant amount, which makes estimates less sensitive to extreme problem points (or outliers) on the transformed variable.
- The semi-log model has the two interpretations for the coefficients. Namely, the coefficient of a housing attribute can be interpreted not only as its implicit or hedonic price, but also as its percent of the average house price (McCluskey & Rausser, 2001).

Thus, a model equation that can be used to measure the influences of the environmental risk and perceived risk on the house prices is

$$\text{Ln } V = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + e,$$

where Ln V = Natural log of market value of single family housing units

$\alpha$  = Regression intercept

$X_1$  = Structural attributes

$X_2$  = Neighborhood attributes

$X_3$  = Locational attributes

$X_4$  = City dummy variables

$X_5$  = Environmental hazard attributes (estimated and perceived)

$X_6$  = Hazard mitigation attributes

$e$  = Error term

### 3.4. Self-Insurance Theory

A basic premise in determining the relationship between housing prices and environmental hazards is that the hazards have negative impacts on house prices. This premise is based upon *Self-Insurance Theory* (Ehrlich & Becker, 1972). Common examples of self-insurance include installing a burglar alarm to hinder thieves from breaking into a house, wearing a helmet while bicycling, and installing lightning rods or sprinkler systems (Brookshire et al., 1985). Regarding housing, this theory maintains that people expend money on self-protection in lieu of market insurance to purchase their houses in less vulnerable areas so they avoid (or at least minimize) disaster losses, as long as they believe that the marginal benefits of the expenditures exceed the marginal costs. In this context, self-insurance and market insurance can be viewed as

complements or substitutes for each other. Beron, Murdoch, Thayer, and Vijverberg (1997) stipulate that because people are willing to offer more for a house with a lower probability of loss from environmental hazards (e.g., earthquakes), a hedonic price exists for the risk from those hazards. Conversely, if a house is situated in an area that is at risk from natural or technological hazards, people will become aware of the hazards and will consider potential external costs such as health risks and property damage. This, in turn, will result in the reduction of housing prices. With regard to multiple environmental hazards, proximity to hazard sources should be one of attributes affecting property values, just as other housing attributes such as structural and neighborhood amenities also affect property values. Moreover, self-insurance theory implies that people can invest in hazard mitigation activities including installing storm shutters and elevating houses to prevent future losses from natural or man-made disasters.

### **3.5. Research Rationales and Hypotheses**

#### Rationale 1

In deciding on their residences, households emphasize three attributes, given their budget and time constraints. These are space, accessibility, and environmental amenities (Fujita, 1989). Assuming these nonmarketed attributes to be normal goods, we can expect that more affluent households will purchase more positive externalities instead of avoiding more negative externalities (Liu, 1996). This implies that there will be a relationship between the spatial distribution of environmental risk and social/economic/demographic characteristics because there is empirical evidence that the

more affluent put a higher value on environmental amenities, whereas the poor choose their homes in the communities more vulnerable to environmental risk (Liu, 1996). In regard to chemical risk, Hamilton (1995) provides several arguments to explain why the level of exposure to the chemical risk may vary by ethnicity. Namely, owners of chemical facilities try to locate in communities with disadvantaged ethnic minorities, where compensation due to economic loss is unlikely, and where heterogeneous income and ethnic groups have different propensities for political participation. These arguments are supported by several studies showing that technological hazards such as toxic-waste sites and industrial pollution are more likely to be found in areas with high proportions of minority households (Bullard, 1983; Berry, 1977).

***Hypothesis 1:*** Scientifically estimated environmental risks of floods, hurricanes, and toxic chemical releases are related to household characteristics.

### Rationale 2

Some research shows that environmental risk perception is positively correlated with higher socioeconomic status (Taylor, 1989; Van Liere & Dunlap, 1980). In particular, previous studies maintained that higher public risk perception was found among females (Slovic, 1992; Savage, 1993), ethnic minorities (Adeola, 1994), less educated, poorer people (Pilisuk & Acredolo, 1988), younger people, and low-income groups (Savage, 1993).

***Hypothesis 2:*** Public risk perceptions of floods, hurricanes, and toxic chemical releases are related to household characteristics.

### Rationale 3

Slovic (1987) defines public risk perception as the intuitive judgments people make in evaluating environmental risks. Scientific assessments of the risks of natural and technological hazards are based upon scientifically estimated data, but these are generally based upon proximity to the hazard source. Thus, risk area residents' perceptions could be related to SEERs either because authorities have informed them of the risk directly, because peers (friends, relatives, neighbors and coworkers) have transmitted this information, because they have obtained SEERs through the mass media, or because they are basing their risk perception on the same environmental cues (proximity to rivers, bays, and chemical plants), as scientists use in computing SEERs (Drabek, 1986).

***Hypothesis 3:*** Scientifically estimated environmental risks of natural and technological hazards are positively related to public risk perceptions of floods, hurricanes, and toxic chemical releases.

### Rationale 4

The property value of housing units situated in areas at risk from natural and technological hazards will be less than those of housing units situated outside the risk areas, other things being equal, because the property value of a housing unit vulnerable to environmental hazard will be discounted by market mechanisms in which prospective buyers in aggregate offer lower prices in riskier areas. If this is true, perceived risks from various hazards will be negatively capitalized into residential housing prices.

***Hypothesis 4:*** Scientifically estimated environmental risks of floods, hurricanes, and toxic chemical releases are negatively related to housing prices.

#### Rationale 5

According to Ehrlich and Becker (1972), self-insuring means selecting a residence in a relatively safer area. Thus, individual buyers will offer to pay less for housing units that they consider to riskier, other things being equal (Brookshire et al., 1985).

***Hypothesis 5:*** Public risk perceptions of floods, hurricanes, and toxic chemical releases are negatively related to housing prices.

#### Rationale 6

If a housing unit has implemented hazard mitigation measures (e.g., being elevated and having installed storm shutters) or it is protected by collective hazard mitigation measures (e.g., protection works, local floodplain regulations, and building codes), its property value is expected to be higher than if such mitigation measures are absent.

***Hypothesis 6:*** Household hazard mitigation measures are positively related to housing prices.

The findings of this research can be summarized in a conceptual model that identifies the attributes affecting housing prices directly and indirectly (see Figure 3-1).



These factors include structural, neighborhood, location, submarkets (i.e., city), demographic characteristics, scientifically estimated environmental risk, perceived risk, and individual hazard mitigation measures. The variables representing structural, neighborhood, location, and submarkets are well known to be related to house prices and will be controlled by entering them first into the hedonic price regression analysis. The risks and risk perceptions from environmental hazard attributes, which are main focus areas in this research, are divided into technological hazards (chemical releases) and those from natural hazards (floods and hurricanes). It is hypothesized that household characteristics are related to scientifically estimated risk as well as perceived risk, which, in turn, are both negatively capitalized into housing prices.

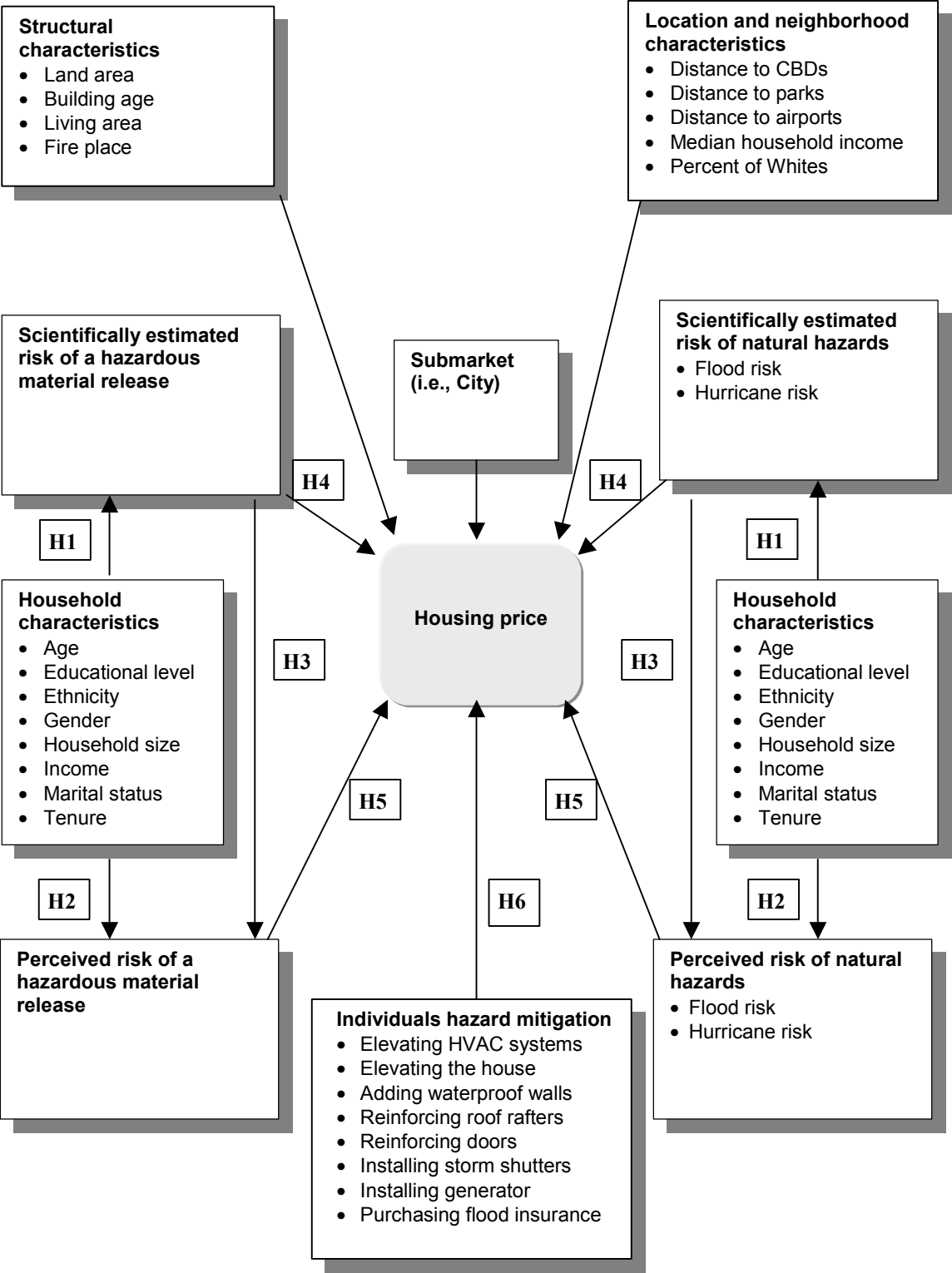


Figure 3-1. Housing price model based upon hypotheses

## **CHAPTER IV**

### **METHODS AND DATA**

#### **4.1. Introduction**

This chapter consists of several parts. The first part describes the study design including study procedure, study area, study population, and unit of analysis. The second part describes the research methods including survey method, geographic information systems (GIS) techniques, and statistical analyses. The chapter concludes with a description of study variables and measurements including household characteristics, environmental risk perceptions, hazard mitigation actions, environmental risk characteristics, housing prices, and structural, locational and neighborhood characteristics.

#### **4.2. Study Design**

##### ***4.2.1. Study Procedure***

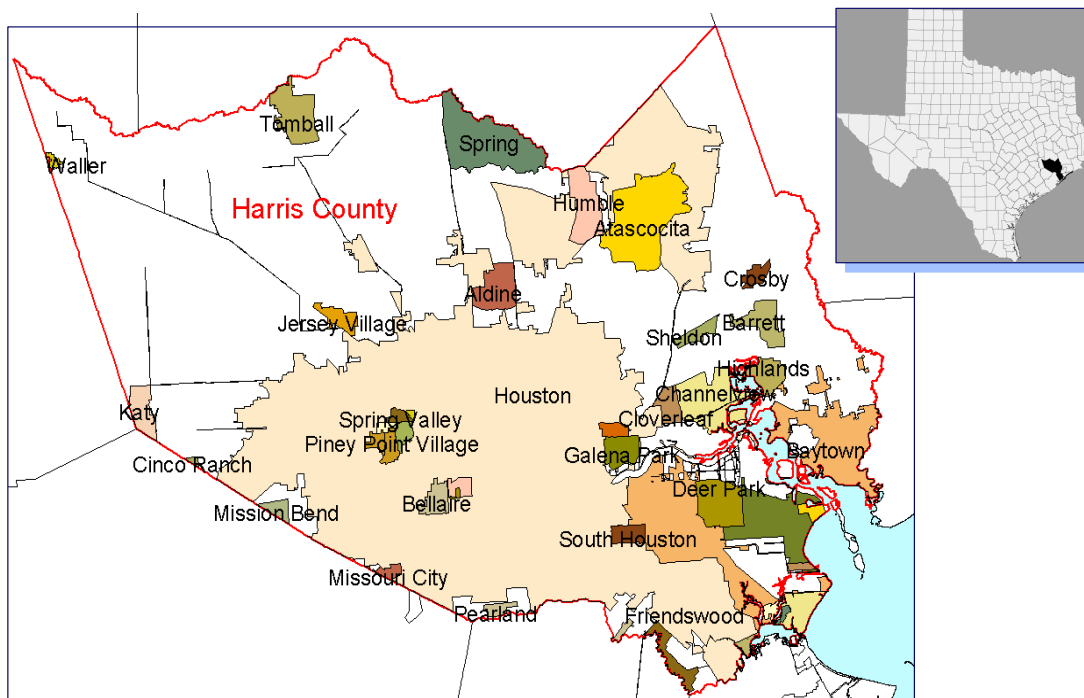
This research is a cross-sectional, current study because data on independent variables (environmental risk variables, and structural, locational and neighborhood attributes) were all collected at one time. The study consists of: 1) parcel data including structural characteristics and appraised values for single-family residences; 2) mail survey data on respondents' perceptions of environmental risks, their hazard mitigation measures, and their socio/economic/demographic characteristics; 3) census data on neighborhood characteristics; and 4) spatial data on three types of environmental risks

(i.e., flood, hurricane, and chemical risk), the locations of Central Business District (CBD), parks, and airports, and boundary maps of neighborhood, city, and county. The six hypotheses about the relationships among these variables were tested using correlations, Analysis of Variance tests (ANOVAs), Multivariate Analysis of Variance tests (MANOVAs), and hedonic regression analyses.

#### ***4.2.2. Study Area***

The study area is Harris County, Texas (see Figure 4-1). According to the 2000 census data, Harris County is the third largest county in the United States, with an area of 1,729 square miles, a population of 3,400,578 living in 1,298,130 housing units, and a median household income of \$39,037. Although urban, recreational, and industrial development continues to attract people, the county has experienced natural and technological disasters including hurricanes, floods, tornadoes, and chemical accidents. In addition, there is a continuing potential for such disasters to cause property damage and casualties. In June 2001, Tropical Storm Allison devastated major areas of the county and neighboring communities, claiming 22 lives, and damaging 20,000 homes and 5,000 other buildings at an estimated cost of \$20 billion. The impact of a great hurricane (e.g., Saffir-Simpson Category Four or Five) is even greater. Also, the hundreds of petrochemical manufacturing and distribution facilities create a significant risk of hazardous material releases from fixed-site facilities or in transportation. In fact, a recent headline in the Houston Chronicle said that Harris County was ranked first in the U.S. for the likelihood of chemical disasters. It should also be noted that the dynamics of

toxic releases would be changed considerably if such releases occurred as a secondary disaster, e.g., as a consequence of a flood, tornado, or hurricane. The proximity of many hazardous facilities to the coastline has raised concerns because of the susceptibility of these facilities to flooding resulting from a storm surge.



**Figure 4-1. Map of Harris County study area**

#### ***4.2.3. Study Population and Unit of Analysis***

The target population for this research consisted of single-family dwelling owners residing within Harris County in 2002. The unit of analysis used to test the hypothesis was the single-family housing unit and the household that owned it.

### **4.3. Research Methods**

The methods used to investigate the six hypotheses that were specified in the previous chapter included a mail survey, geographic information systems (GIS) modeling, and statistical analyses.

#### ***4.3.1. Survey Method and Respondents' Household Characteristics***

To randomly sample the required number of respondents and to identify the structural characteristics and the property values for single-family housing units, a list of countywide single-family residential property records (the sample frame of this study) was obtained from the Harris County Appraisal District. This data listed the following information: Parcel ID, address, owner name, land use code, appraised/market value, and other structural characteristics (e.g., year built, number of stories, living area, and the number of bedrooms and bathrooms).

Based upon the residential parcel records, stratified random sampling was employed to select 800 households. There were four stratification variables that were defined by the three environmental hazards (floods, hurricanes and chemical releases) and a no-risk area. Two hundred households were selected that were vulnerable to each hazard (see Table 4-1). In the cases selected for flood risk, the FEMA's flood insurance map for Harris County was used to randomly select 100 households in the 100-year flood plain and 100 households in the 500-year flood plain. In the cases selected for hurricane risk, 40 cases were selected from households located in each of the five hurricane risk areas. In the cases selected for chemical risk, 40 cases were randomly selected at increments of 0.5 mile from zero to 2.5 miles from the nearest hazardous

material facility. The remaining 200 households were randomly selected from an area comparatively free from these three types of hazards. Statistical power analysis showed that a sample size of 800 would have a 95% confidence interval with 0.035 sampling error.

The odds of some parcels being missing from the list of Harris County’s single-family residential units depended upon the completeness of the list. As long as the County Appraisal District had an exhaustive list of single-family residential units, there is little chance of a household being omitted. In reality, the appraisal roll might contain “clerical errors, multiple appraisal errors, or errors in the property's form or location described on the roll” (Section 25.25(c) of the Texas Tax Code). Also, there is some possibility of a parcel being duplicated if it appears twice in the appraisal roll. Additionally, some households might be duplicated in the sample if they own more than one single-family housing unit. Moreover, some households might have been included in the list even though the house was vacant, undeveloped, or demolished at the time of the survey. However, the number of duplicates, erroneous inclusions, and omissions is believed to be small.

**Table 4-1. Sample stratum and number of sample**

Stratum	Number Of Sample And Sub-Stratum	Total
Flood Risk	100: 100-year flood plain 100: 500-year flood plain	200
Hurricane Risk	40: Per each of the five hurricane risk areas	200
Chemical Risk	50: At increments of 0.5 mile between 0 and 2.5 miles	200
No Risk Area	200: Areas outside the three types of risks above	200

During September, October and November of 2002, a mail survey was conducted following Dillman's (1999) procedures. Because this mail survey research involved human subjects, the study received approval from the Institutional Review Board (IRB) that specified the information to be explained to the respondents about the research before the survey began (see Appendix 1 for the IRB approval). The initial mailing contained a cover letter (see Appendix 2), a questionnaire (see Appendix 3), and a pre-stamped return envelope. The initial packet was sent on September 15, 2002 to the 800 selected households. A reminder postcard was sent to each subject within one week. Those members of the sample who did not return a questionnaire within two weeks were sent a second packet. The third packet was sent to non-respondents on November 15, 2002. A total of 321 out of the sampled 800 single-family homeowners returned questionnaires for a gross response rate of 40.1%. However, one household was no longer at its original address, and two households turned out to live outside the study area. Because these three households were not replaced, this yielded an adjusted response rate of 40.4%.

The household characteristics (namely, social, economic, and demographic characteristics) of the respondents (single family residential owners) are shown in Table 4-2. By age, respondents were broken into five groups. Because the number of 20-29 year-old respondents was small, they were combined with the group of 30-39 year-olds to produce a group of 20s and 30s. Ages 40-49 accounted for 28.7% of the respondents, followed by 50-59 year-olds (25.5%). The majority of the respondents were over 40 years old (about 80%; arithmetic mean,  $M=51.6$  years). Educational attainment consisted



of five groups. The group with less than high school diplomas had the smallest number (3.7%), whereas 13.4% had high-school diplomas and 28.0% had some college. The group with college degrees had the highest number, accounting for 29.3% of the sample, whereas the group with graduate school degrees accounted for 24.3%. About 60% of the respondents were male, while about 36 % were female, and 4% of the respondents did not indicate their gender. A plurality (36.1%) of the respondents was in households composed of two persons, and 20.6% were in households composed of three persons. The most frequent category of marital status was 'Married' (73.2%) whereas the least frequent was 'Widowed' (5.6%). For yearly household income, the respondents were divided into seven groups. 62.9% had an income of more than \$50,000 whereas 7.8% of the participants had income of less than \$23,999. The distribution of ethnicity was White (66.6%), Hispanic (10.6%), Black (8.7%), Asian (5.0%), and Others (4.1%). Others included American Indians and persons who declined to report their ethnicity. About 47% lived at the current residence for more than ten years.

**Table 4-2. Household characteristics of the respondents**

Variables	Frequency	Percent	Variables	Frequency	Percent
<u>Age</u>			<u>Income</u>		
20s and 30s	52	16.2	Less than \$14,000	6	1.9
40s	92	28.7	\$14,000-\$23,999	19	5.9
50s	82	25.5	\$24,000-\$34,999	28	8.7
60s	79	24.6	\$35,000-\$49,999	24	7.5
Missing	16	5.0	\$50,000-\$70,000	57	17.8
			\$70,000-\$100,000	73	22.7
			Over \$100,000	72	22.4
<u>Education</u>			<u>Marital status</u>		
Less than high school	10	3.1	Missing	42	13.1
High school/ GED	43	13.4			
Some college	90	28.0	Married	235	73.2
College graduate	94	29.3	Single	21	6.5
Graduate degree	78	24.3	Divorced	43	13.4
Missing	6	1.9	Widowed	18	5.6
			Missing	4	1.2
<u>Gender</u>			<u>Ethnic identity</u>		
Male	193	60.1	Black	28	8.7
Female	114	35.5	White	212	66.0
Missing	14	4.4	Hispanic	34	10.6
<u>Household Size</u>			<u>Tenure</u>		
1	49	15.3	1-4 yrs	103	32.1
2	116	36.1	5-9 yrs	64	19.9
3	66	20.6	10-14yrs	42	13.1
4	49	15.3	15-19 yrs	31	9.7
Over 5	41	12.7	Over 20 yrs	77	24.0
			Missing	4	1.2

#### ***4.3.2. Use of GIS (Geographic Information System) Techniques***

The past twenty years have seen the steadily growing impact of information technology that is redefining the basic nature of information management. The adoption and implementation of GIS (Geographic Information Systems) is one type of information technology now used in areas such as agriculture, forestry, business, environment, government, urban planning, transportation, and land and resource management. A GIS integrating five key components (hardware, software, data, people, and methods) can be defined as a computerized database containing spatially referenced data, as well as techniques to systematically capture, store, retrieve, manipulate, analyze, process, update, and display the data. GIS allows users to manage geographic data more efficiently and enhances the decision-making process for management purposes. ESRI (<http://www.gis.com/whatisgis/index.html>) explains GIS as follows:

*[GIS] is a computer-based tool for mapping and analyzing things that exist and events that happen on earth. GIS technology integrates common database operations such as query and statistical analysis with the unique visualization and geographic analysis benefits offered by maps. The major challenges we face in the world today--overpopulation, pollution, deforestation, natural disasters--have a critical geographic dimension.*

In this present research, GIS techniques were used to match housing units to spatial characteristics of hazard variables (such as flood and hurricane boundaries), neighborhood variables (such as median household income and ethnic composition in the census block group), and locational variables (such as airports, parks, and CBD). To

organize, manage, analyze, and display spatial information, variables such as locational characteristics, neighborhood characteristics, and environmental risk were geo-referenced into a study area map.

GIS provides five specific benefits. First, it helps find spatial features with ease and speed. For instance, it can identify the area in which a sampled housing unit is located. Second, it can be used to map quantities such as the number of housing units in each risk area. Third, compared to manual calculation techniques, GIS can more precisely measure the distance between one point (i.e., a particular house) and another (i.e., a chemical plant). Fourth, GIS can be used to create a density map showing such characteristics as the percentage of white population or crime rate in a neighborhood. In addition to these benefits, GIS can be used to produce maps that display spatial distributions of hedonic housing prices as well as other analysis maps for visual effects.

All GIS data were geo-referenced with the Texas Statewide Mapping System; Lambert Conformal Conic for the projection, North American Datum (NAD) 1927 for the datum, and feet for the unit of measure.

#### ***4.3.3. Statistical Analyses***

Statistical analyses employed include correlation tests, ANOVA tests, MANOVA tests, and hedonic price regression analyses. Correlational analyses were implemented to empirically test relationships of household characteristics with scientifically estimated environmental risk (SEER) and perceived risk, as well as the relationship between SEER and individuals' perceived risk. ANOVA tests were

performed to determine whether there would be any difference in means among household characteristic groups (such as age, ethnicity, educational level, gender, and income) and different levels of environmental risk. MANOVA tests were performed to determine whether there would be any difference in means over perceived risk among groups with different household characteristics and levels of each of SEERs. Lastly, hedonic price regression analysis was used to estimate the implicit price for each of the environmental risks and household hazard mitigation measures.

#### **4.4. Variables and Measurement**

##### ***4.4.1. Household Characteristics, Environmental Risk Perception and Hazard***

###### ***Mitigation Actions***

The mail survey data included self-reports of single-family residential owners' perceived risks, hazard mitigation activities, and social, economic, and demographic features (see Appendix 3 for the survey instrument). As shown in Table 4-3, respondents were asked to rate their level of concern about the likelihood of three types of consequences (i.e., "Major damage to your home", "Injury to you or members of your household", and "Health problems to you or members of your household") for each type of hazard within the next 10 years. The response scales for risk perception were anchored by "Not at all likely" (=1) and "Almost a certainty" (=5).

**Table 4-3. Concept, variable, and operational measure of risk perception**

Concept	Variables	Operational Measures
Perceived Natural/ Technological Risk	Perceived flood risk	Rated concern about property damage to home
		Rated concern about injury to family
		Rated concern about health problems to family
	Perceived hurricane risk	Rated concern about property damage to home
		Rated concern about injury to family
		Rated concern about health problems to family
	Perceived chemical risk	Rated concern about property damage to home
		Rated concern about injury to family
		Rated concern about health problems to family

The response categories for the hazard mitigation activities were “No” (=0) and “Yes” (=1). The questionnaire included a list of hazard mitigation activities such as ‘raising heating, ventilating and cooling (HVAC) equipment above flood level’, ‘raising fuel tanks above flood level’, ‘raising electrical system components above flood level’, ‘raising my house above flood level’, ‘adding waterproof veneer to exterior walls’, ‘installing storm shutters’, ‘reinforcing doors to the house and garage’, ‘buying an electric generator’, and ‘purchasing flood insurance’. For social, economic, and demographic features, the questionnaire included age, gender, tenure at the present home, ethnic identity, marital status, household size, educational achievement, and income level.

All variables with the exception of duration of community tenure and age were measured as categorical variables. Ethnic identity was measured as five categorical variables, Black, White, Hispanic, Asian, and Other. Marital status was measured by “Married”, “Single”, “Divorced”, and “Widowed”. Educational attainment was measured by “Less than high school”, “High school diplomas”, “Some college education”, “College graduate”, and “Graduate degrees”. Yearly household income was

measured by “Less than \$14,000”, “\$14,000-\$24,999”, “\$24,000-\$34,999”, “\$35,000-\$49,999”, “\$50,000-\$69,999”, “\$70,000-\$100,000”, and “over \$100,000”. Finally, household size was measured as the number of people in each of four categories: “Under 6 years old”, “Between 6 and 18 years old”, “Between 19 and 64 years old”, and “65 years old and over”.

#### ***4.4.2. Environmental Risk Variables***

GIS techniques were used to delineate the spatial distribution of risk from flood, hurricane, and hazardous material facilities, and then to overlay each of the risk maps onto the parcel map that contained the locations of sampled housing units. Table 4-4 describes the variables, their concepts, and the operational measures for environmental risk of floods, hurricanes, and hazardous material releases.

**Table 4-4. Concept, variable, and operational measure of environmental risk**

Concept	Variables	Operational Measures
Natural/ Technological Risk	Scientifically estimated flood risk	Each floodplain zone is rated by the probability of flood occurrence. The 100-YFP zone is rated with the highest value of “5”, and the 500-YFP zone rated with the second lowest value of “1” while the zone without the flood risk is rated with the lowest value of “0”
	Scientifically estimated hurricane risk	Five zones of hurricane risk areas and one zone of non-risk area are used, and displayed on top of the map of the respondents’ houses to assign each of the housing units to the relevant value with the highest rating of “5” and the lowest rating of “0”, depending upon the risk zone
	Scientifically estimated chemical risk	Distance between house and its nearest Toxic Release Inventory (TRI) site

Flood risk was assessed using the Federal Emergency Management Agency's (FEMA) Flood Insurance Rate Map (FIRM) for year 1996 in Harris County. This map identified areas most susceptible to flooding, which correspond to the 100- and 500-year flood plains. The 100-year flood plain (YFP) is the area that has an expected recurrence interval of 100 years, whereas the 500-YFP has an expected recurrence interval of 500 years. Flood risk areas were overlapped with the parcel map of the survey respondents' housing units to determine the level of flood risk at the housing unit level (see Figures 4-2 and 4-3). The 100-YFP areas were given an index of "5" since they were the most susceptible to flooding, while the 500-YFP areas were indexed as "1" since they are less susceptible to flood damage. The areas outside the 500-YFP were indexed "0".

To identify the hurricane risk areas, the hurricane risk area boundary map was used that was developed at the Hazard Reduction & Recovery Center at Texas A&M University for the Texas Division of Emergency Management.



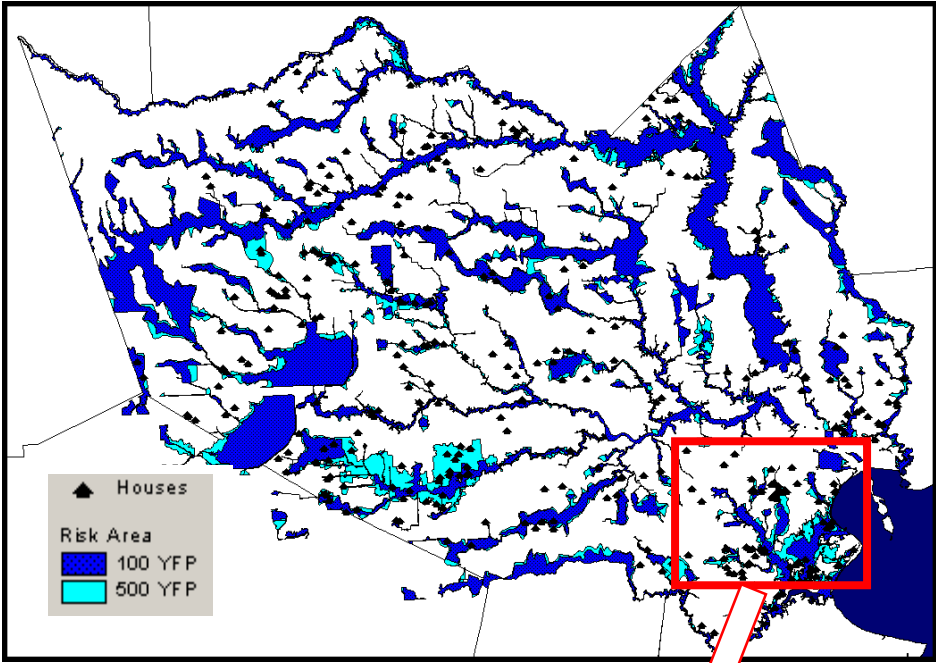


Figure 4-2. Map of flood risk

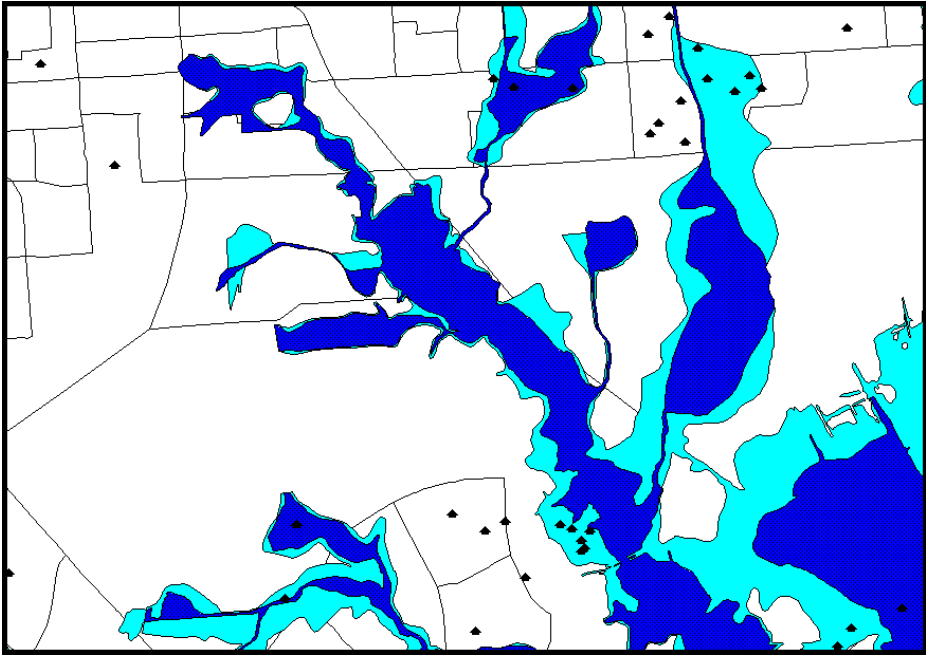


Figure 4-3. Inset map of flood risk

Using the Saffir/Simpson scale (see Table 2-5), this map divides hurricane risk areas into five categories that correspond to a hurricane's intensity. Specifically, hurricane risk areas were estimated using a computer program, called SLOSH (Sea, Lake, and Overland Surges from Hurricanes) to define risk areas from storm surge and the Inland Wind Decay Model to define risk areas from hurricane-driven wind (Lindell et al., 2001). The most susceptible areas are those that lie along the shoreline, at low elevations, or close to the waterfront.

Thus, populations living in hurricane Risk Area 1 would be most vulnerable to surge and wind damage in the event of all category hurricanes. As one moves farther inland, populations become less vulnerable to wind and surge action from a hurricane. With the exception of areas free from hurricane hazard, the area identified as Risk Area 5 is least subject to a hurricane and would only be affected by flooding and wind damage in the event of a Category 5 hurricane. The hurricane risk area map was superimposed upon the parcel map to decide each housing unit's hurricane risk level (see Figures 4-4 and 4-5). Hurricane Risk Area 1 was given a index of "5" since the area was the most susceptible to all categories of hurricanes, while hurricane Risk Area 5 was rated as "1" since the area was susceptible only to a Category 5 hurricane. Areas outside these hurricane categories were indexed as "0".

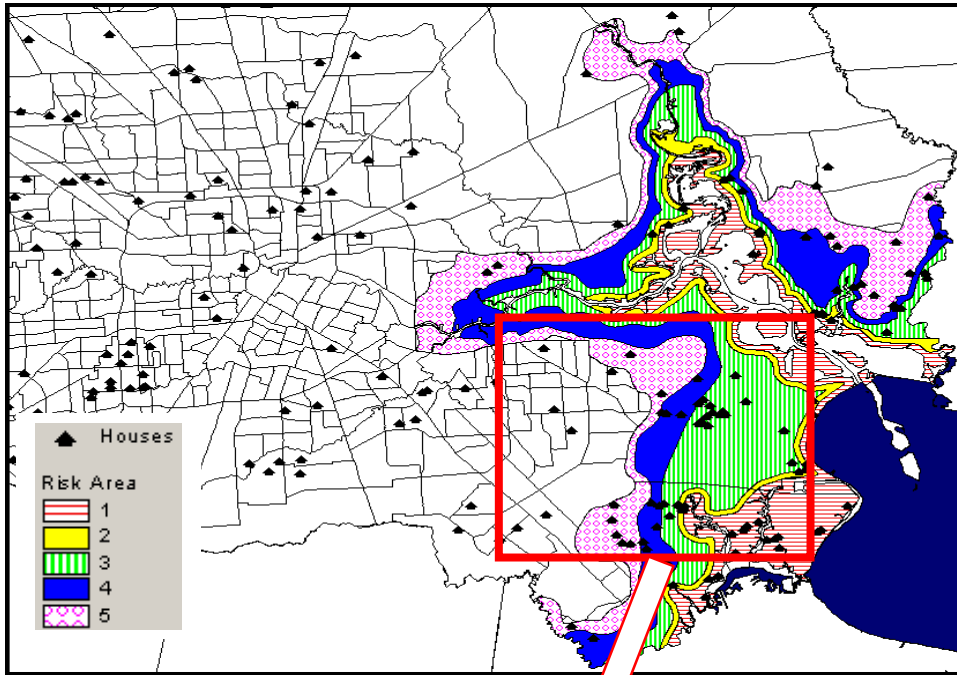


Figure 4-4. Map of hurricane risk

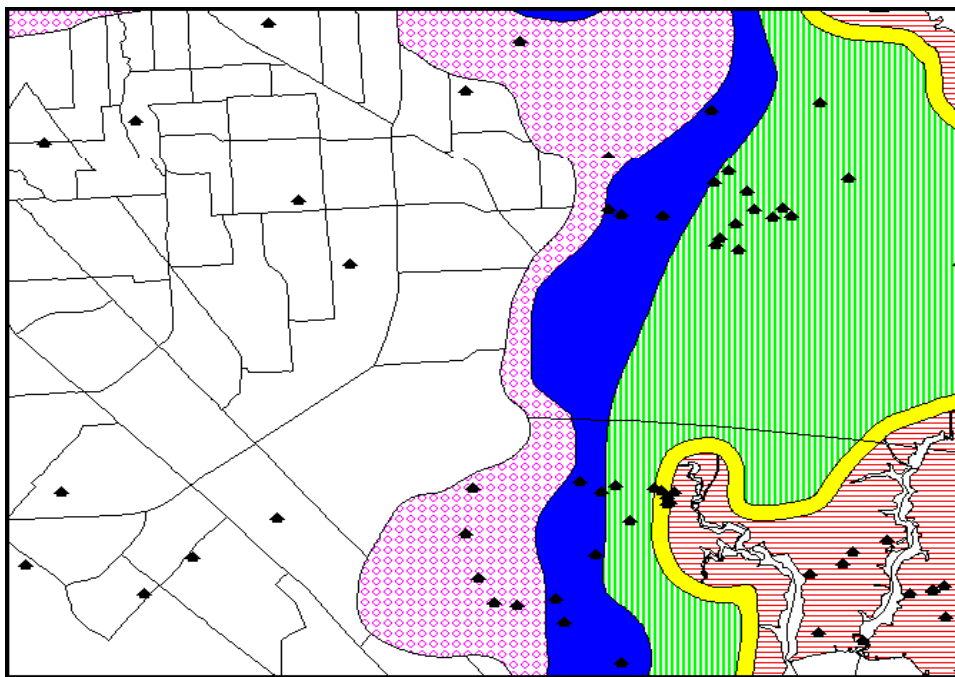


Figure 4-5. Inset map of hurricane risk

The measure of chemical risk was based upon Toxic Release Inventory (TRI) facility data for 2000. This data base was developed and published on the Internet by the U.S. Environmental Protection Agency (<http://www.epa.gov/tri/>). As of 2000, there were 2206 TRI sites in Harris County. The data base has information on the locations, types and quantities of nearly 650 chemicals being stored on-site, the types and amounts of toxic chemical annually being released into the environment, and other waste management activities from various industries that use, store, and produce hazardous chemicals or materials.

GIS made it possible to geocode the TRI sites by means of their latitudes and longitudes. The TRI location map was overlapped with the parcel map to measure the distance from each respondent housing unit to its nearest TRI site (see Figures 4-6 and 4-7).

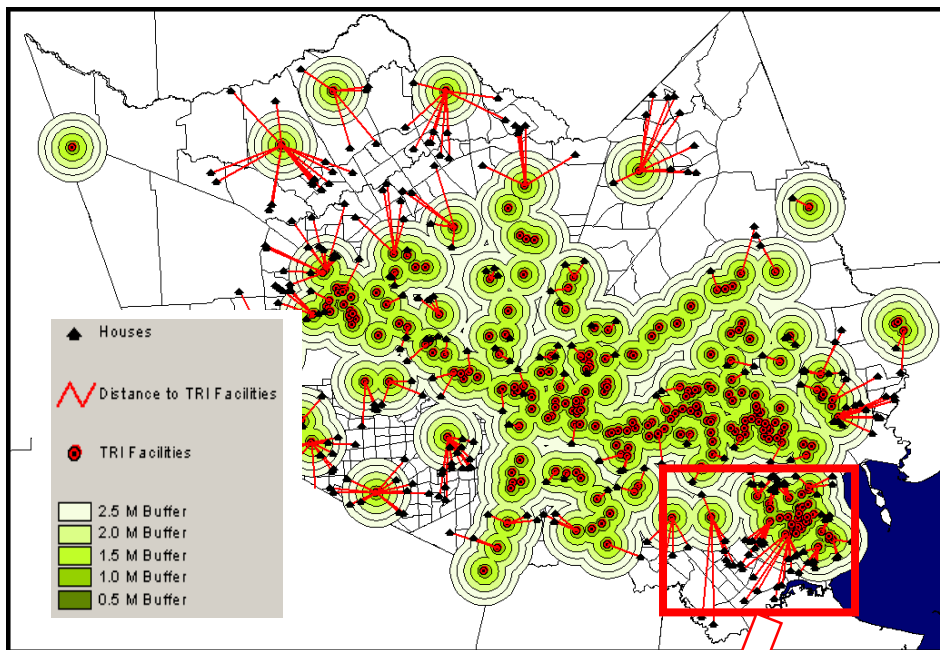


Figure 4-6. Map of chemical risk

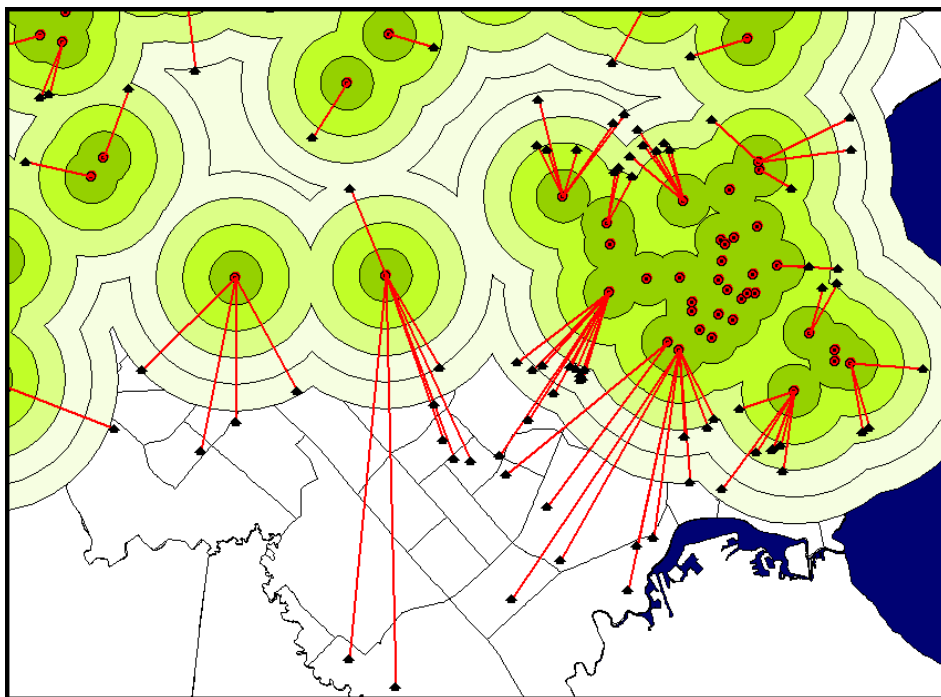


Figure 4-7. Inset map of chemical risk

#### ***4.4.3. Housing Price and Structural Characteristics***

The dependent variable in the hedonic price model is the market value of each single-family residential housing unit. Generally, housing prices can be obtained from three different secondary sources: self-reported home values by census block from the Census, sale prices from multiple listing service (MLS), and the appraised/market values from a county appraisal district (Shultz, 1993). First, the housing prices from the Census data are inexpensive, but they can be out of date and are estimated only at a highly aggregated level. Second, the sale prices from MLS are costly, but the data more accurately represent actual market values. Given the large number of households in this study, the cost of MLS data would be prohibitively expensive. Consequently, this research utilized the market values estimated from the Harris County Appraisal District (HCAD). Since the HCAD estimates the market value for each house every year, county-wide comprehensive data was obtained at a reasonable cost. The disadvantage of using these market values from the appraisal district is that the market values might not represent exact real sale prices.

Table 4-5 describes the variables, their concepts, and operational measures for housing prices and structural characteristics. The market value of a housing unit is estimated by county appraisers, based upon the actual sale prices of comparable neighboring houses sold recently. In this research, the terms housing prices and property values are used interchangeably with the term market values.

HCAD also provided data on each parcel's structural characteristics, including the lot area, living area, age of the house in years, and presence of a fireplace.

**Table 4-5. Concept, variable, and operational measure of property value and structural characteristics**

Concept	Variable	Operational Measure
Property values	Market value	The market values of single family housing units
Structural characteristics	Lot size	Square feet of lot
	Living area	Square feet of living area
	Age of house	Age of house since built
	Fireplace	Presence of a fireplace

#### ***4.4.4. Locational and Neighborhood Characteristics***

Table 4-6 describes the variables, their concepts, and operational measures for locational and neighborhood characteristics. The locational data on airports and parks were obtained from the GIS data clearing house operated by the Department of Public Infrastructure of Harris County. The map of airports included the locations of the two major airports within the county: William P. Hobby and Bush Intercontinental Airport. The map of parks included the locations of parks at all levels within the county. The location of Houston's Central Business District (CBD) was geocoded into the county boundary map using the address matching method. GIS analyses were implemented to measure direct distances between the survey respondents' houses and the nearest airport (see Figure 4-8). In the same way, direct distances were measured between those houses and CBD as well as between the houses and the nearest park (see Figures 4-9 and 4-10).

With regard to neighborhood characteristics, the census boundary data including block groups, cities, and county were derived from the TIGER (Topologically Integrated Geographic Encoding and Referencing) files produced by the U.S. Bureau of the Census. Household characteristics aggregated at the census block-group level were drawn from 2000 Summary Tape Files 3 developed by the U.S. Bureau of Census. In

this research, Census block group was treated as neighborhood. According to the Bureau of Census (2000), a block group is composed of several census blocks that generally contain between 600 and 3,000 people, with an optimum size of 1,500 people. The demographic characteristics included the percentage of white persons and median household income (see Figures 4-11 and 4-12).

**Table 4-6. Concept, variable, and operational measures for locational and neighborhood characteristics**

Concept	Variable	Operational Measure
Locational characteristics	Distance to CBD	Nearest distance between house and CBD
	Distance to airport	Nearest distance between house and airport
	Distance to park	Nearest distance between house and park
Neighborhood characteristics	Percentage of Whites	Percentage of Whites in neighborhood
	Household income	Median household income in neighborhood



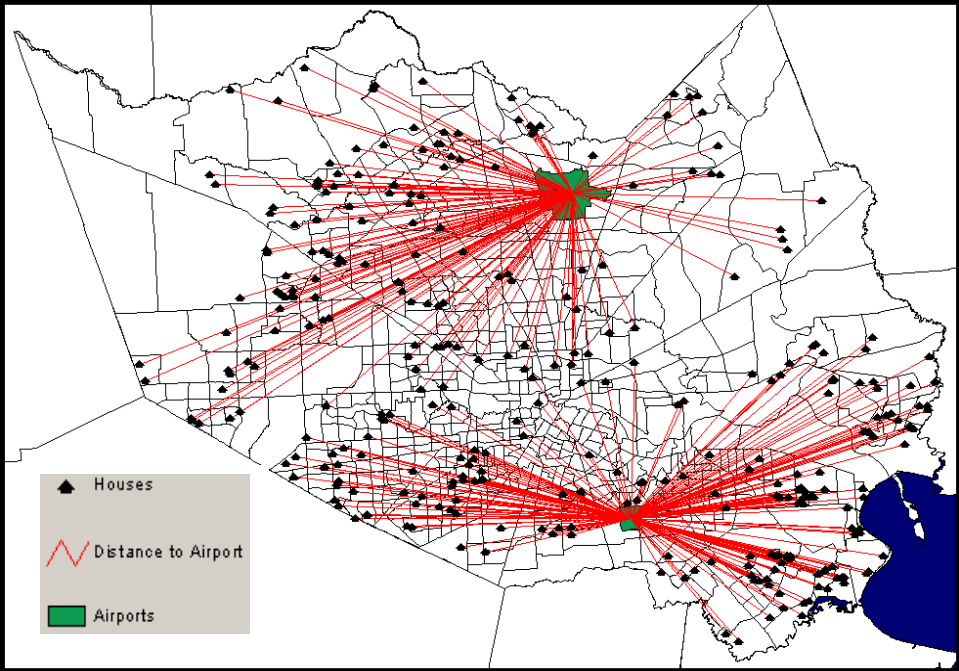


Figure 4-8. Distance from the houses to airport

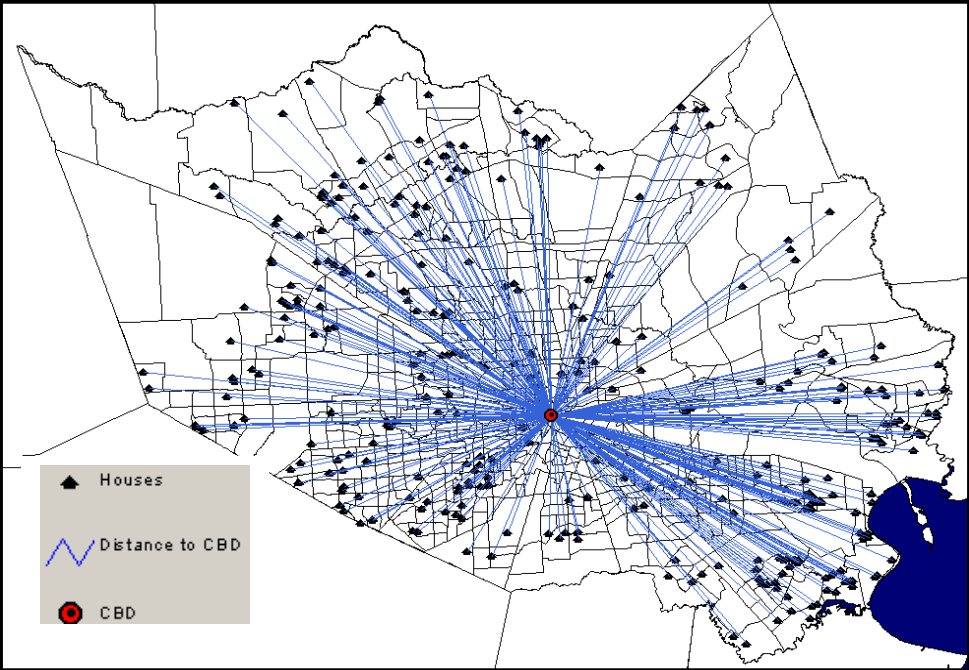


Figure 4-9. Distance from the houses to CBD

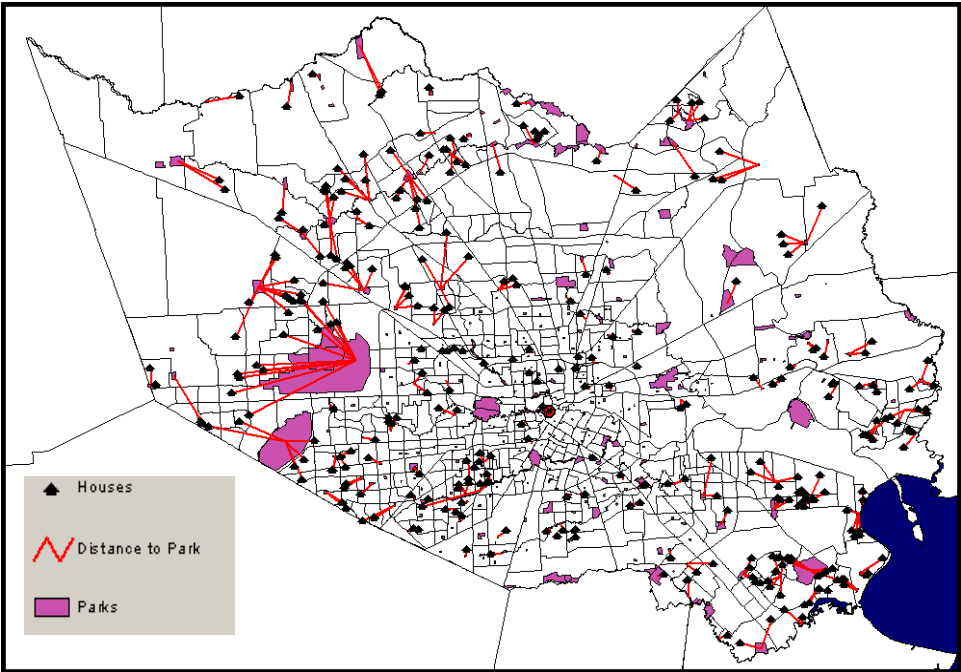


Figure 4-10. Distance from the houses to park

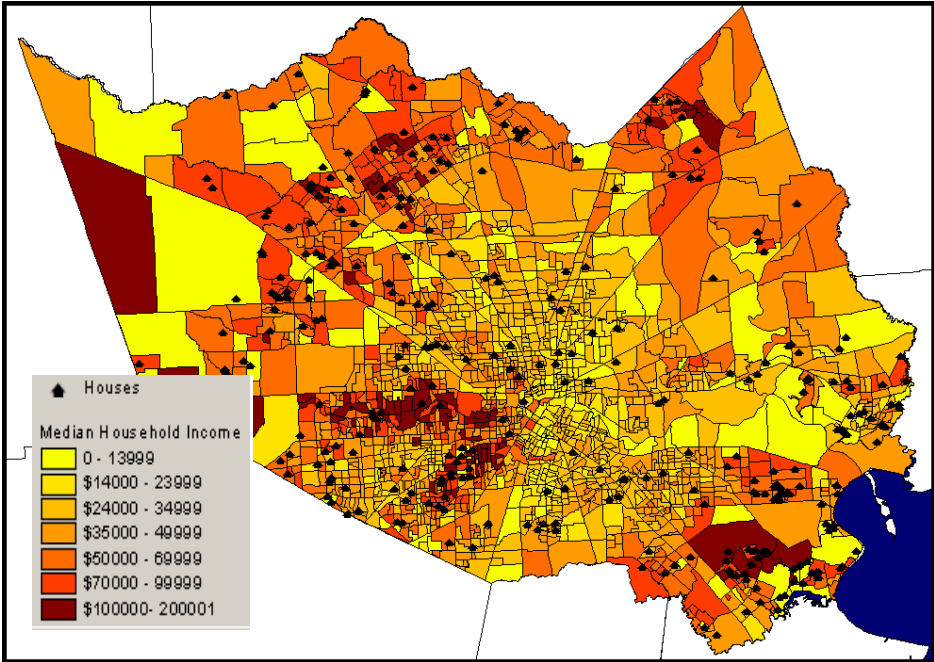


Figure 4-11. Median household income in the neighborhood (Census block group)

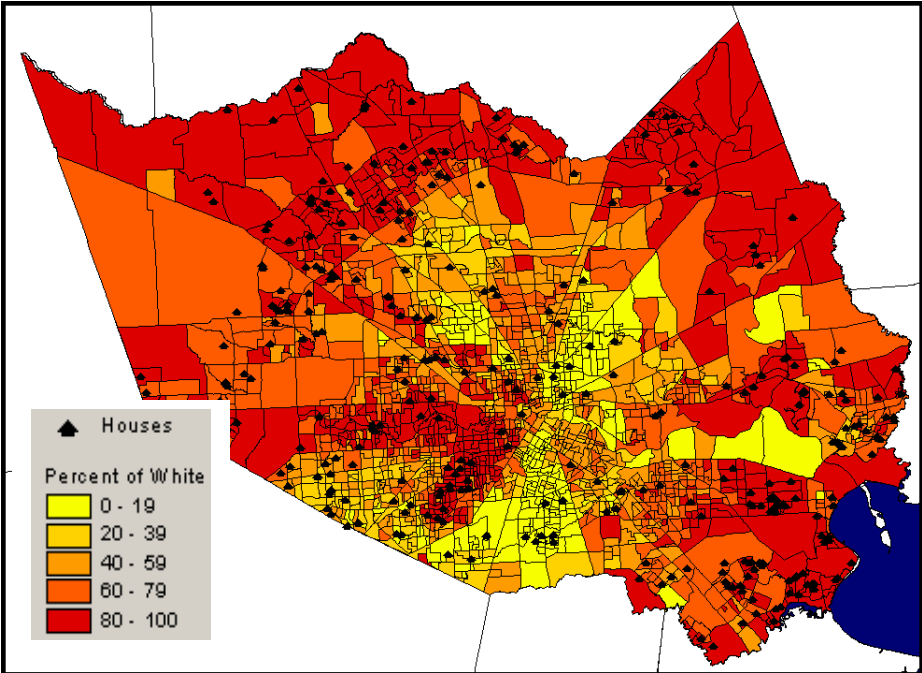


Figure 4-12. Percent of Whites in the neighborhood (Census block group)

**CHAPTER V**

**ANALYSES AND RESULTS:**

**HOUSEHOLD CHARACTERISTICS AND SCIENTIFICALLY**

**ESTIMATED ENVIRONMENTAL RISKS (SEERS)**

**5.1. Introduction**

This chapter presents analyses testing the first hypothesis that scientifically estimated environmental risks (SEERs) are related to household characteristics (such as social, economic, demographic characteristics). Its first part shows descriptive characteristics including the survey respondents and SEERs of floods, hurricanes, and hazardous material releases. Correlational analyses were conducted to examine which household characteristics are related to any SEERs. Analysis of Variance (ANOVA) tests were performed to investigate mean differences over SEERs among groups with different household characteristics.

**5.2. Descriptive Characteristics of SEERs**

As noted in the previous chapter, three types of environmental risks – floods, hurricanes, and hazardous materials – were scientifically measured by using GIS techniques. Meanwhile, respondents were asked to report their social, economic, and household characteristics in a survey questionnaire. Table 5-1 shows descriptive characteristics including the means, standard deviations, and minimum and maximum values of SEERs. Table 5-2 indicates the number and frequency for each level of SEERs.

For SEER of floods, respondents' homes were categorized into three groups: 100-year flood plain (YFP), 500-YFP, and the no-risk areas. Among single-family residents who returned their questionnaires, there were 227 houses (70.9 %) outside the two flood plain areas, 50 houses (15.6%) in 500-YFP areas, and 44 houses (13.8%) in 100-YFP areas. Overall, 29.4% were located in an area with an identifiable level of flood risk. The mean for flood risk was 0.84.

For SEER of hurricanes, the respondents' homes were divided into six groups, with the first group residing outside hurricane risk areas, and the remaining five groups residing in areas with an identifiable level of hurricane risk. There were 231 houses (72.2%) with no hurricane risk, and the remaining 90 houses (27.8%) were almost equally spread over different hurricane risk areas. The mean for hurricane risk was 0.83.

For SEER of hazardous materials, 122 houses (38.1%) were found to be comparatively safe, because they were located over 2.5 miles away from any TRI facilities. The mean for chemical risk was 2.26 (miles). The minimum and maximum distances from TRI facilities were 0.18 and 7.73, respectively.

**Table 5-1. Descriptive characteristics of SEERs**

Variable	M	SD	N	Min.	Max.
Flood risk	.84	1.698	321	0	5
Hurricane risk	.83	1.535	321	0	5
Chemical risk	2.26	1.41	321	0.18	7.73

**Table 5-2. Number and frequency for each level of SEERs**

Flood Risk			Hurricane Risk			Chemical Risk		
	n	%		n	%	Level	n	%
No-risk	227	70.9	No-risk	231	72.2	Over 2.5 mi. <sup>c</sup>	122	38.1
500 YFP <sup>a</sup>	50	15.6	5 <sup>b</sup>	18	5.6	2 to 2.49 mi.	32	10.0
100 YFP	44	13.8	4	18	5.6	1.5 to 1.99 mi.	49	15.3
			3	21	6.6	1 to 1.49 mi.	64	20.0
			2	14	4.4	0.5 to 0.99 mi.	33	10.3
			1	19	5.9	0 to 0.49 mi.	21	6.6
Total	321	100		321	100		321	100

<sup>a</sup>YFP is Year Flood Plain.

<sup>b</sup>Hurricane Risk Area 5 corresponds to the least vulnerable area except “No-Risk” area, whereas Hurricane Risk Area 1 corresponds to the most vulnerable area.

<sup>c</sup>Miles.

### 5.3. Correlational Analyses

Table 5-3 shows the correlations among social, economic, and demographic variables, and the three types of SEERs. Not surprisingly, AGE was negatively correlated with INCOME ( $r = -0.28$ ), whereas EDU was positively correlated with yearly household income ( $r = 0.42$ ). Additionally, AGE was positively correlated with TENURE ( $r = 0.62$ ), while HSIZE (household size) was negatively correlated with TENURE ( $r = 0.23$ ).

Contrary to Hypothesis 1, there were no statistically significant relationships between most of the household characteristics (AGE, SEX, HSIZE, STATUS, and TENURE) and scientifically estimated environmental risks of the two natural hazards (flood risk – FR and hurricane risk – HR). Only two household characteristics (EDU and INCOME) were positively correlated with HR ( $r = 0.13$  and  $r = 0.14$  each), but none were correlated with FR. These results indicate that the greater the yearly household income and educational attainment, the greater the hurricane risk.

Consistent with the hypothesis, scientifically estimated chemical risk (CR) was correlated with all of the household characteristics except for SEX. It should be noted that a negative relationship between any household characteristic (e.g., AGE) and CR means that the older they are, the greater the chemical risk, because chemical risk, (which was measured by distance), decreases with increments of distance. Specifically, AGE and TENURE were negatively correlated with chemical risk ( $r = -0.11$ , and  $r = -0.23$ , respectively), whereas EDU, HSIZE, INCOME, and STATUS were positively correlated with CR ( $r = 0.15$ ,  $r = 0.12$ ,  $r = 0.24$ , and  $r = 0.15$ , respectively). In sum, Hypothesis 1 was partially supported regarding the relationship between the risk of natural hazards and household characteristics, but was fully supported regarding the relationship between chemical risk and household characteristics.

**Table 5-3. Correlation coefficients of household characteristics with SEERs**

	M	SD	1	2	3	4	5	6	7	8	9	10
1. AGE	51.57	12.88	1.00									
2. EDU	3.59	1.10	-0.03	1.00								
3. SEX	0.63	0.48	0.04	0.11	1.00							
4. HSIZE	1.79	1.38	-0.30**	-0.06	0.06	1.00						
5. INCOME	5.20	1.65	-0.27**	0.42**	0.20**	0.12	1.00					
6. STATUS	0.74	0.44	-0.10	0.01	0.37**	0.38**	0.40**	1.00				
7. TENURE	153.5	139.1	0.62**	-0.13*	-0.10	-0.23**	-0.31**	-0.17**	1.00			
8. FR	0.84	1.70	0.07	-0.01	0.07	0.03	0.03	-0.07	0.10	1.00		
9. HR	0.83	1.54	0.00	0.13*	0.01	-0.09	0.14*	0.00	0.02	-0.02	1.00	
10. CR	2.26	1.41	-0.11*	0.15**	0.03	0.12*	0.24**	0.15**	-0.23**	-0.14*	-0.18**	1.00

1. age on last birthday; 2: educational attainment; 3: sex (males = 1); 4: household size;

5: yearly household income; 6: marital status (married = 1); 7: tenure; 8: flood risk; 9: hurricane risk; 10: chemical risk

\*.  $p < 0.05$ . \*\*.  $p < 0.01$ . N = 279 to 321

#### **5.4. ANOVA Tests**

ANOVA tests using a Type I error level of  $p = 0.05$  were performed to investigate mean differences in SEERs among different categories of age, educational attainment, yearly household income, and ethnicity. Another reason ANOVAs were conducted is that correlation can only detect linear relationships, but ANOVA can detect non-linearity.

##### ***5.4.1. Age and SEERs***

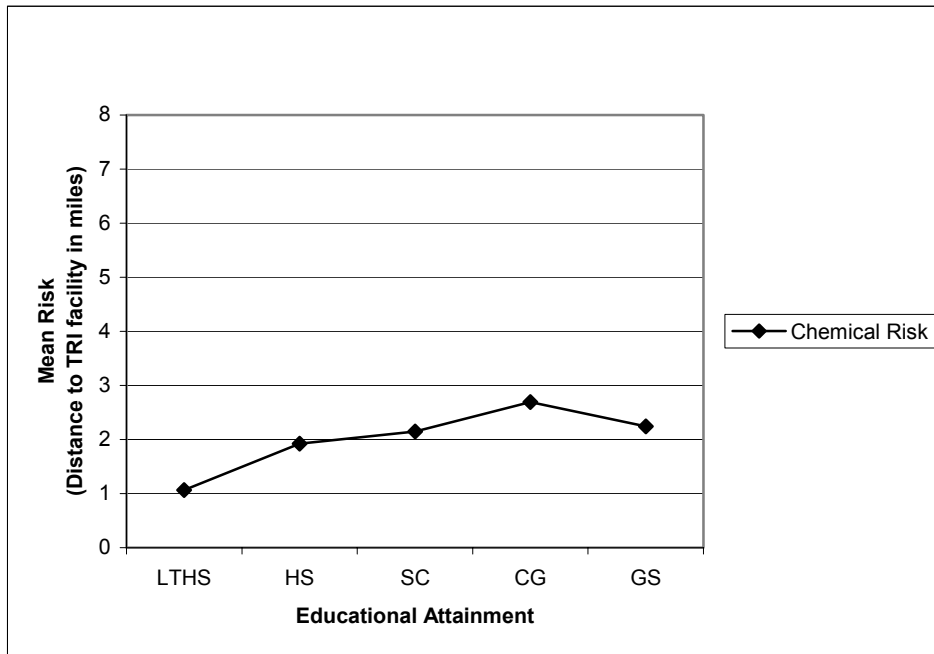
The participants were categorized into four age groups: 1) 20s to 30s; 2) 40s; 3) 50s; 4) over 60s. Appendix 4 indicates means, standard deviation, and number of cases for ANOVAs of SEERs by age group. It must be noted again that flood and hurricane risk were measured by a five-scale category, whereas the chemical risk was estimated by measuring the distance in miles from each house to its nearest TRI facility. Therefore, the higher the mean value of the flood risk and hurricane risk, the higher the risk of each, whereas the higher the mean distance from a chemical facility, the lower the chemical risk. The ANOVA results showed that the means for the three types of SEERs among the different age groups were not statistically significant (see Appendixes 5 and 6).



#### ***5.4.2. Educational Attainment and SEERs***

The respondents were categorized into five groups by educational attainment: 1) Less than high school education (LTHS); 2) High school diplomas (HS); 3) Some college education (SC); 4) College graduate degrees (CG); 5) Graduate school degrees (GS). Appendix 7 indicates that means, standard deviation, and number of cases for the five groups.

ANOVA test results showed the differences in mean ratings for both flood and hurricane risk among the groups with different educational attainments were not statistically significant, but the differences for CR were significant ( $F = 4.59$ ,  $p < 0.01$ , see Appendix 8). Figure 5-1 shows the mean levels of chemical risk across groups with different educational attainment. LTHS group and HS group resided, on average, within 1.06 miles and 1.92 miles of the nearest TRI facility each, whereas the group with CG resided farthest away from the nearest TRI facility (2.69 miles). Post test results by the means of Tukey's HSD showed that the mean of the group with CG was significantly different from the means of the LTHS group and the HS group at Mean Difference (MD = 1.63,  $p < 0.01$ , and MD = 0.77,  $p = 0.02$ , respectively (see Appendix 9).



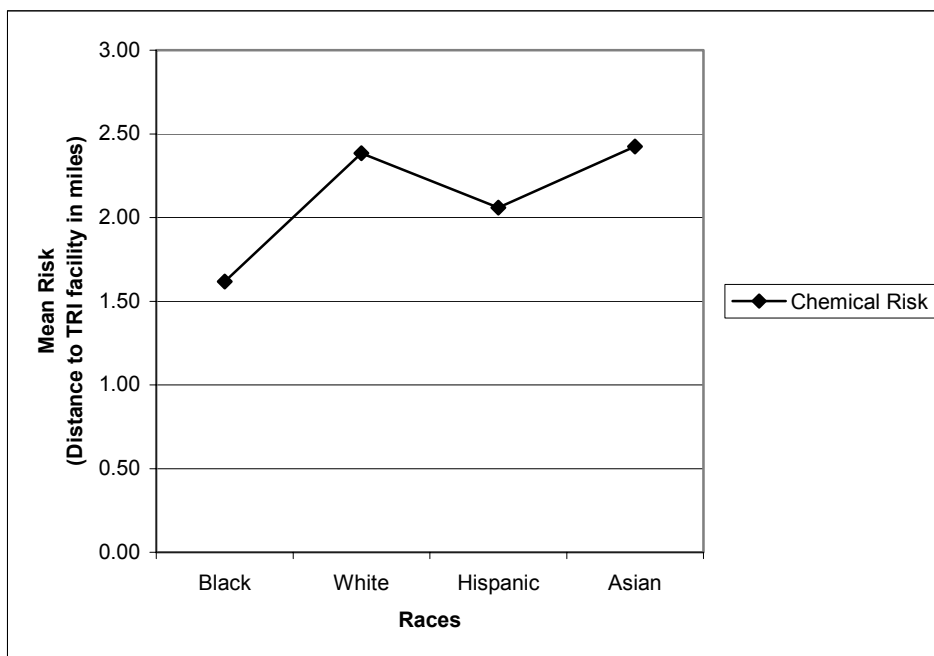
**Figure 5-1. Mean risk of chemical hazard by educational attainment**

#### ***5.4.3. Ethnicity and SEERs***

For ethnic identity, the respondents were categorized into five groups: Black, White, Hispanic, Asian, and Others. Appendix 10 shows the number of cases, means, standard deviations, and standard errors for the five ethnic groups. The Other group, which includes American Indians and persons who did not indicate their ethnic identity, was excluded from the analysis because of its heterogeneity and small size.

ANOVA tests showed that the means for CR were significant at  $F = 2.82$  and  $p < 0.05$  (see Appendix 11). Figure 5-2 shows the mean levels of chemical risk across the

ethnic groups. Blacks and Hispanics resided, on average, within 1.62 miles and 2.06 miles of the nearest TRI facility each, whereas Whites and Asians resided farther away from the nearest TRI facility (2.38 and 2.42 miles, respectively). More detailed multiple comparisons using Tukey's HSD revealed that Blacks were different from Whites (MD = -0.77,  $p < 0.05$ , see Appendix 12).



**Figure 5-2. Mean risk of chemical hazard by ethnicity**

#### ***5.4.4. Household Size and SEERs***

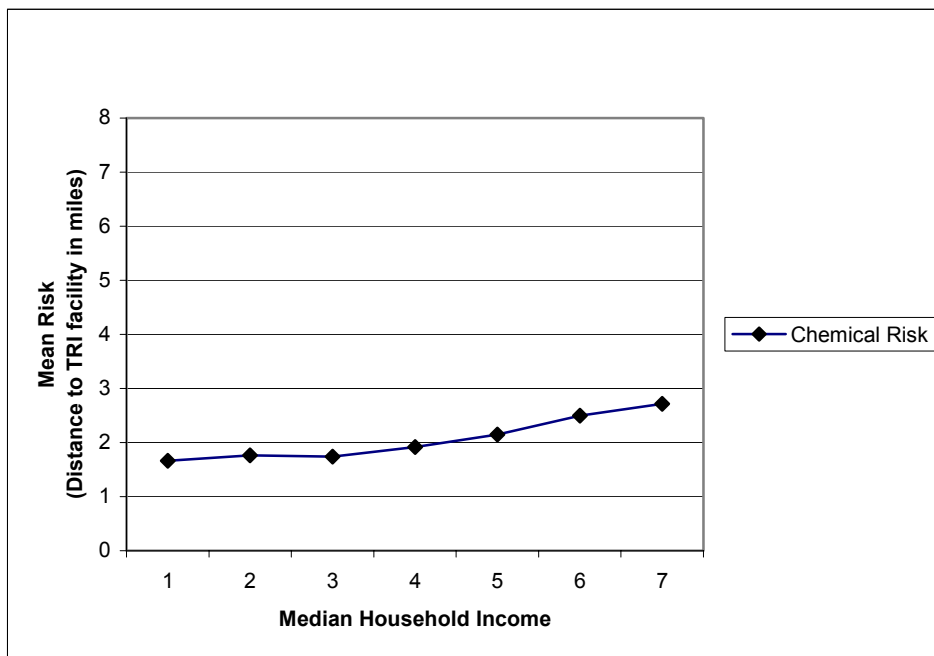
For household size, the respondents were categorized into five groups differentiated by the number of persons living together ranging from one person through over five persons, including the respondent. Appendix 13 indicates that means, standard deviation, and number of cases for the five groups. One-way ANOVA tests were performed to see if there were mean differences for each environmental risk among the different income groups. The results of these analyses showed that the groups had no statistically significant differences in their mean levels of the three types of SEERs (see Appendix 14).

#### ***5.4.5. Yearly Household Income and SEERs***

For yearly household income, the respondents were categorized into seven groups: 1) Less than \$14,000; 2) \$14,000-\$23,999; 3) \$24,000-\$34,999; 4) \$35,000-\$49,999; 5) \$50,000-\$69,999; 6) \$70,000-\$100,000; 7) Over \$100,000. Appendix 15 shows the number of cases, means, standard deviations, and standard errors for the seven groups with different yearly household incomes across SEERs of floods, hurricanes, and hazardous material releases.

The ANOVA table in Appendix 16 indicates that the means for FR and HR among the different income groups did not vary significantly by income group, but the means for CR were significant ( $F = 3.09$ ,  $p = 0.01$ ). Figure 5-3 shows mean values for CR gradually increased with income except for a slight reduction in the \$24,000-\$34,999 income category. The group with less than \$14,000 income resided, on average, at a

distance of 1.66 miles from any TRI facility (the highest risk of a hazardous material exposure). By contrast, the group of over \$100,000 income that resided at an average distance of 2.72 from any TRI facility (the lowest level of risk). More detailed multiple comparisons were conducted among the income groups over CR by the means of Tukey's HSD. The post test revealed that only the mean difference (MD) between the group with \$24,000-\$34,999 income and the group with over \$100,000 income for CR was significant at MD = -0.98 (p = 0.03, see Appendix 17).



**Figure 5-3. Mean risk of chemical hazard by yearly household income**

#### 5.4.6. Tenure and SEERs

The respondents were categorized into five groups, depending upon years during which they lived in their current residence: 1) 0-4.99 years; 2) 5-9.99 years; 3) 10-14.99 years; 4) 15-19.99 years; 5) Over 20 years. Appendix 18 displays the means, standard deviation, and number of cases for the five groups. The ANOVA table in Appendix 19 indicates that the means for FR and HR did not vary significantly with tenure in the neighborhood, but the means for CR were significant at  $F = 5.62$  and  $p < 0.01$ . Figure 5-4 shows mean values for CR gradually decreased with tenure. More detailed multiple comparisons using Tukey's HSD revealed that the group with tenure of over 20 years was different from both the group with tenure of 0-4.99 years ( $MD = -0.90$ ,  $p < 0.01$ ) and the group with tenure of 5-9.99 years ( $MD = -0.77$ ,  $p = 0.01$ , see Appendix 20).

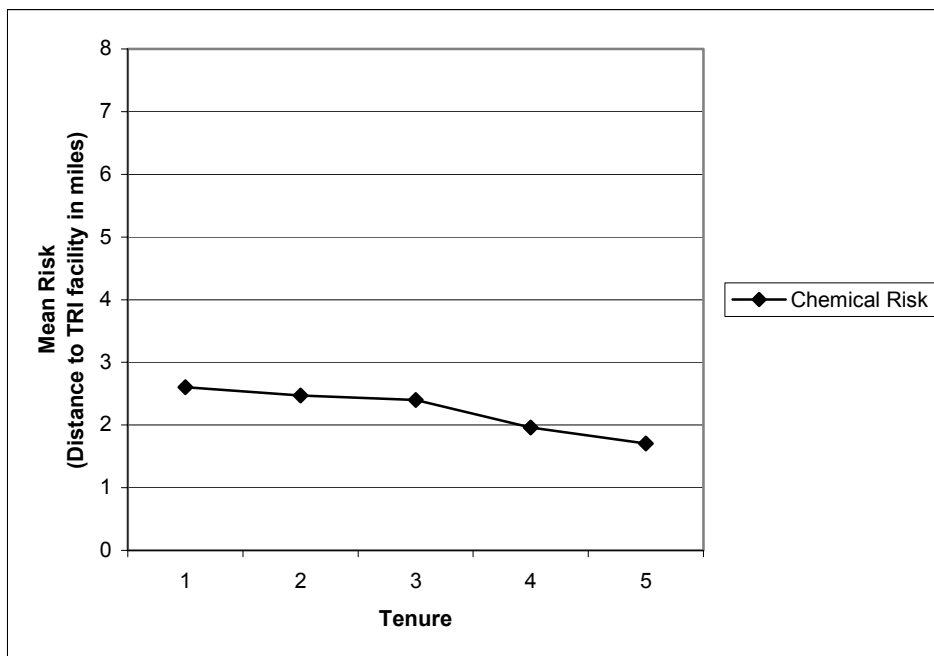


Figure 5-4. Mean risk of chemical hazard by tenure

## **CHAPTER VI**

### **ANALYSES AND RESULTS:**

### **HOUSEHOLD CHARACTERISTICS AND RISK PERCEPTIONS**

#### **6.1. Introduction**

This chapter presents analyses and findings which test the second hypothesis that perceived risks of a flood, hurricane, and hazardous material release are related to household characteristics. It starts by showing descriptive characteristics of the survey respondents' perceived risks. Correlation analyses were conducted to determine whether household characteristics were related to the respondents' perceived risks. Multivariate Analysis of Variance (MANOVA) tests were performed to investigate mean differences over risk perceptions among different groups that were broken down by age, educational attainment, ethnicity, household size, yearly household income, and tenure. Additionally, this chapter examines whether the level of SEERs corresponds to the level of risk perceptions for each group with different household characteristics.

#### **6.2. Descriptive Characteristics of Perceived Risks**

As mentioned in Chapter V, the survey respondents used a five-category Likert scale to rate their concerns of future major consequences from hurricanes, floods, and hazardous material releases. Table 6-1 shows the means, standard deviations, the number of cases, minimums, and maximums for the respondents' risk perceptions. Tables 6-2, 6-3, and 6-4 show the number of cases and the percentages for the risk perception items

measured. Perceptions of consequences resulting from a flood and hurricane increased gradually from injury, through health problems, to property damage. Conversely, their perceived risk of a hazardous material release increased gradually from property damage, to injury, and to health problems. Overall, the respondents' perception of property damage to the respondents' home from a hurricane yielded the highest mean ( $M = 3.02$ ), followed by property damage from a flood ( $M = 2.57$ ), and by health problems from a hazardous material release ( $M = 2.42$ ). Conversely, the mean for the perception of injury to the respondents from a flood ( $M = 1.89$ ) was lowest, followed by property damage from a hazardous material release ( $M = 2.10$ ).

**Table 6-1. Descriptive characteristics of risk perception**

Variable	Measures	Acronym	Mean	Std. Deviation	N
Risk perception of a flood	Property damage	PDF	2.57	1.19	320
	Injury	IJF	1.89	0.93	317
	Health problems	HPF	2.21	1.15	317
Risk perception of a hurricane	Property damage	PDH	3.02	1.11	316
	Injury	IJH	2.28	0.98	315
	Health problems	HPH	2.29	1.06	315
Risk perception of a hazardous material release	Property damage	PDHM	2.10	1.09	318
	Injury	IJHM	2.24	1.13	318
	Health problems	HPHM	2.42	1.19	318



**Table 6-2. Number and frequency of each level of risk perception on floods**

Level	Property Damage		Injury		Health Problems	
	n	%	n	%	n	%
1	66	20.6	129	40.2	103	32.1
2	98	30.5	113	35.2	104	32.4
3	91	28.3	61	19	70	21.8
4	38	11.8	8	2.5	20	6.2
5	27	8.4	6	1.9	20	6.2
Total	320	99.7	317	98.8	317	98.8
Missing	1	0.3	4	1.2	4	1.2
Total	321	100	321	100	321	100

**Table 6-3. Number and frequency of each level of risk perception on hurricanes**

Level	Property Damage		Injury		Health Problems	
	n	%	n	%	n	%
1	25	7.8	75	23.4	87	27.1
2	78	24.3	110	34.3	94	29.3
3	118	36.8	105	32.7	101	31.5
4	56	17.4	16	5.0	21	6.5
5	39	12.1	9	2.8	12	3.7
Total	316	98.4	315	98.1	315	98.1
Missing	5	1.6	6	1.9	6	1.9
Total	321	100.0	321	100.0	321	100.0

**Table 6-4. Number and frequency of each level of risk perception on hazardous material releases**

Level	Property Damage		Injury		Health Problems	
	n	%	n	%	n	%
1	119	37.1	103	32.1	89	27.7
2	92	28.7	90	28.0	84	26.2
3	73	22.7	84	26.2	89	27.7
4	23	7.2	27	8.4	35	10.9
5	11	3.4	14	4.4	21	6.5
Total	318	99.1	318	99.1	318	99.1
Missing	3	0.9	3	0.9	3	0.9
Total	321	100.0	321	100.0	321	100.0

### 6.3. Correlational Analyses

Correlational analyses were conducted to examine the overall relationship between household characteristics and risk perception items addressing the major environmental concerns from floods, hurricanes, and hazardous material releases (see Table 6-5). AGE, HSIZE (household size) and STATUS (marital status) showed no significant relationship with any risk perception items. EDU had a negative relationship with perceived risk of property damage from a flood (PDF), injury from a hurricane (IJH), health problems from a hurricane (HPH), and property damage from a hazardous material release (PDHM) with correlation coefficients of -0.15, -0.15, -0.12, and -0.11, respectively. These correlations indicated that the higher the level of education, the less the concern of PDF, IJH, HPH, and PDHM. SEX (male coded as "1") was negatively correlated with all of the risk perception items (IJF:  $r = -0.15$ ; HPF:  $r = -0.13$ ; PDH:  $r = -0.16$ ; IJH:  $r = -0.17$ ; HPH:  $r = -0.17$ ; PDHM:  $r = -0.22$ ; IJHM:  $r = -0.16$ ; HPHM:  $r = -0.17$ ), except for PDF ( $r = -0.11$ ). These correlations indicated that females had a higher level of perceived risk than did males. INCOME (yearly household income) was negatively correlated with perceived risk of HPF ( $r = -0.17$ ), PDH ( $r = -0.14$ ), and HPH ( $r = -0.13$ ). TENURE (tenure at present home) was positively correlated only with perceived risk of PDH ( $r = 0.17$ ).

**Table 6-5. Correlation coefficients of household characteristics with risk perception**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. AGE	1.00															
2. EDU	-0.03	1.00														
3. SEX	0.04	0.11	1.00													
4. HSIZE	-0.30**	-0.06	0.06	1.00												
5. INCOME	-0.27**	0.42**	0.20**	0.12	1.00											
6. STATUS	-0.10	0.01	0.37**	0.38**	0.40**	1.00										
7. TENURE	0.62**	-0.13*	-0.10	-0.23**	-0.31**	-0.17**	1.00									
8. PDF	0.00	-0.15**	-0.11	-0.07	-0.11	-0.09	0.07	1.00								
9. IJF	-0.07	-0.11	-0.15*	0.07	-0.09	-0.03	-0.03	0.55**	1.00							
10. HPF	0.00	-0.07	-0.13*	0.03	-0.17**	-0.09	0.09	0.64**	0.68**	1.00						
11. PDH	0.07	-0.11	-0.15**	-0.05	-0.14*	-0.09	0.17**	0.63**	0.35**	0.43**	1.00					
12. IJH	0.00	-0.15**	-0.17**	0.03	-0.08	-0.05	0.07	0.45**	0.60**	0.55**	0.57**	1.00				
13. HPH	0.05	-0.12*	-0.16**	-0.01	-0.13*	-0.07	0.10	0.47**	0.58**	0.70**	0.55**	0.82**	1.00			
14. PDHM	0.02	-0.11*	-0.22**	0.05	-0.10	-0.09	0.06	0.32**	0.43**	0.45**	0.41**	0.50**	0.55**	1.00		
15. IJHM	-0.01	-0.08	-0.16**	0.07	-0.09	-0.06	0.04	0.31**	0.41**	0.46**	0.39**	0.47**	0.51**	0.85**	1.00	
16. HPHM	0.00	-0.05	-0.17**	0.05	-0.07	-0.03	0.08	0.28**	0.33**	0.48**	0.34**	0.40**	0.48**	0.75**	0.88**	1.00

1. age on last birthday; 2: educational attainment; 3: sex (males = 1); 4: household size; 5: yearly household income; 6: marital status (married = 1); 7: tenure; 8: property damage from a flood; 9: injury from a flood; 10: health problems from a flood; 11: property damage from a hurricane; 12: injury from a hurricane; 13: health problems from a hurricane; 14: property damage from a hazardous material release; 15: injury from a hazardous material release; 16: health problems from a hazardous material release.

\*.  $p < 0.05$ . \*\*.  $p < 0.01$ .  $N = 279$  to  $321$ .

## 6.4. MANOVA Tests

### 6.4.1. Age and Perceived Risk

Appendix 21 shows means, standard deviation, and number of cases for risk perception attributes across four age groups: 1) 20s to 30s; 2) 40s; 3) 50s; 4) over 60s. The significance of differences in means for the respondents' risk perceptions among age groups was assessed by using MANOVA, which simultaneously tests the effect of the independent variable (between-subjects – age groups) upon the dependent variables (perceived risk items). The analysis showed that the respondents did not have

significantly different perceptions about potential consequences across the age groups (see Appendixes 22, 23, and 24).

#### ***6.4.2. Educational Attainment and Perceived Risk***

Appendix 25 shows means, standard deviation, and number of cases for risk perception attributes across the five levels of educational attainment: 1) Less than high school education; 2) High school diplomas; 3) Some college education; 4) College graduate degrees; 5) Graduate school degrees. MANOVA tests showed that there was no effect of educational attainment upon the risk perception variables (see Appendixes 26, 27, and 28).

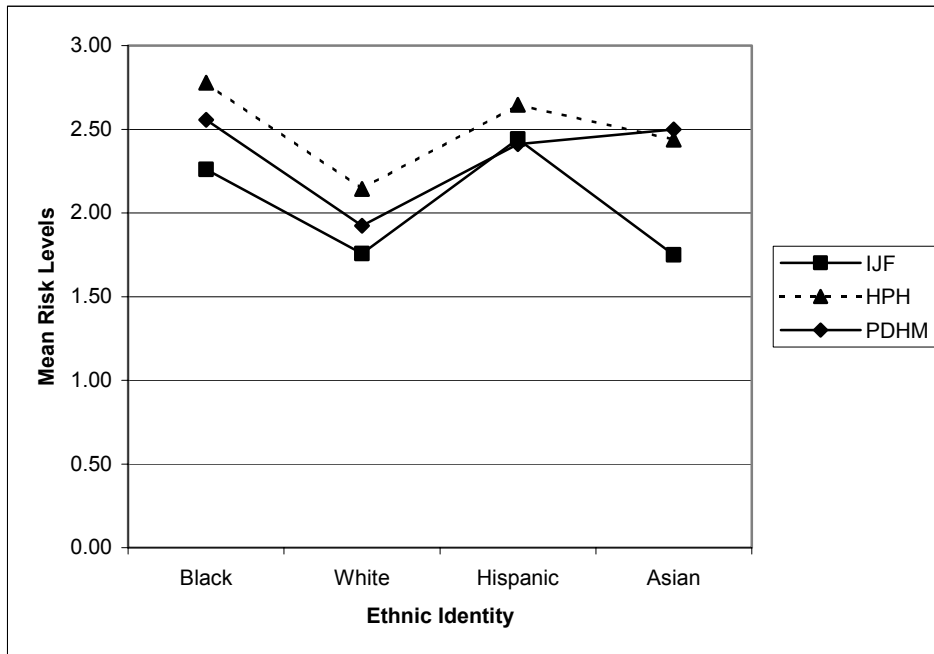
#### ***6.4.3. Ethnicity and Perceived Risk***

Appendix 29 shows means, standard deviation, and number of cases for risk perception attributes across five ethnic groups: Black, White, Hispanic, Asian, and Other. The Other group, which includes American Indians and persons who did not indicate their ethnic identity, was excluded from the analysis because of its heterogeneity and small size.

MANOVA tests showed that there was an effect of the ethnic groups upon perceived risk of flood ( $F = 2.18, p < 0.01$ , see Appendix 30), hurricane ( $F = 2.94, p < 0.01$ , see Appendix 31), and hazardous material ( $F = 1.88, p = 0.33$ , see Appendix 32). Tests of the between-subjects effect revealed significant differences for perceived risk of

IJF ( $F = 4.90$ ,  $p < 0.01$ , see Appendix 33), HPH ( $F = 3.31$ ,  $p = 0.01$ , see Appendix 34), and PDHM ( $F = 4.60$ ,  $p < 0.01$ , see Appendix 35).

Figure 6-1 profiles the ethnic groups in terms of their mean ratings for their perceived risk of IJF, HPH, and HPHM. The profile for IJF shows that Hispanics had a higher mean rating than any other ethnic group, followed by Blacks, Whites, and Asians. It is noticeable that, even though the Hispanic group had lived in areas with a low level of flood risk (see Chapter V for details), they had the highest level of concerns about this hazard. The profile for HPH shows that Whites had the lowest mean rating, which contrasts with their high level of hurricane risk. The profile for HPHM shows that Asians had the highest mean rating even though, on average, they lived farther away from TRI sites than any other ethnic groups. As expected, Blacks lived nearest to TRI sites and had the highest mean ratings of PDHM, whereas Whites had the lowest ratings, which corresponded to their low level of chemical risk.



**Figure 6-1. Mean risk perception of IJF (injury from a flood), HPH (health problems from a hurricane), and PDHM (property damage from a hazardous material), by ethnicity**

More detailed multi-comparison tests using Tukey's HSD showed that mean differences (MDs) between Blacks and Whites, and between Whites and Hispanics for IJF were significant (MD = -0.50,  $p = 0.05$ , and MD = -0.61,  $p < 0.01$ , respectively). The mean of Blacks for HPH was significantly different from that of Whites (MD = 0.63,  $p = 0.03$ ), and the mean difference for PDHM between Blacks and Whites was also significant (MD = 0.63,  $p = 0.03$ , see Appendix 36).

#### ***6.4.4. Household Size and Perceived Risk***

Appendix 37 shows means, standard deviation, and number of cases for risk perception attributes across five groups differentiated by the number of persons living together, ranging from 1-5 persons. The multivariate tests showed that the respondents did not have significantly different perceptions about potential consequences regardless of household size (see Appendixes 38, 39, and 40).

#### ***6.4.5. Yearly Household Income and Perceived Risk***

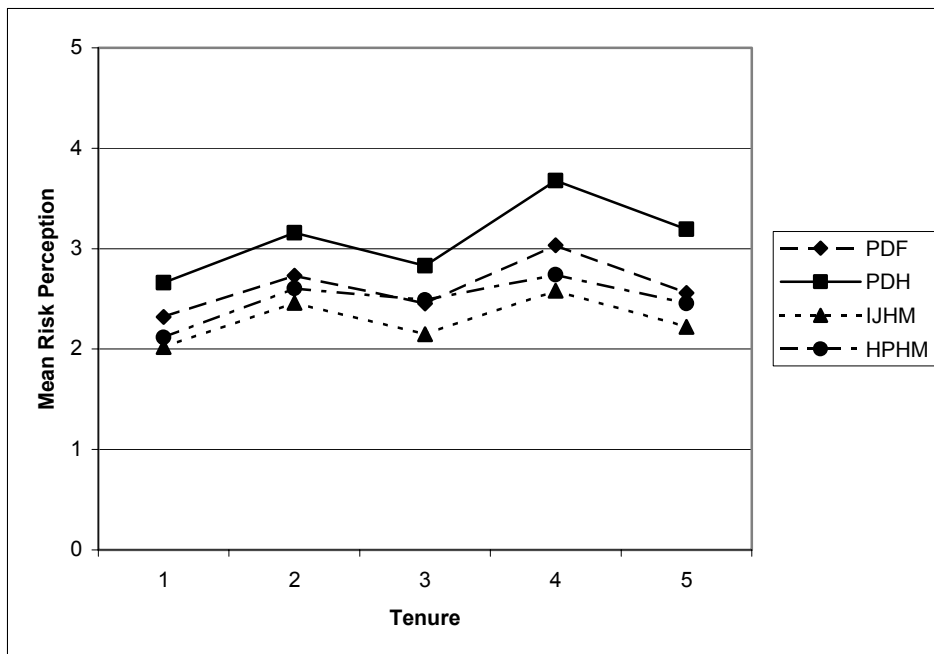
Appendix 41 shows the number of cases, means, standard deviations, and standard errors for risk perception items across seven groups with different yearly household income. MANOVA tests revealed that risk perception items did not show statistically significant differences among groups (see Appendixes 42, 43, and 44).

#### ***6.4.6. Tenure and Perceived Risk***

Appendix 45 shows the number of cases, means, standard deviations, and standard errors for risk perception items across five groups with different years of tenure: 1) 0-4.99 years; 2) 5-9.99 years; 3) 10-14.99 years; 4) 15-19.99 years; 5) Over 20 years.

MANOVA tests showed that the tenure groups differed in the perceived risk of a hurricane risk ( $F = 2.50, p < 0.01$ ), but not upon the perceived risk of a flood and a hazardous material (see Appendixes 46, 47, and 48). Tests of the between-subjects effect revealed that the means for perceived risk of PDF ( $F = 2.82, p < 0.03$ , see Appendix 49),

PDH ( $F = 6.95$ ,  $p < 0.01$ , see Appendix 50), IJHM ( $F = 3.00$ ,  $p = 0.04$ , see Appendix 51), and HPHM ( $F = 3.76$ ,  $p = 0.03$ , see Appendix 50) among the tenure groups were statistically significant. These results are profiled in Figure 6-2. The curves showed erratic fluctuations rather than a systematic trend.



**Figure 6-2. Mean risk perception of PDF (property damage from a flood), PDH (property damage from a hurricane), IJHM (injury from a hazardous material), and HPHM (health problems from a hazardous material), by tenure**



Multi-comparison tests using Tukey's HSD showed that mean differences (MDs) between the group with tenure of 0-4.99 years and the group with tenure of 15-19.99 years for IJF were significant (MD = -0.71,  $p = 0.02$ ). The mean of the group with 0-4.99 years of tenure for HPH was significantly different from those of the groups with 5-9.99 years (MD = -0.50,  $p = 0.03$ ), 15-19.99 years (MD = -1.02,  $p < 0.01$ ), and over 20 years (MD = -0.53,  $p = 0.01$ ) of tenure. There was no mean difference for IJHM and PDHM among any groups (see Appendix 52).

**CHAPTER VII**  
**ANALYSES AND RESULTS:**  
**SCIENTIFICALLY ESTIMATED ENVIRONMENTAL RISKS**  
**(SEERS) AND RISK PERCEPTIONS**

**7.1. Introduction**

This chapter presents the analyses that test the third hypothesis that SEERs are positively related to public risk perception of the hazards. Correlation analyses were conducted to examine whether SEERs were related to the respondents' perceived risk. MANOVA tests were performed to investigate mean differences of risk perception among different groups that were broken down by level of each of SEERs.

**7.2. Correlational Analyses**

As shown in Table 7-1, scientifically estimated risks of natural hazards were significantly related only to respondents' ratings of property damage from a flood ( $r = 0.18$ ) and property damage from a hurricane ( $r = 0.21$ ). However, scientifically estimated flood and hurricane risks were not significantly related to perceptions of injury and health problems from these hazards. Hazardous material risk was related to all three categories of risk perception of a hazardous material release with correlation coefficients of  $-0.18$ ,  $-0.20$ , and  $-0.22$  (all significant  $p < 0.01$ ). These coefficients have negative signs because chemical risk was measured by distance from the nearest TRI facility, so risk is inversely related to distance.

**Table 7-1. Correlation coefficients of environmental risks with risk perception**

	1	2	3	4	5	6	7	8	9	10	11	12
1. FR	1.00											
2. HR	-0.02	1.00										
3. CR	-0.14*	-0.18**	1.00									
4. PDF	0.18**	0.03	-0.13*	1.00								
5. IJF	0.08	0.00	-0.06	0.55**	1.00							
6. HPF	0.07	0.01	-0.11*	0.64**	0.68**	1.00						
7. PDH	0.08	0.21**	-0.19**	0.63**	0.35**	0.43**	1.00					
8. IJH	0.04	0.03	-0.10	0.45**	0.60**	0.55**	0.57**	1.00				
9. HPH	0.07	0.10	-0.15**	0.47**	0.58**	0.70**	0.55**	0.82**	1.00			
10. PDHM	0.05	0.08	-0.18**	0.32**	0.43**	0.45**	0.41**	0.50**	0.55**	1.00		
11. IJHM	0.07	0.10	-0.20**	0.31**	0.41**	0.46**	0.39**	0.47**	0.51**	0.85**	1.00	
12. HPHM	0.06	0.12*	-0.22**	0.28**	0.33**	0.48**	0.34**	0.40**	0.48**	0.75**	0.88**	1.00

1: flood risk; 2: hurricane risk; 3: chemical risk; 4: property damage from a flood; 5: injury from a flood; 6: health problems from a flood; 7: property damage from a hurricane; 8: injury from a hurricane; 9: health problems from a hurricane; 10: property damage from a hazardous material release; 11: injury from a hazardous material release; 12: health problems from a hazardous material release.

\*.  $p < 0.05$ . \*\*.  $p < 0.01$ .  $N = 313$  to  $321$ .

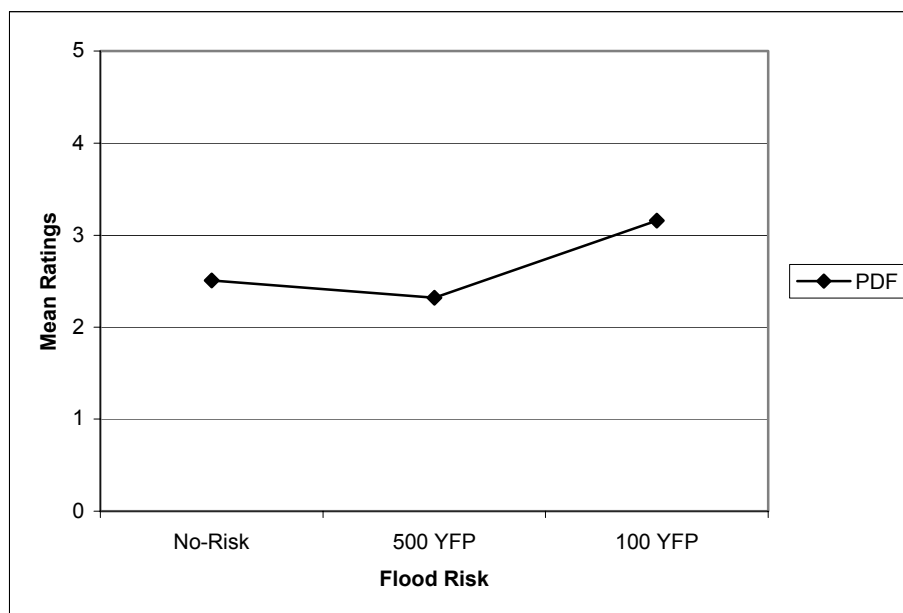
### 7.3. MANOVA Tests

#### 7.3.1. Relationships Between SEER and Risk Perception for Floods

Appendix 53 shows means, standard deviation, and number of cases for risk perception attributes across three groups who lived in areas with different levels of scientifically estimated flood risk: no flood risk areas, 500-YFP areas, and 100-YFP areas. The three groups who were differentiated by levels of SEER of floods were asked to rate their perceptions in terms of property damage, injury, and health effects. The significance of differences in means for the respondents' perceived risk among the groups was assessed by using MANOVA tests, which showed that the groups differed significantly in their perceived risk of floods ( $F = 2.93$ ,  $p < 0.01$ , see Appendix 54). Tests of between-subjects effect revealed that the means for perceived damage from a

flood (PDF) among the groups were statistically significant ( $F = 7.92$ ,  $p < 0.01$ , see Appendix 55).

Figure 7-1 profiles the three groups in terms of the respondents' mean ratings for PDF. The group that resided in the 100-YFP area had the highest mean ratings for PDF. The groups that resided in areas free from flood risk and in the 500-YFP area had lower mean ratings for PDF than the group in the 100-YFP area.



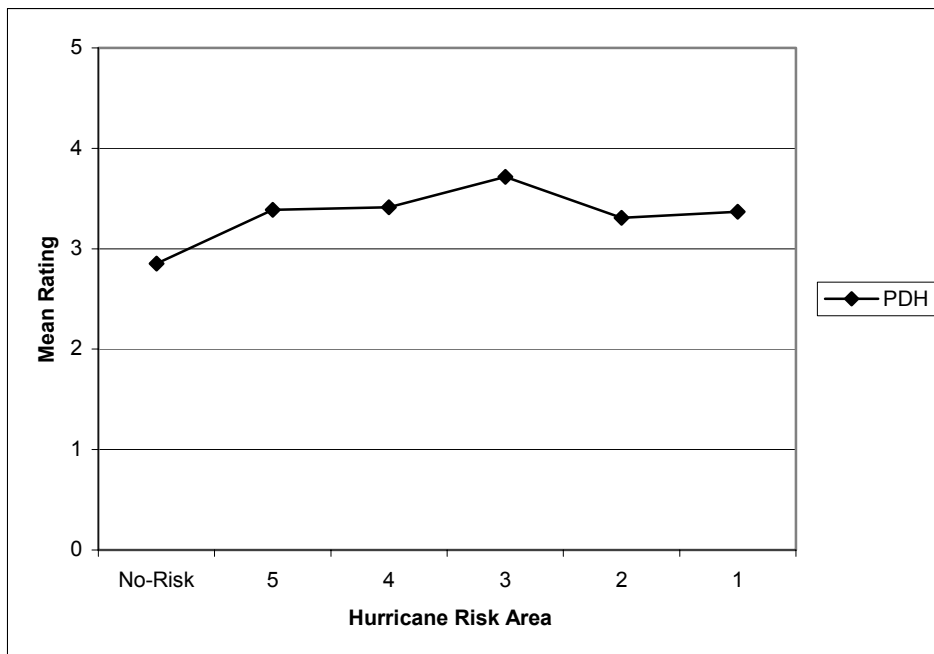
**Figure 7-1. Mean ratings of perceived risk of PDF (property damage from a flood), by flood risk level**

Tukey's HSD showed that mean differences (MDs) for PDF between the flood risk free area and the 100 YFP area ( $MD = -0.70, p < 0.01$ ), and between the 100 YFP area and the 500 YFP area ( $MD = -0.87, p < 0.01$ ) were significant (see Appendix 56). However, the mean for PDF in the flood risk free area was not significantly different from that in the 500 YFP area. Additionally, the tests revealed the respondents' judgments about injury and health problems from a flood had no differences in their mean ratings, regardless of the levels of flood risk.

### ***7.3.2. Relationships Between SEER and Risk Perception for Hurricanes***

Appendix 57 indicates means, standard deviation, and number of cases pertaining to the respondents' perception of adverse consequences from a hurricane by the six categories of hurricane risk. MANOVA test showed that there was a significant overall effect ( $F = 2.30, p < 0.01$ , see Appendix 58). Tests of between-subjects effect revealed that the means for perceived damage from a hurricane (PDH) among the groups were statistically significant ( $F = 4.37, p < 0.01$ , see Appendix 59).

Figure 7-2 profiles the six groups in terms of their mean ratings for PDH. The group that resided in hurricane risk-free areas was concerned least about PDH, but there was no clear trend across the levels of hurricane risk.



**Figure 7-2. Mean ratings of perceived risk of PDH (property damage from a hurricane), by hurricane risk level**

Note: Hurricane Risk Area 5 corresponds to the least vulnerable area except the “No-Risk” area, whereas Hurricane Risk Area 1 corresponds to the most vulnerable area.

The post test results showed that only the mean difference for PDH between hurricane risk free area and Risk Area 3 was significant ( $MD = -0.87$ ,  $p < 0.01$ , see Appendix 60). Respondents’ judgments about injury and health problems resulting from a future hurricane showed no differences in their mean ratings, regardless of the levels of hurricane risk.

**CHAPTER VIII**

**ANALYSES AND RESULTS:**

**SCIENTIFICALLY ESTIMATED ENVIRONMENTAL RISKS**

**(SEERS), RISK PERCEPTIONS, HAZARD MITIGATION**

**MEASURES, AND HOUSING PRICES**

**8.1. Introduction**

This chapter presents the analyses that test Hypotheses 4, 5, and 6, by determining the influence on housing prices of SEERs of floods, hurricanes and hazardous material releases, risk perceptions of those hazards, and household hazard mitigation measures. To this end, the hedonic price regression model was utilized. All of the other variables that might affect the housing prices, such as structural, locational, neighborhood and submarket variables were incorporated into the model as control variables. This chapter first shows descriptive characteristics of the variables in the model. Next, statistical diagnostic tests were used to test whether the model satisfies several assumptions of a classical regression model. Finally, this chapter interprets the coefficients derived from the regression model.

## **8.2. Descriptive Characteristics of the Model**

Housing prices were modeled to determine if SEERs, risk perceptions, and hazard mitigation measure actions influenced housing prices. Table 8-1 shows the model's descriptive statistics including the mean and standard deviation of each variable. As shown in Table 8-1, the model included four structural characteristic variables, three locational (or distance) variables, two neighborhood variables, sixteen sub-market variables (e.g., city dichotomies), eight hazard mitigation variables, three SEER variables, and three risk perception variables.



**Table 8-1. Characteristics of the hedonic price model**

Concept	Variable	Unit	Min.	Max.	Mean	Std. Deviation
Housing price	Market value	US \$	14,600	905,000	142,126	105,716
	Market value	Log \$	9.59	13.72	11.66	0.63
Structural characteristics	Land area	Square ft.	1,738	152,460	11,442	12,952
	House age	Years	1	102	24.78	16.85
	Living area	Square ft.	768	5,584	2,120	832
	Fire place	Dichotomy	0	2	0.74	0.50
Locational characteristics	Distance to airport	Miles	1.07	32.05	14.23	5.80
	Distance to CBD	Miles	0.57	30.92	16.77	6.34
	Distance to park	Miles	0.07	4.85	1.25	0.98
Neighborhood characteristics	Household income	US \$	14,177	200,001	63,116	27,047
	Percent White	Percent	0	99.41	72.05	24.08
City	Baytown	Dichotomy	0	1	0.09	0.28
	Bellaire	"	0	1	0.02	0.15
	Channelview	"	0	1	0.01	0.11
	Crosby	"	0	1	0.01	0.10
	Cypress	"	0	1	0.03	0.18
	Deer Park	"	0	1	0.01	0.10
	Friendswood	"	0	1	0.01	0.08
	Highlands	"	0	1	0.01	0.10
	Humble	"	0	1	0.03	0.17
	Katy	"	0	1	0.03	0.18
	Kingwood	"	0	1	0.01	0.08
	La Porte	"	0	1	0.08	0.26
	Pasadena	"	0	1	0.01	0.11
	Seabrook	"	0	1	0.04	0.21
	Spring	"	0	1	0.05	0.22
Tomball	"	0	1	0.02	0.15	
Hazard mitigation activities	Elevating HVAC systems	"	0	1	0.17	0.37
	Elevating the house	"	0	1	0.09	0.28
	Adding water proof wall	"	0	1	0.08	0.27
	Reinforcing roof rafters	"	0	1	0.10	0.30
	Reinforcing walls	"	0	1	0.11	0.31
	Installing storm shutters	"	0	1	0.03	0.18
	Installing a generator	"	0	1	0.12	0.32
	Purchasing flood insurance	"	0	1	0.53	0.50
Environmental risk	Floods	Six categories	0	5	0.82	1.68
	Hurricanes	Six categories	0	5	0.84	1.54
	Hazardous materials	Miles	0	7.73	2.25	1.40
Risk perception	Floods	Five categories	1	5	2.19	0.92
	Hurricanes	Five categories	1	5	2.51	0.92
	Hazardous materials	Five categories	1	5	2.24	1.07

N = 308 to 317

As noted earlier, respondents' environmental risk perception of each hazard was measured by three questions: their concerns about major damage to their home, injury to themselves or members of their household, and health problems for themselves or members of their household, resulting from a flood, hurricane, or hazardous material release. Correlational and factor analyses were conducted for possible variable reduction. As reported in Table 7-1, the correlation coefficients of the three indicators for flood risk perception ranged from 0.55 to 0.68 ( $p < 0.01$ ). The coefficients of the indicators for hurricane risk perception ranged from 0.55 to 0.82 ( $p < 0.01$ ) and the coefficient values of the indicators for chemical risk perception ranged from 0.75 to 0.88 ( $p < 0.01$ ). These results mean that the three risk perception indicators associated with each environmental hazard were so highly correlated that they could be interpreted as a single dimension of risk perception. The results of a principal components factor analysis showed that a three-factor solution explained over 80.96% of variance (see Table 8-2). Following a Varimax rotation, the three indicators for chemical risk perception loaded on Factor 1 (see Table 8-3). The three indicators for flood risk perception also were considered as a single factor even though property damage from floods cross-loaded onto Factor 3. Finally, the three indicators for hurricane risk perception were also considered as a single factor, even though factor loadings for injuries and health problems crossloaded onto Factor 2.

**Table 8-2. Factor analysis: Total variance explained by each component for risk perception**

Compo.	Initial Eigen Values			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	Variance	% of Cumulative %
1	5.15	57.20	57.20	5.15	57.20	57.20	2.76	30.61	30.61
2	1.38	15.37	72.58	1.38	15.37	72.58	2.71	30.08	60.69
3	0.75	8.38	80.96	0.75	8.38	80.96	1.82	20.27	80.96
4	0.68	7.60	88.56						
5	0.37	4.10	92.66						
6	0.24	2.66	95.32						
7	0.21	2.36	97.68						
8	0.12	1.31	98.99						
9	0.09	1.01	100.00						

**Table 8-3. Rotated component matrix: Three components for risk perception**

Variable	Component		
	1. Chemical risk perception	2. Flood risk perception	3. Hurricane risk perception
PDF	0.10	0.52	0.64
IJF	0.17	0.88	0.10
HPF	0.29	0.82	0.23
PDH	0.22	0.16	0.92
IJH	0.28	0.60	0.48
HPH	0.34	0.66	0.43
PDHM	0.85	0.26	0.21
IJHM	0.92	0.22	0.17
HPHM	0.91	0.20	0.11

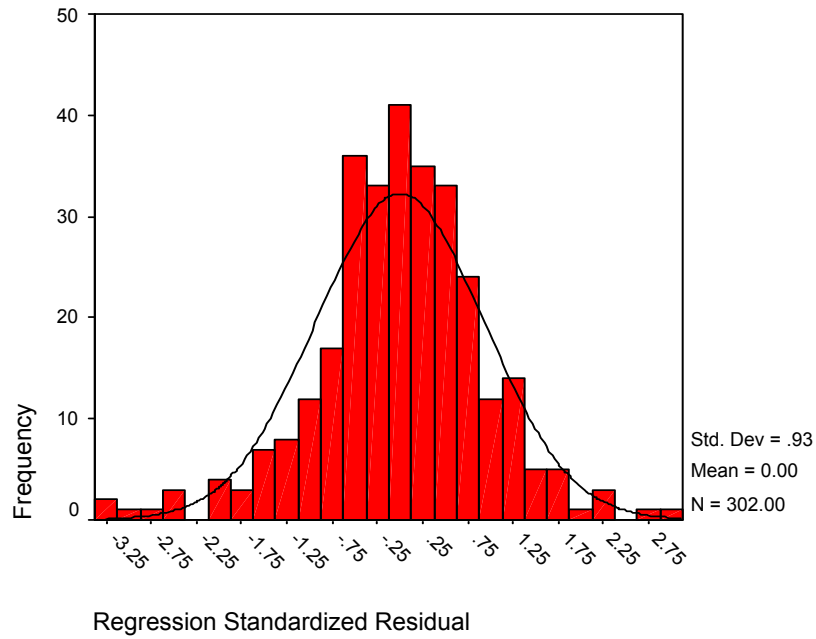
### **8.3. Statistical Diagnostic Tests for the Residential Property Value Model**

Three sets of analyses were conducted to verify that the assumptions of the classical regression model had been met. First, four outliers were deleted because the problem points had standardized residuals of over 3.3 ( $\alpha = 0.001$ ) by casewise residual diagnostics or they had leverage of over 0.5. Second, multicollinearity diagnostics were conducted by inspecting the tolerance level and VIF (Variance Inflation Factor) of the predictor variables. In general, tolerance values below 0.1 and VIF values above 10 suggest a multicollinearity problem. Table 8-4, which shows the tolerance level and VIF value for each variable, indicates that the data had no significant problems with collinearity.

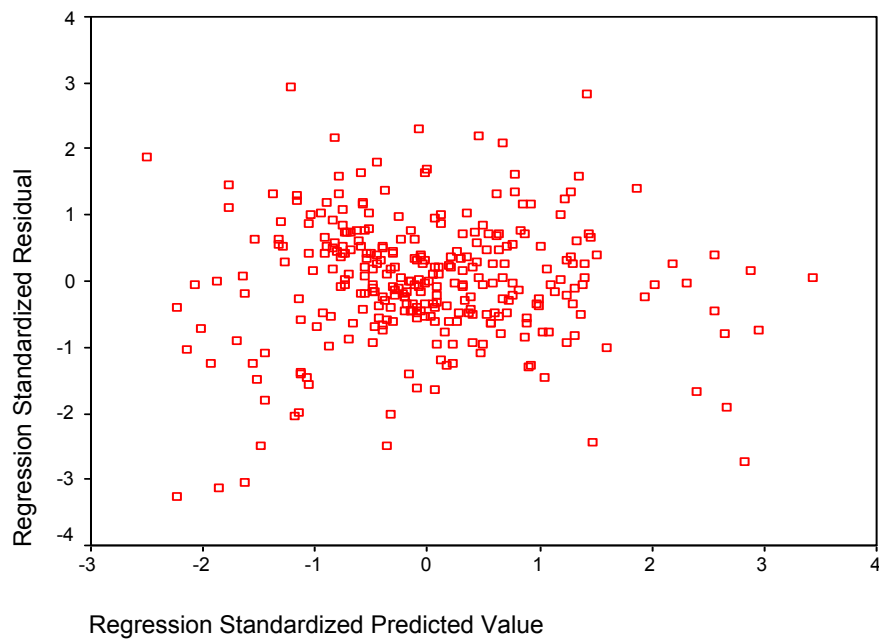
**Table 8-4. Tolerance values and Variance Inflation Factors (VIFs)**

Variable	Measure	Collinearity Statistics	
		Tolerance	VIF
Structural characteristics	Land area	0.75	1.33
	House age	0.45	2.22
	Living area	0.39	2.58
	Fire place	0.50	2.02
Locational characteristics	Distance to airport	0.34	2.92
	Distance to CBD	0.15	6.54
	Distance to park	0.40	2.48
Neighborhood characteristics	Household income	0.35	2.89
	Percent White	0.42	2.37
City	Baytown	0.39	2.59
	Bellaire	0.80	1.25
	Channelview	0.80	1.25
	Crosby	0.89	1.12
	Cypress	0.71	1.40
	Deer Park	0.85	1.18
	Friendswood	0.81	1.24
	Highlands	0.66	1.51
	Humble	0.74	1.36
	Katy	0.58	1.72
	Kingwood	0.86	1.17
	La Porte	0.45	2.24
	Pasadena	0.84	1.19
	Seabrook	0.44	2.26
	Spring	0.65	1.55
Tomball	0.76	1.31	
Hazard mitigation activities	Elevating HVAC systems	0.67	1.50
	Elevating the house	0.69	1.45
	Adding water proof wall	0.76	1.31
	Reinforcing roof rafters	0.65	1.55
	Reinforcing walls	0.76	1.31
	Installing storm shutters	0.89	1.13
	Installing a generator	0.77	1.29
	Purchasing flood insurance	0.75	1.33
SEER	Floods	0.76	1.31
	Hurricanes	0.27	3.67
	Hazardous materials	0.34	2.97
Risk perception	Floods	0.40	2.47
	Hurricanes	0.38	2.62
	Hazardous materials	0.61	1.65

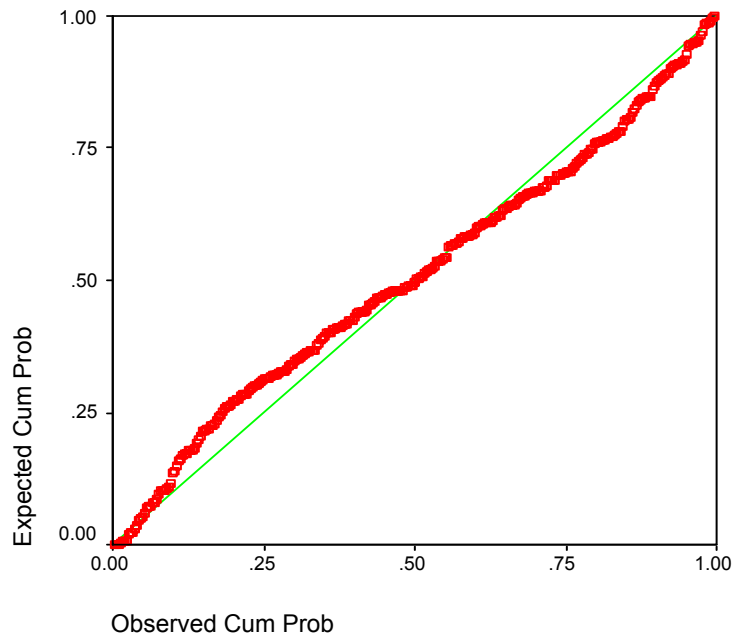
Third, residual plot analyses were conducted to test for heteroskedasticity – a condition in which the errors,  $e_i$ , in the regression model do not have common variance. As Figure 8-1 shows, the residuals appear to be approximately normally distributed, which means the error term has equal variance and is independent across observations. Figure 8-2 shows the scatter plot of the standardized residuals with the standardized predicted values. In general, a residual scatter plot with a divergent or convergent fan shape suggests heteroskedasticity, whereas a plot with a symmetric pattern such as a cloud of points indicates homoskedasticity. The residuals for these data look symmetrical and spread out at random throughout the range of the estimated dependent variable, which suggests that the error terms in the semi-log regression model meets the requirement for homoskedasticity. Additionally, Figure 8-3 shows the standardized normal P-P plot of the residuals where the cumulative proportion observed is plotted against the cumulative proportion expected. The points generally cluster around a straight line, indicating that the residuals approximate a normal distribution.



**Figure 8-1. Histogram of standardized residuals**



**Figure 8-2. Scatter plot of the standardized residuals on the standardized predicted values**

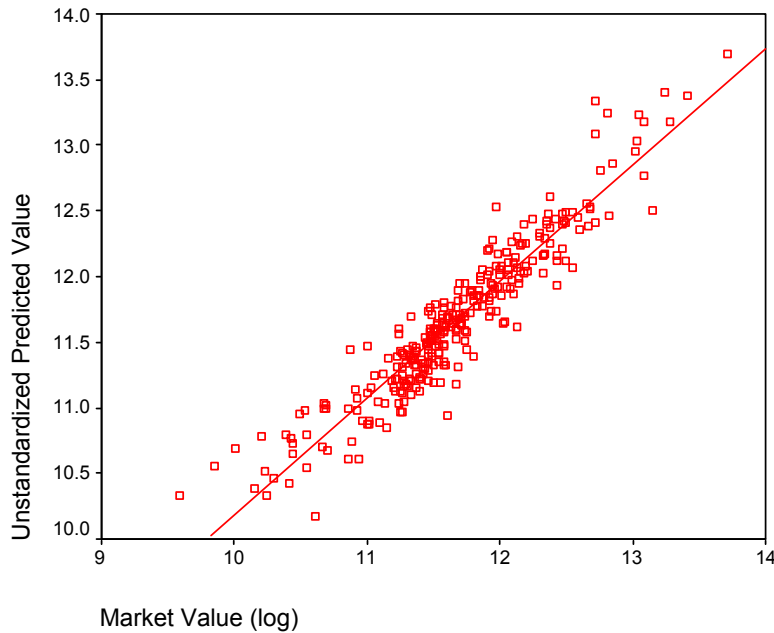


**Figure 8-3. Standardized normal P-P plot of the residuals**

#### **8.4. Determinants of Residential Property Values**

The equation predicting residential property values from structural, locational, and neighborhood characteristics, together with hazard mitigation, SEER and perceived risk, explained over 87 % of the variation in housing prices. Although there were 39 predictor variables in the equation, the sample consisted of 321 single-family housing units, thus yielding an acceptable  $N/p$  (sample size to predictor variable ratio) of 8.2. The high adjusted  $R^2$  value (= 0.87) was slightly lower than the 0.933 value obtained by Gordon et al. (1989), and slightly higher than the 0.81 value yielded by McClelland et al. (1990). Figure 8-4 shows a plot of the observed values (market value of house in a log form) versus the predicted values, indicating how well the hedonic regression model fits the data.





**Figure 8-4. The scatter plot of the observed values (market value of house in a log form) versus the predicted values**

As seen in Table 8-5, the regression coefficients for the structural characteristic variables had the expected signs and were statistically significant at  $p < 0.01$ . When the four structural characteristic variables were controlled for, other indicators of the characteristics such as the number of bedrooms and bathrooms were not statistically significant, so they were omitted (see Appendix 61 for the complete matrix of correlations among the variables).

All the locational (or distance) variables also had the expected sign and direction at  $p < 0.05$ . The positive sign on the coefficient for distance to airport means that the nearer a house is to the airport, the lower the housing price. The other two locational variables, distance to the nearest park and distance to the central business district (CBD) had negative signs, indicating the property value of a house located closer to parks and

the CBD would be higher than comparable houses located elsewhere. Other location variables such as distance to railroad, hospital, golf course, shoreline, and water bodies were not included due to a considerable amount of multicollinearity among these variables. The coefficients of the two neighborhood characteristics had the expected signs and were statistically significant at  $p < 0.01$ . Other neighborhood variables, such as the percent of occupied housing units and the percent of single-family housing units, were omitted due to their poor correlation with housing price and negligible regression coefficients.

The city dichotomy variables to test the effect of separate sub-markets on the housing price were not statistically significant with the exception of Bellaire and Cypress. Interestingly, the sign of Bellaire was positive but that of Cypress was negative. This is an indication that Bellaire had higher housing prices than otherwise predicted, whereas Cypress had lower housing prices than otherwise predicted.

Contrary to the sixth hypothesis, the hazard mitigation variables had regression coefficients that were not statistically significant. These results indicate that none of the hazard mitigation measures had a significant influence on the property values.

For the variables representing SEERs, the natural hazards (flood and hurricane) had no impact on the property values. Similarly, for the variables representing environmental risk perception, the respondents' perceptions of these natural hazards had no influence on the property values. These findings showed that the SEERs and perceived risks of the natural hazards did not follow the fourth and fifth hypotheses, respectively.

**Table 8-5. Determinants of residential property values**

Concept	Variable	B	Std. Error	t	Sig.
	(Constant)	10.72	0.11	101.32	0.00**
Structural characteristics	Land area	0.000006	0.000001	4.95	0.00**
	House age	-0.0097	0.001	-8.33	0.00**
	Living area	0.0004	0.00003	14.25	0.00**
	Fire place	0.1179	0.04	3.21	0.00**
Locational characteristics	Distance to airport	0.0090	0.00	2.33	0.02*
	Distance to CBD	-0.0312	0.01	-5.85	0.00**
	Distance to park	-0.0465	0.02	-2.23	0.03*
Neighborhood characteristic	Household income	0.000003	0.000001	3.28	0.00**
	Percent White	0.0077	0.001	9.05	0.00**
City	Baytown	0.0028	0.08	0.04	0.97
	Bellaire	0.3241	0.10	3.33	0.00**
	Channelview	-0.1836	0.15	-1.24	0.22
	Crosby	-0.0842	0.14	-0.60	0.55
	Cypress	-0.2106	0.09	-2.43	0.02*
	Deer Park	-0.1475	0.14	-1.03	0.30
	Friendswood	-0.2265	0.18	-1.26	0.21
	Highlands	0.0120	0.16	0.07	0.94
	Humble	-0.0782	0.09	-0.87	0.38
	Katy	-0.0384	0.09	-0.42	0.68
	Kingwood	-0.1835	0.17	-1.05	0.29
	La Porte	-0.0688	0.07	-0.93	0.35
	Pasadena	-0.0033	0.12	-0.03	0.98
	Seabrook	0.0397	0.10	0.41	0.68
	Spring	-0.1241	0.08	-1.60	0.11
Tomball	0.0507	0.11	0.47	0.64	
Hazard mitigation activities	Elevating HVAC systems	-0.0320	0.04	-0.73	0.47
	Elevating the house	0.0238	0.06	0.42	0.67
	Adding water proof wall	-0.0316	0.06	-0.57	0.57
	Reinforcing roof rafters	0.0267	0.05	0.49	0.62
	Reinforcing walls	-0.0058	0.05	-0.12	0.91
	Installing storm shutters	0.1216	0.08	1.49	0.14
	Installing a generator	-0.0692	0.05	-1.47	0.14
	Purchasing flood insurance	0.0431	0.03	1.43	0.16
SEER	Floods	0.0124	0.01	1.35	0.18
	Hurricanes	0.0035	0.02	0.21	0.83
	Hazardous materials	0.0377	0.02	2.35	0.02*
Risk perception	Floods	0.0033	0.02	0.15	0.88
	Hurricanes	-0.0120	0.02	-0.52	0.61
	Hazardous materials	-0.0319	0.02	-2.03	0.04*

R = 0.942; R<sup>2</sup> = 0.887; Adjusted R<sup>2</sup> = 0.870.

Plausible reasons why these SEERs and perceived risk of the two natural hazards had no effect upon the housing price can be explained as follows. First, the respondents tended not to know their house's risk from the natural hazards. In the mail survey, the respondents were asked if they offered a lower price for their home because of the hazards of floods and hurricanes. The response categories for this question were: 1) "Yes"; 2) "No, discovered this hazard after purchase"; and 3) "No, not vulnerable to this hazard". Unexpectedly, six respondents specified that they did not offer a lower price, even though they discovered this hazard when they bought it. The answers to these question reveal three important facts: whether the respondents knew the house was subject to any natural hazard before or after they purchased it, whether they offered a lower price for their home, and whether their judgment of the presence or absence of risk of any natural hazard was correct.

The crosstabulation of the SEER for floods and house offer price was statistically significant ( $\chi^2 = 19.08$ ,  $p < 0.01$ , see Table 8-6). Table 8-7 shows that 5.1% of the respondents purchasing the house in the area with the highest level of flood risk (i.e., 100-year flood plain) offered a lower housing price due to the flood risk, whereas 48.7% did not offer a lower price because they failed to discover the flood hazard until after purchase. It is notable that 46.2% of them still believe that their home is not vulnerable to the hazard, even though the house is located at the area with the highest flood risk. By contrast, only 2.1% purchasing a house in the area with the second highest flood risk (i.e., 500-year flood plain) offered a lower home price, and 21.7% discovered the hazard after purchase. However, 69.6% of them believe that their home is not vulnerable to the

hazard. As noted above, three respondents (0.01%) did not offer a lower home price despite their discovering the hazard before purchasing their houses.

**Table 8-6. Chi-square tests of flood risk and house offer price**

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	19.08	6	0.00**
Likelihood Ratio	16.96	6	0.01*
Linear-by-Linear Association	8.97	1	0.00**
N of Valid Cases	294		

**Table 8-7. Crosstab of flood risk and house offer price**

			Offering a lower home price				Total
			Yes	No <sup>a</sup>	No, Not Vulnerable <sup>b</sup>	No, Vulnerable <sup>c</sup>	
Flood risk	No-risk	Count	8	46	152	3	209
		%	3.83	22.01	72.73	1.44	
	500 YFP	Count	1	10	32	3	46
		%	2.17	21.74	69.57	6.52	
	100 YFP	Count	2	19	18	0	39
		%	5.13	48.72	46.15	0.00	
Total		Count	11	75	202	6	294
		%	3.74	25.51	68.71	2.04	

<sup>a</sup> No, discovered this hazard after purchase. <sup>b</sup> No, not vulnerable to this hazard.

<sup>c</sup> No, even though they discovered this hazard when they bought it.

The crosstabulation of the SEER for hurricanes and home offer price also was statistically significant ( $\chi^2 = 40.34$ ,  $p < 0.01$ , see Table 8-8). Table 8-9 shows that 12.5% of the respondents purchasing a house in Risk Area 1 (the area with the highest level of the SEER for hurricane) offered a lower home price, whereas 37.5% did not offer a lower price because they discovered the hurricane hazard after purchase. Moreover, 5 persons (1.79%) did not offer a lower home price despite their discovering the hazard

before purchasing their houses. It was noteworthy that 37.5% of them believed that their home was not vulnerable to the hazard, even though the house was located at the area with the highest hurricane risk. Similar patterns can be seen for the remaining risk areas. Only a small percentage (0-11.76%) offered a lower price and much larger percentages (13.33-9.41%) reported discovering the hazard after purchase. The majority (50-80%) did not believe that they were vulnerable, even though they live in a designated risk area.

**Table 8-8. Chi-square tests of hurricane risk and house offer price**

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	40.34	15	0.00**
Likelihood Ratio	30.51	15	0.01*
Linear-by-Linear Association	5.99	1	0.01*
N of Valid Cases	279		

**Table 8-9. Crosstab of hurricane risk and house offer price**

		Offering a lower home price				Total	
		Yes	No <sup>a</sup>	No, Not Vulnerable <sup>b</sup>	No, Vulnerable <sup>c</sup>		
Hurricane risk	No-risk	Count	4	37	162	2	205
		%	1.95	18.05	79.02	0.98	100
	RA 5 <sup>d</sup>	Count	0	2	12	1	15
		%	0.00	13.33	80.00	6.67	100
	4	Count	0	4	10	0	14
		%	0.00	28.57	71.43	0.00	100
	3	Count	2	5	10	0	17
		%	11.76	29.41	58.82	0.00	100
	2	Count	1	3	6	2	12
		%	8.33	25.00	50.00	16.67	100
	1	Count	2	6	6	2	16
		%	12.50	37.50	37.50	12.50	100
Total		Count	9	57	206	7	279
		%	3.23	20.43	73.84	2.51	100

<sup>a</sup> No, discovered this hazard after purchase. <sup>b</sup> No, not vulnerable to this hazard.

<sup>c</sup> No, even though they discovered this hazard when they bought it.

<sup>d</sup> Hurricane Risk Area 5 corresponds to the least vulnerable area except “No-Risk” Area whereas Hurricane Risk Area 1 corresponds to the most vulnerable area.

There are several principal conclusions to be drawn from Tables 8-6 through 8-9. First, there are no significant differences across levels of SEER for natural hazards in buyers’ tendency to lower their offers because of risk. Second, homeowners in areas of lower risk are less likely to recognize their vulnerability. Third, almost half of those in the highest and the second highest risk area fail to recognize their hurricane vulnerability.

In regard to reasons why SEERs and risk perceptions of the natural hazards had no effect on housing prices, another explanation is that the respondents tended to have little concern about the consequences of the two natural hazards. As specified in Chapter VII, the correlational analysis revealed that SEERs of floods and hurricanes were significantly related only to respondents’ perceived risk of property damage from a flood

( $r = 0.18$ ) and from a hurricane ( $r = 0.21$ ), but not related to injury and health problems from these hazards. Additionally, the respondents' perceptions of consequences resulting from floods and hurricanes increased gradually from injury, to health problems, and to property damage (see Tables 6-3, 6-4, and 6-5). These results suggest that the respondents perceived property damage to be the most significant risk from floods and hurricanes, but had little concern about injuries and health problems, presumably because these two natural hazards provide ample forewarning to allow people to protect their health and safety. Of course, forewarning provides little opportunity to reduce property damage significantly even though it can greatly reduce the risks of personal injury and health problems.

Finally, the absence of significant regression coefficients for hurricane and flood risk can be explained by the fact that the threat of extreme events may be offset by the attractiveness of normal conditions. Namely, people would regard a proximity to a river or a sea as a natural amenity rather than as a natural disamenity. By contrast, "normal" conditions for a chemical facility can produce low levels of chronic risk that result in adverse health effects from cumulative (rather than catastrophic) exposure.

In sum, housing prices tended to act according to the predictions of behavioral decision theory (Slovic et al., 1984) in connection with natural hazards. That is, people tend to act as if the probability of an extreme climatic event is zero, simply believing that it will not harm them or their property. This condition can occur when people have no information on hazards to which they are vulnerable, or if they feel optimistic about their hazard vulnerability. When these beliefs are salient, people who want to buy a house



tend to put a higher priority on the immediately obvious environmental amenities (e.g., a home's natural beauty), and ignore long-term disamenities such as natural hazards. In fact, according to a study that evaluated the effects of local floodplain regulations on property value, three out of four owners perceived no impact of a flood vulnerability on housing prices and only 9% of the owners expected that their home value would remain the same or decrease in the next five years (Bollens et al., 1988). These reasons may explain why the housing prices for these data were not influenced by SEERs and perceived risk of the natural hazards.

However, the SEER and perceived risk of hazardous materials was statistically significant, which is consistent with the fourth and fifth hypotheses. The effect of SEER and perceived risk of chemical hazard upon housing prices can be explained by the fact that people living near hazardous material facilities tend to have a higher concern about the consequences of chemical hazards than those of the natural hazards. Presumably, this is because they are given the cue for potential chemical disasters almost daily: chemical facilities with black smoke and flames coming out of smokestacks, or safety warning signs like "Keep Out", "Danger", and "Hazardous Material Zone" (Kim, 1996). Kim (1996) claimed that if a community has chemical facilities near residential areas and if local residents believe that the risk from these facilities influences the whole community, the community will be more likely to develop a technological disaster subculture (Weller & Wenger, 1972). The main characteristic of communities with technological disaster subcultures is a higher threat perception, which is especially likely to occur when the

threats from chemical facilities are so vivid that they are impossible to hide, as when there is a chemical mishap (Kim, 1996).

### 8.5. Implicit Prices of Property Value Determinants

As noted above, the coefficients from the hedonic price model can be interpreted as percents or the marginal implicit price in US dollars by using the equation in Table 8-10. The marginal implicit price was based on the mean of housing prices (\$142,125) in the sample.

**Table 8-10. Equation for calculating the marginal implicit price**

Model	Dependent Variable	Independent Variable	Coefficient As Percent	Coefficient As Implicit Price
Semi-log	Log (y)	x	$\% \Delta y = (100 * B_1) \Delta x$	$P \Delta y = (B_1 * P) \Delta x$

Note: P = Mean price of property value.

Source: Wooldridge (1999).

Table 8-11 shows marginal implicit price for each variable. For the structural characteristic variables, a 100 square foot increase in a land area would tend, on average, to result in a house price increase of \$85 ( $0.85 * 100$ ) or about 0.06%. A single year's increase in a house's age accounted for a decrease of \$1,381 in the average property value. The effect of living area on the property value was much higher than land area, accounting for \$5,103 ( $51.03 * 100$ ) for a 100 square foot increase in living area. The presence of a fireplace increased the average property value by approximately 11.8%.

For the locational variables, a one-mile increase in distance from the nearest airport contributed to an increased house price of \$1,276 or about 0.90% in the average

property value. Conversely, the property value decreased by \$4,439 for every one-mile increase in distance from CBD and \$6,612 for every one-mile increase in distance from the nearest park.

For neighborhood variables, a \$10,000 increase in neighborhood median household income contributed to a property value increase of about \$3,846. Also, the incremental value associated with to a 1% increase in White residents in a neighborhood was about \$1,088.

For the variables representing the submarket effects, houses that were in the city of Bellaire were, on average, \$46,064 more expensive than outside that city, whereas houses in the city of Cypress were, on average, \$29,928 less expensive.

Finally, it is notable that a one-mile increase in distance from the nearest TRI site would result in an increase in housing price by about \$5,362. Also, a unit increase in risk perception of a hazardous material would contribute to a housing price decline of \$4,541, about 3.19%. However, as indicated earlier, the SEERs of the natural hazards and hazard mitigation activities had no influence on the housing prices.

**Table 8-11. Implicit price for each variable**

Concept	Variable	Sig.	%	Dollars
	(Constant)	0.00**		
Structural characteristics	Land area	0.00**	0.0006	0.85
	House age	0.00**	-0.97	-1381
	Living area	0.00**	0.04	51
	Fire place	0.00**	11.79	16759
Locational characteristics	Distance to airport	0.02*	0.90	1276
	Distance to CBD	0.00**	-3.12	-4439
	Distance to park	0.03*	-4.65	-6612
Neighborhood characteristics	Household income	0.00**	0.0003	0.38
	Percent White	0.00**	0.77	1088
City	Baytown	0.97	0.28	404
	Bellaire	0.00**	32.41	46064
	Channelview	0.22	-18.36	-26098
	Crosby	0.55	-8.42	-11974
	Cypress	0.02*	-21.06	-29928
	Deer Park	0.30	-14.75	-20957
	Friendswood	0.21	-22.65	-32197
	Highlands	0.94	1.20	1701
	Humble	0.38	-7.82	-11110
	Katy	0.68	-3.84	-5453
	Kingwood	0.29	-18.35	-26085
	La Porte	0.35	-6.88	-9785
	Pasadena	0.98	-0.33	-473
	Seabrook	0.68	3.97	5643
	Spring	0.11	-12.41	-17633
Tomball	0.64	5.07	7211	
Hazard mitigation activities	Elevating HVAC systems	0.47	-3.20	-4554
	Elevating the house	0.67	2.38	3382
	Adding water proof wall	0.57	-3.16	-4498
	Reinforcing roof rafters	0.62	2.67	3796
	Reinforcing walls	0.91	-0.58	-822
	Installing storm shutters	0.14	12.16	17281
	Installing a generator	0.14	-6.92	-9841
	Purchasing flood insurance	0.16	4.31	6131
SEER	Floods	0.18	1.24	1756
	Hurricanes	0.83	0.35	495
	Hazardous materials	0.02*	3.77	5362
Risk perception	Floods	0.88	0.33	476
	Hurricanes	0.61	-1.20	-1708
	Hazardous materials	0.04*	-3.19	-4541

## **CHAPTER IX**

### **CONCLUSIONS**

#### **9.1. Introduction**

This research investigated the relationship between household characteristics, scientifically estimated environmental risks (SEERs), and environmental risk perceptions. Also this study tested the influences of SEERs, environmental risk perceptions, and hazard mitigation measures on housing prices. Household characteristics, environmental risk perceptions, and hazard mitigation measures were measured through a mail survey. SEER of floods was measured using FEMA's flood insurance rate map, whereas SEER of hurricanes were measured using Hazard Reduction & Recovery Center's hurricane risk area map, and SEER of hazardous material releases was measured using EPA's TRI data. The data were processed in a GIS to delineate the spatial distribution of risk from flood, hurricane, and hazardous material facilities. By overlapping each risk map onto the county parcel map, the level of environmental risk from each of these hazards could be assigned to each survey respondent's house. GIS techniques were also used to match housing units to spatial characteristics of locational variables (such as airports, parks, and CBD) and neighborhood variables (such as median household income and ethnic composition in the census block group). The relationships among these different types of variables were examined by means of statistical analyses such as correlational analyses, ANOVA, MANOVA, and hedonic price regression analyses. Correlational analyses were used

mainly to determine the relationship between respondents' household characteristics and SEER, and between respondents' household characteristics and their risk perceptions. ANOVA and MANOVA tests were used to see if there were any differences in the mean risks and risk perceptions of groups having different household characteristics. Finally, hedonic price regression analyses were used to investigate whether variables of SEER, perceived risk, and hazard mitigation measures were related to housing prices.

## **9.2. Research Findings and Conclusions**

### ***9.2.1. Household Characteristics and SEERs***

Previous research has found that people, regardless of their' race, age, and socio-economic status, tend to ignore their vulnerability to natural hazards (Drabek, 1986), and to choose their residence with little or no consideration of the presence of natural hazards. One fundamental reason for neglecting the risk from natural hazards is that people do not have enough knowledge on how hazardous their natural environment is (Covello, 1983). Meanwhile, other research has consistently documented significant relationships between household characteristics and environmental risk from technological hazards. For instance, empirical findings indicate that Afro-Americans, other minority groups, and low-income households are more likely to live in health-threatening environmental conditions (Bullard, 1990; Mohai & Bryant, 1992). Adeola (1994, 2000) also indicated that ethnicity (i.e., Blacks) was significantly related to households' proximity to hazardous waste dumpsites or petrochemical facilities in the Baton Rouge Standard Metropolitan Statistical Area, Louisiana. Another study found

that about 60% of Blacks and over 53% of Hispanics lived and worked in neighborhoods with one or more hazardous waste sites (Kriesel et al., 1996).

The first hypothesis of the present research is that scientifically estimated environmental risks (SEERs) of natural and technological hazards are related to household characteristics. This hypothesis is based upon findings from past research that the affluent tend to choose their home in communities with environmental amenities, whereas the poor tend to be limited to living in communities more vulnerable to environmental risk (Liu, 1996; Hamilton, 1995).

The results of this research showed that there were no statistically significant relationships between most of the household characteristics (age, ethnicity, gender, household size, marital status, tenure at the present home) and the SEERs of the two natural hazards (a flood and a hurricane). These results support Drabek's findings (1986) that people tend to underestimate or ignore natural hazards in selecting their residence regardless of age, sex, household size, marital status, and house tenure. Educational attainment and yearly household income were positively correlated with hurricane risk, but not with flood risk.

Consistent with the hypothesis, SEER of hazardous materials was correlated with all household characteristics such as age, educational attainment, household size, yearly household income, marital status, and tenure at present home. Specifically, those at greatest risk from chemical hazards are older, have lived longer in their communities, all less educated, have smaller households and lower incomes, and are unmarried. Lastly,

consistent with the findings of many previous studies, there were significant differences between Whites and Blacks for SEERs of hazardous material releases.

### ***9.2.2. Household Characteristics and Environmental Risk Perceptions***

Previous studies maintained that higher levels of public risk perceptions were found among females (Slovic, 1992; Savage, 1993), ethnic minorities (Adeola, 1994), less educated, and poorer people, (Pilisuk and Acredolo, 1988), younger people, and low-income groups (Savage, 1993). Thus, the second hypothesis of this research was that public risk perceptions of hurricanes, floods, and toxic chemical releases are related to household characteristics.

The results showed that there were no statistically significant relationships between some household characteristics (i.e., age, household size, marital status) and risk perception indicators addressing potential consequences of any occurrence resulting from a flood, hurricane, or hazardous material release. Thus, the results did not support Savage's findings (1993) that younger people had a higher level of risk perception. Partially consistent with the findings of Pilisuk & Acredolo (1988), educational attainment had a negative relationship with property damage from a hurricane (PDH), the injury from a hurricane (IJH), and property damage from a hazardous material release (PDHM). These results indicate that the higher the level of education, the lower the concern of PDF, IJH, and PDHM. Gender (male = 1) was negatively correlated, except for property damage from a flood, with all of the risk perception items. These correlations indicated that females had a higher level of perceived risk than did males,



which support the findings of Slovic (1992) and Savage (1993). Partly consistent with the result of Savage (1993), yearly household income was also negatively correlated with all risk perception attributes except for property damage from a flood (PDF) and injury from a flood (IJF). Blacks had a higher level of perceived risk of injury from a flood, health problems from a hurricane, property damage from a hazardous material, compared with Whites. Finally, tenure at present residence was positively related only to perceived damage from a hurricane, but not related to any risk perception indicators. It is noticeable that the persons with the longest duration of current residence had no higher threat perception of chemical hazards, even though they were most vulnerable to the level of chemical risk.

In sum, the results of this research showed little differences in risk perceptions of technological and natural hazards across groups with different household characteristics. Specifically, risk perceptions of the respondents did not differ by age, household size, and marital status. By contrast, educational level, gender, and yearly household income were negatively related to perceived risk of the natural hazards, whereas educational attainment and gender were negatively related to perceived risk of hazardous material releases. Persons who are White, more educated, male, and have higher income tended to have a lower concern about the consequences of the natural hazards, whereas persons who are more educated and male tended to have a lower concern about the consequences of technological hazards. Additionally, the results showed no apparent evidence that there existed a significant difference among different household characteristic groups

between their levels of risk perceptions of property damage and their levels of risk perceptions of injury and health problems.

### ***9.2.3. SEERs and Risk Perceptions***

Because disasters of floods, hurricanes, and hazardous material releases can result in effects including loss of life and property, health problems, and community disruption, people at risk of environmental hazards would be expected to have greater risk perceptions than those at no risk (Bullard, 1990; Maser & Solomon, 1990). Thus, the third hypothesis of this research is that SEERs of natural and technological hazards are related to risk perception of floods, hurricanes, and toxic chemical releases. The rationale for this hypothesis is that risk perception can be based upon scientific data released by public authorities that both are based upon environmental cues such as proximity to hazard sources – rivers, bays, and chemical plants (Drabek, 1986).

The results of this research demonstrated that SEER of floods was positively related to respondents' perception of property damage from a flood, but not related to injury or health problems from a flood. Also, SEER of hurricanes was related only to property damage from a hurricane, but not related to injury or health problems from a hurricane. These results suggest that environmental cues such as proximity to rivers and bays do not much contribute to an increase in the respondents' perception of safety and health problems resulting from natural hazards. The fact that there was a significant correlation with property damage suggests that risk area residents believe that they can protect themselves (e.g., by evacuating), but not their property.

Consistent with Hypothesis 3, SEER of hazardous materials was related to all three categories of risk perception of a hazardous material release; property damage, injury, and health problems from a hazardous material release. This result indicates that the higher the SEER of chemical hazard, the higher the risk perception associated with that hazard, suspecting that proximity to hazardous material facilities is an environmental cue that increases the level of respondents' perception of technological hazards.

#### ***9.2.4. SEERs, Risk Perceptions, Hazard Mitigation Measures, and Housing Prices***

Previous studies have maintained that SEERs and perceived risks are negatively related to housing prices, and that hazard mitigation measures are positively related to housing prices (Soule & Vaughan, 1973; Daminaos & Shabman, 1976; Muckleston, 1983). The results of this research showed that neither the SEERs of natural hazards (floods and hurricanes) nor risk perceptions of these hazards had impacts on housing prices. These results support the findings of previous studies that natural hazards do not affect housing prices (Muckleston, 1983; Schaffer, 1990; Zimmerman, 1979). Plausible reasons are that people tend to ignore the risk of these events (Babcock & Mitchell, 1981), and that the physical attractiveness of properties (trees, forests, rivers, streams, seas) tends to overshadow the negative aspects of the potential vulnerability to natural hazards (Bollens et al., 1988).

However, this research also revealed that the SEER of hazardous material releases and risk perceptions of this hazard were significant housing price determinants.

These results support the findings of previous studies that technological hazard influence housing prices (Clark & Neives, 1994; Dale et al., 1999; Gawande & Jenkins-Smith, 2001; McClelland et al., 1990; McCluskey & Rausser, 1999). Finally, none of the variables representing household hazard mitigation measures contributed to the explanation of housing prices. This finding is especially informative because none of the previous research studied the effects of household hazard mitigation measures upon housing prices.

In sum, findings from the natural hazards were consistent with behavioral decision theory (Slovic et al., 1984) which maintains that people tend to ignore vulnerability to natural hazards, whereas findings from hazardous materials were consistent with the notion of self-insurance theory (Ehrlich & Becker, 1972) which maintains that people are willing to offer more for a house with a lower probability of loss from environmental hazards. A plausible explanation that accounts for both sets of findings is that locations at risk of natural hazards tend to have characteristics of both amenity (e.g., proximity to water and natural view) and disamenity (e.g., risk), whereas locations at risk of technological hazards tend to have characteristics of disamenity only.

### **9.3. Contributions**

This research contributes to the literature in many ways. First, this research tests, for the first time, whether household characteristics are related to multiple environmental risks of floods, hurricanes and hazardous materials, as well as related to perceived risk of potential consequences from these hazards. The results show that household

characteristics have low correlations with SEER and perceived risk of natural hazards, but are significantly correlated with SEER of hazardous materials. It is notable that there is no significant correlation between household characteristics and perceived risk of hazardous materials except for educational attainment and gender.

Second, this research contributes to the literature on environmental hazards by examining the relationship between SEERs and public risk perceptions. This overcomes a major limitation of existing research, which has failed to examine the potential difference between scientifically estimated risk and perceived risk – in some case even using the scientifically estimated risk (i.e., distance from a hazardous facility to sampled houses) as a proxy for public risk perceptions in testing a relationship between environmental risk and housing prices (Clark et al., 1997). The finding that SEERs and perceived risks are consistently related for chemical hazard but not for flood or hurricane hazard shows that SEERs and risk perceptions are not equivalent.

Finally, this research has made a contribution by investigating the relationship between multiple hazards and housing prices. This research provides evidence that residents had very low levels of environmental concern about the potential effects of natural hazards and that vulnerability to natural hazards had no impact on housing prices. This finding partly explains the fact that despite continuing governmental expenditures on disaster prevention measures, economic losses from natural hazards have been rising than falling. In other words, people have little awareness of or concern about any adverse consequences of natural hazards. As a result, they consider only amenities such as structural, neighborhood, and locational attributes, and tend to build or purchase

residences in areas that are vulnerable to natural hazards such as earthquakes, floods and hurricanes (Turner et al., 1979; Bollens et al., 1988). The results of the present study are consistent with McPherson and Saarinen' (1977) findings that flood plain dwellers in Tucson, Arizona had no perception of the flood danger and tended to underestimate the potential damage from an extreme flood.

#### **9.4. Implications and Recommendations**

As specified in Chapter VIII, SEERs and perceived risk of the two natural hazards, with the exception of the chemical hazard, had no effect upon the housing price. To increase the public's hazard awareness of floods and hurricanes as well as reduce economic and life loss in case of natural disasters, governments should let prospective home buyers know, through a hazard disclosure statement, whether the residential property lies within areas subject to any types of natural hazards. If people are informed about natural hazard vulnerability, it is more likely that they will consider the level of environmental risk in selecting their residence and that offer a lower price for a house with a higher level of risk.

To generate this information, local governments should conduct community-wide hazard risk identification and vulnerability analyses including damage assessment. To that end, GIS technology should be utilized to develop digital maps showing areas at risk from various natural hazards, and these maps should be made available to the public. Additionally, risk areas vulnerable to natural hazards should be incorporated into community zoning maps and land use maps. Based upon these activities, governments

should formulate policies to prevent development in hazard-prone areas and to mitigate potential economic and environmental losses. At the same time, governments should continue to explain how vulnerable citizens' homes are to natural hazards, as well as what type of mitigation measures are appropriate. If people are provided with information on potential damage from natural hazards, the effects of the hazards can be reflected properly in housing prices and the likelihood of post-occupancy household mitigation activities can be increased to reduce future losses (Bollens et al., 1988).

Several areas of future research are suggested. First, this study indicated that minority groups, especially Blacks, had a disproportionate exposure to chemical risk. An old black woman wrote on her questionnaire that since she moved to her present residence, the number of chemical facilities increased in her surrounding area, the prices of nearby houses decreased, and some neighbors have had symptoms of health problems. The inequitable distribution of hazardous material facilities is an issue of the environmental justice (Liu, 1996; Yoon, 1996), which needs additional research to examine the process of hazardous material facilities' site selection. Such research can test whether facility owners target ethnic minorities, or whether they simply select sites adjacent to existing facilities where the land is cheap, or where the tax rate is low.

Second, future studies addressing relationships between housing prices and environmental hazards need to incorporate a variety of environmental and technological risks into hedonic price regression models in order to better improve the housing price model's explanatory power as well as to avoid potential specification biases. In that sense, this study has some limitation because it considers only the risk of three major

hazards (hurricanes, floods, chemical releases) due to some difficulty in obtaining relevant data. Therefore, effects of the other environmental risks (e.g., water and air pollution, Brownfield, and other locally unwanted land uses) remain uninvestigated. Additionally, it is recommended that future research test what types of chemical facilities are more likely to increase people's threat perception as well as to affect a house price.

Third, Shultz (1993) found the effects of open space amenities on housing prices for owner-occupied structures were different from their effects on rental housing prices. Therefore, future research can demonstrate whether housing price determinants (i.e., estimated and perceived environmental risk) are different among owner-occupied and rental housing.

### **9.5. Study Limitations**

There are several limitations related to this research. First, this research used assessed values of houses, instead of sales prices. The value assessed by the tax appraisal office tends to be lower than actual sale price, which would seem to suggest that the use of assessed values might weaken the findings of this research. However, the assessed value of a housing unit is estimated by the appraisers on the basis of recent sales of comparable neighboring homes so the difference is expected to be small. Even if there is a significant downward bias in the assessed values, this is expected to be relatively constant across all properties and would have no net effect on any of the regression weights.



Second, this research used FEMA's flood insurance rate map (FIRM) for Harris County, but this source needs updating mainly because these FIRMs were produced in the late 1970s and early 1980s. This old map may have some problems with its accuracy as follows (Jones et al., 1998; USGS, 2001):

- The original estimates, which were calculated on the basis of only a few decades of annual peak flow data, may not be enough to estimate accurately the 100- or 500-year floods,
- Flow estimates calculated for only one or a few locations on a stream may be inaccurate because flood flow is unique to any location on a stream and increases in the downstream direction, and
- Flood frequency estimates may change over time for various reasons, including change in land use or watershed, or an increase or decrease in the peak flow record since the flood maps developed.

However, error resulting from the use of the outdated data is not expected to cause any systematic bias, because this error does not make the measurement (i.e., levels of flood risk) shift in a predictable direction.

Third, this research utilized various GIS-based data. Even though GIS tools are very powerful, they are subject to different types of accuracy and precision problems simply because digital maps reflect only the scientific estimates of facts, but not necessarily real facts on the ground. Accuracy in GIS data "refers to the relationship between measurement and the reality it purports to represent, whereas precision refers to the degree of detail in the reporting of a measurement in arithmetic calculation"

(Goodchild, 1993, p. 94). These problems can be introduced when GIS users digitize, convert, and overlay data. Additionally, the accuracy of data depends upon human errors and the technology including GIS applications and measuring devices available at the time the data were made (Goodchild, 1993). However, it is difficult, time-consuming, and costly to validate data accuracy. Moreover, errors introduced at the development stage of data might not be found unless the data providers have information on data quality available to the public. In housing price research, GIS is generally used to measure distance and assign some estimates (e.g., income, educational attainment at the neighborhood level) to properties of interest. It does not seem that the process in these analyses distorts the study results. For instance, Sirpal (1994) found that different sizes of shopping centers had influenced housing prices of residential housing units in a radial fashion for several miles. This finding suggests that errors of a few meters in this study would not bias the results.

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**APPENDIXES**

## Appendix 1: Institutional Review Board (IRB) approval letter



Office of Research Compliance

October 2, 2002

Administration and  
Special Programs

Academy for  
Advanced  
Telecommunication  
and Learning  
Technologies

Institute for  
Scientific Computation

Laboratory Animal  
Resources and Research

Microscopy and  
Imaging Center

Office of  
Business Administration

Office of Graduate Studies

Office of Sponsored Projects

Texas A&M University  
Research Park



Texas A&M  
University

1112 TAMU

318 Administration Building

College Station, Texas

77843-1112

979.845.8585

FAX 979.862.3176

### MEMORANDUM

**TO:** Seonn-Nam Hwang  
Landscape Architecture and Urban Planning  
MS 3137

**SUBJECT:** Environmental Amenities and Disamenities, and Housing Prices:  
Using GIS Techniques  
2002-480

**Approval Date:** October 2, 2002 to October 1, 2003

The Institutional Review Board – Human Subjects in Research, Texas A&M University has reviewed and approved the above referenced protocol. Your study has been approved for one year. As the principal investigator of this study, you assume the following responsibilities:

**Renewal:** Your protocol must be re-approved each year in order to continue the research. You must also complete the proper renewal forms in order to continue the study after the initial approval period.

**Adverse events:** Any adverse events or reactions must be reported to the IRB immediately.

**Amendments:** Any changes to the protocol, such as procedures, consent/assent forms, addition of subjects, or study design must be reported to and approved by the IRB.

**Informed Consent/Assent:** All subjects should be given a copy of the consent document approved by the IRB for use in your study.

**Completion:** When the study is complete, you must notify the IRB office and complete the required forms.

Dr. E. Murl Bailey, Chair  
Institutional Review Board –  
Human Subjects in Research

**Appendix 2: Mail survey cover letter**

TEXAS A&M UNIVERSITY  
 College of Architecture  
 Landscape Architecture and Urban Planning

*September 15, 2002*

Dear Residents:

Harris County, the third largest county in the United States, continues to experience strong growth, so it is critical that the community develop in ways that are more sustainable and sensitive to residents' needs. This study will investigate how environmental disamenities (such as natural and technological hazards) and neighborhood amenities are related to people's satisfaction with their homes and neighborhoods. It will also document what actions residents are taking in order to reduce or prevent any losses resulting from potential hazards. Your contribution to this effort will help us to understand ways to build a disaster-resistant community.

You are one of a small number whom we have selected, using a scientific random process, to provide their opinions on these issues. We hope you will participate in our study, which will take approximately 10 minutes of your time. For the results to truly represent the thinking of the residents of Harris County, it is important that each questionnaire be completed and returned on time.

In order to ensure anonymity, no names will be used on the questionnaire. Instead, there is an identification number that is used for mailing purposes only. This is so that we can remove your name from the mailing list when you return your survey packet. There are no risks associated with your participation and you may refuse to answer any question that makes you feel uncomfortable.

This research has been reviewed and approved by the Institutional Review Board- Human Subjects in Research, Texas A&M University. For research-related problems or questions regarding subjects' rights, you can contact the Institutional Review Board through Dr. Michael W. Buckley, Director of Support Services, Office of the Vice President for Research at (979) 458-4067.

We thank you in advance for investing your valuable time in this study. Please return the survey in the enclosed business reply envelope as soon as possible. If you want to receive a summary of the results of this study, please write, "study results requested" on the back of the return envelope.

If you have any questions, feel free to contact us. Thank you for your help.

Best wishes,

**Seong-Nam Hwang, Ph. D. Candidate**  
 Hazard Reduction & Recovery Center  
 Landscape Architecture and Urban Planning  
 Texas A&M University, 3137 TAMU  
 College Station, TX 77843-3137  
 Phone: (979) 845-1010 Fax: 845-5121  
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**Michael Lindell, Ph.D.**  
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 Web Site: <http://hrrc.tamu.edu/>

### Appendix 3. Survey instrument

## Environmental Amenities and Disamenities in Harris County, Texas

This survey is to better understand how Harris County residents feel about environmental amenities and disamenities. Please answer all of the questions. If you have suggestions on any questions, please feel free to use the space in the margins. Thank you for your participation.



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## Appendix 3. (continued)



### Risk Perception and Hazard Mitigation Measures

	Yes	No
1. Is any of the following statements true about your experience with <i>floods</i> ?		
a. Your immediate family's property has been damaged.....	<input type="checkbox"/>	<input type="checkbox"/>
b. You or an immediate family member has been injured.....	<input type="checkbox"/>	<input type="checkbox"/>
c. Property of a friend, relative, neighbor, or coworker you know personally has been damaged.....	<input type="checkbox"/>	<input type="checkbox"/>
d. A friend, relative, neighbor, or coworker you know personally has been injured.....	<input type="checkbox"/>	<input type="checkbox"/>
2. Is any of the following statements true about your experience with <i>hurricanes</i> ?		
a. Your immediate family's property has been damaged.....	<input type="checkbox"/>	<input type="checkbox"/>
b. You or an immediate family member has been injured.....	<input type="checkbox"/>	<input type="checkbox"/>
c. Property of a friend, relative, neighbor, or coworker you know personally has been damaged.....	<input type="checkbox"/>	<input type="checkbox"/>
d. A friend, relative, neighbor, or coworker you know personally has been injured.....	<input type="checkbox"/>	<input type="checkbox"/>
3. Is any of the following statements true about your experience with <i>hazardous material releases</i> ?		
a. You or an immediate family member has been injured.....	<input type="checkbox"/>	<input type="checkbox"/>
b. A friend, relative, neighbor, or coworker you know personally has been injured.....	<input type="checkbox"/>	<input type="checkbox"/>
4. How likely do you think it is that in the next 10 years there will be a <i>flood</i> that will cause...	<i>Not at all likely</i>	<i>Almost a certainty</i>
a. Major damage to your home.....	1 2 3	4 5
b. Injury to you or members of your household.....	1 2 3	4 5
c. Health problems to you or members of your household.....	1 2 3	4 5
5. How likely do you think it is that in the next 10 years there will be a <i>hurricane</i> that will cause...	<i>Not at all likely</i>	<i>Almost a certainty</i>
a. Major damage to your home.....	1 2 3	4 5
b. Injury to you or members of your household.....	1 2 3	4 5
c. Health problems to you or members of your household.....	1 2 3	4 5
6. How likely do you think it is that in the next 10 years there will be a <i>hazardous material release</i> that will cause...	<i>Not at all likely</i>	<i>Almost a certainty</i>
a. Major damage to your home.....	1 2 3	4 5
b. Injury to you or members of your household.....	1 2 3	4 5
c. Health problems to you or members of your household.....	1 2 3	4 5
7. To what extent have you relied on each following sources in deciding how much you are at risk from environmental hazards?	<i>Not at all</i>	<i>To a very great extent</i>
a. Local newspapers.....	1 2 3	4 5
b. Local radio stations.....	1 2 3	4 5
c. Local television stations.....	1 2 3	4 5
d. National television.....	1 2 3	4 5
e. The Internet.....	1 2 3	4 5
f. Friends, relatives, neighbors, and coworkers.....	1 2 3	4 5
g. Local authorities.....	1 2 3	4 5

## Appendix 3. (continued)

8. Have you done any of the following for your home?	Yes	No
a. Raised heating, ventilating, and cooling equipment above flood level.....	<input type="checkbox"/>	<input type="checkbox"/>
b. Raised electrical system components above flood level.....	<input type="checkbox"/>	<input type="checkbox"/>
c. Raised the house above flood level.....	<input type="checkbox"/>	<input type="checkbox"/>
d. Added waterproof veneer to exterior walls.....	<input type="checkbox"/>	<input type="checkbox"/>
e. Reinforced roof rafters against high winds.....	<input type="checkbox"/>	<input type="checkbox"/>
f. Reinforced doors to the house and garage.....	<input type="checkbox"/>	<input type="checkbox"/>
g. Purchased materials for temporary storm shutters.....	<input type="checkbox"/>	<input type="checkbox"/>
h. Installed permanent storm shutters.....	<input type="checkbox"/>	<input type="checkbox"/>
i. Bought an electric generator.....	<input type="checkbox"/>	<input type="checkbox"/>
j. Purchased flood insurance.....	<input type="checkbox"/>	<input type="checkbox"/>



### Neighborhood Environment and Residential Satisfaction

9. To what extent did you consider each of the following when you chose your home?	<i>Not at all</i>			<i>To a very great extent</i>	
a. Proximity to your or any of your family members' work place.....	1	2	3	4	5
b. Proximity to your or any of your family members' school.....	1	2	3	4	5
c. Proximity to public services (such as fire, police and hospitals).....	1	2	3	4	5
d. Proximity to shopping facilities.....	1	2	3	4	5
e. Proximity to public parks.....	1	2	3	4	5
f. Proximity to wood lands.....	1	2	3	4	5
g. Proximity to water body.....	1	2	3	4	5
h. Safety from floods.....	1	2	3	4	5
i. Safety from hurricanes.....	1	2	3	4	5
j. Safety from hazardous material releases.....	1	2	3	4	5
k. Safety from environmental pollution.....	1	2	3	4	5
l. Safety from crime.....	1	2	3	4	5
m. Profit from future sale.....	1	2	3	4	5

10. How satisfied are you now with the following in your home and neighborhood?	<i>Not at all</i>			<i>Very much</i>	
a. Proximity to your or any of your family members' work place.....	1	2	3	4	5
b. Proximity to your or any of your family members' school.....	1	2	3	4	5
c. Proximity to public services (such as fire, police and hospitals).....	1	2	3	4	5
d. Proximity to shopping facilities.....	1	2	3	4	5
e. Proximity to public parks.....	1	2	3	4	5
f. Proximity to wood lands.....	1	2	3	4	5
g. Proximity to water body.....	1	2	3	4	5
h. Safety from floods.....	1	2	3	4	5
i. Safety from hurricanes.....	1	2	3	4	5
j. Safety from hazardous material releases.....	1	2	3	4	5
k. Safety from environmental pollution.....	1	2	3	4	5
l. Safety from crime.....	1	2	3	4	5
m. Profit from future sale.....	1	2	3	4	5

## Appendix 3. (continued)

11. How important would each of the following be in deciding whether you move from your present home in the next 5 years?	<i>Not at all</i>				<i>Very important</i>
a. Flood risk.....	1	2	3	4	5
b. Hurricane risk.....	1	2	3	4	5
c. Hazardous material release risk.....	1	2	3	4	5
d. Others (please specify).....	1	2	3	4	5

### Background Information



12. How many years have you lived in your current residence?

\_\_\_\_\_ Years \_\_\_\_\_ Months

13. How soon are you planning to move out of your current residence?

- ① 0 - 2½ years    ② 2½ - 5 years    ③ 5 - 7½ years    ④ 7½ - 10 years    ⑤ More than 10 years

14. Please indicate your:

a. Occupation: \_\_\_\_\_    b. Age: \_\_\_\_\_ Years    c. Gender: ① Male    ② Female

d. Ethnic/Racial identity:

- ① African American    ② Caucasian    ③ Hispanic    ④ Asian/Pacific Islander    ⑤ Other (            )

15. Number of people currently living with you.

- a. \_\_\_\_: Under 6 years old    b. \_\_\_\_: between 6 and 18 years old  
c. \_\_\_\_: Between 19 and 64 years old    d. \_\_\_\_: 65 years old and over

16. Your marital status.

- ① Married    ② Single (Never married)    ③ Divorced    ④ Widowed

17. Do you own or rent the home where you now live?

- ① Own    ② Rent (Please go to 19)    ③ Other (Please go to 19)

18. Did you offer a lower price for your home when you bought because of any of the following hazards?

	<i>Yes</i>	<i>No, discovered this hazard after purchase</i>	<i>No, not vulnerable to this hazard</i>
a. Flood risk.....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
b. Hurricane risk.....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
c. Hazardous material release risk.....	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

19. Your highest level of education.

- ① Less than high school    ② High school/ GED    ③ Some college/ vocational school  
④ College graduate    ⑤ Graduate/ professional school

20. Your yearly household income before taxes last year.

- ① Less than \$14,000    ② \$14,000 – \$23,999    ③ \$24,000 – \$34,999  
④ \$35,000 – \$49,999    ⑤ \$50,000 – \$70,000    ⑥ \$70,000 – \$100,000    ⑦ Over \$100,000

**Thank you for your participation. Your answer will be treated confidentially.**

**Please return your completed questionnaire in the pre-addressed, postage-paid envelope provided.**

**Appendix 4. Descriptive characteristics of scientifically estimated environmental risk (SEER) of floods, hurricanes, and hazardous materials by age group**

Variable	Age Group	N	Mean	Std. Deviation	Std. Error
Flood risk	20s to 30s	52	0.38	1.19	0.17
	40s	92	0.87	1.66	0.17
	50s	82	1.02	1.85	0.20
	Over 60s	79	0.87	1.79	0.20
	Total	305	0.83	1.69	0.10
Hurricane risk	20s to 30s	52	0.87	1.52	0.21
	40s	92	0.85	1.64	0.17
	50s	82	0.79	1.4	0.15
	Over 60s	79	0.81	1.52	0.17
	Total	305	0.83	1.52	0.09
Chemical risk	20s to 30s	52	2.35	1.64	0.23
	40s	92	2.44	1.32	0.14
	50s	82	2.39	1.45	0.16
	Over 60s	79	1.89	1.29	0.15
	Total	305	2.27	1.42	0.08

**Appendix 5. ANOVA test: SEER among age groups**

Variable		Sum of Squares	df	Mean Square	F	Sig.
Flood risk	Between Groups	13.71	3	4.57	1.62	0.18
	Within Groups	849.43	301	2.82		
	Total	863.13	304			
Hurricane risk	Between Groups	0.24	3	0.08	0.03	0.99
	Within Groups	701.55	301	2.33		
	Total	701.79	304			
Chemical risk	Between Groups	15.39	3	5.13	2.59	0.05*
	Within Groups	595.56	301	1.98		
	Total	610.94	304			



**Appendix 6. Multiple comparisons by Tukey's HSD: SEER of hazardous materials among age groups**

Variable	(I) Age <sup>a</sup>	(J) Age	Mean Difference (I-J)	Std. Error	Sig.
Chemical risk	1	2	-0.08	0.24	0.99
		3	-0.04	0.25	1.00
		4	0.46	0.25	0.26
	2	1	0.08	0.24	0.99
		3	0.05	0.21	1.00
		4	0.54	0.22	0.06
	3	1	0.04	0.25	1.00
		2	-0.05	0.21	1.00
		4	0.50	0.22	0.11
	4	1	-0.46	0.25	0.26
		2	-0.54	0.22	0.06
		3	-0.50	0.22	0.11

<sup>a</sup> Age category: 1)20s to 30s; 2) 40s; 3) 50s; 4)over 60s.

**Appendix 7. Descriptive characteristics of SEER by group with different educational level**

Variable	Educational Group	N	Mean	Std. Deviation	Std. Error
Flood risk	LTHS <sup>a</sup>	10	1.00	2.11	0.67
	HS <sup>b</sup>	43	1.02	1.95	0.30
	SC <sup>c</sup>	90	0.86	1.81	0.19
	CG <sup>d</sup>	94	0.55	1.32	0.14
	GS <sup>e</sup>	78	1.05	1.75	0.20
	Total	315	0.84	1.69	0.10
Hurricane risk	LTHS	10	0.60	1.35	0.43
	HS	43	0.63	1.31	0.20
	SC	90	0.67	1.32	0.14
	CG	94	0.79	1.45	0.15
	GS	78	1.19	1.89	0.21
	Total	315	0.83	1.52	0.09
Chemical risk	LTHS	10	1.06	0.53	0.17
	HS	43	1.92	1.45	0.22
	SC	90	2.15	1.31	0.14
	CG	94	2.69	1.48	0.15
	GS	78	2.24	1.37	0.16
	Total	315	2.27	1.42	0.08

<sup>a</sup> Less than high school. <sup>b</sup> High school. <sup>c</sup> Some college education. <sup>d</sup> College graduate. <sup>e</sup> Graduate school.

**Appendix 8. ANOVA test: SEER among groups with different educational attainments**

Variable		Sum of Squares	df	Mean Square	F	Sig.
Flood risk	Between Groups	12.94	4	3.23	1.13	0.34
	Within Groups	889.13	310	2.87		
	Total	902.06	314			
Hurricane risk	Between Groups	15.09	4	3.77	1.64	0.16
	Within Groups	714.31	310	2.30		
	Total	729.40	314			
Chemical risk	Between Groups	37.81	4	9.45	4.95	0.00**
	Within Groups	591.69	310	1.91		
	Total	629.51	314			

**Appendix 9. Multiple comparisons by Tukey's HSD: SEER of hazardous materials among groups with different educational attainments**

Variable	(I) EDU <sup>a</sup>	(J) EDU	Mean Difference		Sig.
			(I-J)	Std. Error	
Chemical risk	1	2	-0.86	0.49	0.39
		3	-1.08	0.46	0.13
		4	-1.63	0.46	0.00**
		5	-1.18	0.46	0.09
	2	1	0.86	0.49	0.39
		3	-0.22	0.26	0.91
		4	-0.77	0.25	0.02*
		5	-0.32	0.26	0.75
	3	1	1.08	0.46	0.13
		2	0.22	0.26	0.91
		4	-0.55	0.20	0.06
		5	-0.10	0.21	0.99
	4	1	1.63	0.46	0.00**
		2	0.77	0.25	0.02*
		3	0.55	0.20	0.06
5		0.45	0.21	0.21	
5	1	1.18	0.46	0.09	
	2	0.32	0.26	0.75	
	3	0.10	0.21	0.99	
	4	-0.45	0.21	0.21	

<sup>a</sup> Educational attainment: 1) Less than high school education; 2) High school diplomas; 3) Some college education; 4) College degrees; 5) Graduate school.

**Appendix 10. Descriptive characteristics of SEER by ethnic group**

Variable	Ethnic group	N	Mean	Std. Deviation	Std. Error
Flood risk (FR)	Black	28	1.46	2.28	0.43
	White	212	0.73	1.57	0.11
	Hispanic	34	0.74	1.62	0.28
	Asian	16	0.94	1.65	0.41
	Other <sup>a</sup>	13	0.85	1.86	0.52
	Total	303	0.81	1.67	0.10
Hurricane risk (HR)	Black	28	0.54	1.40	0.27
	White	212	0.94	1.61	0.11
	Hispanic	34	0.26	0.83	0.14
	Asian	16	0.44	0.89	0.22
	Other <sup>a</sup>	13	0.92	1.50	0.42
	Total	303	0.80	1.50	0.09
Chemical risk	Black	28	1.62	0.97	0.18
	White	212	2.38	1.48	0.10
	Hispanic	34	2.06	1.30	0.22
	Asian	16	2.42	0.94	0.24
	Other <sup>a</sup>	13	2.22	1.73	0.48
	Total	303	2.27	1.42	0.08

<sup>a</sup> includes American Indians and persons who declined to report their ethnicity.

**Appendix 11. ANOVA test: SEER among ethnic groups**

Variable		Sum of Squares	df	Mean Square	F	Sig.
Flood risk	Between Groups	13.92	3	4.64	1.68	0.17
	Within Groups	790.65	286	2.76		
	Total	804.57	289			
Hurricane risk	Between Groups	17.86	3	5.95	2.68	0.05
	Within Groups	635.72	286	2.22		
	Total	653.59	289			
Chemical risk	Between Groups	16.52	3	5.51	2.82	0.04*
	Within Groups	557.73	286	1.95		
	Total	574.25	289			

**Appendix 12. Multiple comparisons by Tukey's HSD: SEER of hazardous materials among ethnic groups**

Variable	(I) Ethnicity	(J) Ethnicity	Mean Difference (I-J)	Std. Error	Sig.
Chemical risk	1	2	-0.77	0.28	0.03*
		3	-0.44	0.36	0.60
		4	-0.81	0.44	0.26
	2	1	0.77	0.28	0.03*
		3	0.32	0.26	0.59
		4	-0.04	0.36	1.00
	3	1	0.44	0.36	0.60
		2	-0.32	0.26	0.59
		4	-0.36	0.42	0.82
	4	1	0.81	0.44	0.26
		2	0.04	0.36	1.00
		3	0.36	0.42	0.82

**Appendix 13. Descriptive characteristics of SEER by household size**

Variable	Household Size <sup>a</sup>	N	Mean	Std. Deviation	Std. Error
Flood risk	1	49	0.88	1.74	0.25
	2	116	0.81	1.71	0.16
	3	66	0.83	1.71	0.21
	4	49	0.71	1.51	0.22
	5	41	1.05	1.86	0.29
	Total	321	0.84	1.70	0.09
Hurricane risk	1	49	1.31	1.94	0.28
	2	116	0.86	1.48	0.14
	3	66	0.64	1.30	0.16
	4	49	0.67	1.46	0.21
	5	41	0.71	1.54	0.24
	Total	321	0.83	1.54	0.09
Chemical risk	1	49	2.01	1.30	0.19
	2	116	2.05	1.30	0.12
	3	66	2.61	1.57	0.19
	4	49	2.39	1.43	0.20
	5	41	2.40	1.45	0.23
	Total	321	2.26	1.41	0.08

**Appendix 14. ANOVA test: SEER among groups with different household size**

		Sum of Squares	df	Mean Square	F	Sig.
Flood risk	Between Groups	2.74	4	0.68	0.23	0.92
	Within Groups	920.16	316	2.91		
	Total	922.90	320			
Hurricane risk	Between Groups	15.51	4	3.88	1.66	0.16
	Within Groups	738.74	316	2.34		
	Total	754.25	320			
Chemical risk	Between Groups	17.67	4	4.42	2.25	0.06
	Within Groups	619.98	316	1.96		
	Total	637.65	320			

**Appendix 15. Descriptive characteristics of SEER by group with different yearly household incomes**

Variable	Income Group <sup>a</sup>	N	Mean	Std. Deviation	Std. Error
Flood risk	1	6	0.17	0.41	0.17
	2	19	0.58	1.57	0.36
	3	28	0.96	1.93	0.37
	4	24	0.75	1.67	0.34
	5	57	0.95	1.81	0.24
	6	73	0.59	1.48	0.17
	7	72	0.93	1.70	0.20
	Total	279	0.79	1.66	0.10
Hurricane risk	1	6	0.33	0.82	0.33
	2	19	0.37	1.21	0.28
	3	28	0.71	1.24	0.23
	4	24	0.46	1.14	0.23
	5	57	0.67	1.39	0.18
	6	73	1.11	1.72	0.20
	7	72	1.00	1.71	0.20
	Total	279	0.83	1.53	0.09
Chemical risk	1	6	1.66	2.00	0.82
	2	19	1.76	1.16	0.27
	3	28	1.74	1.38	0.26
	4	24	1.92	1.36	0.28
	5	57	2.15	1.22	0.16
	6	73	2.50	1.41	0.16
	7	72	2.72	1.58	0.19
	Total	279	2.29	1.44	0.09

<sup>a</sup> Yearly house income: 1) Less than \$14,000; 2) \$14,000-\$23,999; 3) \$24,000-\$34,999; 4) \$35,000-\$49,999; 5) \$50,000-\$69,999; 6) \$70,000-\$100,000; 7) Over \$100,000.

**Appendix 16. ANOVA test: SEER among groups with different yearly household incomes**

Variable		Sum of Squares	df	Mean Square	F	Sig.
Flood risk	Between Groups	9.85	6	1.64	0.59	0.74
	Within Groups	756.10	272	2.78		
	Total	765.94	278			
Hurricane risk	Between Groups	18.52	6	3.09	1.33	0.24
	Within Groups	631.22	272	2.32		
	Total	649.74	278			
Chemical risk	Between Groups	36.80	6	6.13	3.09	0.01*
	Within Groups	540.16	272	1.99		
	Total	576.96	278			

**Appendix 17. Multiple comparisons by Tukey's HSD: SEER of chemical hazard among groups with different yearly household incomes**

(i) Income	(j) Income	Mean difference (i-j)	Std. Error	Sig.
1	2	-0.10	0.66	1.00
	3	-0.08	0.63	1.00
	4	-0.25	0.64	1.00
	5	-0.49	0.60	0.98
	6	-0.83	0.60	0.80
	7	-1.06	0.60	0.57
2	1	0.10	0.66	1.00
	3	0.02	0.42	1.00
	4	-0.15	0.43	1.00
	5	-0.38	0.37	0.95
	6	-0.73	0.36	0.41
	7	-0.95	0.36	0.12
3	1	0.08	0.63	1.00
	2	-0.02	0.42	1.00
	4	-0.18	0.39	1.00
	5	-0.41	0.33	0.87
	6	-0.76	0.31	0.20
	7	-0.98	0.31	0.03*
4	1	0.25	0.64	1.00
	2	0.15	0.43	1.00
	3	0.18	0.39	1.00
	5	-0.23	0.34	0.99
	6	-0.58	0.33	0.58
	7	-0.80	0.33	0.20
5	1	0.49	0.60	0.98
	2	0.38	0.37	0.95
	3	0.41	0.33	0.87
	4	0.23	0.34	0.99
	6	-0.35	0.25	0.80
	7	-0.57	0.25	0.26
6	1	0.83	0.60	0.80
	2	0.73	0.36	0.41
	3	0.76	0.31	0.20
	4	0.58	0.33	0.58
	5	0.35	0.25	0.80
	7	-0.22	0.23	0.97
7	1	1.06	0.60	0.57
	2	0.95	0.36	0.12
	3	0.98	0.31	0.03*
	4	0.80	0.33	0.20
	5	0.57	0.25	0.26
	6	0.22	0.23	0.97

**Appendix 18. Descriptive characteristics of SEER by tenure**

Variable	Tenure Group <sup>a</sup>	N	Mean	Std. Deviation	Std. Error
Flood risk	1	103	0.63	1.48	0.15
	2	64	0.69	1.46	0.18
	3	42	0.86	1.75	0.27
	4	31	0.97	1.83	0.33
	5	77	1.23	2.04	0.23
	Total	317	0.85	1.71	0.10
Hurricane risk	1	103	0.83	1.56	0.15
	2	64	0.78	1.52	0.19
	3	42	0.81	1.50	0.23
	4	31	0.61	1.38	0.25
	5	77	1.04	1.64	0.19
	Total	317	0.85	1.54	0.09
Chemical risk	1	103	2.60	1.53	0.15
	2	64	2.47	1.31	0.16
	3	42	2.40	1.39	0.21
	4	31	1.96	1.40	0.25
	5	77	1.70	1.16	0.13
	Total	317	2.27	1.41	0.08

<sup>a</sup> Tenure at present home: 1) 0- 4.99 years; 2) 5-9.99 years; 3) 10-14.99 years; 4) 15-19.99 years; 5) Over 20 years.

**Appendix 19. ANOVA test: SEERs among tenure groups**

Variable		Sum of Squares	df	Mean Square	F	Sig.
Flood risk	Between Groups	18.40	4	4.60	1.59	0.18
	Within Groups	901.63	312	2.89		
	Total	920.03	316			
Hurricane risk	Between Groups	4.92	4	1.23	0.51	0.73
	Within Groups	746.51	312	2.39		
	Total	751.43	316			
Chemical risk	Between Groups	42.28	4	10.57	5.62	0.00**
	Within Groups	587.00	312	1.88		
	Total	629.28	316			



**Appendix 20. Multiple comparisons by Tukey's HSD: Chemical risk among tenure groups**

Variable	(I) Tenure	(J) Tenure	Mean Difference (I-J)	Std. Error	Sig.
Chemical risk	1	2	0.13	0.22	0.97
		3	0.20	0.25	0.93
		4	0.64	0.28	0.15
		5	0.90	0.21	0.00**
	2	1	-0.13	0.22	0.97
		3	0.07	0.27	1.00
		4	0.51	0.30	0.44
		5	0.77	0.23	0.01*
	3	1	-0.20	0.25	0.93
		2	-0.07	0.27	1.00
		4	0.44	0.32	0.66
		5	0.69	0.26	0.07
	4	1	-0.64	0.28	0.15
		2	-0.51	0.30	0.44
		3	-0.44	0.32	0.66
		5	0.26	0.29	0.90
	5	1	-0.90	0.21	0.00**
		2	-0.77	0.23	0.01*
		3	-0.69	0.26	0.07
		4	-0.26	0.29	0.90

**Appendix 21. Descriptive characteristics of risk Perception by age group**

Variable	Measure	Acronym	Group	N	Mean	Std. Deviation	Std. Error
Risk perception of a flood	Property damage	PDF	20s to 30s	52	2.44	1.27	0.18
			40s	92	2.61	1.05	0.11
			50s	82	2.50	1.23	0.14
			Over 60s	79	2.63	1.23	0.14
			Total	305	2.56	1.18	0.07
	Injury	IJF	20s to 30s	52	1.88	1.00	0.14
			40s	92	2.03	0.91	0.09
			50s	81	1.85	0.96	0.11
			Over 60s	77	1.79	0.86	0.10
			Total	302	1.90	0.93	0.05
Risk perception of a hurricane	Health problems	HPF	20s to 30s	52	2.13	1.21	0.17
			40s	92	2.25	1.04	0.11
			50s	81	2.20	1.20	0.13
			Over 60s	77	2.23	1.18	0.13
			Total	302	2.21	1.14	0.07
	Property damage	PDH	20s to 30s	52	2.73	1.03	0.14
			40s	92	3.00	1.02	0.11
			50s	82	3.06	1.21	0.13
			Over 60s	76	3.16	1.14	0.13
			Total	302	3.01	1.11	0.06
	Injury	IJH	20s to 30s	52	2.21	0.98	0.14
			40s	92	2.35	0.88	0.09
			50s	81	2.23	0.99	0.11
			Over 60s	76	2.32	1.05	0.12
			Total	301	2.29	0.97	0.06
	Health problems	HPH	20s to 30s	52	2.17	1.08	0.15
			40s	92	2.27	1.00	0.10
			50s	81	2.23	1.02	0.11
			Over 60s	76	2.43	1.16	0.13
			Total	301	2.29	1.06	0.06
Risk perception of a hazardous material release	Property damage	PDHM	20s to 30s	52	2.02	1.04	0.14
			40s	92	2.13	0.97	0.10
			50s	81	2.05	1.08	0.12
			Over 60s	79	2.18	1.22	0.14
			Total	304	2.10	1.08	0.06
	Injury	IJHM	20s to 30s	52	2.15	1.09	0.15
			40s	92	2.35	1.05	0.11
			50s	81	2.17	1.09	0.12
			Over 60s	79	2.25	1.22	0.14
			Total	304	2.24	1.11	0.06
	Health problems	HPHM	20s to 30s	52	2.33	1.13	0.16
			40s	92	2.49	1.06	0.11
			50s	81	2.43	1.22	0.14
			Over 60s	79	2.43	1.31	0.15
			Total	304	2.43	1.18	0.07

**Appendix 22. Multivariate test: Perceived risk of floods among age groups**

Effect	Value	Hypothesis		Error df	Sig.
		F	df		
Intercept	Wilks' Lambda	0.15	3	295	0.00
AGE	Wilks' Lambda	0.97	9	718	0.56

**Appendix 23. Multivariate test: Perceived risk of hurricanes among age groups**

Effect	Value	Hypothesis		Error df	Sig.
		F	df		
Intercept	Wilks' Lambda	0.10	6	291	0.00
AGE	Wilks' Lambda	0.95	18	824	0.70

**Appendix 24. Multivariate test: Perceived risk of hazardous materials among age groups**

Effect	Value	Hypothesis		Error df	Sig.
		F	df		
Intercept	Wilks' Lambda	0.18	3	298	0.00
AGE	Wilks' Lambda	0.98	9	725	0.83

**Appendix 25. Descriptive characteristics of risk perception by groups with different levels of educational attainment**

Variable	Measure	Acronym	Group	N	Mean	Std. Deviation	Std. Error
Risk perception of a flood	Property damage	PDF	LTHS	10	3.30	1.70	0.54
			HS	43	2.77	1.27	0.19
			SC	90	2.71	1.14	0.12
			CG	94	2.34	1.11	0.11
			GS	78	2.45	1.17	0.13
			Total	315	2.56	1.19	0.07
	Injury	IJF	LTHS	10	2.40	1.58	0.50
			HS	42	2.00	0.96	0.15
			SC	89	1.98	0.93	0.10
			CG	93	1.73	0.81	0.08
			GS	78	1.87	0.90	0.10
			Total	312	1.89	0.92	0.05
	Health problems	HPF	LTHS	9	2.44	1.67	0.56
			HS	42	2.43	1.27	0.20
			SC	90	2.28	1.16	0.12
CG			93	1.99	1.05	0.11	
GS			78	2.26	1.11	0.13	
Total			312	2.21	1.15	0.07	
Risk perception of a hurricane	Property damage	PDH	LTHS	10	3.00	1.56	0.49
			HS	42	3.31	1.00	0.15
			SC	90	3.12	1.10	0.12
			CG	93	2.84	1.07	0.11
			GS	77	2.94	1.13	0.13
			Total	312	3.01	1.11	0.06
	Injury	IJH	LTHS	10	2.40	1.35	0.43
			HS	43	2.67	0.97	0.15
			SC	89	2.36	1.03	0.11
			CG	92	2.10	0.91	0.10
			GS	77	2.19	0.87	0.10
			Total	311	2.29	0.97	0.06
	Health problems	HPH	LTHS	10	2.30	1.25	0.40
			HS	43	2.67	1.02	0.16
			SC	89	2.36	1.12	0.12
CG			92	2.01	0.97	0.10	
GS			77	2.29	0.98	0.11	
Total			311	2.28	1.05	0.06	
Risk perception of a hazardous material release	Property damage	PDHM	LTHS	10	2.10	1.29	0.41
			HS	43	2.58	1.18	0.18
			SC	90	2.14	1.08	0.11
			CG	93	1.82	0.98	0.10
			GS	78	2.14	1.05	0.12
			Total	314	2.11	1.08	0.06
	Injury	IJHM	LTHS	10	2.10	1.29	0.41
			HS	43	2.63	1.11	0.17
			SC	90	2.29	1.11	0.12
			CG	93	1.99	1.05	0.11
			GS	78	2.29	1.14	0.13
			Total	314	2.24	1.12	0.06
	Health problems	HPHM	LTHS	10	2.30	1.25	0.40
			HS	43	2.74	1.16	0.18
			SC	90	2.49	1.18	0.12
CG			93	2.13	1.13	0.12	
GS			78	2.54	1.21	0.14	
Total			314	2.42	1.18	0.07	

<sup>a</sup>Less than high school. <sup>b</sup> High school. <sup>c</sup> Some college education. <sup>d</sup> College graduate. <sup>e</sup> Graduate school.

**Appendix 26. Multivariate test: Perceived risk of floods among educational groups**

Effect	Value	F	Hypothesis		Error df	Sig.
			df			
Intercept	Wilks' Lambda	0.25	311.77	3	304	0.00
EDU	Wilks' Lambda	0.96	1.02	12	805	0.43

**Appendix 27. Multivariate test: Perceived risk of hurricanes among educational groups**

Effect	Value	F	Hypothesis		Error df	Sig.
			df			
Intercept	Wilks' Lambda	0.18	458.46	3	303	0.00
EDU	Wilks' Lambda	0.95	1.39	12	802	0.17

**Appendix 28. Multivariate test: Perceived risk of hazardous materials among educational groups**

Effect	Value	F	Hypothesis		Error df	Sig.
			df			
Intercept	Wilks' Lambda	0.29	255.04	3	307	0.00
EDU	Wilks' Lambda	0.94	1.55	12	813	0.10

**Appendix 29. Descriptive characteristics of public risk perception by ethnicity**

Variable	Measure	Ethnic group	N	Mean	Std. Deviation	Std. Error
Risk perception of a flood	Property damage (PDF)	Black	28	2.64	0.99	0.19
		White	212	2.5	1.15	0.08
		Hispanic	34	2.88	1.3	0.22
		Asian	16	2.06	1.12	0.28
		Other	13	3.08	1.71	0.47
		Total	303	2.56	1.19	0.07
	Injury (IJF)	Black	27	2.26	0.81	0.16
		White	210	1.76	0.85	0.06
		Hispanic	34	2.44	1.05	0.18
		Asian	16	1.75	1.13	0.28
		Other	13	2.08	1.19	0.33
		Total	300	1.89	0.93	0.05
	Health problems (HPF)	Black	27	2.44	0.97	0.19
		White	211	2.1	1.11	0.08
		Hispanic	33	2.55	1.2	0.21
		Asian	16	2.13	1.31	0.33
		Other	13	2.54	1.61	0.45
		Total	300	2.2	1.15	0.07
Risk perception of a hurricane	Property damage (PDH)	Black	27	2.93	1.24	0.24
		White	211	3.01	1.12	0.08
		Hispanic	33	3.03	1.10	0.19
		Asian	16	2.69	0.79	0.20
		Other	13	3.69	1.32	0.36
		Total	300	3.02	1.13	0.06
	Injury (IJH)	Black	27	2.44	1.05	0.20
		White	209	2.20	0.94	0.07
		Hispanic	34	2.65	1.01	0.17
		Asian	16	2.25	0.86	0.21
		Other	13	2.38	1.26	0.35
		Total	299	2.28	0.98	0.06
	Health problems (HPH)	Black	27	2.78	1.05	0.20
		White	209	2.14	1.02	0.07
		Hispanic	34	2.65	1.12	0.19
		Asian	16	2.44	0.96	0.24
		Other	13	2.31	1.32	0.36
		Total	299	2.28	1.07	0.06
Risk perception of a hazardous material release	Property damage (PDHM)	Black	27	2.56	1.12	0.22
		White	211	1.92	1.02	0.07
		Hispanic	34	2.41	1.02	0.17
		Asian	16	2.50	1.10	0.27
		Other	13	2.54	1.45	0.40
		Total	301	2.09	1.08	0.06
	Injury (IJHM)	Black	27	2.48	1.01	0.20
		White	211	2.11	1.09	0.07
		Hispanic	34	2.53	1.11	0.19
		Asian	16	2.56	1.31	0.33
		Other	13	2.54	1.45	0.40
		Total	301	2.23	1.12	0.06
	Health problems (HPHM)	Black	27	2.70	1.03	0.20
		White	211	2.31	1.18	0.08
		Hispanic	34	2.59	1.10	0.19
		Asian	16	2.75	1.24	0.31
		Other	13	2.62	1.56	0.43
		Total	301	2.41	1.18	0.07

**Appendix 30. Multivariate test: Perceived risk of floods among ethnic groups**

Effect		Value	Hypothesis		Error df	Sig.
			F	df		
Intercept	Wilks' Lambda	0.27	260.89	3	292.00	0.00
Ethnicity	Wilks' Lambda	0.92	2.18	12	772.85	0.01*

**Appendix 31. Multivariate test: Perceived risk of hurricanes among ethnic groups**

Effect		Value	Hypothesis		Error df	Sig.
			F	df		
Intercept	Wilks' Lambda	0.22	339.28	3	291	0.00
Ethnicity	Wilks' Lambda	0.89	2.94	12	770	0.00**

**Appendix 32. Multivariate test: Perceived risk of hazardous materials among ethnic groups**

Effect		Value	Hypothesis		Error df	Sig.
			F	df		
Intercept	Wilks' Lambda	0.30	224.06	3	294	0.00
Ethnicity	Wilks' Lambda	0.93	1.88	12	778	0.03*

**Appendix 33. Tests of between-subjects effects: Perceived risk of floods among ethnic groups**

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	PDF	11.00 <sup>a</sup>	4	2.75	2.01	0.09
	IJF	15.54 <sup>b</sup>	4	3.89	4.90	0.00
	HPF	9.85 <sup>c</sup>	4	2.46	1.90	0.11
Intercept	PDF	812.54	1	812.54	592.43	0.00
	IJF	492.53	1	492.53	620.52	0.00
	HPF	651.49	1	651.49	503.67	0.00
Ethnicity	PDF	11.00	4	2.75	2.01	0.09
	IJF	15.54	4	3.89	4.90	0.00**
	HPF	9.85	4	2.46	1.90	0.11
Error	PDF	403.23	294	1.37		
	IJF	233.36	294	0.79		
	HPF	380.29	294	1.29		
Total	PDF	2346.00	299			
	IJF	1309.00	299			
	HPF	1825.00	299			
Corrected Total	PDF	414.23	298			
	IJF	248.90	298			
	HPF	390.13	298			

<sup>a</sup>R Squared = .027 (Adjusted R Squared = .013).

<sup>b</sup>R Squared = .062 (Adjusted R Squared = .050).

<sup>c</sup>R Squared = .025 (Adjusted R Squared = .012).

**Appendix 34. Tests of between-subjects effects: Perceived risk of hurricanes among ethnic groups**

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	PDH	7.92 <sup>a</sup>	4	1.98	1.59	0.18
	IJH	6.55 <sup>b</sup>	4	1.64	1.73	0.14
	HPH	14.49 <sup>c</sup>	4	3.62	3.31	0.01
Intercept	PDH	1112.47	1	1112.47	890.53	0.00
	IJH	670.70	1	670.70	708.58	0.00
	HPH	711.97	1	711.97	649.98	0.00
Ethnicity	PDH	7.92	4	1.98	1.59	0.18
	IJH	6.55	4	1.64	1.73	0.14
	HPH	14.49	4	3.62	3.31	0.01*
Error	PDH	366.02	293	1.25		
	IJH	277.34	293	0.95		
	HPH	320.95	293	1.10		
Total	PDH	3080.00	298			
	IJH	1831.00	298			
	HPH	1878.00	298			
Corrected Total	PDH	373.95	297			
	IJH	283.88	297			
	HPH	335.44	297			

<sup>a</sup> R Squared = .021 (Adjusted R Squared = .008).

<sup>a</sup> R Squared = .023 (Adjusted R Squared = .010).

<sup>a</sup> R Squared = .043 (Adjusted R Squared = .030).



**Appendix 35. Tests of between-subjects effects: Perceived risk of hazardous materials among ethnic groups**

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	PDHM	20.48 <sup>a</sup>	4	5.12	4.61	0.00
	IJHM	10.85 <sup>b</sup>	4	2.71	2.19	0.07
	HPHM	8.00 <sup>c</sup>	4	2.00	1.44	0.22
Intercept	PDHM	675.77	1	675.77	608.13	0.00
	IJHM	709.12	1	709.12	572.14	0.00
	HPHM	798.16	1	798.16	574.94	0.00
Ethnicity	PDHM	20.48	4	5.12	4.61	0.00**
	IJHM	10.85	4	2.71	2.19	0.07
	HPHM	8.00	4	2.00	1.44	0.22
Error	PDHM	328.92	296	1.11		
	IJHM	366.87	296	1.24		
	HPHM	410.92	296	1.39		
Total	PDHM	1668.00	301			
	IJHM	1878.00	301			
	HPHM	2170.00	301			
Corrected Total	PDHM	349.40	300			
	IJHM	377.72	300			
	HPHM	418.92	300			

<sup>a</sup> R Squared = .059 (Adjusted R Squared = .046).

<sup>b</sup> R Squared = .029 (Adjusted R Squared = .016).

<sup>c</sup> R Squared = .019 (Adjusted R Squared = .006).

**Appendix 36. Multiple comparisons by Tukey's HSD: Risk perception among ethnic groups**

Variable	Measure	(I) Ethnicity	(J) Ethnicity	Mean Difference (I-J)	Std. Error	Sig.	
Risk perception of a flood	Injury (IJF)	1	2	0.50	0.18	0.03*	
			3	-0.18	0.23	0.86	
			4	0.51	0.28	0.27	
		2	1	-0.50	0.18	0.03*	
			3	-0.68	0.16	0.00**	
			4	0.01	0.23	1.00	
		3	1	0.18	0.23	0.86	
			2	0.68	0.16	0.00**	
			4	0.69	0.27	0.05*	
		4	1	2	-0.51	0.28	0.27
				3	-0.01	0.23	1.00
			2	3	-0.69	0.27	0.05*
4	0.63			0.21	0.02*		
Risk perception of a hurricane	Health problems (HPH)		1	2	0.63	0.21	0.02*
				3	0.13	0.27	0.96
		4		0.34	0.33	0.72	
2	1	2	-0.63	0.21	0.02*		
		3	-0.50	0.19	0.04*		
		4	-0.29	0.27	0.69		
	3	1	-0.13	0.27	0.96		
		2	0.50	0.19	0.04*		
		4	0.21	0.31	0.91		
4	1	2	-0.34	0.33	0.72		
		3	0.29	0.27	0.69		
	2	3	-0.21	0.31	0.91		
		4	0.63	0.21	0.02*		
	Risk perception of a hazardous material release	Property damage (PDHM)	1	2	0.63	0.21	0.02*
				3	0.14	0.27	0.95
4				0.06	0.33	1.00	
2			1	-0.63	0.21	0.02*	
			3	-0.49	0.19	0.05*	
			4	-0.58	0.27	0.14	
3			1	-0.14	0.27	0.95	
			2	0.49	0.19	0.05*	
			4	-0.09	0.31	0.99	
4			1	-0.06	0.33	1.00	
			2	0.58	0.27	0.14	
			3	0.09	0.31	0.99	

**Appendix 37. Descriptive characteristics of risk perception by groups with different household size (HSIZE)**

Variable	Measure	Acronym	HSIZE	N	Mean	Std. Deviation	Std. Error
Risk perception of a flood	Property damage	PDF	1	48	2.54	1.17	0.17
			2	116	2.72	1.28	0.12
			3	66	2.42	0.99	0.12
			4	49	2.63	1.20	0.17
			5	41	2.34	1.20	0.19
			Total	320	2.57	1.19	0.07
	Injury	IJF	1	46	1.78	0.92	0.14
			2	115	1.87	1.01	0.09
			3	66	1.85	0.81	0.10
			4	49	2.02	0.88	0.13
			5	41	2.00	0.95	0.15
			Total	317	1.89	0.93	0.05
	Health problems	HPF	1	47	2.13	1.21	0.18
			2	114	2.19	1.25	0.12
			3	66	2.21	0.98	0.12
4			49	2.31	1.06	0.15	
5			41	2.24	1.20	0.19	
Total			317	2.21	1.15	0.06	
Risk perception of a hurricane	Property damage	PDH	1	46	2.96	1.15	0.17
			2	114	3.16	1.18	0.11
			3	66	2.98	1.05	0.13
			4	49	2.94	1.07	0.15
			5	41	2.85	1.04	0.16
			Total	316	3.02	1.11	0.06
	Injury	IJH	1	44	2.11	1.06	0.16
			2	115	2.30	1.09	0.10
			3	66	2.36	0.94	0.12
			4	49	2.35	0.86	0.12
			5	41	2.20	0.75	0.12
			Total	315	2.28	0.98	0.06
	Health problems	HPH	1	44	2.18	1.17	0.18
			2	115	2.34	1.18	0.11
			3	66	2.36	0.94	0.12
4			49	2.31	0.94	0.13	
5			41	2.15	0.91	0.14	
Total			315	2.29	1.06	0.06	
Risk perception of a hazardous material release	Property damage	PDHM	1	46	1.96	1.23	0.18
			2	116	2.05	1.07	0.10
			3	66	2.23	1.09	0.13
			4	49	2.18	1.07	0.15
			5	41	2.12	1.05	0.16
			Total	318	2.10	1.09	0.06
	Injury	IJHM	1	46	2.09	1.21	0.18
			2	116	2.14	1.12	0.10
			3	66	2.45	1.07	0.13
			4	49	2.31	1.10	0.16
			5	41	2.29	1.17	0.18
			Total	318	2.24	1.13	0.06
	Health problems	HPHM	1	46	2.26	1.31	0.19
			2	116	2.34	1.21	0.11
			3	66	2.61	1.11	0.14
4			49	2.45	1.12	0.16	
5			41	2.46	1.25	0.19	
Total			318	2.42	1.19	0.07	

**Appendix 38. Multivariate test: Perceived risk of floods among groups with different household size**

Effect	Value	F	Hypothesis		Error df	Sig.
			df			
Intercept	Wilks' Lambda	0.16	528.02	3	309	0.00
HSIZE <sup>a</sup>	Wilks' Lambda	0.96	1.01	12	817.83	0.44

<sup>a</sup>Household size

**Appendix 39. Multivariate test: Perceived risk of hurricanes among groups with different household size**

Effect	Value	F	Hypothesis		Error df	Sig.
			df			
Intercept	Wilks' Lambda	0.12	731.25	3	307	0.00
HSIZE	Wilks' Lambda	0.98	0.61	12	812.54	0.84

**Appendix 40. Multivariate test: Perceived risk of hazardous materials among groups with different household size**

Effect	Value	F	Hypothesis		Error df	Sig.
			df			
Intercept	Wilks' Lambda	0.20	411.90	3	311	0.00
HSIZE	Wilks' Lambda	0.98	0.50	12	823.12	0.92

**Appendix 41. Descriptive characteristics of public risk perception by groups with different yearly household incomes**

Variable	Measure	Acronym	Group	N	Mean	Std. Deviation	Std. Error
Risk perception of a flood	Property damage	PDF	1	6	2.83	1.33	0.54
			2	19	3.11	1.63	0.37
			3	28	2.54	1.20	0.23
			4	24	2.88	1.08	0.22
			5	57	2.46	1.09	0.14
			6	73	2.45	1.16	0.14
			7	72	2.51	1.15	0.14
			Total	279	2.57	1.18	0.07
	Injury	IJF	1	6	2.00	1.10	0.45
			2	18	1.83	1.10	0.26
			3	28	2.07	1.12	0.21
			4	24	2.04	0.91	0.19
			5	56	2.09	0.94	0.13
			6	73	1.89	0.92	0.11
			7	72	1.74	0.77	0.09
			Total	277	1.92	0.93	0.06
	Health problems	HPF	1	6	2.67	1.37	0.56
			2	19	2.79	1.78	0.41
			3	28	2.32	1.09	0.21
			4	24	2.38	1.06	0.22
			5	56	2.38	1.15	0.15
			6	73	2.16	1.12	0.13
7			72	2.00	0.99	0.12	
Total			278	2.25	1.16	0.07	
Risk perception of a hurricane	Property damage	PDH	1	6	3.33	1.37	0.56
			2	19	3.58	1.26	0.29
			3	28	3.04	1.14	0.22
			4	23	3.30	1.06	0.22
			5	56	2.86	1.03	0.14
			6	72	2.94	1.11	0.13
			7	72	2.89	1.07	0.13
			Total	276	3.00	1.11	0.07
	Injury	IJH	1	6	2.50	1.52	0.62
			2	18	2.17	0.92	0.22
			3	28	2.50	1.17	0.22
			4	24	2.58	0.97	0.20
			5	55	2.24	1.02	0.14
			6	72	2.21	0.90	0.11
			7	72	2.21	0.87	0.10
			Total	275	2.28	0.97	0.06
	Health problems	HPH	1	6	2.67	1.37	0.56
			2	18	2.44	1.25	0.29
			3	28	2.54	1.14	0.22
			4	24	2.46	1.14	0.23
			5	55	2.20	1.03	0.14
			6	72	2.21	0.99	0.12
7			72	2.14	1.00	0.12	
Total			275	2.27	1.05	0.06	

**Appendix 41. (continued)**

Variable	Measure	Acronym	Group	N	Mean	Std. Deviation	Std. Error
Risk perception of a hazardous material release	Property damage	PDHM	1	6	2.17	0.98	0.40
			2	19	2.00	1.05	0.24
			3	28	2.43	1.03	0.20
			4	24	2.46	1.35	0.28
			5	56	2.18	1.05	0.14
			6	73	1.92	1.06	0.12
			7	72	2.00	1.01	0.12
			Total	278	2.10	1.07	0.06
Injury	IJHM	1	6	2.50	1.05	0.43	
		2	19	2.21	1.23	0.28	
		3	28	2.32	0.98	0.19	
		4	24	2.42	1.21	0.25	
		5	56	2.34	1.07	0.14	
		6	73	2.10	1.16		
		7	72	2.08	1.10	0.13	
		Total	278	2.21	1.11	0.07	
Health problems	HPHM	1	6	2.67	1.03	0.42	
		2	19	2.47	1.39	0.32	
		3	28	2.46	0.96	0.18	
		4	24	2.50	1.25	0.26	
		5	56	2.55	1.14	0.15	
		6	73	2.27	1.18	0.14	
		7	72	2.32	1.23	0.15	
		Total	278	2.40	1.18	0.07	

**Appendix 42. Multivariate test: Perceived risk of floods among groups with different yearly household incomes**

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Wilks' Lambda	0.23	297.23	3	268	0.00
Income	Wilks' Lambda	0.92	1.29	18	759	0.19

**Appendix 43. Multivariate test: Perceived risk of hurricanes among groups with different yearly household incomes**

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Wilks' Lambda	0.17	418.77	3	265	0.00
Income	Wilks' Lambda	0.93	1.13	18	750	0.32

**Appendix 44. Multivariate test: Perceived risk of hazardous materials among groups with different yearly household incomes**

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Wilks' Lambda	0.28	227.27	3	269	0.00
Income	Wilks' Lambda	0.94	0.94	18	761	0.53

**Appendix 45. Descriptive characteristics of risk perception by tenure groups**

Variable	Measure	Acronym	Tenure	N	Mean	Std. Deviation	Std. Error
Risk perception of a flood	Property damage	PDF	1	103	2.32	1.11	0.11
			2	64	2.73	1.17	0.15
			3	42	2.45	1.23	0.19
			4	31	3.03	1.08	0.19
			5	77	2.58	1.21	0.14
			Total	317	2.56	1.18	0.07
	Injury	IJF	1	103	1.83	0.90	0.09
			2	63	2.00	1.00	0.13
			3	42	1.83	1.01	0.16
			4	31	2.13	0.67	0.12
			5	75	1.79	0.87	0.10
			Total	314	1.88	0.91	0.05
	Health problems	HPF	1	103	2.03	1.01	0.10
			2	63	2.30	1.23	0.15
			3	42	2.05	1.17	0.18
4			31	2.58	0.89	0.16	
5			76	2.30	1.28	0.15	
Total			315	2.21	1.14	0.06	
Risk perception of a hurricane	Property damage	PDH	1	103	2.66	1.01	0.10
			2	64	3.14	1.10	0.14
			3	41	2.83	1.07	0.17
			4	31	3.68	1.01	0.18
			5	74	3.22	1.15	0.13
			Total	313	3.01	1.11	0.06
	Injury	IJH	1	103	2.13	0.93	0.09
			2	63	2.32	1.01	0.13
			3	41	2.27	0.74	0.12
			4	31	2.68	0.94	0.17
			5	74	2.30	1.07	0.12
			Total	312	2.28	0.97	0.05
	Health problems	HPH	1	103	2.15	0.96	0.09
			2	63	2.25	1.11	0.14
			3	41	2.24	0.92	0.14
4			31	2.68	0.94	0.17	
5			74	2.36	1.20	0.14	
Total			312	2.29	1.05	0.06	
Risk perception of a hazardous material release	Property damage	PDHM	1	103	1.89	0.98	0.10
			2	63	2.27	1.15	0.15
			3	41	2.07	0.93	0.15
			4	31	2.39	1.15	0.21
			5	77	2.09	1.14	0.13
			Total	315	2.09	1.07	0.06
	Injury	IJHM	1	103	2.02	1.04	0.10
			2	63	2.46	1.20	0.15
			3	41	2.15	0.96	0.15
			4	31	2.58	1.20	0.22
			5	77	2.22	1.11	0.13
			Total	315	2.23	1.11	0.06
	Health problems	HPHM	1	103	2.12	1.07	0.11
			2	63	2.60	1.21	0.15
			3	41	2.49	1.14	0.18
4			31	2.74	1.12	0.20	
5			77	2.45	1.27	0.15	
Total			315	2.41	1.18	0.07	



**Appendix 46. Multivariate test: Perceived risk of floods among tenure groups**

Effect	Value	F	Hypothesis		Error df	Sig.
			df			
Intercept	Wilks' Lambda	0.16	547.86	3	307	0.00
Tenure	Wilks' Lambda	0.95	1.36	12	813	0.18

**Appendix 47. Multivariate test: Perceived risk of hurricanes among tenure groups**

Effect	Value	F	Hypothesis		Error df	Sig.
			df			
Intercept	Wilks' Lambda	0.11	816.53	3	304	0.00
Tenure	Wilks' Lambda	0.91	2.50	12	805	0.00**

**Appendix 48. Multivariate test: Perceived risk of hazardous materials among tenure groups**

Effect	Value	F	Hypothesis		Error df	Sig.
			df			
Intercept	Wilks' Lambda	0.19	431.65	3	308	0.00
Tenure	Wilks' Lambda	0.95	1.46	12	815	0.14

**Appendix 49. Tests of between-subjects effects: Perceived risk of floods among tenure groups**

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	PDF	15.09 <sup>a</sup>	4	3.77	2.81	0.03
	IJF	3.88 <sup>b</sup>	4	0.97	1.17	0.32
	HPF	9.46 <sup>c</sup>	4	2.36	1.86	0.12
Intercept	PDF	1805.42	1	1805.42	1345.28	0.00
	IJF	965.09	1	965.09	1161.45	0.00
	HPF	1326.72	1	1326.72	1045.00	0.00
Tenure	PDF	15.09	4	3.77	2.81	0.03*
	IJF	3.88	4	0.97	1.17	0.32
	HPF	9.46	4	2.36	1.86	0.12
Error	PDF	414.69	309	1.34		
	IJF	256.76	309	0.83		
	HPF	392.30	309	1.27		
Total	PDF	2468.00	314			
	IJF	1373.00	314			
	HPF	1918.00	314			
Corrected Total	PDF	429.78	313			
	IJF	260.64	313			
	HPF	401.76	313			

<sup>a</sup>R Squared = .035 (Adjusted R Squared = .023).

<sup>b</sup>R Squared = .015 (Adjusted R Squared = .002).

<sup>c</sup>R Squared = .024 (Adjusted R Squared = .011).

**Appendix 50. Tests of between-subjects effects: Perceived risk of hurricanes among tenure groups**

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	PDH	31.56 <sup>a</sup>	4	7.89	6.95	0.00
	IJH	7.43 <sup>b</sup>	4	1.86	2.01	0.09
	HPH	7.14 <sup>c</sup>	4	1.78	1.64	0.16
Intercept	PDH	2510.09	1	2510.09	2210.87	0.00
	IJH	1421.41	1	1421.41	1538.06	0.00
	HPH	1418.08	1	1418.08	1301.05	0.00
Tenure	PDH	31.56	4	7.89	6.95	0.00**
	IJH	7.43	4	1.86	2.01	0.09
	HPH	7.14	4	1.78	1.64	0.16
Error	PDH	347.41	306	1.14		
	IJH	282.79	306	0.92		
	HPH	333.53	306	1.09		
Total	PDH	3196.00	311			
	IJH	1902.00	311			
	HPH	1957.00	311			
Corrected Total	PDH	378.97	310			
	IJH	290.22	310			
	HPH	340.66	310			

<sup>a</sup> R Squared = .083 (Adjusted R Squared = .071).

<sup>b</sup> R Squared = .026 (Adjusted R Squared = .013).

<sup>c</sup> R Squared = .021 (Adjusted R Squared = .008).

**Appendix 51. Tests of between-subjects effects: Perceived risk of hazardous materials among tenure groups**

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	PDHM	8.77	4	2.19	1.93	0.11
	IJHM	12.01	4	3.00	2.49	0.04
	HPHM	15.04	4	3.76	2.77	0.03
Intercept	PDHM	1205.61	1	1205.61	1059.54	0.00
	IJHM	1371.47	1	1371.47	1138.22	0.00
	HPHM	1615.87	1	1615.87	1189.97	0.00
Tenure	PDHM	8.77	4	2.19	1.93	0.11
	IJHM	12.01	4	3.00	2.49	0.04*
	HPHM	15.04	4	3.76	2.77	0.03*
Error	PDHM	352.74	310	1.14		
	IJHM	373.53	310	1.20		
	HPHM	420.95	310	1.36		
Total	PDHM	1736.00	315			
	IJHM	1950.00	315			
	HPHM	2260.00	315			
Corrected Total	PDHM	361.51	314			
	IJHM	385.54	314			
	HPHM	435.99	314			

<sup>a</sup> R Squared = .024 (Adjusted R Squared = .012).

<sup>b</sup> R Squared = .031 (Adjusted R Squared = .019).

<sup>c</sup> R Squared = .034 (Adjusted R Squared = .022).

**Appendix 52. Multiple comparisons by Tukey's HSD: Risk perception among tenure groups**

Variable	Measure	(I) Tenure <sup>a</sup>	(J) Tenure	Mean Difference (I-J)	Std. Error	Sig.
Risk perception of a flood	Property damage (PDF)	1	2	-0.41	0.19	0.18
			3	-0.13	0.21	0.97
			4	-0.71	0.24	0.02*
			5	-0.24	0.18	0.65
		2	1	0.41	0.19	0.18
			3	0.28	0.23	0.75
			4	-0.30	0.25	0.76
			5	0.17	0.20	0.91
		3	1	0.13	0.21	0.97
			2	-0.28	0.23	0.75
			4	-0.58	0.27	0.22
			5	-0.11	0.22	0.99
		4	1	0.71	0.24	0.02*
			2	0.30	0.25	0.76
			3	0.58	0.27	0.22
			5	0.47	0.25	0.31
		5	1	0.24	0.18	0.65
			2	-0.17	0.20	0.91
			3	0.11	0.22	0.99
			4	-0.47	0.25	0.31
Risk perception of a hurricane	Property damage (PDH)	1	2	-0.50	0.17	0.03
			3	-0.17	0.20	0.91
			4	-1.02	0.22	0.00**
			5	-0.53	0.16	0.01*
		2	1	0.50	0.17	0.03*
			3	0.33	0.21	0.54
			4	-0.52	0.23	0.18
			5	-0.03	0.18	1.00
		3	1	0.17	0.20	0.91
			2	-0.33	0.21	0.54
			4	-0.85	0.25	0.01*
			5	-0.36	0.21	0.41
		4	1	1.02	0.22	0.00**
			2	0.52	0.23	0.18
			3	0.85	0.25	0.01*
			5	0.49	0.23	0.21
		5	1	0.53	0.16	0.01*
			2	0.03	0.18	1.00
			3	0.36	0.21	0.41
			4	-0.49	0.23	0.21

<sup>a</sup> Tenure at present home: 1) 0- 4.99 years; 2) 5-9.99 years; 3) 10-14.99 years; 4) 15-19.99 years; 5) Over 20 years.

**Appendix 52. (continued)**

Variable	Measure	(I) Tenure <sup>a</sup>	(J) Tenure	Mean Difference (I-J)	Std. Error	Sig.
Risk perception of a hazardous material release	Injury (IJHM)	1	2	-0.44	0.18	0.09
			3	-0.13	0.20	0.97
			4	-0.56	0.22	0.09
			5	-0.20	0.17	0.74
		2	1	0.44	0.18	0.09
			3	0.31	0.22	0.61
			4	-0.12	0.24	0.99
			5	0.24	0.19	0.70
		3	1	0.13	0.20	0.97
			2	-0.31	0.22	0.61
			4	-0.43	0.26	0.46
			5	-0.07	0.21	1.00
		4	1	0.56	0.22	0.09
			2	0.12	0.24	0.99
			3	0.43	0.26	0.46
			5	0.36	0.23	0.54
		5	1	0.20	0.17	0.74
			2	-0.24	0.19	0.70
			3	0.07	0.21	1.00
			4	-0.36	0.23	0.54
Health problems (HPHM)	1	2	-0.49	0.19	0.07	
		3	-0.37	0.22	0.42	
		4	-0.63	0.24	0.07	
		5	-0.34	0.18	0.31	
	2	1	0.49	0.19	0.07	
		3	0.12	0.23	0.99	
		4	-0.14	0.26	0.98	
		5	0.15	0.20	0.94	
	3	1	0.37	0.22	0.42	
		2	-0.12	0.23	0.99	
		4	-0.25	0.28	0.89	
		5	0.03	0.23	1.00	
	4	1	0.63	0.24	0.07	
		2	0.14	0.26	0.98	
		3	0.25	0.28	0.89	
		5	0.29	0.25	0.77	
	5	1	0.34	0.18	0.31	
		2	-0.15	0.20	0.94	
		3	-0.03	0.23	1.00	
		4	-0.29	0.25	0.77	

<sup>a</sup> Tenure at present home: 1) 0 – 4.99 years; 2) 5 – 9.99 years; 3) 10 – 14.99 years; 4) 15 – 19.99 years; 5) over 20 years.

**Appendix 53. Descriptive characteristics of risk perception by flood risk**

Measure	Acronym	Group	N	Mean	Std. Deviation	Std. Error
Property damage	PDF	No-risk	226	2.51	1.20	0.08
		500 YFP	50	2.32	0.91	0.13
		100 YFP	44	3.16	1.24	0.19
		Total	320	2.57	1.19	0.07
Injury	IJF	No-risk	224	1.89	0.94	0.06
		500 YFP	50	1.70	0.71	0.10
		100 YFP	43	2.12	1.07	0.16
		Total	317	1.89	0.93	0.05
Health problems	HPF	No-risk	224	2.21	1.17	0.08
		500 YFP	50	2.02	1.00	0.14
		100 YFP	43	2.47	1.18	0.18
		Total	317	2.21	1.15	0.06

**Appendix 54. Multivariate test: Perceived risk of floods among groups with different levels of flood risk**

Effect		Value	F	Hypothesis		Sig.
				df	Error df	
Intercept	Wilks' Lambda	0.21	398.57	3	311.00	0.00
Flood risk	Wilks' Lambda	0.95	2.93	6	622.00	0.01*

**Appendix 55. Tests of between-subjects effects: Perceived risk of floods among groups with different levels of flood risk**

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	PDF	21.00 <sup>a</sup>	2	10.50	7.92	0.00
	IJF	4.02 <sup>b</sup>	2	2.01	2.43	0.09
	HPF	4.65 <sup>c</sup>	2	2.33	1.79	0.17
Intercept	PDF	1337.36	1	1337.36	1008.45	0.00
	IJF	679.41	1	679.41	822.18	0.00
	HPF	934.12	1	934.12	719.46	0.00
Flood risk	PDF	21.00	2	10.50	7.92	0.00**
	IJF	4.02	2	2.01	2.43	0.09
	HPF	4.65	2	2.33	1.79	0.17
Error	PDF	415.09	313	1.33		
	IJF	258.65	313	0.83		
	HPF	406.39	313	1.30		
Total	PDF	2497.00	316			
	IJF	1383.00	316			
	HPF	1944.00	316			
Corrected Total	PDF	436.09	315			
	IJF	262.67	315			
	HPF	411.04	315			

<sup>a</sup>R Squared = .048 (Adjusted R Squared = .042).

<sup>b</sup>R Squared = .015 (Adjusted R Squared = .009).

<sup>c</sup>R Squared = .011 (Adjusted R Squared = .005).

**Appendix 56. Multiple comparisons by Tukey's HSD: Perceived risk of floods among groups with different levels of flood risk**

Dependent Variable	(I) Flood Risk	(J) Flood Risk	Mean Difference		Sig.
			(I-J)	Std. Error	
Risk perception of property damage	0	1	0.16	0.18	0.63
		5	-0.70	0.19	0.00**
	1	0	-0.16	0.18	0.63
		5	-0.87	0.24	0.00**
	5	0	0.70	0.19	0.00**
		1	0.87	0.24	0.00**



**Appendix 57. Descriptive characteristics of risk perception by hurricane risk**

Measure	Acronym	Group	N	Mean	Std. Deviation	Std. Error
Property damage	PDH	0	228	2.85	1.07	0.07
		1	18	3.39	1.14	0.27
		2	17	3.41	1.00	0.24
		3	21	3.71	0.90	0.20
		4	13	3.31	1.65	0.46
		5	19	3.37	0.96	0.22
		Total	316	3.02	1.11	0.06
Injury	IJH	0	227	2.25	0.91	0.06
		1	18	2.56	1.04	0.25
		2	17	2.00	0.71	0.17
		3	21	2.62	1.28	0.28
		4	13	2.38	1.56	0.43
		5	19	2.21	0.98	0.22
		Total	315	2.28	0.98	0.06
Health problems	HPH	0	227	2.22	1.02	0.07
		1	18	2.56	1.15	0.27
		2	17	2.18	0.81	0.20
		3	21	2.71	1.31	0.29
		4	13	2.62	1.50	0.42
		5	19	2.37	0.96	0.22
		Total	315	2.29	1.06	0.06

**Appendix 58. Multivariate test: Perceived risk of hurricanes among groups with different levels of hurricane risk**

Effect	Value	Hypothesis		Error df	Sig.	
		F	df			
Intercept	Wilks' Lambda	0.20	411.17	3	306.00	0.00
Hurricane risk	Wilks' Lambda	0.90	2.30	15	845.13	0.00**

**Appendix 59. Tests of between-subjects effects: Perceived risk of hurricanes among groups with different levels of hurricane risk**

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	PDH	25.47 <sup>a</sup>	5	5.09	4.36	0.00
	IJH	5.58 <sup>b</sup>	5	1.12	1.17	0.32
	HPH	8.28 <sup>c</sup>	5	1.66	1.49	0.19
Intercept	PDH	1356.35	1	1356.35	1162.20	0.00
	IJH	663.87	1	663.87	696.06	0.00
	HPH	723.95	1	723.95	652.12	0.00
Hurricane risk	PDH	25.47	5	5.09	4.36	0.00**
	IJH	5.58	5	1.12	1.17	0.32
	HPH	8.28	5	1.66	1.49	0.19
Error	PDH	359.45	308	1.17		
	IJH	293.76	308	0.95		
	HPH	341.92	308	1.11		
Total	PDH	3241.00	314			
	IJH	1932.00	314			
	HPH	1992.00	314			
Corrected Total	PDH	384.92	313			
	IJH	299.34	313			
	HPH	350.20	313			

<sup>a</sup>R Squared = .066 (Adjusted R Squared = .051).

<sup>b</sup>R Squared = .019 (Adjusted R Squared = .003).

<sup>c</sup>R Squared = .024 (Adjusted R Squared = .008).

**Appendix 60. Multiple comparisons by Tukey's HSD: Perceived risk of hurricanes among groups with different levels of hurricane risk**

Variable	(I) HR <sup>a</sup>	(J) HR	Mean Difference (I-J)	Std. Error	Sig.
Risk perception of property damage	0	1	-0.54	0.26	0.31
		2	-0.57	0.27	0.30
		3	-0.87	0.25	0.01*
		4	-0.46	0.31	0.66
		5	-0.52	0.26	0.33
	1	0	0.54	0.26	0.31
		2	-0.02	0.37	1.00
		3	-0.33	0.35	0.94
		4	0.08	0.39	1.00
		5	0.02	0.36	1.00
	2	0	0.57	0.27	0.30
		1	0.02	0.37	1.00
		3	-0.30	0.35	0.96
		4	0.10	0.40	1.00
		5	0.04	0.36	1.00
	3	0	0.87	0.25	0.01*
		1	0.33	0.35	0.94
		2	0.30	0.35	0.96
		4	0.41	0.38	0.89
		5	0.35	0.34	0.91
4	0	0.46	0.31	0.66	
	1	-0.08	0.39	1.00	
	2	-0.10	0.40	1.00	
	3	-0.41	0.38	0.89	
	5	-0.06	0.39	1.00	
5	0	0.52	0.26	0.33	
	1	-0.02	0.36	1.00	
	2	-0.04	0.36	1.00	
	3	-0.35	0.34	0.91	
	4	0.06	0.39	1.00	

<sup>a</sup> Levels of hurricane risk

**Appendix 61. Matrix of correlations among the housing attribute variables**

Variable	1	2	3	4	5	6	7
1. Market Value (Log)	1.00	0.90**	0.38**	0.19**	-0.58**	0.82**	0.51**
2. Market Value	0.90**	1.00	0.37**	0.23**	-0.46**	0.77**	0.41**
3. Number of Stories	0.38**	0.37**	1.00	-0.05	-0.36**	0.54**	0.44**
4. Land Area	0.19**	0.23**	-0.05	1.00	0.03	0.19**	0.06
5. House Age	-0.58**	-0.46**	-0.36**	0.03	1.00	-0.50**	-0.35**
6. Living Area	0.82**	0.77**	0.54**	0.19**	-0.50**	1.00	0.68**
7. Number of Beds	0.51**	0.41**	0.44**	0.06	-0.35**	0.68**	1.00
8. Number of Baths	0.72**	0.64**	0.57**	0.08	-0.56**	0.80**	0.65**
9. Distance to Airport	0.16**	0.11**	0.12*	0.11*	-0.23**	0.16**	0.09
10. Distance to CBD	0.09	-0.05	0.18**	0.13*	-0.33**	0.23**	0.22**
11. Distance to Main Road	0.12*	0.03	0.12*	-0.08	-0.25**	0.22**	0.31**
12. Distance to Park	0.14*	0.04	0.19**	0.00	-0.42**	0.20**	0.21**
13. Distance to Shoreline	0.15	0.08	0.12*	-0.05	-0.36**	0.16**	0.21**
14. Income	0.68	0.59**	0.38**	-0.02	-0.45**	0.61**	0.46**
15. Percent of Whites	0.50	0.37**	0.16**	0.12*	-0.24**	0.36**	0.19**
16. Percent of Occupied Units	0.14	0.02	-0.08	-0.24**	-0.24**	0.07	0.21**
17. Percent of Single Family Units	0.00	-0.01	0.05	-0.22**	-0.04	0.02	0.04
18. Baytown	-0.11	-0.09	-0.05	0.14*	0.16**	-0.01	-0.09
19. Bellaire	0.28**	0.40**	0.09	-0.04	-0.10	0.11	-0.02
20. Channelview	-0.13*	-0.09	-0.07	0.20**	0.17**	-0.08	-0.10
21. Crosby	-0.01	-0.02	0.01	0.01	-0.01	-0.02	-0.05
22. Cypress	0.12*	0.14*	0.16**	0.05	-0.13*	0.21**	0.13**
23. Deer Park	0.00	-0.02	-0.06	-0.01	-0.06	-0.04	-0.05
24. Friendswood	0.04	0.04	0.04	-0.01	-0.05	0.06	0.01

\*.  $p < 0.05$ . \*\*.  $p < 0.01$ .  $N = 313$  to  $317$ .

**Appendix 61. (Continued)**

Variable	1	2	3	4	5	6	7
25.Highlands	-0.09	-0.07	-0.06	0.21**	0.16**	-0.12*	-0.10
26.Humble	0.04	0.02	0.06	-0.02	-0.09	0.09	0.12*
27.Katy	-0.01	-0.04	-0.05	-0.04	-0.14*	-0.03	0.04
28.Kingwood	0.00	-0.02	-0.05	-0.01	-0.03	-0.02	0.01
29.La Porte	-0.07	-0.11	-0.05	-0.04	-0.03	-0.09	-0.08
30.Pasadena	-0.10	-0.08	-0.07	-0.03	0.11	-0.10	-0.02
31.Seabrook	0.02	0.00	0.03	-0.01	-0.02	0.04	0.06
32.Spring	-0.03	-0.05	0.01	-0.02	-0.09	-0.03	-0.04
33.Tomball	0.04	0.01	0.00	0.14*	-0.12*	0.04	0.04
34.Elevating HVAC Systems	-0.03	0.00	0.01	0.00	-0.04	0.02	-0.01
35.Elevating the House	0.02	0.05	-0.02	-0.04	-0.03	0.02	-0.05
36.Adding Water Proof Wall	0.04	0.06	-0.08	-0.01	-0.09	0.00	-0.05
37.Reinforcing Roof Rafters	-0.02	-0.03	-0.05	-0.03	-0.09	0.00	-0.07
38.Reinforcing Walls	0.00	-0.02	0.01	-0.04	-0.04	0.04	0.01
39.Installing Storm Shutters	-0.02	-0.02	-0.08	-0.01	0.06	-0.09	-0.12*
40.Installing a Generator	-0.08	-0.07	-0.06	0.13*	0.07	-0.03	-0.09
41.Purchasing Flood Insurance	0.15**	0.13**	-0.05	-0.01	-0.06	0.10	0.07
42.Flood Risk	0.04	0.06	-0.12*	-0.02	0.00	0.01	0.07
43.Hurricane Risk	-0.04	-0.06	0.06	0.03	0.03	0.04	-0.01
44.Chemical Risk	0.28**	0.20**	0.17**	0.05	-0.29**	0.34**	0.25**
45.Flood Risk Perception	-0.19**	-0.19**	-0.11	-0.05	0.11	-0.14*	-0.04
46.Hurricane Risk Perception	-0.20**	-0.17**	-0.09	0.01	0.14*	-0.14*	-0.09
47.Chemical Risk Perception	-0.26**	-0.22**	-0.07	0.00	0.14*	-0.20**	-0.12*

**Appendix 61. (Continued)**

Variable	8	9	10	11	12	13	14
1. Market Value (Log)	0.72**	0.16**	0.09	0.12*	0.14*	0.15**	0.68**
2. Market Value	0.64**	0.11*	-0.05	0.03	0.04	0.08	0.59**
3. Number of Stories	0.57**	0.12*	0.18**	0.12*	0.19**	0.12*	0.38**
4. Land Area	0.08	0.11*	0.13*	-0.08	0.00	-0.05	-0.02
5. House Age	-0.56**	-0.23**	-0.33**	-0.25**	-0.42**	-0.36**	-0.45**
6. Living Area	0.80**	0.16**	0.23**	0.22**	0.20**	0.16**	0.61**
7. Number of Beds	0.65**	0.09	0.22**	0.31**	0.21**	0.21**	0.46**
8. Number of Baths	1.00	0.13*	0.22**	0.20**	0.20**	0.18**	0.55**
9. Distance to Airport	0.13**	1.00	0.49**	-0.04	0.45**	0.39**	0.18**
10. Distance to CBD	0.22**	0.49**	1.00	0.30**	0.41**	0.22**	0.23**
11. Distance to Main Road	0.20**	-0.04	0.30**	1.00	0.14*	0.26**	0.25**
12. Distance to Park	0.20**	0.45**	0.41**	0.14*	1.00	0.55**	0.23**
13. Distance to Shoreline	0.18**	0.39**	0.22**	0.26**	0.55**	1.00	0.23**
14. Income	0.55**	0.18**	0.23**	0.25**	0.23**	0.23**	1.00
15. Percent of Whites	0.30**	0.22**	0.46**	0.18**	0.15**	0.05	0.55**
16. Percent of Occupied Units	0.14*	-0.08	0.00	0.26**	0.17**	0.23**	0.35**
17. Percent of Single Family Units	-0.01	0.01	-0.02	0.22**	0.12*	0.20**	0.44**
18. Baytown	-0.04	0.28**	0.33**	-0.22**	-0.13*	-0.32**	-0.16**
19. Bellaire	0.13*	-0.07	-0.24**	-0.13*	-0.11*	-0.05	0.15**
20. Channelview	-0.14*	0.00	-0.01	-0.09	-0.08	-0.12*	-0.12*
21. Crosby	0.00	0.01	0.05	0.05	0.01	-0.06	0.03
22. Cypress	0.12*	0.19**	0.18**	0.23**	0.14*	0.30**	0.24**
23. Deer Park	-0.02	-0.08	-0.02	0.01	0.01	-0.08	-0.01
24. Friendswood	0.06	-0.05	0.05	-0.08	-0.01	-0.08	-0.05

**Appendix 61. (Continued)**

Variable	8	9	10	11	12	13	14
25.Highlands	-0.11*	0.06	0.04	-0.14*	-0.04	-0.10	-0.08
26.Humble	0.08	-0.16**	0.11*	0.14*	0.13*	0.08	0.04
27.Katy	-0.05	0.47**	0.20**	0.09	0.44**	0.33**	0.04
28.Kingwood	0.01	-0.07	0.08	0.15**	-0.04	0.06	0.09
29.La Porte	-0.08	-0.06	0.14*	0.15**	0.10	-0.26**	-0.04
30.Pasadena	-0.10	-0.16**	-0.08	-0.03	0.03	-0.09	-0.07
31.Seabrook	0.04	0.03	0.23**	0.03	-0.04	-0.24**	0.08
32.Spring	0.01	-0.19**	0.12*	0.19**	-0.03	0.29**	0.03
33.Tomball	0.04	0.11*	0.22**	-0.01	0.17**	0.30**	0.01
34.Elevating HVAC Systems	0.07	-0.01	0.02	0.00	-0.04	-0.13*	-0.07
35.Elevating the House	-0.02	-0.04	-0.05	0.02	-0.06	-0.10	-0.02
36.Adding Water Proof Wall	0.02	0.02	0.08	0.07	-0.01	0.07	0.15**
37.Reinforcing Roof Rafters	0.04	0.04	0.08	0.01	0.04	-0.01	-0.10
38.Reinforcing Walls	-0.01	-0.03	0.03	0.10	0.07	-0.03	-0.01
39.Installing Storm Shutters	-0.12*	-0.01	-0.09	-0.07	-0.08	-0.08	0.01
40.Installing a Generator	-0.07	0.00	0.12*	0.02	-0.05	-0.13*	-0.01
41.Purchasing Flood Insurance	0.08	0.04	0.06	0.06	-0.04	-0.16**	0.11
42.Flood Risk	0.05	0.01	-0.12*	-0.11*	-0.13*	-0.07	-0.06
43.Hurricane Risk	0.02	0.03	0.41**	0.05	-0.18**	-0.56**	0.00
44.Chemical Risk	0.30**	0.02	0.38**	0.31**	0.18**	0.42**	0.23**
45.Flood Risk Perception	-0.13*	-0.11*	-0.05	-0.04	0.03	-0.07	-0.14*
46.Hurricane Risk Perception	-0.16**	-0.17**	-0.05	0.02	-0.13*	-0.21**	-0.13*
47.Chemical Risk Perception	-0.15**	-0.12*	-0.04	0.00	-0.08	-0.19**	-0.14*

**Appendix 61. (Continued)**

Variable	15	16	17	18	19	20	21
1. Market Value (Log)	0.50**	0.14*	0.00	-0.11	0.28**	-0.13*	-0.01
2. Market Value	0.37**	0.02	-0.01	-0.09	0.40**	-0.09	-0.02
3. Number of Stories	0.16**	-0.08	0.05	-0.05	0.09	-0.07	0.01
4. Land Area	0.12*	-0.24**	-0.22**	0.14*	-0.04	0.20**	0.01
5. House Age	-0.24**	-0.24**	-0.04	0.16**	-0.10	0.17**	-0.01
6. Living Area	0.36**	0.07	0.02	-0.01	0.11	-0.08	-0.02
7. Number of Beds	0.19**	0.21**	0.04	-0.09	-0.02	-0.10	-0.05
8. Number of Baths	0.30**	0.14*	-0.01	-0.04	0.13*	-0.14*	0.00
9. Distance to Airport	0.22**	-0.08	0.01	0.28**	-0.07	0.00	0.01
10. Distance to CBD	0.46**	0.00	-0.02	0.33**	-0.24**	-0.01	0.05
11. Distance to Main Road	0.18**	0.26**	0.22**	-0.22**	-0.13*	-0.09	0.05
12. Distance to Park	0.15**	0.17**	0.12*	-0.13*	-0.11*	-0.08	0.01
13. Distance to Shoreline	0.05	0.23**	0.20**	-0.32**	-0.05	-0.12*	-0.06
14. Income	0.55**	0.35**	0.44**	-0.16**	0.15**	-0.12*	0.03
15. Percent of Whites	1.00	0.09	0.12*	0.04	0.09	0.04	0.05
16. Percent of Occupied Units	0.09	1.00	0.54**	-0.16**	0.01	-0.20**	-0.08
17. Percent of Single Family Units	0.12*	0.54**	1.00	-0.15**	0.07	-0.06	0.06
18. Baytown	0.04	-0.16**	-0.15**	1.00	-0.05	-0.04	-0.03
19. Bellaire	0.09	0.01	0.07	-0.05	1.00	-0.02	-0.01
20. Channelview	0.04	-0.20**	-0.06	-0.04	-0.02	1.00	-0.01
21. Crosby	0.05	-0.08	0.06	-0.03	-0.01	-0.01	1.00
22. Cypress	0.13*	-0.01	0.13*	-0.06	-0.03	-0.02	-0.02
23. Deer Park	0.09	0.07	0.06	-0.03	-0.01	-0.01	-0.01
24. Friendswood	0.05	0.06	-0.04	-0.02	-0.01	-0.01	-0.01



**Appendix 61. (Continued)**

Variable	15	16	17	18	19	20	21
25.Highlands	0.07	-0.18**	-0.08	-0.03	-0.01	-0.01	-0.01
26.Humble	0.07	0.09	0.01	-0.05	-0.03	-0.02	-0.02
27.Katy	0.06	0.09	0.09	-0.06	-0.03	-0.02	-0.02
28.Kingwood	0.07	0.05	0.07	-0.02	-0.01	-0.01	-0.01
29.La Porte	0.16**	0.03	0.01	-0.09	-0.04	-0.03	-0.03
30.Pasadena	0.03	0.00	0.04	-0.04	-0.02	-0.01	-0.01
31.Seabrook	0.16**	-0.03	-0.09	-0.07	-0.03	-0.02	-0.02
32.Spring	0.12*	0.10	0.10	-0.07	-0.03	-0.03	-0.02
33.Tomball	0.10	-0.07	-0.09	-0.05	-0.02	-0.02	-0.01
34.Elevating HVAC Systems	-0.04	-0.05	-0.12*	0.07	0.05	-0.04	0.04
35.Elevating the House	0.00	-0.08	0.00	0.02	0.11	-0.03	-0.03
36.Adding Water Proof Wall	0.11	0.03	0.10	-0.05	0.04	-0.03	-0.03
37.Reinforcing Roof Rafters	-0.01	-0.06	-0.12*	0.12*	0.02	-0.04	-0.03
38.Reinforcing Walls	-0.02	0.04	0.04	0.00	0.02	-0.04	-0.03
39.Installing Storm Shutters	-0.08	0.01	0.07	0.01	0.10	-0.02	-0.02
40.Installing a Generator	0.10	-0.08	0.02	0.03	0.01	0.23**	-0.04
41.Purchasing Flood Insurance	0.14*	0.13*	0.01	0.05	0.06	-0.12*	-0.11
42.Flood Risk	-0.17**	0.01	-0.03	-0.05	0.05	-0.06	-0.05
43.Hurricane Risk	0.23**	-0.15**	-0.15**	0.29**	-0.08	0.01	-0.05
44.Chemical Risk	0.25**	0.13*	0.05	-0.06	-0.07	-0.09	0.05
45.Flood Risk Perception	-0.11	0.04	0.05	0.03	-0.04	-0.02	-0.11*
46.Hurricane Risk Perception	-0.08	0.00	0.08	0.02	-0.01	0.09	-0.07
47.Chemical Risk Perception	-0.14*	0.05	0.08	0.05	-0.07	0.02	-0.04

**Appendix 61. (Continued)**

Variable	22	23	24	25	26	27	28
1. Market Value (Log)	0.12*	0.00	0.04	-0.09	0.04	-0.01	0.00
2. Market Value	0.14*	-0.02	0.04	-0.07	0.02	-0.04	-0.02
3. Number of Stories	0.16**	-0.06	0.04	-0.06	0.06	-0.05	-0.05
4. Land Area	0.05	-0.01	-0.01	0.21**	-0.02	-0.04	-0.01
5. House Age	-0.13*	-0.06	-0.05	0.16**	-0.09	-0.14*	-0.03
6. Living Area	0.21**	-0.04	0.06	-0.12*	0.09	-0.03	-0.02
7. Number of Beds	0.13*	-0.05	0.01	-0.10	0.12*	0.04	0.01
8. Number of Baths	0.12*	-0.02	0.06	-0.11*	0.08	-0.05	0.01
9. Distance to Airport	0.19**	-0.08	-0.05	0.06	-0.16**	0.47**	-0.07
10. Distance to CBD	0.18**	-0.02	0.05	0.04	0.11*	0.20**	0.08
11. Distance to Main Road	0.23**	0.01	-0.08	-0.14*	0.14*	0.09	0.15**
12. Distance to Park	0.14*	0.01	-0.01	-0.04	0.13*	0.44**	-0.04
13. Distance to Shoreline	0.30**	-0.08	-0.08	-0.10	0.08	0.33**	0.06
14. Income	0.24**	-0.01	-0.05	-0.08	0.04	0.04	0.09
15. Percent of Whites	0.13*	0.09	0.05	0.07	0.07	0.06	0.07
16. Percent of Occupied Units	-0.01	0.07	0.06	-0.18**	0.09	0.09	0.05
17. Percent of Single Family Units	0.13*	0.06	-0.04	-0.08	0.01	0.09	0.07
18. Baytown	-0.06	-0.03	-0.02	-0.03	-0.05	-0.06	-0.02
19. Bellaire	-0.03	-0.01	-0.01	-0.01	-0.03	-0.03	-0.01
20. Channelview	-0.02	-0.01	-0.01	-0.01	-0.02	-0.02	-0.01
21. Crosby	-0.02	-0.01	-0.01	-0.01	-0.02	-0.02	-0.01
22. Cypress	1.00	-0.02	-0.01	-0.02	-0.03	-0.03	-0.01
23. Deer Park	-0.02	1.00	-0.01	-0.01	-0.02	-0.02	-0.01
24. Friendswood	-0.01	-0.01	1.00	-0.01	-0.01	-0.02	-0.01

**Appendix 61. (Continued)**

Variable	22	23	24	25	26	27	28
25.Highlands	-0.02	-0.01	-0.01	1.00	-0.02	-0.02	-0.01
26.Humble	-0.03	-0.02	-0.01	-0.02	1.00	-0.03	-0.01
27.Katy	-0.03	-0.02	-0.02	-0.02	-0.03	1.00	-0.02
28.Kingwood	-0.01	-0.01	-0.01	-0.01	-0.01	-0.02	1.00
29.La Porte	-0.05	-0.03	-0.02	-0.03	-0.05	-0.05	-0.02
30.Pasadena	-0.02	-0.01	-0.01	-0.01	-0.02	-0.02	-0.01
31.Seabrook	-0.04	-0.02	-0.02	-0.02	-0.04	-0.04	-0.02
32.Spring	-0.04	-0.02	-0.02	-0.02	-0.04	-0.04	-0.02
33.Tomball	-0.03	-0.01	-0.01	-0.01	-0.03	-0.03	-0.01
34.Elevating HVAC Systems	-0.03	-0.04	-0.04	0.13*	-0.03	0.01	-0.04
35.Elevating the House	0.01	0.09	-0.03	0.09	0.01	-0.06	-0.03
36.Adding Water Proof Wall	0.02	-0.03	-0.02	-0.03	0.02	0.01	-0.02
37.Reinforcing Roof Rafters	-0.06	0.08	-0.03	-0.03	0.01	0.05	-0.03
38.Reinforcing Walls	-0.06	0.07	-0.03	-0.03	0.00	-0.01	-0.03
39.Installing Storm Shutters	-0.03	-0.02	-0.01	-0.02	-0.03	-0.03	-0.01
40.Installing a Generator	-0.01	-0.04	-0.03	-0.04	0.00	-0.02	-0.03
41.Purchasing Flood Insurance	-0.01	0.09	0.08	-0.11	-0.07	0.01	-0.09
42.Flood Risk	-0.09	-0.03	-0.04	0.05	-0.08	0.01	-0.04
43.Hurricane Risk	-0.10	-0.01	0.03	-0.05	-0.09	-0.10	-0.04
44.Chemical Risk	0.27**	-0.08	0.30**	-0.13*	0.23**	-0.01	0.15**
45.Flood Risk Perception	0.00	0.00	0.00	-0.08	-0.04	-0.06	-0.09
46.Hurricane Risk Perception	-0.01	0.06	0.03	0.03	-0.07	-0.13*	-0.10
47.Chemical Risk Perception	-0.08	0.03	-0.07	0.01	-0.06	-0.06	-0.09

**Appendix 61. (Continued)**

Variable	29	30	31	32	33	34	35
1. Market Value (Log)	-0.07	-0.10	0.02	-0.03	0.04	-0.03	0.02
2. Market Value	-0.11	-0.08	0.00	-0.05	0.01	0.00	0.05
3. Number of Stories	-0.05	-0.07	0.03	0.01	0.00	0.01	-0.02
4. Land Area	-0.04	-0.03	-0.01	-0.02	0.14*	0.00	-0.04
5. House Age	-0.03	0.11	-0.02	-0.09	-0.12*	-0.04	-0.03
6. Living Area	-0.09	-0.10	0.04	-0.03	0.04	0.02	0.02
7. Number of Beds	-0.08	-0.02	0.06	-0.04	0.04	-0.01	-0.05
8. Number of Baths	-0.08	-0.10	0.04	0.01	0.04	0.07	-0.02
9. Distance to Airport	-0.06	-0.16**	0.03	-0.19**	0.11*	-0.01	-0.04
10. Distance to CBD	0.14*	-0.08	0.23**	0.12*	0.22**	0.02	-0.05
11. Distance to Main Road	0.15**	-0.03	0.03	0.19**	-0.01	0.00	0.02
12. Distance to Park	-0.10	0.03	-0.04	-0.03	0.17**	-0.04	-0.06
13. Distance to Shoreline	-0.26**	-0.09	-0.24**	0.29**	0.30**	-0.13*	-0.10
14. Income	-0.04	-0.07	0.08	0.03	0.01	-0.07	-0.02
15. Percent of Whites	0.16**	0.03	0.16**	0.12*	0.10	-0.04	0.00
16. Percent of Occupied Units	0.03	0.00	-0.03	0.10	-0.07	-0.05	-0.08
17. Percent of Single Family Units	0.01	0.04	-0.09	0.10	-0.09	-0.12*	0.00
18. Baytown	-0.09	-0.04	-0.07	-0.07	-0.05	0.07	0.02
19. Bellaire	-0.04	-0.02	-0.03	-0.03	-0.02	0.05	0.11
20. Channelview	-0.03	-0.01	-0.02	-0.03	-0.02	-0.04	-0.03
21. Crosby	-0.03	-0.01	-0.02	-0.02	-0.01	0.04	-0.03
22. Cypress	-0.05	-0.02	-0.04	-0.04	-0.03	-0.03	0.01
23. Deer Park	-0.03	-0.01	-0.02	-0.02	-0.01	-0.04	0.09
24. Friendswood	-0.02	-0.01	-0.02	-0.02	-0.01	-0.04	-0.03

**Appendix 61. (Continued)**

Variable	29	30	31	32	33	34	35
25.Highlands	-0.03	-0.01	-0.02	-0.02	-0.01	0.13*	0.09
26.Humble	-0.05	-0.02	-0.04	-0.04	-0.03	-0.03	0.01
27.Katy	-0.05	-0.02	-0.04	-0.04	-0.03	0.01	-0.06
28.Kingwood	-0.02	-0.01	-0.02	-0.02	-0.01	-0.04	-0.03
29.La Porte	1.00	-0.03	-0.06	-0.07	-0.04	0.04	0.04
30.Pasadena	-0.03	1.00	-0.02	-0.03	-0.02	0.10	-0.04
31.Seabrook	-0.06	-0.02	1.00	-0.05	-0.03	0.04	-0.01
32.Spring	-0.07	-0.03	-0.05	1.00	-0.03	-0.02	-0.07
33.Tomball	-0.04	-0.02	-0.03	-0.03	1.00	-0.06	-0.04
34.Elevating HVAC Systems	0.04	0.10	0.04	-0.02	-0.06	1.00	0.39**
35.Elevating the House	0.04	-0.04	-0.01	-0.07	-0.04	0.39**	1.00
36.Adding Water Proof Wall	0.24**	-0.03	-0.06	0.11	-0.04	0.14*	0.21**
37.Reinforcing Roof Rafters	0.11	-0.04	-0.07	0.03	0.03	0.36**	0.32**
38.Reinforcing Walls	0.06	0.05	0.03	-0.02	0.03	0.27**	0.23**
39.Installing Storm Shutters	0.02	-0.02	0.05	-0.04	-0.03	0.08	0.01
40.Installing a Generator	0.17**	-0.04	0.13*	0.11	-0.05	0.09	0.07
41.Purchasing Flood Insurance	0.14*	-0.01	0.16**	-0.06	-0.07	0.02	0.08
42.Flood Risk	0.07	-0.06	0.02	-0.07	-0.07	-0.02	-0.05
43.Hurricane Risk	0.39**	-0.06	0.53**	-0.13*	-0.08	0.04	0.04
44.Chemical Risk	-0.22**	-0.07	-0.12*	0.25**	0.12*	-0.12*	-0.08
45.Flood Risk Perception	0.05	0.05	0.02	-0.08	0.03	0.08	0.05
46.Hurricane Risk Perception	0.16**	0.06	0.00	-0.07	-0.01	0.09	0.08
47.Chemical Risk Perception	0.12*	0.14*	0.06	-0.09	0.02	0.10	0.08

**Appendix 61. (Continued)**

Variable	36	37	38	39	40	41	42
1. Market Value (Log)	0.04	-0.02	0.00	-0.02	-0.08	0.15**	0.04
2. Market Value	0.06	-0.03	-0.02	-0.02	-0.07	0.13*	0.06
3. Number of Stories	-0.08	-0.05	0.01	-0.08	-0.06	-0.05	-0.12*
4. Land Area	-0.01	-0.03	-0.04	-0.01	0.13*	-0.01	-0.02
5. House Age	-0.09	-0.09	-0.04	0.06	0.07	-0.06	0.00
6. Living Area	0.00	0.00	0.04	-0.09	-0.03	0.10	0.01
7. Number of Beds	-0.05	-0.07	0.01	-0.12*	-0.09	0.07	0.07
8. Number of Baths	0.02	0.04	-0.01	-0.12*	-0.07	0.08	0.05
9. Distance to Airport	0.02	0.04	-0.03	-0.01	0.00	0.04	0.01
10. Distance to CBD	0.08	0.08	0.03	-0.09	0.12*	0.06	-0.12**
11. Distance to Main Road	0.07	0.01	0.10	-0.07	0.02	0.06	-0.11**
12. Distance to Park	-0.01	0.04	0.07	-0.08	-0.05	-0.04	-0.13**
13. Distance to Shoreline	0.07	-0.01	-0.03	-0.08	-0.13*	-0.16**	-0.07
14. Income	0.15*	-0.10	-0.01	0.01	-0.01	0.11	-0.06
15. Percent of Whites	0.11	-0.01	-0.02	-0.08	0.10	0.14*	-0.17**
16. Percent of Occupied Units	0.03	-0.06	0.04	0.01	-0.08	0.13*	0.01
17. Percent of Single Family Units	0.10	-0.12*	0.04	0.07	0.02	0.01	-0.03
18. Baytown	-0.05	0.12*	0.00	0.01	0.03	0.05	-0.05
19. Bellaire	0.04	0.02	0.02	0.10	0.01	0.06	0.05
20. Channelview	-0.03	-0.04	-0.04	-0.02	0.23**	-0.12*	-0.06
21. Crosby	-0.03	-0.03	-0.03	-0.02	-0.04	-0.11	-0.05
22. Cypress	0.02	-0.06	-0.06	-0.03	-0.01	-0.01	-0.09
23. Deer Park	-0.03	0.08	0.07	-0.02	-0.04	0.09	-0.03
24. Friendswood	-0.02	-0.03	-0.03	-0.01	-0.03	0.08	-0.04

**Appendix 61. (Continued)**

Variable	36	37	38	39	40	41	42
25.Highlands	-0.03	-0.03	-0.03	-0.02	-0.04	-0.11	0.05
26.Humble	0.02	0.01	0.00	-0.03	0.00	-0.07	-0.08
27.Katy	0.01	0.05	-0.01	-0.03	-0.02	0.01	0.01
28.Kingwood	-0.02	-0.03	-0.03	-0.01	-0.03	-0.09	-0.04
29.La Porte	0.24**	0.11	0.06	0.02	0.17**	0.14*	0.07
30.Pasadena	-0.03	-0.04	0.05	-0.02	-0.04	-0.01	-0.06
31.Seabrook	-0.06	-0.07	0.03	0.05	0.13*	0.16**	0.02
32.Spring	0.11	0.03	-0.02	-0.04	0.11	-0.06	-0.07
33.Tomball	-0.04	0.03	0.03	-0.03	-0.05	-0.07	-0.07
34.Elevating HVAC Systems	0.14*	0.36**	0.27**	0.08	0.09	0.02	-0.02
35.Elevating the House	0.21**	0.32**	0.23**	0.01	0.07	0.08	-0.05
36.Adding Water Proof Wall	1.00	0.22**	0.10	0.09	0.16**	-0.04	0.01
37.Reinforcing Roof Rafters	0.22**	1.00	0.41**	0.07	0.12*	0.06	0.02
38.Reinforcing Walls	0.10	0.41**	1.00	0.06	0.11	0.07	-0.08
39.Installing Storm Shutters	0.09	0.07	0.06	1.00	0.12*	0.06	0.15**
40.Installing a Generator	0.16**	0.12*	0.11	0.12*	1.00	0.04	0.16**
41.Purchasing Flood Insurance	-0.04	0.06	0.07	0.06	0.04	1.00	0.23**
42.Flood Risk	0.01	0.02	-0.08	0.15**	0.16**	0.23**	1.00
43.Hurricane Risk	0.02	0.04	0.03	0.00	0.19**	0.23**	-0.01
44.Chemical Risk	0.00	-0.05	-0.07	-0.13*	-0.08	-0.09	-0.13*
45.Flood Risk Perception	-0.04	0.17**	0.06	0.07	0.09	0.19**	0.10
46.Hurricane Risk Perception	0.04	0.18**	0.09	0.03	0.07	0.15*	0.08
47.Chemical Risk Perception	-0.05	0.00	0.05	0.08	0.05	0.04	0.06

**Appendix 61. (Continued)**

Variable	43	44	45	46	47
1. Market Value (Log)	-0.04	0.28**	-0.19**	-0.20**	-0.26**
2. Market Value	-0.06	0.20**	-0.19**	-0.17**	-0.22**
3. Number of Stories	0.06	0.17**	-0.11	-0.09	-0.07
4. Land Area	0.03	0.05	-0.05	0.01	0.00
5. House Age	0.03	-0.29**	0.11	0.14*	0.14*
6. Living Area	0.04	0.34**	-0.14*	-0.14*	-0.20**
7. Number of Beds	-0.01	0.25**	-0.04	-0.09	-0.12
8. Number of Baths	0.02	0.30**	-0.13*	-0.16**	-0.15**
9. Distance to Airport	0.03	0.02	-0.11*	-0.17**	-0.12*
10. Distance to CBD	0.41**	0.38**	-0.05	-0.05	-0.04
11. Distance to Main Road	0.05	0.31**	-0.04	0.02	0.00
12. Distance to Park	-0.18**	0.18**	0.03	-0.13*	-0.08
13. Distance to Shoreline	-0.56**	0.42**	-0.07	-0.21**	-0.19**
14. Income	0.00	0.23**	-0.14*	-0.13*	-0.14*
15. Percent of Whites	0.23**	0.25**	-0.11	-0.08	-0.14*
16. Percent of Occupied Units	-0.15**	0.13*	0.04	0.00	0.05
17. Percent of Single Family Units	-0.15**	0.05	0.05	0.08	0.08
18. Baytown	0.29**	-0.06	0.03	0.02	0.05
19. Bellaire	-0.08	-0.07	-0.04	-0.01	-0.07
20. Channelview	0.01	-0.09	-0.02	0.09	0.02
21. Crosby	-0.05	0.05	-0.11*	-0.07	-0.04
22. Cypress	-0.10	0.27**	0.00	-0.01	-0.08
23. Deer Park	-0.01	-0.08	0.00	0.06	0.03
24. Friendswood	0.03	0.30**	0.00	0.03	-0.07



**Appendix 61. (Continued)**

Variable	43	44	45	46	47
25.Highlands	-0.05	-0.13*	-0.08	0.03	0.01
26.Humble	-0.09	0.23**	-0.04	-0.07	-0.06
27.Katy	-0.10	-0.01	-0.06	-0.13*	-0.06
28.Kingwood	-0.04	0.15**	-0.09	-0.10	-0.09
29.La Porte	0.39**	-0.22**	0.05	0.16**	0.12*
30.Pasadena	-0.06	-0.07	0.05	0.06	0.14*
31.Seabrook	0.53**	-0.12*	0.02	0.00	0.06
32.Spring	-0.13*	0.25**	-0.08	-0.07	-0.09
33.Tomball	-0.08	0.12*	0.03	-0.01	0.02
34.Elevating HVAC Systems	0.04	-0.12*	0.08	0.09	0.10
35.Elevating the House	0.04	-0.08	0.05	0.08	0.08
36.Adding Water Proof Wall	0.02	0.00	-0.04	0.04	-0.05
37.Reinforcing Roof Rafters	0.04	-0.05	0.17**	0.18**	0.00
38.Reinforcing Walls	0.03	-0.07	0.06	0.09	0.05
39.Installing Storm Shutters	0.00	-0.13*	0.07	0.03	0.08
40.Installing a Generator	0.19**	-0.08	0.09	0.07	0.05
41.Purchasing Flood Insurance	0.23**	-0.09	0.19**	0.15*	0.04
42.Flood Risk	-0.01	-0.13*	0.10	0.08	0.06
43.Hurricane Risk	1.00	-0.19**	0.04	0.15*	0.11*
44.Chemical Risk	-0.19**	1.00	-0.11*	-0.16**	-0.22**
45.Flood Risk Perception	0.04	-0.11*	1.00	0.69**	0.46**
46.Hurricane Risk Perception	0.15*	-0.16**	0.69**	1.00	0.54**
47.Chemical Risk Perception	0.11*	-0.22**	0.46**	0.54**	1.00

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