UNDERSTANDING EVACUATION DECISION, DEPARTURE TIMING AND DESTINATION CHOICE OF HOUSEHOLDS IN HIGH FLOOD RISK AREAS USING DISCRETE CHOICE MODEL

BY

MA BERNADETH LIM

A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY (ENGINEERING AND TECHNOLOGY)
SIRINDHORN INTERNATIONAL INSTITUTE OF TECHNOLOGY
THAMMASAT UNIVERSITY
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A Dissertation Presented

By

MA BERNADETH LIM

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Abstract

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by

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A number of Asian countries has experienced catastrophic disasters in the recent past. Hydro-meteorological disasters such as typhoons and floods were the most prevalent disasters that caused havoc to these countries among other disaster types. Evacuation is an essential preparedness measure in disaster management. Involving complex behavioral considerations, it requires careful modeling and planning to minimize chaos and confusion during evacuation operations. Effective modeling of evacuation travel behavior depends on effective modeling of evacuation aspects including the decision whether to fully or partially evacuate or stay in the area threatened by hazard, evacuation timing, destination type choice, mode and route choice. Using discrete choice models, this study seeks to investigate the behavioral complexities focusing on the first three decisions in the first stages of evacuation demand modeling. Data was collected through a face to face post-event survey from flood affected households in Quezon City, Philippines. Results show that evacuation decision is determined by a combination of household characteristics and capacity-related factors (gender, educational level, presence of children, and number of years living in the residence, house ownership, number of house floor levels, type of house material), as well as hazard-related factors (distance from source of flood, level of flood damage, and source of warning). Results of the binary logit model estimates for

departure timing indicate that households put importance on hazard-related factors and their capacity to cope with flood when making their decisions. Factors that determine the flood evacuation departure time constitutes the type of work of the head of the household, house ownership, the number of house floors, distance of their homes from the source of flood, and the flood level. On the other hand, the multinomial logit evacuation destination model estimates show capacity related characteristics (income, presence of flood equipment), hazard-related factors (distance from the source of hazard, source of warning) and evacuation destination specific characteristics (cost, travel distance to destination and duration of stay at the destination) as factors that are significant to this type of choice.

Findings in this research provide useful insights for evacuation managers and planners in preparing for future flood evacuations. Insights in evacuation decision can be used to design appropriate programs to encourage full evacuation compliance of households especially those that live nearest to the flood source, as well as those who have houses with 2 or more floor levels. Evacuation planners can also develop alternative strategies to increase full evacuation compliance of households with children since these households seem less likely to fully evacuate. Evacuation compliance of households can be improved through the design and conduct of educational programs to increase awareness about hazards and disasters and enhance preparedness for future evacuations. People with disaster education are those who are best prepared and capable to manage a disaster, they may also be more willing to take preventive measures.

In terms of departure timing, authorities could design appropriate strategies to encourage those that are living very near the source of flood and have house floor levels more than a floor to evacuate immediately once the government recommended them to evacuate. This can be done by educating and/or providing them with benefits of evacuating earlier such as highly prioritizing them to be moved to secured evacuation centers with provision of vehicles as needed, food, water, medical assistance and other basic needs. Households that own their house can be encouraged can be involved in leading evacuation movements in the future. In order to encourage households who are renting their homes to also evacuate well ahead of time, security guards should be provided in areas of residence to keep them from worries of looting and house security.

Above all, government officials, when issuing future evacuation advice, should also specify the timing of evacuation by specific groups of households in addition to other evacuation related content of the message (e.g. routes to take when evacuating according to specified destinations such as evacuation centers). The model developed here can be used to predict the number of households evacuating at specific timing which can be utilized to plan for staged evacuation movement in the future.

Findings from the destination analysis can be used by the government to prepare evacuation warnings with concrete information to communicate to people in order to be prepared ahead of time. They could also encourage those who have been going to friends/families in order to decrease the demand of going to public evacuation centers. In this sense, the government could also prepare for the supplies such as food, water and medicine and be able to let evacuees have better situation during future evacuations. This in turn could reduce the necessity of large numbers of public shelter/church facilities.

Models developed in this study and its predictive ability and specifications were also validated.

Keywords: Evacuation, Modeling, Discrete Choice, Evacuation Decision, Travel Behavior, Mode, Destination, Departure Time, Flood

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Chapter 1
Introduction

The background and motivation of conducting this study, the objectives, the scope and limitation are presented in this chapter.

1.1 Rationale

Disasters, natural or man-made, such as hurricanes, floods, major chemical accidents, and conflicts may come in unlimited diversities. It is the event that "causes serious disruption of the functioning of society, causing widespread human, material or environmental losses, which exceed the ability of the affected people to cope using their own resources" (Abarquez, 2004). It has been evident that disasters are becoming more frequent and have been causing severe and tremendous damages to the people, economy, and properties (e.g. Allen, 2006; Torrente et al., 2008). Flood events alone are prevalent worldwide. The impacts of flood disasters are becoming more catastrophic due to increasing disaster risks. One of the reasons for these disasters is the build-up of settlements in flood prone areas (Campion and Venzke 2013).

In Metro Manila, Philippines alone, records show a number of major flood disasters such as Joan and Patsy, Angela, and Ketsana, which happened in 1970, 1995 and 2009, respectively. Recorded deaths and losses in 1970 and 1995 events were 768 with around PHP 4 billion, and 1000 with PHP 10.8 billion losses, respectively (Quezon City Government and Earthquake and Megacities Initiative, QCG and EMI 2013). The 2009 floods were most intense in terms of intensity-frequency-duration (IFD) impact, which was estimated to be equivalent to a 120-year return period (QCG and EMI 2013). This rainfall event was the highest in the country's forty-year record, with estimated losses of around PHP 11 billion (USD 275 million). In succeeding years, more flood events continued to happen, affecting millions of people with rising cost of damage, prompting better preparedness and emergency management for future flood events. For instance, the August 2013 and typhoon-induced floods caused damages in agriculture and infrastructure reached PHP138 million (USD 3 million) (UNOCHA, 2013).

Increased risk should be anticipated and predicted in order to minimize unimaginable impacts of future disasters (Fedeski and Gwilliam, 2007). The occurrence of hydro-meteorological hazards such floods can be anticipated in advance. Their impacts can also be estimated at a certain level. With this, it is possible that people at risk can prepare so that impacts of future disasters could be averted. One effective measure that all level of governments does before disaster strikes an area at risk is evacuation. In fact, the National Disaster Risk Reduction Management Framework of the Philippines or Republic Act 10121 specifies two types of evacuation that can be enforced by the local governments based on timing, which are preemptive evacuation and forced evacuation (NDRRMC, 2010). Preemptive and forced evacuations are executed prior and during the disaster event, respectively. Regardless of the type of evacuation orders, careful planning, simulation and drills are carried out to prepare community people for possible evacuation in the future. Evacuation planning is a way to identify the best strategy for evacuation under the most probable disaster scenario. However, the success relies on complex factors, like warning time, time to prepare and respond by the population affected, distribution of information and how instructions are provided, available routes, condition of traffic in the network, and traffic management measures (Lindell and Prater, 2007). Transportation, therefore, is particularly important to these operations. Researchers proposed that traffic simulation of an evacuation should take into account, evacuees’ travel behavior (Dow and Cutter, 2000; Pel, et al., 2010; Pel et al., 2012). Doing so would limit chaos and delays in moving evacuees to safety. Thus, identifying and analyzing the complex factors affecting the evacuation travel-related decisions is crucial for better planning and evacuation operations. A behaviorally-sound evacuation modeling is important for smooth execution of evacuation during the event of disasters. Models that capture behavior of households increase the ability of understanding more details on the evacuation process and decision making. The behavioral models can be incorporated to the bigger behavioral model set and into, for instance a simulation framework in order to model the details of the evacuation process while illuminating the behavior that can't be easily seen from separate analysis done for every decision making (Mesa-arango et al., 2013).

Households are faced with decision-making during emergency situations that include evacuation decision, departure time, destination, mode and route (Pel et al., 2012). Evacuation decision is the decision to either fully, partially or do not evacuate members of the household at all. Departure time choice describes when the household actually leaves the area at risk. Destination choice describes where the households go when leaving the area at risk. Mode choice describes which mode of transport is preferred when leaving the area at risk. And route choice describes what route evacuees take when moving from area at risk to their chosen destination. All these decisions involve complex behavioral factors influencing each household of various characteristics and situations at the period of choosing (e.g. Simonovic and Ahmad, 2005).

1.2 Statement of the problem

With the recognition of the importance of considering evacuation behavior, research efforts have been done in areas of evacuation-related decisions such as evacuation decision, departure timing and destination choices. In the area of evacuation decision, much effort in understanding the influential factors to this decision has been put forward in research. These studies include a mixture of social research and evacuation modeling. However, effects of factors that have been identified vary from significant to insignificant across types of hazards (Murray-Tuite and Wholshon, 2013). In addition, models that have been developed to quantify travel-related decision have not captured the combination of the characteristics of the household (such as socio-economic and capacity to cope), hazard-related characteristics (such as hazard intensity/severity and frequency, distance from the hazard) and other factors such as presence of warning and communication strategies. Integration of these factors that are based on disaster management concepts is close to understanding the reality of behavior in evacuation. Moreover, risk perception is important to understand evacuation decision (Dash and Gladwin, 2007). Risk perception is associated with environmental cues (Siebeneck et al., 2012), as well as the characteristics of the hazard (Brommer and Senkbeil, 2010).

Inputs to risk perception and eventually to evacuation decision should be combinations of household characteristics and capacity to cope with floods and hazard-related factors.

The importance of understanding decision making in terms of evacuation timing has been highlighted in studies. For instance, Pel et al. (2011) in their study on evacuee behavior analysis addressed some traffic model's limitations. Results of their study made the authors stress the need for more behavioral analysis on departure timing of evacuees. Further, the authors suggested that parameter settings in traffic models should be given careful attention. This is due to these type of model's limitations to accommodate suitable actual data. This limitation, if not addressed could result to models that are not correctly calibrated because of the use of traffic data that represent regular daily traffic conditions. Moreover, Li et al. (2013) constructed a response curve for evacuation with a 2011 traffic data. Their findings also made them recommend that more empirical data from different cases are needed to have reliable evacuation response model. The authors have strongly noted that the behavior analysis is very important to better understand decision making process made in times of evacuation. Evacuation time has been mostly analyzed using response curves using traffic data during evacuation (e.g. Radwan et al., 1985; Tweedie et al., 1986; Lindell and Prater, 2007). However, using the response curve do not provide disaggregate information on where evacuees came from, the types of households and their characteristics, the type of evacuation warning they received from the government, among others. These pieces of information are important for capturing behaviors that could allow planners to design appropriate evacuation strategies.

In terms of the destination type choice, although there are a number of research efforts in understanding the destination of evacuees at risk from hazard, bulk, if not all of the studies were focused in the context of developed countries where culture, capacity and resources which affect households' response to evacuation orders as well as in making travel decisions differ from developing countries. In addition, most of the evacuation studies conducted is specific to hurricanes, despite recognition that evacuation planning should be viewed specific to the hazard (e.g. hurricane, flood) (Murray-Tuite and Wholshon, 2013). These are also true to the studies conducted in other travel-related decisions during evacuation such as evacuation decision and departure timing. Therefore, understanding and modeling travel behavior in the onset of other hazards such as flood, in the context of developing Asia, is appropriate.

1.3 Objectives of the study

This study aims to understand the complex behavioral factors that determine evacuation-travel choices of households located at high flood-risk areas. This study seeks to identify strong influential factors for evacuation-related decisions building from the many factors found in the literature. Upon identifying these factors, this study also aims to translate this behavior into models that could quantify travel behavior. Specifically, this study is conducted to:

- Identify the factors that determine evacuation decision, departure time choice, and destination choice of households at the onset of flood evacuation;
- Develop and validate models of evacuation decision, departure timing and destination choice;
- Provide policy recommendations for planning future flood evacuations.

1.4 Significance of the study

This study contributes to the evacuation travel behavior modeling research endeavor, particularly, with consideration to flood hazard. It is a significant step towards understanding evacuation travel behavior in the context of Asian developing countries.

Specifically, this study identifies factors that influence travel behavior of households when at risk of impending hazard. It is an effort towards bringing together sociologists, evacuation managers and transportation planners in an endeavor to work together for better evacuation planning. Before implemented in practice, research needs to prove that integration of the factors from the viewpoint of these researchers can contribute to better understanding what is really happening during emergencies, hence better evacuation planning. This study is an initial step towards development of comprehensive evacuation plans in the onset of flood evacuation in the Philippines.

During the research design phase, comprehensive survey design was developed to be able to elicit information on flood experience from the households covered in this study. Details in the survey questionnaire was based on evacuation experience of households during a major flood event in 2013. In the form of revealed preference survey questionnaire, it was developed to acquire information on the socio-demographic and personal details of the household, specifically the household head, evacuation decision and reasons of not evacuating, their destination in case the household evacuated, their timing of evacuation, and other evacuation-related information. These information, are then used to develop various decision models that capture variables in every stage of evacuation decision making process, including the decision to evacuate or not, their departure timing and their destination.

It is envisaged by the research team and the government of Quezon City that the outputs of this study can be used in developing an evacuation plan. In terms of the results of evacuation decision model, outputs are helpful for the government to determine possible demand for evacuation centers and allocation of needed resources whenever an evacuation is implemented. Results from departure timing models developed are useful in understanding the timing response of evacuees in flood disasters. Thereby, governments can make use of the results to develop strategies to increase compliance of preemptive evacuation, hence, reducing casualties during flood events. From the destination type models, having a better understanding on the characteristics of households will help governments and researchers determine what encourage households to go to preferred destinations. This information for instance can be used for identifying the evacuation center demand and improving settings and locations. The government can also prepare for information on evacuation centers when issuing the evacuation warning to the population at risk.

1.5 Scope and limitation

This study focuses on understanding the factors that affect the travel decisions made at household level during evacuation. This study focuses on the demand side travel behavior that includes evacuation decision, departure time choice, and destination choice defined as follows:

- Evacuation decision: the decisions of the households either partial, full, or no evacuation.
- Departure timing: the timing of evacuation of households according to their evacuation decision.
- Destination: the ultimate type of destinations, the place where households go for safety until they return back to their homes.

This study does not cover the mode and route choice as it compasses analysis that could include many aspects of transportation facilities. Models of evacuation travel behavior of households are also developed here to quantify travel behavior. Decisions on the part of planning authorities that is more complex and covers all aspects of travel demand modeling, including the demand and the supply side, is not covered in this study. Only the household-level decision is covered. Also, only the decisions of households living in high flood risk areas, hence those who received mandatory evacuation notice is the focus of this study. Households not living in high flood risk areas are not included.

Chapter 2
Literature Review

Modeling evacuation lies on the ability of adequately modeling each evacuation behavior aspect (Cheng et al., 2008). Models that predict who evacuates and who stays behind (evacuation decision), where do they evacuate and what type (destination), and by what mode of transportation (mode), gives information that are important for emergency management and planning (Cuellar et al., 2009). First, forecasting evacuation behavior based on scenarios makes researchers identify infrastructures needed due to increased demands. This helps identify evacuation centers and other possible evacuation destinations and resources. Second, knowing where the people evacuate to can help prepare for and allocate resources to the number of evacuees, accordingly. This information also helps in giving right information to emergency workers for proper actions done, when there is a population at risk who have not been able to evacuate ahead of time. Third, predictions on relocations can be used in planning while bringing government officials and other major evacuation players to coordinate and work hand in hand for the benefit of people at risk being served.

Large number of factors are considered by households when deciding to evacuate. The complex factors are to be taken into account when deciding when to give warning for evacuation- either earlier when the hazard is still unpredictable, or later when the hazard details are more certain but there is less time for evacuees to prepare and evacuate (Hasan et al. 2011). Information on the destination choice, on one hand, is essential in determining the needs for evacuation facilities and know its sufficiency in case an actual evacuation occurs. The models can benefit governments and researchers through recognition of which factors are important when deciding to use evacuation centers designated, other alternative destinations and cooperation possibilities with these destinations. It also helps planning for what strategies is better between increasing capacities and/or issuing warnings to evacuate early enough ensuring evacuation is done as fast as possible (Mesa-arango et al., 2013).

Review of practices and efforts in research on modeling travel behavior during evacuation is presented in this chapter. The travel demand-related decisions including evacuation decision, departure time, and destination choice are reviewed here. Modeling evacuation decision is a crucial part in estimating evacuation demand during emergency as it involves complex behavioral factors considering both environmental and social elements. Understanding the circumstances of the individuals/households to evacuate is primarily important for authorities. This can be explicitly understood by studying the factors that determine the evacuation decision making. By doing this, authorities are able to devise, design, and develop strategies to persuade individuals/households to evacuate, thereby, decreasing loss of lives in the event of disasters (Hsu and Peeta, 2013). Departure time of evacuees is essential in determining the demand for evacuation. Evacuation demand models are used in finding for the number of people who will evacuate and their departure time patterns. Destination choice is described as the location where evacuees choose to go during evacuation. It is classified as ultimate and proximate. Ultimate destinations are described as evacuee destination where they stay until they can go back to their homes. While proximate destinations are meeting points of evacuees where vehicles are stationed to bring them to their destinations (Murray-Tuite and Wholshon, 2013).

2.1 Modeling Evacuation Travel Behavior

Evacuation planning models evolved from the classic four-step transportation planning model that include the stages of demand estimation, trip distribution, mode split, and trip assignment. Abdelgawad and Abdulhai (2010a) exemplified the four-step model as a complete set of integrated tools for modeling and managing transportation systems under emergency evacuation. Yin et al. (2014) also assessed a comprehensive evacuation plan for hurricane with the use of a model which is an agent-based travel demand system. The system incorporated econometric and statistical models that take into account the decision-making behavior of evacuees including evacuation decision, destination and the type of accommodation, mode and vehicle usage, as well as departure time choice in addition to pre-evacuation activities.

2.1.1 Evacuation-related decision and demand modeling

In the first stage, evacuation demand models forecast how many evacuates and the timing of their departure. Usually, evacuation demand modeling is done in three steps, as detailed in Pel et al. (2012). In the first step, the area that needs to be evacuated is identified. This step is important when communicating with the people who need to evacuate. Disaster managers identify this region through risk assessment, which accounts for the interactions between hazard, capacity, and vulnerability of an area (Abarquez and Murshed, 2004). The second step is to determine the number of people that will evacuate. This is important in determining the demand of evacuees. The third step is to identify the departure time or loading rates of evacuees.

The second stage is the evacuation distribution of which the origin–destination is either assumed using the potential locations of shelters or estimated from the destination choices of evacuees gathered from past evacuation events (e.g., Mesa-Arango et al. 2013). The third stage is the mode split which specifies the type of mode taken by evacuees. With the recognition of the need of considering the population who depends on mass transit or other modes of transport in evacuating, research efforts have also been toward multimodal evacuation planning (e.g., Abdelgawad and Abdulhai 2010b; Shiwakoti et al. 2013). Recently, studies have been conducted to understand how evacuees choose the mode they take when evacuating (e.g., Sadri et al. 2014a). The last stage is the trip assignment which describes the movement of evacuees to safer places through the transportation networks. Traffic assignment is related to determining routes that evacuees choose to take of which studies are now increasing in this area (e.g., Sadri et al., 2014b; Akbarzadeh and Wilmot 2015; Lim et al. 2015a, b).

The evacuation decision of people at risk from hazard is analyzed and estimated in the second step under the first stage of estimating evacuation demand. Evacuation decision is seen in two different fronts in evacuation modeling. Some evacuation modeling studies assumes “one rule fits all”, where the whole population at risk evacuates. This considers the lead time while missing out the behavior of the evacuees (Sorensen and Vogt, 2006). This is especially applicable to those investigations using optimization, simulation, and optimization-simulation based evacuation modeling studies, specifically on evacuation time estimates (Pel et al., 2010). Huibregtse et al. (2010) investigated a large evacuation considering partial evacuation using stochastic optimization-simulation based modeling. This investigation is understandable due to the limitation of real household data and the limitation of carrying out a full enumeration survey in a large area. On the other hand, travel behavior studies consider the evacuation decision of every individual/household in modeling with the use of acceptable statistical analysis such as logistic regression (e.g. Fu and Wilmot 2004). A behavior-based model predicts an outcome of whether people evacuate or stay. This is according to the recognition in research that an individual/household's evacuation decision is dependent on behavioral factors. Evacuation decision interpretation are taken from empirical models developed using data gathered for a specific hazard type (e.g. Hasan et al., 2011). When compared to network analysis, regression models are better in predictive ability, as well as in capturing behavioral complexities (Wilmot and Mei, 2004).

Evacuees' departure timing can be modeled either sequentially or simultaneously modeled with evacuation decision (Pel et al., 2012). In the sequential modeling approach, evacuees' departure time choice is modeled after estimating the percentage of people deciding to evacuate. This is usually done through the application of exogenous response curve indicating evacuees' percentage leaving in specified period of time interval. The departure curve has been useful for traffic operations, congestion, and therefore the network clearance time in emergency evacuation. Loading the evacuation demand in stages has the potential to better utilize the existing capacity of the transportation system as opposed to simultaneous evacuation which potentially gridlocks in the network (Abdelgawad and Abdulhai, 2010a). Generation of evacuation departure curves can be done in two ways. First, response curves are constructed based on post evacuation surveys. Second, planners' knowledge and judgment with data to create general functions are used to estimate departure time. The first approach applies response curve of different rates such as slow, medium and fast. Example of this is the one developed by the United States Army Corps of Engineers (2000) from post-evacuation surveys and behavioral analyses. This incorporates the zero time point where the decision is done after issuance of evacuation, which reflects the share of evacuees who left before the evacuation order is given. Although this approach is simple to use, the transferability of such profiles to other evacuation events is an issue as well as its insensitivity to the dynamics of the evacuation process (Abdelgawad and Abdulhai, 2010a). Model transferability is defined by Koppelman et al. (1985) as "the application of a model formulated and estimated in one context to another context". Checking the issue of whether the estimated parameters of a model can be used in another context, is an area that is being newly investigated in the context of evacuation research (e.g. Hasan et al., 2012). A model is more useful when it can be applied to another context (e.g. city or area or can be used for data collected from one hurricane or flood event to another). Further to the second approach to sequential modeling, the departure response curve assumes to follow different distributions e.g. instantaneous departure, Poisson, Rayleigh, sigmoid curve, uniform, and Weibull distribution. The Weibull distribution and sigmoid curve produces the most realistic results when compared to other types of curves (Pel et al., 2012).

In the simultaneous approach, evacuation decision and departure time choice was modeled simultaneously using the binary logit model that shows time-dependence (e.g. Fu and Wilmot, 2004; Fu et al., 2006). Binary logit model is iteratively estimated to predict the number of people deciding to evacuate and depart immediately, an/or those that are deciding to evacuate later. As detailed in Pel et al. (2012), the way the repeated binary logit model performs depends on how relative evacuation decision utilities are accurately estimated. Another approach in simultaneous modeling is the development of mathematical models using data from surveys, and evacuation demand scheduling optimization (staging). This approach determines the optimal or "near-optimal" evacuation schedule that achieves a certain objective such as minimizing network clearance time (Pel et al., 2011). However, solving this problem is mathematically and computationally demanding and requires the interaction between an optimization model and a dynamic model of the transportation system.

The second stage of evacuation demand estimation is taking into account the destination choice of evacuees. Most studies classify destinations as emergency or public shelters, hotels and motels, and friends/family. For example, in the study of Whitehead et al. (2000) actual evacuation shares to public shelters, hotels/motels, friends/family, and others are 5%, 16%, 70.5% and 8.5%, respectively. 6%, 16% and 70% stayed in public shelters, hotels/motels, and with peers, respectively (Whitehead, 2003). On the other hand, 3%, 29% and 54% stayed in public shelters, hotels/motels, and with peers according to Lindell et al. (2011). While evacuation rates revealed based on responses on hypothetical hurricane were 12.2%, 23.6%, 59.9%, and 4.3% for those who went to pubic shelter hotel/motel, and friends/family, respectively. Further, finding using data from hurricanes that happened in the past indicate that 5% to 25% go to public shelters, while 20% to 40% go to hotels/motels, and 45% to 70% go to their friends/family (Cuellar et al., 2009). Additionally, Wu et al. (2012) pointed out that only about 3% go to public shelters, while 18% and 61% stay in hotels/motels and with friends/relatives, respectively. The general trends of shares of destination are widely dominated by friends/family. These results, however, are mostly taken from the context of the developed countries primarily in the United States of America (USA). This trend might vary in the context of other countries where socio-economic conditions of vulnerable communities are different.

2.2 Variables that are Significant to Evacuation-related Travel Decisions

2.2.1 Factors affecting evacuation decision

Factors that determine evacuation decision of individuals/households have been extensively studied for evacuation planning and modeling. Earlier studies in understanding what influences evacuation decision were conducted in the field of social sciences and evacuation. Perry (1979) organized findings from studies and formulated conceptual framework of interrelated hypotheses describing variables found to be factors of decision to evacuate. He identified eight hypothetical relationships of major variables to evacuation. According to him, the likelihood of evacuation is higher when: the individual’s adaptive plan is more precise, the individual’s real threat perception is greater, the level of perceived personal risk is higher, household members are together, one’s relationship to extended kinsmen is closer, and one’s participation in the community is greater. Studies in evacuation also revealed influential factors to evacuation decision. For instance, a Sorensen et al. (1987), as cited in Stopher et al. (2004), also identified interrelationships of influential factors towards evacuation behavior, which consist of demographic characteristics, risk sensitivity, social ties, concerns over risk coping ability, attitude toward risk managers, hazard characteristics, and situational characteristics, that include a general model of evacuation behavior.

Dash and Gladwin (2007) also carried out a comprehensive review on factors important in determining evacuation decision. In their review, they looked at a broad range of influential factors determining evacuation decision from findings in three broad research areas including evacuation research, risk perception and warning. It was highlighted that "risk perception is one of the key factors in understanding the evacuation decision-making process". In understanding risk perception and its effect on evacuation related decision, Lindell and Hwang (2008) in their study investigated environmental proximity, personal experience and the influence to perceived risk and hazard response. These factors are analyzed according to types of hazard including flood, hurricane, and toxic chemical. Findings show that ethnicity, gender, hazard experience, hazard proximity, income and risk information affect perceived risk. Results also revealed that effects of some factors are specific to the hazard type. For these reasons, Lindell and Hwang (2008) emphasized that taking into account specific recipients of warning messages and the medium of communication is important. This helps increase adoption of hazard adjustment by households that have low perceived risk. This is supported by Siebeneck and Cova (2012), who asserted that when the risk perception level is high, people more likely decide to evacuate. They added that risk perception is associated with environmental cues and hazard-related factors according to past evacuation experience. However, findings in a recent study on relationship of actual view of risk and perception from floods and evacuation was that flood perception is not related to the actual risk. Nevertheless, actual risk from flood seems to be important environmental cue to perception of risk as well as the evacuation decision before the hurricane landfall (Wallace, Poole, and Horney, 2014). On the other hand, the more an organization managing disaster (e.g. US Federal Emergency Management Agency, FEMA) have established integrity, the higher the probability of people complying to evacuation message from them (Kim and Oh, 2014). Also, when people are knowledgeable on existing disaster plans, the higher is the likelihood of evacuation compliance. However, due to the nature of evacuation decision as a social process involving credibility of the warning sources, community and household factors, risk perception, and the government, it is then suggested that these factors should be further investigated. Specific factors including numbers of children and pets, risk perceptions, as well as social networks, should be subject to empirical studies (Kim and Oh, 2014).

Risk is the interaction of hazard, vulnerability, and capacity. Hence, a person's perceived risk and their evacuation decision is affected by these factors. Hazard is defined by its characteristics. Vulnerability and capacity are related to the characteristics of households at risk. Ii is therefore suggested that risk perception is a combination of a broad range of factors grouped into characteristics of the household, capacity-related, and hazard-related factors. In order to analyze evacuation decision in a complex behavioral manner, risk perception should be explained by a cluster of factors that include socio-demographic, capacity-related, and hazard-related factors (see Figure 1).

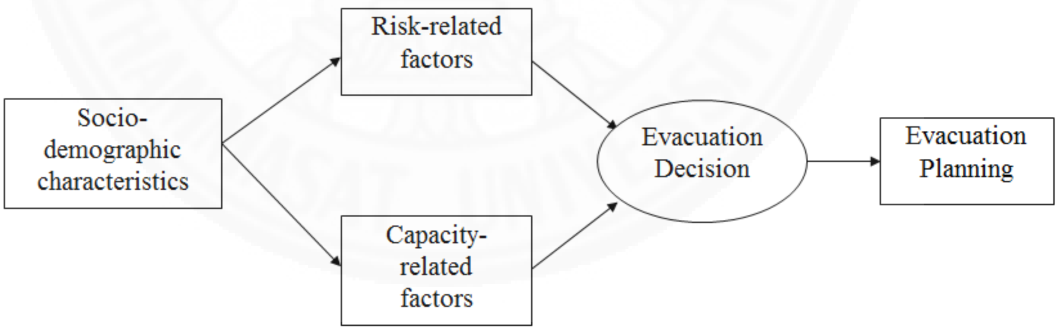


Figure 1. Relationship of individual/household characteristics, risk and capacity-related factors to evacuation planning

A long list of factors that influence evacuation decision can be identified from comprehensive reviews on evacuation behavior done by Dash and Gladwin (2007), and Murray-Tuite and Wholshon (2013). These factors include age, gender, educational attainment, household income and size, presence of children and elderly, disability, ethnicity, race, social networks, type of residence (single- or multiple family), number of years in the residence, type of housing, objective and perceived risk, social, economic, risk variables, presence of pet in the household, hazard duration, frequency, location and magnitude, past hazard or evacuation experience, knowledge on the hazard, geographic location, the warning message itself, presence of warning, and mandatory evacuation notice. According to the context of the area at risk, the effect of these factors can encourage or discourage compliance to evacuation warning.

Evacuation decision models are then assessed against the combination of three identified broad group of factors which are the characteristics of the household, their capacities and hazard-related ones. Table 2.1 presents this summary in addition to the latest literature available. The table shows that efforts have been put forward in evacuation modeling towards incorporating these elements of risk perception for better understanding of how people decide to evacuate. However, a little can be learned on consideration of the adaptive capacity of households/individuals in areas at risk from impending hazard. As such, a study by Der-Martirosian et al. (2014) focused on the adaptive capacity of veterans considering seven surrogate measures of household emergency preparedness. Although the research efforts discussed in Table 2.1 contributed towards considering behavioral aspect in evacuation planning and modeling, the combination of complex factors, including characteristics of the decision maker (individual/household), their capacities to cope with the disaster, as well as hazard-related factors including hazard characteristics that are associated with evacuation decision, are not well-captured. Therefore, further research is appropriate in the area of evacuation decision making.

Table 2.1. Evacuation decision models and significant factors

Author	Hazard Considered	Significant Factors		
		Socio-demographic characteristics	Capacity-related	Risk-related
Whitehead *et al.* (2001)	Hurricane	income, race, sex, education, housing type, pet holders, presence of young children, presence of elderly children	x	hurricane characteristics, perceived risk
Fu and Wilmot (2004)	Hurricane	housing type	x	distance from storm, forward speed, flooding possibility, presence of evacuation warning, time-of-day
Stopher *et al.* (2004)	Bushfires	age, gender, presence of younger children, presence of old age adults, length of stay in residence, number of vehicles	x	fire type, fire distance, temperature, wind speed and direction
Charnkol and Tanaboriboon (2006)	Tsunami	number of household members, marital status, level of education	disaster knowledge, past experience, presence of ship/vessel	distance to nearest shore
Fu *et al.* (2006)	Hurricane	housing type	x	distance from storm, flooding possibility, forward speed, time of day, presence of evacuation warning, time-to-landfall, wind speed
Hasan et al. (2011)	Hurricane	work during evacuation, number of children, house ownership status, type of housing (mobile), income and level of education	previous hurricane experience	Geographic location, source of notice for evacuation, type of evacuation notice received

2.2.2 Departure timing and variables that affect decision-making

Studies that have identified important variables that significantly affect evacuation departure time choice include that of Charnkol and Tanaboriboon (2006) in case of tsunami, as well as Pel et al. (2010), Li et al. (2013), Dixit et al. (2012) and Hasan et al. (2013) in case of hurricane. Charnkol and Tanaboriboon (2006) investigated the evacuation departure timing of evacuee in the case of hypothetical tsunami in Thailand. A behavioral analysis for transients and permanent residents was conducted to understand their response patterns. Response patterns included fast, medium, and slow, with preparation and response time periods of 60, 45, 30, and 15 minutes. In the analysis, the age, number of family members, distance from the seashore, presence of disaster knowledge prior to the disaster, the number of children in the family, type of employment, marital status and educational attainment was found to influence evacuation departure decision making. Insights could be derived from the study. Transients were found to evacuate faster compared to permanent residents. As the number of family members increase, the less likely the family belongs to the quick response group. Additionally, those living nearer the shore has higher probability of evacuating earlier compared to those living farther from shore. Also, those who or their relatives had tsunami experience had higher likelihood of evacuating faster. Also, those who knew about disasters had higher probability of being in the quick response group than those who do not know about disasters. The more children the household has, the less likely they evacuate faster. While teenagers due to lack in tsunami experience have higher likelihood of being in the slow to respond group. This may also be due to their ignorance and underestimation of risks at hand. Moreover, private employees have higher likelihood of responding quicker than other employees. Although marital status and educational level was found to be significant at some level, the authors recommended future investigation in these factors.

On the other hand, Pel et al. (2010) in his earlier work focusing on departure time choice, proposed a model of integrating traveler information and compliance behavior using macroscopic simulation package. Their findings show the need to incorporate traveler information and compliance into evacuation models. They suggested that there is a need to understand the impacts of changing information and evacuation decision results that are obviously related to many behavioral aspects. Moreover, Li et al. (2013) constructed, using traffic data from the 2011 Hurricane Irene, developed an evacuation response curve, which shows an S-shaped one. The curve shows a sharp upward direction during the time that evacuation warning was issued. S-curves is widely used but with varied different mathematical functions. To capture the behavior of evacuees, response curves are calibrated and compared using empirical data indicating that the curve calibrated with Logit and Rayleigh functions are best fit empirical data used. The results of analysis of evacuation behavior and the calibrated response models may be useful for planning purposes in other areas with similar hazard context.

Dixit et al. (2012) conducted a similar research in understanding behavior of evacuees by using the theory of risk developed and connecting it to economic theory with behavior under threat. This study provides the first step toward explicitly incorporating risk aversion into the modeling framework for estimating time-dependent evacuation demand. Using Hurricane Andrew response data, evacuation departure time choice model is proposed. Risk attitudes are modeled using specified constant relative risk aversion. Results showed the presence of children influence the time preparation of the household when staying at home. In addition, the length of time spent in that area, time of the day, and presence of mandatory evacuation order also influence behavior on risks. Further research will be needed to use actual revealed mobilization time and the time used to prepare to weather the storm, to develop robust estimates.

Hasan et al. (2013) also developed a model of evacuation time using a random-parameter hazard-based method. Findings include household's geographic location, shelter type, location and time to reach destination in a normal time, time between decision making and actual evacuation, living or not in a mobile house, educational level, income, and type of evacuation warning received are factors that affect the behavior. In addition, usual travel time to destination, household location and number of children have random parameters. The following insights can be taken from this study for evacuation planning. First, actual travel time going to destinations during normal days can influence departure timing decision. Households that decide to go to destination needing longer time compared to normal days will leave earlier than those moving to other places. Second, households evacuating at a later time have probability to leave just after the decision than those evacuating earlier. Third, households with lower income are more likely to evacuate later than households with higher income. Fourth, households that received either mandatory or recommended evacuation notice are more likely to evacuate earlier.

2.2.3 Determinants of destination choice

A number of studies have investigated the factors that evacuees put importance to in making their decisions to which destinations they evacuate to. Whitehead et al. (2000) in their study identified key factors such as hurricane characteristics, income, householder's race, sex, education, housing type, pet holders, presence of young children, presence of elderly children, and perceived risk. Using hypothetical hurricane data from 673 households that indicated evacuation, two destination models including hotel/motel and public shelters were estimated, compared to friends/families and other destinations denoted as other. Results of the hotels/motels model revealed that higher income households have higher probability of choosing the destination type. Moreover, households living in mobile homes, have medium to high flood risk perception, pets, white with higher level of education are less likely to go to hotels/motels. Households staying in mobile homes are almost two times less likely to go to such destination. The estimation results of the public shelter model indicated that households that have higher incomes have lesser probability of choosing the shelter destination. Also, households that are female, white, with pets, and more years of education have lower likelihood of choosing a shelter.

Cheng and Wilmot (2008) developed separate models for going to destinations including friends/relatives and to hotels/motels. For the model of friends/relatives, factors affecting destination choice are distance to the destination, population in destination, risk indicator to indicate destination's vulnerability to hurricane, destination ethnic percentage, and Metropolitan area indicator. The higher the distance to evacuation destination, the lower likelihood of being chosen. The variable population indicates the size of population proportional to destination being chosen. While the risk indicator variable, indicates that areas at risk of hurricane are less likely to be chose as destinations. In addition, the metropolitan area indicator suggests preference of evacuees to go to a metropolitan area. Also, the higher the percentage of white people in the destination, the more people gets to choose this destination type. In terms of the results for the hotels/motels model, factors are distance to the destination, number of hotels/motels at destination, risk indicator, destination ethnic percentage and interstate highway proximity indicator. The signs of the variables including the distance to destination, risk indicator of destinations vulnerability to hurricane, and ethic percentage in the model are similar to those in the friend/relative model. The number of hotels available in the destination as well as the presence of interstate highway, affect attraction of the destination. Overall results of the study showed that evacuees choose closer and safe destinations rather than farther ones. However, the authors noted that result is more obvious to evacuees to the hotels/motels than to friends/relatives where destination type choice is limited. From this, it can be seen that distance may not well represent impedance. And authors suggested dynamic destination type choice model to be used for a time-dependent assessment of available destination, real-time travel time and destination hurricane threat. Therefore, this study was extended in Cheng and Wilmot (2013).

Cheng and Wilmot (2013) developed a time-dependent disaggregate models of destination choice incorporating factors such as hurricane properties, evacuee and destination characteristics, as well as network conditions. The friends/relative model had significant factors such as the time-dependent travel time between zones, origin-destination travel time, availability of accommodation in destination, predicted path of storm, major metropolitan area and ethnic similarity. The accommodation available in destination, indicates the greater the accommodation availability at friends and relatives, the higher likelihood that the destination is chosen. Further, the probability that destination zone is in the path of storm, indicates that when the predicted probability that a hurricane will pass through the zone where that destination is, there is a less likelihood of it being selected. Major metropolitan area indicator indicates that evacuees are more likely to choose that destination with major metropolitan area. The ethnic similarity indicates that there is a higher likelihood of having friends and relatives in that zone having similar ethnicity. For hotel/motel model, factors that were included are travel time, remaining availability of accommodation in destination, predicted path of the storm, major metropolitan area and ethnic similarity. Effects of travel time, availability of hotel/motel in destination, predicted storm path, and ethnic similarity, have similar effects to that of the results in the friends/relatives model. The presence of interstates indicates that there is higher likelihood that evacuees are attracted to destinations with interstates.

In addition, findings in Mesa-arango et al. (2013), in their study of ultimate destination covering public shelters, churches, and other destination types as "others", include hurricane position during the time of evacuation, geographic location of household, their race, income, time of preparation, evacuation plan changes, major hurricanes previous experiences, working household members during evacuation, and evacuation notices, as factors influencing decision making. Using the data from Hurricane Ivan 2004, a nested logit model among four alternatives is estimated. Results showed that the households with previous experience evacuating due to major hurricane have lower probability of selecting public shelter and churches, with marginal increment in the likelihood of selecting the other 3 alternatives. The distance indicator has marginal preference for the selection of hotel if hurricane is located farther from where the household is located. Also, white households are more likely to select "others" destination by 6.41% and are less likely to choose the other destination types by 0.75%. Low-income households with 2004 income less than USD 25,000 are more likely to select public shelter/church. Also, their likelihood of choosing friends/relatives and others increases in smaller percentage. This indicates that low-income households have lower likelihood of choosing hotel which is more costly, than choosing from the other destination types. Public shelter/church, usually placed near residential areas, and hence, have lower costs of transportation compared to other types, evacuees more likely choose as they also do not need to pay a fee when staying there. Moreover, households with short time of preparations have lower likelihood of choosing hotels, which need time for finding and booking one. Hotels can be fully booked with evacuees during evacuation period, hence prior reservation is needed. In addition, households who have received either mandatory or recommended evacuation warning, have higher probability of choosing a hotel. Also, households with some members having work during evacuation, are more likely to stay in a hotel or “other”. Households with previous evacuation experience may have prepared an emergency plan, and hence may be independently planning for their own logistics as confirmed in other hazards such as earthquakes (Schonhardt 2012).

In another study, Wu et al. (2012) have identified factors that are correlated to destination decision based on surveys of Hurricane Katrina and Hurricane Rita evacuees conducted beginning approximately 4 months after those hurricanes struck. The study consisted of analysis of elements of evacuation logistics including destination type choices. Overall evacuees stayed at the destinations on an average of 13.8 days away from home. The average cost of stay was USD 1,137 per household for food, transportation and lodging. Married evacuees and those with larger households and children were less likely to stay with friend/relatives. While younger, married evacuees with larger households, children and higher income level have higher probability of staying in hotels/motels. Whites and evacuees with higher education and income tended to avoid public shelters. Females reported longer and married evacuees reported shorter evacuation durations. Married evacuees, larger households, and those with children, higher education and higher income had higher food costs. Larger households and those with children and higher income had higher lodging costs. Households living far from coast have lower likelihood of staying in hotels/motels; higher likelihood of staying in public shelters with shorter evacuation durations and lower costs for food and lodging.

Chapter 3
Methodology

This chapter presents the methodology employed in conducting this research. Specifically, the study area, methods used for data collection, model estimation and model validation are presented in this chapter.

3.1 Research Framework

Figure 2 below shows the framework of this study. First, literature review was conducted in order to identify research gaps. Then the factors identified in past research to determine travel behavior were identified. Data was collected through face to face interview with households living in high flood risk areas in Quezon City, Philippines. After data collection, data was summarized in excel sheet, data was verified and checked for logical consistencies. After cleaning and validating the data collected, factors in broad groups were identified including the household characteristics, household capacity-related characteristics, risk-related characteristics, mode-specific and destination-specific characteristics. These were used to determine factors that are significant to each household travel-related decision. Methods of conducting each of the mentioned steps are presented and discussed in the following sections.

3.2 Study Area

Data was collected in Quezon City, Philippines. With an area of 16,112.58 hectares, it is considered the largest city among 16 in Metro Manila, Philippines (Figure 3). Official census in 2010 indicates that the city has a population of about 2.68 million, which is approximately one-fourth of Metro Manila's population of more than 11 Million, and about 3% of the Philippines' population of 88.5 million (Quezon City Planning and Division Office, 2013). The city is prone to flooding due to heavy rains, mainly because of its rolling terrain. The situation is aggravated by the presence of a 700-hectare reservoir, the La Mesa dam, at the northern part of the city, and the low grade terrain with several waterways in southern areas (QCG and EMI, 2013). During heavy rainfall

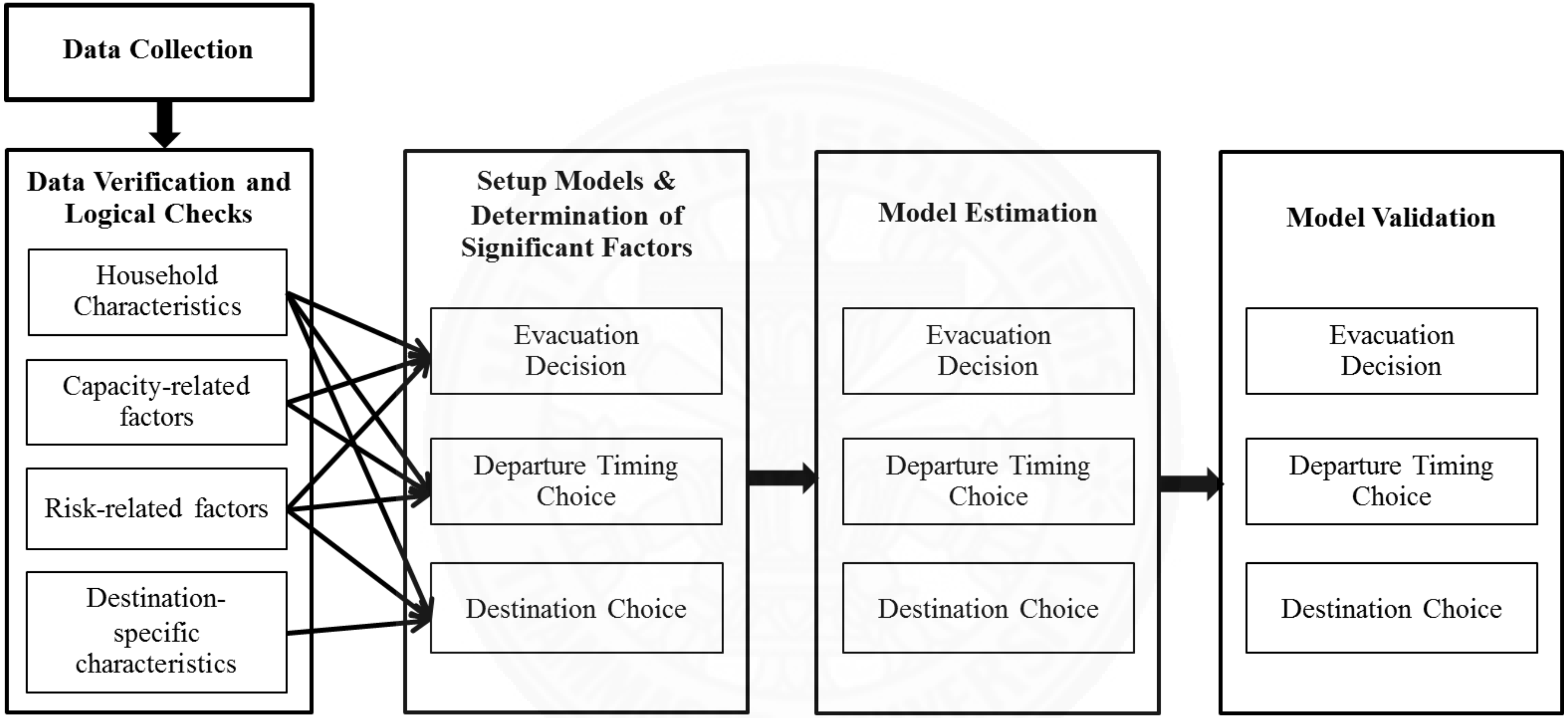


Figure 2. Research Framework

events, the water level in the dam can exceed its threshold level of 80.15 meters. Consequently, overflow water combined with rainfall flows to several sub-districts in the northern part and downstream areas. The impacts of floods on the communities are intensified by anthropogenic factors like canals that are clogged, illegal settlements, lack of preparedness of the people and poor urban planning. About 700,000 people are affected by flooding. 16% lives in low susceptible areas, 30% in moderate susceptible areas, and 54% in high flood susceptible areas. By 2050, affected areas can increase by as much as 7% due to climate change (QCG and EMI, 2013).

In August 2013, Quezon City was once again affected by a flood event in Metro Manila. From the National Disaster Risk Reduction Management Council (NDRRMC, 2013) report, during early morning of 17 August 2013, low pressure area in northeast Itbayat, Batanes, Philippines developed into a tropical depression, named “Trami”, which further intensified to tropical storm before noon of the following day. Then the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) subsequently issued several rainfall advisories. The Marikina River, East boundary of Quezon City, reached alert level 2 on 18 August, reaching the critical height of 19 meters. This forced authorities, to evacuate thousands families. The storm further intensified to 10-40 mm/hour on 20 August while the southwest monsoon continued to affect the Philippines causing severe flooding and 58 casualties and deaths. Flood levels reached up to the roofs of houses near the source of flood. This flood was the basis for the post flood survey in this study, to understand evacuation behavior of households. In addition, 643,281 households were affected and the costs of damage were more than 14 Million USD. Records from QCG show that less than 9000 families in Quezon City went to evacuation shelters (Social Services Development Department, SSDD 2013). In Metro Manila, less than one million people went to public shelters and to families and friends (United Nations Office for the Coordination of Humanitarian Affairs, UNOCHA 2013).

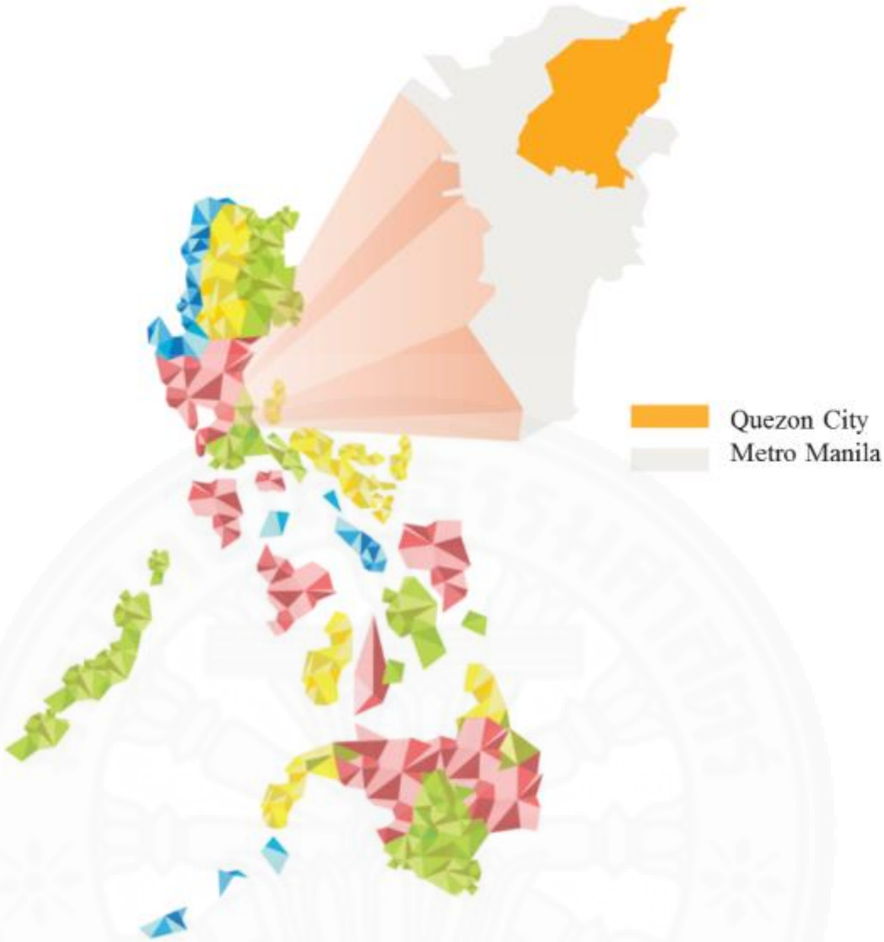


Figure 3. Location of Quezon City in Metro Manila, Philippines
Source: Quezon City Socio-Ecological Profile (2010)

3.3 Data collection

In order to investigate evacuation behavior of households in the study area, first, courtesy call was done at the office of the Head of Quezon City, then to the sub-districts and villages. This was important to ensure safety of researchers, easier access to target households, and building rapport with households in flood prone villages that were the prospects for data collection. The flood risk areas in Quezon City were identified from initial interviews with government officials. The QCG selected a number of sub-districts that heavily suffered from the impacts of the 2013 flood event with history of evacuation. Selected sub-districts include Bagong Silangan, Bahay Toro, Roxas and Sto. Domingo. These sub-districts are located in flood-prone areas as indicated in Figure 4.

The survey questionnaire was designed to solicit evacuation information based on actual experience during a flood event in August 2013. In order to elicit information from households that were relevant to their evacuation decision making, the questionnaire was divided into 3 sections. The first section consisted of socio-economic and households' characteristics. The second section was major part of the interview was about their evacuation experience during the flood on August 2013. Then section 3 covered households' comments and suggestions for improving situations in future evacuations. More information can be found in the survey questionnaire used (detailed in Appendix A).

Initial interviews were conducted with household heads in selected sub-districts in order to validate appropriateness of the survey questionnaire developed. Questions that were not appropriate were removed and questions were revised according to the pilot survey results. The full face to face household interviews were conducted between December 2013 and April 2014. Trained interviewers conducted the face to face interviews with households to make sure of the standard quality of information collected. Each interview with households took an average of 15 minutes to complete.
During the interview process, the respondents were given a brief introduction to the study being conducted. This was to ensure they understood the context which was the basis of their answers to the questions. The interviewers also made sure that the household experienced flooding during mid-August 2013 before proceeding with the interviews. The questionnaire was prepared in the English language and translated into Filipino.

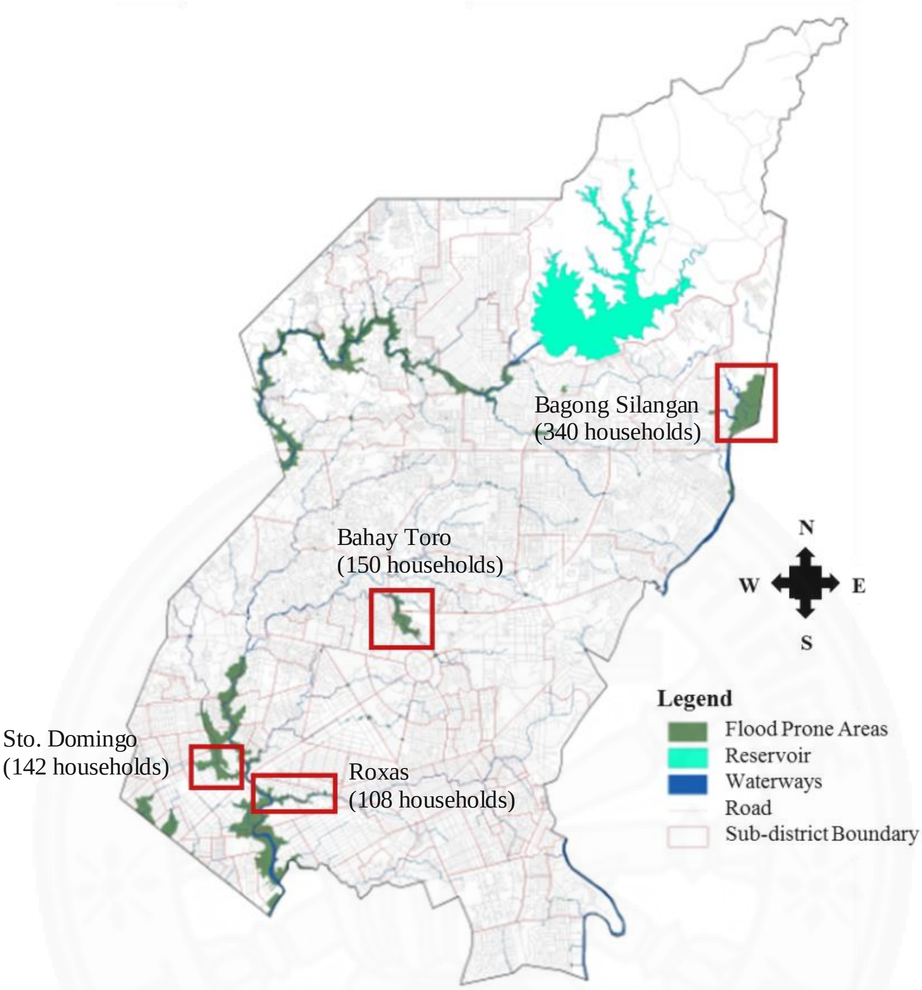


Figure 4. Flood Prone Areas in Quezon City, Philippines and the Number of Households Interviewed in Selected Sub-Districts

Source: QCPDO (2013)

Solicited information during the first part of the interview include age, gender, educational attainment, type of work, household income, vehicle ownership, presence of pets, the number of members in the family, age of every member, presence of small children of equal or less than 10 years old, presence of senior citizens more than 60 years old, number of years the household have been living in the residence, home ownership status, type of house material, and the number of house floor levels were also identified. Covered in the second part of the interview are hazard-related information such as the level of flood, number of days their houses were flooded, and level of damage in their house, with choices of no damage, slightly damaged, and severely damaged. Respondents chose “not damaged” if no parts of the house structures were broken or destroyed by the flood, and if they only needed to clean the house after flood. Slightly damaged was chosen if some parts of the house, excluding major structures, were damaged (e.g. floor tiles or mats were torn). Severely damaged was selected for the houses where structural parts, such as roof or ceiling and walls, were destroyed by the flood. Inquiries on whether they received evacuation warning and its source, whether they evacuated or not, and the type of evacuation the household did (partial or full evacuation) were also part of the interview. For the type of evacuation, partial evacuation was noted for households who evacuated, but some members of the family were left at the house, whereas, full evacuation was noted for those who evacuated all members of the family. Additional evacuation details were also solicited, such as presence of flood equipment or preparedness measures the household had and whether they had previous flood experience prior to the 2013 flood event. If the household evacuated, they were further asked about their subsequent decisions of departure timing, where they headed to, what mode and route they took when evacuating. Subsequent information was also asked under each decision made. For instance, for departure timing, households that are risk-averse (households that evacuated before the flood reached their homes) or risk-tolerant (households that evacuated when floodwaters have reached their homes), were indicated as those that evacuated before or during the flood. The destination type choice included those that went to the public evacuation centers, church/seminary or to friends’/relatives’ homes.

From the four sub-district areas where interviews were conducted, 740 household interviews were completed. The number of households interviewed in each of the sub-district covered as indicated in Figure 4, are 340, 150, 142 and 108 for Bagong Silangan, Bahay Toro, Sto. Domingo, and Roxas, respectively. During the interviews, 10 of approached households refused to undergo such interview. Hence, the total household approached for interviews was 750. From this, the response rate, which represents the completed interviews (740), divided by the sum of completed interviews plus those who refused to undergo interview (750) is 98%. The response rate is high as every household approached were very cooperative and willing to share their experiences, motivated by the hope that the study results could reach concerned people, who in turn could help them have a better situation during future evacuations. In addition, coordination with relevant officials from the city level down to the village level contributed to the high interview response rate.

After interviews were completed, data was summarized in an excel sheet. The summarized data was cross-checked for validity based on the questions asked. Data with missing and invalid information was removed from data used for analysis. The data was then summarized and coded according to the requirement of statistical tool used for the method of modeling utilized in this study. Resulting valid samples used for analysis of evacuation decision, departure timing and destination are detailed in chapters 4, 5 and 6.

3.4 Variable Selection

After identifying number of valid samples used for analysis of evacuation-related decision, the stepwise selection was used to identify variables that are included in the models. The stepwise backward elimination method is an effective and efficient way of reducing a large number of explanatory variables (Steyerberg et al., 2004). First, all variables from the data gathered were tested for significance. Individual variables were assessed whether it should be included in the model with the use of statistical test with resulting p-values. Insignificant variables were removed one by one, the remaining variables were repeatedly subjected to statistical test until the desired combination of variables that gave a significant model is met.

3.5 Model Estimation

The Discrete choice modeling framework was used for setting up and estimating models. Discrete choice models have been increasingly recognized as method of analyzing factors that influence decision-making process. It is an informative way of analyzing discrete outcomes in with dependent variables as set of categorical or ordinal form. Discrete choice models postulate that an alternative is selected if the utility is higher than the utility of any other alternatives. The outcome is the probability of selecting an alternative that has a utility higher than that of other alternatives. Extensive application of discrete choice models in many disciplines exists in the literature. Examples of these are in the field of social sciences (Lewis and Noguchi, 2009), medicine (Kwak and Matthews 2002; Tay et al., 2009), economics (Pryanishnikov and Zigova 2003; Zaghdoudi, 2013), transportation (Scott and Kanaroglou, 2002; Fujiwara and Zhang 2005; Zhang, Kuwano, Lee, and Fujiwara, 2009), and evacuation modeling (e.g. Charnkol, Hanaoka, and Tanaboriboon, 2007; Mesa-Arango et al., 2013; Sadri, Ukkusuri, Murray-Tuite, and Gladwin, 2014). One form of discrete choice model is Logit, as detailed in Hosmer and Lemeshow (2000) and Train (2009). Advantage of logit model is its simplicity and closed form estimation, in addition to its ability to capture behavioral context of decision-making. The binary logit is used when there are 2 alternatives being analyzed, while Multinomial Logit (MNL) model is used when there are more than two alternatives. It is generated with the assumption that the random terms are distributed IID Gumbel which is also called Weibull.

Equation 1 shows the form of discrete choice utility function utilized in this study. The logit model specifies that the utility function (U_{ih}), consists of a systematic term ($\boldsymbol{\beta}' X_{ih}$) and a random term ($\varepsilon_{ih}$) as presented in the Equation. Where $\boldsymbol{\beta}$*s* are vector of parameters to be estimated: $\boldsymbol{X}_{ih}$ is the vector of independent variables that determine the decision *i*, of household *h*; and ε_{ih} accounts for the effects of attributes that are not observed, difference in taste variations, and the use of proxy variables on observed choice.

$$U_{ih}=\boldsymbol{\beta}'\boldsymbol{X}_{ih}+\varepsilon_{ih} \qquad (1)$$

The probability of the outcome of an evacuation-related decisions *i* of household *h* is shown in Equation 2, where *j* is the outcome decision.

$$P_{ih}=\frac{e\,(\boldsymbol{\beta}'\boldsymbol{X}_{ih})}{\sum_i^j e(\boldsymbol{\beta}'\boldsymbol{X}_{ih}} \qquad (2)$$

The coefficients $\boldsymbol{\beta}'$ in Equation 2 are determined by the maximum likelihood estimation with log likelihood function presented in Equation 3. In the equation, *H* is the number of households and *J* is the outcome type under the choice (evacuation decision, departure timing and destination) of the household, *h* being investigated.

$$LL = \sum_{i=1}^{J} \sum_{h=1}^{H} log(P_{ih}) \quad (3)$$

The null hypothesis for testing the significance of the whole model is "all coefficients in the utility function take zero as its value. The null hypothesis is statistically rejected if the estimated parameter is different from zero at 0.05 level of significance. Stata version 12.0 was used to estimate the logit models in this study.

3.6 Validation of model specification and predictive ability

The significance of independent variables to decision outcomes is assessed using the t-statistics. Moreover, model fit is assessed using pseudo R^2. According to the experience in Hensher, Rose and Greene (2005), 0.3 R^2 value of a discrete choice model indicates a decent model fit.

3.6.1 Correct classificaton rate and are under the curve

The predictive model performance can be evaluated using the correct classification rate (CCR) compared to the base rate. The base rate indicates the "proportion of correct classification expected to occur by chance alone" (Liu et al. 2012, 2014). The increment in the CCR compared to the base rate indicates the improvement in accuracy of prediction with the addition of significant variables in the model. The base rate is calculated as the sum of the squares of the percentage of outcomes in the data.

The ability of the model to distinguish correctly the different outcomes based on a specified cutoff point (discrimination) is evaluated using the area under the receiver operating characteristics (ROC) curve (AUC), which indicates the probability of a model to rank randomly chosen positive case (sensitivity) to be higher than randomly chosen negative case (specificity). AUC values ranges from 0 to 1. The closer the value to 1, the more the model is being able to discriminate. In general, Hosmer and Lemeshow (2000) outlined that AUC values ranging from 0.9 to 1 indicate outstanding discrimination, values from 0.8 to less than 0.9 indicate excellent discrimination, and values from 0.7 to less than 0.8 indicate acceptable discrimination, respectively. The overall AUC for MNL models is obtained by calculating the weighted average of each evacuation-related outcome category (Provost and Domingos, 2001; Chen et al. 2015).

3.6.2 Likelihood ratio-based validation test

A statistical test based on Likelihood Ratio (LR) test was done to assess the validity of model specification. In this LR test, null hypothesis is tested if there is no significant difference between the parameters of the model estimated using two sample subgroups from the whole data, used to estimate the model. The validity of the model specification is supported when the null hypothesis is not rejected. The method detailed in Hasan et al. (2013) and Sadri et al. (2014) is employed in this study. The whole data used for estimating a model for evacuation decision, departure timing and destination type (detailed in chapters 4,5 and 6 respectively), was divided into two sections, namely, Sample group 1 and Sample group 2. These sample subgroups were divided by random sampling. Each of the sample groups has approximately half of the whole data. The two sample groups were used to estimate separate models with the same specifications. The test statistics used to calculate is shown in Equation 4.

$$LR=-2[LL(\beta_{full})-LL(\beta_{sgroup1})-LL(\beta_{sgroup2})] \quad (4)$$

In the equation, the $LL(\beta_{full})$, $LL(\beta_{sgroup1})$ and $LL(\beta_{sgroup2})$ are the model convergence log-likelihood estimated using the whole data- Sample group 1 and Sample group 2, respectively. The resulting LR value is $\chi 2$-distributed with degrees of freedom as the number of parameters estimated, not including the model constant). This LR is then compared to the critical value, $\chi 2$ at 5% significance level, which can be determined by using the values in the Table presented in Appendix B. When the LR is less than critical value, then, null hypothesis is not rejected. Therefore, validity of the model specification is supported.

Chapter 4
Analysis of Household Flood Evacuation Decision Model

This section discusses the model significance, goodness of fit, and the results of the parameter estimation for partial and full evacuation. The third outcome, no evacuation was the basis for model estimation. The MNL is used to model the evacuation decision.

4.1 Data, Variables and Correlation

571 observations were used for analysis of evacuation decision. From this data, 18.6% of the households did not evacuate, 21.4% partially evacuated, and 60.1% fully evacuated. The procedure of stepwise selection of variables resulted in a list of explanatory variables that includes gender and educational attainment of the household head, presence of small children, number of years living in the residence, house ownership, number of house floor levels, type of house materials, distance of the houses from source of flood, level of damage of the house from the flood, and source of evacuation warning. Table 4.1 shows the categories and percentage of selected variables in the data.

Table 4.2 shows the correlation matrix of variables included in the model. The interrelationships among variables indicate very low to medium level correlation. The distance from the source of flood is significantly correlated to number of floors with r =-0.322. This indicates that households living nearer the source of flood could have built additional floor levels so as to avoid evacuating every time flood occurs. Correlation between the presence of child and gender (r=0.123), indicates that households with children who are 10 years old or younger are also most likely having male heads. Further, household heads who are educated at a level higher than elementary level are also more likely having houses that are more than 1 floor high, as indicated with the r=0.176. Similarly, households with houses more than 1 floor level have been living in their residence at least 10 years already (r=0.154).

Table 4.1. Summary of variables used in the estimation of evacuation decision model

Variable	Categories	Number	Percentage
Gender of the head of the household (GEN)	Female	97	17.0
	Male	474	83.0
Educational attainment of the head of the household (EDUC)	Elementary	127	22.2
	High School	299	52.4
	Diploma/college	106	18.6
	Graduate	39	6.8
Presence of small children of less than or equal to 10 years old (CHILD)	No small child	208	36.4
	Small child is present	363	63.6
Number of years living in the present residence (YLIVE)	<10 years	165	28.9
	10-20 years	208	36.4
	>20 years	198	34.7
House ownership status (HOWN)	Rented	159	27.8
	Owned	412	72.2
Number of house floor levels (FLOOR)	1 floor level	292	51.1
	>1 floor level	279	48.9
House material type (HMAT)	Wood/half-concrete	295	51.7
	Concrete	276	48.3
Distance from the source of flood hazard (DIST)	0-10 meters	230	40.3
	11-20 meters	181	31.7
	21-30 meters	28	4.9
	>30 meters	132	23.1
Level of damage from the previous flood event (DAM)	Not damaged	179	31.3
	Damaged or severely damaged	392	68.7
Source of evacuation warning (SWARN)	Friends/relatives/television/radio	267	46.8
	Sub-district/village official	304	53.2
Total number of observations used in analysis, N		571	100

Focusing on the correlation between evacuation decision and other variables, results indicate that the presence of small children aged 10 years or younger, the house ownership, the distance (farther) from the source of flooding, damage level (slight or severe), and source of evacuation warning (from authorities) are correlated with evacuation decision. These indicate that households having small children 10 years old or younger, owns the house, lives farther the source of flood, had slight damage in their house during a past flood event, and obtained evacuation waning from authorities, are more likely to evacuate. In addition, evacuation decision is correlated with gender (household head is male), educational attainment (higher than elementary level), number of years living in the residence (more than 10 years), number of house floor levels (more than 1 house floor level), and house material (made of concrete). These result means the lesser the likelihood of evacuation for households having a male head, obtained higher educational level than elementary, lived longer than 10 years in the residence, have more than 1 floor level of house made of concrete. The detailed result of the estimation is given in the next section.

4.2 Parameter estimates

The utility function (ED_{ih}), of the MNL consists of a systematic term ($\boldsymbol{\beta'}X_{sih}$, $\boldsymbol{\beta' Y}_{cih}$, $\boldsymbol{\beta'}Z_{rih}$) and a random term ($\varepsilon_{ih}$), as presented in Equation 5. $\boldsymbol{\beta}s$ are vector of parameters to estimated: $\boldsymbol{X}_{sih}$, $\boldsymbol{Y}_{cih}$ and $\boldsymbol{Z}_{rih}$, are vectors of household characteristics, household capacity-related factors, and hazard-related factors, respectively, that determine the evacuation decision i, of household h.

$$ED_{ih}=\boldsymbol{\beta}'\boldsymbol{X}_{sih}+\boldsymbol{\beta}'\boldsymbol{Y}_{cih}+\boldsymbol{\beta}'\boldsymbol{Z}_{rih}+\varepsilon_{ih} \tag{5}$$

The probability of the outcome of an evacuation decision i of household h is shown in Equation 6, where j is the outcome evacuation decision of which include full evacuation, partial evacuation, and no evacuation.

$$P_{ih}=\frac{e\,(\boldsymbol{\beta}'\boldsymbol{X}_{sih}+\boldsymbol{\beta}'\boldsymbol{Y}_{cih}+\boldsymbol{\beta}'\boldsymbol{Z}_{rih})}{\sum_i^j e(\boldsymbol{\beta}'\boldsymbol{X}_{sih}+\boldsymbol{\beta}'\boldsymbol{Y}_{cih}+\boldsymbol{\beta}'\boldsymbol{Z}_{rih})} \tag{6}$$

The coefficients $\boldsymbol{\beta'}$ in Equation 5 are determined by maximum likelihood estimation (MLE) with log likelihood function presented in Equation 7. In the equation, H is the number of households and J is the type of outcome evacuation decision of the household, h. In estimating the evacuation decision model, the evacuation outcome, no evacuation was used as the reference category. Hence, parameters for full and partial evacuation were estimated and are presented in the following sub sections.

Table 4.2. Correlation matrix of variables included in the model

	EDEC	GEN	EDUC	CHILD	YLIVE	HOWN	FLOOR	HMAT	DIST	DAM	SWARN
EDEC	1										
GEN	-.028	1									
EDUC	-.127**	.038	1								
CHILD	.025	.123**	.039	1							
YLIVE	-.100*	-.079	-.012	-.050	1						
HOWN	.150**	-.031	.023	-.072	.325**	1					
FLOOR	-.455**	-.071	.176**	.005	.154**	-.057	1				
HMAT	-.163**	-.001	.053	-.127**	-.066	.061	.015	1			
DIST	.280**	.078	-.019	-.073	-.127**	.181**	-.322**	.177**	1		
DAM	.199**	-.044	.041	.006	.130**	-.049	.034	-.283**	-.047	1	
SWARN	.120**	.062	.011	-.024	.068	.217**	-.102*	.113**	.210**	-.013	1

*Correlation is significant at 5%; **Correlation is significant at 1% level

$$LL = \sum_{i=1}^{I} \sum_{h=1}^{H} log(P_{ih}) \quad (7)$$

The following presents and discusses the parameter estimation for partial and full evacuation as detailed in Tables 4.3 and 4.4, respectively. For partial evacuation, gender of the household head, presence of small child less than or equal to 10 years old, house ownership status, number of house floor levels, house material, level of damage the flood incurred to the house, and source of warning are the significant factors to decision. Gender, number of floor levels, level of damage and source of warning are significant at 0.01 while the rest are significant at 0.05. The results for full evacuation model shows gender of household head, number of years in residence, house ownership status, type of house material, number of house floor levels, flood damage, and distance from the source of flood are significant factors. Gender, the house ownership status, type of house material, number of house floor levels, type of house material, and flood damage, are significant at 0.01 while the remaining are significant at 0.05. It can be observed that the significant factors common to both types of decision outcomes with the same level of significance of 0.01 include the gender, number of house floor levels, and flood damage. While house ownership, type of house material and the source of warning, are significant to both decision type models, with differences in the level of significance. The presence of small children and source of warning are significant to only the partial evacuation decision. While the distance from the source of flood and number of years living and the in the residence is significant to only the full evacuation decision.

The gender of the head of the household with coefficient (β=-1.367 and β=-1.139 for partial and full evacuations, respectively), means that when everything else remains constant, the male head of a household has higher probability of not evacuating members of the household than females do. This result goes with findings in earlier studies (Lindell et al., 2005; Morrow and Gladwin, 2005; Horney, MacDonald, Van Willigen, Berke, and Kaufman, 2010). In addition, results also support Cahyanto et al. (2014) in the case of tourists; Ng, Behr, and Diaz (2014) in the case of respondents with medical concerns; and Riad, Norris, and Ruback (1999) as well as in Lindell et al. (2005) in household evacuations with permanent residents.

For the number of house floor levels, households living in a house with more than 1 floor level have higher likelihood of not evacuating as indicated by coefficients (β=-2.470 for partial evacuation and β=-3.237 for full evacuation). The household tends to stay at home as they feel more secure, safe, and comfortable with food and supplies they had prepared. The effect of this variable in decision making is a new finding in this study.

On the other hand, the coefficients for the level of flood damage of β=1.006 and β=1.595 for partial and full evacuations, respectively, means that the more likely households evacuate when there is less damage in the house. This indicates the awareness that the households have in relation to property damage. A new significant factor found to influence decision making, this factor experienced by the households might influence how they perceive risk for future flood events. This may indicate that existing and/or forecasted flood damage assessments can be used to encourage evacuation compliance. It can also be factored-in to predictive models for planning purposes. However, this needs further investigation.

Households that own the house are more likely to evacuate than those renting, indicated by the coefficient (β=0.832 for partial and β=1.219 for full evacuation). This result can be related to the security of the household's belongings. If they own the house, they can secure their belongings and evacuate. However, for those who are renting, there is a possibility that other people are able to access their place, which has been raised as households' concern about their belongings being stolen or damaged. House ownership type in this study was found to affect evacuation decision, which goes with findings in Ng et al. (2014) that owning the house increases likelihood of evacuation. Whereas findings in Hasan et al. (2011) showed that house ownership is not significant at usual 5 or 10% level although it is included in the model due to the belief of it to have influence in the decision making process.

Additionally, households with homes built with concrete material have a higher probability of staying at home when compared to others whose houses are made of wood. This is stipulated by the coefficients (β=-0.776 for partial and β=-1.052 for full evacuation). This is a new factor found to influence evacuation decision making in this research.

The source of evacuation warning (β=0.883 for partial evacuation) shows that households are more likely to evacuate when they hear it from the authorities rather than only hearing it from any other source such as friends or relatives, television or radio. Although they hear from other sources, they chose to wait for the official advice, which enforces their decision to evacuate. Result here also goes with findings in the literature. Fischer et al. (1995) mentioned that evacuation has higher likelihood of happening if the person at risk is mandated to do so, directly contacted by proper authority more than once, and previous evacuation warnings are proven accurate. Warning from local authorities rather than the media were also strongly correlated with the decision (Lindell et al., 2005; Mileti et al. 2006; Taylor et al., 2007). Respondents receiving voluntary/mandatory evacuation warning have higher probability of evacuating compared to those who did not receive any (Whitehead et al., 2000; Dash, 2002; Fu and Wilmot, 2004). Also, Hasan et al. (2011 and 2012) also in their findings stated that households who did receive mandatory evacuation warning from authorities have higher likelihood of evacuating. These results indicate the importance of trust, or where the evacuation warning comes from, to the decision making process. As Kim and Oh (2014) suggest, the integrity of the authorities is important to encourage evacuation compliance. Nevertheless, official evacuation warnings should be channeled to all sorts of available sources for wide dissemination (Durage, Kattan, Wirasinghe, and Ruwanpura, 2014).

In the case of households that have small children, results show that they are likely to partially evacuate, as stipulated with the coefficient (β=0.812). This result supports past studies where it was found that presence of children increases evacuation likelihood (Fischer et al. 1995; Dash, 2002; Cahyanto et al., 2014). This is also related to some findings that the number of children influences household evacuation decision (Hasan et al. 2012; Ng et al., 2014).

Table 4.3. Result of model estimation for full evacuation

Variable	Coefficient, β	t-stat	p-value	s.e.	OR	95% confidence interval	
						lower	upper
Constant	3.127	4.637	0.000	0. 674		1.805	4.449
Household characteristics							
Indicator variable for GEN (1 for male, 0 otherwise)	-1.139**	-2.730	0.006	0.417	-0.680	-1.957	-0.321
Indicator variable EDUC (1 for higher than elementary graduate, 0 otherwise)	-0.196	-1.106	0.269	0.177	-0.178	-0.543	0.151
Indicator variable for CHILD (1for households with small children aged ≤ 10, 0 otherwise)	0.287	0.951	0.3420	0.302	1.332	-0.305	0.878
Indicator variable for YLIVE (1 for households living in the residence ≥ 10 years, 0 otherwise)	-0.555**	-2.829	0.005	0.196	-0.426	-0.939	-0.170
Capacity-related factors							
Indicator variable for HOWN (1 for owned house, 0 otherwise)	1.219**	3.524	0.000	0.346	3.384	0.541	1.897
Indicator variable for FLOOR (1 for floor levels more than 1, 0 otherwise)	-3.237**	-7.580	0.000	0.427	-0.961	-4.073	-2.400
Indicator variable for HMAT (1 for house concrete material, 0 otherwise)	-1.052**	-3.410	0.001	0.308	-0.651	-1.657	-0.448
Hazard-related factors							
Indicator variable for DIST (1 for those living at a distance of more than 10m from source of hazard, 0 otherwise)	0.366*	2.489	0.013	0.147	1.442	0.078	0.653
Indicator variable for DAM (1 for slight/severe damage, 0 if not damaged)	1.595**	4.885	0.000	0.326	4.928	0.955	0.235
Indicator variable for SWARN (1 if the source of warning are authorities, 0 otherwise)	0.498	1.683	0.092	0.296	1.645	-0.082	1.078

*significant at 5% level; **Significant at 1% level

Table 4.4. Result of model estimation for partial evacuation

Variable	Coefficient, β	t-stat	p-value	s.e.	OR	95% confidence interval	
						lower	upper
Constant	1.654	2.306	0.021	0.717		0.248	3.059
Household characteristics							
Indicator variable for GEN (1 for male, 0 otherwise)	-1.367**	-3.166	0.002	0.432	-0.745	-2.213	-0.521
Indicator variable EDUC (1 for higher than elementary graduate, 0 otherwise)	0.138	0.736	0.461	0.188	1.148	-0.230	0.506
Indicator variable for CHILD (1for households with small children aged ≤ 10, 0 otherwise)	0.812*	2.444	0.015	0.332	2.252	0.016	1.462
Indicator variable for YLIVE (1 for households living in the residence ≥ 10 years, 0 otherwise)	-0.303	-1.468	0.142	0.207	-0.261	-0.709	0.102
Capacity-related factors							
Indicator variable for HOWN (1 for owned house, 0 otherwise)	0.832*	2.275	0.023	0.366	2.298	0.115	1.549
Indicator variable for FLOOR (1 for floor levels more than 1, 0 otherwise)	-2.470**	-5.512	0.000	0.448	-0.915	-3.349	-1.592
Indicator variable for HMAT (1 for house concrete material, 0 otherwise)	-0.776*	-2.373	0.018	0.327	-0.540	-1.418	-0.135
Hazard-related factors							
Indicator variable for DIST (1 for those living at a distance of more than 10m from source of hazard, 0 otherwise)	0.041	0.257	0.797	0.160	1.042	-0.272	0.355
Indicator variable for DAM (1 for slight/severe damage, 0 if not damaged)	1.006**	2.952	0.003	0.341	2.735	0.338	10.675
Indicator variable for SWARN (1 if the source of warning are authorities, 0 otherwise)	0.883**	2.788	0.005	0.317	2.418	0.262	1.503

*significant at 5% level; **Significant at 1% level

On another note, it is interesting to note that those living farther than 10 meters from the source of flood hazard are more likely to fully evacuate. This is indicated by the coefficient in case of the full evacuation model (β=0.366). The result shows opposite effect of the distance to decision making process when compared to existing literature. For instance, past studies on hurricanes show that the distance of the storm to the household location indicates that the nearer the storm, the more likely a household would evacuate (Bourque et al., 1971; Cutter and Barnes, 1982; Houts et al., 1984; Bourque and Russell, 1994; Fu and Wilmot, 2004; Carnegie and Deka, 2010). A study in the case of tsunami also reports that the nearer the respondents are from the seashore, the higher the likelihood of evacuating earlier than others (Charnkol and Tanaboriboon, 2006). The authors also outlined that the probability of being in early evacuation decreases with increase in distance from shore. Further, the authors recognized that the result may be due the awareness of those living nearer the shore of higher risk and damage posed to them than those located further. The difference can be attributed to the nature of hurricane and tsunami in past studies and recurring flood hazard in this current study. It should also be noted that the thresholds used in this study are actual distances of households located in high risk areas, which are very much different from those used in past studies. It should also be taken into account that from the correlation matrix in Table 4.2, distance has some significant level of correlation to number of floors (r =-0.322), which means that those who are living nearer the source of flood might have built additional floor levels to cope with flooding and to avoid frequent evacuations.

More to the significant variables, the number of years living in the residence has a coefficient (β=-0.555 for full evacuation), indicating that households living in their residence more than 10 years have less probability to fully evacuate compared to those who have lived in the area for lesser number of years. This finding also supports earlier studies on hurricane (e.g. Baker 1979; Gladwin and Peacock, 1997) and bushfires (Stopher et al., 2004).

Last but not the least, the level of education of the household head is included in the models due to reasons of significance in studies (Whitehead et al., 2000; Hasan et al., 2011; 2012; Durage et al., 2014). It was also outlined in Ben-Akiva and Lerman (1985) that variables, believed to have some level of influence on the decision, can be included in the model. The effect of educational attainment to evacuation decision-making, however, as found in this study, is opposite from that of earlier research. The higher the level of education a respondent has, the more likely that the household evacuates (Whitehead et al., 2000; Hasan et al. 2011; 2012). This difference in result may be due to the fact that the respondents in this study are the household heads, while the earlier studies' respondents were either unspecified, or not the household heads and can also be just anyone from the household. The difference is also attributed to the difference in the threshold used. In this study, household heads with education higher than elementary level was used, while post graduate level was the basis of comparison in hurricane studies.

Findings in this study indicate that the factors influencing evacuation decision are a combination of the characteristics of the household and their capacities to cope with flood, as well as hazard-related factors. Household characteristics and capacities that determine evacuation decision in this study include gender and educational attainment of the household head, presence of small children of less than or equal to 10 years old, the number of years living in the residence, house ownership, number of floors, and the type of house material. Hazard-related factors include distance from the source of flood, the level of damage, and the source of evacuation warning. These findings support recommendations in the literature, which emphasize that how people perceive risk is a function of the hazard characteristics and environmental cues (Siebeneck and Cova, 2012), and the decision maker's characteristics (Lindell et al., 2005). New influential factors revealed in this study include the type of house material, and the level of flood damage. The type of house material indicates the capacity of the household to cope with flooding. A lower likelihood of evacuation exists when the household lives in a house with concrete material. It is indicated in the correlation matrix presented in Table 4.2 that this factor has some level of significant correlation with the level of flood damage. This may be related to the vulnerability of a household when making a decision (Lindell, 2013), as found in the case of an earthquake, where structural damage increases the likelihood of evacuation (Bourque et al., 1971; Bourque and Russell, 1994). Table 4.5 gives a summary of the variables that has been investigated here and are found to influence decision-making, against the variables that has been investigated in past research.

Table 4.5. Summary of variables significant to decision making as investigated in this study and findings in earlier literature

Variables	**Investigated in the study?**				**Variable effect and its relation to findings in past studies**
	Earlier studies		**This Study**		
	Yes	No	Yes	No	
GEN	√		√		consistent with findings in Lindell et al., 2005; Morrow and Gladwin, 2005; Horney, et al., 2010; Cahyanto et al., 2014; Ng, Behr and Diaz, 2014; Riad, Norris and Rubback, 1999
EDUC	√		√		opposite results in earlier studies (due to difference in
CHILD	√		√		goes with findings in Fischer et al., 1995; Dash 2002; Cahyanto et al., 2014; related to findings in Hasan et al., 2012; Ng et al., 2014
YLIVE	√		√		supports findings in Baker 1979; Gladwin and Peacock, 1997; Stopher at al., 2004
HOWN	√		√		consistent with findings in Ng et al., 2014; partly supports findings in Hasan et al., 2011 which shows non-significance at 5 or 10% level, although included in their proposed model
FLOOR		√	√		*Effect of this variable is a new finding in this study*
HMAT		√	√		*Effect of this variable is a new finding in this study*
DIST	√		√		opposite findings in earlier studies (due to difference in nature of hazard) such as Bourque et al., 1971; Cutter and Barnes, 1982; Houts et al., 1984; Bourque and Russel, 1994; Fu and Wilmot, 2004; Carnegie and Deka, 2010
DAM		√	√		*Effect of this variable is a new finding in this study*
SWARN	√		√		goes with earlier findings in Fischer et al., 1995; Whitehead et al., 2000; Dash 2002; Fu and Wilmot 2004; Lindell et al., 2005; Mileti et al., 2006; Taylor et al., 2007; Hasan et al 2011; 2012

Table 4.6 shows model fit and predictive accuracy of estimated MNL models. The partial and full evacuation model is significant with associating p-value of 0.000. This indicates the significance of the model parameters, hence supporting the existence of a relationship between dependent and independent variables. McFadden Pseudo R^2 of the model, 0.229, is within the range of 0.15-0.30 as found in evacuation decision models in earlier literatures. For instance, Hasan et al. (2011) reported adjusted R^2 of 0.171 for the evacuation decision random parameter model and 0.166 for the fixed-parameter model estimated in their study. Hasan et al. (2012) compared evacuation decision models for three different Hurricane contexts, and reported adjusted-R^2 values ranging from 0.159 to 0.289. Cahyanto et al. (2014) reported a Nagelkerke R^2 of 0.23 in the estimated ordered probit model for tourists' evacuation decision. Additionally, according to the experience in Hensher, Rose and Greene (2005), 0.3 R^2 value of a discrete choice model indicates a decent model fit.

Table 4.6. Model fit, accuracy of prediction and other results

Model parameters	**Values**
LR chi^2 (20)	248.548
Prob > chi^2 (χ^2)	0.000
Log likelihood at convergence	-417.328
Log likelihood at 0	-541.603
McFadden R^2	0.229
Correct classification rate (CCR)	68.0%
CCR base rate	44.2%
AUC	0.79

To evaluate the model prediction accuracy, base rate CCR was calculated and compared to the resulting model CCR. As shown in Table 4.5, the base rate CCR is 44.2%, while the model CCR is 68%. These results indicate that there is an improvement in the model predictive accuracy with addition of significant independent variables. Resulting AUCs for no evacuation, partial and full evacuation are 0.878, 0.690 and 0.797, respectively. From these, calculated overall AUC is 0.790 indicating that the model has an acceptable level of discrimination (Hosmer and Lemeshow, 2000).

4.3 Validation of model specification

The resulting values of these are equal to -417.328, -196.319, and −209.121 for *LL* (β_{full}), *LL* ($\beta_{sgroup1}$) and *LL* ($\beta_{sgroup2}$), respectively. After calculation, LR is 23.776, which is χ_2-distributed with 20 degrees of freedom. χ critical value for significance level of 5%, $\chi_{0.05,20}$ equals 31.410. Since the resulting LR equal to 23.776 is lesser than critical value of χ, then the null hypothesis is not rejected. Therefore, the validity of the specification of the model is supported.

Chapter 5
Understanding Evacuation Departure Timing Choice of Households with Binary Logit Model

This chapter presents the results for the analysis of household's departure timing between two choice alternatives. The departure time choices of households were grouped into two categories. The first group consists of risk-averse households that evacuated before the flood, after hearing recommended evacuation advice from the government (evacuation timing referred to as before). The other group consists of risk-tolerant households that evacuated when floodwaters are in their vicinity (evacuation timing referred to as during). These then were coded along with the independent variables and analyzed using the binary logit model. The data used for analysis, parameter estimates and other model information as well as model validation are presented and discussed here.

5.1 Analysis Data, Selected Variables and Inter-correlations

Data used for analysis consists of 38.7% households that evacuated before the flood, and 61.3% that evacuated during the flood. For analysis of the variables that are included in the model for departure time choice, several variables were initially considered. Most of these variables were collected based from findings in earlier literature. These variables were age, educational attainment and type of work of the head of the household, gender, marital status, household monthly income, number of household members, presence of children, presence of senior citizen and pet in the household, vehicle ownership, distance from the source of hazard, flood level, the level of flood damage and source of warning. Moreover, variables such as the number of floors of their house and the type of house material were included in the analysis. These variables were revealed by households during the interviews as factors they take into account in making their decision.

First, all variables were included in the model and assessed for inclusion using resulting p-values. Variables with highest p-value ($p \geq 0.05$) were removed one at a time.

Remaining variables were subjected to the same procedure until significant variables were retained while having a significant model. The resulting variables included in the model are presented in Table 5.1. Information on the variables, description and the corresponding percentage in the data is presented in the Table.

Table 5.1. Summary of variables included in departure time model

Variable	Variable categories	Frequency	Percent
TDEC (evacuation timing of households)	evacuated before flood	180	38.7
	evacuated during the flood	285	61.3
TWORK (type of work of the household head)	Part- time worker	156	33.5
	Full-time worker	309	66.5
HOWN (House ownership type)	Rented	114	24.5
	Owned	351	75.5
FLOOR (Number of house floor levels)	1 floor level	284	61.1
	>1 floor level	181	38.9
DIST (Distance from the source of flood hazard)	0-10 meters	283	60.9
	11-20 meters	39	8.4
	21-30 meters	26	5.6
	>30 meters	117	25.2
FLEVEL (level of flood experienced by the household)	< 1 meter	354	79.1
	≥ 1 meter	111	23.9
Total number of observations used in analysis, N		465	100

The correlation matrix, indicating the overall statistical relationship between variables is presented in Table 5.2. The interrelationships among variables indicate low to medium level correlation.

The relationship of departure timing with selected independent variables included in the model is indicated. The result in the table shows that households choose the timing of evacuation based on some characteristics and hazard related factors including the type of work, house ownership, number of house floor levels, distance of house from the source of flood, and flood level. Departure time during the flood is correlated with the full-time worker, owning the house located at a distance of more than 10 meters from source of flood. These means that when the household head is a full time worker and owns that house at a distance from the source of flood farther than 10 meters, the household tends to evacuate when the flood has already reached their home. On the other hand, correlation of departure during the flood with number of floor levels (more than one), and the level of flood (greater than one meter) indicates that household heads living in a house with more than 1 floor, experienced more than a meter of flood level, are less likely to evacuate during the flood. Since the correlation provides information on the effect of only one variable at a time on the departure timing, a binary logit model is estimated to evaluate the effects of multiple variables on departure time choice. Detailed result of the estimation is presented in Section 5.2.

Table 5.2. Correlation matrix of selected variables

	TDEC	TWORK	HOWN	FLOOR	DIST	FLEVEL
TDEC	1					
TWORK	0.078	1				
HOWN	0.135**	-0.034	1			
FLOOR	-0.209**	0.025	0.014	1		
DIST	0.321**	-0.024	0.110*	-0.273**	1	
FLEVEL	-0.259**	-0.013	-0.049	0.178**	-0.361**	1

*significant at 5% level; **significant at 1% level

5.2 Parameter estimates

Binary logit model for any household, *h*, evacuating before the flood, *b* or during the flood, *d*, respectively, is represented by the utility functions in Equation 8 and Equation 9. In these equations, $\boldsymbol{\beta'}_b$ and $\boldsymbol{\beta'}_d$ are vectors of parameters estimated for the model for households, *h*, that evacuated before, *b* and during, *d*, the flood, respectively. $\boldsymbol{X}_{bh}$ and $\boldsymbol{X}_{dh}$ are vectors of the factors that households put importance to, in their evacuation departure time decision-making. ε_{bh} and ε_{dh} accounts for the effects of unobserved attributes and preferences on observed choice *b* and *d*, respectively.

$$U_{bh} = \beta_{bh}^{'} X_{bh} + \varepsilon_{bh} \tag{8}$$

$$U_{dh} = \beta_{dh}^{'} X_{dh} + \varepsilon_{dh} \tag{9}$$

The probability that a household evacuates before or during the flood is denoted by P_{bh} and P_{dh}, respectively, which are presented in Equation 10 and Equation 11.

$$P_{bh} = \frac{e^{\beta'_{bh} X_{bh}}}{e^{\beta'_{bh} X_{bh}} + e^{\beta'_{dh} X_{dh}}} \tag{10}$$

$$P_{dh} = \frac{e^{\beta'_{dh} X_{dh}}}{e^{\beta'_{bh} X_{bh}} + e^{\beta'_{dh} X_{dh}}} \tag{11}$$

In the estimation of binary logit models, the category outcome, evacuated before, *b* was used as the reference category. Hence, the model parameter estimated for households that evacuated during the flood are presented here. Table 5.3 presents the estimation results for departure timing. Result here shows the coefficients for the model of households that evacuated during the flood. Evacuation before the flood was the basis for parameter estimation. According to results, the Likelihood Ratio (LR) $\chi 2$ – distributed, is equal to 76.589 with associating p-value of 0.000 and is significant at 0.05 level. This result indicates the significance of model parameters. Therefore, the existence of relationship between the dependent and independent variables is supported. In addition, factors that households take into account when deciding when to evacuate include the type of work of the head of the household, house ownership, the number of floors their house have, distance from the source of flood and the flood level.

The type of work, with coefficient of -0.474 indicate that household heads working full-time are less likely to evacuate during the flood. This means that they evacuate before the flood which is reasonable. They need to secure members of the household before even going to work. Related to findings of Charnkol and Tanaboriboon (2006), private employees have higher probability to respond quickly. Although the threshold of comparison differs between these studies due to data availability (private/public employment in Charnkol and Tanaboriboon (2006); full time/part-time workers in this current study), similar result is observed.

Table 5.3. Estimated parameters for departure time choice model

Variable	Coefficient	s.e.	t-stat	p-value	OR	95% confidence interval	
						lower	upper
Constant	0.852	0.364	2.343	0.019	-	0.139	1.565
Household characteristics							
Indicator variable for TWORK (1 for full-time worker, 0 for part time worker)	-0.474*	0.225	-2.106	0.035	-0.378	-0.916	-0.033
Indicator variable for HOWN (1 for households that own the house, 0 otherwise)	-0.646*	0.257	-2.516	0.012	-0.476	-1.150	-0.143
Indicator variable for FLOOR (1 for households with house floor levels more than 1, 0 otherwise)	0.629**	0.225	2.792	0.005	1.876	0.188	1.071
Hazard-related factors							
Indicator variable for DIST (1 for households living from source of flood more than 10 meters, 0 otherwise)	-0.371***	0.084	-4.420	0.000	-0.310	0.536	-0.207
Indicator variable for FLEVEL (1 for households who experienced flood level more than 1 meter, 0 otherwise)	0.771**	0.248	3.108	0.002	2.163	0.285	1.258

*significant at 5% level; **significant at 1% level; ***significant at 0.1% level

House ownership has coefficient of -0.646, which indicates that households that own the house are more likely to evacuate before the flood. This confirms the significant correlation (r = -0.209) between departure timing and house ownership indicted in the correlation matrix in Table 5.2. Households that own their house could prepare and keep their belongings well ahead of time, secure their homes before leaving the house when compared to those renting. This may be related to security and looting issues as elicited from interviewed households renting their homes. According to them, they do not leave until flooding occurs to ensure as possible their belongings are intact.

On the other hand, the number of house floor levels with coefficient 0.629 shows that households living in a house with more than a floor level have higher likelihood of evacuating, when floodwaters are already in their home vicinity. Also, households that live at a distance of more than 10 meters (farther) from the source of flood are less likely to evacuate during the flood. This is according to the coefficient of -0.371. As indicated in the correlation matrix (in Table 5.2), the medium level correlation between departure timing and distance (r=0.321) is significant at 0.01 level. There is also some level of correlation between floor and distance (r = -0.273). This means that those who are living nearest the source of flood may have built additional floors on their houses so they plan to decide to evacuate only when floodwaters have reached their homes. This can also be observed in the context of the study area and revealed in the interviews. Households nearest flood source mentioned that it is a way for them to adopt to flood risk to build higher floor levels.

Additionally, flood level indicator variable shows a coefficient of 0.771. This is an indication of a higher probability of evacuating during the flood for households that experience flood level more than 1 meter high. This also confirms the significant level of correlation between departure timing and the flood level (r = -0.259) as indicated in Table 5.2. This indicates the flood risk tolerance of households who decides to wait until their house is at a flood level they could bear before deciding to move to safer places. Table 5.2 also shows a significant medium level correlation between flood level and distance from the flood source (r=-0.361). This indicates the high flood risk that households located nearer the flood source experience higher flood level. This may also indicate that households nearer the source of flood have been adopting to floods by building higher floor levels as shown by significant correlation between floor and flood level (r = 0.178), hence, significantly influencing their timing of evacuation.

The factors found here to affect the evacuation timing such as the distance of house location from the source of flood, house number of floors and flood level, indicates that households put importance on hazard-related factors when making their evacuation time decisions. Table 5.4 summarizes the variables that were found to significantly affect the departure timing with a note on the findings in past research.

Table 5.4. Summary of variables significant to departure time decision making as investigated in this study and findings in earlier literature

Variables	**Investigated in the study?**				**Variable effect and its relation to findings in past studies**
	Earlier studies		**This Study**		
	Yes	No	Yes	No	
TWORK	√		√		Similar results with Charnkol and Tanaboriboon, 2006 who used private/public employment type in their data
HOWN		√	√		*effect is a new finding in this study*
FLOOR		√	√		*effect is a new finding in this research*
DIST		√	√		*effect is a new finding in this research*
FLEVEL		√	√		*Effect of this variable is a new finding in this study*

The ability of the model to discriminate, measured by the AUC which is equal to 0.744 with correct classification rate of 76% (Table 5.5). This indicates acceptable level of discrimination according to the general rule outlined by Hosmer and Lemeshow (2000).

Table 5.5. Departure time choice model fit and other information

Model Information	**Values**
Pseudo R-squared	0.123
Log likelihood at convergence	-272.061
Log likelihood at 0	-310.356
CCR	76%
Base CCR	52.6%
AUC	0.744

5.3 Internal validation

To further statistically investigate validity of the model specification, an LR based test employed. The calculated values for $LL(\beta_{full})$, $LL(\beta_{sample1})$ and $LL(\beta_{sample2})$ are –272.06, –135.95 and −131.26, respectively. From these values, LR is equal to 9.68, χ^2 distributed with 5 degrees of freedom. Since the critical value of χ at 5% significance level or 95% level of confidence, $\chi^2_{0.05,\,5}$ is equal to 11.07, the null hypothesis is failed to be rejected. Hence, the validity of the specification of the model is supported.

Chapter 6

Development of a Household Destination Type Choice Model

This chapter presents and discusses the results of analyzing evacuation destination type behavior of households in Quezon City. An MNL model was estimated and validated. First, the data used for analysis is presented, variables included in the model and model parameters are presented and discussed.

6.1 Data, Variables Included in the Model and Their Correlations

Original data set used in analysis of destination type choice includes socio-demographic characteristics of the household and capacity related ones (age, gender, marital status, educational status, presence of senior citizen, presence of small children), household capacity-related information (household monthly income, house ownership, house floor levels, type of house material) hazard-related information (distance of residence from the source of hazard, presence of flood equipment/materials, source of evacuation warning) and destination specific information (distance travelled to the destination, cost of stay at the destination, duration of stay at the destination). To select variables included in the model, stepwise method was used. After the process, variables selected include a range of household characteristics and capacity related ones (household income), hazard-related information (distance of residence from the source of hazard, presence of flood equipment/materials, source of warning) and destination specific information (distance travelled to the destination, cost of stay at the destination, duration of stay). Table 6.1 presents the variables used in analysis and its descriptions. The data indicates that most of the households (48.6%) went to public shelters, 23.0% went to church/seminary and 28.4% went to their friends'/relatives' homes. Most of the evacuees stayed in their destinations within 1-2 days.

Table 6.2 presents the correlation matrix of selected variables. Partial results on the correlations of selected variables to the destination type choice, exists. The correlation matrix indicates possible influencing factors of evacuation decision. It can be seen that household distance from the source of flood (r=-0.151), presence of equipment/materials for flood (r=-0.035), source of warning (r=-0.154), evacuation distance (r=-0.204), and duration of stay at the destination (r=-0.128) are correlated with the destination type choice. This shows the likelihood that households living at a distance at least 10 meters from the flood source, with flood equipments, evacuate at longer distances, stayed longer in the destination, and have received evacuation warning from authorities, less likely go to evacuation centers or to church and seminaries. On the other hand, household income (r=0.131) and the cost (r=0.068) indicates the higher likelihood of evacuees to go to either evacuation centers or to church/seminaries. There is also some level of correlation between the duration and the cost of stay at the destination (r=0.269). This indicates that households that stay longer in the destination were more likely to spend more. This is however, dependent on the type of destination of which could be more detailed in the results of multivariable analysis using the logit model structure details in the next section.

Table 6.1. Variables used in destination choice model

Variable	Description	Frequency	% in Data
Destination choice (DDEC)	public shelter	226	48.6
	church/seminary	107	23.0
	friends/relatives' house	132	28.4
Capacity related characteristics			
Monthly income of the household (in Philippine peso, PHP) (INCOME)	1,000-5,000	143	30.8
	5,001-10,000	222	47.7
	>10,000	100	21.5
Presence of prepared equipment/materials for flood (EQUIP)	Otherwise	404	86.9
	With equipment	61	13.1
Hazard related characteristics			
Distance from the source of flood hazard (DIST)	0-10m	283	60.9
	11-20m	39	8.4
	21-30m	26	5.6
	>30	117	25.2
Source of evacuation warning (SWARN)	Friends/relatives/television/radio	199	42.8
	Sub-district/village official	266	57.2
Destination specific characteristics			
Cost for food and water while staying at the destination (DCOST)	No cost incurred	341	73.3
	Cost ranged from PHP 100-2,000	124	26.7
	10-200 meters	111	23.9

Distance travelled to destination (EDIST)	200-400 meters	44	9.5
	>400 meters	310	66.7
Duration of stay at the destination (DUR)	1-2 days	379	81.5
	3-4 days	77	16.6
	>4 days	9	1.9
Total number of observations used in analysis, N		465	100

Table 6.2. Correlation matrix of variables included in the destination choice model

Variables	DDEC	INCOM	DIST	EQUIP	SWARN	DCOST	EDIST	DUR
DDEC	1							
INCOM	0.131*	1						
DIST	-0.151*	-0.181	1					
EQUIP	-0.035*	0.041	0.099	1				
SWARN	-0.154*	0.004	0.186	-0.012	1			
DCOST	0.068*	0.070	-0.200	-0.110	0.050	1		
EDIST	-0.204	0.118	-0.153	0.022	-0.020	0.171	1	
DUR	-0.128*	-0.062	0.081	0.036	0.103	0.269	0.013	1

*significant at 5% level; **significant at 1% level; ***significant at 0.1% level

6.2 Parameter estimates

Choice alternatives considered in the MNL model for destination choice include the public shelters, church/seminary and friends/relatives. The variables that were included in the estimation were household socio-demographic and other related characteristics, capacity-related factors; risk-related characteristics and destination-specific factors as detailed in Section 6.1. The utility function for destination type choice is shown in Equation 12. Where $\boldsymbol{W_{ih}}$, $\boldsymbol{X_{ih}}$, $\boldsymbol{Y_{ih}}$ and $\boldsymbol{Z_{ih}}$ are vectors of household characteristics, capacity-related factors, risk-related factors and destination-specific factors, respectively; $\boldsymbol{\beta}$, $\boldsymbol{\lambda}$, $\boldsymbol{\gamma}$ and $\boldsymbol{\xi}$ are vectors of coefficients to be estimated for W, X, Y, and Z, respectively; and $\boldsymbol{\varepsilon}$ are error terms that take into account differences in preference and taste variations in choosing destination type choice.

$$U_{ih} = \beta W_{ih} + \lambda X_{ih} + \gamma Y_{ih} + \xi Z_{ih} + \varepsilon_{ih} \qquad (12)$$

The probability of that an alternative, i of an evacuation destination type of household, h is shown in Equation 13, where I is the number of alternatives of an evacuation decision.

$$P_{ih} = \frac{e^{W_{ih}+\lambda X_{ih}+\gamma Y_{ih}+\xi Z_{ih}}}{\sum_i^I e^{W_{ih}+\lambda X_{ih}+\gamma Y_{ih}+\xi Z_{ih}}} \tag{13}$$

The coefficients $\boldsymbol{\beta}$, $\boldsymbol{\lambda}$, $\boldsymbol{\gamma}$ and $\boldsymbol{\xi}$ in Equation 12 are with the maximum likelihood estimation method. The log-likelihood function, *LL,* is in Equation 14. *H* is designated as the number of households and *I* is the number of outcome evacuation decision of the households.

$$LL = \sum_{i=1}^{J} \sum_{h=1}^{H} log(P_{ih}) \tag{14}$$

We present the result of model estimation for those who went to the public shelters and to church/seminary in Table 6.3. The destination of friends/relatives was the basis for estimation. Discussions on parameters estimates results here are compared to the friends'/relatives' destination. The model shows significance (p=0.000) which means that the hypothesis that a relationship exists between independent and the dependent variables, is established. Pseudo-R^2 of the model is 0.110.

First we present here the result of parameter estimates for those who went to public shelters. Capacity-related characteristics (income, presence of flood equipment), hazard-related factors (distance from the source of hazard, source of warning) and evacuation destination specific characteristics (cost, travel distance to destination and duration of stay at the destination) are its determinants. These factors are significant at 0.05.

The income of the household with coefficient (β= -0.491) means that when everything else remains constant, households with income greater than PHP 5,000 (more than USD 100) have lower likelihood of going to public shelter when compared to family/friends' house. For presence of equipment/materials prepared for flood, the coefficient (β=0.358), indicates that households that has prepared flood equipment/materials have higher probability of going to public shelters. The distance from the source of hazard with coefficient (β=0.832), means households living farther the source of flood have also higher likelihood of going to public shelters. The households also give importance to the source of evacuation warning when determining where to evacuate. The result indicates that when evacuation advice comes from authorities, households more likely choose public shelters. The cost of staying at destination, β=-0.002, indicates that when households have to spend some money for food, water and other needs when staying in the destination, the less likely that they will stay in that evacuation center in future evacuations. The distance travelled when evacuating, with coefficient, β=0.798, indicates that those who have traveled more than 200 meters when going to destination are more likely to choose public shelters. Those that traveled a distance less than 200 meters are more likely to go to their friends'/relatives' homes. They tend to go to their friends/relatives homes near them, but safe enough from floods. The duration of stay variable indicator with coefficient (β=0.835), indicates that households that stayed more than 2 days at destination more likely go to public evacuation centers.

Results of the model estimation for church/seminaries are presented here. Result shows that presence of equipment/materials prepared for flood, cost of staying at destination, distance travelled when evacuating and the duration of stay are significant at 0.050. The variable indicator for equipment/materials prepared for flood has a coefficient (β=1.218), which means that households that has prepared flood equipment/materials are more likely to go to church/seminaries than going to family/friends' house. For the cost of staying at the destination, with coefficient (β=-0.003), this means that when households have to spend some money for food, water and other needs when staying in that destination, the less likely that they will stay in that evacuation center in future evacuations. For the distance travelled when evacuating, the coefficient (β=0.761), indicates that those who have traveled more than 200 meters when going to destination are more likely to go to church/seminaries than to friends'/relatives house. For duration of stay with coefficient (β=0.352), this indicates that households that stayed more than 2 days at destination are more likely go to church/seminaries compared to going to friends'/relatives house. In addition, household's income,

Table 6.3. Parameter estimates of the model for those who went to the public shelters

Variable	β	s.e.	OR	t-stat	p-value	95% confidence interval	
						lower	upper
Constant	-0.695	0.319		-2.180	0.029	-1.319	-0.070
Capacity-related characteristics							
Indicator variable for INCOM (1for income >PHP 5,000, 0 o.w.)	-0.491	0.172	-0.388	-2.859	0.004	-0.828	-0.154
Indicator variable for EQUIP (1 for those who have equipment for flood, 0 o.w.)	0.358	0.422	1.430	0.847	0.397	-0.470	1.186
Hazard-related characteristics							
Indicator variable for DIST (1 for >20 m house location from source of flood, 0 o.w.)	0.222	0.101	1.248	2.200	0.028	.024	0.420
Indicator variable for SWARN (1 if authorities are source of evacuation advice, 0 o.w.)	0.604	0.243	1.829	2.484	0.013	0.127	1.080
Evacuation destination-specific characteristics							
Indicator variable for DCOST (1 if households paid some costs for instance food/ water while staying at destination, 0 o.w.)	-0.002	0.001	-0.002	-2.778	0.005	-0.003	0.000
Indicator variable for EDIST (1 for travel distance to destination > 200 m, 0 o.w.)	0.798	0.142	2.220	5.600	0.000	0.518	1.077
Indicator variable for DUR (1 if households stayed more than 2 days at destination, 0 o.w.)	0.835	0.311	3.306	2.689	0.007	0.227	1.444

*significant at 5% level; **significant at 1% level; ***significant at 0.1% level

Table 6.4. Parameter estimates of the model for households that went to church/seminaries

Variable	β	s.e.	t-stat	p-value	OR	95% confidence interval	
						lower	upper
Constant	-0.704	0.369	-1.905	0.057		-1.428	0.020
Capacity-related characteristics							
Indicator variable for INCOM (1for income >PHP 5,000, 0 o.w.)	-0.301	0.199	-1.511	0.131	-0.260	-0.692	0.089
Indicator variable for EQUIP (1 for those who have equipment for flood, 0 o.w.)	1.218	0.426	2.856	0.004	3.379	0.382	2.053
Hazard-related characteristics							
Indicator variable for DIST (1 for >20 m house location from source of flood, 0 o.w.)	-0.031	0.124	-0.245	0.806	-0.030	-0.274	0.213
Indicator variable for SWARN (1 if authorities are source of evacuation advice, 0 o.w.)	-0.544	0.282	-1.926	0.054	-0.419	-1.097	0.010
Evacuation destination-specific characteristics							
Indicator variable for DCOST (1 if households paid some costs for instance food/ water while staying at destination, 0 o.w.)	-0.003	0.001	-2.497	0.013	-0.003	-0.005	0.001
Indicator variable for EDIST (1 for travel distance to destination > 200 m, 0 o.w.)	0.761	0.172	4.436	0.000	2.141	0.425	1.097
Indicator variable for DUR (1 if households stayed more than 2 days at destination, 0 o.w.)	0.352	0.389	0.904	0.366	1.422	-0.411	1.114

*significant at 5% level; **significant at 1% level; ***significant at 0.1% level

distance of the house from the source of flood, and the source of warning are also included in the model due to evidences of significance in the literature.

Table 6.5. Destination choice model information

Model Information	Values
Prob > chi^2	2.56E-16
Log likelihood at convergence	-433.189
Log likelihood at 0	-486.484
R-squared	0.109552
CCR	57%
CCR base rate	37%
AUC	0.7

Table 6.6. Summary of variables significant to destination type choice and findings in earlier literature

Variables	**Investigated in the study?**				**Variable effect and its relation to findings in past studies**
	Earlier studies		**This study**		
	Yes	No	Yes	No	
INCOME	√		√		similar to findings in Mesa-arango et al., 2013
EQUIP		√	√		*new finding in this study*
DIST	√		√		goes with findings in Cheng et al., 2008; Wu et al., 2012
SWARN	√		√		similar to findings in Mesa-arango et al., 2013
DCOST		√	√		*new finding in this study*
EDIST	√		√		related to findings in Cheng et al., 2008; Wu et al., 2012
DUR		√	√		*effect is a new finding in this study*

It should be noted that the distance travelled to the destination and the cost of evacuation to that destination has some level of correlation (r=0.171) as indicated in Table 6.2. The cost of evacuation and duration of stay at the destination has also some level of correlation (r=0.269) as indicated in Table 6.2. For both models, those that do not have money to spend go to their friends/relatives who are more likely located very accessible from their residence location. In addition, household that are willing to travel more distances go to public shelters or to church/seminaries which are more likely to be located farther the high flood risk areas. In summary, variables that were found to significantly affect the destination choice against the findings in past research are presented in Table 6.6.

6.3 Model validation

The values of these are –433.189, –213.571 and –213.340, respectively. The value of LR is 12.558 with 14 degrees of freedom. Since the critical value of χ at 5% significance level or 95%, $\chi^2_{0.05,14,}$ is equal to 23.69, then, the null hypothesis that parameters across different samples are equal, is accepted. Hence, validity of the specification of the model result is established.

Chapter 7
Conclusions and Recommendations

Flooding events, which are prevalent in developing countries, are becoming more frequent and severe. In major urban areas, more citizens are at risk of flooding as settlements in near-flood prone areas continue to increase. It is then important that preparedness measures such as evacuation plans be arranged in order to minimize damage to properties and loss of lives in future disasters.

The occurrence of hydro-meteorological hazards such as hurricanes and floods can be anticipated in advance and impacts can also be estimated at a certain level. It is then possible that people at risk can prepare so that impacts of future disasters could be minimized. Evacuation is one effective measure to move people at risk to safety before a disaster strikes. Planning for evacuation is a way to identify the best strategy for the most probable disaster scenario. In doing this, modeling is helpful in taking into account complexities involved in decision making processes. Evacuation modeling is used to better understand conditions of the network conditions and the effect of traffic management strategies. This is done by providing predicted departure patterns from homes as well as arrival patterns to destinations, time of travel, average speeds, queue lengths, rates of traffic flow, among others. Understanding destination choice behavior of evacuees is one important subject that government officials need to know. Destination choice analysis is an important step towards development of an evacuation plan. Output from its analysis serves as input for assigning traffic to road networks, which is important for identifying congestion and delay that might happen during evacuation (Cheng et al. 2008). Hence, officials can plan ahead to mitigate congestion and delays.

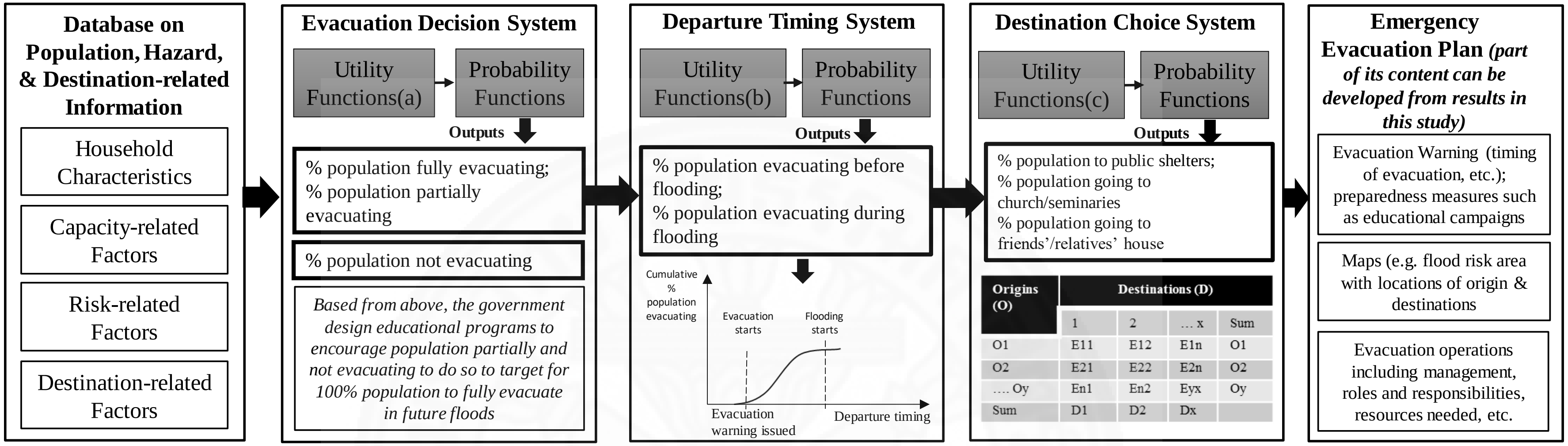
The importance of capturing behavior of decision makers for an evacuation has been realized in research. This study sought to understand different behavioral contexts of evacuation decision making, from the decision to evacuate or not, departure timing and destinations choices. Results of the logit models developed here can be incorporated in an evacuation plan. As the models capture behavioral complexities of each decision making covered in this study, it can be modelled sequentially. This can be done my setting up a simulation system that contains the models developed in this study. Simulation framework is presented in Figure 5. While a numerical example of how results in this study can be applied is detailed in Appendix C. Given records of the population in the City, the model developed for evacuation decision making can be an input to estimate the demand or number of households evacuating. Then, how many of these evacuating or their preference on when they are departing will then be an input which will generate response curves to show the demand at specific periods of time. Then, according to specific periods of time, the destination choice model will generate a matrix of where the evacuees are going and the total number of evacuees. Hence estimating whether the demand of evacuees going to a number of destinations, x, from certain number of origins (where evacuees come from), y, is sufficient against existing resources. These results can be used in developing an emergency local flood plan (see Appendix D for example of contents). A comprehensive example can be found in Lake Mcquarie City Council (2013), part of which is an evacuation plan that essentially contains elements such as evacuation warning to the public, evacuation operations including roles and responsibilities, and maps, among other considerations. An example of a flood evacuation map is presented in Appendix E, extracted from California Department of Water Resources (2011).

Following sections details what can be concluded from each of the evacuation decision investigated in this research.

7.1 Conclusions

7.1.1 Evacuation decision

Evacuation decision is a key input to evacuation plans and models. The importance of careful examination of complex factors in evacuation decision making process has been recognized in research for better evacuation planning. Towards understanding of the complexities of evacuation decision-making while considering risk perception, this



a Utility functions for evacuation decision as presented in equation 5 in the manuscript, with coefficients as estimated and presented in Tables 4.3 and 4.4 for full and partial evacuation, respectively, are used here. Then probabilities are estimated based on equation 6 which will result to identifying the percentage of the population evacuating fully and partially. Those not evacuating should be encouraged to do so by authorities through educational programs, etc. as detailed in the manuscript.

b Utility functions for departure timing decision as presented in equations 8 and 9, with coefficient for departure timing before the flood as estimated and presented in Table 5.3 are used here. Then probabilities are estimated based on equations 10 and 11 and will result to identifying the percentage of the evacuating population before or during the flood. Those evacuating during the flood should be encouraged by authorities to do preemptive evacuation in future flood events.

c Utility functions for destination choice as presented in equation 12, and coefficients as estimated and presented in Tables 6.3 and 6.4 for evacuation to public shelters and church/seminaries, respectively are used here. Then probabilities are estimated based on equation 13 that results to identified percentage of the population going to respective destinations from their homes or identified origins.

Figure 5. Simulation system framework of how results in this study can be used by flood emergency/evacuation planners

study investigated whether influential factors to evacuation decision is a combination of household characteristics and capacities to cope with flooding and hazard-related factors. Using the data collected from 4 sub-district areas in Quezon City Philippines, an MNL model was estimated.

Results in this study show that evacuation decision can be determined by a combination of household characteristics and capacities to cope with flood and hazard-related factors. Significant factors to evacuation decision include household characteristics (gender, educational level, presence of children less than or equal to 10 years old, and number of years living in the residence); capacity-related factors (house ownership, number of floors, type of house material); and hazard-related ones (distance from source of flood, level of flood damage, and source of warning). The results also indicate that risk perception of decision makers can be explained by the combination of these broad groups of factors. Particularly, the capacities of households to cope with flood hazards are an important influence to the decision making process. These results also provide insights that can be used to design appropriate programs to encourage full evacuation compliance of households especially those that live nearest to the flood source, as well as those who have houses with 2 or more floor levels. Additionally, evacuation planners can develop alternative strategies to increase full evacuation compliance of households with children since these households seem less likely to fully evacuate.

7.1.2 Departure timing

Understanding evacuation timing behavior of evacuees is one important subject that government officials need to know in order to decide when to issue emergency evacuation orders. Evacuation timing behavior has been mostly analyzed using response curves using traffic data during evacuation. However, using the response curve do not provide disaggregate information which are important for capturing behaviors that could allow planners to design appropriate evacuation strategies. Therefore, understanding decision making in terms of evacuation timing is needed as fundamental analysis for better evacuation planning and management (e.g. Pel *et al.*, 2011; Li *et al.,* 2013).

This study sought to understand the evacuation timing behavior of flood evacuees. Data were gathered from household heads in selected sub-districts in Quezon City, Philippines. Using these data, a binary logit model was estimated. Vital influential factors to departure time decision making is explicitly shown out of the analysis in this study. The factors are the type of work of the household head, house ownership, number of house floor levels, distance of house from the source of flood, and the flood level.

Insights for evacuation planning could be derived from results of this study. First, households put importance on hazard-related factors and their security when making their decision to either evacuate before or during the flood. Households that have house with more than a floor level, living very near the source of flood, and those located in areas susceptible to flood level more than 1-meter high, are more likely to evacuate when floodwaters are already in their home vicinity. This indicates the flood risk tolerance of households who decides to wait until their house is at a flood level they could bear before deciding to move to safer places.

7.1.3 Destination

To understand the destination evacuation behavior of households in a developing country, analysis is done here. An evacuation destination model is also developed and proposed. Findings support earlier findings in evacuation destination behavior at some level. For instance, evacuees more likely choose closer safe destinations (Cheng et al 2008; Wu et al., 2012). Similar to Mesa-arango et al. (2013), those that have received evacuation warnings from the government officials have higher likelihood of going to public shelters. Likewise, findings here showed that low income households are more likely to choose public shelters which goes in general with findings in Mesa-arango et al. (2013).

Outputs of this study could be used by government agencies in developing an evacuation plan. It is helpful in identifying demand for evacuation centers, identifying appropriate ones and allocating evacuees in each evacuation center so as to minimize evacuation time and properly manage available resources in evacuating people at risk. Results from this study help evacuation planners and managers. For them, knowing characteristics of certain people at risk to floods and their capacities to cope with flood, certain characteristics of the hazard, and the characteristics of identified evacuation destinations, the planners or government officials could use the model presented here to find the households that will go their chosen destination study (public shelters, church/seminaries, friends'/relatives' homes). The information then could be used to find out if existing facilities are adequate for certain number of people.

7.2 Recommendations and Future Research

This section presents further recommendations and future studies that can be done specific to each of the evacuation related decision being investigated. Although proposed models indicate usefulness in the contexts of the study area, model transferability to other areas or contexts were not investigated, as this is not included in the scope of the study. This can be investigated in the future as a next step to this current study.

The following subsections further details specific recommendations and future studies for evacuation decision, departure timing and destination choices.

7.2.1 Evacuation decision

Since findings in this study indicate the need for encouraging certain groups of people to comply to evacuation warning, it is recommended that evacuation compliance of households can be improved through the design and conduct of educational programs to increase awareness about hazards and disasters and enhance preparedness for future evacuations, improvement of participatory risk communication and households' involvement in providing local knowledge and support for disaster preparedness based from Luo, Shaw, Lin, and Joerin (2014). Since people with disaster education are those who are best prepared and capable to manage a disaster, they may also be more willing to take preventive measures.

Although results provide insights regarding the behavior of evacuees in making their decision to fully, partially evacuate or do not evacuate at all, the predictive ability of the model is only at acceptable level. The results indicate that there are some effects that might have not been captured in the model. A limitation of the MNL model is independence from irrelevant alternatives (IIA), which holds that ratio of choice probabilities of any two alternatives is not affected by any other alternative. The IIA MNL property comes from assumption that the probability distribution of alternatives, are independent identical distributed (IID). A way to relax the IID assumption is to allow the probability distribution to correlate while the IID assumption is retained, which is defined in the specification of a nested logit (NL) model. This is a preferred extension to the MNL (Ben-Akiva and Lerman, 1985). In using NL model, gathering more samples with information according to specification of the model from other flood prone areas in Quezon City will be helpful. For instance, the information on actual number of households that evacuated according to the type of evacuation should be collected. Particularly designing survey instruments to gather information based on hypothetical scenarios can be helpful for more robust model estimates.

Moreover, this study is limited due to disaggregate information on evacuation details that are not readily available to validate the model and compare if it is representative of the whole population. Therefore, validation of the model during actual evacuation is a study to be done in the future. This is an important step before being able to put to use any proposed model. In addition to the multivariate analysis in the model, understanding integration of factors and developing an index for a broad group of factors, including the household characteristics, capacity, and hazard-related ones is another subject for investigation. Further, how evacuees choose by what mode of transportation, and which available routes they take can be investigated next. Cheng et al. (2008) emphasized that a model’s ability to predict evacuation situation depends on sufficiently modeling each behavior aspect of evacuation. In addition to modeling evacuation decision, predictive models that forecast by what mode of transportation, is a key input for managing and planning future evacuations as detailed by Cuellar et al. (2009). Evacuation behavior prediction provides information regarding sufficiency or insufficiency of infrastructures to meet the demand of evacuees.

7.2.2 Departure timing

It is recommended according to results of the study that authorities design appropriate strategies to encourage those that are living very near the source of flood and have house floor levels more than a floor to evacuate immediately once the government recommended them to evacuate. This can be done by educating and/or providing them with benefits of evacuating earlier such as highly prioritizing them to be moved to secured evacuation centers with provision of vehicles as needed, food, water, medical assistance and other basic needs. Second, since households that own their house, with the head working full time, are more likely to evacuate before the flood, the government can encourage these groups to do the same in future evacuation and involve them in leading evacuation movements. Third, in order to encourage households who are renting their homes to also evacuate well ahead of time, security guards should be provided in areas of residence to keep them from worries of looting and house security. Also, when issuing future evacuation advice, government officials should also specify the timing of evacuation by specific groups of households in addition to other evacuation related content of the message (e.g. routes to take when evacuating according to specified destinations such as public shelters). The model developed here can be used to predict the number of households evacuating at specific timing which can be utilized to plan for staged evacuation movement in the future.

Results for departure timing is also subjected to couple of limitations. First, departure timing analyzed in this study considered only those living in high flood risk areas. Households who were recommended to evacuate or those who voluntarily evacuated should also be taken into account in future studies. This has some implications in network traffic conditions during evacuation. Future studies can also include modeling departure time choice based on their actual evacuation timing for better understanding of the distribution of evacuees at specific time interval within the given evacuation time period.

7.2.3 Destination Choice

Since results indicates the demand for public shelters, the government can identify whether existing facilities is enough or not. Then, the government officials can prepare ahead, ready to communicate to people whenever flood strikes. They can also encourage those who have been going to friends/families to continue to do so in future floods in order to decrease the demand of going to public evacuation centers shelters. Moreover, government officials in charge of developing evacuation plans can prepare evacuation warnings with concrete information to communicate to people in order to be prepared ahead of time. Mesa-arango et al. (2013) some ways of how the destination choice information can be valuable. These are recognition of demand for public shelters and improving facilities/services for evacuation; development of evacuation messages specific to population groups and providing specific advice on which shelter they should go to; development of cooperative programs with hotels to provide accommodation to some segment of the demand; as well as recognition of other areas that can be attractive to evacuees to limit congestion and delays in moving people to safety. The government can also prepare for the needed stuff (e.g. food, water, medicine) and be able to let evacuees have better situation during future evacuations. Destination predictions when used as a planning tool can bring evacuation players together for better evacuation management in the future. Although the model result is promising, it might only be applicable to the 4 sub-district areas. Expanding study area might be useful in understanding travel behavior for the whole city. This is a subject for future research. Analysis at the sub-district level could also provide insights that are not obvious when making a city-wide analysis. Analysis at more disaggregate level and its advantage has been recognized in research (e.g. Wu et al. 2012).

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Appendices

Appendix A
Survey Questonnaire

Household Area Code/Location: ___________________

This survey form is intended for data collection for the research project entitled "Modeling Travel Behavior for Flood Evacuation" being conducted by the SIIT graduate student. Targeted to the head of the household (male/female), the questions here are based on information and travel-related decisions that you have made during floods at the period of typhoon "Maring" which happened during late of August this year. Floods during this period caused a total damage of and affected in various ways. The end goal of this study then is to be able to develop/recommend preparedness measures to minimize the loss of lives and property damage in case of future floods.

Your effort in providing your answers as accurate as you can is highly appreciated in order to produce realistic and reliable data for development of evacuation models. Please be ensured that the personal information you will provide in this questionnaire will be kept **confidential** and only the data analysis results will be included in the report of the study. Your participation in this survey does not cost you anything. You just have to complete this questionnaire and hand over to the person in charge.

<u>Part I. Socio-demographic & Household-relevant Information:</u>

Please tick appropriate box of your answer and provide your answer to items that require detail.

1. Age: _____________ years
2. Gender: ☐ Male ☐ Female
3. Marital Status: ☐ Single ☐ Married ☐Widower ☐Others specify):______
4. Number Household Members:______________

Member # :	Relationship (wife/husband/child/grandchild, etc.)	Age
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		

5. Level of Education: ☐ Primary ☐ Elementary ☐ Highschool ☐ Diploma ☐ Undergraduate ☐ Graduate ☐ Others specify):_____________________________

6. Type of Work: ☐ Full time ☐ Part Time ☐ Not employed ☐Others (specify):_____________________

7. Nature of Work: ☐ Government ☐ Private ☐ Self-Employed ☐Others (specify):___________________

8. Address of workplace: ____

9. Household Income per month: ____

10. House Ownership Type:☐ Own House ☐ Renting House/Apartment ☐ Provided by Employer ☐Others (specify):_______________________________

11. Number of house floors: ☐ 1 ☐ 2 ☐ 3 ☐ others (specify): _______________

12. Material of the house: ☐ concrete ☐ half-concrete ☐wood ☐others (specify):______________________________

13. How many years are you living in your home: (e.g. 2 years, 20 years, whole life, etc.): ______________________ years

14. How far is your home located from the source of flood? __________ Meters or _________ kilometers

15. Does your family have personal vehicles? ☐ Yes ☐ No

If yes, how many and what type of vehicles do the family own? ☐ Jeep: how many?______ ☐ Motorcycle: how many? ____ ☐ Others (specify): _______how many? _____

16. Do you have pets? ☐ Yes ☐ No

17. Do you have health problem or sickness? ☐ Yes ☐ No

18. Are you, covered by any form of health insurance or health plan?

☐ Yes ☐ No

19. Do you have any boat/life vest or any equipment prepared for flood?

☐ Yes ☐ No

20. a. Did you experience flood in the past even before "Maring" period which happened August this year? ☐ Yes ☐ No

b. If your answer above (20.a) is no, do you have knowledge about flood before flood "Maring" happened? ☐ Yes ☐ No

c. If your answer above (20.a) is yes, how many times have you experienced flood? ☐ once ☐ twice ☐ more than twice ☐Others(specify):___________

e. During most of your experience, did you evacuate your place?

☐ Yes ☐ No

<u>Part II. Information Related to Flood Experience During "Maring"</u>

21. Did you experience flood during the typhoon "Maring" period which happened August this year? ☐ Yes ☐ No

22. If your answer above is no, answer the questions in part III. If the answer is yes, continue answering from question number 23.

23. What was the effect of flood to your home? ☐Not damaged ☐damaged ☐ seriously damaged ☐Others (specify):____________________

24. Approximately how high was the flood in your place? _______________________ meters

25. How long was your home flooded? __________________________ days/hours

26. How many times was your place flooded this year?

☐once ☐ 2 times ☐ 3 times ☐ 4 times ☐ others (specify):________________

27. Before the flood, did you hear an advice to evacuate your place due to possibility of flooding? ☐ Yes ☐ No

a. Where did you get most of your news about the flood/evacuation advice?

☐TV ☐Radio ☐Friend/family ☐head of village/barangay

☐Others (specify):______________________

b. According to the warning, what time of the day was flood expected to reach your home? ______________________

☐ AM (0:01-6:00) ☐ Mid-day (6:01-12:00) ☐PM (12:01-6:00)

☐ NIGHT (6:01-12:00)

28. Did you evacuate from your house according to the evacuation advice?

☐ Yes ☐ No

a. If your answer in 27 is no, please proceed answering from item 30 onwards.

b. If your answer is yes, please answer the following questions:

i). When did you evacuate in relation to when the flood reached your home?

☐ hours before ☐ when flood is flowing to place ☐ when my home is flooded ☐ others (specify):______________________

Please indicate the time of the day when you evacuated based on your answer above. (e.g.: 1:00pm, 9:00am, 6:00pm, etc.) _______________

☐ AM (0:01-6:00) ☐ Mid day(6:01-12:00) ☐PM (12:01-6:00) ☐Night (6:01-12:00)

ii) Did you evacuate with the whole members of the family, or some members were left at home and evacuated later?

☐ Evacuated the whole family ☐ Some evacuated and some were left home ☐Others specify):_____________________________________

iii) Where did you go when you evacuated?

☐evacuation center provided by government ☐friends'/relatives house

☐ workplace ☐others (specify):_____________________

Please indicate where the place is located? (e.g. QC High School, Holiday Inn, etc.) ______________________________

iv) How long did you stay in the place before going back home?

_____________days/hours

v) Approximately how much did you pay for staying in the place (for example: 500 pesos/day)? Specify: ________ pesos/day

Answer this section only if your answer in item 28 is no.

29. For each of the following, indicate if it was a reason why you, personally, did not evacuate based on the evacuation advice?

a. I did not have a car or a way to leave. ☐ Yes ☐ No

b. I was physically unable to leave. ☐ Yes ☐ No

c. I had to care for someone who was physically unable to leave. ☐ Yes ☐ No

d. I thought the flood and its aftermath would not be as bad as it was. ☐ Yes ☐ No

e. I worried that my possessions would be stolen or damaged if I left. ☐ Yes ☐ No

f. I didn't want to leave my pet. ☐ Yes ☐ No

g. Others (specify):____

Part III. Suggestions/comments on problems faced during floods or on how to improve conditions in future flood/evacuation:

____

____

____

____

Thank you very much for your participation!

Research Team

Appendix B

Chi-square Distribution Critical Values According to the Number of Degrees of Freedom

DF	$\chi^2_{.100}$	$\chi^2_{.050}$	$\chi^2_{.025}$	$\chi^2_{.010}$	$\chi^2_{.005}$
1	2.706	3.841	5.024	6.635	7.879
2	4.605	5.991	7.378	9.210	10.597
3	6.251	7.815	9.348	11.345	12.838
4	7.779	9.488	11.143	13.277	14.860
5	9.236	11.070	12.833	15.086	16.750
6	10.645	12.592	14.449	16.812	18.548
7	12.017	14.067	16.013	18.475	20.278
8	13.362	15.507	17.535	20.090	21.955
9	14.684	16.919	19.023	21.666	23.589
10	15.987	18.307	20.483	23.209	25.188
11	17.275	19.675	21.920	24.725	26.757
12	18.549	21.026	23.337	26.217	28.300
13	19.812	22.362	24.736	27.688	29.819
14	21.064	23.685	26.119	29.141	31.319
15	22.307	24.996	27.488	30.578	32.801
16	23.542	26.296	28.845	32.000	34.267
17	24.769	27.587	30.191	33.409	35.718
18	25.989	28.869	31.526	34.805	37.156
19	27.204	30.144	32.852	36.191	38.582
20	28.412	31.410	34.170	37.566	39.997
30	40.256	43.773	46.979	50.892	53.672

Appendix C

Numerical Example of Application of the Models Estimated in this Study

Appendix C.1. Generated Sample Household Dataset and Coded

HH No	GEN	EDUC	TWORK	INCOME	CHILD	YLIVE	HOWN	FLOOR	HMAT	EQUIP	DIST	FLEVEL	DAM	SWARN	DCOST	EDIST	DUR
1	1	4	1	1	2	1	1	1	2	1	1	1	1	1	1	1	3
2	2	2	1	1	1	1	1	1	1	1	2	1	1	1	1	2	2
3	1	2	1	1	2	2	2	1	2	2	3	2	1	1	2	2	3
4	1	3	1	1	2	3	1	1	2	2	4	1	1	1	2	3	3
5	2	2	2	2	2	2	1	2	1	1	2	2	2	2	2	2	3
6	2	2	2	1	1	3	1	2	2	1	1	2	1	2	1	2	3
7	2	1	1	1	2	1	2	1	2	1	1	1	2	2	2	2	2
8	1	1	1	3	1	2	2	1	2	1	4	1	1	1	1	2	3
9	1	3	1	3	2	2	1	1	2	1	1	2	2	1	1	3	1
10	2	4	2	3	1	1	1	1	2	1	2	2	2	2	2	1	1
11	1	1	1	1	2	1	1	1	1	2	4	1	1	1	2	3	2
12	2	2	1	2	1	3	1	1	2	1	2	1	1	2	1	1	1
13	2	1	1	2	2	2	1	1	1	1	2	2	2	2	1	2	3
14	2	2	1	2	2	3	2	2	1	1	3	2	2	1	1	2	3
15	2	1	2	2	1	3	1	2	1	1	4	1	2	2	2	1	3
16	2	1	2	3	2	3	1	2	2	2	4	2	1	2	1	1	3
17	1	4	2	2	2	1	1	2	1	2	4	1	2	2	2	3	3
18	1	1	1	2	1	3	2	1	1	1	1	1	1	2	1	1	2
19	2	1	1	3	1	1	2	1	2	1	2	1	2	2	1	1	2

HH No	GEN	EDUC	TWORK	INCOME	CHILD	YLIVE	HOWN	FLOOR	HMAT	EQUIP	DIST	FLEVEL	DAM	SWARN	DCOST	EDIST	DUR
20	2	4	2	1	2	3	2	2	1	1	4	1	1	2	2	1	2
21	1	4	1	3	2	3	2	1	1	2	1	2	1	2	1	1	1
22	1	4	2	1	2	3	1	1	1	2	4	2	1	2	1	2	3
23	2	3	2	2	1	2	2	1	1	2	4	2	2	2	1	1	1
24	2	2	2	3	2	2	2	2	1	2	2	2	1	2	1	1	3
25	1	1	2	1	2	1	2	1	2	1	1	2	1	1	2	3	3
26	1	4	2	2	1	2	2	2	2	2	1	2	2	2	2	1	2
27	1	1	2	3	1	2	1	2	1	1	4	1	1	1	2	1	1
28	1	3	2	2	1	3	1	1	1	1	2	2	2	1	2	3	3
29	1	4	2	2	1	1	2	2	1	2	2	1	2	2	1	2	3
30	1	1	2	3	2	2	2	2	2	1	2	2	1	2	1	1	3
31	2	3	2	1	1	2	1	2	2	1	1	2	1	2	1	3	1
32	2	3	2	3	2	1	2	1	2	2	1	1	1	1	2	2	1
33	2	1	2	1	2	3	2	2	2	2	3	1	1	1	2	1	2
34	1	4	1	1	2	3	1	1	1	2	4	2	2	2	1	3	1
35	1	2	2	3	2	2	2	1	2	1	1	2	1	2	1	1	3
36	1	3	1	2	2	2	1	2	2	1	3	2	1	1	1	1	3
37	1	4	2	1	1	3	1	2	1	1	3	2	2	1	2	1	2
38	1	2	2	2	2	1	1	1	1	1	4	1	2	2	1	1	3
39	2	3	1	2	2	3	1	1	1	1	2	2	2	2	2	1	3
40	2	4	1	2	2	2	1	1	2	2	1	1	2	2	2	1	3
41	2	2	1	3	2	2	2	2	2	1	2	2	1	2	2	1	3
42	1	3	1	1	2	2	2	2	1	2	1	2	2	1	1	1	2
43	2	2	1	3	1	3	2	1	2	1	4	1	1	2	2	2	1
44	1	3	2	3	2	1	2	2	1	1	2	2	2	1	2	1	3

HH No	GEN	EDUC	TWORK	INCOME	CHILD	YLIVE	HOWN	FLOOR	HMAT	EQUIP	DIST	FLEVEL	DAM	SWARN	DCOST	EDIST	DUR
45	1	4	2	3	1	1	1	1	1	2	1	2	2	2	1	2	3
46	2	3	1	3	2	2	1	1	1	1	2	2	1	1	2	2	1
47	1	3	1	2	2	3	1	1	2	2	1	2	1	2	1	3	3
48	1	3	1	3	1	3	1	2	2	1	3	2	2	2	1	1	3
49	1	2	1	3	1	1	2	1	1	1	3	2	1	1	1	3	2
50	2	4	1	1	1	2	2	2	1	1	2	2	2	1	2	3	2
51	2	2	1	1	2	3	2	2	2	2	2	1	2	1	1	2	2
52	2	1	1	1	2	2	1	1	1	1	4	2	2	2	2	2	1
53	1	2	2	1	1	3	2	2	2	2	3	1	1	1	2	1	2
54	2	4	2	2	1	2	2	2	2	2	4	1	1	1	2	1	2
55	2	4	1	3	2	3	2	2	2	1	1	2	1	1	1	1	1
56	2	2	2	1	1	3	2	2	1	1	3	2	2	1	1	3	1
57	1	1	1	2	1	1	2	1	1	1	2	1	1	1	2	1	2
58	1	3	1	3	2	3	1	2	2	1	1	2	1	1	2	3	1
59	2	2	2	1	2	3	2	2	2	2	4	2	1	1	1	1	2
60	2	1	2	2	2	1	2	1	1	1	3	2	2	2	2	3	3
61	1	1	2	1	2	3	1	1	2	2	4	1	1	2	1	3	3
62	1	1	2	1	1	3	2	1	1	1	4	2	1	2	2	3	1
63	1	3	1	3	2	2	1	1	2	2	3	2	2	2	2	3	2
64	1	4	2	2	1	1	2	1	1	1	2	1	2	2	1	2	3
65	2	3	2	3	2	1	1	2	1	2	3	2	1	1	1	1	3
66	1	2	2	2	1	2	2	1	1	2	3	2	1	1	2	2	2
67	2	3	1	1	2	1	2	2	1	2	4	2	1	1	1	1	3
68	2	2	1	1	1	2	1	1	2	1	4	1	2	2	2	2	3
69	1	3	2	3	2	3	2	1	1	1	1	1	1	1	2	2	2

HH No	GEN	EDUC	TWORK	INCOME	CHILD	YLIVE	HOWN	FLOOR	HMAT	EQUIP	DIST	FLEVEL	DAM	SWARN	DCOST	EDIST	DUR
70	2	2	2	1	1	1	1	1	1	1	3	2	1	1	2	2	3
71	1	2	2	1	2	2	1	1	2	2	3	1	1	1	2	2	2
72	1	3	1	2	1	2	1	1	2	1	2	2	1	1	2	2	3
73	2	3	1	3	2	1	1	1	1	2	2	1	2	2	2	1	1
74	1	2	2	2	1	1	1	1	1	1	4	1	2	2	1	2	3
75	2	4	2	1	1	2	1	1	1	2	4	2	2	1	1	3	1
76	2	3	2	2	1	2	1	1	1	1	1	1	1	2	1	3	3
77	2	4	2	1	2	1	1	2	2	2	4	1	2	1	2	1	3
78	1	1	2	2	2	3	1	2	2	2	3	2	2	2	2	2	1
79	1	3	2	2	1	3	2	2	2	2	1	2	2	2	2	2	2
80	1	3	2	2	2	3	1	2	1	2	4	1	1	2	1	2	1
81	1	1	1	2	2	1	1	2	2	1	1	2	1	1	2	3	2
82	1	1	2	2	2	3	1	2	2	2	2	2	2	2	1	2	1
83	1	1	2	2	2	3	2	2	2	2	3	2	1	2	2	3	3
84	2	4	2	2	2	2	2	2	2	1	4	2	2	2	1	3	2
85	1	1	2	3	2	2	2	2	1	1	1	2	1	1	2	1	1
86	1	2	2	1	1	2	2	1	1	2	3	2	1	2	1	3	1
87	1	4	2	3	1	3	2	2	2	2	4	2	2	1	2	1	2
88	1	3	1	2	2	1	1	1	2	2	1	2	1	1	2	1	3
89	1	1	1	1	1	3	2	1	1	1	2	1	1	2	2	1	3
90	1	4	1	1	1	1	1	2	2	1	3	2	1	2	2	2	2
91	1	4	2	2	2	3	2	2	1	1	1	1	1	1	1	3	1
92	2	2	2	2	1	1	1	2	1	2	4	1	1	2	2	3	1
93	1	3	1	1	2	3	2	1	1	2	3	2	2	1	2	3	3
94	2	4	1	1	2	3	1	2	1	2	2	2	2	2	2	1	3

HH No	GEN	EDUC	TWORK	INCOME	CHILD	YLIVE	HOWN	FLOOR	HMAT	EQUIP	DIST	FLEVEL	DAM	SWARN	DCOST	EDIST	DUR
95	1	4	2	3	2	2	2	1	2	2	3	2	2	1	2	1	1
96	1	2	1	3	2	1	2	1	1	2	4	1	2	1	2	1	1
97	2	3	2	1	2	2	1	2	1	1	2	1	1	1	2	3	1
98	1	3	1	2	1	1	1	1	2	1	3	1	1	1	2	1	2
99	1	2	1	2	1	3	1	2	2	2	2	1	1	2	2	2	2
100	2	4	1	3	2	2	2	1	2	1	2	1	1	2	2	2	1
101	2	2	2	2	1	3	1	1	2	1	2	2	2	2	1	2	2
102	2	4	1	2	2	3	2	2	1	1	1	1	2	2	1	3	3
103	2	3	2	3	1	3	1	2	2	1	1	2	1	1	1	1	3
104	2	1	2	1	1	2	1	2	1	1	1	1	2	1	2	3	3
105	2	1	1	1	2	1	2	2	2	1	1	1	2	2	1	1	1
106	2	4	2	3	2	3	2	1	2	2	4	1	1	2	2	1	2
107	1	1	2	2	1	3	1	2	1	1	4	2	1	1	1	1	1
108	1	4	2	3	1	1	2	1	2	1	1	1	2	2	2	2	1
109	2	4	2	2	1	1	2	1	1	2	2	2	2	2	2	3	1
110	2	2	2	1	2	1	1	1	1	1	3	1	1	2	2	1	1
111	2	2	1	3	2	2	2	2	1	1	2	1	1	2	2	2	3
112	1	3	1	3	1	2	2	1	2	2	1	1	2	2	2	3	1
113	2	2	2	1	1	2	2	1	2	2	4	1	1	1	1	1	3
114	2	2	2	3	1	3	2	1	1	1	3	1	2	1	1	2	1
115	2	3	2	2	1	1	2	2	1	1	2	1	1	1	1	1	2
116	1	4	2	3	1	2	1	2	1	1	2	2	1	1	1	3	2
117	1	2	2	1	1	3	1	2	2	2	3	2	1	2	1	3	2
118	2	4	2	1	1	1	1	2	1	1	1	2	1	1	1	2	2
119	1	4	1	2	1	1	2	1	2	2	4	1	1	2	2	2	1

HH No	GEN	EDUC	TWORK	INCOME	CHILD	YLIVE	HOWN	FLOOR	HMAT	EQUIP	DIST	FLEVEL	DAM	SWARN	DCOST	EDIST	DUR
120	2	3	2	2	2	2	1	1	1	2	3	2	2	1	2	1	3
121	1	3	2	3	1	1	2	1	2	1	4	1	1	1	2	3	2
122	2	3	2	2	2	2	2	1	1	1	1	1	1	1	1	2	3
123	2	2	2	1	1	1	2	2	1	1	2	1	1	1	2	1	2
124	1	3	1	1	2	3	2	1	2	2	1	2	1	1	2	2	2
125	2	4	2	1	2	1	2	2	2	2	1	2	2	1	2	1	1
126	1	2	1	2	2	3	1	2	2	2	1	2	1	2	2	1	1
127	1	1	2	2	2	1	1	1	1	1	2	2	2	2	2	3	2
128	2	3	2	1	2	3	1	2	2	1	3	1	2	1	1	1	1
129	1	2	2	3	1	2	2	1	1	1	2	2	1	2	2	1	2
130	1	2	2	2	1	2	2	1	1	1	2	2	2	1	2	1	1
131	1	4	1	3	1	1	2	1	1	2	4	2	1	1	2	2	3
132	2	1	2	2	2	1	1	1	1	2	3	2	1	1	1	1	1
133	2	1	1	1	1	2	1	1	2	1	2	1	1	2	1	1	3
134	2	4	1	2	2	2	1	1	2	2	3	1	1	1	2	2	2
135	2	3	2	3	1	2	1	2	2	2	4	2	2	1	1	1	2
136	2	4	2	3	1	1	1	2	1	2	2	1	1	1	1	3	1
137	2	1	1	2	2	1	2	2	1	1	3	1	1	1	1	1	1
138	2	4	2	3	2	3	2	1	1	2	4	2	1	1	2	2	1
139	2	3	1	1	1	2	1	2	2	2	3	1	1	1	1	2	3
140	2	1	2	3	1	2	2	1	2	2	1	1	1	2	2	1	1
141	1	2	1	2	1	1	2	1	2	1	2	2	1	1	2	2	2
142	2	2	2	1	1	2	2	2	2	2	1	1	2	1	1	3	3
143	2	4	1	1	2	1	2	1	2	2	1	2	1	1	2	1	2
144	2	2	2	1	1	3	1	1	2	1	3	1	1	1	2	1	2

HH No	GEN	EDUC	TWORK	INCOME	CHILD	YLIVE	HOWN	FLOOR	HMAT	EQUIP	DIST	FLEVEL	DAM	SWARN	DCOST	EDIST	DUR
145	2	3	2	1	1	3	1	2	1	1	2	1	2	2	1	3	3
146	1	4	1	3	1	1	1	1	1	1	1	1	2	2	2	1	2
147	2	4	1	2	1	1	1	1	2	2	1	2	2	1	2	2	2
148	2	1	1	1	1	3	1	2	2	2	1	2	1	2	1	2	2
149	2	2	1	2	1	1	2	1	2	2	3	1	1	2	1	2	1
150	2	1	1	2	2	3	2	1	1	1	4	2	1	1	2	2	3
151	2	1	2	1	2	2	1	2	1	2	2	1	2	2	2	3	2
152	1	2	1	2	1	2	1	2	1	2	2	1	1	2	2	2	3
153	2	2	1	3	2	1	2	1	2	1	2	2	2	1	1	3	2
154	1	4	1	1	2	3	2	1	2	1	2	1	2	2	1	3	1
155	2	1	1	2	1	3	1	1	1	2	1	2	1	1	2	1	2
156	2	3	2	2	1	1	2	2	2	2	4	2	2	1	1	1	2
157	1	4	2	3	2	3	2	2	1	1	2	2	1	2	1	2	3
158	1	1	2	3	2	3	2	2	2	1	1	2	2	1	2	3	1
159	1	2	1	3	2	3	2	2	1	1	4	2	2	2	2	3	2
160	2	3	1	3	2	1	2	2	1	2	2	1	1	2	1	2	2
161	1	2	2	2	2	2	2	2	1	1	4	2	2	2	2	2	1
162	2	2	1	3	2	3	1	2	1	1	4	2	2	2	2	3	3
163	1	4	1	2	2	1	1	1	1	2	4	2	2	1	1	1	1
164	2	2	2	1	2	2	1	2	2	2	2	1	1	2	1	2	3
165	1	1	1	2	2	2	2	2	2	1	4	1	2	1	2	1	1
166	2	1	2	1	1	3	1	1	1	1	2	1	1	1	2	2	3
167	2	3	1	1	1	2	2	1	2	1	1	1	2	1	2	2	3
168	1	2	2	3	1	1	1	1	1	2	4	1	1	1	1	1	2
169	1	4	1	1	2	1	1	2	1	2	2	1	1	2	2	3	3

HH No	GEN	EDUC	TWORK	INCOME	CHILD	YLIVE	HOWN	FLOOR	HMAT	EQUIP	DIST	FLEVEL	DAM	SWARN	DCOST	EDIST	DUR
170	1	3	1	2	1	2	1	1	1	2	1	2	2	1	1	1	1
171	1	1	2	3	2	3	2	2	2	1	1	2	1	2	1	2	2
172	1	3	1	1	1	3	1	2	2	2	2	1	2	1	2	3	2
173	2	2	1	2	1	2	2	2	2	2	2	1	1	2	2	1	3
174	2	1	1	3	1	1	2	2	1	2	4	2	2	2	2	1	3
175	2	4	1	2	2	2	2	1	1	1	2	1	1	2	2	2	1
176	1	2	2	3	1	1	2	1	1	1	2	2	2	1	2	1	3
177	1	2	2	3	1	1	1	1	2	1	1	1	2	2	2	3	1
178	1	1	2	2	1	1	2	1	1	1	4	2	1	2	1	1	1
179	1	1	1	2	1	1	2	1	2	1	1	2	2	2	2	3	3
180	2	2	2	2	2	2	1	1	1	2	3	1	2	2	2	3	1
181	2	3	1	2	2	1	1	2	2	1	4	2	1	1	1	2	3
182	1	4	1	1	1	1	2	2	1	1	1	1	2	2	1	1	1
183	2	2	2	1	1	1	1	2	1	2	3	1	2	2	2	2	2
184	1	2	2	2	2	1	1	2	2	1	2	2	1	1	1	1	2
185	2	3	2	1	2	1	1	1	1	1	3	2	1	2	1	1	3
186	2	3	2	1	1	3	2	1	2	2	4	2	1	1	1	3	1
187	2	2	1	1	1	1	2	2	2	2	4	2	1	1	1	1	3
188	1	4	2	2	2	1	2	2	1	2	4	1	2	2	1	2	1
189	2	1	1	1	2	3	2	1	2	1	4	1	1	1	1	3	1
190	2	2	2	2	2	3	1	1	1	2	2	1	1	1	1	2	2
191	2	3	1	1	1	1	2	2	1	2	4	1	1	1	2	3	1
192	2	2	1	1	2	1	1	2	1	2	3	1	1	2	1	2	1
193	1	2	2	3	1	1	1	2	1	2	4	1	2	1	1	2	1
194	2	2	1	3	1	2	1	2	2	1	3	1	2	2	1	2	2

HH No	GEN	EDUC	TWORK	INCOME	CHILD	YLIVE	HOWN	FLOOR	HMAT	EQUIP	DIST	FLEVEL	DAM	SWARN	DCOST	EDIST	DUR
195	1	4	1	3	2	3	2	1	1	1	4	1	2	1	1	2	3
196	1	3	2	2	1	1	2	2	2	1	2	2	1	2	1	1	2
197	2	1	1	3	2	2	1	2	1	2	3	2	1	2	2	3	3
198	2	4	2	1	1	3	1	2	1	2	3	1	1	2	2	1	3
199	1	4	2	3	1	1	2	2	2	1	4	2	2	1	2	1	1
200	1	4	1	3	2	1	2	1	1	1	4	1	2	2	2	2	1
201	2	4	2	3	2	1	1	2	2	1	1	2	1	1	1	2	1
202	1	3	2	3	1	3	1	2	2	1	3	1	1	1	2	3	1
203	2	3	2	1	1	3	1	2	2	1	3	2	2	1	2	2	2
204	1	3	1	1	1	1	1	2	2	2	2	1	2	1	1	3	3
205	1	3	1	3	1	3	1	1	2	2	4	1	2	2	1	2	3
206	2	3	2	2	2	2	2	1	2	2	3	1	2	1	2	1	2
207	1	3	1	2	1	1	1	1	2	1	3	2	2	2	1	3	2
208	2	4	2	2	1	3	1	2	2	1	2	1	2	2	1	2	1
209	2	1	2	2	1	3	2	2	2	1	2	1	2	2	2	3	1
210	1	2	1	2	1	1	1	1	2	1	3	2	2	2	1	3	2
211	1	1	1	3	2	2	2	2	2	2	4	2	2	2	1	2	3
212	2	3	1	2	1	2	2	1	2	1	4	2	1	1	2	1	2
213	2	4	2	3	2	3	2	1	1	2	2	1	2	1	2	3	1
214	2	4	1	1	1	1	1	1	1	1	2	1	2	1	2	3	2
215	1	2	1	2	2	1	2	2	1	2	1	2	1	2	2	2	1
216	1	1	1	2	2	1	1	2	2	2	4	1	2	2	2	2	2
217	1	2	1	1	2	1	2	1	2	1	3	2	2	2	1	2	2
218	2	3	1	2	2	2	2	1	2	1	4	1	1	1	1	3	3
219	2	1	2	1	2	1	2	1	2	1	2	1	2	2	1	1	1

HH No	GEN	EDUC	TWORK	INCOME	CHILD	YLIVE	HOWN	FLOOR	HMAT	EQUIP	DIST	FLEVEL	DAM	SWARN	DCOST	EDIST	DUR
220	2	3	1	1	2	1	1	2	2	1	1	2	1	1	1	2	2
221	2	2	1	2	2	1	1	1	1	2	1	2	1	2	1	3	1
222	1	2	1	2	2	2	1	2	1	1	2	1	2	1	2	1	1
223	1	3	2	3	1	3	2	2	1	2	2	1	2	2	1	3	3
224	1	4	2	1	2	1	2	1	2	1	4	2	2	1	2	3	2
225	2	3	2	3	2	3	2	1	1	1	4	1	1	2	1	2	1
226	1	2	1	2	1	3	2	1	2	1	1	1	1	1	1	1	3
227	1	1	1	3	2	2	2	1	1	2	1	1	2	2	2	1	3
228	2	4	1	3	1	2	2	1	1	2	2	1	1	1	1	2	1
229	2	4	2	3	2	2	1	1	1	1	4	2	1	2	1	3	2
230	2	3	2	1	2	2	2	1	1	2	3	2	2	1	2	1	1
231	1	1	2	3	1	3	1	2	2	2	3	1	2	2	2	3	2
232	1	4	1	1	1	2	2	1	1	1	3	2	2	1	2	2	3
233	1	3	1	3	2	3	2	2	2	1	4	2	1	2	2	1	2
234	2	2	2	2	1	1	2	1	1	1	4	1	2	2	2	1	1
235	2	1	2	2	2	1	2	2	2	2	1	1	1	2	1	3	3
236	2	4	2	2	2	3	2	1	2	1	3	1	2	2	1	3	1
237	2	4	2	2	1	3	1	1	2	1	2	2	1	1	1	3	3
238	1	4	2	3	2	1	1	2	1	2	3	2	1	2	1	3	1
239	2	1	2	2	1	2	2	2	2	2	3	1	2	2	1	2	2
240	2	4	1	1	2	2	2	2	1	1	1	2	1	2	1	3	1
241	1	1	2	3	2	1	1	2	2	2	1	1	1	1	1	1	1
242	2	4	1	1	1	1	1	1	2	2	1	1	1	2	1	2	3
243	1	3	2	2	1	3	2	2	2	2	1	1	2	1	1	3	1
244	1	3	1	1	1	2	1	1	1	1	2	2	1	1	2	3	1

HH No	GEN	EDUC	TWORK	INCOME	CHILD	YLIVE	HOWN	FLOOR	HMAT	EQUIP	DIST	FLEVEL	DAM	SWARN	DCOST	EDIST	DUR
245	2	4	2	1	1	3	1	1	1	2	1	2	1	2	1	3	1
246	1	4	1	1	1	3	1	2	2	1	2	1	1	1	2	3	3
247	1	2	2	2	2	2	1	1	1	1	2	2	2	1	2	1	1
248	2	4	2	3	2	2	1	1	2	1	4	1	1	1	2	3	3
249	2	2	2	3	2	1	2	1	2	1	3	1	1	1	2	1	3
250	2	3	1	1	2	2	2	1	2	1	2	2	2	2	1	1	3
251	1	3	1	1	1	3	1	2	1	2	2	2	1	1	2	2	1
252	2	1	2	1	2	3	1	2	2	1	2	1	2	2	1	3	2
253	1	2	1	3	2	3	1	1	2	2	3	1	1	2	2	1	3
254	1	2	1	3	1	3	1	1	1	1	1	1	1	2	2	3	2
255	1	3	1	3	1	2	1	2	1	2	4	1	2	2	2	1	2
256	2	3	1	2	1	3	2	2	2	1	3	2	1	1	1	2	2
257	2	2	1	2	1	3	2	2	2	2	4	1	2	1	2	3	3
258	1	4	2	2	2	3	2	2	2	2	4	2	1	2	2	1	2
259	2	4	2	1	2	3	1	2	1	2	3	1	2	1	2	2	3
260	1	1	1	1	1	1	1	2	1	2	2	1	2	1	2	2	3
261	2	1	1	3	2	3	2	2	2	1	2	2	2	1	1	1	2
262	1	3	2	2	1	2	1	2	2	2	1	2	1	1	2	3	3
263	1	2	2	2	1	3	2	1	2	1	3	2	1	1	1	1	3
264	1	3	1	2	2	1	2	1	2	2	3	2	2	1	2	3	2
265	2	2	2	1	1	1	2	1	1	1	1	2	2	2	1	3	3
266	2	1	2	3	2	1	2	1	2	1	2	2	2	1	2	2	1
267	1	4	1	3	1	1	1	2	2	1	4	1	1	2	2	3	1
268	1	1	1	2	1	2	2	1	2	1	1	1	2	2	2	3	1
269	1	1	2	1	1	3	2	2	2	1	3	2	2	2	2	3	3

HH No	GEN	EDUC	TWORK	INCOME	CHILD	YLIVE	HOWN	FLOOR	HMAT	EQUIP	DIST	FLEVEL	DAM	SWARN	DCOST	EDIST	DUR
270	2	1	1	3	2	2	1	1	1	1	1	1	2	1	2	3	2
271	2	1	2	1	1	2	2	1	2	1	3	1	2	2	2	3	1
272	2	2	2	3	1	1	2	2	2	1	1	1	2	1	1	1	1
273	1	3	1	3	1	2	1	1	2	1	4	2	1	1	1	1	3
274	2	2	1	1	1	1	2	2	1	1	2	2	2	2	2	3	3
275	1	3	2	1	1	3	2	1	2	1	3	2	2	1	2	1	3
276	2	2	1	3	1	3	2	1	1	1	2	1	2	1	1	2	1
277	1	1	2	3	1	1	2	2	1	2	2	1	2	2	2	1	3
278	2	4	2	1	2	1	1	1	1	1	1	1	1	1	2	3	1
279	2	4	1	3	1	3	2	2	2	1	1	2	2	1	1	1	1
280	1	2	1	3	1	3	1	2	2	1	2	1	2	2	2	3	1
281	2	1	1	3	1	1	2	2	2	1	2	2	2	2	2	2	2
282	2	2	2	3	1	1	1	1	1	2	1	1	1	2	2	1	2
283	2	4	1	1	1	3	2	2	1	1	4	1	1	1	1	2	1
284	2	4	2	1	2	1	1	1	1	2	2	2	2	2	1	2	3
285	1	1	2	1	2	1	2	1	1	2	2	1	1	2	1	2	1
286	1	3	2	3	1	1	2	1	2	1	3	1	2	2	1	3	3
287	1	2	1	3	1	2	2	1	2	1	4	2	1	2	1	1	1
288	1	2	2	2	2	1	2	1	2	1	3	2	2	1	2	3	1
289	2	1	2	2	2	1	1	1	2	1	2	1	1	1	2	3	1
290	2	4	2	1	2	3	2	1	1	1	1	2	2	2	2	1	3
291	2	2	2	2	2	2	2	2	2	1	3	1	1	2	1	3	2
292	1	1	1	3	1	2	2	1	1	2	1	1	1	2	2	1	1
293	2	3	2	1	1	2	2	2	2	2	4	2	1	1	2	3	3
294	1	1	2	1	1	1	2	1	1	2	2	2	1	1	2	3	1

HH No	GEN	EDUC	TWORK	INCOME	CHILD	YLIVE	HOWN	FLOOR	HMAT	EQUIP	DIST	FLEVEL	DAM	SWARN	DCOST	EDIST	DUR
295	2	3	2	1	2	2	1	1	2	2	4	2	1	2	1	2	1
296	1	4	1	2	1	3	2	1	1	2	1	1	1	1	2	3	3
297	1	3	1	2	2	2	1	2	1	1	4	2	2	1	2	3	1
298	1	4	2	3	1	1	1	1	1	2	4	2	2	2	2	3	2
299	1	2	2	2	1	2	1	2	1	1	2	2	1	2	2	2	3
300	1	2	2	2	2	2	2	1	2	1	2	1	2	1	1	1	3

Appendix C.2. Variables and Categories in Household Data Set and Coding Used

Variable	Coding	Categories/ Description	Frequency	Percent (%)
Gender of the head of the household (GEN)	1	Female	147	49.0
	2	Male	153	51.0
Educational attainment of the head of the household (EDUC)	1	Elementary	67	22.3
	2	High School	81	27.0
	3	Diploma/college	75	25.0
	4	Graduate	77	25.7
TWORK (type of work of the household head)	1	Part- time worker	139	46.3
	2	Full-time worker	161	53.7
Monthly income of the household (in Philippine peso, PHP) (INCOME)	1	1,000-5,000	100	33.3
	2	5,001-10,000	104	34.7
	3	>10,000	96	32.0
Presence of small children of less than or equal to 10 years old (CHILD)	1	No small child	152	50.7
	2	Small child is present	148	49.3
Number of years living in the present residence (YLIVE)	1	<10 years	109	36.3
	2	10-20 years	90	30.0
	3	>20 years	101	33.7
HOWN (House ownership type)	1	Rented	142	47.3
	2	Owned	158	52.7
FLOOR (Number of house floor levels)	1	1 floor level	159	53.0
	2	>1 floor level	141	47.0
House material type (HMAT)	1	Wood/half-concrete	145	48.3
	2	Concrete	155	51.7
Presence of prepared equipment/materials for flood (EQUIP)	1	No equipment	169	56.3
	2	With equipment	131	43.7
DIST (Distance from the source of flood hazard)	1	0-10 meters	73	24.3
	2	11-20 meters	85	28.3
	3	21-30 meters	64	21.3
	4	>30 meters	78	26.1
FLEVEL (level of flood experienced by the household)	1	< 1 meter	148	49.3
	2	≥ 1 meter	152	50.7
Level of damage from the previous flood event (DAM)	1	Not damaged	158	52.7
	2	Damaged or severely damaged	142	47.3
Source of evacuation warning (SWARN)	1	Friends/relatives/television/radio	148	49.3
	2	Sub-district/village official	152	50.7

Variable	Coding	Categories/ Description	Frequency	Percent (%)
Cost for food and water while staying at the destination (DCOST)	1	No cost incurred	136	45.3
	2	Cost ranged from PHP 100-2,000	164	54.7
Distance travelled to destination (EDIST)	1	10-200 meters	109	36.3
	2	200-400 meters	92	30.7
	3	>400 meters	99	33.0
Duration of stay at the destination (DUR)	1	1-2 days	106	35.3
	2	3-4 days	87	29.0
	3	>4 days	107	35.7
	Total number of observations, N		300	100.0

Appendix C.3. Utility and Probability Functions and Calculation Results for Evacuation Decision

UTILITY			PROBABILITY				HOUSEHOLD EVACUATION DECISION (1 indicates the decision)		
Partial	Full	No evac (basis of estimation)	Partial	Full	No evac	Total	Full	Partial	No evac
0.9	-0.44	0	0.599	0.157	0.244	1	1	0	0
-0.738	-0.056	0	0.197	0.390	0.413	1	0	0	1
1.235	1.348	0	0.415	0.464	0.121	1	0	1	0
0.279	-0.256	0	0.427	0.250	0.323	1	1	0	0
-0.81	-1.468	0	0.266	0.138	0.597	1	0	0	1
-3.748	-5.323	0	0.023	0.005	0.972	1	0	0	1
1.84	2.321	0	0.360	0.583	0.057	1	0	1	0
0.326	1.623	0	0.186	0.680	0.134	1	0	1	0
1.465	0.796	0	0.574	0.294	0.133	1	1	0	0
0.651	0.593	0	0.406	0.383	0.212	1	1	0	0
1.385	2.298	0	0.267	0.666	0.067	1	0	1	0
-1.237	-1.72	0	0.198	0.122	0.681	1	0	0	1
1.522	1.965	0	0.360	0.561	0.079	1	0	1	0
-1.123	-0.936	0	0.189	0.228	0.582	1	0	0	1
-1.981	-1.382	0	0.099	0.181	0.720	1	0	0	1
-2.951	-3.742	0	0.049	0.022	0.929	1	0	0	1
1.218	0.566	0	0.550	0.287	0.163	1	1	0	0
1.559	1.52	0	0.460	0.443	0.097	1	1	0	0

UTILITY			PROBABILITY				HOUSEHOLD EVACUATION DECISION (1 indicates the decision)		
Partial	**Full**	**No evac (basis of estimation)**	**Partial**	**Full**	**No evac**	**Total**	**Full**	**Partial**	**No evac**
1.069	2.4	0	0.195	0.738	0.067	1	0	1	0
-0.929	-2.059	0	0.259	0.084	0.657	1	0	0	1
2.785	1.219	0	0.787	0.164	0.049	1	1	0	0
2.076	1.098	0	0.666	0.250	0.084	1	1	0	0
1.9	3.237	0	0.202	0.768	0.030	1	0	1	0
-0.984	-1.844	0	0.244	0.103	0.653	1	0	0	1
1.318	1.367	0	0.431	0.453	0.115	1	0	1	0
0.036	-1.207	0	0.444	0.128	0.428	1	1	0	0
-2.2	-1.781	0	0.087	0.132	0.782	1	0	0	1
1.167	1.372	0	0.394	0.484	0.123	1	0	1	0
1.156	0.766	0	0.502	0.340	0.158	1	1	0	0
-0.531	-1.561	0	0.327	0.117	0.556	1	0	0	1
-3.307	-4.964	0	0.035	0.007	0.958	1	0	0	1
0.227	-0.164	0	0.404	0.273	0.322	1	1	0	0
-3.043	-3.387	0	0.044	0.031	0.925	1	0	0	1
3.082	2.693	0	0.580	0.393	0.027	1	1	0	0
2.036	1.114	0	0.654	0.260	0.085	1	1	0	0
-1.929	-3.304	0	0.123	0.031	0.846	1	0	0	1
-1.124	-1.695	0	0.215	0.122	0.663	1	0	0	1
3.412	4.195	0	0.310	0.679	0.010	1	0	1	0
1.495	1.018	0	0.542	0.336	0.122	1	1	0	0
1.119	-0.041	0	0.610	0.191	0.199	1	1	0	0

UTILITY			PROBABILITY				HOUSEHOLD EVACUATION DECISION (1 indicates the decision)		
Partial	**Full**	**No evac (basis of estimation)**	**Partial**	**Full**	**No evac**	**Total**	**Full**	**Partial**	**No evac**
-1.76	-2.896	0	0.140	0.045	0.815	1	0	0	1
0.603	-0.17	0	0.498	0.230	0.272	1	1	0	0
-0.323	0.231	0	0.243	0.422	0.335	1	0	1	0
0.947	0.751	0	0.453	0.372	0.176	1	1	0	0
2.753	2.418	0	0.562	0.402	0.036	1	1	0	0
-0.091	-0.52	0	0.364	0.237	0.399	1	0	0	1
1.039	-0.856	0	0.665	0.100	0.235	1	1	0	0
-1.155	-2.053	0	0.218	0.089	0.693	1	0	0	1
1.502	2.668	0	0.226	0.724	0.050	1	0	1	0
-1.397	-1.426	0	0.166	0.162	0.672	1	0	0	1
-1.94	-2.354	0	0.116	0.077	0.807	1	0	0	1
1.604	2.697	0	0.239	0.713	0.048	1	0	1	0
-2.35	-2.731	0	0.082	0.056	0.862	1	0	0	1
-3.097	-3.341	0	0.042	0.033	0.925	1	0	0	1
-2.711	-4.707	0	0.062	0.008	0.930	1	0	0	1
-1.935	-1.223	0	0.100	0.205	0.695	1	0	0	1
1.323	2.498	0	0.222	0.719	0.059	1	0	1	0
-2.314	-4.591	0	0.089	0.009	0.902	1	0	0	1
-2.864	-3.217	0	0.052	0.037	0.911	1	0	0	1
2.698	4.105	0	0.194	0.793	0.013	1	0	1	0
0.886	0.634	0	0.457	0.355	0.188	1	1	0	0
1.682	2.618	0	0.268	0.683	0.050	1	0	1	0

UTILITY			PROBABILITY				HOUSEHOLD EVACUATION DECISION (1 indicates the decision)		
Partial	**Full**	**No evac (basis of estimation)**	**Partial**	**Full**	**No evac**	**Total**	**Full**	**Partial**	**No evac**
2.43	2.026	0	0.570	0.380	0.050	1	1	0	0
3.626	4.003	0	0.402	0.587	0.011	1	0	1	0
-2.217	-2.836	0	0.093	0.050	0.856	1	0	0	1
1.199	2.113	0	0.263	0.657	0.079	1	0	1	0
-1.344	-1.251	0	0.169	0.185	0.646	1	0	0	1
0.154	1.162	0	0.218	0.596	0.186	1	0	1	0
1.764	0.917	0	0.625	0.268	0.107	1	1	0	0
-0.697	0.31	0	0.174	0.476	0.349	1	0	1	0
0.403	0.129	0	0.412	0.313	0.275	1	1	0	0
-0.312	-0.72	0	0.330	0.219	0.451	1	0	0	1
2.101	2.128	0	0.465	0.478	0.057	1	0	1	0
2.6	3.908	0	0.210	0.775	0.016	1	0	1	0
0.323	1.324	0	0.225	0.612	0.163	1	0	1	0
-0.061	-0.675	0	0.384	0.208	0.408	1	0	0	1
-1.808	-2.123	0	0.128	0.093	0.779	1	0	0	1
-0.619	-1.374	0	0.301	0.141	0.558	1	0	0	1
-0.405	-1.566	0	0.356	0.111	0.533	1	0	0	1
-0.532	-1.943	0	0.339	0.083	0.578	1	0	0	1
-1.984	-3.089	0	0.116	0.038	0.845	1	0	0	1
-0.66	-1.74	0	0.305	0.104	0.591	1	0	0	1
-0.793	-1.75	0	0.278	0.107	0.615	1	0	0	1
-0.396	-0.961	0	0.327	0.186	0.486	1	0	0	1

UTILITY			PROBABILITY				HOUSEHOLD EVACUATION DECISION (1 indicates the decision)		
Partial	**Full**	**No evac (basis of estimation)**	**Partial**	**Full**	**No evac**	**Total**	**Full**	**Partial**	**No evac**
-0.679	-1.373	0	0.288	0.144	0.568	1	0	0	1
2.082	2.611	0	0.354	0.601	0.044	1	0	1	0
-1.027	-1.162	0	0.214	0.187	0.598	1	0	0	1
0.762	-0.244	0	0.546	0.200	0.255	1	1	0	0
1.6	1.886	0	0.395	0.526	0.080	1	0	1	0
-1.417	-2.734	0	0.185	0.050	0.765	1	0	0	1
-0.568	-2.516	0	0.344	0.049	0.607	1	0	0	1
-2.243	-2.063	0	0.086	0.103	0.811	1	0	0	1
2.852	3.244	0	0.394	0.583	0.023	1	0	1	0
-0.837	-2.415	0	0.284	0.059	0.657	1	0	0	1
2.517	2.551	0	0.473	0.489	0.038	1	0	1	0
3.361	4.916	0	0.173	0.821	0.006	1	0	1	0
-2.561	-3.757	0	0.070	0.021	0.909	1	0	0	1
0.032	0.201	0	0.317	0.376	0.307	1	0	1	0
-2.34	-3.818	0	0.086	0.020	0.894	1	0	0	1
0.986	-0.051	0	0.579	0.205	0.216	1	1	0	0
-0.231	-0.125	0	0.297	0.330	0.374	1	0	0	**1**
-0.046	-1.562	0	0.441	0.097	0.462	1	0	0	1
-4.493	-6.017	0	0.011	0.002	0.987	1	0	0	1
-2.684	-2.423	0	0.059	0.077	0.864	1	0	0	1
-0.63	-0.916	0	0.276	0.207	0.517	1	0	0	1
0.765	0.126	0	0.502	0.265	0.233	1	1	0	0

UTILITY			PROBABILITY				HOUSEHOLD EVACUATION DECISION (1 indicates the decision)		
Partial	**Full**	**No evac (basis of estimation)**	**Partial**	**Full**	**No evac**	**Total**	**Full**	**Partial**	**No evac**
-2.503	-2.336	0	0.069	0.082	0.848	1	0	0	1
2.809	2.585	0	0.538	0.430	0.032	1	1	0	0
2.259	2.864	0	0.341	0.624	0.036	1	0	1	0
0.998	1.095	0	0.405	0.446	0.149	1	0	1	0
-0.984	-1.844	0	0.244	0.103	0.653	1	0	0	1
2.368	2.226	0	0.510	0.442	0.048	1	1	0	0
-0.903	0.288	0	0.148	0.487	0.365	1	0	1	0
0.535	2.014	0	0.167	0.735	0.098	1	0	1	0
-2.238	-2.27	0	0.088	0.085	0.826	1	0	0	1
-1.868	-3.101	0	0.129	0.038	0.834	1	0	0	1
-2.299	-3.452	0	0.089	0.028	0.883	1	0	0	1
-2.973	-4.051	0	0.048	0.016	0.936	1	0	0	1
1.926	2.088	0	0.431	0.506	0.063	1	0	1	0
0.956	1.441	0	0.332	0.540	0.128	1	0	1	0
0.905	1.786	0	0.262	0.632	0.106	1	0	1	0
0.7	0.333	0	0.457	0.316	0.227	1	1	0	0
-2.376	-2.074	0	0.076	0.103	0.821	1	0	0	1
0.988	-0.135	0	0.589	0.192	0.219	1	1	0	0
-1.099	-2.002	0	0.227	0.092	0.681	1	0	0	1
-1.569	-3.897	0	0.170	0.017	0.814	1	0	0	1
3.192	3.659	0	0.379	0.605	0.016	1	0	1	0
-2.593	-3.403	0	0.068	0.030	0.902	1	0	0	1

UTILITY			PROBABILITY				HOUSEHOLD EVACUATION DECISION (1 indicates the decision)		
Partial	**Full**	**No evac (basis of estimation)**	**Partial**	**Full**	**No evac**	**Total**	**Full**	**Partial**	**No evac**
2.041	2.245	0	0.424	0.520	0.055	1	0	1	0
2.164	3.342	0	0.229	0.744	0.026	1	0	1	0
1.819	2.642	0	0.291	0.662	0.047	1	0	1	0
-0.023	0.793	0	0.233	0.528	0.239	1	0	1	0
-1.072	-0.969	0	0.199	0.220	0.581	1	0	0	1
-0.688	-1.402	0	0.287	0.141	0.572	1	0	0	1
-3.061	-2.769	0	0.042	0.057	0.901	1	0	0	1
-2.932	-3.685	0	0.049	0.023	0.927	1	0	0	1
-1.661	-1.225	0	0.128	0.198	0.674	1	0	0	1
0.658	0.68	0	0.394	0.402	0.204	1	0	1	0
-4.108	-4.73	0	0.016	0.009	0.975	1	0	0	1
-0.281	-0.116	0	0.285	0.337	0.378	1	0	0	1
0.685	1.25	0	0.306	0.539	0.154	1	0	1	0
-2.49	-2.452	0	0.071	0.074	0.855	1	0	0	1
0.365	-0.36	0	0.459	0.222	0.319	1	1	0	0
-2.079	-1.852	0	0.098	0.122	0.780	1	0	0	1
-1.787	-2.506	0	0.134	0.065	0.801	1	0	0	1
2.753	2.418	0	0.562	0.402	0.036	1	1	0	0
-0.273	-0.271	0	0.302	0.302	0.396	1	0	0	1
-3.886	-5.127	0	0.020	0.006	0.974	1	0	0	1
0.242	0.975	0	0.259	0.538	0.203	1	0	1	0
0.244	1.268	0	0.219	0.610	0.172	1	0	1	0

UTILITY			PROBABILITY				HOUSEHOLD EVACUATION DECISION (1 indicates the decision)		
Partial	Full	No evac (basis of estimation)	Partial	Full	No evac	Total	Full	Partial	No evac
-0.948	-1.272	0	0.232	0.168	0.600	1	0	0	1
-1.261	-2.211	0	0.203	0.079	0.718	1	0	0	1
1.136	1.993	0	0.272	0.641	0.087	1	0	1	0
3.056	2.128	0	0.693	0.274	0.033	1	1	0	0
-1.523	-1.336	0	0.147	0.178	0.675	1	0	0	1
-1.926	-0.995	0	0.096	0.244	0.660	1	0	0	1
0.356	-1.652	0	0.545	0.073	0.382	1	1	0	0
-0.752	-1.385	0	0.274	0.145	0.581	1	0	0	1
1.168	1.067	0	0.451	0.408	0.140	1	1	0	0
-0.543	-1.485	0	0.321	0.125	0.553	1	0	0	1
1.471	1.622	0	0.418	0.486	0.096	1	0	1	0
-1.031	-1.291	0	0.219	0.169	0.613	1	0	0	1
2.805	3.305	0	0.369	0.609	0.022	1	0	1	0
-2.592	-4.115	0	0.069	0.015	0.916	1	0	0	1
-0.326	0.268	0	0.238	0.432	0.330	1	0	1	0
-1.482	-0.97	0	0.141	0.236	0.623	1	0	0	1
0.118	0.589	0	0.287	0.459	0.255	1	0	1	0
0.711	1.815	0	0.222	0.669	0.109	1	0	1	0
0.13	-1.761	0	0.493	0.074	0.433	1	1	0	0
1.429	1.561	0	0.420	0.479	0.101	1	0	1	0
-0.875	-2.482	0	0.278	0.056	0.666	1	0	0	1
-2.079	-2.917	0	0.106	0.046	0.848	1	0	0	1

UTILITY			PROBABILITY				HOUSEHOLD EVACUATION DECISION (1 indicates the decision)		
Partial	**Full**	**No evac (basis of estimation)**	**Partial**	**Full**	**No evac**	**Total**	**Full**	**Partial**	**No evac**
-2.572	-3.183	0	0.068	0.037	0.895	1	0	0	1
-0.543	0.947	0	0.140	0.620	0.240	1	0	1	0
1.762	1.001	0	0.610	0.285	0.105	1	0	0	0
2.467	3.897	0	0.190	0.794	0.016	1	0	1	0
1.701	1.758	0	0.446	0.472	0.081	1	0	1	0
2.288	3.728	0	0.188	0.793	0.019	1	0	1	0
2.395	3.173	0	0.306	0.666	0.028	1	0	1	0
1.701	2.135	0	0.367	0.566	0.067	1	0	1	0
-2.952	-3.522	0	0.048	0.027	0.924	1	0	0	1
1.115	0.4	0	0.550	0.269	0.180	1	1	0	0
-1.278	-0.834	0	0.163	0.254	0.584	1	0	0	1
-1.805	-2.919	0	0.135	0.044	0.821	1	0	0	1
1.136	0.899	0	0.474	0.374	0.152	1	1	0	0
-1.068	-0.463	0	0.174	0.319	0.507	1	0	0	1
-3.07	-2.394	0	0.041	0.080	0.879	1	0	0	1
2.05	1.785	0	0.527	0.405	0.068	1	1	0	0
-0.532	0.216	0	0.208	0.439	0.354	1	0	1	0
-0.532	-0.879	0	0.293	0.207	0.499	1	0	0	1
-2.156	-1.538	0	0.087	0.161	0.752	1	0	0	1
-1.472	-2.142	0	0.170	0.087	0.742	1	0	0	1
-0.753	0.173	0	0.177	0.447	0.376	1	0	1	0
-2.357	-2.441	0	0.080	0.074	0.846	1	0	0	1

UTILITY			PROBABILITY				HOUSEHOLD EVACUATION DECISION (1 indicates the decision)		
Partial	**Full**	**No evac (basis of estimation)**	**Partial**	**Full**	**No evac**	**Total**	**Full**	**Partial**	**No evac**
3.031	3.414	0	0.398	0.583	0.019	1	0	1	0
-0.764	-1.685	0	0.282	0.112	0.606	1	0	0	1
-1.913	-2.501	0	0.120	0.067	0.813	1	0	0	1
-2.614	-3.931	0	0.067	0.018	0.915	1	0	0	1
-0.421	-0.052	0	0.252	0.364	0.384	1	0	0	1
4.52	5.022	0	0.376	0.620	0.004	1	0	1	0
-2.937	-4.816	0	0.050	0.008	0.942	1	0	0	1
-3.044	-4.146	0	0.045	0.015	0.940	1	0	0	1
-3.405	-3.69	0	0.031	0.024	0.945	1	0	0	1
-1.473	-1.807	0	0.165	0.118	0.718	1	0	0	1
1.356	1.55	0	0.405	0.491	0.104	1	0	1	0
1.012	1.608	0	0.315	0.571	0.114	1	0	1	0
1.921	2.294	0	0.385	0.559	0.056	1	0	1	0
-2.425	-3.754	0	0.080	0.021	0.899	1	0	0	1
-2.007	-1.947	0	0.105	0.112	0.783	1	0	0	1
1.783	2.49	0	0.313	0.635	0.053	1	0	1	0
0.557	0.766	0	0.356	0.439	0.204	1	0	1	0
-0.765	0.092	0	0.182	0.428	0.390	1	0	1	0
1.582	1.543	0	0.461	0.444	0.095	1	1	0	0
0.544	1.147	0	0.293	0.536	0.170	1	0	1	0
0.645	-0.516	0	0.544	0.170	0.285	1	1	0	0
0.028	0.102	0	0.328	0.353	0.319	1	0	1	0

UTILITY			**PROBABILITY**				**HOUSEHOLD EVACUATION DECISION (1 indicates the decision)**		
Partial	**Full**	**No evac (basis of estimation)**	**Partial**	**Full**	**No evac**	**Total**	**Full**	**Partial**	**No evac**
3.427	3.996	0	0.357	0.631	0.012	1	0	1	0
0.047	0.379	0	0.299	0.416	0.285	1	0	1	0
1.881	2.687	0	0.295	0.660	0.045	1	0	1	0
-3.075	-4.62	0	0.044	0.009	0.947	1	0	0	1
0.916	0.363	0	0.506	0.291	0.203	1	1	0	0
-0.326	-0.827	0	0.334	0.203	0.463	1	0	0	1
0.412	-0.148	0	0.448	0.256	0.297	1	1	0	0
2.861	3.472	0	0.345	0.635	0.020	1	0	1	0
1.403	1.374	0	0.451	0.438	0.111	1	1	0	0
0.038	-0.226	0	0.366	0.281	0.353	1	1	0	0
3.68	3.957	0	0.427	0.563	0.011	1	0	1	0
0.067	0.216	0	0.323	0.375	0.302	1	0	1	0
1.012	0.514	0	0.507	0.308	0.184	1	1	0	0
1.788	2.66	0	0.281	0.672	0.047	1	0	1	0
-1.431	-1.661	0	0.167	0.133	0.700	1	0	0	1
2.481	3.316	0	0.295	0.680	0.025	1	0	1	0
-0.476	-1.776	0	0.347	0.095	0.558	1	0	0	1
2.065	3.988	0	0.125	0.859	0.016	1	0	1	0
-1.636	-2.511	0	0.153	0.064	0.784	1	0	0	1
1.73	1.355	0	0.536	0.369	0.095	1	1	0	0
-1.844	-2.61	0	0.128	0.060	0.812	1	0	0	1
0.171	-1.395	0	0.487	0.102	0.411	1	1	0	0

UTILITY			PROBABILITY				HOUSEHOLD EVACUATION DECISION (1 indicates the decision)		
Partial	**Full**	**No evac (basis of estimation)**	**Partial**	**Full**	**No evac**	**Total**	**Full**	**Partial**	**No evac**
-1.663	-1.026	0	0.122	0.232	0.646	1	0	0	1
-0.749	-2.602	0	0.306	0.048	0.646	1	0	0	1
-1.984	-3.089	0	0.116	0.038	0.845	1	0	0	1
-0.396	-1.368	0	0.349	0.132	0.519	1	0	0	1
-1.288	-2.064	0	0.197	0.090	0.713	1	0	0	1
0.464	0.332	0	0.399	0.350	0.251	1	1	0	0
-0.226	-1.426	0	0.391	0.118	0.491	1	0	0	1
-2.947	-4.708	0	0.049	0.008	0.942	1	0	0	1
2.144	2.41	0	0.413	0.539	0.048	1	0	1	0
-0.647	-1.036	0	0.279	0.189	0.532	1	0	0	1
0.171	0.764	0	0.274	0.495	0.231	1	0	1	0
1.854	1.74	0	0.488	0.435	0.076	1	1	0	0
-2.309	-3.46	0	0.088	0.028	0.884	1	0	0	1
-2.027	-2.879	0	0.111	0.047	0.842	1	0	0	1
0.983	0.072	0	0.563	0.226	0.211	1	1	0	0
0.865	0.105	0	0.529	0.248	0.223	1	1	0	0
-0.035	-0.08	0	0.334	0.320	0.346	1	0	0	1
-3.579	-4.066	0	0.027	0.016	0.957	1	0	0	1
-2.67	-1.909	0	0.057	0.122	0.821	1	0	0	1
-0.338	-1.972	0	0.385	0.075	0.540	1	0	0	1
-1.679	-2.547	0	0.147	0.062	0.791	1	0	0	1
-0.973	-0.363	0	0.182	0.335	0.482	1	0	0	1

UTILITY			PROBABILITY				HOUSEHOLD EVACUATION DECISION (1 indicates the decision)		
Partial	**Full**	**No evac (basis of estimation)**	**Partial**	**Full**	**No evac**	**Total**	**Full**	**Partial**	**No evac**
-2.078	-2.158	0	0.101	0.093	0.806	1	0	0	1
-2.823	-4.323	0	0.055	0.012	0.932	1	0	0	1
0.12	0.506	0	0.298	0.438	0.264	1	0	1	0
2.682	3.302	0	0.342	0.635	0.023	1	0	1	0
1.942	2.89	0	0.269	0.693	0.039	1	0	1	0
0.998	2.189	0	0.215	0.706	0.079	1	0	1	0
-1.376	-2.368	0	0.188	0.070	0.743	1	0	0	1
2.092	2.618	0	0.355	0.601	0.044	1	0	1	0
-0.599	-0.442	0	0.251	0.293	0.456	1	0	0	1
0.598	1.101	0	0.312	0.516	0.172	1	0	1	0
0.807	2.211	0	0.181	0.738	0.081	1	0	1	0
-2.187	-1.897	0	0.089	0.119	0.792	1	0	1	1
-0.23	0.012	0	0.283	0.361	0.356	1	0	1	0
-0.487	0.019	0	0.233	0.387	0.380	1	0	1	0
1.264	1.905	0	0.314	0.597	0.089	1	0	1	0
0.494	1.648	0	0.209	0.663	0.128	1	0	1	0
0.742	1.354	0	0.301	0.555	0.143	1	0	1	0
0.309	-0.527	0	0.461	0.200	0.339	1	1	0	0
-2.517	-3.399	0	0.072	0.030	0.898	1	0	0	1
-1.334	-2.223	0	0.192	0.079	0.729	1	0	0	1
-1.401	-0.837	0	0.147	0.258	0.595	1	0	0	1
0.104	0.076	0	0.348	0.338	0.314	1	1	0	0

UTILITY			PROBABILITY				HOUSEHOLD EVACUATION DECISION (1 indicates the decision)		
Partial	Full	No evac (basis of estimation)	Partial	Full	No evac	Total	Full	Partial	No evac
-2.624	-2.844	0	0.064	0.051	0.884	1	0	0	1
2.239	1.932	0	0.543	0.399	0.058	1	1	0	0
3.018	3.283	0	0.425	0.554	0.021	1	0	1	0
2.753	3.513	0	0.312	0.668	0.020	1	0	1	0
1.347	1.925	0	0.329	0.586	0.085	1	0	1	0
2.544	3.498	0	0.272	0.706	0.021	1	0	1	0
-0.84	-0.625	0	0.219	0.272	0.508	1	0	0	1
2.424	1.675	0	0.640	0.303	0.057	1	1	0	0
-1.719	-2.53	0	0.142	0.063	0.794	1	0	0	1
1.862	2.075	0	0.418	0.517	0.065	1	0	1	0
-3.235	-3.145	0	0.036	0.040	0.924	1	0	0	1
1.323	2.498	0	0.222	0.719	0.059	1	0	1	0
0.098	-0.342	0	0.392	0.252	0.355	1	1	0	0
1.09	0.434	0	0.539	0.280	0.181	1	1	0	0
-0.106	-0.291	0	0.340	0.282	0.378	1	0	0	1
2.876	3.516	0	0.339	0.642	0.019	1	0	1	0
-1.261	-2.211	0	0.203	0.079	0.718	1	0	0	1
2.2	2.577	0	0.389	0.568	0.043	1	0	1	0
						TOTAL	**58**	**102**	**140**

Utility and Probability results above were calculated using the models estimated as follows:

Utility function for full evacuation decision (from Table 4.3):

ED_{fullih}= 3.127 – 1.139 GEN_{ih} – 0.196 $EDUC_{ih}$ + 0.287 $CHILD_{ih}$ – 0.555 $YLIVE_{ih}$ + 1.219 $HOWN_{ih}$ – 3.237 $FLOOR_{ih}$ – 1.052 $HMAT_{ih}$ + 0.366 $DIST_{ih}$ + 1.595 DAM_{ih} + 0.498 $SWARN_{ih}$

Utility function for full evacuation decision (from Table 4.4):

ED_{partih}= 1.654 – 1.367 GEN_{ih} + 0.138 $EDUC_{ih}$ + 0.812 $CHILD_{ih}$ – 0.303 $YLIVE_{ih}$ + 0.832 $HOWN_{ih}$ – 2.470 $FLOOR_{ih}$ – 0.776 $HMAT_{ih}$ + 0.041 $DIST_{ih}$ + 1.006 DAM_{ih} + 0.883 $SWARN_{ih}$

Probability function for full evacuation decision:

$$P_{fullih} = \frac{e(ED_{fullih})}{\sum_i^j e\,(ED_{ih})}$$

Probability function for partial evacuation decision:

$$P_{partih} = \frac{e(ED_{partih})}{\sum_i^j e\,(ED_{ih})}$$

Probability function for no evacuation decision:

$$P_{partih} = \frac{e(0)}{\sum_i^j e\,(ED_{ih})}$$

From Results in Appendix C.3 Above:

Percent households to fully evacuate = 58/300 = 19.3%
Percent households to partially evacuate = 102/300 = 34.0%
Percent households that will not evacuate = 140/300 = 46.7%

Appendix C.4. Utility and Probability Functions and Calculation Results for Departure Timing

Utility		Probability			Household Departure Timing (1 indicates decision)	
During flood	**Before flood**	**During flood**	**Before flood**	**Total**	**Evacuate During flood**	**Evacuate Before flood**
0.761	0	0.682	0.318	1	1	0
0.144	0	0.536	0.464	1	1	0
-0.352	0	0.413	0.587	1	0	1
0.115	0	0.529	0.471	1	1	0
-0.998	0	0.269	0.731	1	0	1
1.532	0	0.822	0.178	1	1	0
0.687	0	0.665	0.335	1	1	0
-0.352	0	0.413	0.587	1	0	1
1.161	0	0.762	0.238	1	1	0
-0.197	0	0.451	0.549	1	0	1
0.115	0	0.529	0.471	1	1	0
-0.256	0	0.436	0.564	1	0	1
0.886	0	0.708	0.292	1	1	0
-0.055	0	0.486	0.514	1	0	1
-0.701	0	0.332	0.668	1	0	1
0.412	0	0.602	0.398	1	1	0
1.041	0	0.739	0.261	1	1	0
0.687	0	0.665	0.335	1	1	0
-0.101	0	0.475	0.525	1	0	1
-0.359	0	0.411	0.589	1	0	1

Utility		Probability			Household Departure Timing (1 indicates decision)	
During flood	Before flood	During flood	Before flood	Total	Evacuate During flood	Evacuate Before flood
0.419	0	0.603	0.397	1	1	0
0.412	0	0.602	0.398	1	1	0
-0.826	0	0.304	0.696	1	0	1
1.161	0	0.762	0.238	1	1	0
0.761	0	0.682	0.318	1	1	0
1.515	0	0.820	0.180	1	1	0
-0.998	0	0.269	0.731	1	0	1
0.67	0	0.662	0.338	1	1	0
1.058	0	0.742	0.258	1	1	0
1.532	0	0.822	0.178	1	1	0
0.144	0	0.536	0.464	1	1	0
0.419	0	0.603	0.397	1	1	0
-0.256	0	0.436	0.564	1	0	1
-0.33	0	0.418	0.582	1	0	1
-0.826	0	0.304	0.696	1	0	1
-0.701	0	0.332	0.668	1	0	1
0.79	0	0.688	0.312	1	1	0
-0.73	0	0.325	0.675	1	0	1
-0.33	0	0.418	0.582	1	0	1
-0.352	0	0.413	0.587	1	0	1
-0.359	0	0.411	0.589	1	0	1
0.316	0	0.578	0.422	1	1	0
-0.455	0	0.388	0.612	1	0	1

Utility		Probability			Household Departure Timing (1 indicates decision)	
During flood	**Before flood**	**During flood**	**Before flood**	**Total**	**Evacuate During flood**	**Evacuate Before flood**
0.39	0	0.596	0.404	1	1	0
-0.826	0	0.304	0.696	1	0	1
-0.055	0	0.486	0.514	1	0	1
-0.33	0	0.418	0.582	1	0	1
1.532	0	0.822	0.178	1	1	0
-0.256	0	0.436	0.564	1	0	1
0.144	0	0.536	0.464	1	1	0
-0.33	0	0.418	0.582	1	0	1
-0.998	0	0.269	0.731	1	0	1
0.019	0	0.505	0.495	1	1	0
-0.256	0	0.436	0.564	1	0	1
0.687	0	0.665	0.335	1	1	0
0.744	0	0.678	0.322	1	1	0
1.687	0	0.844	0.156	1	1	0
0.916	0	0.714	0.286	1	1	0
0.744	0	0.678	0.322	1	1	0
0.574	0	0.640	0.360	1	1	0
0.373	0	0.592	0.408	1	1	0
-0.101	0	0.475	0.525	1	0	1
1.316	0	0.789	0.211	1	1	0
0.945	0	0.720	0.280	1	1	0
1.687	0	0.844	0.156	1	1	0
-0.101	0	0.475	0.525	1	0	1

Utility		Probability			Household Departure Timing (1 indicates decision)	
During flood	**Before flood**	**During flood**	**Before flood**	**Total**	**Evacuate During flood**	**Evacuate Before flood**
1.041	0	0.739	0.261	1	1	0
2.161	0	0.897	0.103	1	1	0
0.174	0	0.543	0.457	1	1	0
0.39	0	0.596	0.404	1	1	0
0.019	0	0.505	0.495	1	1	0
0.574	0	0.640	0.360	1	1	0
0.545	0	0.633	0.367	1	1	0
0.002	0	0.500	0.500	1	1	0
0.648	0	0.657	0.343	1	1	0
-0.359	0	0.411	0.589	1	0	1
0.27	0	0.567	0.433	1	1	0
-0.455	0	0.388	0.612	1	0	1
0.545	0	0.633	0.367	1	1	0
1.532	0	0.822	0.178	1	1	0
2.161	0	0.897	0.103	1	1	0
0.545	0	0.633	0.367	1	1	0
1.019	0	0.735	0.265	1	1	0
1.532	0	0.822	0.178	1	1	0
-0.072	0	0.482	0.518	1	0	1
1.041	0	0.739	0.261	1	1	0
0.373	0	0.592	0.408	1	1	0
1.048	0	0.740	0.260	1	1	0
0.545	0	0.633	0.367	1	1	0

Utility		Probability			Household Departure Timing (1 indicates decision)	
During flood	Before flood	During flood	Before flood	Total	Evacuate During flood	Evacuate Before flood
-0.084	0	0.479	0.521	1	0	1
1.041	0	0.739	0.261	1	1	0
1.019	0	0.735	0.265	1	1	0
0.373	0	0.592	0.408	1	1	0
1.048	0	0.740	0.260	1	1	0
0.174	0	0.543	0.457	1	1	0
1.316	0	0.789	0.211	1	1	0
-0.701	0	0.332	0.668	1	0	1
0.402	0	0.599	0.401	1	1	0
-0.084	0	0.479	0.521	1	0	1
-0.369	0	0.409	0.591	1	0	1
0.648	0	0.657	0.343	1	1	0
0.648	0	0.657	0.343	1	1	0
0.67	0	0.662	0.338	1	1	0
1.419	0	0.805	0.195	1	1	0
0.174	0	0.543	0.457	1	1	0
-0.072	0	0.482	0.518	1	0	1
1.687	0	0.844	0.156	1	1	0
0.174	0	0.543	0.457	1	1	0
0.945	0	0.720	0.280	1	1	0
1.019	0	0.735	0.265	1	1	0
0.545	0	0.633	0.367	1	1	0
-0.101	0	0.475	0.525	1	0	1

Utility		Probability			Household Departure Timing (1 indicates decision)	
During flood	**Before flood**	**During flood**	**Before flood**	**Total**	**Evacuate During flood**	**Evacuate Before flood**
2.161	0	0.897	0.103	1	1	0
1.019	0	0.735	0.265	1	1	0
0.174	0	0.543	0.457	1	1	0
0.402	0	0.599	0.401	1	1	0
0.27	0	0.567	0.433	1	1	0
0.687	0	0.665	0.335	1	1	0
-0.472	0	0.384	0.616	1	0	1
1.515	0	0.820	0.180	1	1	0
0.916	0	0.714	0.286	1	1	0
0.761	0	0.682	0.318	1	1	0
0.27	0	0.567	0.433	1	1	0
1.058	0	0.742	0.258	1	1	0
1.019	0	0.735	0.265	1	1	0
-0.826	0	0.304	0.696	1	0	1
1.79	0	0.857	0.143	1	1	0
0.545	0	0.633	0.367	1	1	0
0.277	0	0.569	0.431	1	1	0
0.773	0	0.684	0.316	1	1	0
-0.369	0	0.409	0.591	1	0	1
-0.072	0	0.482	0.518	1	0	1
0.174	0	0.543	0.457	1	1	0
1.019	0	0.735	0.265	1	1	0
1.144	0	0.758	0.242	1	1	0

Utility		Probability			Household Departure Timing (1 indicates decision)	
During flood	**Before flood**	**During flood**	**Before flood**	**Total**	**Evacuate During flood**	**Evacuate Before flood**
1.687	0	0.844	0.156	1	1	0
0.277	0	0.569	0.431	1	1	0
0.299	0	0.574	0.426	1	1	0
0.27	0	0.567	0.433	1	1	0
1.515	0	0.820	0.180	1	1	0
1.019	0	0.735	0.265	1	1	0
1.144	0	0.758	0.242	1	1	0
-0.369	0	0.409	0.591	1	0	1
-0.084	0	0.479	0.521	1	0	1
-0.472	0	0.384	0.616	1	0	1
-0.072	0	0.482	0.518	1	0	1
1.048	0	0.740	0.260	1	1	0
1.316	0	0.789	0.211	1	1	0
				TOTAL	**102**	**46**

Utility and Probability results above were calculated using the models estimated as follows:

Utility function for departure timing during flood (from Table 5.3):

$TDEC_{dih} = 0.852 - 0.474\ TWORK_{ih} - 0.646\ HOWN_{ih} + 0.629\ FLOOR_{ih} - 0.371\ DIST_{ih} + 0.771\ FLEVEL_{ih}$

Probability function for departure timing during flood:

$$P_{beforeih} = \frac{e(TDEC_{dih})}{\sum_i^j e(TDEC_{ih})}$$

Probability function for departure timing before flood:

$$P_{partih} = \frac{e(0)}{\sum_i^j e\,(TDEC_{ih})}$$

From Results in Appendix C.4 Above:

Percent households to evacuate during flood = *102/148 = 68.9%*
Percent households to evacuate before flood = *68/148 = 31.1%*

Appendix C.5. Utility and Probability Functions and Calculation Results for Destination

Utility			Probability				Household Destination Choice (1 indicates decision)		
Public shelter	**Church/ seminaries**	**Friends/ relatives**	**Public shelters**	**Church/ seminaries**	**Friends/ relatives**	**Total**	**Public shelters**	**Church/ seminaries**	**Friends/ families**
3.299	1.452	0	0.837	0.132	0.031	1	1	0	0
4.897	3.366	0	0.817	0.177	0.006	1	1	0	0
5.917	4.096	0	0.859	0.139	0.002	1	1	0	0
3.864	1.314	0	0.910	0.071	0.019	1	1	0	0
3.781	1.518	0	0.887	0.092	0.020	1	1	0	0
2.243	1.668	0	0.599	0.337	0.064	1	1	0	0
1.471	-0.432	0	0.725	0.108	0.167	1	1	0	0
5.082	3.744	0	0.788	0.207	0.005	1	1	0	0
4.432	1.337	0	0.946	0.043	0.011	1	1	0	0
6.03	3.251	0	0.939	0.058	0.002	1	1	0	0
2.577	0.255	0	0.852	0.084	0.065	1	1	0	0
2.308	-0.077	0	0.839	0.077	0.083	1	1	0	0
1.609	0.82	0	0.604	0.275	0.121	1	1	0	0
5.725	2.794	0	0.946	0.050	0.003	1	1	0	0
2.766	1.028	0	0.807	0.142	0.051	1	1	0	0
4.893	2.971	0	0.867	0.127	0.006	1	1	0	0
2.933	1.47	0	0.778	0.180	0.041	1	1	0	0
4.624	2.639	0	0.872	0.120	0.009	1	1	0	0
4.79	2.555	0	0.897	0.096	0.007	1	1	0	0
1.801	2.122	0	0.393	0.542	0.065	1	0	1	0
4.853	2.851	0	0.875	0.118	0.007	1	1	0	0

Utility			Probability				Household Destination Choice (1 indicates decision)		
Public shelter	**Church/ seminaries**	**Friends/ relatives**	**Public shelters**	**Church/ seminaries**	**Friends/ relatives**	**Total**	**Public shelters**	**Church/ seminaries**	**Friends/ families**
2.921	0.306	0	0.887	0.065	0.048	1	1	0	0
4.078	0.514	0	0.957	0.027	0.016	1	1	0	0
3.632	0.573	0	0.932	0.044	0.025	1	1	0	0
3.768	1.822	0	0.858	0.123	0.020	1	1	0	0
2.822	2.318	0	0.601	0.363	0.036	1	1	0	0
2.713	0.267	0	0.867	0.075	0.058	1	1	0	0
2.537	0.816	0	0.795	0.142	0.063	1	1	0	0
4.077	2.285	0	0.845	0.141	0.014	1	1	0	0
5.366	3.347	0	0.879	0.117	0.004	1	1	0	0
3.522	1.958	0	0.807	0.169	0.024	1	1	0	0
3.695	0.869	0	0.922	0.055	0.023	1	1	0	0
2.193	0.765	0	0.740	0.177	0.083	1	1	0	0
5.45	2.064	0	0.963	0.033	0.004	1	1	0	0
6.523	3.555	0	0.950	0.049	0.001	1	1	0	0
4.493	1.63	0	0.936	0.053	0.010	1	1	0	0
4.482	2.629	0	0.856	0.134	0.010	1	1	0	0
4.432	1.337	0	0.946	0.043	0.011	1	1	0	0
3.571	2.713	0	0.689	0.292	0.019	1	1	0	0
5.365	1.573	0	0.973	0.022	0.005	1	1	0	0
2.278	1.256	0	0.684	0.246	0.070	1	1	0	0
4.539	2.148	0	0.907	0.083	0.010	1	1	0	0
4.062	3.014	0	0.731	0.256	0.013	1	1	0	0
1.829	0.786	0	0.661	0.233	0.106	1	1	0	0

Utility			Probability				Household Destination Choice (1 indicates decision)		
Public shelter	**Church/ seminaries**	**Friends/ relatives**	**Public shelters**	**Church/ seminaries**	**Friends/ relatives**	**Total**	**Public shelters**	**Church/ seminaries**	**Friends/ families**
4.876	1.275	0	0.966	0.026	0.007	1	1	0	0
4.249	3.395	0	0.694	0.296	0.010	1	1	0	0
4.631	2.882	0	0.845	0.147	0.008	1	1	0	0
3.164	2.366	0	0.670	0.302	0.028	1	1	0	0
4.123	0.874	0	0.948	0.037	0.015	1	1	0	0
5.695	4.127	0	0.825	0.172	0.003	1	1	0	0
1.447	1.299	0	0.477	0.411	0.112	1	1	0	0
1.669	1.268	0	0.538	0.360	0.101	1	1	0	0
2.415	0.734	0	0.784	0.146	0.070	1	1	0	0
2.269	0.329	0	0.802	0.115	0.083	1	1	0	0
3.597	0.985	0	0.908	0.067	0.025	1	1	0	0
5.008	2.129	0	0.941	0.053	0.006	1	1	0	0
2.317	0.85	0	0.752	0.174	0.074	1	1	0	0
4.893	2.971	0	0.867	0.127	0.006	1	1	0	0
2.233	0.204	0	0.807	0.106	0.087	1	1	0	0
1.804	0.354	0	0.715	0.168	0.118	1	1	0	0
3.939	1.033	0	0.931	0.051	0.018	1	1	0	0
2.195	0.768	0	0.740	0.178	0.082	1	1	0	0
3.3	1.989	0	0.765	0.206	0.028	1	1	0	0
5.466	3.234	0	0.900	0.097	0.004	1	1	0	0
3.262	1.861	0	0.778	0.192	0.030	1	1	0	0
2.684	1.066	0	0.790	0.157	0.054	1	1	0	0
1.985	1.963	0	0.473	0.462	0.065	1	1	0	0

Utility			Probability				Household Destination Choice (1 indicates decision)		
Public shelter	**Church/ seminaries**	**Friends/ relatives**	**Public shelters**	**Church/ seminaries**	**Friends/ relatives**	**Total**	**Public shelters**	**Church/ seminaries**	**Friends/ families**
2.098	1.118	0	0.668	0.251	0.082	1	1	0	0
2.073	0.686	0	0.727	0.182	0.091	1	1	0	0
4.125	0.877	0	0.948	0.037	0.015	1	1	0	0
3.571	2.713	0	0.689	0.292	0.019	1	1	0	0
2.506	1.623	0	0.669	0.277	0.055	1	1	0	0
2.823	2.855	0	0.478	0.494	0.028	1	0	1	0
1.582	0.385	0	0.663	0.200	0.136	1	1	0	0
4.899	3.369	0	0.817	0.177	0.006	1	1	0	0
1.607	0.817	0	0.604	0.274	0.121	1	1	0	0
5.253	4.192	0	0.740	0.256	0.004	1	1	0	0
2.906	1.035	0	0.827	0.127	0.045	1	1	0	0
5.721	2.399	0	0.962	0.035	0.003	1	1	0	0
3.127	2.775	0	0.572	0.403	0.025	1	1	0	0
4.224	2.535	0	0.834	0.154	0.012	1	1	0	0
5.242	3.262	0	0.875	0.121	0.005	1	1	0	0
4.788	2.552	0	0.897	0.096	0.007	1	1	0	0
2.329	2.014	0	0.547	0.399	0.053	1	1	0	0
2.997	1.924	0	0.718	0.246	0.036	1	1	0	0
2.241	1.665	0	0.599	0.337	0.064	1	1	0	0
3.464	1.902	0	0.806	0.169	0.025	1	1	0	0
5.181	1.732	0	0.964	0.031	0.005	1	1	0	0
5.281	2.856	0	0.914	0.081	0.005	1	1	0	0
4.317	2.179	0	0.884	0.104	0.012	1	1	0	0

Utility			Probability				Household Destination Choice (1 indicates decision)		
Public shelter	**Church/ seminaries**	**Friends/ relatives**	**Public shelters**	**Church/ seminaries**	**Friends/ relatives**	**Total**	**Public shelters**	**Church/ seminaries**	**Friends/ families**
2.884	0.715	0	0.855	0.098	0.048	1	1	0	0
4.638	3.806	0	0.692	0.301	0.007	1	1	0	0
3.99	1.791	0	0.885	0.098	0.016	1	1	0	0
4.272	1.819	0	0.909	0.078	0.013	1	1	0	0
4.666	2.47	0	0.892	0.099	0.008	1	1	0	0
2.195	0.768	0	0.740	0.178	0.082	1	1	0	0
4.249	3.395	0	0.694	0.296	0.010	1	1	0	0
4.323	2.577	0	0.842	0.147	0.011	1	1	0	0
3.351	2.747	0	0.632	0.346	0.022	1	1	0	0
4.247	3.392	0	0.695	0.295	0.010	1	1	0	0
3.833	2.121	0	0.832	0.150	0.018	1	1	0	0
3.328	0.653	0	0.905	0.062	0.032	1	1	0	0
2.799	0.224	0	0.879	0.067	0.054	1	1	0	0
5.317	2.981	0	0.908	0.088	0.004	1	1	0	0
4.703	2.061	0	0.926	0.066	0.008	1	1	0	0
1.311	0.05	0	0.644	0.182	0.174	1	1	0	0
1.445	0.907	0	0.550	0.321	0.130	1	1	0	0
2.685	1.603	0	0.711	0.241	0.048	1	1	0	0
3.704	1.796	0	0.853	0.126	0.021	1	1	0	0
5.475	4.161	0	0.786	0.211	0.003	1	1	0	0
2.762	0.633	0	0.846	0.101	0.053	1	1	0	0
3.558	1.391	0	0.875	0.100	0.025	1	1	0	0
3.262	1.861	0	0.778	0.192	0.030	1	1	0	0

Utility			Probability				Household Destination Choice (1 indicates decision)		
Public shelter	**Church/ seminaries**	**Friends/ relatives**	**Public shelters**	**Church/ seminaries**	**Friends/ relatives**	**Total**	**Public shelters**	**Church/ seminaries**	**Friends/ families**
1.358	0.413	0	0.608	0.236	0.156	1	1	0	0
4.482	2.629	0	0.856	0.134	0.010	1	1	0	0
2.75	-0.142	0	0.893	0.050	0.057	1	1	0	0
5.366	3.347	0	0.879	0.117	0.004	1	1	0	0
4.626	2.642	0	0.872	0.120	0.009	1	1	0	0
4.177	2.172	0	0.870	0.117	0.013	1	1	0	0
3.829	1.726	0	0.874	0.107	0.019	1	1	0	0
1.005	1.364	0	0.357	0.512	0.131	1	0	1	0
5.059	2.887	0	0.893	0.102	0.006	1	1	0	0
3.092	3.187	0	0.466	0.513	0.021	1	0	1	0
4.187	2.944	0	0.767	0.221	0.012	1	1	0	0
5.115	2.94	0	0.893	0.101	0.005	1	1	0	0
4.577	2.276	0	0.901	0.090	0.009	1	1	0	0
3.005	2.693	0	0.561	0.411	0.028	1	1	0	0
4.886	2.047	0	0.938	0.055	0.007	1	1	0	0
3.108	1.076	0	0.851	0.111	0.038	1	1	0	0
3.215	1.498	0	0.820	0.147	0.033	1	1	0	0
5.426	3.795	0	0.833	0.163	0.004	1	1	0	0
3.599	1.377	0	0.880	0.095	0.024	1	1	0	0
4.897	3.366	0	0.817	0.177	0.006	1	1	0	0
4.675	3.397	0	0.776	0.216	0.007	1	1	0	0
1.704	0.467	0	0.679	0.197	0.124	1	1	0	0
4.76	3.888	0	0.701	0.293	0.006	1	1	0	0

Utility			Probability				Household Destination Choice (1 indicates decision)		
Public shelter	**Church/ seminaries**	**Friends/ relatives**	**Public shelters**	**Church/ seminaries**	**Friends/ relatives**	**Total**	**Public shelters**	**Church/ seminaries**	**Friends/ families**
3.511	1.028	0	0.898	0.075	0.027	1	1	0	0
5.941	2.365	0	0.970	0.027	0.003	1	1	0	0
0.647	0.146	0	0.470	0.285	0.246	1	1	0	0
0.647	0.146	0	0.470	0.285	0.246	1	1	0	0
3.067	1.09	0	0.844	0.117	0.039	1	1	0	0
3.104	0.681	0	0.882	0.078	0.040	1	1	0	0
3.093	1.416	0	0.811	0.152	0.037	1	1	0	0
2.954	1.935	0	0.708	0.255	0.037	1	1	0	0
4.617	1.715	0	0.939	0.052	0.009	1	1	0	0
5.917	4.096	0	0.859	0.139	0.002	1	1	0	0
3.398	1.873	0	0.799	0.174	0.027	1	1	0	0
4.43	1.334	0	0.946	0.043	0.011	1	1	0	0
						TOTAL	144	4	0

Utility and Probability results above were calculated using the models estimated as follows:

Utility function for evacuation to public shelters (from Table 6.3):

$DDEC_{pih} = -0.695 - 0.491\ INCOME_{ih} - 0.358\ EQUIP_{ih} + 0.222\ DIST_{ih} + 0.604\ SWARN_{ih} - 0.002\ DCOST_{ih} + 0.798\ EDIST_{ih} + 0.835\ DUR_{ih}$

Utility function for evacuation to church/seminaries (from Table 6.4):

$DDECc_{ih} = -0.704 - 0.301\ INCOME_{ih} + 1.218\ EQUIP_{ih} - 0.031\ DIST_{ih} - 0.544\ SWARN_{ih} - 0.003\ DCOST_{ih} + 0.761\ EDIST_{ih} + 0.352\ DUR_{ih}$

Probability function for evacuation to public shelters:

$$P_{pih} = \frac{e(DDEC_{pih})}{\sum_i^j e\,(DDEC_{ih})}$$

Probability function for evacuation to church/seminaries:

$$P_{cih} = \frac{e(DDEC_{cih})}{\sum_i^j e\,(DDEC_{ih})}$$

Probability function for evacuation to friends/relatives:

$$P_{fih} = \frac{e(0)}{\sum_i^j e\,(DDEC_{ih})}$$

From Appendix C.5 above, the following are the % of households going to different destination types:

Percent households to evacuate to public shelters	=	*144/148 = 97.3%*
Percent households to evacuate to church/seminaries	=	*4/148 = 2.7%*
Percent households to evacuate to friends/relatives	=	*0%*

Appendix D

Example of Contents of a Comprehensive Flood Emergency Preparedness Plan

I. Introduction
- 1.1 Purpose of the plan
- 1.2 Authority
- 1.3 Area covered by the plan
- 1.4 Flooding and its effects
- 1.5 Responsibilities

II. Preparedness
- 2.1 Plan Maintenance
- 2.2 Coastal/Floodplain risk management
- 2.3 Development of warning systems
- 2.4 Public education
- 2.5 Training
- 2.6 Resources

III. Response or Evacuation Operations Plan
- 3.1 Control arrangements
- 3.2 Operational management
- 3.3 Response operations
- 3.4 Strategies
- 3.5 Situational information gathering and analysis
- 3.6 Communication systems
- 3.7 Managing evacuation and rescue operations
- 3.8 Supplies and operations

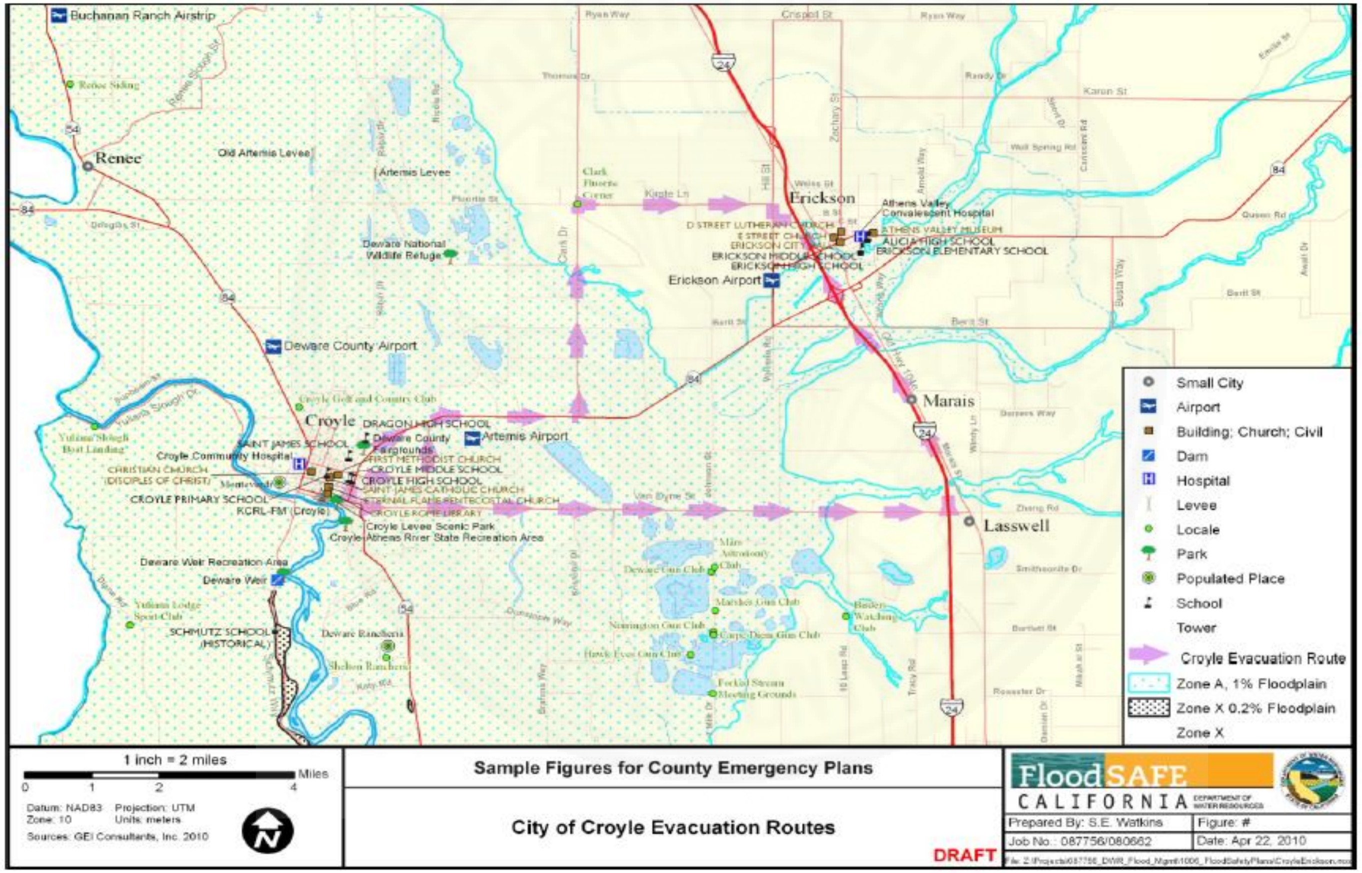
IV. Recovery

V. Maps and Charts

Source: Lake Macquarie City Council (2013)

Appendix E

Example of Evacuation Map



Source: California Department of Water Resources (2011)