2016

Hurricane Emergency Evacuation Study for Coastal Regions of Rhode Island

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HURRICANE EMERGENCY EVACUATION STUDY FOR
COASTAL REGIONS OF RHODE ISLAND

BY

ALOLADE OYINLOLA CAMPBELL

A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN

CIVIL AND ENVIRONMENTAL ENGINEERING

UNIVERSITY OF RHODE ISLAND

2016

DOCTOR OF PHILOSOPHY DISSERTATION
OF
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2016

ABSTRACT

Hurricane landfalls have great potential to cause human injuries, loss of lives and loss or damage of properties. Currently, the prediction of a hurricane hit at a given location has significantly improved owing to the advancements in meteorology and other contributing technologies such as satellite sensing systems among others. In spite of the developments in hurricane track forecast, the most common risk aversion strategy in response to hurricanes still remains the emergency evacuation of the flood zones under the direction and coordination of government officials.

Rhode Island, known as the Ocean State, is the smallest state within the continental United States of America. Nonetheless, it boasts about 384 coastal miles along the Atlantic Ocean. Past history indicates a non-negligible risk posed by hurricanes to the coastal regions of Rhode Island with yearly frequencies of a hurricane hit within 75 nautical miles of central Providence, RI, at 5%, 6% and 2% for categories 1, 2, and 3, respectively as derived from the *“Tropical Cyclones of the North Atlantic Basin from 1851 to 2001”* database from the National Oceanic and Atmospheric Administration.

Given the devastating effect of hurricane Katrina, 2005, Campbell et al, 2007, conducted a hurricane risk assessment study for the state of Rhode Island using selected socio-economic factors, which pointed to Warwick, Newport, Barrington, Narragansett and Providence as the towns most potentially vulnerable to storm surges. To further the previous work, hypotheses are put forward in this study to query the association between the household socioeconomic and demographic attributes, the decision to evacuate, the behavior at evacuation and the evacuation preparedness level

for a sample of earlier mentioned towns as well as Jamestown. The aim is to apprehend the data necessary to the calibration of a hurricane evacuation model rooted in the anticipated behavior of evacuating households. To this end, the study 1) probes heads of households using a survey instrument 2) conducts statistical analyses of the gathered data 3) compares the behavioral data obtained with the generic ones derived for southern states, and 4) develops a behavioral evacuation model of the RI flood zones. Based on the insights gained, it further provides in conclusion some suggestions on the desirable modifications to the survey that may promote further evacuation model enhancements given the simplifying assumptions made.

The findings show that about 80% of Rhode Islanders are willing to comply with evacuation notices when issued by government officials. Head of household's age, education, household income, and prior hurricane evacuation experience do not display any association with the decision to evacuate. There seems to be a relationship between race and the decision to evacuate, chi-square p-value of 0.025, but the percentage of minority in the sample size is too low to reach a conclusive result. The findings highlight the positive association between hurricane workshops/meetings/classes participation and hurricane risk preparedness.

The survey analysis further confirmed that not all the owned household vehicles would be used at evacuation. It provided the basis for deriving a cross-classification table for owned household vehicles versus evacuating household vehicles, which enables the conversion of evacuating households into evacuating vehicles. The attractions, as obtained from the survey, were 68% for friend and family homes, 17% for shelters, and 15% for hotels/inns/bed-and-breakfasts. It is worthy to note that the

total person-occupancy of 8,448 at 18 Red Cross-designated shelters in Rhode Island will not suffice to satisfy the evacuee demand of about 36,700 persons in a major hurricane scenario.

A gravity model was used for the purpose of trip distribution to friend and family homes outside of the flood zones. The friction factor was modeled by a Gamma function calibrated using the percentage of evacuating households willing to travel within given distances at evacuation. The resulting gamma function parameters a , b and c obtained equaled 50.057, 0.047, 0.008, respectively. A traffic loading curve, generated from the survey results, points to about 65% of the evacuating households as willing to leave the evacuation zone within the first three hours following a mandatory evacuation notice by government officials.

The traffic assignment results were discussed by color coding the network to present the volume to capacity ratios for all links over the entire Rhode Island Statewide Travel Demand Model network. The interstate freeways within Rhode Island and its neighboring states operate at steady states with volume to capacity ratios lesser than 0.9. However, some arterials and major local roadways in the evacuation area municipalities operate at or over capacity. Finally, future studies could modify the model to 1) simulate a dynamic evacuation that accounts for the delays in reaching evacuation orders on a township basis. They could also 2) deploy a revised survey instrument as proposed with a potential to enhance evacuation planning model accuracies.

ACKNOWLEDGMENTS

Firstly, I would like to express my sincere gratitude to Dr. Natacha Thomas for her guidance and constructive criticisms at every stage of this project and in particular for her unalloyed support throughout the duration of my studies. Secondly, my deepest appreciations go toward the members of my dissertation committee members: Dr. Christopher Hunter, Dr. Wayne Lee, Dr. Liliana Gonzalez, Dr. Farad Atash and to my TransCAD training session teacher, Paul Ricotta. Their commitment in terms of time, analytical suggestions and comments have greatly helped to enhance the quality of my dissertation. The overly generous allowance of TransCAD software usage and guidance by Caliper Corporation could never be repaid in a single lifetime.

I wish to express my gratitude to varied government officials who were instrumental in allowing access to the much needed data necessary for my dissertation. I cannot but extend my thanks to Francisco Lovera, Steve Kurt and Philip D’Ercole of the Rhode Island Department of Transportation, who gladly provided me with actual data, including evacuation road maps in GIS format and past evacuation traffic flow data during Irene and Sandy hurricanes, or alternately the insight on where to probe for such. I would also like to thank Vincent Flood of the Statewide Planning Program of the State of Rhode Island Division of Planning for the provision of the Rhode Island Statewide Travel Demand Model, instrumental in the determination of background traffic at evacuation. Mark Brodeur, Director of Tourism, Rhode Island Commerce Corporation, relayed the names of hotels, motels, and tourist housing

attractions of all sorts within the state; thereby enabling determination of their locations, capacities and occupancies.

I would also like to thank my colleagues at MassDOT for their support during the period of my study and the completion of this program. I especially wish to acknowledge the following individuals: Pamela Haznar, Bob Gregory, Tony Masse, Ayoola Olaoye, Faina Veinstein, Rich Olivera, Rich Madsen, Joe Frawley and Hud Quistorff. Sincere appreciations also to those special ladies, the prayer warriors, the ever attentive ears and reliable shoulders to lean on during moments of anxieties and frustrations whose support over the years have greatly enriched my life and made life worth living, they include: Wura Adamolekun, Adeola Olukosi, Adeola Andrew, Adebisi Umoye, Adenike Adeyemo and Omolara Omotosho. I also wish to acknowledge my late father Chief Akin Akinyemi who would have loved to witness the completion of this program, but now resting at the feet of his creator. Words are perhaps not enough to express my unfettered appreciation and thanks to my Mum Mrs. Bisi Akinyemi for her unalloyed love and support over the years.

Last but not the least, I would like to acknowledge my husband, Bolaji and our children—Toni, Tona, and Teni for their understanding, love and support throughout the course of my study at the University of Rhode Island. I like to acknowledge in particular, my study companion Tona for his labor of love. And finally, I give thanks to Jesus Christ my Savior and the sustainer of my strength.

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CHAPTER 1

INTRODUCTION

1.1 Problem Statement

Although Rhode Island (RI), also known as the Ocean State, is the smallest state within the continental United States of America (USA), it boasts 384 miles of tidal shoreline along the Atlantic Ocean, including the coastlines of the islands contained within the bay (Aquidneck Island, Block Island, Goat Island, etc.). Despite RI's far north location, its frequencies of strikes from the varied hurricane categories, catalogued over a 100-year span, are non-negligible (Campbell et al., 2007). According to previous source, the yearly frequency of a hurricane coming within 75 nautical miles of central Providence, RI, as derived from the "*Tropical Cyclones of the North Atlantic Basin from 1851 to 2001*" (Kerski, 2005), is approximately 13%. Specifically, this frequency equals 5%, 6% and 2% for hurricanes of categories 1, 2 and 3, respectively. The lack of occurrence of hurricanes of categories 4 and 5 should not be construed as a lack of potentially damaging hurricanes. Historically, it can be shown that after hurricanes pass the outer banks of Cape Hatteras, North Carolina, they tend to decrease their strengths and simultaneously increase their forward speeds with further northward movement (Army Corps of Engineers, 1995). The increases in forward speed compensate for any decrease in hurricane strength, as measured by its category. A category 2 hurricane traveling at 60 mph might potentially cause more damage than a category 4 hurricane moving at 20 mph (Pielke and Pielke, 1997).

Further, faster forward hurricane speeds lead to shorter notice periods of the threats faced, typically 12 hours in the north versus 36 hours down south.

Campbell et al, 2007, further conducted a risk assessment study for the state of Rhode Island, which pointed to Warwick, Newport, Barrington, East Providence, Narragansett and Providence as the towns most potentially at risk from hurricane storm surges using selected socio-economic factors. Past history indicates a non-negligible risk posed by hurricanes to the coastal regions of Rhode Island. Hurricanes have the great potential to cause human injuries, loss of lives, and loss or damage of properties. It remains critical that the coastal regions of Rhode Island enhance their preparedness to adequately mitigate and respond to hurricane threats.

1.2 Study Justification and Significance

There are limited risk aversion strategies for government officials to undertake in response to hurricanes. The most common strategy entails the emergency evacuation of the households in the flood zones and of the mobile homes. Unlike other potentially as disastrous events that are natural, the timely predetermination of a hurricane strike is possible owing to the advancements in meteorology and to the evolvement of contributing technologies such as satellite sensing systems among others. This predetermination, affords a short notice period of a hurricane hit, prior to landfall, which in turn affords a restricted time window for the evacuation of a threatened population.

The closer a hurricane to a landing, the higher the accuracy level of its forecast likelihood to strike at specific locations; hurricane paths/tracks are best predicted short term. Hence, meteorologists only forecast strikes with a high degree of precision

within a relatively short period before landfall, and most especially for the northeastern region given higher forward speeds. When timing the enactment of a hurricane response, a compromise must be reached between minimizing false hurricane alerts and increasing notice period. Further, short notices often bring about additional challenges to the immense responsibility of state officials who coordinate the evacuation with local emergency managers. Hence, there is a need for extensive pre-planning and coordination of the evacuation movement to contain it within a restricted and prescribed time window that reflects a rather high strike likelihood.

Adding to these challenges, state emergency operation centers lacked until recently the ability to anticipate the extent to which flood zone households would forego mass evacuation. This is partly due to a lack of integration of the sociological findings on the hurricane evacuation behavior into transportation planning models of the hurricane evacuation process (Lindell and Prater, 2007). Several studies (Lindell and Prater, 2007) support the view that the efficiency of an evacuation does not only depend on the operational ability of the highway infrastructure, but largely on the response of the evacuating public. Like the characteristics of the hurricane threat itself, human response varies and is dependent upon several factors. Prior knowledge of how people will respond to both publicly sanctioned and spontaneously generated forms of information can improve not only the way we develop evacuation plans but also the process by which we apply such plans during the course of an emergency (ORNL, 1999).

Predicting how people will respond during an emergency evacuation situation warrants probing into their level of resiliency. Resilience relates to the coping

capability, the ability to adapt, by resisting or changing and to maintain an acceptable level of functioning and structure. Resilience is bolstered by the availability of resources, whether material or conceptual, necessary for accomplishing an effective response and the proficiency in their use by those facing the disaster. Preparedness relates to the readiness to demonstrate resilience and thus can be used as a proxy for resilience. The joint understanding of the preparedness and of the exposure of a population to a disaster helps anticipate the risk faced by the population and also the probable response, or behavior, during an emergency evacuation. The importance of hurricane preparedness was brought to the forefront by the devastations due to hurricanes Katrina, Rita and Wilma in 2005.

Overall factors that influence community response to emergency evacuation during the onset of a hurricane event as highlighted by Lindell et al., 2005, include: personal perception of risk, information source and type, local authority action, household location and structural characteristics, gender and age, presence of children or persons with disability in the household, storm-specific threats, time of day, provision of evacuation transportation assistance and development and dissemination of traffic management plans. The details of household level data on demographics, social links, preparedness or risk, and other characteristics, as cited above, are essential to the understanding of the behavioral patterns at evacuation toward building a reliable evacuation model. These patterns at evacuation could not be ascertained through the demographic data (U.S. Census, 2000) utilized in Campbell et al., 2007. Further, these calibration parameters are not readily available for the Northeastern regions of the United States. Typically, default data from post-hurricane behavioral

surveys conducted in the southeastern regions is used instead; owing to their higher overall frequency of threat occurrences.

There exists a strong need for a behavioral analysis, which can provide some insights into human responses to a future evacuation notice, in RI. The ability to predict the behavioral patterns of evacuees under emergency situation is of vital interest to transportation planners and to emergency preparedness in RI. This will enable the necessary calibration parameters for a socio-behavioral evacuation model. A lack of behavioral data hinders this ability at present for the coastal region of RI.

Typically, evacuation planning models make unreliable assumptions upon their calibration parameters for human response; namely the total compliance of warned households and warned households only, the evacuation of all registered vehicles in warned households and the achievement of equilibrium flows on evacuation routes. Behavioral research can help ascertain, using empirical data, the vast majority of calibration parameters; such as the number of evacuating vehicles per household, the number of evacuating trailers per household, the percentage of households evacuating early, the departure time distribution of evacuees, the extent of the shadow evacuation (made of evacuees that do not necessitate evacuation) and other factors needed to generate effective and efficient evacuation plans.

1.3 Study Objectives

This study aims at:

1. Using a survey instrument to capture both, the household preparedness and the anticipated evacuation behavior of the exposed populations in the coastal towns of Rhode Island upon notice.

2. Comparing the parameters gathered from the instrument with their counterpart default/generic values.
3. Building socio-behavioral evacuation models and utilizing the evacuation information gathered from the instrument to calibrate these models.
4. Refining the survey instrument to enhance in hindsight the quality of information gathered in the future on the preparedness and evacuation pattern data to be.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Hurricane Evacuation Preparedness

Sutton and Tierney (2006) provide an extensive review of the literature on disaster preparedness within the social structures of a community. Per the study, preparedness requires collaboration rather than top-down direction. Hence, there is a need for individual responsibility as well as local coordination and continuity of plans. Further, in quantifying the preparedness of a social unit, intrinsic as well as extrinsic contributions through various social links to other social units must be gauged. The report acknowledges the use of different social units of analysis in disaster preparedness research and guidance: the households, the businesses, and the communities and organizations. It further summarizes the common metrics of household preparedness: 1) hazard knowledge, 2) management, direction and coordination of emergency operations, 3) formal and informal response agreements, 4) resource acquisition to ensuring the smooth execution of emergency functions, 5) life safety protection, 6) property protection, 7) emergency coping and restoration of key functions, and 8) initiation of recovery activities.

The Tubman Center for Public Policy conducted a survey on household preparedness and anticipated hurricane evacuation behavior in RI and derived the specifics cited within this paragraph. Twenty five percent (25%) believe a strike by a major hurricane to be very likely in Rhode Island in the near future. On the other hand, 45% 23% and 7% find the same to be "somewhat likely", "not very likely", or "don't

know" and did not answer, respectively. In a major hurricane hit on RI, 20%, 42%, 35% and 3% believe that their residences would be "very vulnerable", "somewhat vulnerable", "not very vulnerable", or "don't know" and did not answer. Twenty eight percent (28%), have knowledge of the official evacuation routes, 68% do not, and 4% "don't know" whether they have this knowledge or did not answer.

As for management support, only 10% were confident in the ability of the government to help in a hurricane disaster (Tubman Center for Public Policy, 2006). To provide enhanced planning guidance to emergency management as to afford efficient and effective coordination at evacuation, transportation planners and traffic engineers have long used traffic simulation and planning models. The paragraphs that follow summarize the review of the literature on evacuation modeling and numerous parameters that need to be calibrated to enhance the fidelity of such models.

2.2 Hurricane Evacuation Modeling Frameworks

Early researchers approached hurricane evacuation demand forecasting similarly to urban travel demand forecasting. Lewis (1985) was first to pursue this approach. He tackled the following three critical questions pertaining to hurricane evacuation, as posed by civil defense and other emergency officials, using traditional urban travel demand models:

1. What is the clearance time required to get the evacuees to their respective destinations?
2. Which roadways should be selected for use in the evacuation network?
3. What traffic control measures can improve the efficiency of the critical roadway segments?

Complex actions are required to creatively fold the activities within emergency traffic evacuation into the generic transportation planning trip-based steps; namely trip generation, trip distribution, modal split and route assignment. Lewis (1985) identified the hurricane evacuation activities to model within transportation planning as evacuation travel patterns, estimation of travel demand, calculation of clearance times, and development of traffic control measures. Each of these model steps utilize different calibration parameters that require evacuees information, routes information and other external factors, thereby resulting into separate sub models that are interconnected although allowing for no feedback. Lewis (1985) made the following evacuation travel pattern assumptions:

- All evacuees are residents living in surge flood areas of coastal regions and/or wind-vulnerable residents living inland in mobile homes or substandard housing.
- Evacuation trips are home-based and trip destinations are Red Cross public shelters, hotels/motels, friends/relatives houses, or out-of-the-county or -study-areas. Some background trip-making that include shopping trips to gather supplies and relocate from places of work to home, in order to prepare households for evacuation, also occur during a hurricane evacuation.

Lewis suggested that transportation modeling exercises are best performed on a county-by-county basis because evacuation orders are generally issued by a county commission or committee acting under the advice of the civil defense director. Meanwhile, he also brought attention to multi-county evacuation trip movements, which occur simultaneously during the course of modeling. If a lack of acceptable

shelter destinations exists, trips must proceed out of the county to shelters in a neighboring county or state. He reckoned the following five general evacuation trip patterns exist:

1. In-county origins to in-county destinations
2. In-county origins to out-of-county destinations
3. Out-of-county origins to in-county destinations
4. Out-of-county origins to out-of-county destinations
5. Background traffic

To estimate trip/vehicular demand during a hurricane evacuation, Lewis (1985) further developed a forecasting process (Fig. 1). Although flexible in scenarios, it reflects the urban travel demand forecasting methodology and terminology, with zonal delineation, zonal data development, network preparation, trip generation, trip distribution and trip assignment as main tasks.

Lewis (1985) established evacuation zones within the study area, which then became the geographic units for traffic analysis. A database included, for each evacuation zone, the number of dwelling units, the resident population data, the tourist population data and the vehicle ownership data. In preparing an evacuation roadway network, all roadway characteristics were weighed (number of lanes, surrounding land use, facility type and elevation, and lateral clearance). Roadways inundated by heavy rains early in the evacuation process were not deemed suitable for evacuation. Lewis (1985) defined trip generation as for the generic urban travel demand model and as comprising trip production and trip attraction. Evacuation trips were then distributed

for producing evacuation zones amongst “attracting” evacuation zones, or vice versa, creating a trip table that matches trip origins to their destinations.

Figure 1. Process for Forecasting Hurricane Evacuation Travel Demand

This trip table, representing point evacuation trip-making under certain hurricane and behavioral assumptions, is then assigned to the evacuation network. All evacuation travel patterns are accounted link by link and estimates of background traffic are added. Lewis (1985) recommended that the clearance time calculation be carried using two steps:

1. Identifying critical links/intersections in the evacuation road network by using volume to capacity ratio for each roadway link in the evacuation network.
2. Performing travel time/queuing delay analyses

Southworth, (1991) on the other hand, treated regional evacuation modeling as a five-step process also designed based on traditional urban travel demand models. This five-step process, involves an additional model component, a traffic departure time (often termed a traffic loading rate or traffic mobilization) sub-model. It retains the 4 components of Lewis' (1985) model albeit renamed as traffic generation, destination selection, traffic route selection (often termed a traffic route assignment), and a user specified plan set-up, analysis and revision sub-model.

To simulate a realistic major population evacuation using the above steps, the following information are required (Southworth, 1991):

- a. An accurate description of the transportation infrastructure, most notably the highway network.
- b. An accurate description of the spatial distribution of population, by time of day and type of activity.
- c. An accurate representation of vehicle utilization during emergency of the type under consideration.
- d. An accurate representation of the timing of people's response to the emergency, and how this timing varies by a person's location and current activity at the time he/she finds out about the threat.
- e. An accurate representation of evacuee route and destination selection behavior.
- f. An accurate representation of any traffic management controls that may be incorporated within the evacuation plan.

- g. An accurate representation of any non-evacuation based protective actions (e.g., in situ sheltering) taken by significant population sub-groups within the risk area.

A full understanding of the 4 common model steps, assumptions and limitations helps determine its suitability, and identify appropriate modifications for generating realistic hurricane evacuation outcomes. Next, we review these common steps of the basic hurricane evacuation models proposed by Lewis (1985) and Southworth (1991).

2.3 Hurricane Evacuation Trip Generation

Trip generation constitutes the initial step of evacuation modeling, which forecasts trips to and from transportation analysis zones (TAZs) within the model. A trip's "*origin*" refers to its starting TAZ and a trip's "*destination*" to its ending TAZ. These terms, origin and destination, thus help define the direction of a trip. An origin is viewed as producing trips and a destination as attracting the same. A trip generation model consists of two sub-models, namely a trip-production model, determining the number of trips starting at a TAZ, and a trip-attraction model, determining the number of trips ending at a TAZ. Despite being the first step in the evacuation modeling process, trip generation has received the least attention within past studies ((NCDOT, 2000; Jha et al., 2004; Radwan et al., 2005). Wilmot, Modali, and Chen, 2006)). Ziliaskopoulos and Peeta (2001) deemed the deployment of dynamic traffic assignment (DTA) models challenged by the lack of proper techniques for estimating and predicting time-dependent origin-destination demands.

Hurricane evacuation trip generation typically involved the translation of number of evacuation zone residents into number of evacuating vehicles with the basic use of census information (Southworth, 1991). Thus, it was assumed that all residents evacuate in a synchronic mass movement. Lindell, 2007, wrote that “One of the most common misconceptions is that there is an undifferentiated “public” when, in fact, there are many population segments that differ in their hazard knowledge, family roles, and household resources. In particular, emergency managers must distinguish among residents, transients, and special facility populations because these population segments differ in their willingness and ability to evacuate (Drabek, 1996; Urbanik, 2000).” Other studies evacuate a flat percentage of the evacuation residents. Unfortunately, there are no empirical data or theoretical foundations for a flat percentage rate of vehicles evacuating (Lindell et al., 2007). Latter authors and article suggest basing the number of evacuating vehicles on the number of evacuating households since fifty years of disaster research has identified the household as the basic unit of evacuation. Yet, determination of the number of households evacuating realistically requires specialized/evacuation trip information and behavioral data for its estimation on a time progressive basis. Trip generation is thus intrinsically behaviorally defined by the decision choices of individual households whether and when to evacuate. These decisions must be accounted in transportation evacuation models using various methods.

Lindell et al., 2007, state “There are three parameters affecting trip generation that emergency managers can estimate from US Census data for their jurisdictions. These are the size and distribution of the resident population, the number of persons

per residential household, and the size and distribution of the transit dependent resident population.” In truth, additional information such as household vehicle ownership number, household occupancy per room, etc. can also be gathered. In addition, according to Lindell et al., 2007, data from two variables can be collected from the Local Visitors’ Bureau. These are the size and distribution of the transient population and the number of evacuating vehicles per transient household. Finally, there are four variables that must be estimated from behavioral research. These are the number of evacuating vehicles per residential household, the number of evacuating trailers per residential household, the percentage of residents’ protective action recommendation (PAR) compliance/spontaneous evacuation, and the percentage of transients’ PAR compliance/spontaneous evacuation” (Lindell et al., 2007). Stated data can be determined for evacuees headed to shelters, hotels and motels versus friends’ homes.

Evacuation Trip Origins – Although households within an impacted zone may be encouraged, warned or mandated to evacuate, due to various lacks of resources, attitudes toward hurricanes, or lack of trust in the warning source, some households may decide against evacuation. Likewise, there may be no need to evacuate for some households residing outside of the evacuation zones, a non-negligible number of households may elect to do so. Finally, background traffic may include those involving retail activities in other activities outside of the evacuation zones, passing through the state from bordering or even far-away states in-route to their destinations within or outside the state proper. These choices, to evacuate or not to evacuate, to travel in, out or through the state must be accounted by transportation evacuation

models since they impact the overall vehicular demand placed on the transportation infrastructure at evacuation. Background traffic is easily assessed from urban planning model by the metropolitan planning organization.

Demographic variables have limited value in explaining people's warning responses. Quarantelli (1980, p. 43 as quoted by Lindell, 2007) stated "studies dealing with demographic characteristics and evacuation are simply not conclusive." Baker (1991 as quoted by Lindell, 2007) reached a similar conclusion for hurricane evacuation studies. Thus, message source and characteristics are the most important determinants of household warning response (Lindell, 2007). Household hurricane evacuation warning from potentially varied sources, warning dissemination rate within the threatened population, evacuation decisions following warning receipts and delays evacuating post decisions are the prime determinants of time-based demands at evacuation anywhere. Whether people receive a warning and when they receive one has been the subject of substantial research over the past five decades (Lindell, Pratter and Perry, 2007).

"The process of warning dissemination generates a distribution of times at which households first receive a warning (Lindell et al., 2007)." The cumulative distribution of warning receipt over time is nonlinear (Rogers and Sorensen, 1988). The rate of warning receipt first increases and later decreases over time (Lindell et al., 2007). "Warning compliance refers to the percentage of those warned to evacuate who actually do so. Spontaneous evacuation, also known as *evacuation shadow*, refers to evacuation by those who are outside the risk area and therefore not warned to evacuate (Lindell et al., 2007)."

Important demographic characteristics, such as sex, age, education, income, ethnicity, marital status, presence of children in the home, prior hazard experience and previous false alarms have inconsistent correlations with the evacuation decision Baker (1991). Baker, 1991 agreed that hurricane evacuation is most strongly related to people's perceptions of risk, storm-specific threat factors, the hazardousness of households' locations, the characteristics of the structures in which they live, and actions by local authorities.

Gladwin et al. 2001, also developed an ethnographic model identifying a number of issues that impact flood zone residents when deciding whether to evacuate due to an approaching hurricane. These include awareness of evacuation zone, awareness of evacuation order, and belief in compliance with an evacuation order. Evacuation decision was also found to hinge on the source of the evacuation warning by Driscoll and Salwen's, 1996. Likewise, the Taubman Center for Public Policy, 2006, relates compliance to warning sources in a hurricane evacuation study for Rhode Island. Assuming a warning issuance by the US Weather Service, 60% would obey, 34% would not, 6% "don't know" or did not answer. Assuming a warning issuance by a media outlet, 68% would obey, 24% would not, 8% "don't know" or did not answer. Assuming a warning issuance by a government official, 77% would obey, 16% would not, 7% "don't know" or did not answer. Assuming a warning issuance by a friend or relative, 29% would obey, 58% would not, 13% "don't know" or did not answer.

One of various methods employed in the literature to address evacuation decision choice is the compliance rate method, which involves two steps. At first, the number of households within the hurricane flood zones is estimated and then

multiplied by the evacuation compliance rate, which then provides an estimate of the total number of evacuees from the zones. The use of a compliance rate parallels that of a cross-classification rate in conventional urban transportation planning. But, participation rates do not derive from statistical analysis of past data contrarily to conventional cross classification rates. Subjective judgment based on analyst experience with past storms often lead to the assumed compliance rates (Wilmot and Mei 2004).

Logistic regression of specified demographic and behavioral factors has been used for estimating evacuation trip generation. Logistic regression is used in place of regular linear regression because the dependent variable is a binary variable (evacuation versus non-evacuation), which violates the assumptions underlying regular linear regression analysis. (Irwin and Hulbert 1995) used logistic regression to estimate the probability that an individual would evacuate using the post-storm survey data of Hurricane Andrew. Variables used for developing the model include the perception of the possibilities for being hurt if not evacuating, the perceived ability of the home to withstand the storm, prior hurricane experience, gender, marital status, education, age, and race of the owner. The estimated model indicated that perception of risk, type of dwelling, gender, and age significantly affected the probability of evacuating during hurricane Andrew (Irwin et al, 1995).

Another study based on a sample of 940 households following hurricane Bonnie, Regional Development Service (RDS) and other departments of East Carolina University (RDS, 1999) also used logistic regression to estimate the probability that a household will evacuate at the onset of a hurricane as shown in Table 2.1. The overall

regression model was found to be statistically significant at the 99% confidence level. Table 2.1 presents the analysis of the evacuation decision, where the dependent variable represents the evacuation decision, 1 if evacuating and 0 otherwise. The most influential variables were whether a mandatory evacuation order had been issued or not, the risk of flooding, whether the neighbors evacuated or not, and the type of housing structure (RDS 1999). The common practice in the above two models was to include some subjective perceptions as independent variables because they were found to be statistically significant. However, it must be recognized that while these variables may contribute to explaining evacuation behavior, they are not good variables for forecasting because they cannot be measured and cannot be predicted in hypothetical scenarios in which the analyst may want to apply the model (Wilmot and Mei 2004).

Table 1. The Analysis of the Evacuation Decision Based on Selected Variables

Variable	Parameter Estimate	Standard Error	t-value	p-value	Odds Ratio
INTERCPT	-6.24	0.91	-6.89	0.0001	.
MANDATOR	1.40	0.26	5.32	0.0001	4.04
VOLUNTAR	0.44	0.24	1.85	0.0638	1.55
FLODRISK	0.50	0.12	4.01	0.0001	1.65
EVACPLAN	0.34	0.19	1.77	0.0760	1.40
VEHICLE	0.95	0.58	1.62	0.1055	2.57
WORKFUL	-0.36	0.19	-1.84	0.0651	0.70
NEIGEVAC	0.89	0.11	7.89	0.0001	2.45
PETS	-0.62	0.19	-3.18	0.0015	0.54
MOBHOME	1.83	0.24	7.55	0.0001	6.22
EDUC	0.10	0.05	2.16	0.0306	1.11
Model Chi-square	317.549			(p=0.0001)	

In an attempt to identify superior methods of evacuation trip generation demand estimation, Wilmot et al, 2004, compares the relative performance of several models; namely compliance rate model, logistic regression model, and three different types of neural network models. The methodology employed in the study was to use a portion of a data set of past hurricane behavior to calibrate a variety of evacuation travel demand model types, test each model's ability to reproduce observed evacuation decisions on the remaining portion of the data set, and compare their performances.

The compliance rate was estimated based on flooding potential of the home, type of housing, and hurricane intensity (PBS&J 2000b, 2001). The logistic regression model was a disaggregate model describing the likelihood that a household would evacuate based on the characteristics of the household, the location of the home with respect to the closest body of water, and whether an evacuation order was issued or not. The goodness of fit of the logistic regression model was evaluated using the likelihood ratio index, the Hosmer–Lemeshow test, and the receiver operating characteristic (ROC) curve (Hosmer and Lemeshow 2000).

Tourists and Seasonal Households—Other vulnerable group of people to be considered during the hurricane trip generation phase are the tourists. Coincidentally, there is greater attraction for tourists to the coastal towns at the same period of high probability for hurricane landfalls than any other time of the season. Ritchie (2009) argued that little attention has been given to the actual behavior of visitors in the event of a crisis and also that visitors' behaviors studies in the event of a crisis have focused more on the past travelers or future travelers (Beirman, 2006; Pearlman & Melnik, 2008). The best conceivable reason for the scarcity of studies on how on-site visitors

behave in the event of a crisis can be attributed to the inherent difficult nature of contacting on-site tourists in the aftermath of a disaster event.

Drabek, 2000, examined how on-site visitors behave in the event of a crisis, which led to the need to better examine this area to fully understand the expectations necessary to assist tourists in the event of a crisis. Cahyanto, 2011, gathered responses from 533 tourists visiting Orlando and Fort Lauderdale using a 2-page questionnaire. Cahyanto's studies found that individual characteristics (i.e. past experience with hurricane impacts, risk belief, involvement with hurricanes, and knowledge about hurricanes), demographics (i.e. gender, and place of residence) and travel related variables (i.e. transportations, travel party composition) significantly influenced tourist evacuation decisions.

By means of the 2009 surveys of hotels, motels, resorts, bed and breakfasts, seasonal housing rentals, and recreational vehicle parks, Baker, 2009, provided insight into the tourist evacuation pattern at the onset of a hurricane landfall. Baker concluded that 70% of tourists evacuate impulsively before an evacuation order is issued, and after the order is issued, while the remaining 30 percent of tourists evacuate at the same time as the mobile home park residents.

Evacuation Trip Destinations—With regards to hurricane evacuation, trip destinations may be categorized into private or public destinations within the state and outside of the impacted flood zones, or completely outside the state. Private destinations include the private homes of friends, relatives or any member of one's social network and at times a secondary home. Public destinations include public shelters and hotels. Evacuation typically takes place outside of the zones anticipated to be impacted by

storm surges, whether in-state or out-of-state. With hurricane evacuation, the possibility exists for attractions to residential TAZs, contrarily to the norm for urban transportation planning models. Trip destinations, whether to shelters or houses of friends and relatives, etc., may be located within residential areas as long as outside of the hurricane evacuation zones.

2.4 Hurricane Evacuation Departure Time

The second aspect of evacuation travel demand is the estimation of the time at which the evacuees begin to evacuate, the evacuation departure time. This departure time reflects the time lag from the emergency detection to the start of evacuation. It usually differs by location and may be affected by factors such as warning mechanism, relative distance to emergency site, structure inhabited, and personalization of the emergency warning (Sorensen, 1991). “There is a modest amount of empirical data on household departure time distributions. Lindell and his colleagues (Lindell, et al., 1985; Lindell & Perry, 1987, 1992) reported warning and preparation times from four floods and the eruption of Mt. St. Helens and Sorensen and Rogers (1989) reported warning and preparation time data from two hazardous materials spills. These data can be used directly to estimate departure times for these hazard agents and can also be used to construct estimated departure time distributions for other hazard agents as well (Lindell et al., 2007).”

Glickman (1986) pointed out that there are substantial differences between daytime and nighttime population distributions, which also affect the time of departure during hurricane evacuation. Nonetheless exceptional evacuation models should have the ability to load the evacuation trips onto the highway network in the order in which

trips are generated rather than to load all the trips onto the network at the same time. Two approaches are commonly used to determine evacuation departure time. This is sometimes carried out by using the departure time obtained from historic evacuation data to generate behavioral response curves or develop mathematical models (Sorensen and Mileti 1989; Rogers and Sorensen 1991; National Center for Transportation and Industrial Productivity 2007).

Hurricane Evacuation Mobilization Curves—Response or mobilization curves estimate the proportion of the total evacuation demand that departs within each time period during evacuation. The US Army Corps of Engineers proposed three different response curves, for slow, medium, and rapid responses respectively, based on behavioral analysis of past storms as shown in Fig.2. The x-axis in Fig.2 represents the period when the evacuees are leaving the hurricane zone and the y-axis displays the percentage of the evacuees leaving at certain period. The negative on the x-axis depicts the evacuees leaving before the official evacuation announcement. The main advantage of these static curves lies in their simplicity while their weakness is the very static nature where an average response is not sensitive to changing conditions or the particular circumstances surrounding each hurricane. Moreover, they may not reflect the true shape of the response curves nor the capacity constraints that may vary significantly by region.

Figure 2. Hurricane Evacuation Response Curves (Army Corps of Engineers (COE), 2000)

Tweedie et al (1986) determined hurricane mobilization curve in Fig.3 using parameters from information obtained during several meetings with key experts within the Civil Defense Office of Oklahoma. The data was then approximated by a Rayleigh probability distribution function.

Figure 3. Hurricane Mobilization Curve (Tweedie et al (1986))

$$F_t = 1 - e^{-\frac{t^2}{T}}$$

Where F_t is the percentage of the population mobilized by time t and T is a parameter the analyst can adjust, to control both the slope of the traffic loading curve and also the maximum time at which all evacuees are assumed to have mobilized.

Radwan et al (1985) and Hobeika et al (1998) used a logistic curve to model the loading time of trips onto the highway network during an evacuation from a natural disaster in their MASSVAC model:

$$P(t) = \frac{1}{1 + e^{-\alpha(t-H)}}$$

where:

$P(t)$ = the cumulative percentage of the total trips generated at time t

A = the parameter that represents the response of the public to the disaster

H = the half loading time; the time at which half of the vehicles in the system have been loaded onto the highway network.

Southworth and Chin (1987) rearranged MASSVAC model above equation by setting

$$\delta \equiv e^{\alpha H}$$

$$P(t) = \frac{1}{1 + \delta e^{-\alpha t}}$$

When $t = 0$, then

$$\delta = \frac{1 - P(0)}{P(0)}$$

Where δ is the ratio of the proportion of vehicles not yet loaded to those already loaded on the network at the time officials issue an evacuation notice or order. $P(0)$ is known as the percent of shadow evacuees (Lewis, 1985; US Army Corps of Engineers, 2000). This number is important since the percent of evacuees who leave before officials issue an evacuation notice or order are known to some degree from past studies.

2.5 Hurricane Evacuation Trip Distribution

Trip distribution also known as the destination choice is the second step of the four-step modeling in both, the urban transportation and evacuation planning and emergency management models. The output from this process will be the input to traffic assignment, necessary for the assessment of trip vehicle miles traveled, travel and clearance times, network congestion and delay estimates. In essence, trip distribution is a matching process of the productions and attractions to obtain an origin-destination trip table. Trip-making under hurricane evacuation satisfies an attraction to safety harbors and critically connects the evacuees to their desired safety regions within a specific timeframe.

Although the origins of the trips are known to certain extent during a time period at hurricane evacuation, the destination patterns of the evacuees to the safety zones are not usually well defined. Trip destinations under hurricane evacuation may be categorized into private or public destinations within the state and outside of the impacted flood zones, or completely outside the state. Private destinations include the private homes of friends, relatives or any member of one's social network and at times a secondary home. Public destinations include public shelters and hotels. In the study conducted by Taubman, 2006, 42%, have knowledge of the location of the closest designated emergency shelter, 56 % do not, and 2% "don't know" whether they have this knowledge or did not answer (Taubman Center for Public Policy, 2006). In an evacuation 82% could stay with someone in another community; whereas 15% and 3% could not, "don't know" if they could or did not answer, respectively (Taubman Center for Public Policy, 2006).

A certain practice for dealing with trip distribution at hurricane evacuation is to assign evacuees to destinations, or evacuation routes, subjectively (NCDOT, 2000; Jha et al., 2004; Radwan et al., 2005). Another concept is based on the fundamental assumption that trip distribution patterns derived from historical data are good indicators of trip distribution patterns that would result from future hurricanes. Spatial distribution of evacuation trips following past hurricanes has been studied extensively in the south-east and the gulf regions. The destinations of the evacuees in almost all hurricane evacuation studies found that friends or relatives and hotels or motels are the most common destinations during hurricane evacuation. In southwest Louisiana during Hurricane Andrew, these two destinations comprised 64% and 13% respectively of all evacuation trips (Irwin et al. 1995). In Alabama, these two figures were 55 - 68% and 17 - 26% during hurricanes (Mei 2002). In North Carolina, they were 68.8% and 16.2% (RDS 1999). The percentage of the evacuees who went to public shelters was only 12%, 3.8% and 6.4%, respectively in the three studies mentioned above.

Southworth (1991), indicates that the choice of an evacuation destination under threat tends to be modeled in one of the following ways:

- Evacuees are assumed to exit the at-risk area by heading for the closest destination (in terms of distance and/or expected travel time).
- Evacuees will display some degree of dispersion in their selection of area exit points, depending upon such factors as the location of friends and relatives and the speed of the hazard onset.

- Evacuees will head for pre-specified destinations, according to an established evacuation plan.
- Evacuees will exit the at-risk area on the basis of traffic conditions on the network at the time they try to leave the area.

Southworth (1991) suggested that the best destination model will be the second method where an evacuation plan accompanied by an operative traffic flow policies will be the best method. Chen (2005) argued that the first assumption works effectively in modeling small urban systems or rural evacuations when the hazard is approaching rapidly but the third option, which seems to be the most complicated, is the closest to reality for hurricane evacuation.

Travel demand modeling utilizes various types of trip distribution models: growth factor models (Fratar model, Detroit model, etc.), the gravity model, intervening opportunity model. The gravity model is still the most frequently used trip distribution method. In the gravity model, travel distance or travel time is the measure of impedance used to control the distribution of destinations.

Formulation of the Gravity Model — The gravity model was originally motivated by the observation that flow decreases as a function of the distance separating zones, just as the gravitational pull between two objects decreases as a function of the distance between the objects. This Newtonian analogy has now been replaced with the hypothesis that the trips between zones i and j are a function of the number of trips originating in zone i and the relative attractiveness and accessibility of j with respect to other zones in the transportation planning model. The assumption behind the gravity

model is that the number of trips produced by zone i and attracted to zone j is proportional to:

- The number of trips produced by zone i
- The number of trips attracted by zone j
- A function (often called the impedance function) of the relative spatial separation or impedance between the zones.

Many different measures of impedance can be used such as travel distance, travel time or travel cost. The gravity model can be singly – constrained to either production or attraction or doubly constrained to both production and attraction. In a singly-constrained gravity model the flow between zones is calculated from one of the following equations below depending on whether the balancing is constrained by production or attraction:

$$T_{ij} = P_i \cdot \frac{A_j f(d_{ij})}{\sum_z A_z f[d_{iz}]} \quad (\text{Constrained by productions})$$

$$T_{ij} = A_j \cdot \frac{P_i f(d_{ij})}{\sum_z P_z f[d_{iz}]} \quad (\text{Constrained by attractions})$$

where:

T_{ij} = the forecast flow produced by zone i and attracted to zone j .

P_i = the forecast flow number of trips produced by zone i .

A_i = the forecast flow number of trips attracted by zone i .

d_{ij} = the impedance between zone i and zone j .

$f(d_{ij})$ = the friction factor between zone i and zone j .

Several impedance functions derive the relative attractiveness of each zone in the urban planning models. Popular choices include the exponential and inverse power functions, typically used in entropy models, and the gamma function recommended in U.S planning practice. The following equations relate to the various cited functions:

Exponential

$$f(d_{ij}) = e^{-c.(d_{ij})} \text{ where } c > 0$$

Inverse Power

$$f(d_{ij}) = d_{ij}^{-b} \text{ where } b > 0$$

Gamma (combined) function

$$f(d_{ij}) = a.d_{ij}^{-b} . e^{-c.(d_{ij})} \text{ where } a > 0, b > 0 \text{ } c \geq 0$$

As an alternative to impedance functions, a friction factor lookup table (essentially a discrete impedance function) at times relates the impedance to the attractiveness between zones. The value derived from the impedance function is the friction factor and the matrix containing the friction factors for i, j pairs, the friction factors matrix. The most adopted functional form for $f(c_{ij})$ is the negative exponential, as expressed here to be $\exp(-a.c_{ij})$ for a suitably calibrated travel time-decay parameter, a .

Both the parameters, a and c_{ij} , have been well studied and estimated by regional planning agencies to replicate the daily journey-to-work trip flows. However, in the case of seldom enacted regional evacuations, there is little behavioral evidence for selecting values of a , short of the general concept of Newtonian gravity i.e. $f(c_{ij}) = (c_{ij})^2$. Setting the distance-decay parameter, a , to a very large value, the spatial interactions implied by the equations will direct evacuees to the nearest destinations; thereby making trips extremely sensitive to extra travel (Southworth, 1991). However, in hurricane evacuation, people are not as concerned about the proximity of destinations as they are about getting out of the path of the oncoming hurricane and finding refuge (Chen, 2005).

2.5.1 Hurricane Evacuation Trip Distribution Using Gravity Model Concept

Most traffic simulation models have not developed the process of destination selection in emergency evacuation settings except the Oak Ridge Emergency Management System (Southworth, 1991). The most common and at the same time most readily adaptable expression of destination selection is some form of spatial interaction model Southworth 1991, such models have the general form:

$$T_{ij} = N_i \times P_{ij}$$

$$P_{ij} = \frac{W_j \times f(c_{ij})}{\sum_j w_j \times f(c_{ij})}$$

where:

T_{ij} = the number of evacuees traveling from origination node i to shelter j

N_i = the number of evacuees located at i

P_{ij} = the probability of travelling from i to j

W_j = a measure of the attraction potential, or desirability of sheltering
(or simply exiting the at-risk area) at location j

$f(c_{ij})$ = a function of the travel time from i to j

The above equation derives from the most widely used gravity model, which explicitly relates flows between zones to the inter-zonal impedances to travel. The modified evacuation model described above represents the “production constrained” spatial interaction model (Wilson, 1970). There are also several potential impedance functions that can be used to derive the relative attractiveness (W_j) of each zone. The W_j terms in the equation represent composite indices of specific relevance to the type of evacuation taking place and such parameter as number of beds available can be included in the overnight evacuation planning (Southworth, 1991).

2.5.2 Hurricane Evacuation Trip Distribution Using Opportunity Model Concept

Intervening Opportunity Model uses an ordinal or ranking methodology for allocating production trips to attraction zones. In the intervening opportunity model the competing attraction zones are ranked from the best preferred to the least preferred using a calculated measured impedance between production and attraction zones quite unlike the gravity model where the quantitative attractiveness is compared to the quantitative attractiveness of all other possible attraction zones to calculate the proportion of trips to allocate to that zone (Caliper Corporation, 2012). Stopher and Meyburg (1975) state that, in concept, the intervening opportunity model is a somewhat more satisfying formulation of trip distribution than gravity model because the model has a “stronger conceptual base, and attempts to address the problem of individual behavior.” Once the ranking takes place in the intervening opportunity model, declining percentages of trips are allocated from the highest to the lowest attractions. For example 50% of all production trips may be allocated to the most preferred 25% to the second highest and 15% to the third highest.

Wilmot, Modali, and Chen (2006) compared the use of the gravity model, intervening opportunity model and extended intervening opportunity model on hurricane evacuation destination choice. Through a series of tests between the predicted trips by the models and observed trips, the study suggested that gravity model performs better than the intervening opportunity model, and the extended intervening opportunity model performs better than the gravity model.

2.6 Hurricane Evacuation Modal Split

Modal split is the third stage of travel demand modelling. It aims to determine the breakdown by travel mode (such as automobile, walking, bicycling, transit, train and so on) of the total trips between pairs of zones. Modal split analysis estimates the probability of choosing a particular mode of travel. The factors that affect the choice of a mode are socio-economic factors (automobile ownership, age, income) and also modal service related factors like travel time, accessibility, frequency of operation, and overall direct and indirect costs.

In this hurricane evacuation study, attention will be directed solely to the automobile mode. Hence, the modal split step will be skipped. However, some provisions to account for households with no vehicle will be discussed in Chapter 5.

2.7 Hurricane Evacuation Route Assignment

The main challenge recognized by many analysts during a large-scale hurricane evacuation is that the envisioned hazardous event is usually accompanied by all people evacuating at the same time (Alsnih and Stopher 2004; Wolshon et al. 2005a). Routes exiting an evacuation area are often both limited in number and insufficient in capacity to handle the unusual surge in traffic demand that results from the concurrent evacuation activities. In vehicular traffic networks, travel times are flow dependent and increase nonlinearly with higher densities; leading eventually to traffic slowdowns and then queues. This is the incident observed under hurricane evacuation conditions, in which the transportation system degrades after demand overwhelms supply (Sbayti and Mahmassani , 2006). Many attempts have been directed toward easing the

congestion during hurricane evacuation since it does not border solely on loss of productivity and environmental degradation as it is in the day-to-day congestion but more on the prevention of disastrous and life threatening occurrences. Amongst these endeavors is the use of traffic simulation models for investigating emergency evacuation scenarios.

Efforts directed to investigate hurricane evacuation scenarios using traffic simulation modeling unveil complexities and limitations in dealing with route choice at evacuation. Traffic assignment models are the basic tool used by transportation planners to develop road space plans over a transportation network that estimate the pattern of traffic flows over a network. These models are also employed to approximate the movement of evacuees over time in an emergency evacuation scenario. Route choice models during emergency evacuation are very intricate partly due to the fact that behavior in an evacuation scenario could be significantly different from that under normal commuting conditions.

In most emergency evacuation study assumptions regarding route choice have to be made. Understanding the assumptions that underlie the route choice models, and the limitations they engender, will help identify those combinations of models and assumptions that are appropriate for, or compatible with, evacuation scenarios. The study will further review the various route choice techniques other authors have used and the attained advantages. This review will help further expand on the most promising approaches. Techniques that are used to represent transportation route choices are described in section 2.7.1. Some selective route choice models are

described in section 2.7.2. Studies of the impact of route choice model simulations at hurricane evacuation are described in section 2.7.3.

2.7.1 Routes Representation Techniques

This section classifies and describes some of the common approaches used by transportation practitioners for modeling route choice by automobile users. Most transportation modeling applications adopt a graph theoretic representation of the physical network. That is, intersections are represented as nodes, and roadways are represented as links or arcs (the terms are equivalent), which end at nodes. Fig. 4 shows typical transportation networks for the Rhode Island metropolitan area.

Links may be identified by their tail and head nodes, also called A-Nodes and B-Nodes, and may represent one- or two-way streets. Associated with each link is a collection of attribute values, such as distance, number of lanes, speed limit, capacity and uncongested travel time. Nodes could also have attributes associated with them, such as intersection delays or transfer waiting times on transit. These network graphs, including related link and node attributes, are easily implemented in a Geographical Information Systems (GIS) environment.

Figure 4. Rhode Island Statewide Travel Demand Model Network (RISM,2006)

2.7.2 Route Choice Models (Algorithms and Behaviors)

The theory and application of route choice models has been around now for over five decades (see for example, Wardrop, 1952; Wachs 1957; Tagliacozzo and Frizio, 1973; Vaziri and Lam, 1983; Sheffi, 1984). This section discusses network algorithms based on the category of behavior they represent. Assuming that individual traveler

choices interact with network characteristics to minimize marginal user costs/travel times (notably capacity) the user optimal equilibrium flows prevail. Given steady state conditions, the resulting flow pattern can be established using the shortest path algorithm. Given congested flow conditions, algorithms establishing user optimal equilibrium travel times, which satisfy Wardrop's First Principle, must be enacted.

In 1952, a British traffic engineer, Wardrop proposed the following network equilibrium principles which states that "the journey times on all routes actually used are equal and less than those which would be experienced by a single vehicle on any unused route" This is known as Wardrop's first principle or condition for user – optimum (UO) assignment. The key behavioral assumption underlying the user equilibrium assignment model is that every traveler has perfect information concerning the values of the alternative network attributes, all travelers choose the route that minimize their travel time or travel cost and all travelers have the same valuation scale for network attributes. No individual travelers can unilaterally reduce their travel time by changing paths (Sheffi, 1985). The consequence of the UE principle is that all used paths for O-D pairs have the same marginal costs.

User optimal equilibrium flows assume that travel times on all links are known with certainty by travelers in real-time. Such assumption may be difficult to satisfy. If not satisfied, a more realistic assumption is that travel times are stochastic, perhaps due to traveler perception errors. User optimal equilibrium flows obtained under this latter assumption derive from stochastic algorithms. Conceivably, a traveler may seek to optimize multiple objectives resulting in travel patterns determined through algorithms that follow the "labeling" approach.

Additionally, assuming that operators can impose travelers' choices that interact with network attributes to minimize average and total, rather than marginal, user costs/travel times, system optimal equilibrium flows prevail. Ensuing equilibrium flows satisfy Wardrop's second principle, "the average journey time is a minimum". Route flow assignments that satisfy this principle have been referred as System Optimal (SO) route choices. The discussion that follows reviews in more depth the algorithms derived to achieve user optimal route choices on highway networks.

Shortest Path Algorithm –Assuming no congestion on network or constant travel times on links and paths, and perfect information on the state of the network by drivers, an "All-or-Nothing" assignment can be adopted to solve the user-equilibrium route assignment problem. An "All-or-Nothing" traffic assignment ignores that link travel times are flow dependent and that multiple path could be used to carry traffic for each specific O-D pair given congestion (Caliper Corporation, 2012). Hence, the totality of trips between each O-D pair gets loaded on the shortest path between this pair. Shortest paths between pairs can be obtained through solving the "Shortest Path Problem." Dijkstra (1959) and Ahuja, Magnanti and Orlin (1993) provide a well-established solution for the "Shortest Path Problem". Jan, Horowitz and Peng (2000) examined driver route choice data recorded by Global Positioning System (GPS) receivers, and presented anecdotal evidence that the subject travelers in Lexington, Kentucky, did not select the shortest path. Those authors stated that the data do not allow further analysis of why the drivers did not choose the shortest path.

User Equilibrium (UE)–When the network becomes congested and travel time becomes variable, as with emergency evacuation scenarios, the traffic assignment

problem becomes more complex. Travel time derives from the flows, themselves dependent on travel time to form a nonlinear and nested relationship between the both. Transportation planning applications commonly use the Bureau of Public Roads (BPR) formulation for estimating congested travel time on links (U.S. Department of Commerce, 1964). This formula computes congested times as:

$$T_c = T_0 \left[1 + \alpha \left(\frac{V}{C} \right)^\beta \right]$$

where:

T_c = the congested travel time on a link

T_0 = the free-flow travel time

V = the hourly volume

C = the hourly “practical” capacity, and

α and β = calibration parameters. Typically, $\alpha = 0.15$ and $\beta = 4.5$

Wardrop’s first principle has been a great aid in formulating the flow-dependent shortest path assignment as done below.

$$\min_{(h)} z(h) = \sum_a \int_0^{f_a} c_a(x) dx$$

$$s.t.: \sum_{r \in R_{pq}} h_r = d_{pq}, \quad p \in P; q \in Q$$

$$h_r \geq 0, \quad r \in R_{pq}, \quad p \in P; q \in Q$$

Where:

$$f_a \equiv \sum_{pq} \sum_{r \in R_{pq}} h_r \delta_r^a, \quad a \in A$$

where:

d_{pq} = fixed flow from zone p to zone q (vehicles/hour)

h_r = flow on route r , a route from zone p to zone q that belongs to the set of routes R_{pq} , connecting zone p to zone q

$\delta_r^a = 1$, if link a belongs to route r from zone p to zone q , and 0 otherwise

$c_a(f_a)$ = generalized travel cost function for link a which depends only on f_a the flow on link a

Once formulated, the user optimal equilibrium problem can be solved using heuristic algorithms. Such algorithms use an iterative approach, which alternates between finding shortest paths for fixed travel times and recalculating travel times based on new link volumes and the BPR formula, stated above, until a state of travel time equilibrium is reached. Such equilibrium attains based on travelers' choices of routes and thus route flows (dependent upon travel times), and link travel times (dependent upon link flows). When travelers, who seek to minimize their travel times, have no more incentives to change routes, the iteration calculations have reached a state corresponding to Wardrop's first principle.

Stochastic User Equilibrium (SUE)– The simplest route choice models assume that travelers minimize a single variable such as total or marginal distance traveled, total or marginal travel time, total or marginal travel cost from trip origins to destinations. The rationale is to assign all trips to routes so that no driver can unilaterally enhance the average or marginal values experienced for the sought-after variable, as explained above. Such routes are assumed to be those that travelers would rationally choose given perfect information on the state of the network, or on the choices made by other drivers and the implications for the variable to minimize. Using a shortest path algorithm wholly assumes that the traveler being modeled is aware of all the links (and their costs) that are used by the algorithm.

Travel time and travel cost on network paths and links are expected to be flow dependent. Travel distances on network paths and links are of course constant and can always be available to drivers pre-planning their trips. For the commute-to-work,

assuming no incidents on the network, its state can be gauged with relative precision using past observations given the repetitiveness of flows. The availability of information on the state of travel time, for instance, over all network links or alternate paths to all drivers is dubious in the absence of the implementation of traveler information systems under emergency evacuation. Hence, equilibrium flows become elusive under such conditions.

An alternative equilibrium model was proposed by Daganzo and Sheffi (1977) called Stochastic User Equilibrium or SUE, since the assumption that backs the user equilibrium model may not provide very realistic descriptions of loaded traffic networks (Slavin, 1996). This model is premised on the assumption that travelers have imperfect information about network paths and/or vary in their perceptions of network attributes. Based on the variation in traveler perceptions of network attributes including the level of service experienced, utilized paths may not necessarily have identical marginal costs. Stochastic assignment often adopts the multinomial logit (MNL) model for spreading travelers among different feasible path. MNL assumes that travelers have the same error distribution in the utility term, the Type I Extreme Value or Gumbel distribution. In the case of stochastic assignment, these errors are theorized to result from perception errors of travelers. This model is commonly written as follows:

$$P(i) = \frac{e^{-\theta L_i}}{\sum_{j \in C_n} e^{-\theta L_j}}$$

where:

$P(i)$ = the probability of a traveler using path i , (assuming homogenous traveler characteristics)

C_n = the choice set of feasible paths for individual n

L_i, L_j = the length (impedance) of paths i and j , respectively

θ = a utility coefficient or “spread parameter.

Dial (1971) developed the STOCH algorithm to assign trips among links according to the MNL formulation without having to explicitly identify or “enumerate” the possible paths in C_n . The STOCH algorithm uses a choice set consisting of all paths given only links that would take a traveler further away from the origin and closer to the destination. Such paths may be called “efficient” or “reasonable” in the stochastic traffic assignment literature. As in the case of deterministic user equilibrium, an iterative procedure can be used to achieve consistency between the travel times assumed during stochastic loading and the travel times that would result from applying a congestion relation to those assigned flows.

The Labeling Approach—This approach was proposed by Ben-Akiva, Bergman, Daly and Ramaswamy (1984), where objective functions or labels are used for generating multiple possible paths that might be considered by those traveling from a given origin to a given destination. It is assumed that different travelers may have different objective functions in seeking routes. Some drivers may wish only to minimize travel time. Others may feel uncomfortable making difficult maneuvers, and therefore avoid lane changes, freeways, heavily-congested roads or left turns at intersections without protected signals. Still others, perhaps making trips for non-work purposes or with considerable arrival time flexibility, may seek out scenic routes. Each of these criteria may correspond to a different route being preferred, and thus, each route can be “labeled” by the criterion (or criteria) for which it is optimum.

System Optimum Route Choice— Attaining the system optimum flows requires that the flows be directed along routes in some manner. With the current development of

real time traffic data systems, system optimal route choice has become increasingly important in transportation planning route modeling process and also greatly favored for evacuation modeling if the data are available.

2.7.3 Impact of Route Choice Models on Simulation during Evacuation

Evacuation modeling approaches have tended to merge somewhat into two different styles of route selection and route planning model in recent years. The first style has evolved from the traffic engineering literature and is based upon detailed simulation, either of individual vehicle movements ("micro-simulation") or of the movements of limited numbers of vehicles forming part of a traffic stream or "platoon" ("meso-simulation") coupled to relatively simple evacuee route selection logic. The second style of modeling termed "macro-simulation" relies upon a more aggregate representation of traffic as a series of flows, while attempting to match this demand for road space to the capacity of the highway systems. Only the former supports the implementation of Wardrop's principles given steadily flowing traffic vehicles with no bottlenecks or traffic jams.

Conventional planning applications, known as static, model traffic at deterministic flow values that do not change over time. Thus, the conditions of the highway network at the beginning of the simulation remain unchanged throughout the entire traffic loading period. This assumption of non-fluctuating flows, make static traffic assignment very unsuitable for evacuation modeling given the oversaturated conditions, with buildup of queues, that generally ensues from a restricted evacuation window through which to evacuate at-times large number of evacuees simultaneously. Hobeika and Kim (1998) compared two different traffic assignment (static models)

procedures for nuclear power plant evacuation modeling that use a traffic simulator and concluded that a user equilibrium (UE) assignment utilized in MASSVAC 4.0 showed better results than a shortest-path algorithm in MASSVAC 3.0 based on two performance measures, namely, evacuation time and the number of congested links.

Using the dynamic features of network flows and given the Wardrop's second principle, or system optimal (SO) route choice control theory, a number of simulation-based dynamic traffic assignment (DTA) modules have been developed in the recent past such as VISTA, CONTRAM, DynaMIT, and DYNASMART-P. Sattayhatewa and Ran, 2004, came up with a system optimal dynamic traffic assignment (SO-DTA) model specifically designed for nuclear power plant evacuations. Their model addresses two different evacuation applications: minimization of total evacuation travel time of the disaster zone without predefining a target evacuation time, and minimization of travel times for each origin–destination (O-D) pair.

Ziliaskopoulos, 2002 came up with the cell-based model which has been applied by a number of authors to solve the emergency evacuation. This model is built on the well-embraced cell transmission to represent traffic dynamics and has an appealing simple linear programming structure. Tuydes and Ziliaskopoulos, 2006 extended the earlier work to yield the optimal evacuation contraflow.

CHAPTER 3

METHODOLOGY

Evacuation traffic models have three basic inputs: evacuee information, route information and external information (Chang, 2003) all meant to inform the evacuation modeling effort. The evacuee information subdivides into demographic and socio-economic information, anticipated behavioral information, and preparedness information, all geared relevant to trip production derivations. Evacuees' demographic and socio-economic information includes residents' population, number of vehicles per household, household income, race, number of children in the household, availability of pets in the household, type of house structure and so forth. Evacuee anticipated behavioral information includes inputs such as compliance with evacuation notice or participation rate, destination percentages and so forth. Evacuee preparedness information relates to such as the acknowledgement of residing within a hurricane prone zone, as well as the presence or absence of household evacuation plan.

Route information includes inputs such as TAZs, designated evacuation routes, roadway geometry, archived real-time traffic data collected during past hurricane threats. *External information* includes inputs such as the government policies in place towards evacuation, the location of destinations/ trip attractions such as shelter and hotels in non-evacuation zones. It also relates to information on the transient/tourist population towards the derivation of their trip productions and attractions, such as the extent and location of hotels within the evacuation zones. In essence, it relates to all the external factors that indirectly affect resident evacuation/trip production decisions.

The vast majority of this data informs trip attraction derivations. The discussion that follows considers the data relevance to evacuating households and evacuee response information within section 3.1, data relevant to the network and route information are in section 3.2, and lastly data relevant to evacuation trip attraction, the hotel, motel and residential occupancy data are within Section 3.3.

3.1 Data Relevant to Residential Evacuating Households

Much of the data relevant to evacuating households in Rhode Island was collected using a two-stage research process. The first data collection was developed by researchers for the Rhode Island Multi-modal Hurricane Evacuation Plan Project, University of Rhode Island (URI), sponsored by the Rhode Island Department of Transportation (RIDOT) and probing anticipated evacuee response behavior. Secondly evacuating households data were sourced using GIS platform from RIGIS, Rhode Island State Travel Demand Model and US Census Data 2010 for RI (later discussed Sections 3.2 and 3.3). The former evacuee households' data research design was developed through research team members meeting in weekly discussion groups. The research focus was to ascertain the level of hurricane preparedness of Rhode Islanders and the effect demographic attributes might have on evacuation decisions. The target respondent was the head of a Rhode Island household.

The primary direction for the research design is specifically looking at household preparedness and the decision to evacuate or not. To this end, a survey instrument was designed and analyzed within the 2-stage process. The survey scrutinized the six dimensions of household hurricane preparedness specified by Sutton and Tierney (2006) including 1) hazard knowledge, 2) formal and informal response plans and

agreements, 3) life safety protection, 4) property protection, 5) initiation of recovery, and 6) emergency coping and restoration of key functions.

Although some earlier studies suggested ambivalence effect of demographic and socio-economic attributes on the evacuation decision (Baker, 1991; Lindell, 2007), the first objective of the research team was to probe further this hypothesis in view of the Hurricane Katrina evacuation outcomes. Secondly, some earlier research on evacuation warning had repeatedly confirmed that people are most likely to take protective action if they believe that they and their loved ones are at risk (Mileti et. al 1975; Baker 1979; Drabek 1986; Baker 1991; Fitzpatrick and Mileti 1994; Lindell and Perry 1992; Gladwin et. al. 2001; Tierney et al 2001, Lindell and Perry 2004). Based on the afore-mentioned concept, the research team also examined the preparedness of heads of households in the coastal towns of Rhode Island.

A random sampling of evacuation preparedness focused on the five communities believed to be most at-risk based on the results of Campbell et al. (2007): Warwick, Newport, Barrington, East Providence and Narragansett. In addition, Jamestown was surveyed, largely due to its island location and its limited access to mainland. In final analysis, the evacuation zone C, in Providence, was substituted for East Providence due to the perceived uncertainty with which the barrier might actually curtail the storm surge from a major hurricane (this barrier has been reinforced since). Thus, both the towns, Jamestown and Providence, tie to evacuation risk uncertainties not captured by the above-mentioned risk study. Zone C further displayed the highest level/index of persons without automobile, 1,304, a risk contributing factor well accounted for by the study. The selected towns encompass Warwick, Newport, Barrington, Providence,

Narragansett and Jamestown with a combined population of 323,667 (Census Bureau, 2000) and individualized populations of 84,772, 26,475, 16,819, 173,618, 16,361 and 5,622 respectively.

Statistical analysis led to the minimum sample size needed to provide reliable proportion parameter estimates for a population that is not normally distributed. Let ME denote the desired margin of error as shown in the eq. 3-1 below;

$$ME = Z_{\alpha/2} \sqrt{\frac{\hat{p}(1 - \hat{p})}{n}} \quad 3.1$$

where:

$Z_{\alpha/2}$ = the z-score, 1.96 for a 95% confidence interval

$\hat{p}$ = the point estimator of the population proportion (p),

n = the sample size.

Solving this equation for n provides a formula for the sample size that will provide a desired chosen margin of error.

$$n = \frac{(Z_{\alpha/2})^2 \hat{p}(1 - \hat{p})}{ME^2} \quad 3.2$$

Given that the population parameter is unknown, for an initial assessment, the value of 50% is used to minimize the deviation of the assumed value from that actual. The margin of error is set at 5% and z-score of 1.96 is selected for a 95% confidence interval which translates into;

$$\frac{1.96^2 \times (0.5) \times (1 - 0.5)}{0.05^2} = 384.16$$

Based on this information, it was determined that a sample size of 400 respondents would be adequate. Assuming a response rate of about 16%, the research team decided to generate 2,500 survey questionnaires.

3.1.1 Survey Instrument Design for Capturing Evacuee Response

Survey questionnaires as research instruments provide respondents with a greater opportunity to offer more considered responses and to verify their information. A major concern was to construct a survey instrument that was brief and concise but thorough enough to obtain essential data. In the process of developing the final survey, numerous revisions took place to identify the key necessary questions.

Several questions were developed based on the guiding hypotheses that inform the hurricane preparedness issues. Particular preparedness focus was organized into five areas: 1) hazard knowledge; 2) perception about hurricane evacuation shelters; 3) knowledge derived from previous hurricane experiences and availability of personal evacuation plans; 4) decisions at time of evacuation; and 5) demographics. Finally, previous hurricane-based surveys and questionnaires were reviewed, including the "Harvard University Questionnaire for Residents of Southern Atlantic and Gulf Coast States" and the "Rhode Island survey on Hurricane Gloria/Mid Atlantic/Northeast, Phase II", 1987.

Particular aims of the survey questions were as follows:

1. Preparedness among the respondents for the eventuality of hurricanes,
2. Perception about hurricane evacuation shelters,
3. Medical supplies and their usage at the time of hurricane emergency,
4. Knowledge about emergency items list,
5. Knowledge about flood zones,
6. Insurance information and awareness of what to carry out of the house at the time of emergency evacuation,
7. Destination in the eventuality of emergency evacuation,

8. Travel distance and travel time to the destination in the eventuality of an emergency evacuation,
9. Means of transportation used at emergency evacuation,
10. Willingness by the people to evacuate their homes located in the flood zones at the time of emergency,
11. Anticipated time frame to start to evacuate the flood zones,
12. Anticipated time frame to return home in the aftermath of the hurricane,
13. Age, educational level, and ethnicity,
14. Ownership status and estimated value of home, monthly wages,
15. Number of children, senior citizens and vehicles in the household.

3.1.2 Survey Measure of Scale

The measures of scale utilized in the survey for most of the data responses are such as; Agree/Disagree, Yes/No, Presence/Absence, Low/Medium/High, 1/2/3, etc. The data response obtained from the survey can thereby be classified as qualitative data. A direct compilation of the responses by the respondents to the questionnaires was made.

Category 1 questions probed the respondents' assessment of their exposure to a major hurricane, their state of preparedness and their perception of shelter conditions. Categories 2 and 3 questions investigated the attributes that are important for the deduction of the respondents' behavioral pattern upon hurricane threat: stockpiling of the resources necessary for an effective response, and acquiring knowledge that ensures effective performance of disaster-mitigation related tasks. The survey enumerates nine important resources; namely food and water for three days and all members of the family, battery-operated radio, flashlight, first aid kit, extra batteries, cell phone, at least \$300 in cash, and sterno stove (non-electric device). A unit score

is allocated to the possession of each of these emergency items by a respondent. The scores were summed up with their total for each respondent ranging from 0 to 9.

Category 4 questions sought after the demographic attributes of the respondents. *Age* is reported in years as a discrete variable. *Education* is reported within these eight categories: 1-elementary school, 2-middle school, 3-high school, 4-community college, 5-trade school, 6-bachelor degree, 7-graduate school, 8-professional school. *Home ownership* is coded as an indicator variable with 1 to represent a homeowner and 0, a renter. *Length of residence* is classified into six categories representing the number of years that the respondent had lived in the community. *Number of vehicles* in a household and the *Number of vehicles for evacuation* were reported as discrete variables. They measured the total number of vehicle holdings per household and the total number of vehicles expected to be used for evacuation. *Number of persons under the age of 18 years* and *Number of persons 65 years and above* in households were coded as mere indicator variables, with 1 conveying the presence of either and 0, their absence. *Estimated home value* is classified into ten classes and *Household income* into six.

3.1.3 Survey Dissemination

The methods utilized in conducting the survey dissemination were by the following: mail, in-person and over the University of Rhode Island's website. The primary method of distributing the surveys was through the mail. The mailed surveys were prepared by the company Survey Sampling International, located in Fairfield, CT. With their services they were able to refine the mailings to residents whose zip codes are located in the six communities namely Providence, Warwick, Barrington,

Newport, Narragansett, and Jamestown but not necessarily in the evacuation zones. A total of 2000 pre-paid envelopes were mailed out by URI's post office.

The mailing surveys were designed in ways in which once a person completed them they could just fold them in half, staple or tape the loose ends, remove the sticker with their address on it in order to remain anonymous, and finally return the prepaid postage where it would be received by URI Multimodal Hurricane Evacuation Plan Project. The in-person surveys' dissemination was by placing the questionnaires at the malls, public libraries, community clubs, and churches in the selected communities where residents randomly chose to participate in the survey process out of their own volition. The last dissemination method was by placing a link for the surveys on the University of Rhode Island's website, where the residents in the selected communities who chose to participate in the survey process were able to go online and fill out the survey.

3.2 Data Relevant to the Network and Route Information

Vital to this study are the Rhode Island hurricane surge inundation areas (evacuation zones), Rhode Island road network system, Rhode Island hurricane evacuation routes, and the Rhode Island emergency plan for hurricane evacuation. The Rhode Island hurricane surge inundation area (GIS format) was sourced from Rhode Island Geographic Information System (RIGIS), the RI state travel demand base model that includes the TAZs and roadway network information was collected from the Rhode Island Division of Planning, Rhode Island's metropolitan planning organization (MPO), and the RI hurricane evacuation routes was obtained from the Rhode Island Department of Transportation (RIDOT).

3.2.1 Evacuation Zones in Rhode Island Coastal Regions

The Rhode Island hurricane evacuation zones are as shown in Figs. 5, 5a, 5b, 5c, 5d and 5e were mapped using the RI evacuation zone layer that was downloaded from the Rhode Island Geographic Information System (RIGIS). This section discusses the derivation of the zones as detailed in the Rhode Island Hurricane Evacuation Study Hurricane Surge Inundation Maps, July 2009. The U.S. Army Corps of Engineers, New England District prepared the Rhode Island hurricane surge inundation map to identify the land areas potentially exposed to hurricane storm surges. These land areas are determined for hurricane categories spanning from the Saffir /Simpson hurricane scale, which assigns an intensity category to a hurricane based on its maximum sustained wind speed as shown in Table 2.

Table 2. Saffir / Simpson Hurricane Scale

Category	Maximum Sustained Wind Speed (mph)
1	74 - 95
2	96 - 110
3	111 - 130
4	131 - 155
5	> 155

The Rhode Island hurricane evacuation zones were determined using the model for Sea, Lake and Overland Surges from Hurricanes (SLOSH). SLOSH Model was developed by the National Weather Service to calculate potential surge heights from hurricanes. The SLOSH models for the Rhode Island Hurricane Evacuation Study were run by the Storm Surge Group, National Hurricane Center, and National Centers for Environmental Prediction, National Oceanic and Atmospheric

Administration, Miami Florida. The SLOSH model calculated the hurricane surge elevation that would result from over 500 combinations of hurricane category, landfall location, forward speed, and direction. The Boston SLOSH model basin was used, assuming a peak hurricane surge at mean high water.

For each hurricane category, the hurricane surge elevation that results from the worst case combination of hurricane landfall location, forward speed, and direction at each location along the coast was used in preparing the hurricane surge inundation mapping. The horizontal projection of this map is Rhode Island State Plane NAD83 feet and all elevation data was referenced to the NAVD88 vertical datum. SLOSH hurricane surge elevations have an accuracy of +/- 20%. The vertical accuracy of all elevation datasets varies while horizontal accuracy is approximately +/- 3 meters.

Evacuation area A corresponds to that area exposed to tidal flooding for minor hurricanes (categories 1 and 2). Evacuation area B pertains to that area exposed to major hurricanes' flooding (category 3 and above). Evacuation area C represents that area exposed due to the probable failure of the Fox Point Hurricane Barrier in the city of Providence. A special case existed in the City of Providence due to the Fox Point Hurricane Barrier. The top of the barrier is at elevation 24.18 feet NAVD88. According to the National Hurricane Center's SLOSH model, which was used to create the Hurricane Surge Inundation Areas cited in process step 1, the peak worst-case category 2 hurricane surge water surface elevation just seaward of the barrier is 14.7 feet, and the peak worst-case category 3 hurricane surge water surface elevation just seaward of the barrier is 19.6 feet NAVD88. These are still-water

elevations, and do not include wave run-up. Therefore, the worst-case category 2 & 3 still-water surge would not be expected to overtop the barrier. Waves on top of the category 3 surge could overtop the barrier, but no wave run-up analysis was done (Rhode Island Hurricane Evacuation Study Hurricane Surge Inundation Maps, July 2012). Nevertheless, current study considers all of the evacuation area C as exposed under severe hurricane threat. Future studies will investigate the structural soundness of this assumption.

3.2.2 RI Statewide Travel Demand Model

This section reviews the Rhode Island Statewide Travel Demand model (RISM), as derived for the journey-to-work, to determine applicability of its roadway network and model calibration to a hurricane evacuation scenario. RISM was procured from the State of Rhode Island Division of Planning. It was created in the 1990s by the Statewide Planning Program (RISPP) of the Rhode Island State Division of Planning in association with the RIDOT. It was updated using the 2000 Census demographic data and the contemporaneous roadway network in 2006 and lastly in 2011 (the version used in this study). RISM's network was changed to reflect the road centerline layer of the RIDOT statewide GIS. This layer extends the modeling possibilities to scenarios other than the journey-to-work and particularly to evacuation scenarios as contemplated herein. The RISM network model contains all roads classified above local and un-classified.

Figure 5. Map of Rhode Island Hurricane Evacuation Zones

Figure 1. Map of Rhode Island Hurricane Evacuation Zones (Providence Area)

Figure 2. Map of Rhode Island Hurricane Evacuation Zones (Bristol and Kent Counties)

Figure 3. Map of Rhode Island Hurricane Evacuation Zones (Washington and Newport Counties)

Figure 4. Map of Rhode Island Hurricane Evacuation Zones (Washington and Newport Counties)

Figure 5. Map of Rhode Island Hurricane Evacuation Zones (Washington County)

Rhode Island Transportation Analysis Zones

RISM, obtained from Statewide Planning as explained above, divides the state of Rhode Island into traffic analysis zones (TAZs).with centroids. Centroid connectors are coded network links that load or feed the TAZ trip data on to the model network in the trip assignment step. . In total, there are 904 TAZs within the state of Rhode Island connected to 957 centroids as shown in Fig. 11.

Figure 11. Rhode Island Statewide Travel Demand Model Network

The Rhode Island Statewide Model contains 1,257 TAZs including 904 for the entire state of Rhode Island as well as 353 for bordering towns, namely 286 in Massachusetts and 67 in Connecticut. The building block of the RISM TAZ is the census block, the smallest census geographic unit. A TAZ aggregates all, and only, the census blocks within a block group; thereby coinciding with geographically with this block group. The unit of aggregation allows for the population and household data available at the census block to be directly transferable to a unique TAZs; thereby promoting spatially accurate data. Year 2000 population, number of households, and number of vehicles data used in the RISM was obtained from Caliper Corporation's census CDs. The CDs contained population and household data at the block level and the number of vehicles at the block group level for Rhode Island and portions of Massachusetts and Connecticut. Table 3, shows the total household data by state.

Table 3. Total Household Data by State in RISM

STATE	RHODE ISLAND	MASSACHUSETTS	CONNECTICUT	TOTAL
Population	1,048,319	339,735	77,495	1,465,549
Households	408,424	130,473	30,534	569,431
Average Household Size	2.57	2.6	2.54	2.57
# of Autos	658,520	215,697	55,130	929,347
Autos per Household	1.61	1.65	1.81	1.63
Retail Employment	87,818	33,176	6,780	127,774
Non-Retail Employment	378,481	104,512	22,650	505,643

Table 2.2- RI Statewide Planning Program Technical Paper Number 157 (2006, updated 2011)

The Population forecasts for each town in Rhode Island were included by the RISPP for the years 2005, 2010, 2015, 2020, 2025, and 2030. The model includes forecasts for both households and vehicles for 2005, 2010, 2015, 2020 and 2025.

External stations in the model explicitly refers to some outside the RISM model TAZs through which traffic enters the model from Massachusetts and Connecticut, . Each roadway that crosses the model's geographic boundaries is assigned an external station TAZ number. External stations differ from the other TAZs as they only load traffic onto the network and possess no socioeconomic or geographic attributes. There are 35 external TAZs in the Rhode Island Statewide Model. The external station volumes derive from the following:

- i. Trips from outside the model area to outside the model area (external-to-external, denoted as 'EE')
- ii. Trips from outside the model area to inside the model area (external-to-internal, denoted as 'EI').
- iii. Trips from inside the model area to outside the model area (internal-to-external, denoted as 'IE').

RISM Calibration – The four steps traditional travel demand modeling was utilized in building the model. Similar to many travel demand models the RISM is based on the three trip purposes methods namely home-based work (HBW), home-based other (HBO), and non-home-based (NHB). The home-based work trips represent trips traveling between a people's home (produced) and work (attracted) without stopping between the two locations. Home-based other trips are trips traveling between home

and a non-work destination without stopping between the two locations. Non-home-based trips include all other trips where neither end is the home.

The person trip productions were calculated using a cross- classification method that incorporates a 20-cell matrix of households by size and auto availability. The rates vary by trip purposes and areas (urban and rural) as shown in Tables 4 through 9

Table 4. RISM Daily Weekday Person Trip Rates per Household (HBW) – Urban

# of	1 PER	2 PER	3 PER	4+ PERS
0	3.24	5.88	0.77	0.87
1	5.88	0.92	1.13	1.35
2	5.88	1.07	1.35	1.56
3	5.88	1.07	1.56	1.76
4-plus	5.88	1.07	1.76	1.98

Table 4.2- RI Statewide Planning Program Technical Paper Number 157 (2006, updated 2011)

Table 5. RISM Daily Weekday Person Trip Rates per Household (HBO) – Urban

# of	1 PER	2 PER	3 PER	4+ PERS
0	1.58	2.83	3.40	4.99
1	2.83	4.08	5.43	7.94
2	2.83	4.64	6.35	9.53
3	2.83	4.64	7.37	10.67
4-plus	2.83	4.64	8.61	11.91

Table 4.3 RI Statewide Planning Program Technical Paper Number 157 (2006, updated 2011)

Table 6. RISM Daily Weekday Person Trip Rates per Household (NHB) – Urban

# of	1 PER	2 PER	3 PER	4+ PERS
0	0.64	1.19	1.40	1.73
1	1.19	1.62	2.16	2.70
2	1.19	1.94	2.59	3.24
3	1.19	1.94	3.03	3.57
4-plus	1.19	1.94	3.46	4.00

Table 4.4 RI Statewide Planning Program Technical Paper Number 157 (2006, updated 2011)

Table 7. RISM Daily Weekday Person Trip Rates per Household (HBW) – Rural

# of	1 PER	2 PER	3 PER	4+ PERS
0	3.24	5.17	0.82	1.03
1	5.17	0.87	0.97	1.30
2	5.17	1.03	1.13	1.51
3	5.17	1.03	1.30	1.66
4-plus	5.17	1.07	1.40	1.83

Table 4.5- RI Statewide Planning Program Technical Paper Number 157 (2006, updated 2011)

Table 8. RISM Daily Weekday Person Trip Rates per Household (HBO) – Rural

# of	1 PER	2 PER	3 PER	4+ PERS
0	1.58	2.94	4.64	6.92
1	2.49	4.08	5.89	8.61
2	2.49	4.99	6.69	10.20
3	2.49	4.99	7.60	11.34
4-plus	2.49	5.33	8.51	12.48

Table 4.6- RI Statewide Planning Program Technical Paper Number 157 (2006, updated 2011)

Table 9. RISM Daily Weekday Person Trip Rates per Household (NHB) – Rural

# of	1 PER	2 PER	3 PER	4+ PERS
0	0.76	1.29	2.06	2.37
1	1.07	1.83	2.49	3.03
2	1.07	2.27	2.91	3.57
3	1.07	1.49	3.24	4.00
4-plus	1.07	1.49	3.67	4.00

Table 4.7- RI Statewide Planning Program Technical Paper Number 157 (2006, updated 2011)

On the other hand, the trips attracted to zones were estimated using a regression process and is calculated using the following equations:

$$\text{HBW Attractions} = 2.03 * \text{Total Employment}$$

$$\text{HBO Attractions} = (13.05 * \text{Retail Employment}) + (2.26 * \text{Non-Retail Employment}) + (0.9 * \text{Number of Households})$$

$$\text{NHB Attractions} = (1.39 * \text{Retail Employment}) + (1.78 * \text{Non-Retail Employment})$$

The trip balancing is performed using the procedure in TransCAD Planning – Balance where the trips produced were held constant in the procedure as there is generally a greater degree of reliability in production (household) model data than attraction (activity center/work) model data. Trip attractions are then scaled to the productions. Table 3.8 shows the number of year 2000 trips by trip purpose and compares them to default percentages from NCHRP Report 365, “Travel Estimation Techniques for Urban Planning”.

Table 10. RISM Percent Distribution by Trip Purpose

Trip Purpose	Modeled	%	NCHRP
Home-based Work	1,214,359	20.9%	20.0%
Home-based Other	3,279,188	56.5%	57.0%
<u>Non-home-based</u>	<u>1,307,628</u>	<u>22.6%</u>	<u>23.0%</u>
Total	5,801,175	100%	100%

Table 4.8- RI Statewide Planning Program Technical Paper Number 157 (2006, updated 2011)

Prior to trip distribution step the travel time between each TAZ is calculated based on the model base year highway network. The highway skim matrix contains the travel times between each TAZ. The travel time between external stations, known as impedance, is set to a very high value (300 minutes) so that trips between external TAZs are not distributed. All external-to- external trips are also defined using the EE trip table. The intra-zonal travel time is calculated based on the average travel time to the closest three TAZs multiplied by a factor of 0.17. The trip distribution step matches trip productions to trip attractions. The trip distribution is calculated using a gravity model. The gravity model used in the Statewide model is based on typical travel demand model exponential equations with c-values equal to

0.195 for home- based work trips; 0.145 for home-based other trips; and 0.135 for non-home-based trips. These c-values are exponential coefficients are to weight the relationship between travel time and the attraction between two TAZs. The c-values were slightly adjusted to achieve more accurate trip patterns and average trip lengths. The adjusted values are 0.100 for home-based work trips; 0.200 for home-based other trips; and 0.200 for non-home- based trips. The maximum number of iterations was increased from 10 to 35 and the convergence factor was held constant at 0.001. The output of the trip distribution step is the production/attraction (P-A) matrix. The production/attraction trip table is transposed (row and column data are swapped), and then divided by two in order to convert to origin/ destination (O-D) matrix. O-D matrix is also converted from a person trip table to a vehicle-trip table by applying average auto-occupancy rates, home-based work–1.12, home-based other – 1.56, and non-home-based– 1.56. The final aspect of the trip distribution step is to append the EE trip table onto the vehicle trip tables for home-based work trips, home-based other trips, and non- home-based trips. All four tables are then summed and the total trip table is entered into the traffic assignment step of the model. The Planning Traffic Assignment procedure of TransCAD prompts the user for the appropriate OD trip table to be assigned to the network. The traffic assignment step loads the total vehicle-trip table calculated in the trip distribution step onto the model network to simulate traffic flow for a particular analysis year. The process predicts travelers route choices and identifies paths between origins and destinations that will have the shortest travel times or costs. To improve model

assignment results, the minimum number of equilibrium iterations was increased from 7 to 40, and the convergence criteria was reduced from 0.01 to 0.005.

3.2.3. Evacuation Roadway Network

Evacuation routes (truly road networks) derived through past efforts by RIDOT, in combination with the Rhode Island Emergency Management Agency (RIEMA), jointly with other State Agencies, transportation professionals and mostly the coastal RI communities, for ease of emergency hurricane evacuation. These routes were provided in GIS format by RIDOT's GIS division. The study confirms the availability of these routes within RISM. Since evacuation routes/roads are classified above local, the study anticipates their modeling by RISM. The paragraphs that follow describe the derivation effort by state and local government officials of the RI evacuation routes utilized by the current study. Initially, varied local hurricane evacuation routes existed as derived by individual communities (within their local emergency response plans) without any coordination amongst themselves (not even for neighboring communities), let alone regionally. Stakeholder meetings, encompassing DOT personnel, local CEOs, local Emergency Management Directors and fire/police personnel in the coastal communities, addressed the potential traffic snarls and road capacity problems that could result from implementing the set of individual plans. Stated meetings lead to the following delineations on maps:

1. Primary and secondary roads to be used for hurricane evacuation (Such roads are not susceptible to flooding)
2. Traffic control points (typically located at intersections to aid in directional flow and closed roads)

3. Shelters
4. Evacuation Signs (to be relocated)
5. Potential assets that would be needed (personnel to aid in implementing traffic control during evacuation)

Field trips and SLOSH maps confirmed that the proposed roads were the least susceptible to flooding by surges. RIDOT's GIS section further assessed the routes and digitized them. The communities were then provided with hard color copies to review and amend as needed. Thereafter, regional meetings ensured a coordinated regional evacuation through the appropriate revisions to evacuation routes and flows (e.g. no "dumping" of evacuees into neighboring states).

Once the evacuation routes were finalized, RIDOT created a web server to display them and allow users to interactively determine their locations relative to the flood zones, shelters and evacuation routes. Currently, Rhode Island coastal roadways display emergency evacuation route signs, round blue with directional arrows, as shown in Fig 12. These routes do not necessarily lead to shelters or a particular place but rather away from the evacuation zones (shaded in blue in Fig.7) and towards higher and safer ground. The hurricane evacuation routes, also known as Emergency Evacuation Blue Routes, were procured from RIDOT in GIS format and mapped onto the Rhode Island Statewide Model network as shown in Fig. 7 to expand the latter's road network as necessary for hurricane evacuation.

Figure 12. Evacuation Route Signs

Figure 13. The Hurricane Evacuation Routes (Emergency Evacuation Blue Routes)

3.3 Data Relevant to the Non-Residential Evacuees and the Trip Attractions

External information in this study entails mainly three necessary data inputs that have an indirect effect on the hurricane evacuation clearance time of residents within the evacuation zones. These consist of 1) the tourists' population in the coastal evacuation area, 2) the probable locations of attraction outside the evacuation zone, and lastly 3) the behavioral and travel pattern of Rhode Island residents that are not in evacuation mode which might provide the background traffic at evacuation.

3.3.1 Rhode Island Seasonal Homes, Hotels, Motels, Inns, and Camps.

The current study considered tourists among those vulnerable to potential losses of life and property upon hurricane landfalls in Rhode Island. To this end, it first gathered from US Census 2010 data seasonal houses in Rhode Island obtained from the Caliper Corporation. It further estimates the extent of seasonal households within the evacuation areas using GIS analytical methodology and some assumptions in Chapter 5. Secondly, the names of all hotels, motels, inns, bed-and-breakfast, and camps located within or outside of the evacuation zones are collected from the Rhode Island Department of Commerce and Tourism. The facility names lead to the determination of facility occupancies using an online search. TransCAD software helps convert the hotel data into GIS point data, as shown in the Fig.10. The GIS hotel layer with the inundation map are useful for differentiating hotels from which tourists might evacuate as opposed to those that may attract evacuees, residential and non-residential/touristic, given their respective locations within or outside the evacuation zones.

3.3.2 Rhode Island Red Cross Hurricane Evacuation Shelters

Emergency hurricane shelters in Rhode Island operate under a system developed by the American Red Cross. These shelters are located outside the flood zones and meet state building codes for harbor against hurricane threat agents (wind, storm surge, landslide and tornado). Hurricane shelters operate under Red Cross guidelines and provide basic first aid only. Thus, individuals receiving home healthcare need other forms of sheltering and possibly a more suitable evacuation destination at the onset of hurricanes. Pets are not allowed in public shelters but daily

living assistance animals are allowed to accompany their owners. As a result, other options need be considered for animal sheltering at hurricane evacuations.

Each locality has a list of facilities, often public schools, which have been designated as emergency shelters in the advent of hurricanes. The listing of designated emergency Red Cross shelters was collected in GIS format from RIDOT as shown in Fig. 11.

Figure 14. Rhode Island Hotels, Motels, Inns and Bed-Breakfasts

Figure 1. Rhode Island Red Cross Hurricane Shelters and their Capacities

3.3.3 Rhode Island Census Data for Households with Occupancy per Room Less than One

The last and most important trip attractors during hurricane emergency evacuation are the houses of family/relatives or friends. It is very challenging to determine the specific houses, outside the evacuation zones, that will attract evacuees. This study utilizes as desirability contributors to residential homes, outside of the flood areas, the occupancy per bedroom ratio and the distance to these areas.

One of the study assumption is that the greater the number of homes and apartments with occupancy per room less than 1 in a TAZ, the stronger the attractiveness of this TAZ to evacuees. The households in Rhode Island with the occupancy per room less than 1 are sourced from US Census 2010 data shown in Fig. 11B. The second assumption is the distance the evacuees' households are willing to travel. Question 4f of the survey instrument designed for the study probed the anticipated travel distance of heads of households at hurricane evacuations and the survey results are in Table 2 and discussed later in Chapter 4. The anticipated pattern of evacuee travel distances, based on survey results, will be used to calibrate the friction factor. The friction factor parameters will be then utilized in the evacuation modeling to distribute the evacuees to their destinations. (Refer to Chapter 5, Section 5.2).

CHAPTER 4

SURVEY ANALYSIS AND FINDINGS

4.1 Evacuee Survey Outcomes

479 people within the evacuation and non-evacuation zones of the coastal study area of Rhode Island responded to the survey. The overall response rate achieved was approximately 20% for completed surveys over the total administered. A compilation of the data reported by respondents in survey questionnaires is as shown in Tables 1 and 2, Appendix A. The paragraphs that follow describe the compiled descriptive statistics from the survey data. They then discuss the respondents' demographics and the findings on all six dimensions of household preparedness: hazard knowledge, formal and informal response plans, life safety protection, property protection, emergency coping and restoration of key functions, and initiation of recovery.

Respondents' Demographics Statistics

Table 1, displays the demographic statistics of respondents. Age was reported as an integer and averaged 52 years with a standard deviation of 16 years. The highest education achieved equaled 0 (0.2)%, 1%, 21%, 8%, 2%, 32%, 28% and 7% (for the eight (8) reporting categories, elementary school, middle school, high school, community college, trade school, bachelor program, graduate school and professional school, respectively). Racial background, reported within each of six (6) categories, equaled 90%, 4%, 0 (0.7)%, 1%, 2% and 2% for Caucasian, African American, Asian American, Native American, Hispanic and two or more of the previous races. Seventy

nine percent (79%) reported home ownership status whereas 21% reported rental status. Housing type, declared within five (5) categories, equaled 76%, 12%, 8%, 4%, and 0 (0.4)% for single family homes, duplex or multiple family homes, apartment buildings, condominiums and mobile homes, respectively. The length of community residence, reported within six (6) categories, equaled 5%, 24%, 13%, 19%, 30% and 9% for less than 1 year, 1 to 5 years, 6 to 10 years, 11 to 20 years, more than 20 years and entire life. Twenty eight (28)% and 31% of heads of household agreed, whereas 72% and 69% disagreed to having persons under the age of 18 and above the age of 65 in their households, respectively. Thirty four (34)% lived in the evacuation zones whereas 66% did not.

Respondents' Hazard Knowledge

Table 2 conveys compiled respondents' knowledge of hurricane hazards. Questions 1c, 4c and 1d probed the awareness of the hazard posed by hurricanes to respondents. In response to 1c, twenty four percent (24%) agreed and 74% disagreed that their homes were likely to be flooded in a major hurricane. Out of the 74% that disagreed, 55% did not live in the evacuation zones whereas 19% did. Out of the 24% that agreed, only 15% resided in the evacuation zones and 9% did not.

Answers to question 4c could not be verified for the potential for riverine flooding under hurricane threat given the lack of knowledge of exact respondent addresses for survey privacy reason. Also inland/riverine flooding maps did not exist at the time of initiation of thesis conduct. Fifty two (52)% answered that they "do not know" the evacuation zone in which their house resides. Although the wind hazard risk is ubiquitous, only 71% agreed and 27% disagreed that their homes were likely to be

damaged by wind in a major hurricane. Approximately 2% did not answer the questions related to evacuation zone and potential wind damage awareness.

Respondents' Formal and Informal Response Plans

The survey probed the evacuation decision, timeframe, destination, transportation mean, distance, and travel time. With regards to the evacuation decision 80% agreed and 18% disagreed, given 2% missing data that they would leave their homes if they were asked to evacuate by government officials. Still, 57% agreed and 39% disagreed that they would evacuate following an evacuation advice from an elected official, given 4% missing data. Compliance with an evacuation advice increases when the advice source becomes weather services, 61% agreed and 35% disagreed, police officers or firefighters, 75% agreed and 21% disagreed given 4% missing data. An outstanding 53% agreed and 43% disagreed that they would like to ponder their own concern about the severity of a hurricane in making the evacuation decision given 4% missing data. With regards to the decision not to evacuate, possible reasons cited included: no official notice (38%), crowded roads (31%), well-built and safe home (30%), worries about possessions getting stolen (29%) or pets (24%), evacuation unnecessary per officials (21%).

Disregarding respondents not in the evacuation zones, 71% anticipate leaving in less than 6 hours, 6% between 6 and 12 hours and 8% later than 12 hours, given 12% missing data and 3% undecided. With regards to evacuation destination, 46%, 11%, 10%, 3%, and 27% would be housed by a friend or family member, in public shelters, in hotels or motels, elsewhere, and "do not know", respectively, given 3% missing data. Eighty six percent (86%) of respondents anticipate evacuating using own

cars; 1%, friend's cars; 2%, public transportation, 4%, walking or cycling given that 4% that "do not know" and 3% missing data.

Respondents' Life Safety Protection

Questions 3h, 3i, 3j, 3k, 3l and 4b, probed the plans for life safety protection under hurricane threat. Seventy four percent (74%) of respondents agreed, 25% disagreed, given 1% missing data, that someone in their households takes prescription drugs on a regular basis. Only 36% agreed, 41% disagreed, given 1% missing data and 22% to which the topic did not apply, that all of their household members maintain a three-week supply of their regular prescription drugs. Further, that the prescription coverage of their household members prevented the collection of extra medicine supplies, 48% agreed, 28% disagreed given 1% missing data and 22% to which the question did not apply.

That someone in their households would require outside help to evacuate due to a chronic illness or disability, 11% agreed and 88% disagreed given 1% missing data. That they had pre-arranged help for the evacuation of the chronically ill or disabled person in their households, 2% agreed, 9% disagreed, given 1% missing data and 88% to which the topic did not apply. Finally, 90% agreed and 9% disagreed, given 1% missing data, that they had health insurance or health plan coverage.

Respondents' Property Protection

Question 4b probed the plans for the protection of property by the heads of household respondents. Seventy four (74)%, 16%, and 7% agreed whereas 25%, 83%, and 92% disagreed, given 1% missing data, that they owned home, flood and rental insurance, respectively.

Respondents' Emergency Coping and Restoration of Key Functions

Question 4a probed the availability of plans for emergency coping and the restoration of key function by heads of household respondents under hurricane threats. Eighty one percent (81%) and 61% agreed whereas 17% and 37% disagreed, given 2% missing data, that they had enough food and water for three days for each member of their families, respectively. Sixty three percent (63%), 88%, 73%, 74%, 88%, 36% and 35% agreed; 36%, 10%, 25%, 24%, 10%, 62%, 63%, given 2% missing data, that they owned battery-operated radios, flashlights, first-aid kits, extra batteries, cell phones, cash and stenos respectively.

Respondents' Initiation of Recovery

Eighty four percent (84%), 67%, 51% and 57% agreed whereas 13%, 30%, 45% and 40% disagreed, given 3% missing data, that at evacuation they would carry proofs of health insurance, prescription drugs, homeowners insurance and social security cards, respectively.

Table 1. Survey Results - Questions 5 (A-E)

		Responses (%)								Missing data
5a	Age (years)	18 -29	30 - 41	42- 53	54 - 65	66 - 77	78- 89		90	
		3.74	11.43	20.58	29.73	21.21	8.94		2.5	1.87
	I have completed the following educational level	Elementary	Middle School	High School	Community College	Trade School	Bachelor Degree	Graduate School	Professional School	
5b		0.21	1.04	19.74	8.11	2.08	32.85	28.69	6.86	0.42
5c	I belong to the following racial or ethnic group	Caucasian	African American	Asian American		Native American	Latino / Hispanic		Others	
		86.69	3.95	0.62		0.62	1.46		3.13	3.53
5d	My housing status is the following	Own					Rent			
		78.17					20.37			1.46
5e	My housing unit is	Single family home	Duplex or multi-family home		Apartment building		Condominium		Mobile home	
		75.47	11.23		7.28		4.56		0.21	1.25

Table 2. Survey Results - Questions 5 (H-N)

		Responses (%)								Missing data
5h	I have lived in my community for the following span of time	Less than 1 yr		1-5 yrs	6-10 yrs	11-20yrs	More than 20 yrs		My Entire life	
		3.95		19.75	11.23	16.01	25.16		7.69	16.22
5i	My household contains the following number of vehicles	One Vehicle	Two Vehicles		Three Vehicles		Four Vehicles		Others	
		24.53	40.12		18.71		11.44		4.16	1.04
5j	I would use the following number of vehicles for evacuation	One Vehicle	Two Vehicles		Three Vehicles		Four Vehicles		Others	
		64.24	25.78		3.95		0.42		2.91	2.7
5k		YES					NO			
	My household contains kids (< 18)	28.27					70.48			1.25
5l	My household contains seniors (>65)	30.35					66.74			2.91
5m	The estimated value of my home falls within the following range	Below \$100K	\$100K - \$149K	\$150K - \$199K	\$200K- \$299K	\$300K- \$349K	\$350K - \$399K	\$400K - \$499K	\$500K and above	
		5.2	2.08	5.61	26.61	11.02	8.11	14.55	17.88	8.94
5n	My annual household income is within this range	Below \$25K	\$25K - \$39K		\$40K- \$79K	\$80K - \$120K		Over \$120K	Do not know	
		10.81	11.23		29.73	19.54		16.42	3.95	8.32

Table 3. Survey Results - Questions 1

		Response (%)				
		Strongly Disagree	Disagree	Strongly Agree	Agree	Missing data
1a	I am prepared if a major hurricane strikes my community during the next 6 months	11.23	36.79	40.96	9.15	1.87
1b	I am more prepared for a major hurricane this year than I was last year	13.72	45.95	31.81	6.86	1.66
1c	My home is likely to be flooded in a major hurricane	36.59	37.42	16.84	6.86	2.29
1d	My home is likely to be damaged by wind in a major hurricane	6.03	21.00	56.13	14.97	1.87
1e	I am confident that I would be rescued if a major hurricane hits and I did not evacuate my home	14.35	34.51	40.74	8.32	2.08

Table 4. Survey Results - Questions 2

	Opinion on shelter	Strongly Disagree	Disagree	Strongly Agree	Agree	Missing data
2a	I would have enough clean water to drink	6.86	28.28	51.14	12.06	1.66
2b	I would have enough food to eat	5.2	26.82	54.05	12.06	1.87
2c	I would have the prescription drugs or medicines that I need	10.6	25.99	45.53	14.76	3.12
2d	I would be threatened by violence	25.16	51.97	17.46	2.08	3.33
2e	I would need medical care and I wouldn't be able to get it	11.23	46.78	34.3	4.57	3.12
2f	The shelter would be unsanitary	8.73	44.28	35.97	8.11	2.91
2g	I would be exposed to sick people and could catch their illnesses	7.48	38.67	42.83	8.32	2.7
2h	The shelter would be too crowded and I would not have any privacy	1.87	5.41	29.31	10.4	53.01
2i	I would have a hard time communicating with family outside the shelter	2.7	14.97	25.16	4.36	52.81

Table 5. Survey Results - Questions 3

		YES	NO	Missing data	Not Applicable
3a	I live in an area prone to river flooding.	17.46	81.5	1.04	
3b	My home was threatened or hit by a major hurricane in the past	29.53	68.81	1.66	
3c	I evacuated my home because of this hurricane.	5.82	90.02	4.16	
3d	I am concerned that a major hurricane will hit my community in next 6 months	27.65	71.31	1.04	
3e	I would leave my home, if I were asked to evacuate by government officials due to a major hurricane.	80.45	18.09	1.46	
3f	I have attended some meetings, classes, or workshops on preparing for a hurricane during the past year	9.15	90.43	0.42	
3g	My family has agreed on a phone number to contact outside the region, in the event of a hurricane.	22.45	76.51	1.04	
3h	Someone in my household takes prescription drugs on a regular or ongoing basis	74.43	24.74	0.83	
3i	All of my household members always maintain a three week supply of their regular prescription drugs	35.56	41.16	0.83	22.45
3j	The prescription coverage of my household members prevents the collection of extra medicine supplies	48.45	28.27	0.83	22.45
3k	Someone in my household has a chronic illness or disability that would require outside help during a hurricane evacuation	11.43	87.53	1.04	
3l	If yes, I have pre-arranged help for this chronically ill or disabled person's evacuation	2.08	9.15	1.24	87.53

Table 6. Survey Results - Questions 4(A- D)

4a	At home, I have the following hurricane emergency items:	1	2	3	4	5	6	7	8	9	Missing data	
		3.33	3.53	5.82	8.74	10.60	16.63	18.92	18.50	11.44	2.49	
4b	I am covered at this time by all of the following insurance types:	Yes					No					Missing data
4b1 /4b2	Health insurance/health plan	90.02					9.15					0.83
4b3	Home insurance	74.43					24.74					0.83
4b4	Rental insurance	7.49					91.68					0.83
4b5	Flood insurance	15.59					83.58					0.83
4b	No insurance	6.24					92.93					0.83
4c	My home is located in the following hurricane evacuation zone	Zone A	Zone B	Zone C		Not in evacuation Zone			Do not know		Missing data	
		14.55	8.95	2.49		19.54			51.77		2.7	
4d	Following the evacuation notice, I would plan to leave the flood zones within the timeframe	0 - 1 hr	1- 3 hr	3 - 6 hr		6 -9 hr		9 - 12 hr	> 12 hr	Not in evacuation Zone	Undecided	Missing data
		14.97	28.27	12.27		2.7		2.08	5.82	22.87	1.66	9.36

Table 7. Survey Results - Questions 4(E – J)

4e	If I were to evacuate my home because of a hurricane, I would go to the following destination:	friend/family member's home		A hotel/motel		shelter		Do not know	Others	Undecided	Missing data
		45.95		10.39		11.23		20.59	2.7	6.02	3.12
4f	If I were to evacuate my home because of a hurricane I would travel the following distance	Less than 10 miles	10 - 50 miles		50 - 100 miles	100 - 200 miles	More than 200 miles		Undecided	Missing data	
		31.39	33.47		13.1		8.11		5.41		2.49
4g	If I were to evacuate my home because of a hurricane, I would use the following means of transportation	My Car	Friend's car		Public Transportation	Walking or riding bike	Undecided		Missing data		
		85.86	1.46		2.08		3.12		4.15		3.33
4h	If I were to evacuate my home because of a hurricane, I estimate that I would reach my destination within this timeframe	1 hour	2 hours		3 hours	4 hours	5 hours	Others	Undecided	Missing data	
		51.56	15.8		11.02		2.91		4.16	6.65	1.87
4j	If I had to evacuate because of a major hurricane, I would return home within the following timeframe	Soon as the hurricane is over					Once officials say that it is safe to return			Others	Missing data
		34.93					58.84			1.66	4.57

Table 8. Survey Results Questions 4(I – K)

4I	If I were to evacuate my home within 6 hours of a hurricane evacuation notice, I would take with me the following list of document items:	YES	NO	MISSING DATA
i	Proof of health insurance	83.58	12.89	3.53
ii	Prescriptions for the drugs that my household members take	66.74	29.73	3.53
iii	Proof of homeowner's or renter's insurance	50.94	45.53	3.53
iv	The social security cards of my household members	56.76	39.71	3.53
4K.	Please check all the reasons why you might not evacuate:			
i	I would not know where to go	17.67	69.23	13.10
ii	I would not have a car	5.20	81.70	13.10
iii	I would not know anyone who could give me a ride	3.74	83.16	13.10
iv	I have medical or physical problems that would prevent me from leaving	3.53	83.37	13.10
v	I have to take care of someone who would be physically unable to leave	4.78	82.12	13.10
vi	I would be worried that my possessions would be stolen or damaged	28.90	58.00	13.10
vii	I would not want to leave my pet	23.91	62.99	13.10
viii	I would not be able to afford to leave	6.65	80.25	13.10

Table 9. Survey Results - Questions 4(K –L)

4K	Please check all the reasons why you might not evacuate:	YES	NO	Missing
ix	I would not be able to leave my job	8.52	78.38	13.10
x	I think that my home is well built and that I will be safe at home	30.15	56.75	13.10
xi	I think evacuating would be dangerous	13.93	72.97	13.10
xii	I think the roads would be too crowded to leave	31.19	55.72	13.10
xiii	Some officials said that the evacuation is unnecessary	21	65.9	13.10
xiv	the media said that the evacuation is unnecessary	18.92	67.98	13.10
xv	My friend or relative said that the evacuation is unnecessary	2.91	83.99	13.10
xvi	I think there is a low risk of a hurricane hit	18.3	68.61	13.10
xvii	I received no official notice to evacuate	37.84	49.06	13.10
xviii	I left unnecessarily in the past	4.37	82.54	13.10
4l	The following reasons would convince me to leave for a safer place:			
i	Advice or order by elected officials	57.17	38.88	3.95
ii	Advice from weather service	60.71	35.34	3.95
iii	Advice or order from police or firemen	75.47	20.58	3.95
iv	Advice from friend or relative	18.92	77.13	3.95
v	Concern about severity of hurricane	52.81	43.24	3.95
vi	Concern that hurricane might hit	29.31	66.74	3.95
vii	Heard low risk of a hit	3.95	3.95	3.95
viii	Other reasons	3.53	92.52	3.95

4.2 Hypotheses on Critical factors affecting Evacuee Behavior

The first objective examined whether the demographic and socio-economic respondent attributes affect evacuation decision. Three behavioral variables convey evacuation decision; namely (1) decision to evacuate or not to evacuate, (2) likely time to evacuate, and (3) evacuation destination. Hypotheses A to D probed the effects of the demographic and socio-economic variables on the decisions to evacuate or not to evacuate. Hypothesis E - H probe the respondents' evacuation destination, departure time and number of household vehicles planned to be used at evacuation. The second objective assessed the hazard knowledge of the heads of households and its effect on evacuation preparedness. It further probed whether hurricane workshop participation has an effect on preparedness. Hypothesis I probes the relationship between hurricane evacuation workshop attendances with evacuation preparedness. The Hypotheses are as follows in the below subtitles.

Hypothesis “A”: Relationship between Lower Income and Education Levels with Evacuation Decision.

1. The lower the income [Question: 5n] and the lower the education level [Question: 5b], the larger the proportion of residents who would prefer to evacuate before a hurricane [Question: 3e].

Or

2. Within income and educational levels, there will be no difference between those who would prefer to evacuate before a hurricane.

Hypothesis “B”: Relationship between Evacuation Decision with Age and Income

1. The age and income levels [Question: 5a, 5n] will reflect the evacuation prefer of Rhode Island coastal residents [Question: 3e].

Or

2. Within age and income levels there is no difference between those who prefer to evacuate hurricane zones.

Hypothesis “C”: Relationship between Evacuation Decision with Race, Age and Income.

1. The racial group identification [Question: 5c], age [Question: 5a], and income levels [Question: 5n] will reflect the evacuation preferences of Rhode Island coastal residents [Question: 3e].

Or

2. Within racial group [Question: 5c], age [Question: 5a], and income levels [Question: 5n], there will be no difference between Rhode Island coastal residents who prefer to evacuate [Question: 3e].

Hypothesis “D”: Relationship between Prior Hurricane Evacuation Experiences with Evacuation Decision.

1. Having prior experience with hurricane evacuation [Question: 3c], the larger proportion of residents would evacuate [Question: 3e].

Or

2. Among residents with or without prior experience with hurricane evacuation [Question: 3c], there will be no difference between those who would evacuate [Question: 3e].

Hypothesis “E”: Relationship between Lower Income and Lower Education Levels with Evacuation Destination.

1. The lower the income [Question: 5n] and the lower the education level [Question: 5b], the household will be more likely to go to an evacuation shelter [Question: 4e].

Or

2. Within income and education levels [Question: 5n, 5b], there is no difference between households that prefer to go to an evacuation shelter.

Hypothesis “F”: Relationship between higher Income with Evacuation Time, and Evacuation Travel Distance.

1. Persons with higher incomes [Question: 5n] will be more apt to travel farther distances [Question: 4f] and leave earlier after a notification to evacuate [Question: 4d].

Or

2. Within income levels [Question: 5n], there is no difference to how far [Question: 4f] and how early people will evacuate [Question: 4d].

Hypothesis “G”: Relationship between Household with Young Children and Evacuation Departure Time.

1. Persons with households with young children [Question: 5k] will evacuate faster after an evacuation notice [Question: 4d].

Or

2. Within households with young children [Question: 5k], there will be no difference regarding early evacuation [Question: 4d].

Hypothesis “H”: Relationship between Numbers of Vehicles Owned and the Numbers of Households’ Vehicles planned to be used for Evacuation.

1. Households owning more than one vehicle [Question: 5i] will not utilize all their vehicles during evacuation [Question: 5j]

Or

2. Within households with more than one vehicle [Question: 5i], there is no difference regarding between the number of vehicles owned and the number they will be using during evacuation [Question: 5j].

Hypothesis “I”: Relationship between Hurricane Evacuation Workshop Attendances with Evacuation Preparedness.

1. Persons who attend hurricane evacuation workshops [Question: 3f] are better prepared for a major hurricane [Question: 1a-b, 4a-k].

Or

2. Within the group of persons who attend hurricane evacuation workshops [Question: 3f], there is no difference regarding how prepared they are for a major hurricane [Question: 1z-b, 4a-k].

4.3 Findings on Evacuation Preference Based on Socio-Economics and Demographics Factors

The common variable for *hypothesis A – D* is variable 3e which enquiries about evacuation preference (to evacuate or not to evacuate) of the respondent. Variable 3e as shown in the frequency table (Table 20) below, is a binominal categorical variable that contains 2 levels (Yes=1 and No=0).

In order to confirm whether variable 3e the evacuation preference of the respondent does depend on whether the respondents reside in the evacuation zone or non-evacuation zone, a pre- analysis Chi-Square difference test is performed.

Table 20. Analysis of Variable 3e –Evacuation Preference

3e	Frequency	Percent	Cumulative Frequency	Cumulative Percent
No	87	18.35	87	18.35
Yes	387	81.65	474	100.00

Frequency Missing = 7

The pre-analysis tests the association between evacuation zone and evacuation preference. Variable 4c as shown in the frequency table (Table 21) below is a categorical variable which asked the participants' understanding about which hurricane zone they are living. This variable 4c contains five levels (1= Evacuation Zone A, 2= Evacuation Zone B, 3=Evacuation Zone C, 4=Not in evacuation zone, 5=Don't Know). For the pre-analysis the five groups were collapsed into two classes Evacuation Zone (1=Zone A, 2=Zone B, 3=Zone C), and 4= Not in evacuation zone, together with 5=Don't Know.

Table 21. Analysis of Variable 4c-Evacuation Knowledge

4c	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Zone A	68	14.14	68	14.14
Zone B	41	8.52	109	22.66
Zone C (Providence)	14	2.91	123	25.57
Not in Evac zone	92	19.13	215	44.70
Don't know	253	52.60	468	97.30
Missing	13	2.70	481	100.00

As shown in the Table 22, the row percentage of participants in the non-evacuation zones with preference to evacuate if asked by the government officials is

81.09% while those of the participants who reside in the evacuation zones is 82.72%. Within this sample the difference are not significant. The Chi Square test result P-value (0.664) is greater than $\alpha = 0.05$ and did not support any association between evacuation preference and evacuation zone or not evacuation zone or even if the participants don't know zone. This result displays high evacuation compliance level. (82%) of the RI coastal residents are ready to get out of the path of hazard whether they are in evacuation or non-evacuation or even if they don't know. However the downside is that the roadway might be congested and inhibiting those that really need to get out of harm's way from achieving this with much traffic delay. Thus, hypothesis A-D analyses are using full sample of variable 3e disregarding wherever the respondents are living in evacuation zone or outside of evacuation zone.

Table 22. Relationship between Evacuation Zones versus Evacuation Preference

evaczone(evacuation zone)	3e(Evacuation Preference)		Total
Frequency Percent Row Pct Col Pct	Yes	No	
Not evac zone and Don't Know	253 53.38 81.09 65.37	59 12.45 18.91 67.82	312 65.82
In evac zone	134 28.27 82.72 34.63	28 5.91 17.28 32.18	162 34.18
Total	387 81.65	87 18.35	474 100.00
Statistic	DF	Value	Prob
Chi-Square	1	0.1882	0.6644

Frequency Missing = 7

Hypothesis A

Hypothesis A examines the relationship between lower income and education levels with evacuation preference. In addition to variable 3e, two other variables are

incorporated namely variable 5n and variable 5b. Variable 5n shown in Table 23 is a categorical variable which probes about income level, and contains 6 levels (Less than \$25k=1, \$25k-40k=2, \$40k-80k=3, \$80k-120k=4, Over \$120k=5, Do Not Know=6). This analysis is using the first 5 levels out of 6 levels. This analysis define 6th level (Don't know) and no response as treated missing value as shown in the table below.

Variable 5b shown in Table 24 is a categorical variable which probed about education level the participants completed, and contained 8 levels (Elementary, Middle School, Community College, College (Bachelor's Degree), Graduate School, Professional School, and Trade School).

Table 23. Analysis of Variable 5n –Income Level

il	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Lt \$25k	52	12.29	52	12.29
\$25k-40k	54	12.77	106	25.06
\$40k-80k	143	33.81	249	58.87
\$80k-120k	94	22.22	343	81.09
Over \$120k	80	18.91	423	100.00

Frequency Missing = 58

Some categories had small sample size, therefore this variable was recreated as 4 levels (Less than High School=1, Community College and Trade School=2, Bachelors=3, Graduate and Professional School=4) as shown in the table below.

Table 24. Analysis of Variable 5b – Education Level

edl	Frequency	Percent	Cumulative Frequency	Cumulative Percent
LT HighSc	96	20.04	96	20.04
Trade or CC	46	9.60	142	29.65
Bachelor	159	33.19	301	62.84
GraduateSc	178	37.16	479	100.00

Frequency Missing = 2

Two different Chi-square tests are performed to test the associations between education level and evacuation preference, and between income level and evacuation preference. As shown in the Table 25, the row percentage of participants based on their education level with preference to evacuate if asked by the government within the sample are not significantly different. The Chi Square test result P-value (0.200) is greater than $\alpha = 0.05$ and showed that there is no evidence of the relationship between education level and evacuation preference.

The second Chi-square tests conducted to test relationship between income level and evacuation preference. As shown in the Table 26, the row percentage of participants based on their income level with preference to evacuate displayed lack of significant difference from one income level to the other. The Chi Square test result P-value (0.769) is greater than $\alpha = 0.05$ and result confirmed that there is no evidence of the relationship between income level and evacuation preference.

To confirm whether the conclusion drawn from chi square test for Hypothesis A is correct, two types of logistic regression analyses were performed to investigate higher order interaction between evacuation preference and income and education levels (evacuation preference vs income level *education level). The first logistic regression model involved two-way interaction (il*edl) effect, and did not show any significance (as shown in the table 27 below). This indicated that there was no evidence for existing of higher order interaction, and suggested that another logistic regression model without higher order interaction should be performed. The second logistic regression model excluded the two way interaction effect from model 1, and did not

show any significant effect (as shown below in table 28). This result showed the same conclusion as the chi-square tests for hypothesis A.

Table 25. Relationship between Education Level versus Evacuation Preference

(Education Level) 5b	3e(Evacuation Preference)		Total		
Frequency	No	Yes			
Expected					
Percent					
Row Pct					
Col Pct					
LT High Sc	24	69	93		
	16.945	76.055			
	5.08	14.62	19.7		
	25.81	74.19			
	27.91	17.88			
Trade or CC	7	39	46		
	8.3814	37.619			
	1.48	8.26	9.75		
	15.22	84.78			
	8.14	10.1			
Bachelor	27	129	156		
	28.424	127.58			
	5.72	27.33	33.05		
	17.31	82.69			
	31.4	33.42			
Graduate SC	28	149	177		
	32.25	144.75			
	5.93	31.57	37.5		
	15.82	84.18			
	32.56	38.6			
Total	86	386	472		
	18.22	81.78	100		
Frequency Missing = 9					
Statistic		DF	Value	Prob	
Chi-Square		3	4.642	0.1999	

Table 26. Relationship between Income Level versus Evacuation Preference

il(Income level)	3e(Evacuation Preference)		Total
Frequency Expected Percent Row Pct Col Pct	No	Yes	
Lt \$25k	11	41	52
	9.2278	42.772	
	2.64	9.83	12.47
	21.15	78.85	
	14.86	11.95	
\$25k-40k	11	41	52
	9.2278	42.772	
	2.64	9.83	12.47
	21.15	78.85	
	14.86	11.95	
\$40k-80k	24	116	140
	24.844	115.16	
	5.76	27.82	33.57
	17.14	82.86	
	32.43	33.82	
\$80k-120k	13	80	93
	16.504	76.496	
	3.12	19.18	22.3
	13.98	86.02	
	17.57	23.32	
Over \$120k	15	65	80
	14.197	65.803	
	3.6	15.59	19.18
	18.75	81.25	
	20.27	18.95	
Total	74	343	417
	17.75	82.25	100
Frequency Missing = 64			
Statistic			DF
Chi-Square			4
			Value
			1.822
			Prob
			0.769

Thus, we can conclude that there is no evidence for the relationship between education level and evacuation preference, or between income level and evacuation preference. Hypothesis 2 should be retained.

Table 27. Logistic Regression Model for Evacuation Preference 2-Way Interaction between Income Level and Education Level

Testing Global Null Hypothesis: BETA=0			
Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	17.7066	19	0.5421
Score	17.0863	19	0.5840
Wald	12.6268	19	0.8571
Type 3 Analysis of Effects			
Effect	DF	Wald Chi-Square	Pr > ChiSq
il	4	1.0453	0.9029
edl	3	0.1732	0.9818
il*edl	12	9.1303	0.6918

Table 28. Logistic Regression Model for Evacuation Preference between Income Level and Education Level

Testing Global Null Hypothesis: BETA=0			
Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	4.3096	7	0.7435
Score	4.2986	7	0.7448
Wald	4.2276	7	0.7532
Type 3 Analysis of Effects			
Effect	DF	Wald Chi-Square	Pr > ChiSq
il	4	1.7106	0.7888
edl	3	1.9246	0.5882

Hypothesis B

Hypothesis B examines the relationship between age and income levels with evacuation preference. Variable 3e (evacuation preference) and variable 5n (income level) as earlier discussed and shown in the Table 20 and Table 23 will be used in this analysis. Variable 5a is a continuous variable which probed about the participants' age. A descriptive statistics of variable 5a is as shown in table 29 below.

Table 29. Analysis of Variable 5a- Age (Continuous)

Analysis Variable :				
N	Mean	Std Dev	Minimum	Maximum
472	52.336864	15.748248	18	90

The average of participants' age is comparatively high as a data from random sampling. However, possible explanations for this are "Older people usually have higher response rate than younger people", and "The target area of this study (around evacuate zone) contains more old people, because land value is high". From this variable, a new categorical variable "Age" was created. "Age" variable contains 4 categories: "Below 40 years old", "40 to 50 years old", "50 to 60 years old", and "Above 60 years old" as shown in table 30 below.

Table 30. Analysis of Variable 5a – Age (Categorical)

age	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Below 40yrs	95	20.13	95	20.13
40 to 50yrs	98	20.76	193	40.89
50 to 60yrs	122	25.85	315	66.74
Above 60yrs	157	33.26	472	100

Two chi-square tests are performed to test the associations between age and evacuation preference, and between income level and evacuation preference. As highlighted in the Table 31, the row percentage of participants based on their age class with preference to evacuate did not show any significant difference. The Chi Square test result of P-value (0.901) is greater than $\alpha = 0.05$ confirmed that there is no evidence of the relationship between age and evacuation preference (as displayed in table 31 below). Likewise, chi-square tests result earlier shown in the table 26 between

income level and evacuation preference ($p=.769$), showed no evidence of the relationship.

Table 31. Relationship between Age versus Evacuation Preference

age(Age)	3e(Evacuation Preference)		
Frequency Expected Percent Row Pct Col Pct			
	No	Yes	
Below 40yrs	18 17 3.87 19.35 21.18	75 76 16.13 80.65 19.74	93 20.00
40 to 50yrs	17 17.731 3.66 17.53 20.00	80 79.269 17.20 82.47 21.05	97 20.86
50 to 60yrs	20 22.301 4.30 16.39 23.53	102 99.699 21.94 83.61 26.84	122 26.24
Above 60yrs	30 27.968 6.45 19.61 35.29	123 125.03 26.45 80.39 32.37	153 32.90
Total	85 18.28	380 81.72	465 100.00
Frequency Missing = 16			
Statistic		DF	Value
Chi-Square		3	0.5801
			Prob
			0.9010

Two logistic regression analyses were performed to confirm the conclusions and to investigate higher order interaction between evacuation preference and income level and age (evacuation preference versus income level * age). This analysis used original continuous variable for age variable. The first logistic regression model as shown in table 32 below, involved two-way interaction (5a*il) effect, and did not show any

significance. This indicated that there is no evidence for existing of higher order interaction, and suggested that another logistic regression model without higher order interaction should be performed.

The second logistic regression model (in table 33) excluded the two way interaction effect from first model, and did not show any significant effect. Thus, we can conclude that there is no evidence for the relationship between age and evacuation preference, or between income level and evacuation preference. Hypothesis 2 should be retained.

Table 32. Logistic Regression Model for Evacuation Preference 2-Way Interaction between Income Level and Age

Testing Global Null Hypothesis: BETA=0			
Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	4.8672	9	0.8457
Score	4.7622	9	0.8545
Wald	4.5932	9	0.8682
Type 3 Analysis of Effects			
Effect	DF	Wald Chi-Square	Pr > ChiSq
5a (age)	1	0.0077	0.9302
il	4	1.5	0.8266
5a*il	4	2.5884	0.6289

Table 33. Logistic Regression Model for Evacuation Preference between Income Level and Age Level

Testing Global Null Hypothesis: BETA=0			
Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	2.121	5	0.8322
Score	2.1242	5	0.8317
Wald	2.1056	5	0.8344
Type 3 Analysis of Effects			
Effect	DF	Wald Chi-Square	Pr > ChiSq
5a	1	0.1366	0.7117
il	4	1.9823	0.739

Hypothesis C

Hypothesis C examines the relationship between race, age and income levels with evacuation preference. In addition to variables 3e (evacuation preference), 5a (age) and 5n (income) that have been discussed in the preceding analyses of hypotheses A and B, and their frequencies are as shown in Tables 20, 29 and 23 respectively, variable 5c (race) will be incorporated in this analysis. Variable 5c is a categorical variable that probes about the participants' racial background, and contains 5 classes as shown in the table 34 below.

Table 34. Racial Group

Racial Group				
rg	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Caucasian	417	92.05	417	92.05
African-Ame	19	4.19	436	96.25
Asian-Ame	3	0.66	439	96.91
Native Ame/indian	6	1.32	445	98.23
Latino/Hispanic	8	1.77	453	100.00

Frequency Missing = 28

Some classes contain relatively small number of frequencies and as a result this analysis recreates variable 5c as a binominal (1=Caucasian, 2= Other) as shown in the table 35 below.

Table 35. Racial Group Binominal

Racial Group Binominal				
rg2	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Caucasian	417	89.87	417	89.87
Other	47	10.13	464	100.00

Frequency Missing = 17

Chi-square tests are performed to test the associations between income level and evacuation preference, and between age and evacuation preference and their results

are as earlier shown in Tables 26 and 29. The third Chi-square test was also performed for this analysis to find the associations between racial group and evacuation preference. As shown in the Table 36, the row percentage of Caucasians with preference not to evacuate if asked by the government officials is given as 16.99% while those that are non-Caucasians is 30.43%. The sample difference of proportions is 0.134 and this implied that higher percentages of the other racial group tend to not - evacuate preference as compared to Caucasian racial group. The Chi Square test result P-value (0.025) is less than $\alpha = 0.05$ also confirmed that there is evidence for the relationship between the racial group and evacuation preference.

Table 36. Evacuation Preference by Race

rg2(Racial Group Binominal)	3e(Evacuation Preference)		Total
Frequency Expected Percent Row Pct Col Pct	No	Yes	
Caucasian	70 75.563 15.28 16.99	342 336.44 74.67 83.01	
	83.33	91.44	
Other	14 8.4367 3.06 30.43	32 37.563 6.99 69.57	46 10.04
	16.67	8.56	
Total	84 18.34	374 81.66	458 100.00
Frequency Missing = 23			
Statistic			DF
Chi-Square			1
			Value
			4.9941
			Prob
			0.0254

In addition to the three Chi-square tests conducted for *hypothesis C*, several number of logistic regression analyses were performed to test interaction effects. The tests did not show any interaction and main effect to evacuation preference. Tables 37

and 38 results of logistic regression only account for main effect, and show no significant effect at all independent variables. Thus, there is evidence only for the relationship between the racial group and evacuation preference. However, there is no effect of the income level and age to evacuation preference, or any interaction between age, income level, and racial group.

Table 37. Demographics Variables Versus Evacuation Preference

Testing Global Null Hypothesis: BETA=0			
Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	3.9445	6	0.6842
Score	4.1044	6	0.6625
Wald	4.0263	6	0.6731

Table 38. Demographics Variable and Evacuation Preference (Type 3)

Type 3 Analysis of Effects			
Effect	DF	Wald Chi-Square	Pr > ChiSq
_a	1	0.6262	0.4288
rg2	1	1.3756	0.2409
il	4	1.7075	0.7893

Hypothesis D

Hypothesis D examines the relationship between prior hurricane evacuation experiences with evacuation preference. In addition to variables 3e (evacuation preference), that has been discussed in the preceding analyses of hypotheses A, B and C, and the frequencies are as shown in Tables 20, variable 3c (Having prior experience with hurricane evacuation) will be included in this analysis. Variable 3c is a binomial categorical variable that probes about prior evacuation experience of the participants

and contains 2 levels (Yes=1 and No=0) its frequency is as shown in the Table 39 below.

Table 39. Relationship between Prior Experience versus Hurricane Evacuation

Prior Experience with Hurricane Evacuation				
3c	Frequency	Percent	Cumulative Frequency	Cumulative Percent
No	433	93.93	433	93.93
Yes	28	6.07	461	100.00

Frequency Missing = 20

Chi-square test was performed to test the association between the prior evacuation experience and the evacuation preference. As shown in the Table 40, the row percentage of participants with no prior hurricane evacuation experience and their preference to evacuate (81.31%) versus those that had prior hurricane evacuation experience (89.29%) and preference to evacuate did not show much significant difference. The Chi Square test result of P-value (0.289) is greater than $\alpha = 0.05$ confirmed that there is no relationship between the prior hurricane evacuation experience and the evacuation preference. Fisher Exact test was also performed to confirm this result because only three participants (less than 5 in the sample) are within the group of prior hurricane evacuation experience and preference not to evacuate. The Fisher Exact result also showed that there is no significant relationship between the prior hurricane evacuation experience and the evacuation preference. Thus, hypothesis 2 should be retained.

Table 40. Relationship between Prior Experience versus Evacuation Preference

3c(Prior Experience with Haricane Evacuation)	3e(Evacuation Preference)		
Frequency Expected Percent Row Pct Col Pct	Yes	No	
No	348 350.1 76.32 81.31 93.30	80 77.904 17.54 18.69 96.39	428 93.86
Yes	25 22.904 5.48 89.29 6.70	3 5.0965 0.66 10.71 3.61	28 6.14
Total	373 81.80	83 18.20	456 100.00
Frequency Missing = 25			
Statistic		DF	Value
Chi-Square		1	1.1233
			0.2892
Fisher's Exact Test			
Cell (1,1) Frequency (F)		348	
Left-sided Pr <= F		0.2150	
Right-sided Pr >= F		0.9134	
Table Probability (P)		0.1284	
Two-sided Pr <= P		0.4468	

4.4 Findings on Evacuation Destinations Based on Socio-Economics and Demographics Factors

Hypothesis E

Hypothesis E examines the relationship between lower income and education levels with evacuation destination of the household that will be more likely to go to hurricane evacuation shelter. In addition to variables 5n (income) and 5b (education) as frequencies table shown in Tables 23 and 24, variable 4e (shelter destination) is also utilized in this analysis. Variable 4e is a categorical variable probing about

participant's evacuation destination, and contained five levels (A friend or family's house, A hotel/motel, An evacuation shelter, don't know, other). Originally, this analysis planned to use recreated three levels (friend or family's house, hotel/motel, evacuation shelter) that excluding last two levels (Don't know, other) as missing value form the original five levels as the frequencies shown in Table 41 below.

Table 41. Analysis of Variable (4e) Evacuation Destination

evd	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Other house	221	63.51	221	63.51
Hotel	62	17.82	283	81.32
Shelter	65	18.68	348	100.00

Frequency Missing = 133

However, this approach created large missing values (133) as an alternative another 2 levels variable (Going to shelter (Yes), Not going to shelter (No)) was created from original variable. This case, "Not going to shelter (No)" contained "A friend or family's house, A hotel/motel, Other, Don't know", and only 12 missing as shown in the Table 42 below.

Table 42. Analysis of Destination Shelter

<i>Destination Shelter</i>				
evds	Frequency	Percent	Cumulative Frequency	Cumulative Percent
No	401	86.05	401	86.05
Yes	65	13.95	466	100.00

Frequency Missing = 15

Chi-square tests are performed to test the associations between education level and evacuation destination, and between income level and evacuation destination. As highlighted in the Table 43, the column percentage of participants based on their education level with preference of not choosing hurricane shelters as their destination

did not show any significant difference. The Chi Square test result of P-value (0. 0.745) is greater than $\alpha = 0.05$ that there is no evidence of the relationship between education level and evacuees choosing hurricane shelters as their destination.

Table 43. Education level Versus Evacuees Choosing Hurricane Shelters as Destination

evds by edl					
evds(Going to Shelter)	edl(Education Level)				
Frequency Expected Percent Row Pct Col Pct	LT HighSc	Trade or CC	Bachelor	GraduateSc	
No	78	37	137	147	399
	79.972	36.976	133.29	148.77	85.99
	16.81	7.97	29.53	31.68	
	19.55	9.27	34.34	36.84	
	83.87	86.05	88.39	84.97	
Yes	15	6	18	26	65
	13.028	6.0237	21.713	24.235	14.01
	3.23	1.29	3.88	5.60	
	23.08	9.23	27.69	40.00	
	16.13	13.95	11.61	15.03	
Total	93	43	155	173	464
	20.04	9.27	33.41	37.28	100.00
Frequency Missing = 17					
Statistic			DF	Value	Prob
Chi-Square			3	1.2352	0.7446

Likewise, as highlighted in the Table 44, the column percentage of participants based on their income level with preference of not choosing hurricane shelters as their destination did not show any significant difference. The Chi Square test result of P-value (0. 0.910) is greater than $\alpha = 0.05$ presented that there is no evidence of association between income level and evacuation destination (Going to Shelter).

Two logistic regression analyses were performed to make sure our conclusion and to investigate higher order interaction between evacuation to shelter preference and income and education levels (evacuation to shelter preference versus income level

*education level). The first logistic regression model involved higher (3rd) order interaction (il*edl) effect, and did not show any significance in Table 45.

Table 44. Relationship between Income level versus Evacuees Choosing Hurricane Shelters as Destination

evds by il						
evds(Going to Shelter)	il(Income level)					Total
Frequency Expected Percent Row Pct Col Pct	Lt \$25k	\$25k-40k	\$40k-80k	\$80k-120k	Over \$120k	
No	46	42	119	81	71	359
	45.421	42.8	119.67	82.107	69.005	
	11.19	10.22	28.95	19.71	17.27	87.35
	12.81	11.70	33.15	22.56	19.78	
	88.46	85.71	86.86	86.17	89.87	
Yes	6	7	18	13	8	52
	6.5791	6.1995	17.333	11.893	9.9951	
	1.46	1.70	4.38	3.16	1.95	12.65
	11.54	13.46	34.62	25.00	15.38	
	11.54	14.29	13.14	13.83	10.13	
Total	52	49	137	94	79	411
	12.65	11.92	33.33	22.87	19.22	100.00
Frequency Missing = 70						
Statistic			DF	Value	Prob	
Chi-Square			4	0.7799	0.9411	

This indicated that there was no evidence for existing of higher order interaction, and suggested that another logistic regression model without higher order interaction should be performed. The second logistic regression model excluded the higher order interaction effect from model 1, and did not show any significant effect as shown in Table 46. Thus, this result showed same conclusion as the chi-square tests showing.

Thus, we can conclude that there is no evidence for the relationship between education level and evacuation destination (Going to shelter or not), or between income level and evacuation destination (Going to shelter or not). We should retain hypothesis 2.

Table 45. Logistic Regression Model of Higher (3rd) Order Interaction for Evacuation Shelter Preference versus Income Level and Educational Level

Testing Global Null Hypothesis: BETA=0			
Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	11.4496	19	0.9078
Score	9.3634	19	0.9669
Wald	5.6579	19	0.9986
Type 3 Analysis of Effects			
Effect	DF	Wald Chi-Square	Pr > ChiSq
il	4	0.0023	1
edl	3	0.0418	0.9978
il*edl	12	3.565	0.9901

Table 46. Logistic Regression Model for Evacuation Shelter Preference Versus Income Level and Education Level

Testing Global Null Hypothesis: BETA=0			
Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	1.5751	7	0.9796
Score	1.5414	7	0.9808
Wald	1.53	7	0.9813
Type 3 Analysis of Effects			
Effect	DF	Wald Chi-Square	Pr > ChiSq
il	4	1.0226	0.9063
edl	3	0.7245	0.8674

4.5 Findings on Evacuation Departure Time and Travel Distance Based on Socio-Economics and Demographics Factors

Hypothesis F

Hypothesis F examines the relationship between higher income, evacuation departure time, and evacuation travel distance. Three variables are incorporated in analyzing *hypothesis F*, namely variable 4d (evacuation departure time), variable 4f (travel distance), and lastly variable 5n (income) that has been discussed in the earlier analysis and frequencies as shown in Tables 23. Variable 4d is a categorical variable probing participant's the time they would need before they leave evacuation zone. It contained 4 levels (0-1hour, 1-3hour, 3-6hour, More than 6hour). Originally, this variable had 7 levels (0-1hour, 1-3hour, 3-6hour, 6-9hour, 9-12hour, More than 12hour, I am not in an evacuation zone). However, the 7th level (I'm not in an evacuation zone) was defined as missing value, because there was no reason to include them into this analysis, since they had no will to evacuate. Also, 4th, 5th, and 6th levels had comparatively less number of frequencies than 1st, 2nd, and 3rd.

Thus, this analysis combined 4th, 5th, and 6th level as a new 4th level "more than 6hour." The frequency of this variable 4d is as shown in Table 47 below.

Table 47. Analysis of Variable (4e) Evacuation Departure Time

Variable 4d_Evacuation Time				
et	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0-1hr	73	22.26	73	22.26
1-3hr	138	42.07	211	64.33
3-6hr	64	19.51	275	83.84
>6hr	53	16.16	328	100.00

Frequency Missing = 153

Variable 4f queries participant's evacuation travel distance with 5 levels (Less than 10mile, 10-50mile, 50-100mile, 100-200mile, more than 200mile). Variable 4f was

collapsed to 3 classes (> 10 miles, 10-50miles, < 50miles) as shown in Table 48 because some cell have fewer number when a chi square test was first performed.

Chi-square tests are performed to test the associations between income level and evacuation departure time. As highlighted in the Table 49, within the participants' evacuation departure time classes and certain income level brackets, there are substantial difference between the column percentages that indicated that there is a relationship between evacuation departure time and income at various time level. The chi-square test result of P-value (0. 0.0098) is less than $\alpha = 0.05$ confirmed that there is an evidence of the relationship between income level and early evacuation. However, from this results we could not interpreted any linear fashion. Also, this result did not show "Higher income persons tend to evacuate earlier."

Table 48. Analysis of Variable (4f) Evacuation Travel Distance

Variable 4f Evacuation Distance				
Distance	Frequency	Percent	Cumulative Frequency	Cumulative Percent
<10ml	151	33.41	151	33.41
10-50ml	164	36.28	315	69.69
50-100ml	137	30.31	452	100.00

Frequency Missing = 29

Chi-square tests are also performed to test the associations between income level and evacuation distance. As highlighted in the Table 50, within the participants' anticipated evacuation distance destination away from home and their income level, showed certain substantial difference between the column percentages that indicated that there is relationship between evacuation distance and income at various time level. The chi-square test result p-value (0.0667) as displayed in Table 50 below

showed that there is an evidence of the relationship between income level and evacuation distance at $\alpha=0.1$ level. Thus, the conclusion is that there is an evidence for the relationship between income level and early evacuation and between income level and evacuation distance. In addition, the analyses could not find any linear relationship between income level and early evacuation or between income level and evacuation distance.

Table 49. Relationship between Evacuation Time versus Income Level

et by il						
et(Evacuation Time)	il(Income level)					Total
Frequency Expected Percent Row Pct Col Pct	Lt \$25k	\$25k-40k	\$40k-80k	\$80k-120k	Over \$120k	
0-1hr	7	11	20	7	15	60
	6.6207	7.2414	20.897	13.241	12	
	2.41	3.79	6.90	2.41	5.17	20.69
	11.67	18.33	33.33	11.67	25.00	
	21.88	31.43	19.80	10.94	25.86	
1-3hr	9	10	47	32	23	121
	13.352	14.603	42.141	26.703	24.2	
	3.10	3.45	16.21	11.03	7.93	41.72
	7.44	8.26	38.84	26.45	19.01	
	28.13	28.57	46.53	50.00	39.66	
3-6hr	6	7	24	17	5	59
	6.5103	7.1207	20.548	13.021	11.8	
	2.07	2.41	8.28	5.86	1.72	20.34
	10.17	11.86	40.68	28.81	8.47	
	18.75	20.00	23.76	26.56	8.62	
>6hr	10	7	10	8	15	50
	5.5172	6.0345	17.414	11.034	10	
	3.45	2.41	3.45	2.76	5.17	17.24
	20.00	14.00	20.00	16.00	30.00	
	31.25	20.00	9.90	12.50	25.86	
Total	32	35	101	64	58	290
	11.03	12.07	34.83	22.07	20.00	100.00
Frequency Missing = 191						
Statistic			DF	Value	Prob	
Chi-Square			12	26.2870	0.0098	

Table 50. Relationship between Evacuation Distance versus Income Level

ed2 by il						
ed2(Evacuation Distance 3levels)	il(Income level)					Total
Frequency Expected Percent Row Pct Col Pct	Lt \$25k	\$25k-40k	\$40k-80k	\$80k-120k	Over \$120k	
<10ml	19	21	49	19	21	129
	15.48	16.125	43.215	29.025	25.155	
	4.75	5.25	12.25	4.75	5.25	32.25
	14.73	16.28	37.98	14.73	16.28	
	39.58	42.00	36.57	21.11	26.92	
10-50ml	15	14	50	32	33	144
	17.28	18	48.24	32.4	28.08	
	3.75	3.50	12.50	8.00	8.25	36.00
	10.42	9.72	34.72	22.22	22.92	
	31.25	28.00	37.31	35.56	42.31	
>50ml	14	15	35	39	24	127
	15.24	15.875	42.545	28.575	24.765	
	3.50	3.75	8.75	9.75	6.00	31.75
	11.02	11.81	27.56	30.71	18.90	
	29.17	30.00	26.12	43.33	30.77	
Total	48	50	134	90	78	400
	12.00	12.50	33.50	22.50	19.50	100.00
Frequency Missing = 81						
Statistic		DF	Value	Prob		
Chi-Square		8	14.6326	0.0667		

Hypothesis G

Hypothesis G examines the relationship between early evacuation setting out time, and household with children presence. Two variables are utilized in analyzing *hypothesis G*, namely variable 5k (household with children presence) and variable 4d (evacuation time) that has been discussed in the earlier analysis and frequencies as shown in Tables 47. Variable 5k is a categorical variable that probes about households with young children. This variable had 2 levels (contain kids, not contain kids), 136 participants responded to having children as shown in Table 51 below. The second question further probes how many children they contains to the participants

who answering as they contain kids but only 64 participants answered specific number of children they containing in their house. The mean of the number of children per household using the 64 respondents is 2.14 as shown below in descriptive statistics of table 51 below.

Table 51. Analysis of Children in the Household

Variable 5k Child				
child	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Yes	136	28.63	136	28.63
No	339	71.37	475	100.00

Frequency Missing = 6

N	Mean	Std Dev	Minimum	Maximum
64	2.1406250	1.0818442	1.0000000	6.0000000

Chi-square tests are performed to test the associations between evacuation set out time and household with or without children presence. The test result as displayed in Table 52 below, showed that there is an evidence of the relationship between evacuation setting out time and the household with presence of at least a child at alpha=0.1 level ($p=0.0615$). It seemed that the significant difference were mostly from 3rd and 4th raw (3-6hr and >6hr).

Thus, there is a conclusion that an evidence of the relationship between evacuation time and household with at least one child exists. People who plan to stay in their house more than 6 hours after they get an evacuation notice, tend to contain at least one child. While household with no child plan to stay their house within 3 to 6 hours after they get an evacuation notice.

Table 52. Relationship between Evacuation Time versus Children in the Households

et by child			
et(Evacuation Time)	child(Child)		
Frequency Expected Percent Row Pct Col Pct			
	Yes	No	Total
0-1hr	21 22.222 6.48 29.17 21.00	51 49.778 15.74 70.83 22.77	72 22.22
1-3hr	45 41.975 13.89 33.09 45.00	91 94.025 28.09 66.91 40.63	136 41.98
3-6hr	12 19.444 3.70 19.05 12.00	51 43.556 15.74 80.95 22.77	63 19.44
>6hr	22 16.358 6.79 41.51 22.00	31 36.642 9.57 58.49 13.84	53 16.36
Total	100 30.86	224 69.14	324 100.00
Frequency Missing = 157			
Statistic		DF	Value
Chi-Square		3	7.3497
			0.0615

Hypothesis H

Hypothesis H examines the relationship between number of cars owned in the household and the number of vehicles planned to be used during hurricane evacuation. A descriptive statistics of variables Variable 5i (vehicle owned in the household) and variable 5j the number of the vehicle planned to be used for evacuation are as shown in Table 12. Variables 5i and 5j are both continuous variable. Chi-square tests are performed to test the associations between vehicle owned in the household and the number of the vehicle planned to be used for evacuation in Table 53.

**Table 53. Relationship between Owned Vehicles versus Numbers of Vehicles Use at
Evacuation**

(Owned vehicle)	(no of vehicles for evacuation)			Total	
Frequency Expected Percent Row Pct Col Pct	1	2	Over 3		
1	69	0	0		69 22.77
	22.77	0	0		
	100	0	0		
	34.16	0	0		
2	95	41	0	136 44.86	
	31.35	13.53	0		
	69.85	30.15	0		
	47.03	46.59	0		
Over 3	38	47	13	98 32.34	
	12.54	15.51	4.29		
	38.78	47.96	13.27		
	18.81	53.41	100		
Total	202	88	13	303 100	
	66.67	29.04	4.29		
Frequency Missing = 208					
Statistic		DF	Value	Prob	
Chi-Square		4	82.5072	< .0001	
Likelihood Ratio Chi-Square		4	103.1948	< .0001	
Mantel-Haenszel Chi-Square		1	73.003	< .0001	
Fisher's Exact Test					
Table Probability (P)		5.20E-24			
Two-sided Pr <= P		2.14E-20			
Summary Statistics for iOwnvegrp by evcvehgrp					
Cochran-Mantel-Haenszel Statistics (Based on Table Scores)					
Statistic	Alternative Hypothesis	DF	Value	Prob	
1	Nonzero Correlation	1	73.0030	< .0001	
2	Row Mean Scores Differ	2	74.1613	< .0001	
3	General Association	4	82.2349	< .0001	

The chi-square tests result as displayed showed that there is an evidence of the relationship between vehicle owned in the household and the number of the vehicle planned to be used for evacuation least ($p=0.0001$). However because there cells with zero sample a fisher exact test was also performed to confirm the result. This also supported the previous result. Thus, there is a conclusion that an evidence of the relationship between vehicle owned in the household and the number of the vehicle planned to be used for evacuation.

4. 6 Findings on Hurricane Workshop Attendances and Evacuation Preparedness

Hypothesis I

Hypothesis I examines whether there is a significance difference in the level of evacuation preparation between the respondents who attended some meetings, classes, or workshops for hurricane during the past year and those who did not attended any hurricane discussion. Variables that are utilized in analyzing *hypothesis I* are namely variable 3f (Hurricane Evacuation Workshop Attendance), the following Variables 1a- b (level of preparedness), 4a, 4b, 4c, 4d. Variable 3f is a categorical (binominal) variable which probes about participant's attendance of hurricane evacuation workshops. This variable contains two levels (1=Yes, 0=No) and the frequency is as shown in Tables 54.

Table 54. Analysis of Variable (3f) Evacuation Workshop Attendance

Evacuation Workshop Attendance				
_f	Frequency	Percent	Cumulative Frequency	Cumulative Percent
No	435	90.81	435	90.81
Yes	44	9.19	479	100.00

Frequency Missing = 2

Variable 1a is categorical variables that probes about the level of preparedness for hurricane if it strikes during the next 6 months at the time the survey was been done. Variable 1a had 4 levels (strongly disagree, disagree, strongly agree, agree, don't know) as shown in Table 56.

ANOVA test was performed to test the mean difference of preparations for hurricane variable (1a) across evacuation workshop attendance (3f) and the results are as shown in the Table 55 below.

Table 55. Analysis of Variable Test for the Mean Difference of Preparations for hurricane variable (1a) across Evacuation Workshop Attendance (3f)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	10.5048538	10.5048538	16.23	<.0001
Error	468	302.9419548	0.6473119		
Corrected Total	469	313.4468085			

R-Square		Coeff Var	Root MSE	_a Mean	
0.033514		32.31981	0.804557	2.489362	
Source	DF	Type III SS	Mean Square	F Value	Pr > F
_f	1	10.50485375	10.50485375	16.23	<.0001
Levene's Test for Homogeneity of _a Variance ANOVA of Squared Deviations from Group Means					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
_f	1	0.1507	0.1507	0.23	0.6283
Error	468	300.6	0.6423		
Level of _f	N	1a			
		Mean	Std Dev		
No	426	2.44131455	0.80736735		
Yes	44	2.95454545	0.77623257		

The results showed that there is a significant mean difference of preparations between the workshop attendances. Levene's test also suggests equality of variances that the data met assumption of constant variances. Moreover, result showed the means of preparations across the workshop attendances (No=2.44, Yes=2.95). In

addition, a chi-square test was performed to validate conclusion and is as shown in the Table 56 below. The result showed significant relationship between evacuation preparation and the workshop attendance. The result can be interpreted and concluded that individuals who attend the hurricane evacuation workshop are better prepared for the hurricane during the next six months, than those who did not attend evacuation workshop.

Table 56. Relationship between Evacuation Preparation and the Workshop Attendance

Evac prep 1a by Wk attend 3f				
_a(1a)	_f(3f)			
Frequency Expected Percent Row Pct Col Pct	No	Yes	Total	
1	52 48.945 11.06 96.30 12.21	2 5.0553 0.43 3.70 4.55	54 	11.49
2	168 159.52 35.74 95.45 39.44	8 16.477 1.70 4.55 18.18	176 	37.45
3	172 177.65 36.60 87.76 40.38	24 18.349 5.11 12.24 54.55	196 	41.70
4	34 39.881 7.23 77.27 7.98	10 4.1191 2.13 22.73 22.73	44 	9.36
Total	426 90.64	44 9.36	470 	100.00
Frequency Missing = 11				
Statistic			DF	Value Prob
Chi-Square			3	18.0320 0.0004

Variable 1b is the second preparedness variable which is also a categorical variable that had four levels (strongly disagree, disagree, strongly agree, agree). It probes about whether respondents are more prepared for a major hurricane that year than they were

in the previous year (the year Hurricane Katrina struck). Variable 1b is as shown in Table 58. ANOVA test was performed to test the mean difference of preparations for hurricane Variable 1b across evacuation workshop attendance variable 3f. The results showed (Table 57) that there is a significant mean difference of preparations between those who attended the workshop and those who do not. Levene's test suggests equality of variances that the data met assumption of constant variances. Moreover, result showed the means of preparations across the workshop attendances (No=2.27, Yes=2.81).

Table 57. Analysis of Variable Test for the Mean Difference of Preparations for hurricane variable (1b) across Evacuation Workshop Attendance (3f)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	11.8428513	11.8428513	19.22	<.0001
Error	470	289.5618097	0.6160890		
Corrected Total	471	301.4046610			

R-Square	Coeff Var	Root MSE	_b Mean
0.039292	33.77202	0.784913	2.324153

Source	DF	Type III SS	Mean Square	F Value	Pr > F
_f	1	11.84285133	11.84285133	19.22	<.0001

Levene's Test for Homogeneity of _b Variance ANOVA of Squared Deviations from Group Means					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
_f	1	2.2870	2.2870	3.58	0.0592
Error	470	300.6	0.6396		

Level of _f	N	1b	
		Mean	Std Dev
No	428	2.27336449	0.76976890
Yes	44	2.81818182	0.92189712

Also, a Chi-square test was performed to test same question to validate conclusion. The result showed as on Table 58 shows that there is a significant relationship between evacuation preparation and the workshop attendance. Thus, we can conclude that individuals who attend the hurricane evacuation workshop are more prepared for the hurricane this year than last year.

Table 58. Relationship between Evacuation Preparation and the Workshop Attendance

Evac prep 1b by Wk attend 3f					
_b(1b)	_f(3f)				
Frequency Expected Percent Row Pct Col Pct	No	Yes			Total
1	61	5	66		
	59.847	6.1525			
	12.92	1.06	13.98		
	92.42	7.58			
	14.25	11.36			
2	212	8	220		
	199.49	20.508			
	44.92	1.69	46.61		
	96.36	3.64			
	49.53	18.18			
3	132	21	153		
	138.74	14.263			
	27.97	4.45	32.42		
	86.27	13.73			
	30.84	47.73			
4	23	10	33		
	29.924	3.0763			
	4.87	2.12	6.99		
	69.70	30.30			
	5.37	22.73			
Total	428	44	472		
	90.68	9.32	100.00		
Frequency Missing = 9					
Statistic			DF	Value	Prob
Chi-Square			3	29.3464	<.0001

The third variable is Variable 4a which probes about the kind of hurricane emergency items and how many items each participants were having. The number of

the emergency items possess were then used as a score for preparation. The mean and the standard deviation for variable 4a are as shown in Table 59.

Table 59. Analysis of Variable (4a) of Emergency Items

Analysis Variable : eitem Emergency Items				
N	Mean	Std Dev	Minimum	Maximum
473	6.0909091	2.1712152	0	9.0000000

ANOVA test was performed to test the mean difference of preparations for hurricane using variable 4a across evacuation workshop attendance variable 3f (Table 60). The results showed that there was a significant mean difference of preparations between the workshop attendances but the Levene's test suggests a violation of equality of variances and that the data did not met assumption of constant variances.

Table 60. Analysis of Variable Test for the Mean Difference of Emergency Preparations Items for Hurricane Variable (4a) across Evacuation Workshop Attendance (3f)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	46.332751	46.332751	10.02	0.0017
Error	471	2178.758159	4.625814		
Corrected Total	472	2225.090909			

Levene's Test for Homogeneity of eitem Variance ANOVA of Squared Deviations from Group Means					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
_f	1	270.4	270.4	6.98	0.0085
Error	471	18241.4	38.7290		

Level of _f	N	eitem	
		Mean	Std Dev
No	429	5.99067599	2.20447861
Yes	44	7.06818182	1.51577330

As a result Chi-square test was conducted with a recreated 3 classes for categorical variable 4a (Less than 4 items, 5 to 7 items, and more than 8 items), because some cells contained fairly small frequencies. Chi-square test results between recreated categorical variable 4a and evacuation workshop attendance variable 3f as shown in Table 61 below. The result also showed that there was evidence of the relationship between hurricane emergency items and the workshop attendance. Thus, we can conclude as persons who attend hurricane evacuation workshop tend to have more emergency items to prepare for hurricane than persons who doesn't attend workshop.

Table 61. Relationship between Hurricane Emergency Items and the Workshop Attendance

emitem2 by Wk attend 3f				
emitem2	_f(3f)			
Frequency Expected Percent Row Pct Col Pct	No	Yes	Total	
lt4 items	70 64.478 14.61 98.59 16.09	1 6.5219 0.21 1.41 2.27	71 	14.82
5 to 7 items	161 157.11 33.61 93.06 37.01	12 15.891 2.51 6.94 27.27	173 	36.12
mt8 items	204 213.41 42.59 86.81 46.90	31 21.587 6.47 13.19 70.45	235 	49.06
Total	435 90.81	44 9.19	479 	100.00
Frequency Missing = 2				
Statistic			DF	Value Prob
Chi-Square			2	10.7176 0.0047

Variable 4c is the fourth variable of interest which probes about the participants' knowledge about what evacuation zone of where they are living with respect to

hurricane workshop attendance. Variable 4c is a five levels categorical variable as shown in Table 16 was collapsed into two level in this analysis as 1-those who believe they know the zones they live in and 2- those who do not know as shown in Table 62.

Table 62. Analysis of Variable (4c) Hurricane Evacuation Zone Knowledge

Variable 4c ezk				
ezk	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Known	215	45.94	215	45.94
Unknown	253	54.06	468	100.00

Frequency Missing = 13

Evac Zone belief

ezb	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Evac Zone	109	50.70	109	50.70
Not Evac Zone	106	49.30	215	100.00

Frequency Missing = 266

Chi-square tests were performed to test the association between preparations for variable 4c - hurricane evacuation zone knowledge and evacuation workshop attendance variable 3f as Table 63 below. The test suggests that there was a significant relationship between the workshop attendance and the evacuation zone knowledge. The people who attend the evacuation workshop tend to belief to known their evacuation zone.

The fifth variable analyzed was variable 4d – evacuation time association with evacuation workshop attendance - variable 3f. Variable 4d is a four level categorical data as shown in Table 16. Chi-square tests were performed to test the association between variable 4d – evacuation time and variable 3f evacuation workshop attendance and the results are as shown in Table 64 below. The test suggests that there

was a significant relationship between the workshop attendance and the evacuation time. The people who attend the evacuation workshop tend to stay longer at their house after they get official evacuation notice.

Table 63. Relationship between Hurricane Evacuation Zone Knowledge and Hurricane Workshop Attendance

ezk 4c by Wk attend 3f					
ezk(Evac Zone knowledge)	_f(workshop attendance)		Total		
Frequency	No	Yes			
Expected					
Percent					
Row Pct					
Col Pct					
Known	185	30	215		
	195.3	19.754			
	39.53	6.41	45.94		
	86.05	13.95			
	43.53	69.77			
Unknown	240	13	253		
	229.8	23.246			
	51.28	2.78	54.06		
	94.86	5.14			
	56.47	30.23			
Total	425	43	468		
	90.81	9.19	100		
Frequency Missing = 13					
Statistic			DF	Value	Prob
Chi-Square			1	10.825	0.001

Table 64. Relationship between Evacuation Time and Hurricane Workshop Attendance

4d (et) by Wk attend 3f					
4d (et)	_3f(workshop attendance)		Total		
Frequency	No	Yes			
Expected					
Percent					
Row Pct					
Col Pct					
0-1hr	67	6	73		
	67.213	5.787			
	20.43	1.83	22.3		
	91.78	8.22			
	22.19	23.08			
1-3hr	132	6	138		
	127.06	10.94			
	40.24	1.83	42.1		
	95.65	4.35			
	43.71	23.08			
3-6hr	59	5	64		
	58.927	5.073			
	17.99	1.52	19.5		
	92.19	7.81			
	19.54	19.23			
>6hr	44	9	53		
	48.799	4.201			
	13.41	2.74	16.2		
	83.02	16.98			
	14.57	34.62			
Total	302	26	328		
	92.07	7.93	100		
Frequency Missing = 153					
Statistic			DF	Value	Prob

Table 1. P-Value Summary for the Demographic and Socio - Economic Variables on Evacuation Decision Findings

[illegible]

CHAPTER 5

HURRICANE EVACUATION MODELING AND FINDINGS

This chapter derives a macroscopic travel forecast model for the emergency hurricane evacuation of the Rhode Island flood zones. The TransCAD software by Caliper Corporation constitutes the implementation platform of the four-step travel evacuation model, as discussed in the review of the literature. The analysis and the results achieved in each step, trip generation, trip distribution, and traffic assignment, will be discussed herein. Subsection 5.1 details the hurricane evacuation trip generation and the assumptions underlying the derivation of trip productions and attractions. Subsection 5.2 addresses the evacuation trip distribution and subsections 5.3 and 5.4, the traffic loading rate curve utilized and the traffic assignment model, respectively.

5.1 Hurricane Evacuation Trip Generation

As already discussed in the literature review, trip generation entails two parts, production and attraction, which literally means origin and destination. The production and attraction trips will be discussed separately in separate subsections and then balanced.

5.1.1 Hurricane Evacuation Trip Production

At hurricane emergency evacuation, *Trip productions* initiate at the residential homes, seasonal homes and hotels/inns/bed-and-breakfast within the storm surge zones. The first step for building the trip generation model is to merge the RISM TAZ layer with the RI Hurricane Evacuation Area Map layer, the RI Red Cross Shelters

layer, the RI hotels/inns/bed-and-breakfast layer, and the US Census 2010 RI vehicle numbers in the household, seasonal houses and households with occupancy per room less than one (1) data fields to mention a few.

Residential Evacuee Trip Productions –The U.S. Army Corps of Engineers joined with RIGIS to provide a GIS database of the RI storm surge zones A, B and C, as well as the population residing within these zones. In the event of a major hurricane, category 3, 184,441 persons, the equivalent of 77,154 households, must evacuate the coastal towns of RI. The first task is to determine how many out of these households are actually willing to evacuate for a major hurricane. The survey analysis pointed to about 80% of the RI household as willing to comply with the evacuation order under a major hurricane, if issued by government officials.

On the other hand, the survey data (Question 1c) conveyed that approximately 10% of the population outside of the evacuation zones, often bordering these zones, actually believe that they reside in them and would have a tendency to evacuate despite a lack of necessity. To be conservative, this study assumes that about 20% of the residents within the evacuation TAZs outside of the storm surge areas willingly will evacuate.

The focal point for estimating the number of households willing to evacuate is to convert this number into vehicular trips. However, the facts underlying such a conversion have proven elusive and difficult to establish by the literature. Some studies have assumed that households evacuate using the smallest possible number of vehicles, to keep the family unit together, while others have assumed that they evacuate with all owned cars. The survey analysis conducted within the study scope

confirmed that only about 70% of all owned household vehicles would be used at evacuation. Table 66, below, displays the anticipated vehicle utilization pattern by households at evacuation within the flood zones based on the number of vehicles owned as obtained from the survey. This chapter utilizes these survey results to enable the conversion of evacuating households into evacuating vehicles toward establishing evacuation trip productions. The number of vehicles owned on average by households in the TAZs is sourced from The U.S. Census 2010 for the state of Rhode Island.

Table 66. Auto Utilization at Evacuation versus Owned Household Vehicles

Owned Vehicle/HH	Percentage of Auto Utilization /Household Vehicles		
	1- Vehicle	2- Vehicle	3- Vehicle
1	100	-	-
2	69.85	30.15	-
3+	38.77	47.96	13.27

The census data classifies the households within each TAZ by the number of vehicles they own, number of 0-vehicle households, number of 1-vehicle households, number of 2-vehicle households or number of 3+-vehicle households. Based on this classification, and utilizing the same class ratios, the households within the evacuation zones of each TAZ were categorized by their vehicle ownership as described in Eq. 5.1. Given the breakdown of evacuee households per number of vehicles owned, Eqs. 5.2a, 5.2b, and 5.2c, below, derive the number of vehicles used at evacuation by each class of evacuee household per vehicle ownership. The survey derived values of the

vehicle utilization behavior at evacuation versus the vehicle ownership class, from Table 66, enable the derivation of Eqs. 5.2a to 5.2c. These equations compute the number of vehicles leaving the evacuation zones of TAZ i , for each household vehicle ownership class, by determining the survey ascribed percentage of households evacuating with specific numbers of vehicles and further multiplying these percentages by these specified vehicle numbers.

$$RH_{ei}^x = \frac{RH_{ei} \times RH_i^x}{RH_i} \quad (5.1)$$

$$PR_i^1 = 100\% \times RH_{ei}^1 \times 1 \quad (5.2a)$$

$$PR_i^2 = (0.70 \times 1 + 0.30 \times 2) \times RH_{ei}^2 \quad (5.2b)$$

$$PR_i^3 = (0.39 \times 1 + 0.48 \times 2 + 0.13 \times 3) \times RH_{ei}^3 \quad (5.2c)$$

where:

RH_{ei}^x = Total number of residential households that own x vehicles in the evacuation zones of TAZ i

RH_{ei} = Total number of residential households in the evacuation zones of TAZ i

RH_i = Total number of residential households in TAZ i

RH_i^x = Total number of residential household that own x vehicles within TAZ i

PR_i^x = Evacuation trip productions by residential households that own x vehicles within TAZ i

Lastly, to account for the residential households with no vehicles, 0.5 vehicles is assumed in support of the evacuation movement per household with no vehicle. Some of these households might take a ride with family members from other households or rent a car. Eq. 5.2 d below illustrates the derivation of the number of vehicles used by household with 0-vehicle ownership.

$$PR_i^0 = 0.5 \times RH_{ei}^0 \times 1 \quad (5.2d)$$

Eq. 5.2 below describes the sum total of evacuation trips, PR , produced by residential households within the flood zones of Rhode Island.

$$PR = \sum_i \left(\sum_{x=1}^3 PR_i^x + PR_i^0 \right) \quad (5.2)$$

Touristic and Seasonal Resident Trip Productions –Trip generation at hurricane evacuation cannot be all inclusive without consideration of the touristic and the seasonal households since tourism is Rhode Island's fourth-largest industry. Tourists are mostly attracted to Rhode Island because of its more than 100 beaches and 400 miles of picture-perfect coastline during the summer months, which also happen to overlap with the hurricane season.

Several assumptions are presented to generate the trip productions for the seasonal households. The first assumption is that all the seasonal houses within the evacuation area are occupied at hurricane watch issuance. The second assumption is that the number of households in each of the seasonal homes equals the average household occupancy per house in each TAZ. The third assumption is that the average number of owned vehicles per residential household in each TAZ equals that of a seasonal household; however seasonal households will evacuate all of their vehicles. Following Baker, 2009 (refer to Section 2.3 of the literature review), the fourth assumption is that 70% of the seasonal households will evacuate before mandatory evacuation issuance, leaving behind only 30% to be evacuated with the general/resident population. Using the pre-stated assumptions, the below Eqs. 5.3a and 5.3b were derived;

$$PS_i = 0.3 \times SH_{ei} \times \frac{V_i^{reg}}{RH_i} \quad (5.3a)$$

where:

SH_{ei} = Total number of seasonal houses in the evacuation zones of TAZ i .
 V_i^{reg} = Total number of registered vehicles in TAZ i

RH_i = Total number of residential households within TAZ i
 PS_i = Evacuation trip productions by seasonal households within TAZ i

Eq. 5.3 below describes the sum total of evacuation trips, PS , produced by seasonal households within the flood zones of Rhode Island.

$$PS = \sum_i PS_i \quad (5.3)$$

Similarly, several assumptions are presented to generate the trip productions for touristic households. The first assumption is that the hotels/inns/bed and breakfasts are occupied by the tourists in the evacuation areas at 75% capacity during the hurricane watch issuance. The second assumption is that each room is occupied by a single household that also drove in a single vehicle. Still per Baker, 2009, the third assumption is that 70% of the tourists will evacuate before the mandatory evacuation issuance, leaving behind only 30% to be evacuated with the general/resident population. Future refinements of the survey will endeavor to capture the behavior of touristic and seasonal households at evacuation within coastal RI; thereby confirming or voiding some of the above assumptions.

$$PT_i = 0.3 \times 0.75 \times R_{ei} \quad (5.4a)$$

where:

R_{ei} = Total number of rooms in the evacuation zones from hotels, inns and B&B within TAZ i
 PT_i = Evacuation trip productions by tourists within TAZ i

Eq. 5.4 below describes the sum total of evacuation trips, PT , produced by tourists within the flood zones of Rhode Island.

$$PT = \sum_i PT_i \quad (5.4)$$

The overall number of trips produced at a TAZ i thus equals the sum of trips produced by residential, seasonal households and tourists.

$$P_i = PR_i + PS_i + PT_i \quad (5.5)$$

Further, the overall number of trips generated by the flood zones equals the summation over all TAZs of the trip productions by TAZs. Table 67, details the production of trips that results from residential households, seasonal homes and the hotels in the evacuation zones.

$$P = \sum_i PR_i + PS_i + PT_i \quad (5.6)$$

Table 67.Trip Production

Production	Trips (vehicles)
Residential Home	91975
Seasonal Home	4158
Hotel	1400

5.1.2 Hurricane Evacuation Trip Attractions

At hurricane emergency evacuation, trip attraction locations are usually the homes of friends or family, hotels/inns/bed-and-breakfast and hurricane shelters outside of the hurricane's storm surge path/the flood zones. These attractions can be inside or outside the production municipalities (depending on the hurricane severity and the facilities available in the county). Survey question 4f addressed the attraction locations of hurricane evacuees departing from the coastal RI region. The percentages of attractions obtained by location were 68% for friend and family homes, 17% for shelters, and 15% for hotels/inns/bed-and-breakfast. The travel distances of evacuees

to their attractions/destinations were 32% for less than 10 miles, and 68% for farther than 10 miles.

Vehicular Attractions to Family or Friend Houses – Two variables determine the desirability/attractiveness of the family/friend (residential) houses outside of the evacuation zones. As for trip productions, a number of assumptions underlie the trip attraction modeling for the evacuation of the flood zones under hurricane warning. Firstly, the greater the number of homes and apartments with a ratio of “Occupancy/Room” (census data 2010 field) less than 1 within a TAZ located outside of the evacuation zones, the greater the attraction of evacuees to family/friend houses within this TAZ as a destination. The trip attractions to family/friend houses within TAZs obtain from merging the geographic files of the Rhode Island Census data 2010 for residential houses and apartments with “Occupancy/Room” values less than 1 outside of the evacuation areas. The second variable utilized for family/friend houses trip attraction is the distance the evacuees are willing to travel. This second variable is not applied to the shelters and the hotels/inns/bed and breakfast trip attraction modeling since the determinant factor is thought to be space availability.

Attractions to Shelters – RI operates emergency hurricane evacuation shelters under a system developed by the American Red Cross. These shelters, located outside the storm surge and flood zones, meet state building codes for providing safe harbor for evacuees. Survey analysis established that 17% of RI households within the hurricane evacuation zones are willing to evacuate into shelters. The 8448 total persons’ occupancy at 18 shelters designated by Rhode Island emergency Red Cross, will not

suffice to satisfy this evacuee demand of about 36,700 persons in a major hurricane scenario (that which engenders the evacuation of all the flood zones A, B and C).

In light of pre-stated capacity constraint, the assumption of a first-come, first-serve basis applies. To be conservative, remaining household demands, in excess of capacity, which cannot be accommodated in shelters will be attracted to family or friend houses outside the evacuation zones. (Future survey modifications will probe into the validity of this assumption as quite likely, some of this demand may remain in the flood zones instead).

In computing trip attractions to the shelters, the aim is to simply convert the person-occupancy availability at shelters into a vehicular attraction capacity. Conceivably, a number of evacuees will reach shelters using transportation means other than automobiles. Such evacuees will generate no vehicular trips. It is further assumed that evacuees seek shelter using transportation means other than private vehicles only within TAZs where public shelters are available. For such TAZs, with public shelters, the study tackles residential shelter attractions for residential household by vehicle ownership category, households with no vehicles and all other households. Although the survey showed no preference for sheltering by households with no vehicles over those with vehicles, the study gives priority sheltering to households with no vehicles. Thus for TAZs with shelters, 17% of residential households with no vehicles are estimated to evacuate to public shelters while the remaining 83% are accounted for with 0.5 vehicles and the remaining shelter capacity is assumed to attract households with vehicles. (The survey questionnaire did not probe the alternative plans of households with vehicles desiring to shelter publicly

assuming no availability at shelters, but it is assumed here that they evacuate the flood zones towards destinations other than public shelters). The remaining shelter capacity, post assignment of the 17% non-vehicular evacuees, is converted to vehicle capacity using Eq. 5.5.

$$\frac{\text{Remaining Shelter Capacity}}{\text{Persons / Household}} * \frac{\text{Vehicles}}{\text{Household}} \quad (5.5)$$

Hotels/inns/bed and breakfasts Attractions –The first assumption, following Baker, 2009, is that 70% of the tourists will leave before the evacuation of the general public. The second assumption is that out of the 30% remaining tourists within the evacuation zones, 30% will go to shelters, 30% will go to hotels and 40% will go to friend and family houses outside of the hurricane evacuation zone. Seventy (70%) percent of the total room capacity of each hotel/inn/bed-and-breakfast within the non-evacuation zone is assumed occupied before the hurricane warning issuance. With 70% of the tourists leaving prior to mass evacuation (Baker, 2009), the available rooms at hotel/inn/bed-and-breakfast in the non-evacuation zone is about 77% of room capacity or about 4,280 rooms. Table 68, provides the trips attracted from the residential and seasonal households, and from the hotels in the evacuation zones to destinations in the non-evacuation zones towards friends/ families’ homes, shelters and the hotels.

Table 68. Trip Attraction

Attraction	Capacity (Vehicles)
Friends/Families' Homes	256,037
Shelter	3902
Hotel	4280

5.1.3 Hurricane Evacuation Trip Balancing

Results from the trip generation step can be summarized by the trip balanced Table 69 below. In order to be conservative the available shelter and hotel capacities were not filled to 100%. The shelters' and hotels' capacities were filled up to about 99% and 97% respectively.

Table 69. Trip Balancing

Production	Trips (vehicles)	Attraction	Auto
Residential Home	91975	Families/Friends	89,803
Seasonal Home	4158	Shelter	3,887
Hotel	1400	Hotel	4,171
Quick Sum	97,533	Quick Sum	97,861

5.2 Hurricane Evacuation Trip Distribution

The trip distribution model step matches trip origins to trip destinations and thus determines the frequency distribution of trips attracted to a TAZ from all other TAZs (production). In this study, the trip distribution model matches trip productions from the evacuation zones to trip attractions in the non-evacuation zones. Trip distribution in TransCAD entails three main steps: 1) determination of shortest paths between pairs of origin centroids, in evacuation TAZs, to destination centroids in non-evacuation TAZs within RISM, 2) determination of the production and attraction (PA) matrices (truly origin-destination matrices with entries expressed in household-trips), and 3) conversion of the PA matrices into origin and destination (OD) matrices (in vehicle-trips). The hurricane evacuation model by Southworth, 1991, a replica of the gravity model (Wilson, 1970) derives trip distribution in this study. Eq . 5.2.1 below,

formulate a "production constrained" spatial interaction/trip distribution model (Wilson, 1970) for the trip attractions to family/friend houses.

$$T_{ij} = P_i \frac{A_j \times f(c_{ij})}{\sum A_z \times f(c_{iz})} \quad (5.2.1)$$

$$T_{ij} = A_j \frac{P_i \times f(c_{ij})}{\sum P_z \times f(c_{iz})} \quad (5.2.2)$$

where:

T_{ij} = the number of evacuees traveling from origin TAZ i to family/friend houses in TAZ j

P_i = the number of evacuees located at zone i

A_j = the measure of the attraction potential of available room space in family/friend houses in destination zone TAZ $_j$

c_{ij} = the probable evacuees' travel distance between the evacuation areas in zone i and families/friend houses at zone j

$f(c_{ij})$ = the friction factor, a measure of the impedance to travel between origin zone TAZ $_i$ and destination zone TAZ $_j$.

Eq. 5.2.1 distributes the production at TAZ $_i$ according to the relative attractiveness of all the TAZ zones. The factor $f(c_{ij})$ sets the relative attractiveness/impedance of destinations (family/friend houses) within TAZ $_j$ located outside of the evacuation zones. This factor, as explained later in Section 5.2.1, conveys the impedance of travel/evacuating to a destination TAZ $_j$ given its distance to the origin TAZ $_i$ and the willingness of evacuees to travel such distance to safe harbor. Question 4f of the survey probed this willingness. A_j conveys the attractiveness of a destination TAZ $_j$ based on its "Occupancy/Room" ratio less than one.

Eq. 5.2.2 formulates the "attraction constrained" spatial interaction/trip distribution model. This model is applicable to shelters and hotels/Inns/Bed-and-Breakfasts within TAZs outside of the evacuation zones because as stated earlier and

per survey results, the evacuees attracted to both facility types are greater than the capacities, and thus the demands for these facilities exceed the capacities.

5.2.1 Hurricane Evacuation Trip Distribution Friction Factors

Friction factor is the primary independent variable, which quantifies the impedance or measure of separation between two zones (NCHRP Report 365, 1998). The friction factor decreases when the travel distance from i to j increases. The Gamma function parameters were calibrated based on the distance the evacuees are willing to travel to safe harbor from the survey shown in Table 70.

For the model calibration process Table 70 provides the gamma function parameters used to calculate friction factors, a , b and c equal to 50.057, -0.048, -0.008 respectively. The observed and calculated frequency distribution of trips using the specified gamma values differ somewhat with a closer fit provided within the 10 to 50 miles distance, which was given a higher priority as shown in Figure 17. The distances within which destinations were specified in the survey were not disaggregated enough to allow for a statistical determination, using a log-linear regression, of the gamma function parameters.

Table 70. Evacuation Average Trip Length Data Analysis

Distance	Distance Mid-Point	Weight	Percent	Gamma	Diff
< 10	7.5	1	31.39	42.82	130.68
10-50	30	1	33.47	33.47	0.00
50 - 100	75	1	15.10	22.34	52.40
100 - 200	150	1	8.11	11.85	13.97
> 200	225	1	5.41	6.37	0.92
					197.98

Figure 17. Gamma Function Parameters for Friction Factors

Impedance Matrix – Using the road network layer of RISM and the centroids in the node layer, a short path impedance matrix was created. This was built based upon the travel distances over the highway network from the centroids of all origin TAZs, i , to the centroids of all destination TAZs, j . The accumulated values were placed in a table called skim matrix. Since no path could be built when i equal j , intra-zonal travel time in the skim matrix was computed by taking half of the average travel time from zone i to its three closest TAZs.

5.2.2 Hurricane Evacuation Trip Distribution Procedure

The first assumption of an intervening opportunity model is that trip makers consider potential destinations sequentially, in order of their impedance away from the origin (Rogerson 1993). Based on this assumption the Logistic and Routing Module with selection of Transportation Problem application in TransCAD also known as Hitchcock procedure was applied to the trips balance ending at shelters and hotels to produce trip distribution matrices. A production constrained gravity model was applied to vehicular trips toward friends and families' homes and it converges with 0.01 and 20 iterations. This study does not necessitate transforming PA matrix tables into OD matrix tables since the conversion into vehicle trips was incorporated into the trip generation step as earlier explained. As a result the PA matrix table achieved is the sought after OD matrix table.

5.3 Hurricane Evacuation Traffic Departure Time Sub-Model

The profiling of traffic departure time at hurricane evacuation is often referred to traffic loading rate or traffic mobilization. This section will address some necessary external data necessary to model the evacuation namely, background traffic, time of the day of evacuation and evacuation loading curve. The traffic assignment step required that the existing demand on the road network be defined. Survey question 4d polled the evacuees on the timing of their departure following issuance of a mandatory evacuation notice by government officials. However, the survey was not explicit enough about the time of the day of the notice reception. (Future survey questionnaires should be more explicit in this area.) Based on this oversight the following assumptions are made to carry out the traffic assignment:

- i. The governor has declared a state of emergency.
- ii. The evacuees' must leave the evacuation area within 12 hours.
- iii. The announcement is made shortly before 6:00 A.M (daytime evacuation)
- iv. In the evacuation zones (storm surge risk area) heads of households do not work and both, the public and the private administrations are closed
- v. In the non-evacuation zones (wind risk areas) about 20% of heads of households go to work and 40% of retail and non-retail agencies operate.

5.3.1 Hurricane Evacuation Loading Curve

The purpose of this step is to evaluate the time distribution of the evacuees' departure process. Southworth (1991) outlined four major approaches to define traffic loading curves, which convey the fraction of evacuated population at specific times. The assumptions about evacuees' behavior departure time outlined are based on past empirical data, surveys of intentions of potential evacuees, expert judgment/conceptualization and, simulations of alarm message propagation and perception in the community (Southworth, 1991; Cohn et al., 2006; Stern and Sinuany-Stern, 1989).

In this study, the assumptions about evacuees' behavior at departure time is addressed using the result gathered from the survey (Question 4d in Table 16) about the evacuees' intended timing to leave the flood zones. The data gathered enabled derivation of the loading curve shown in Fig.18. As can be seen from this chart, about 65% of the evacuees leave within the first 3 hours after the mandatory evacuation notice. The loading curve data distribution was used to split the origin-destination matrices into hourly origin-destination matrices at evacuation. Each hourly origin-destination matrix was matched and summed-up with the precise background traffic hourly O-D matrix.

Table 71. Departure Time from Evacuation Zones

Time	End-Point	Percentages	Cumulative Percent
0 - 1 hr.	1	22.64	22.64
1- 3 hr.	3	42.76	65.41
3 - 6 hr.	6	18.56	83.97
6 -9 hr.	9	4.08	88.05
9 - 12 hr.	12	3.15	91.2
> 12 hr.	24	8.8	100

5.3.2 Hurricane Evacuation Background Traffic

The background traffic data comes from the Rhode Island Statewide travel demand model for three different trip purposes: home-based work (HBW), home-based non-work (HBNW), and non-home-based (NHB). These RISM model trip purposes were modified to portray the assumptions made in subsection 5.3 above and the result is shown in Table 5.6.

Table 72. Background Traffic at Evacuation

Trip Purpose (0-24)	Auto
HBW	149,671
HBNW	727,569
NHB	178,585
EE	43,523
QuickSum	1,099,349

Figure 1. Evacuation Traffic Loading Curve

5.4 Hurricane Evacuation Trip Assignment

Traffic assignment was completed using the Dynamic Traffic Assignment module in TransCAD. No changes were made to the RISM network. All links in the network were activated. The OD trip table assigned to the network was the appended worst hour O-D matrix of both the modified base case (background flow) and the evacuation flow. A user traffic assignment equilibrium model (UE), which computes link travel times based on the Bureau of Public Roads (BPR) volume delay function was selected for implementation. The number of equilibrium iterations chosen was from 20 to 40. The convergence criteria utilized was 0.001 for a single departure period within 60 minutes. The convergence factor is a measure of the consistency between the link volumes obtained between consecutive iterations; the smaller the convergence factor, the higher the number of iterations to convergence and the more accurate (closest to equilibrium) the assignment.

The results obtained from the traffic assignment are expressed as the color coded values by volume to capacity ratio (VOC also referred to as v/c ratio) for all the network links in RISM. Volume represents the hourly vehicle demand while the capacity represents the maximum flow rate that can be accommodated by the highway under stable conditions without breakdowns or formations of queues. A v/c ratio lesser than 0.85 generally indicates that adequate capacity is available and vehicles are not expected to experience significant delays or queues. As the v/c ratio approaches 1.0, traffic flow may become unstable, slight and temporary delays and queues may occur. Once the demand exceeds the capacity (a v/c ratio greater than 1.0), traffic flow is unstable and excessive delay and queuing is expected.

Some selected roadways within the network are presented in Figs. 19 to 27 and are discussed in the following paragraphs. Fig. 14 depicts Route 103, Route 114, and Route 136 (Barrington, Warren and East Providence) operating at a v/c between 0.9 and 0.99 while a section of Route 114 in Barrington operates at a v/c above 1. The operation on I-195 within East Providence and Swansea seems stable but heavy with v/c ranging from 0.5 to 0.9. Fig. 20 presents the v/c results for Route 24, Route 138 (Fall River to Portsmouth), Mill Street and Hancock Street (Tiverton). Route 138 from Portsmouth to Fall River operates at v/c ratios ranging from 0.9 to 0.99 while sections of Mill Street and Hancock Street (Tiverton) operate at v/c ratios above 1.00. I-195 around Somerset operates at v/c ratios ranging from 0.8 to 0.9. Fig. 21 depicts the roadway network within Newport and its neighboring towns, where some local roads such as Spring Street, Sherman Street, James T Connell Memorial Road, Vernon Avenue and Broadway Street all seem to be operating near or over capacity. However, the bottleneck does not extend to Jamestown Bridge with v/c ratios ranging from 0.8 to 0.90.

Figs. 22 and 23 show Route 1 from South Kingston to North Kingston operating at v/c ratios of 0.99 up to greater than 1.00. Route 138 (Fig. 22) from Narragansett to Jamestown Bridge operates at reasonable v/c ratios. Fig. 18 also shows Narragansett Route 108 operating at v/c ratios ranging from 0.90 to 0.99, while Bridge Town Road in South Kingstown operates at v/c ratios over 1.00. Figs. 24 and 25 depict Route 4 operating at v/c ratios above 1.00 from North Kingston to East Greenwich, but the operation improves upon merging with I-95. Some parts of Route

1A and Route 403 in North Kingstown operate at v/c ratios between 0.99 to over 1.00, but the greater part operates at v/c ratios within 0.9 and 0.99 (Fig. 19).

As presented in Fig. 25, the segment of Route 115 (Coventry) southward to Route 117 (Warwick) operates at v/c ratios ranging from 0.90 to 0.99. Route 115 becomes more congested around Warwick Neck with a v/c over 1.00. Likewise Route 117A from Warwick to Route 12 (Cranston) operates at v/c ratios within 0.90 and 1.00. Figs. 26 and 27 show I-95 and I-295 operating at stable flow conditions with a v/c around 0.90. The bottlenecks or capacity shortages are mainly within the arterials and local roads. Route 10 (Cranston to Providence), Route 6, Route 146 are all operating near capacity at v/c ratios of 0.90 to 0.99. Some other local roads in Providence are operating at v/c ratios greater than 1 such as Hill Top Avenue, Atwells Avenue, and Raymond Street to mention a few.

Figure 1. Volume and Capacity at Route 103, Route 114, and Route 136 (Barrington, Warren and East Providence)

Figure 2. Volume and Capacity at Route 24, Route 138, Portsmouth (Mill Street and Hancock Street in Tiverton)

Figure 3. Volume and Capacity at Newport (Spring Street, Sherman Street, James T Connell Memorial Road and Broadway Street)

Figure 4. Volume and Capacity at Route 1 and Route 138

Figure 5. Volume and Capacity at Route 108, Bridge Town Road South Kingstown and Route 138

Figure 6. Volume and Capacity at Route 4, Route 1A and Route 403

Figure 7. Volume and Capacity at Route 4, Route 117 and I-95 East Greenwich

Figure 8. Volume and Capacity at Route 6, Route 10, I-95 and I-95 Cranston and Providence

Figure 9. Volume and Capacity at Route

CHAPTER 6

CONCLUSION

In the event of a major hurricane, approximately 184,441 people from 77,154 households will need to evacuate from the various storm surge areas within the coastal towns of the state of Rhode Island (COE, 2006 and RIGIS). In addition, it was also assumed that 43,142 people from 18,047 seasonal households and 23,492 tourists will also leave the evacuation zones while the majority (70%) will depart prior to the issuance of the evacuation notice. Assumptions regarding seasonal households and tourist were based on Baker, 2009 findings.

Using a survey instrument, this study captured the anticipated evacuation behavior and the household preparedness of the exposed populations in the coastal towns of Rhode Island upon notice of hurricane emergency evacuation. The survey results show that about 80% of Rhode Islanders are ready to comply with an evacuation notice if issued by government officials. Further, ten (10)% of the households that perceived that they were located within the evacuation zones are erroneous. Thus, these households may have a tendency to evacuate despite a lack of need. Demographic factors such as head of household's age or education, household income, and prior hurricane evacuation experience do not have any association with the decision to evacuate. However, there seems to be a relationship between race and the decision to evacuate. Still, the percentage of minorities in the sample size is too low to reach a conclusive result.

Study findings also highlight the positive association between partaking in hurricane classes/workshops or outreach meetings of any sorts on hurricane risk preparedness. The study confirmed that not all household owned vehicles will be utilized by hurricane emergency evacuees. Evacuees anticipate fleeing the flood zones with only 70% of the total number of vehicles that they own. Survey analysis further derived a cross classification table of the number of household vehicles used for evacuation versus vehicles owned. In addition with the Census demographic data, this table allows for the estimation of the number of household vehicles utilize at evacuation in trip production modeling.

The percentage breakdown of evacuee trip attractions outside of the storm surge area amounted to 68% toward friend and family homes, 17% toward shelters, and 15% toward hotels/inns/bed-and-breakfast. Seventeen (17)% of RI households in the hurricane evacuation zones are willing to evacuate to shelters in the event of a hurricane evacuation notice. In a major hurricane scenario, the available total capacity of 8,448 persons in the 18 Red Cross-designated shelters of Rhode Island will not suffice to satisfy the resulting evacuee demand of approximately 36,700 persons.

The information gathered from the survey instrument were used to build the parameters that aided step by step socio-behavioral hurricane evacuation models for the state of Rhode Island. Gravity model was used to distribute trips to friend and family homes that possessed the highest percentage of trip attraction. The friction factors for the gravity model were calibrated using a gamma function that replicated the survey-derived percentage of evacuating households willing to travel within various distances. The resulting gamma function parameters a , b and c are 50.057,

0.048, and 0.008, respectively. Based on first assumption of an intervening opportunity model that trip makers consider potential destinations sequentially, in order of their impedance away from the origin (Rogerson 1993), the Logistic and Routing Module with selection of Transportation Problem application in TransCAD also known as Hitchcock procedure was applied to the shelter and hotel attractions. The trip distribution end product was Production and Attraction (PA) matrix tables and in this study can also be regarded as Origin and Destination (OD) matrix tables.

The background traffic data used was from the Rhode Island Statewide Model (RISM) travel demand modeled three trip purposes: home-based work (HBW), home-based non-work (HBNW), and non-home-based (NHB). These RISM model trip purposes were modified to portray these assumptions as follows; 1) The Governor has declared a State of Emergency, 2) The evacuees' must leave the evacuation area within 12 hours, 3) The announcement is made early in the morning before 6:00A.M, 4) The public and the private transactions in the evacuation zones are closed down, 5) 20% of people are going to work and 40% of commercial activities and others are in operation in the non-evacuation zones.

The evacuation traffic loading curve was derived by cumulating the perceived time delay taken by households to evacuate following a notice. In the generated curve about 65% of the evacuating households will leave within 3 hours following an evacuation notice by government officials. This loading curve was compared with the default/generic evacuation traffic loading curve (COE, 2001). The generic traffic loading displayed three scenarios of fast, medium and slow evacuation. The

cumulative curve resulting from the survey compared with the fast evacuation departure but the parameters gathered from the instrument were higher.

Using TransCAD Planning Traffic Assignment DTA module, and the worst hourly demand models matrix output for the background traffic and the step by step evacuation flow matrix, the traffic conditions prevalent at evacuation upon notice hurricane advancement were simulated. The result from the traffic assignment was discussed by colored coding the network in order to present Volume over Capacity (VOC) on the entire RISM network. The interstate freeway within the state and its neighboring states operates at a stable condition with the VOC not greater 0.9. However, some arterials and major local roadways in the evacuation area municipalities displayed VOC to be at or over capacity.

Recommended Future Studies

Future studies can address the following; 1) the model can be modified to simulate a dynamic evacuation to accounts for the delays in reaching evacuation orders on a township basis, 2) development of a survey instrument that will account for the evacuees' destination choice in RI and bordering states municipalities, in order to attain a better friction factor parameters base on the distance that will be travel at evacuation, 3) A survey instrument that will probe whether the evacuees' opting for shelter destination will actually head to friends and families' homes as assumed in the study or remain in the evacuation zone given the insufficient capacity in the shelter. Refining the survey instrument to enhance in hindsight the quality of information gathered in the future on the preparedness and evacuation pattern data to be.

Nevertheless, current study considers all of the evacuation area C as exposed under severe hurricane threat. Future studies will investigate the structural soundness of this assumption.

APPENDICES

Survey In Support Of Multi-Modal Hurricane Evacuation Plans

I: Please respond by circling the option that reflects how you feel about each statement.

	Strongly			Strongly
	Disagree	Disagree	Agree	Agree
a. I am prepared if a major hurricane strikes my community during the next 6 months.....	[1	2	3	4]
b. I am more prepared for a major hurricane this year than I was last year.....	[1	2	3	4]
c. My home is likely to be flooded in a major hurricane.....	[1	2	3	4]
d. My home is likely to be damaged by wind in a major hurricane.....	[1	2	3	4]
e. I am confident that I would be rescued if a major hurricane hits and I did not evacuate my home.....	[1	2	3	4]

II: Please respond by circling the option that reflects your concerns regarding hurricane evacuation shelters.

	Strongly			Strongly
	Disagree	Disagree	Agree	Agree
a. I would have enough clean water to drink.....	[1	2	3	4]
b. I would have enough food to eat.....	[1	2	3	4]
c. I would have the prescription drugs or medicines that I need.....	[1	2	3	4]
d. I would be threatened by violence.....	[1	2	3	4]
e. I would need medical care and I wouldn't be able to get it.....	[1	2	3	4]
f. The shelter would be unsanitary.....	[1	2	3	4]
g. I would be exposed to sick people and could catch their illnesses.....	[1	2	3	4]
h. The shelter would be too crowded and I would not have any privacy.....	[1	2	3	4]
i. I would have a hard time communicating with family outside the shelter.....	[1	2	3	4]

III: Please respond by circling the option that reflects how you feel about each statement.

- a. I live in an area prone to river flooding.[Y / N]
 - b. My home was threatened or hit by a major hurricane in the past. [Y / N]
 - c. I evacuated my home because of this hurricane. [Y / N]
 - d. I am concerned that a major hurricane will hit my community in next 6 months. [Y / N]
 - e. I would leave my home, if I were asked to evacuate by government officials due to a major hurricane. [Y / N]
 - f. I have attended some meetings, classes, or workshops on preparing for a hurricane during the past year. [Y / N]
 - g. My family has agreed on a phone number to contact outside the region, in the event of a hurricane. [Y / N]
 - h. Someone in my household takes prescription drugs on a regular or ongoing basis. [Y / N]
 - i. All of my household members always maintain a three week supply of their regular prescription drugs. [Y / N]
 - j. The prescription coverage of my household members prevents the collection of extra medicine supplies. [Y / N]
 - k. Someone in my household has a chronic illness or disability that would require outside help during a hurricane evacuation. [Y/N]
- If no, please skip question l
- l. If yes, I have pre-arranged help for this chronically ill or disabled person's evacuation. [Y / N]

IV: Please check the items below

- a. At home, I have the following hurricane emergency items:
 - ☐ Enough food for three days for each member of my family
 - ☐ Enough water for three days for each member of my family
 - ☐ A battery-operated radio that works
 - ☐ A flashlight that works
 - ☐ A first aid kit
 - ☐ Extra batteries
 - ☐ A cell phone
 - ☐ At least \$300 in cash
 - ☐ Sterno (Non-electric device) for heating food
- b. I am covered at this time by all of the following insurance types:
 - ☐ Health Insurance
 - ☐ Health Plan
 - ☐ Homeowner's Insurance
 - ☐ Renter's Insurance
 - ☐ Flood Insurance
 - ☐ None
- c. My home is located in the following hurricane evacuation zone:
 - ☐ Zone A or Minor hurricane flood zone
 - ☐ Zone B or Major hurricane flood zone
 - ☐ Zone C in Providence behind the hurricane barriers
 - ☐ Not in an evacuation zone
 - ☐ Don't know
- d. Following the evacuation notice, I would plan to leave the flood zones within the timeframe mentioned below:
 - ☐ 0– 1 hr
 - ☐ 1– 3 hr
 - ☐ 3– 6 hr
 - ☐ 6– 9 hr
 - ☐ 9– 12 hr
 - ☐ > 12 hr
 - ☐ I am not in an evacuation zone

e. If I were to evacuate my home because of a hurricane, I would go to the following destination:

- ☐ A friend or family member's home
- ☐ A hotel/motel
- ☐ An evacuation shelter
- ☐ Do not know
- Other (specify) _____

f. If I were to evacuate my home because of a hurricane, I would travel the following distance:

- ☐ Less than 10 miles
- ☐ 10- 50 miles
- ☐ 50- 100 miles
- ☐ 100- 200 miles
- ☐ More than 200 miles

g. If I were to evacuate my home because of a hurricane, I would use the following means of transportation:

- ☐ My car
- ☐ Friend's car
- ☐ Public transportation
- ☐ Walking or riding a bike

h. If I were to evacuate my home because of a hurricane, I estimate that I would reach my destination within this timeframe:

- ☐ 1 hour
- ☐ 2 hours
- ☐ 3 hours
- ☐ 4 hours
- ☐ 5 hours

Other (specify) _____

i. If I were to evacuate my home within 6 hours of a hurricane evacuation notice, I would take with me the following list of document items:

- ☐ Proof of health insurance
- ☐ Prescriptions for the drugs that my household members take
- ☐ Proof of homeowner's or renter's insurance
- ☐ The social security cards of my household members

j. If I had to evacuate because of a major hurricane, I would return home within the following timeframe:

- ☐ As soon as the hurricane is over
- ☐ Once officials say that it is safe to return
- Other (specify) _____

k. Please check all the reasons why you might not evacuate:

- ☐ I would not know where to go.
- ☐ I would not have a car
- ☐ I would not know anyone who could give me a ride
- ☐ I have medical or physical problems that would prevent me from leaving.
- ☐ I have to take care of someone who would be physically unable to leave.
- ☐ I would be worried that my possessions would be stolen or damaged
- ☐ I would not want to leave my pet
- ☐ I would not be able to afford to leave
- ☐ I would not be able to leave my job
- ☐ I think that my home is well built and that I will be safe at home
- ☐ I think evacuating would be dangerous
- ☐ I think the roads would be too crowded to leave
- ☐ Some officials said that the evacuation is unnecessary
- ☐ the media said that the evacuation is unnecessary
- ☐ My friend or relativesaid that the evacuation is unnecessary
- ☐ I think there is a low risk of a hurricane hit
- ☐ I received no official notice to evacuate
- ☐ I left unnecessarily in the past

l. The following reasons would convince me to leave for a safer place:

- ☐ Advice or order by elected officials
- ☐ Advice from weather service
- ☐ Advice or order from police or firemen
- ☐ Advice from friend or relative
- ☐ Concern about severity of hurricane
- ☐ Concern that hurricane might hit
- ☐ Heard low risk of a hit
- ☐ Other (specify) _____

Survey in Support of Multi-Modal Hurricane Evacuation Plans

We invite you to participate in this survey conducted by researchers from the University of Rhode Island in the aim to determine the preparedness of persons in Rhode Island for hurricane evacuations and the anticipated behavioral patterns during hurricane evacuations in Rhode Island. Behavioral patterns of particular interest are those that impact mainly on transportation system usage and those that impact other anticipated actions. Thank you in advance for your cooperation and time.

Please briefly read the associated cover letter for the project by clicking the following link [CoverLetter](#)

I : Please respond by circling the option that reflects how you feel about each statement.

a. I am prepared if a major hurricane strikes my community during the next 6 months

● Strongly Disagree ● Disagree ● Agree ● Strongly Agree

b. I am more prepared for a major hurricane this year than I was last year

● Strongly Disagree ● Disagree ● Agree ● Strongly Agree

c. My home is likely to be flooded in a major hurricane

● Strongly Disagree ● Disagree ● Agree ● Strongly Agree

d. My home is likely to be damaged by wind in a major hurricane

● Strongly Disagree ● Disagree ● Agree ● Strongly Agree

e. I am confident that I would be rescued if a major hurricane hits and I did not evacuate my home

● Strongly Disagree ● Disagree ● Agree ● Strongly Agree

II: Please respond by circling the option that reflects your **perception regarding hurricane evacuation shelters.**

a. I would have enough clean water to drink

● Strongly Disagree ● Disagree ● Agree ● Strongly Agree

b. I would have enough food to eat

● Strongly Disagree ● Disagree ● Agree ● Strongly Agree

c. I would have the prescription drugs or medicines that I need

● Strongly Disagree ● Disagree ● Agree ● Strongly Agree

d. I would be threatened by violence

● Strongly Disagree ● Disagree ● Agree ● Strongly Agree

e. I would need medical care and I wouldn't be able to get it

● Strongly Disagree ● Disagree ● Agree ● Strongly Agree

f. The shelter would be unsanitary

● Strongly Disagree ● Disagree ● Agree ● Strongly Agree

g. I would be exposed to sick people and could catch their illnesses

● Strongly Disagree ● Disagree ● Agree ● Strongly Agree

h. The shelter would be too crowded and I would not have any privacy

● Strongly Disagree ● Disagree ● Agree ● Strongly Agree

i. I would have a hard time communicating with family outside the shelter

● Strongly Disagree ● Disagree ● Agree ● Strongly Agree

III : Please respond by circling the option that reflects how you feel about each statement

a. I live in an area prone to river flooding.

☐ Yes ☐ No

b. My home was threatened or hit by a major hurricane in the past.

☐ Yes ☐ No

c. I evacuated my home because of this hurricane.

☐ Yes ☐ No

d. I am concerned that a major hurricane will hit my community in next 6 months.

☐ Yes ☐ No

e. I would leave my home, if I were asked to evacuate by government officials due to a major hurricane.

☐ Yes ☐ No

f. I have attended some meetings, classes, or workshops on preparing for a hurricane during the past year.

☐ Yes ☐ No

g. My family has agreed on a phone number to contact outside the region, in the event of a hurricane.

☐ Yes ☐ No

h. Someone in my household takes prescription drugs on a regular or ongoing basis.

☐ Yes ☐ No

i. All of my household members always maintain a three week supply of their regular prescription drugs.

☐ Yes ☐ No

j. The prescription coverage of my household members prevents the collection of extra medicine supplies.

☐ Yes ☐ No

k. Someone in my household has a chronic illness or disability that would require outside help during a hurricane evacuation.

☐ Yes ☐ No

If no, please skip question l

l. If yes, I have pre-arranged help for this chronically ill or disabled person's evacuation.

☐ Yes ☐ No

IV: Please check the items below

a. At home, I have the following hurricane emergency items:

- ☐ Enough food for three days for each member of my family
- ☐ Enough water for three days for each member of my family
- ☐ A battery-operated radio that works
- ☐ A flashlight that works
- ☐ A first aid kit
- ☐ Extra batteries
- ☐ A cell phone
- ☐ At least \$300 in cash

☐ **Sterno (Non-electric device) for heating food**

b. I am covered at this time by all of the following insurance types:

☐ **Health Insurance**

☐ **Health Plan**

☐ **Homeowner's Insurance**

☐ **Renter's Insurance**

☐ **Flood Insurance**

☐ **None**

c. My home is located in the following hurricane evacuation zone:

☐ **Zone A or Minor hurricane flood zone**

☐ **Zone B or Major hurricane flood zone**

☐ **Zone C in Providence behind the hurricane barriers**

☐ **Not in an evacuation zone**

☐ **Don't know**

d. Following the evacuation notice, I would plan to leave the flood zones within the timeframe mentioned below:

☐ **0 – 1 hr**

☐ **1 – 3 hr**

☐ **3 – 6 hr**

☐ **6 – 9 hr**

- ☐ 9 – 12 hr
- ☐ > 12 hr
- ☐ I am not in an evacuation zone

e. If I were to evacuate my home because of a hurricane, I would go to the following destination:

- ☒ A friend or family member's home
- ☒ A hotel/motel
- ☒ An evacuation shelter
- ☒ Do not know

Other (specify)

f. If I were to evacuate my home because of a hurricane, I would travel the following distance:

- ☒ Less than 10 miles
- ☒ 10 - 50 miles
- ☒ 50 – 100 miles
- ☒ 100 – 200 miles
- ☒ More than 200 miles

g. If I were to evacuate my home because of a hurricane, I would use the following means of transportation:

- ☒ My car
- ☒ Friend's car

- **Public transportation**
- **Walking or riding a bike**

h. If I were to evacuate my home because of a hurricane, I estimate that I would reach my destination within this timeframe:

- **1 hour**
- **2 hours**
- **3 hours**
- **4 hours**
- **5 hours**

Other (specify)

i. If I were to evacuate my home within 6 hours of a hurricane evacuation notice, I would take with me the following list of document items:

- ☐ **Proof of health insurance**
- ☐ **Prescriptions for the drugs that my household members take**
- ☐ **Proof of homeowner's or renters' insurance**
- ☐ **The social security cards of my household members**

j. If I had to evacuate because of a major hurricane, I would return home within the following timeframe:

- **soon as the hurricane is over**
- **Once officials say that it is safe to return**

Other (specify)

k. Please check all the reasons why you might not evacuate:

- ☐ **I would not know where to go**
- ☐ **I would not have a car**
- ☐ **I would not know anyone who could give me a ride**
- ☐ **I have medical or physical problems that would prevent me from leaving**
- ☐ **I have to take care of someone who would be physically unable to leave**
- ☐ **I would be worried that my possessions would be stolen or damaged**
- ☐ **I would not want to leave my pet**
- ☐ **I would not be able to afford to leave**
- ☐ **I would not be able to leave my job**
- ☐ **I think that my home is well built and that I will be safe at home**
- ☐ **I think evacuating would be dangerous**
- ☐ **I think the roads would be too crowded to leave**
- ☐ **Some officials said that the evacuation is unnecessary**
- ☐ **the media said that the evacuation is unnecessary**
- ☐ **My friend or relative said that the evacuation is unnecessary**
- ☐ **I think there is a low risk of a hurricane hit**
- ☐ **I received no official notice to evacuate**
- ☐ **I left unnecessarily in the past**

I. The following reasons would convince me to leave for a safer place:

- ☐ Advice or order by elected officials
- ☐ Advice from weather service
- ☐ Advice or order from police or firemen
- ☐ Advice from friend or relative
- ☐ Concern about severity of hurricane
- ☐ Concern that hurricane might hit
- ☐ Heard low risk of a hit

Other (specify)

V: Please check or fill in the items below

a. My age is yrs.

b. I have completed the following educational level:

- ☐ Elementary
- ☐ Middle School
- ☐ High School
- ☐ Community College
- ☐ College (Bachelor's Degree)
- ☐ Graduate School

☐ Professional School

☐ Trade School

c. I belong to the following racial or ethnic group:

☐ Caucasian

☐ African –American

☐ Asian – American

☐ Native American / Indian

☐ Latino / Hispanic

Other (specify)

d. My housing status is the following.

☐ Own

☐ Rent

e. My housing unit is:

☐ A single family home

☐ A duplex or multi-family home

☐ An apartment building

☐ A condominium

☐ A mobile home

f. My zip code is

g. My address or my nearest cross streets are and

h. I have lived in my community for the following span of time:

- ☐ Less than 1 year
- ☐ 1-5 years
- ☐ 6-10 years
- ☐ 11-20 years
- ☐ More than 20 years
- ☐ My Entire life

i. My household contains the following number of vehicles:

- ☐ One
- ☐ Two
- ☐ Three
- ☐ Four

Other (specify)

j. I would use the following number of vehicles for evacuation:

- ☐ One
- ☐ Two
- ☐ Three
- ☐ Four

Other (specify)

k. My household contains kids (younger than 18)

☐ Yes

☐ No

If yes please specify the number of kids

l. My household contains senior citizens (65 or older)

☐ Yes

☐ No

If yes please specify the number of senior citizens

m. The estimated value of my home falls within the following range:

☐ Below \$100,000

☐ \$100,000 - \$149,999

☐ \$150,000 - \$199,999

☐ \$200,000 - \$249,999

☐ \$250,000 - \$299,999

☐ \$300,000 - \$349,999

☐ \$350,000 - \$399,999

☐ \$400,000 - \$449,999

☐ \$450,000 - \$499,999

- **\$500,000 and above**

n. My annual household income falls within the following range:

- **Less than \$25,000**

- **\$25,000 - \$39,999**

- **\$40,000 - \$79,999**

- **\$80,000 - \$120,000**

- **Over \$120,000**

- **Do not know**

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