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Capturing Pre-evacuation Trips and Associative Delays: A Case Study of the Evacuation of Key West, Florida for Hurricane Wilma

Melany Strike Noltenius
University of Tennessee - Knoxville

To the Graduate Council:

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Bruce Ralston, Major Professor

We have read this dissertation and recommend its acceptance:

Shih-Lung Shaw, Tom Bell, Fred Wegmann

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

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A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Melany Strike Noltenius
August 2008

DEDICATION

This dissertation is dedicated to my husband, Juan, and daughter, Cristina. One who let me struggle with my determination to "do-it-myself" before fixing my survey coding errors, and one who took me shopping to "get me out of the house and out of my bad mood."

ACKNOWLEDGEMENTS

I am really very thankful to my major advisor, Dr. Bruce Ralston, for his continuous optimism, guidance, and encouragement that helped my "slow, but steady progress" in the completion of this dissertation. Without his help, and sense of humor, I would never have been able to accomplish this objective.

Dr. Shih-Lung Shaw has been very patient with my many misunderstandings of the application of GIS to transportation. He has proven time and time again that his goal was for me to learn and not languish in my ignorance.

I am indebted to Dr. Tom Bell for his consistent enthusiasm and careful dissertation review . . . nonparametric tests *are* better!

I want to thank Dr. Fred Wegmann. Dr. Wegmann has been instrumental in developing my knowledge of transportation systems for the past six years. He has been very tactful and persistent in helping me through the dissertation process with a great deal of wit.

Finally, I would like to thank Denise Stansberry for calming me and realizing my confused look as a desperate plea to help me through all the necessary paperwork.

ABSTRACT

The time it takes for the residents to evacuate an area is calculated as an evacuation time estimate (ETE). In theory, these time estimates are calculated based on a number of inputs, including clearance time, the impact of traffic management techniques, and the time for the public to prepare to evacuate (Dow, 2000). Evacuation models can calculate clearance times, as well as incorporate the temporal impact of traffic management techniques, like contra-flow traffic. However, these models do not include delays associated with pre-evacuation trips. Because these trips are not well represented in hurricane evacuation models, the evacuation time estimate may be miscalculated (Wilmot and Mei, 2004).

In order to capture pre-evacuation trip behavior, an online survey of residents' responses to the evacuation order associated with Hurricane Wilma in 2005 was conducted. Survey data gathered from the residents of Key West, Florida indicate seven important aspects of pre-evacuation trip making behavior: (1) Socio-demographic variables, which have some association with evacuation behavior, were found to have a very weak to no association with pre-evacuation trip-making; (2) Socio-demographic variables were found to have an association with predicting evacuation behavior for respondents making pre-evacuation trips, and these associations are consistent to what has been found in other studies of evacuation behavior; (3) Delays at stops are longer than delays on links; (4) Trip delays are associated with trip purpose; (5) Residents did not travel from a single origin point directly to an evacuation point, but made various pre-evacuation trips, often exhibiting trip chaining that included traveling toward as well as away from the city; (6) Though the Key West mandatory evacuation for Hurricane Wilma consisted of a phased evacuation based on housing types, the residents did not evacuate based on housing type, and (7) the personal stories offered by respondents indicate that evacuating or not is often

related to job requirements, economic opportunity, previous evacuation experience, and evacuation burnout.

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Chapter 1: Introduction

Events of the past decade have highlighted the importance of understanding how people respond to large scale disasters. The logistical problems associated with Hurricane Katrina in 2005 have made clear the need to improve both the techniques used to model human response to natural hazards and our understanding of human behavior in the face of large scale disasters. Since 1900, hurricanes and hurricane storm surges have killed approximately 16,000 people in the United States. They have also caused more than $300 billion worth of damage (NHC 2006). Of the hurricanes that made landfall since 1900, mandatory evacuations were only issued by officials beginning in 1979 when Florida's governor issued the first mandatory evacuation to warn residents in the Florida Keys to evacuate before Hurricane David made landfall (Kramer 2008). Until this time the National Weather Service (NWS) issued hurricane warnings and watches that residents responded to on an individual basis – there was no mandatory evacuation.

The process leading up to a mandatory evacuation order involves many different agencies. First, the National Oceanic and Atmospheric Administration (NOAA) monitors and predicts weather changes related to hurricane activity (NHC 2006). NOAA then alerts the National Hurricane Center (NHC) of potential hurricane activity. NHC,in turn, decides whether or not to assign the storm a hurricane category based on wind strength and storm surge (NHC 2006). Finally, the NHC notifies both the NWS and local emergency management agencies of predicted hurricane wind strength, storm surge and landfall. The NWS broadcasts a hurricane watch, which is a prediction that a hurricane will develop within 24-36 hours, or a hurricane warning, which is a prediction that a hurricane will make landfall within 24 hours (NHC 2006). At this point, local officials decide whether or not to declare an evacuation warning and/or order a mandatory evacuation to the residents of an area based on hurricane category and landfall

predictions. For example, officials in the City of Key West, Florida will only order a mandatory evacuation if a Category 3 or more hurricane has potential to make landfall (Iannotta 2005).

The NHC calculates hurricane impact projections, like strike probabilities and hurricane intensities, with models, such as HURREVAC (FEMA 2000). Unfortunately, none of these hurricane models can determine with 100% accuracy if a mandatory evacuation should be ordered. This is because technology is still limited in its ability to predict the exact location and timing of a hurricane strike. For example, the NHC can issue only a maximum strike probability of 25% - 36 hours before a hurricane makes landfall (Lindell 2004). Ordering a mandatory evacuation is made even more difficult by the fact it can take up to two days to effectively evacuate a city of approximately 500,000 residents, assuming that the residents are willing and ready to evacuate as soon as the mandatory evacuation order is issued (Goldblatt 2006). Naturally, officials do not want to cry "Wolf" and have residents evacuate without good cause, as this will negate the effect of future mandatory evacuations and cost the residents and city a great deal of money. On the other hand, ordering a mandatory evacuation without providing enough time for residents to leave the area can have devastating effects. This is clearly illustrated by Hurricane Katrina. New Orleans Mayor Ray Nagin called for a mandatory evacuation only 20 hours before the storm made landfall (Bolstad 2005).

In addition to the hurricane models used to predict the location and timing of hurricane landfall, evacuation models are used to determine how much time it takes to evacuate an area. The time it takes for the residents to leave an area is calculated as an evacuation time estimate (ETE). ETEs are estimated as a percentage of all agents traveling past a point at a specific time period. For example, an ETE is calculated as a percentage of all agents (e.g. vehicles) traveling past point X in Y minutes. In theory, these time estimates are calculated based on a number of

inputs, including clearance time, the impact of traffic management techniques, and the time for the public to prepare to evacuate (Dow, 2000).

Evacuation models can provide an estimate of the clearance time for an area, and experienced local officials can provide a rough calculation for the time it takes to order an evacuation and implement traffic management techniques, but there are no readily available studies that have captured the activities and calculated the delay associated with preparation for an evacuation involving pre-evacuation trips. Thus, when evacuation models are used to calculate ETEs, the delay caused by pre-evacuation trips is not well represented nor well understood in hurricane evacuation models (Lindell 2005). As a result, ETEs may be underestimated (Wilmot 2004). Though some evacuation models (e.g. WITNESS, ETIS, and MASSVAC) allow for participation delay based on a specific agent category (resident, visitor, etc.), the models assume all members of each category share the same evacuation delay and behavior (Alshih 2004; Farahmand 1997; Mei 2002).

The main objective of this dissertation is, therefore, to gather and analyze data regarding the inner-city trips that residents make after a mandatory evacuation order has been issued, but before the deadline for evacuating is reached. To clarify, within the context of this dissertation, the phrase "pre-evacuation trips" refers to trips made before evacuating the city, returning home, or going someplace within the city to wait out the storm. More specifically, data regarding trip origin and destination, travel time, trip purpose, which refers to the reason for traveling to a destination, and the time required to complete trip purpose have been collected. In addition, demographic details have been assembled in conjunction with travel information to test for associations between socio-demographic variables and evacuation behavior.

Research Questions

The data gathered have been used to answer four research questions regarding the association between socio-demographic characteristics and trip behavior, travel time, delays and patterns, and the qualitative aspect of evacuating a city. The research questions are:

(1) Do socio-demographic attributes have a statistically significant association with evacuation trip-making?

The literature review, which is presented in Chapter 2, indicated that certain trip-making responses could be associated with demographic attributes, such as gender, age, income, marital status, and home ownership. An anonymous online survey was used to gather data regarding socio-demographic characteristics and pre-evacuation trip-making behavior associated with the 2005 mandatory Hurricane Wilma evacuation in Key West, Florida. The sample data were tested for statistical significance to identify any non-random relationships and predictor variables connected to socio-demographic characteristics and pre-evacuation trip-making behavior.

(2) How much time do travel delays and trip activity delays (e.g. shopping for hurricane supplies) associated with pre-evacuation trips take?

It is not just enough to know that pre-evacuation trips are taken. Insight into delays, which have strong implications for ETEs, is necessary. Do the delays vary by trip purpose? Are the delays are only encountered along transportation routes, which many models assume, or do they take place at stops? In order to explore these questions for the respondents who reported pre-evacuation trips, the survey allowed the respondents to identify as many trips or sequence of trips as needed. The survey further asked the respondent to identify the trip delay and the time needed for trip purpose completion for each trip. Evacuation models calculate ETEs under the assumption that delays occur only on the links between each node. For example, in the MASSVAC evacuation model, all vehicles are assigned to various links at the same time;

vehicles then travel to different links based on underserved capacity at each time interval (Alshih 2004). Trip postponements at nodes that occur because of trip purpose delays are not integrated into that model.

(3) What types of traffic patterns occur after a mandatory evacuation order has been issued?

To test for geographic dispersion of respondent trips, the locations of the first respondent-identified origin and destination nodes were used to identify traffic flows and patterns. Most evacuation models assume that residents will travel from one or many origin nodes to one or many destination nodes located outside the evacuation zone. The models do not assume that agents travel inside the area that is to be evacuated, possibly away from the evacuation outlet, or that agents may travel from outside the evacuation zone into the evacuation zone.

(4) How does one capture the qualitative aspect of evacuation trip-making?

The survey was designed primarily to gather quantitative data – gender, age, marital status, trip purpose, delays, etc. However, the qualitative aspects of the evacuation process can be used to provide a more comprehensive understanding of the "mind set" of respondents under a mandatory evacuation order. These qualitative aspects could consist of underlying reasons as to why a respondent would or would not evacuate, such as job requirements, family history, evacuation experience, etc. As a result, the survey contained areas in which respondents could relate their own personal stories.

The research plan required identification of a survey area, a description of data gathering techniques, and an articulation of the methods used for analyzing the data collected. One of the more important decisions to make was to define the geographic region to be surveyed. To ensure that the residents surveyed had some evacuation experience, and did not simply guess as to the pre-evacuation trips they would take, the research survey was directed to the residents of an area

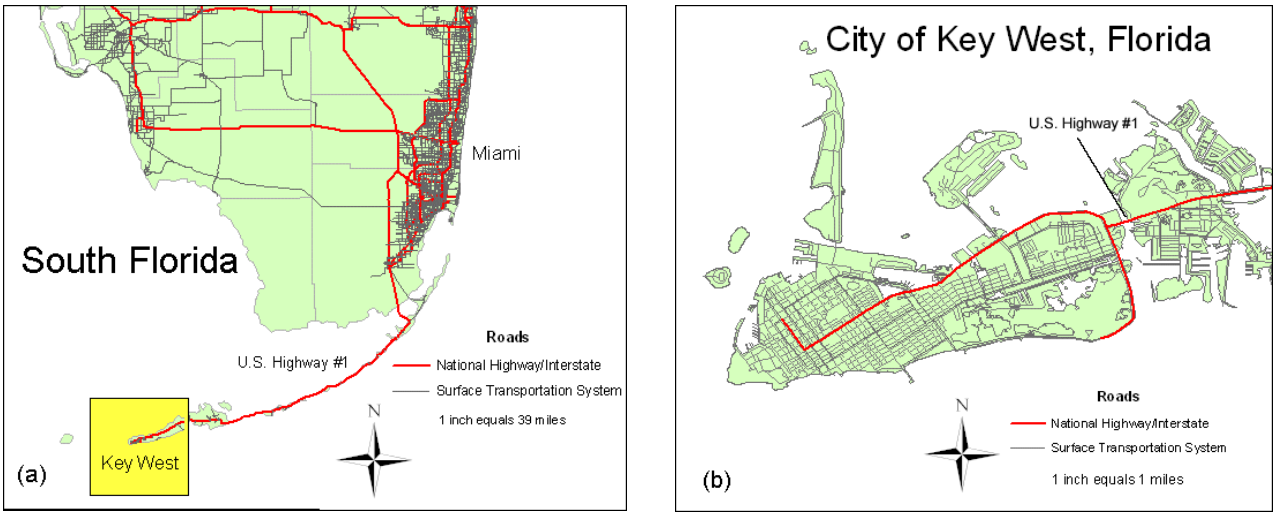

Figure 1: Key West, Florida; (a) Key West, the western most Florida Key; (b) The City of Key West, Florida

that had recent experience with hurricane evacuation. For this study the City of Key West, Florida was chosen (Figure 1: Key West, Florida). In October of 2005, Key West experienced a mandatory evacuation in response to Hurricane Wilma. For Hurricane Wilma, a mandatory evacuation was issued at 6 a.m. to mobile home dwellers and special needs residents; the remaining residents were ordered to evacuate by noon of the same day (Saturday, October 22, 2005). Residents who lived in boats, recreational vehicles or travel trailers were given a mandatory evacuation order on the previous Wednesday, October 19, 2005 (FLDEP 2006). The City of Key West, Florida was chosen as the research location for other reasons. First, the residents of the city had some experience with hurricane evacuation policies and procedures. Three mandatory evacuations had already been issued in Key West during the 2005 Hurricane Season – in July for Hurricane Dennis, in August for Hurricane Katrina, and in September for Hurricane Rita. Even though the last mandatory evacuation was in October 2005 for Hurricane Wilma, Key West residents had a high chance of remembering something about the trips taken

before either leaving the city or waiting out the storm. Second, because there is only one highway out of the city, the survey only needed to identify one exit point for highway-based evacuees to travel toward. This made it easier for respondents to calculate the time needed for evacuation. Third, by identifying a point along U.S. Highway #1 as the exit point, the survey respondents had a physical marker for identifying the trips taken before traveling past this point – a definitive trip end. Fourth, by limiting the geographic region to the City of Key West the survey area was manageable - approximately 5 square miles in size, with approximately 11,000 households (U.S. Census 2006). This made replicating trip origins and destinations in a geographic information system software package less difficult than in a large geographic region. Finally, the City of Key West contains only eight census tracts (9719, 9720, 9721, 9722, 9723, 9724, 9725 and 9726), which limits the number of origin and destination nodes needed to ensure a relatively uniform geographic distribution of respondents across the research area, and yet allowed for variation in the location of origin and destination nodes.

Limitations of the Study

There were certain unavoidable limitations associated with this research. The use of an online survey to gather demographic and pre-evacuation trip-making data meant that only people with internet access could take the survey. Cost constraints narrowed the survey data collection method. In addition, the selection process of notifying households about the survey's existence via a brochure and email notification, and not in person, may have lowered the response rate. Email notifications could only be sent to businesses with an email address listed in the Real Yellow Pages, which may have restricted the dispersion of email notices. The random brochure distribution was used to mitigate this reality. Unfortunately, man-made obstacles, such as gated

communities, limited the brochure distribution in some areas. The two methods of notification were chosen as a means to generate as many responses as possible given the time, financial resources and safety concerns of the researcher. Finally, the survey asked residents to remember what pre-evacuation trips were made after the mandatory evacuation order was issued for Hurricane Wilma, the time it took to make these trips, and to identify road intersections near their trip origin and destination points to represent each trip made. Residents may have forgotten or remembered incorrectly this information because of the time that has passed between the last ordered evacuation for the City of Key West, which was in October 2005 and when they took the online survey in October 2007. The minimum expected sample size of approximately 50 represented a one percent response rate if half of the 11,000 households in the City of Key West were notified of the survey through email notification and brochures. The purpose of calculating a minimum response rate was to allow for some variation in both the demographic characteristics of respondents and the trips made across and within the eight census tracts of the city. Approximately 50 respondents was a realistic response rate for an online survey (Manfreda 2006). The number of useable responses (287) far exceeded these minimal guidelines.

In spite of the limitations of anonymous surveys, this research has merit in bringing attention to the inaccurate calculation of the ETE. It also provides insight into how socio-demographic characteristics affect the ultimate decisions of people who live in an evacuation area. Do residents make pre-evacuation trips to gather people and goods with which to evacuate, or do they make such trips to prepare to ride out the storm? The survey data collected have the potential to provide a framework for further research into evacuation modeling and to expand the attributes contained within these models to more accurately reflect trips taken before evacuation takes place. These survey data include insights into the prevalence of pre-evacuation trip making,

the delays associated with those trips, and the spatial distribution of such trips. Any such findings can be used to develop more accurate evacuation models. This research can be used to bring attention to the miscalculated ETE, and presents a methodology for collecting data to analyze this problem. Finally, this research can be used to help city officials create policies associated with mandatory evacuations.

Dissertation Organization

Chapter 2 reviews the literature on human behavior in evacuation situations. This literature is used to identify the variables included in the survey and to generate hypotheses about how those variables might be associated with the propensity for making pre-evacuation trips, and whether or not those making such trips evacuate or wait out the storm. The third chapter presents the research plan. In this chapter the questionnaire is presented, along with the sampling design used to distribute brochures about the study. The analysis of the data collected is presented in Chapter 4. That chapter is broken into three parts. The first part discusses the quantitative aspects of the data collected. This includes characterizing the "typical" respondent, a non-parametric analysis of the relationship among the classes of respondents (no pre-evacuation trips, pre-evacuation trips and evacuates, and pre-evacuation trips and stays); logistic regression analysis is performed to see if the socio-demographic variables can be used to predict how a respondent will react to an evacuation order. The second part of the analysis looks at the distribution of origins and destinations of pre-evacuation trips. Included in this discussion are the delays, both in route and at stops, for those trips. The final section of Chapter 4 explores people's evacuation stories. The findings in this section can provide policy makers with insights into how different groups, for example merchants, view their evacuation orders. The final

chapter discusses the major findings of this research and how they can influence both policy and modeling of evacuation decision making.

Chapter 2: Literature Review

While there was no literature found directly relating pre-evacuation trip-making to socio-demographic characteristics, there was literature relating demographic and other differences to evacuation behavior. The review of literature on evacuation was undertaken to identify socio-demographic characteristics associated with persons making evacuation trips. This provided a framework for the survey questionnaire. Demographic and other variables found to be associated with evacuation behavior were included in the questionnaire on pre-evacuation trip making. It was hypothesized that the same variables associated with evacuation behavior might be associated with pre-evacuation trip behavior.

Human behavior during an evacuation is affected by a wide variety of seemingly disassociated elements that, when combined, shape human response. Evacuation of an area is influenced by gender, family make-up, and household type (Alsnih 2005). Household trip-making behavior can also be influenced by cultural customs, and personal backgrounds. For example, some cultures look at natural disasters, like hurricanes, as "God's will toward them" and do not try to protect themselves or their property (Neary 2005). These households might be less likely to travel to a hardware store to gather supplies than another household with a less fatalistic attitude. Furthermore, because evacuation notices are generally broadcast in English, residents in an area that do not speak English tend to evacuate more slowly, not really knowing what to do or where to go to get help (Neary 2005). This could cause delays in pre-evacuation trips or affect the choice of whether to evacuate or wait out the storm.

Though evacuation behavior is complex, ETEs need to be calculated for modeling purposes in order to determine at what time a mandatory evacuation order should be issued. In

hurricane models, the ETEs are a measure used to calculate how long it takes for most people to evacuate an area and do not represent the time for an individual evacuee to leave an area. For instance, the ETE for the lower Florida Keys varies from a minimum of 12 hours to a maximum of 24 hours depending on the strength of the hurricane and the Keys to be evacuated, not that it takes an individual 12 to 24 hours to leave the area (Chen 2005). However, the hurricane models used to calculate ETEs, such as MASSVAC or WITNESS, do not take into account pre-evacuation trips and delays, but rather focus on projected transportation network congestion. According to Kenneth Metcalf, Regional Planning Administrator for the State of Florida: "Model outputs are only as accurate as the input assumptions." For example, the ETIS evacuation model incorporates participation rates based on subjective judgment of evacuee behavior from previous storms and not on a statistical analysis of data (Wilmot 2004).

The purpose of the literature review was to examine the association between socio-demographic and other attributes with evacuation behavior (i.e. to evacuate or wait out the storm), and then to hypothesize how these attributes might be associated with pre-evacuation trips. Based on the literature review, evacuation choice is reflected in certain socio-demographic indicators. In this dissertation, these indicators were used to provide a basis for the survey questions, such as the variable of Marital Status, and the specific answer choices of single, married, non-married couple, divorced or widowed.

For example, the literature suggested that income has an impact on whether families evacuate. An income of $40,000 or more was shown to be the point at which income had an impact on whether or not respondents evacuated for Hurricane Georges (Howell 2006). As a result of the literature reviewed, the survey contained the following categories for income level:

Less than $25,000; $25,000-$49,000; $50,000-$99,000; $100,000-$149,000; $150,000-$199,000, and $200,000 or more.

Because of personal backgrounds, people behave differently during an evacuation even though they may share demographic similarities. In one instance, a male respondent who was 45-59 years old waited out the storm after making a trip to Home Depot, while another male respondent of the same age evacuated to Orlando, Florida without making any other trips. Though these respondents shared the same demographic characteristics, their pre-evacuation trip behaviors were random and difficult to predict.

Research has shown that simplified differences in evacuee behavior (to evacuate or to stay put) can be loosely associated with gender, age, income, marital status, presence of children in the home, housing type, and home ownership (Cutter 2006, Dow 2000, Enarson, 1999, Howell 2006, Lindell 2005, McGuckin 2006, Mei 2002, Murray-Tuite, 2005, Wilmot 2004, and Wolshon 2005). Evacuee behavior is "loosely" associated because some researchers have reached different conclusions regarding demographic characteristics, such as the impact of race and education level on evacuee behavior. I hypothesized that socio-demographic attributes were theoretically associated with pre-evacuation trips because there were no available studies that could be used to predict pre-evacuation trips with socio-demographic characteristics. Other factors that affect the decision to evacuate include the length of residency, previous hurricane experience, previous evacuation experience, and the declaration of a mandatory evacuation (Alsnih 2005, Emarson 1999, Dow 2000, Mei 2002 and Neary 2005). Once again, researchers have reached different conclusions regarding whether hurricane experience has a definite impact on evacuation behavior.

Demographic Differences

Certain evacuation behaviors are associated with socio-demographic characteristics. These differences are related to gender, race, age, education and marital status. Though demographics may be related with certain overall probabilities of a behavior, the link between characteristics and behavior is not always consistent.

Emarson (1999) found that women tended to be more responsible for gathering relatives together, picking up medicines, money and other needed supplies, whereas, men spent their pre-evacuation time boarding up homes and businesses during the evacuation of the Red River Valley in Canada. Women were also more likely to evacuate sooner than men, especially women with young children (Enarson, 1999).

Age was also a factor in choosing whether or not to evacuate. There have been no definitive age ranges that can be used to determine if an individual will evacuate. Dow wrote that "evacuation delay was observed for older households" during Hurricane Floyd in South Carolina, but she does not specify the definition of "older" (Dow 2000). Dow's research also showed that households with children were more likely to evacuate than those without; whereas, households comprised completely of adults were more likely not to evacuate. Research by Howell indicated more specifically that residents over 45 years of age were more likely to stay in their homes during the evacuation associated with Hurricane George in Louisiana. This response was shown to be associated with older people living in "better" homes and/or the inability of older persons to evacuate (Howell 2006). Contrary to these studies are the data collected for the Louisiana Population Data Center (Irwin 1995). The survey collected information from respondents living in Louisiana when Hurricane Andrew struck in August 1992. That research indicated that respondents 39 years old or younger were almost equally likely to evacuate or not

evacuate (Table 1: Age by Whether Evacuated during Andrew). The majority of these respondents who were 40 years old or older did not evacuate when Hurricane Andrew struck.

Not surprisingly, income levels were found to be closely related to willingness and ability to evacuate. In the case of the Hurricane Georges evacuation in Louisiana, only 16% of the families with incomes below $25,000 evacuated, while 54% of those with incomes over $80,000 evacuated (Howell 2006). A family income of $40,000 was identified as the threshold where evacuation from the city became more likely than waiting out the storm (Howell 2006). The link between income level and evacuation was also supported by Smith (1999) who interviewed families who evacuated coastal North Carolina for Hurricane Bonnie in 1998. Smith wrote "As income increases evacuations will increase," but Smith did not identify the income levels studied or if the increase in income and evacuation had a perfectly linear relationship (Smith 1999). Interestingly, families with lower incomes who did evacuate tended to go to the homes of other people or shelters rather than leave the city (Smith 1999). This could be related to the definitive link between income levels and car ownership. Families with access to a vehicle were more likely to evacuate than those without, and those without tended to use public transit, if made available (Cutter 2006).

Table 1: Age by Whether Evacuated during Andrew

Age of Respondent	Evacuation	
	Yes	No
<20	47.4%	52.6%
20 – 29	50%	50%
30 – 39	51.8%	48.2%
40 –49	28.9%	71.1%
50 – 59	36.6%	63.4%
60+	28.6%	71.4%

Linked with income, the race of an individual could have some connection with the decision to evacuate, but the literature reviewed did not provide an absolute link between race and evacuation behavior. Howell reported that the relationship between income and race was very definite with only 12% of low income black residents leaving Orleans Parish during Hurricane Georges (Howell 2006). Black residents of New Orleans City were more likely to stay put rather than evacuate during Hurricane Katrina as well (Cutter 2006). However, results by Mei (2002) indicated that less white people (~41%) than black people (~46%) evacuated for Hurricane Andrew in Louisiana.

The literature regarding education level and evacuation behavior was also conflicting. Smith wrote that "education level increases the likelihood of evacuation," but he did not provide a definition for education level, nor did he provide an idea of the different educational levels studied (Smith 1999). On the other hand, Mei's research regarding socio-economic impacts of hurricane evacuation indicated that education level had no association with evacuation behavior. Irrespective of education attainment, only about 40% of respondents chose to evacuate for Hurricane Andrew (Mei 2002). Based on Mei's research, there was not a single educational level that could be linked with a specific evacuation behavior.

Finally, marital status influenced how quickly people evacuated an area, with married couples evacuating later than unmarried singles (Wilmot 2004). Mei's research indicated that more married couples evacuated than singles, but that the difference was very small with 41% of married couples evacuating compared to 39% of singles (Mei 2002). Mei did not indicate whether or not this difference was statistically significant.

Other Differences

Hurricane evacuation behavior was also linked to differences in housing type and ownership, length of residency, and presence of children in a household (Mei 2002). Not surprisingly, evacuation was more likely among residents of mobile homes and less likely among residents of single family dwellings living in Louisiana and Texas during the evacuation for Hurricane Lili (Lindell 2005). This evacuation behavior was supported by Mei's research as well. Almost 90% of mobile home dwellers evacuated for Hurricane Andrew, compared to slightly more than 30% of single-family home dwellers (Mei 2002). In fact, households living in mobile homes were estimated as ten times more likely to evacuate as those in apartments (Alsnih 2005).

In addition, householders who own their homes were less likely to evacuate and tended to engage in property protection behaviors. Mei (2002) found that less than 40% of the people who owned their homes evacuated due to Hurricane Andrew, while about half of people who rented their homes evacuated (Mei 2002). The data gathered did not specify the type of home owned or rented (e.g. single-family homes, mobile homes, condominiums, apartments). Research by Emarson (1999) cited homeowners engaging in property protection behaviors, such as moving furniture, appliances and tools to a higher floor, protecting outdoor equipment and the home itself to prepare for flooding.

Other research suggested that longer-term residents were more likely to remain behind and wait out the storm instead of evacuating. The reason for this behavior was because these residents spent a great deal of time staying well informed on hurricane issues and had stayed behind during previous mandatory evacuation orders (Dow 2000). According to Emarson, people

who lived in an area five years or longer were less likely to evacuate than newcomers, who had lived in an area less than five years (Enarson, 1999). Residents who had previous evacuation experience were more able to ascertain the indirect costs of leaving, such as lost income, and other costs (e.g. food, lodging, traveling) associated with hurricane evacuation (Dow 2000). Long term residents also took into account other factors associated with evacuation, such as delayed access to homes, an inability to protect or repair property quickly, job obligations, and the well being of pets (Dow 2000).

Previous experience of living through a hurricane and seeing the damage caused by the disaster has been shown to influence a person's decision to evacuate (Mei 2002). This behavior extended to people who had not witnessed a hurricane, but who saw the devastation caused by a hurricane on television and other media, such as the effects of Hurricane Katrina (Neary 2005). Households with actual evacuation experience were more likely to evacuate sooner than those without previous experience. As a result of the news coverage of Katrina, people who lived near the coast were more likely to evacuate with a Category 2 or stronger hurricane (Neary 2005). Neary's research also showed that individuals with past hurricane experience felt that they had developed a reliable sense of whether an evacuation was necessary, in spite of any official warning (Neary 2005). Dow supported this premise; her work indicated that some individuals consider themselves to be "Hurricane Savvy." This knowledge is related to the vigilant monitoring of various weather resources, and incorporated past hurricane experiences (Dow 2000). Dow's research indicated that 96% of individuals with previous hurricane experience "believe their general knowledge of hurricane processes is very good to excellent," and 98% "believe their general knowledge of hurricane impacts is very good to excellent" (Dow 2000).

Finally, mandatory evacuation orders increased the likelihood of households evacuating

an area (Alsnih 2005). Evacuation orders can call for voluntary, recommended or mandatory evacuation. The designation of an order is based on a combination of perceived area clearance times based on hurricane landfall, the time needed to implement traffic management elements, as well as the time to make pre-evacuation trips (Dow 2000). For this research, only pre-evacuation trips made after the mandatory evacuation order was issued for Hurricane Wilma in October 2005 in Key West, Florida were studied. Prior research has shown that most people evacuated when a mandatory evacuation was ordered (Wolshon 2004). However, mandatory evacuation cannot be enforced because state laws do not allow for officials to physically remove any person from his/her property.

Summary and Implications for the Survey

Evacuation models fail to capture pre-evacuation trips and associative delays; this leads to the unrealistic calculation of ETEs, and omits important underlying traffic patterns that only arise during times of crises (Murray-Tuite, 2005). Because there were no readily available studies that could provide information about trips taken during the pre-evacuation phase of an evacuation, one of the objectives of my research was to gather and analyze data regarding these trips. The literature review provided a framework for identifying specific demographic variables and the answer choices used in the survey. Based on the literature review, 13 questions regarding demographic characteristics and other data were generated for the survey. The literature review also provided a basis for making theoretical assumptions about the types of pre-evacuation trips made (Table 2: Literature Review Summary). For example, females were assumed to be more likely to evacuate than males, and were assumed to make more trips to gather people together and pick-up supplies. Adults younger than 40 were more inclined to

Table 2: Literature Review Summary		
Category	Variables Used in Survey	Assumed Behavioral Response
Gender	Male; Female	Women more likely to gather supplies and people [4] Women are more likely to evacuate [4]
Age	18-24; 25-44; 45-59; 60-74; 75+	Adults with children are more likely to evacuate [3] Adult only households are less likely to evacuate [3] Adults over 40 are less likely to evacuate [5]
Income	Less than $25,000; $25,000-$49,000; $50,000-$99,000; $100,000-$149,000; $150,000-$199,000; $200,000 or more	People earning $40,000 or more are more likely to evacuate [5, 9]
Race	Black; Hispanic; White; Asian; Pacific; Other	Inconclusive results [2, 5] Non-English speakers are less likely to evacuate [2]
Education	Not a high school graduate; High school graduate; 2-year college; 4-year college; more than 4-year college	Inconclusive results [7, 9]
Marital Status	Married; single; divorced; not married, but co-habitating; widowed;	Married couples are more likely to evacuate [7, 10]
Presence of children or caretaker status	Yes; No	Parents with children are more likely to evacuate [4]
Housing Type	Apartment; Mobile Home; Single-family home	Mobile home dwellers are more likely to evacuate [1,6,7]
Home Ownership	Own; Rent	Homeowners are less likely to evacuate [4, 7] Homeowners are more likely to protect property [7]
Years of Residency	Any number of years	Residents with 5+ years of residency are less likely to evacuate [3, 4]
Previous hurricane experience	Any number of expereinces	People with previous evacuation experience are more likely to evacuate [7, 8]
Vehicles Owned	Any number of vehicles	Residents with more vehicles are more likely to make more trips
[1]Alsnih 2005, [2]Cutter 2006, [3]Dow 2000, [4]Emarson 1999, [5]Howell 2006, [6]Lindell 2005, [7]Mei 2002, [8]Neary 2005, [9]Smith 1999, [10]Wilmot 2004		

evacuate than older adults (Irwin 1995), and were also believed to make more pre-evacuation trips than their older counterparts. One explanation may be that older people do not evacuate because they are more likely to own a single-family home that can withstand the effects of a hurricane.

Hypothetically, people who lived in single-family homes would make pre-evacuation trips to buy materials to protect their homes, but would not make trips in preparation for leaving the area. Thus, individuals who lived in single-family homes would be more likely to make pre-evacuation trips to protect their homes than mobile home residents, who could feel that there was only so much a person could do to protect a mobile home during a hurricane. In addition, mobile homes may make up a higher percentage of rental property than single-family dwellings.

Marital status was also presumed to impact trip-making behavior. In theory, married couples would make more pre-evacuation trips than singles to prepare for the evacuation of two people instead one person. Married couples would also make more trips to protect property because the pair would be more likely to own rather than rent a home. More pre-evacuation trips would theoretically be made in less time by married couples because there would be two individuals traveling the road network using two vehicles. A connection between number, type and time spent on pre-evacuation trips were expected based on car ownership as well as demographic characteristics. In addition, a household with access to a personal vehicle would be more likely to run errands than someone dependent on public transit.

Length of residency in Key West was assumed to impact pre-evacuation trips. Long term residents were thought to make a series of pre-evacuation trips in order to protect and provide for their pets and personal needs, but would stay behind during the storm and not evacuate the area. This was also believed to be reflected in the types and number of pre-evacuation trips made, with

those with less experience making only the pre-evacuation trips that were absolutely necessary before evacuating an area. Finally, the categories of race and education could not be associated with any specific evacuation behavior or any types of pre-evacuation trips. The literature review provided inconclusive results as to evacuation behavior.

The literature on evacuation behavior provides a set of socio-demographic and household characteristics that can be used to study pre-evacuation trip behavior. It is of interest to see if pre-evacuation trip-making behavior mirrors that of evacuation trip making behavior. Will the associations found in the literature review be the same for pre-evacuation trip making? Will the presumed behaviors found in the third column of Table 2 be supported by the survey results? To answer these questions, a research plan needed to be constructed. That is the focus of the next chapter.

Chapter 3: Research Plan

The literature review indicated that certain demographic attributes and other characteristics are indicative of evacuation behavior. One example was that parents with children were more likely to evacuate, while households containing only adults were less likely to do so. The dissertation research plan was developed to verify the associations between demographic and other variables found in the literature review, to review the delays associated with pre-evacuation trips, to explore the spatial pattern of pre-evacuation trips, and to examine a series of personal evacuation stories. A goal of this research is to provide information about real evacuation behavior that can be used to extend current evacuation modeling to more accurately reflect peoples' responses to evacuation orders.

Data Gathering Techniques

With regard to the survey application method, face-to-face surveys were not considered as an option because of the limited number of researchers involved (one), and subsequent costs. Although face-to-face surveys would allow the researcher to gather more accurate and complete responses than telephone surveys or web surveys, the method would take more time to gather the required amount of data needed for the dissertation. Also, the added time spent would have made the costs of data collection unmanageable. Additionally, the University of Tennessee's Institutional Review Board (IRB) requires any researcher collecting data from individuals, who can be identified, to undergo a lengthy review process to guarantee the safety and security of all potential respondents. All respondents would have had to sign a waiver releasing the researcher and the university from any potential liability issues. Telephone interviewing was also discarded as an option because personal information about the household, such as last name and

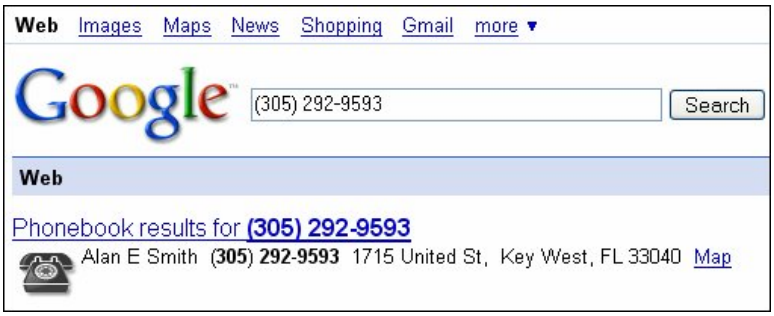

Figure 2: Reverse Lookup Results

address, could be determined by the telephone number. For example, online services provide a reverse lookup for phone numbers that results in a first and last name, full address including zip code and a map (Figure 2: Reverse Lookup Results). Telephone surveys could not, therefore, ensure respondent anonymity. With this in mind, an anonymous survey over the Internet was chosen as the mode for data retrieval.

An anonymous online survey was preferred because the survey could be taken at any time by numerous people; the digital divide not withstanding. Such a survey guaranteed that demographic and trip-making data could not be associated with any identifiable respondent. Another important advantage was that the University of Tennessee's IRB did not have to be intricately involved in the research. According to Brenda Lawson, Compliance Officer for the IRB, the survey questionnaire was exempt from the drawn-out IRB review because "there would be no way to link survey responses back to an individual" (Lawson 2006). A departmental review was all that was required. Also, the anonymous survey allowed respondents to provide commentary of their personal evacuation stories without restraint.

The online survey was created using active server pages (.asp) coupled with visual basic code. The domain name of www.keywestevacuation.com and server space cost $70.00 per year. Responses were directly downloaded to an Access database that was uploaded to a statistical

software package for study. Data were collected quickly with this technique; 287 responses were collected over a three month period. Furthermore, the data from the online survey was validated by writing underlying code to accept certain formats for certain fields. For instance, during a test period one respondent answered that (s)he had witnessed more than 5000 hurricanes. The survey was consequently altered to only allow for two digit responses. In addition, the online survey permitted complicated skip patterns based on whether or not a respondent made pre-evacuation trips. That is, based on a respondent's answer, non-applicable sections of the survey are skipped. Such skip patterns are transparent to the user. Finally, the online survey allowed for the inclusion of maps illustrating the road network of the area; the respondents could pinpoint street intersections they had left from and traveled to during each leg of their pre-evacuation trip by clicking on the map.

The online survey was divided into three sections (See Appendix One: Online Survey Questionnaire). After detailing the nature of the research and contact information, the first section asked if the respondents were currently 18 years old or older and if they had lived in Key West during the Hurricane Wilma evacuation. These preliminary questions narrowed the sample size, but also acted as a gatekeeper - only allowing legal adults who experienced Hurricane Wilma to continue the survey. This limitation was put into place because any interaction with a respondent not currently a legal adult required IRB review. The second section of the survey asked for demographic information, including gender, age, marital status, race or ethnicity, income, education level, presence of children in household, caretaker status, housing type, home ownership, and number of vehicles available for use by the household. The survey responses were limited to predetermined categories in order to limit the types of responses. For instance, education level was limited to the choices of: Not a High School Graduate, High School

Graduate or GED, 2-year College Degree, 4-year College Degree, or Graduate Degree or Higher. No other responses were permitted. The survey asked for a variety of demographic questions; the underlying assumption was that demographic characteristics could act as an indicator for pre-evacuation trip behavior. For example, according to the literature review, it was hypothesized that people who own their homes would be more likely to make pre-evacuation trips to the hardware store to protect their homes, and women would make more trips than men to gather up family members before evacuating.

The categorical answer choices found within the demographic questions were loosely based on the U.S. Census Bureau's American FactFinder Fact Sheet (Figure 3: Key West, Florida Fact Sheet). With regard to income, the U.S. Census Bureau lists ten possible categorical responses, but the survey only allowed for six possible responses (Table 3: Census Categories versus Survey Categories). The survey compiled three census categories into one category because the data needed to find significance between demographic variables and behavior was not as detailed as required by the specific needs of the U.S. Census Bureau.

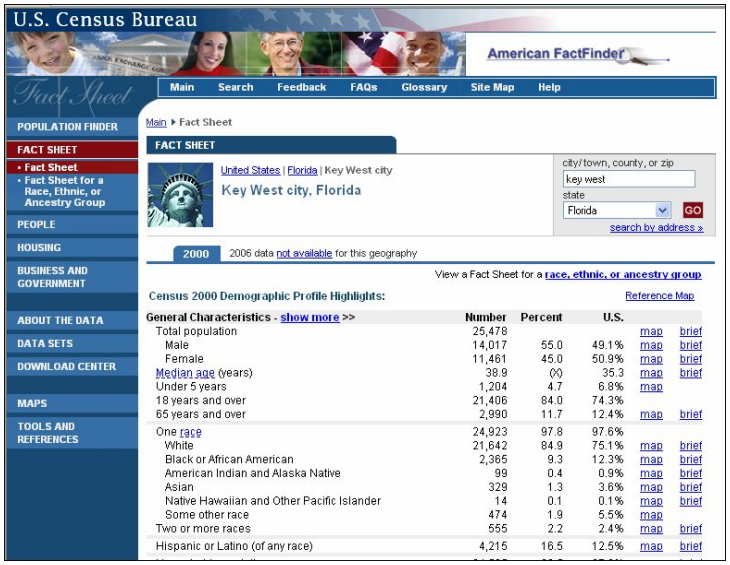

Figure 3: Key West, Florida Fact Sheet

Table 3: Census Categories versus Survey Categories	
Census Categories for Income	Survey Categories for Income
Less than $10,000	$24,999 or less
$10,000 to $14,999	
$15,000 to $24,999	
$25,000 to $34,999	$25,000 to $49,000
$35,000 to $49,999	
$50,000 to $74,999	$50,000 to $99,999
$75,000 to $99,999	
$100,000 to $149,999	$100,000 to $149,999
$150,000 to $199,999	$150,000 to $199,999
$200,000 or more	$200,000 or more

In addition to the demographic data requested, the second section asked for information regarding previous hurricane evacuation experience, the number of times the respondent evacuated and the number of times the respondent waited out a storm. The second section also asks if the respondent engaged in pre-evacuation trips for the Hurricane Wilma evacuation. At this point in the survey, respondents were divided into two pools – those who did not report pre-evacuation trip-making, and those who did. The respondents who did not report trips were sent to a "Submit Survey" page that allowed them to provide personal comments before submitting their answers; the respondents who did report pre-evacuation trip-making were sent to the third section of the survey.

Section Three of the survey asked respondents to provide information concerning the origin and destination for each pre-evacuation trip. This information included the date of the first pre-evacuation trip taken after the evacuation order was issued, the start and end times of each trip, the nearest intersection to both the start and end locations of each trip, the type of transportation used, whether they were a passenger or driver, the number of people in the vehicle, trip purpose, generic destination (e.g. store, work, etc.), and the time it took to complete the trip task. Each respondent was allowed to record any number of trips, but only five

respondents made more than three trips. After the respondents completed the trip-making portion of the survey, they were asked if they evacuated the city or remained behind to wait out the storm. Before submitting the survey these respondents were also given an opportunity to provide personal stories of their experience with the Hurricane Wilma evacuation.

The survey was used to gather data to research demographic variables in conjunction with pre-evacuation trip-making and delay. For example, one married, male evacuee with children reported traveling by himself in his own car to work before he evacuated. He left his origin point at 8 am on October 19, 2005. The trip from the origin to work took ten minutes. He spent four hours at work. His next trip started at approximately noon when he traveled to the Home Depot store. He may have traveled to the hardware store to buy supplies to protect his single-family home. This trip from origin to destination took ten minutes to make. He then reportedly spent four hours at Home Depot completing his trip purpose before returning home. The mandatory evacuation order for residents living in single-family homes was issued at noon on October 22, 2005. Though this respondent spent four hours in Home Depot, he evacuated three days before the mandatory evacuation required him to do so.

Once the survey contents and design were decided upon, it was necessary to determine the methods used to recruit subjects. Two techniques were used: email solicitation and brochure distribution. Survey notifications were emailed to businesses located in the City of Key West that were listed in the Real Yellow Pages at http://www.realpageslive.com (Figure 4: Real Yellow Pages Image). Care was taken to email anonymous business addresses, such as info@chamberofcommerce.com, not johnwilliams@chamberofcommerce.com to protect the anonymity of respondents. The email provided a brief overview of the researcher, the purpose of the research and the web address of the survey. (See Appendix Two: Email Solicitation for the

Figure 4: Real Yellow Pages Image

exact wording of the email). The Yellow Pages listed about 500 businesses that were contacted in this way. Each email sent asked the recipient to forward the message to others so that they might fill in the survey.

More effort was used to distribute brochures randomly throughout Key West. The brochure recipients were chosen by overlaying a land use map of the city on a street map, and identifying all planning zones that allowed for any type of housing. For example, the City of Key West allows for housing in areas that are zoned commercial, but only in historic areas. Following this mixed-use theme, the areas zoned as residential office also permit single and 2-family units. All land uses not relating to residences were also identified in the map, as were areas that were inaccessible. The inaccessible areas included military base housing and gated communities, such as housing near the Key West Golf and County Club (Figure 5: Key West Zoning Map).

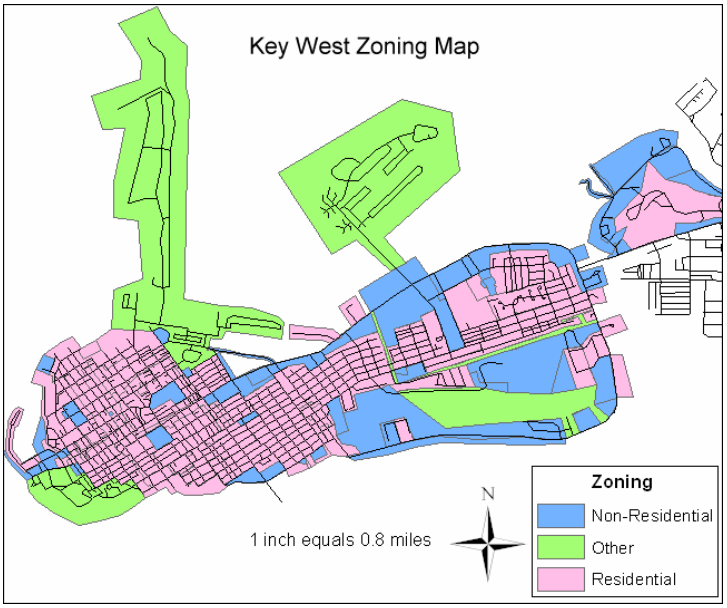

Figure 5: Key West Zoning Map

Half of the streets contained within or adjoining the residential land contained in each of the census tracts were randomly chosen by assigning a number to each of the street segments, and then randomly selecting half of the street segments via their assigned numbers. For example, there are 60 streets either adjoining or intersecting residential sections contained in Census Tract 9724 (Figure 6: Census Tract 9724). These street segments were given a number without replacement between one and sixty by a random number generator. The generator provided a random sequence of 30 numbers that identified specific street segments. Residences along these streets were given brochures explaining the survey's purpose and the internet address. Brochures were delivered to each residence along both sides of each road that was completely contained within a census tract; however, brochures were only distributed to one side of a randomly picked road that was located on the boundary of a census tract. For instance, White Avenue cuts across five census tracts, but brochures were only delivered to residences along one side of the road in two of the census tracts. The goal was to leave promotional

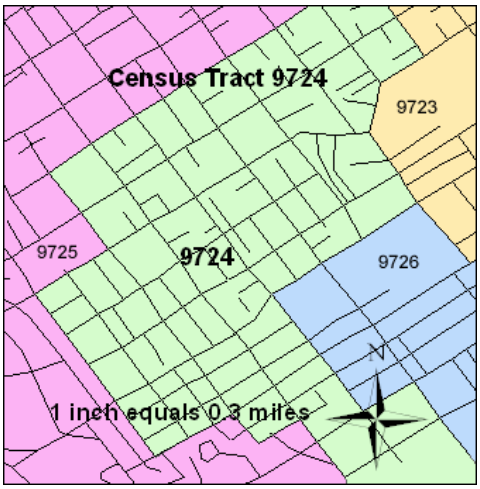

Figure 6: Census Tract 9724

brochures at approximately 2000 households in the City of Key West in order to notify residents of the online survey. This methodology was used to help create a distribution of respondents within each census tract, and assist in the generation of a spatially stratified random sample.

Overall, the total number of brochures and emails distributed totaled ~2500, with the hope of achieving an overall response rate of about 68 survey respondents, who would provide at least one origin and destination node pair. This was the smallest sample size accepted for this research proposal, as it provided for only eight responses per census tract if the responses were distributed equally in each census tract. The needed sample size was derived using the following statistical formula:

$$s \equiv (z / e)^2$$

s is the sample size
z is the confidence level (1.64 for 90% confidence)
e is error rate (20% in this case)

Fortunately, the total number of survey responses (287) surpassed the required number for a 90% confidence level. Of these responses, 206 did not report making any pre-evacuation trips, and 81

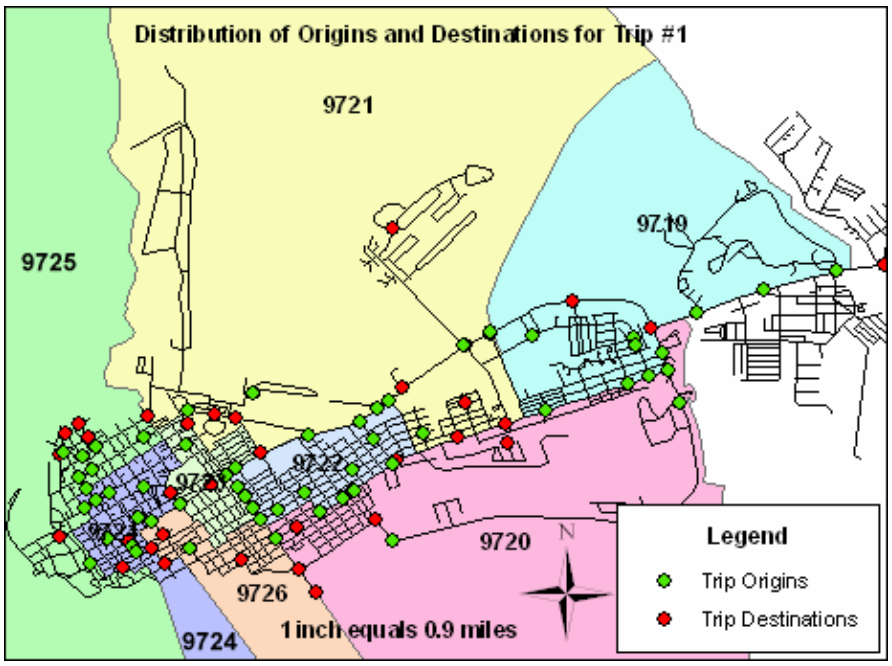

Figure 7: Distribution of Origins and Destinations for Trip #1

respondents did. Seventy-seven survey respondents out of 81 provided at least one usable origin and destination pair coupled with demographic information. Though there was not a perfect distribution of respondents across census tracts because clustering of origins and destinations did occur at major intersections, there was an acceptable distribution of origins and destinations that reflected the flow of traffic created by pre-evacuation trips, meaning that all but one census tract contained the first origin intersection for at least eight respondents (Figure 7: Distribution of Origins and Destinations for Trip #1).

Data Analysis Techniques

The survey data were automatically entered into an Access database, and then analyzed with the SPSS statistical software package. Two main groups of respondents were identified based on evacuation behaviors:

- Respondents who did not make pre-evacuation trips
- Respondents who made pre-evacuation trips

Those who made pre-evacuation trips were further subdivided into two groups:

- Respondents who made pre-evacuation trips, and returned to the city to wait out the storm, and
- Respondents who made pre-evacuation trips and evacuated the city.

Three statistical tests were run on the data – one to test for the most frequent response across all demographic and trip-making categories; one to test for an association between demographic variables and categories within the variables, and one to test for the strength of any association found. In addition, two predictive models based on binary logistic regression were estimated. The first model sought to estimate the probability that a respondent made a pre-evacuation trip, and the second model tried to estimate the probability that a respondent who made a pre-evacuation trip did not subsequently evacuate. Since the data were non-parametric and contained nominal, ordinal and categorical data, the mode, which is the response most often chosen, and median, which is the response found in the middle of a hierarchical list of all response, were used to define an "average" response (Burt 1996). This approach was used to identify the typical respondent for each of the four groups. For instance, the typical respondent who did not report making any pre-evacuation trips was a married, white female, but the typical respondent who did report making pre-evacuation trips was a married, white male. In addition, the mode and median values were used to provide a basis for regrouping the data when required.

The Pearson's Chi-square statistic was used to test for associations between variables. According to the SPSS statistical software package, this test requires that that ""No more than 20% of the categories should have expected frequencies of less than 5." Meeting this requirement resulted in some survey categories being aggregated. For example, the six age

categories were aggregated to two groups: those 44 and younger and those age 45 or older. For each significant Chi-square detected, a Cramer's V statistic was run to test the strength of the association between variables (Burt 1996). Cramer's V is best used with categorical data. The closer the Cramer's V statistic was to the value of 1.0, the stronger the association between the two variables. Results were identified as very weak (<0.20), weak (0.20-<0.40), medium (0.40-<0.60), strong (0.60-<0.80) and very strong (0.80 or more).

Binary logistic regression was used to construct two models. The first model attempted to predict whether or not a respondent made pre-evacuation trips. For this research, respondents who made pre-evacuation trips were given a value of 0, and those who did not make any trips were given a value of 1. The independent variables in that model were taken from the demographic variables in the survey. The second model focused on those who reported pre-evacuation trips. Those who evacuated were given a value of 0, while those who waited out the storm were given a value of 1. The independent variables for both models were derived from the survey responses.

In addition to the demographic variables, four categorical variables were analyzed to see what insights they provided into pre-evacuation trip making: mode of transportation, driver or passenger status, trip purpose, and trip destination. Average travel delay times and delays associated with trip purpose were calculated as well. The spatial distribution of both origin and destination points for all trips were analyzed for traffic flow to test whether or not traffic moved toward an exit point, as is assumed in many evacuation models.

Finally, many of the respondents provided commentary about their personal evacuation experiences, and though these experiences could not be quantified, the stories provided important insights into the evacuation process and state of mind of the respondents during the

mandatory evacuation for Hurricane Wilma. These comments were grouped based on evacuation experience and/or demographic profiles, and were coupled with background material provided by the *Key West Citizen*, the local newspaper. When possible, the comments were also coupled with a particular respondent's demographic and trip-making characteristics. In some cases, respondents emailed the researcher directly about their experiences during Hurricane Wilma. In order to keep the respondent anonymous, the researcher disassociated the respondent's name, email and any other identifying remarks from the story. In these cases, no demographic or trip-making characteristics were associated with the accounts. Overall, the variety of methods used to identify and, to some extent, replicate the evacuation behavior of respondents during Hurricane Wilma provided an intricately detailed account of respondent behavior.

Summary

To gather information on pre-evacuation trips behavior, an internet based questionnaire was developed. The questionnaire sought to capture data on socio-demographics, other variables, and trip-making. Statistical tests were designed to test the association between evacuation behavior and these socio-demographic and other variables. The research plan provided a successful basis for identifying associations between trip-making and evacuation behavior based on socio-demographic and other variables, as well as testing whether or not the associations found in the literature review were applicable to this data set. Average delays associated with trip making and trip purposes were calculated, and the spatial pattern of trips made indicated that respondents who made trips traveled both away and toward the center of town. Finally, the

personal evacuation stories provided an important dimension to the goal of capturing information about real evacuation behavior that can be used to extend current evacuation models.

Chapter 4: Analysis of Survey Results

The purpose of this chapter, which is divided into three major sections, is to analyze the data collected with the online survey. The first section analyzes the relationship between pre-evacuation trip behavior and the variables included in the survey. These variables were defined based on the information gleaned from the literature review in the second chapter. The different groups of respondents are first characterized by their mean and modal values on the survey variables. Non-parametric statistics and binary logistic regression are used to assess the relationships between the variables captured by the survey and pre-evacuation trip making behavior. The second section evaluates the nature and distribution of pre-evacuation trips reported in the survey. The final section summarizes comments made by respondents.

Several people who accessed the survey were not included in the analysis. Of the 349 respondents who accessed the survey, 42 were not living in Key West at the time of the Hurricane Wilma evacuation. Besides the residency requirement, survey respondents had to be at least 18 years old to continue with the survey; 14 respondents did not answer this question, and three answered negatively. In addition, three of the respondents, who did meet the residency and age requirements, did not answer any of the survey questions. Overall, there were 62 respondents that were removed from the survey data, leaving 287 responses suitable for data analysis. Of these, 206 respondents did not report making any trips before evacuating the area or waiting out the storm in the city. Evacuation numbers were not collected for those who did not report any trip-making since the focus of the research was to learn more about the trips and delays associated with preparing to evacuate or preparing to wait out the storm. Eighty-one respondents reported making at least one pre-evacuation trip, but four of those respondents

provided unusable and incomplete information about the origins and destinations; these respondents were removed from the survey pool when the trips were mapped. Of the 81 respondents, 40 reported evacuating the city, and 41 respondents reported waiting out the storm (Table 4: Respondent Break Down).

Evacuation data were analyzed for the 287 respondents who answered the survey and provided complete and accurate information for most of the questions. The data were separated for analysis into four groups based on evacuation behavior: 1) those respondents who did not report any trip-making (206 respondents); 2) those who did report trip-making (81 respondents); 3) those who made trips and evacuated (40 respondents), and 4) those who reported trip-making, but did not evacuate (41 respondents). Because the sample size was small for those who made trips, and the variables were categorical, nonparametric statistical tests were performed for the four groups. Ordinal data groups included age, income, education, and the number of vehicles available to the household. Nominal data groups included marital status, race, the presence of children in the household or caretaker status, housing type, and whether the respondent rented or owned his/her home. The demographic data submitted by those who did not report trips and

Table 4: Respondent Break Down

Total Respondents	*349*
Not living in Key West	42
Not old enough	17
Did not answer survey questions	3
Respondents with usable data	*287*
Did not make any trips	206
Did make trips	81
Inconclusive O-D pair	4
Respondents who made trips	*81*
Evacuated	40
Waited out the storm	41

those who did were analyzed. The same nonparametric tests were run for the trip-making variables submitted by respondents reporting pre-evacuation trips. These trip variables included: transportation mode, driver or passenger status, trip purpose and trip destination. A combination of non-parametric tests and descriptive statistics were used to identify differences and relationships among variables of the four groups.

Data Distribution

Two nonparametric statistics were used to analyze the most frequently selected category of each variable (mode), and the variable found in the middle of the distribution (median) (Burt 1996). These two statistics are different in that the mode may not be unique if the same number of respondents chose two categories equally (Burt 1996). On the other hand, the median represented the middle value in a list of categorical values arranged from highest to lowest so that outliers do not influence the median. Determining the median was applicable to categories that could be ordered from highest to lowest, such as age, income, education, and the number of vehicles available to each household.

Respondents Not Reporting Trips

Based on the mode and median, the typical respondent who did not report any pre-evacuation trip-making was a married, white, female with a 4-year college degree, who did not have caretaker responsibility for either children or someone else. She owned her own single family home, earned $50,000-$99,000 and had two vehicles at her disposal. The only variable where the mode and median were different was the age variable. The median value was 25-44 years old, and the mode was between 45-59 years old (Table 5: Mode and Median for Respondents Not Reporting Trips). The average respondent not reporting any trips for this data

Table 5: Mode and Median for Respondents Not Reporting Trips							
		Gender	Age	Marital	Race	Children	Caretaker
	Valid	196	206	206	206	198	198
	Missing	10	0	8	8		
Median		Female	25-44	Married	White	No	No
Mode		Female	45-59	Married	White	No	No
		Education	Income	Housing	Own/Rent	Vehicles	
	Valid	204	204	204	196	206	
	Missing	2	2	2	10	0	
Median		4-year College	50,000-99,000	Single Family	Own	2	
Mode		4-year College	50,000-99,000	Single Family	Own	2	

set does not seem to reflect the literature review assumption that homeowners are more likely to make trips to protect property or that women would be more likely to make evacuation trips because of their family responsibilities.

Respondents Reporting Trips

First the mode and median for all respondents reporting trips were analyzed, then the respondents were analyzed again after being separated into two groups – those who evacuated and those who did not. The most significant difference between those who did not report pre-evacuation trips and those who did was that men reported making trips more frequently than women. The second noticeable difference was that, unlike those who did not report pre-evacuation trip-making, both mode and median reflect that same age range of 25-44 years old. The other variables were the same between the two groups. Though the literature review indicated that households with children were more likely to make trips to evacuate, the average respondent reporting trips did not have children or caretaker responsibilities (Table 6: Mode and Median for Respondents Reporting Trips).

Table 6: Mode and Median for Respondents Reporting Trips							
		Gender	Age	Marital	Race	Children	Caretaker
	Valid	81	81	81	81	81	81
	Missing	211	211	211	211	211	211
Median		Male	25-44	Married	White	No	No
Mode		Male	25-44	Married	White	No	No
		Education	Income	Housing	Own/Rent	Vehicles	
	Valid	81	81	81	80	81	
	Missing	211	211	211	212	211	
Median		4-year College	50,000-99,000	Single Family	Own	2	
Mode		4-year College	50,000-99,000	Single Family	Own	2	

When analyzing the two groups who made pre-evacuation trips (40 for those who evacuated the city and 41 respondents for those who waited out the storm), differences between them began to emerge. For example, the typical evacuee was female, between 25-44 years old, married without children or caretaker obligations. She had a four-year degree, earned $100,000 - $149,000 per year, and rented either an apartment or single family home (Table 7: Mode and Median for Respondents Who Evacuated). Unlike those not reporting trips, she earned a higher income and had the use of between 1 or 2 vehicles to make pre-evacuation trips, but she also rented instead of owned her home, which may be a reason to evacuate and not remain behind.

The typical respondent who waited out the storm, on the other hand, was male, with many of the same characteristics as the female evacuee – the same age, race, marital status, and caretaker status for children and others, but he had either a 2 or 4 year degree, and earned less money at $50,000 - $99,000 than the female evacuee. He also owned his own single family home, and had two vehicles at his disposal (Table 8: Mode and Median for Respondents Who Waited Out the Storm). The major difference is that the average female, who made pre-

Table 7: Mode and Median for Respondents Who Evacuated							
		Gender	Age	Marital	Race	Children	Caretaker
	Valid	40	40	40	40	40	40
	Missing	0	0	0	0	0	0
Median		Female	25-44	Married	White	No	No
Mode		Female	25-44	Married	White	No	No
		Education	Income	Housing	Own/Rent	Vehicles	
	Valid	40	40	40	35	40	
	Missing	0	0	0	5	0	
Median		4-year College	100,000 –149,000	Apartment	Rent	2	
Mode		4-year College	100,000 –149,000	Single Family	Rent	1	

Table 8: Mode and Median for Respondents Who Waited Out the Storm							
		Gender	Age	Marital	Race	Children	Caretaker
	Valid	41	41	41	41	41	41
	Missing	0	0	0	0	0	0
Median		Male	25-44	Married	White	No	No
Mode		Male	25-44	Married	White	No	No
		Education	Income	Housing	Own/Rent	Vehicles	
	Valid	41	41	41	40	41	
	Missing	0	0	0	1	0	
Median		2-year College	50,000-99,000	Single Family	Own	2	
Mode		4-year College	50,000-99,000	Single Family	Own	2	

evacuation trips, reported evacuating the city, and the average male who made pre-evacuation trips reported waiting out the storm.

The mode and median provided an interesting snapshot of the typical respondent who did not report making any pre-evacuation trips during the Hurricane Wilma evacuation, and those who did, as well as the differences between respondents who made pre-evacuation trips and evacuated, and those who made pre-evacuation trips, but waited out the storm. Across the four groups of respondents, the most significant differences were found in gender, age range, education level, income, home ownership and the numbers of vehicles available (Table 9: Mode and Median Differences Across the Respondent Groups). The other variables remained the same.

Chi-square and Cramer's V

The Chi-square nonparametric test was run on the data to determine whether the variables within the groups were related to a specific evacuation behavior (e.g. trip-making or no trip-making, evacuating or staying behind). Using the SPSS software, the test determined with a 95% confidence level if two variables were more than randomly related. The test was not used to judge the strength of a relationship, but to test if a non-random relationship between two variables existed (Burt 1996). The SPSS software output consisted of a contingency table, which detailed the actual and expected frequencies of responses for each category (Figure 8: Typical Contingency Table Structure).

In cases where the Chi-square value was significant and there was more than one degree of freedom, the Cramer's V statistic was used to calculate the strength of that relationship. The closer the Cramer's V statistic is to 1.0, the stronger the relationship (Burt 1996). In cases where

Table 9: Mode and Median Differences Across Respondent Groups						
Group	*Sex*	*Age*	*Education*	*Income*	*Own/Rent*	*Vehicles*
No Trips Reported	F	25-59	4-year	50,000–99,000	Own	2
Trips Reported	M	25-44	4-year	50,000–99,000	Own	2
Evacuated	F	25-44	4-year	100,000–149,000	Rent	1 or 2
Waited	M	25-44	2 or 4-year	50,000–99,000	Own	2

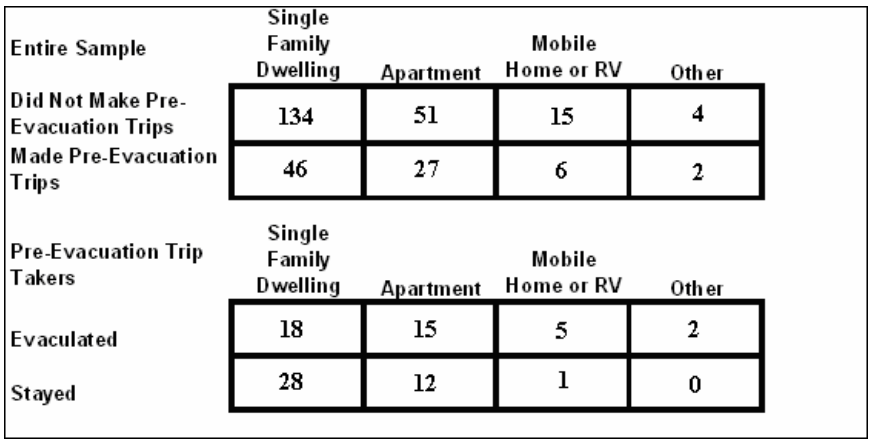

Figure 8: Typical Contingency Table Structure

the Chi-square was significant, but there was only one degree of freedom, the Yates Correction for Continuity was used to verify the Chi-square results. This calculation was necessary because the Chi-square calculation overestimates the significance among variables in a 2 by 2 table (Burt 1996). Every variable pair was tested for statistical significance using SPSS statistical software. Since the focus of this research is on the possible relationships between pre-evacuation behavior and socio-demographic variables, only those results are reported in the chapter. Readers interested in the contingency table analysis between all pairs of socio-demographic variables are referred to Appendix Three: Chi-square Analysis Between Variables.

A requirement of the Chi-square test for contingency tables is that the categories in each cell of the contingency table should have an expected frequency of at least five when there was one degree of freedom, and that 80% of the cells have an expected frequency of at least five in the cases where there was more than one degree of freedom. At first, the Chi-square test was run for all data as reported in the original database, but later the data were aggregated for those categories where these conditions were not met. In the cases where there was an expected frequency problem, columns in the contingency tables were aggregated using the mode and/or median to determine the cut-off point. For example, the mode for all groups regarding marital status indicated that the average respondent was married. Marital status was aggregated to reflect two groups – those who were married or cohabitating and those who were single, divorced or widowed.

Respondents Not Reporting Pre-evacuation Trips and Respondents Who Did

Statistical significance was tested for respondents who did not report trips (206 respondents) and those who did (81 respondents). The variables tested for significance against

whether or not the respondent made a pre-evacuation trip included gender, age, marital status, race, the presence of children in the home and/or caretaker status, education level, income level, housing type, housing ownership and number of vehicles available. Because the conditions were not met to successfully use the Chi-square statistic for some of the variables, age, marital status, race, education and income levels, and number of vehicles available were modified.

The gender variable was tested for statistical significance against whether or not respondents reported making pre-evacuation trips. Ten of the respondents did not identify a gender and were removed from the pool. For the remaining 277 respondents, statistical significance was not found between the variables with a Chi-square value of 0.128. The data set contained approximately the same number of males as females (Table 10: Pre-Evacuation Trips and Gender Cross Tabulation).

Age was the first variable to be changed. The age variable was aggregated to reduce the number of categories that contained less than five expected frequencies. In this case, because more than half of the cells in the original database had less than five expected frequencies, two of the age categories were combined. Respondents who reported being under 18 years old during the evacuation were added to the 24 years or younger category, and respondents who reported being older than 75 were added to the 60-74 years old category to form a 60-plus grouping. After transformation, the resulting Chi-square statistic was not significant at the 0.347 level. The age variable was modified again to reflect those respondents younger than 45 and those 45 years old or older. Slightly more respondents reported being 18-44 years old than 45 years old or older (Table 11: Pre-evacuation Trips and Age Cross Tabulation). Still no significant Chi-square value of 0.790 was calculated.

Table 10: Pre-Evacuation Trips and Gender Cross Tabulation					
			Gender		Total
			Male	Female	
Did Respondent Make Pre-evacuation Trips?	No	Count	97	99	196
		Expected Count	98.4	97.6	196.0
	Yes	Count	42	39	81
		Expected Count	40.6	40.4	81.0
Total		Count	139	138	277
		Expected Count	139.0	138.0	277.0
$X^2 = 0.128$, degrees of freedom = 1, $\alpha = 0.721$					

Table 11: Pre-evacuation Trips and Age Cross Tabulation					
			Age		Total
			18-44	45+	
Did Respondent Make Pre-evacuation Trips?	No	Count	105	101	206
		Expected Count	108.4	97.6	206.0
	Yes	Count	46	35	81
		Expected Count	42.6	38.4	81.0
Total		Count	151	136	287
		Expected Count	151.0	136.0	287.0
$X^2 = 0.790$, degrees of freedom = 1, $\alpha = 0.374$					

With the first run, no changes to the marital status variable were made because each of the marital status categories of single, married, cohabitating, widowed and divorced had at least five expected frequencies. The Chi-square value of 2.934 was not significant between marital status and whether or not the respondents engaged in pre-evacuating trip-making. Marital status was then modified to reflect categories of respondents who identified themselves as single, married/cohabitating, and widowed/divorced. After this transformation, no significant Chi-square value of 2.770 was found. Then, the marital status categories of single, married, cohabitating, widowed and divorced were combined to reflect respondents who lived alone (single, widowed and divorced) and respondents who lived with another adult (married and cohabitating). Slightly more respondents at nearly 57% identified themselves as married or cohabitating than single, widowed or divorced respondents (Table 12: Pre-evacuation Trips and Marital Status Cross Tabulation). Once again, no significant Chi-square value was calculated at at the 0.596 level with regard to marital status and whether or not respondents made pre-evacuation trips.

With regard to race and ethnicity, and pre-evacuation trip-making, there was no statistically significant relationship with a Chi-square value of 7.103 at the 0.311 level before aggregating categories. After transforming the race variable from seven different categories to

Table 12: Pre-evacuation Trips and Marital Status Cross Tabulation

			Marital Status		Total
			Single	Married	
Did Respondent Make Pre-evacuation Trips?	No	Count	87	119	206
		Expected Count	89.0	117.0	206.0
	Yes	Count	37	44	81
		Expected Count	35.0	46.0	81.0
Total		Count	124	163	287
		Expected Count	124.0	163.0	287.0
$X^2 = 0.281$, degrees of freedom = 1, $\alpha = 0.596$					

Table 13: Pre-evacuation Trips and Race Cross Tabulation					
			Race		Total
			Non-Hispanic White	Other	
Did Respondent Make Pre-evacuation Trips?	No	Count	165	41	206
		Expected Count	161.5	44.5	206.0
	Yes	Count	60	21	81
		Expected Count	63.5	17.5	81.0
Total		Count	225	62	287
		Expected Count	225.0	62.0	287.0
$X^2 = 1.245$, degrees of freedom = 1, $\alpha = 0.264$					

three, still there was no statistically significant relationship found. These aggregated categories were: 1) Non-Hispanic White, 2) Black, and 3) Other, which included Hispanic, Asian, Pacific Islander, and Other. The race categories of White, Black, Asian, and Pacific Islander were taken from the U.S. Census Bureau's race categories; the Hispanic variable was added to identity respondents who consider themselves of Hispanic ethnicity, but of any race. With a Chi-square value of 2.762, no statistical significance at the 0.251 level was found. The race variable was further altered to reflect two categories: Non-Hispanic White and Other (Table 13: Pre-evacuation Trips and Race Cross Tabulation).. Almost 80% of respondents considered themselves to be Non-Hispanic White. Still, no statistical significance with a Chi-square value of 1.245 and a significance level at 0.264 was found between the race variable and trip-making behavior.

With regard to the presence of children in the home or caretaker status, eight respondents did not provide this information and were removed from the pool of respondents. Almost 75% of the respondents did not report having to take care of children or others. This means that the data was skewed in one direction (Table 14: Pre-evacuation Trips and Presence of Children and/or Caretaker Responsibility). With a Chi-square value of 1.052, there was no statistical

Table 14: Pre-evacuation Trips and Presence of Children and/or Caretaker Status					
			Children		Total
			Yes	No	
Did Respondent Make Pre-evacuation Trips?	No	Count	47	151	198
		Expected Count	50.4	147.6	198.0
	Yes	Count	24	57	81
		Expected Count	20.6	60.4	81.0
Total		Count	71	208	279
		Expected Count	71.0	208.0	279.0
$X^2 = 1.052$, degrees of freedom = 1, $\alpha = 0.305$					

significance found between the presence of children in the household and/or caretaker status and pre-evacuation trip-making.

With a Chi-square value of 0.862, no statistical significance was found after the education variable was changed to reflect a category which combined both those with a high school diploma or a General Education Degree (GED) with those respondents with less than a high school degree. Two respondents did not report an educational level and were removed from the pool. Education level categories were regrouped again to reflect those with a 2-year degree or less, and respondents who reported earning a 4-year degree or graduate degree. More than 75% of the respondents reported having a 4-year degree or graduate degree, of these less than one-third engaged in pre-evacuation trip-making (Table 15: Pre-evacuation Trips and Education Level Cross Tabulation). The Chi-square test was run to test for a non-random relationship between education level and respondent trip-making behavior. Once again, with a Chi-square significance value at the 0.841 level no non-random relationship was identified.

The income level was the next variable to be tested for the presence of a statistically significant Chi-square. Two respondents did not provide income level information and were removed from the pool. After transforming the variable to reflect the median for those not reporting trips and those who did by separating the respondents into two groups ($49,999 or less

Table 15: Pre-evacuation Trips and Education Level Cross Tabulation					
			Education		Total
			2-year degree or less	4-year degree or more	
Did Respondent Make Pre-evacuation Trips?	No	Count	47	157	204
		Expected Count	47.2	156.8	204.0
	Yes	Count	19	62	81
		Expected Count	18.8	62.2	81.0
Total		Count	66	219	285
		Expected Count	66.0	219.0	285.0
$X^2 = 0.040$, degrees of freedom = 1, $\alpha = 0.841$					

and $50,000 or more), a Chi-square value of 2.811 was found not to be statistically significant (Table 16: Pre-evacuation Trips and Income Level Cross Tabulation).

Housing type, such as single family home, apartment/condominium or other, which included recreational vehicle, mobile home or military housing, was not found to have a statistically significant relationship with whether or not respondents made pre-evacuation trips with a Chi-square value of 2.451. Two of the respondents did not report a housing type and were removed from the pool of respondents. Slightly more than 60% of respondents identified "single family" as their housing type (Table 17: Pre-evacuation Trips and Housing Type Cross Tabulation), and almost 65% of respondents reported owning their own homes (Table 18: Pre-evacuation Trips and Home Ownership Cross Tabulation). When homeownership and pre-evacuation trip-making behavior was analyzed, a Chi-square value of 0.406 indicated that there was no statistical significance. This is counter-intuitive in that, according to the previous literature on the subject, people who rent are more likely to make trips to evacuate (Lindell 2005), and people who own their homes are possibly more likely make trips to protect property (Mei 2002).

Table 16: Pre-evacuation Trips and Income Level Cross Tabulation					
			Income		Total
			$49,999 or less	$50,000+	
Did Respondent Make Pre-evacuation Trips?	No	Count	63	141	204
		Expected Count	57.3	146.7	204.0
	Yes	Count	17	64	81
		Expected Count	22.7	58.3	81.0
Total		Count	80	205	285
		Expected Count	80.0	205.0	285.0
$X^2 = 2.811$, degrees of freedom = 1, $\alpha = 0.094$					

Table 17: Pre-evacuation Trips and Housing Type Cross Tabulation						
			Housing Type			Total
			Single Family	Apartment/ Condominium	Other	
Did Respondent Make Pre-evacuation Trips?	No	Count	137	52	15	204
		Expected Count	131.7	57.3	15.0	204.0
	Yes	Count	47	28	6	81
		Expected Count	52.3	22.7	6.0	81.0
Total		Count	184	80	21	285
		Expected Count	184.0	80.0	21.0	285.0
$X^2 = 2.451$, degrees of freedom = 2, $\alpha = 0.294$						

Table 18: Pre-evacuation Trips and Home Ownership Cross Tabulation					
			Home Ownership		Total
			Own	Rent	
Did Respondent Make Pre-evacuation Trips?	No	Count	128	68	196
		Expected Count	125.7	70.3	196.0
	Yes	Count	49	31	80
		Expected Count	51.3	28.7	80.0
Total		Count	177	99	276
		Expected Count	177.0	99.0	276.0
$X^2 = 0.406$, degrees of freedom = 1, $\alpha = 0.524$					

Table 19: Pre-evacuation Trips and Number of Vehicles Cross Tabulation					
			Vehicles		Total
			1 or less	2+	
Did Respondent Make Pre-evacuation Trips?	No	Count	72	134	206
		Expected Count	70.3	135.7	206.0
	Yes	Count	26	55	81
		Expected Count	27.7	53.3	81.0
Total		Count	98	189	287
		Expected Count	98.0	189.0	287.0
$X^2 = 0.210$, degrees of freedom = 3, $\alpha = 0.646$					

Finally, the number of vehicles available for respondents to use was tested against pre-evacuation trip-making. At first, the number of vehicles was categorized to reflect four categories: no vehicles, one vehicle, two vehicles or three or more vehicles. Only respondents who did not report pre-evacuation trip-making reported having no vehicles. At a value of 5.905, no statistically significant Chi-square was determined. The number of vehicles was changed further to reflect two categories: one or less vehicle and two or more vehicles. Still no relationship with a Chi-square value of 0.210 was found between the number of vehicles available and whether or not respondents engaged in pre-evacuation trip-making (Table 19: Pre-evacuation Trips and Number of Vehicles Cross Tabulation).

Based on the literature review, a number of the variable pairs were expected to generate a statistically significant Chi-square value. This is not supported by the survey results. Females were not more likely than males to make pre-evacuation trips; younger adults were not more likely to make trips, and neither were households with children or respondents with caretaker responsibilities. Furthermore, married couples or respondents who earned $50,000 or more were not more likely to make pre-evacuation trips. Finally, there was no statistical significance between home ownership and pre-evacuation trips or vehicle ownership and trip-making. None

of the variables proved to have more than a random relationship with respondent pre-evacuation trip making behavior.

Trip Making Respondents Who Evacuated and Trip Making Respondents Who Did Not

Despite the results of the previous section, the question still remains whether the socio-demographic classifications are related to leaving or staying for those who made pre-evacuation trips. For those who made such trips, the variables were extended to include, not only gender, age, marital status, race, the presence of children in the home and caretaker status, education level, income level, housing type, housing ownership and number of vehicles available, but also the variables identifying trip purpose, origin and destination, number of persons in the vehicle, and total number of trips made. There were 81 respondents who provided information about whether they evacuated (40 respondents) or waited out the storm (41 respondents), as well as the other information needed for analysis. There were two cases in which the variables resulted in a significant Chi-square statistic. These were between homeownership and evacuation, and the number of trips made and evacuation.

Respondents who made pre-evacuation trips were identified based on whether or not they evacuated. This variable was then tested against gender, presence of children in the household and/or caretaker status, driver or passenger status, housing type, and homeownership. Though gender and evacuation behavior did not generate a statistically significant Chi-square with a value of 0.109, the same number of males as females evacuated, but slightly more males than females waited out the storm (Table 20: Respondent Evacuation and Gender Cross Tabulation) . This result countered the literature review which indicated more females than males would evacuate.

The presence of children in a household and/or caretaker status was tested against evacuation behavior to determine if there was a non-random relationship between these

Table 20: Respondent Evacuation and Gender Cross Tabulation					
			Gender		Total
			Male	Female	
Did the Respondent Evacuate?	Yes	Count	20	20	40
		Expected Count	20.7	19.3	40.0
	No	Count	22	19	41
		Expected Count	21.3	19.7	41.0
Total		Count	42	39	81
		Expected Count	42.0	39.0	81.0
$X^2 = 0.109$, degrees of freedom = 1, $\alpha = 0.742$					

variables. Once again, with a value of 0.312 the Chi-square was not statistically significant. Interestingly, nearly as many respondents with children in the household and/or caretaker responsibility evacuated as stayed behind (Table 21: Respondent Evacuation and Presence of Children and/or Caretaker Status). This result is also counter to the literature review which stated that households with children were more likely to evacuate than those containing only adults.

Driver or passenger status was not found to be statistically significant with regards to evacuation behavior. Because only nine respondents took trips as passengers, half of the categories in each variable had an expected frequency of less than five. As a result, a meaningful Chi-square could not be calculated based on the data available. The same problem occurred when trying to calculate a Chi-square value for housing type and evacuation behavior. In this case, more than 30% of the categories in the housing type variable had an expected frequency of less than five.

A statistically significant Chi-square value was, however, found for the dichotomous variables of evacuation and homeownership. Two respondents who made pre-evacuation trips did not identify homeownership and were dropped from the pool. More respondents who owned their homes than rented did not evacuate for Hurricane Wilma (Table 22: Evacuation and Homeownership Cross Tabulation). The Chi-square value of 5.975 was significant at the 0.015

Table 21: Respondent Evacuation and Presence of Children and/or Caretaker Status					
			Children/Caretaker		Total
			Yes	No	
Did the Respondent Evacuate?	Yes	Count	13	27	40
		Expected Count	11.9	28.1	40.0
	No	Count	11	30	41
		Expected Count	12.1	28.9	41.0
Total		Count	24	57	81
		Expected Count	24.0	57.0	81.0
$X^2 = 0.312$, degrees of freedom = 1, $\alpha = 0.576$					

Table 22: Respondent Evacuation and Homeownership Cross Tabulation					
			Homeownership		Total
			Own	Rent	
Did the Respondent Evacuate?	Yes	Count	19	21	40
		Expected Count	24.3	15.7	40.0
	No	Count	29	10	39
		Expected Count	23.7	15.3	39.0
Total		Count	48	31	79
		Expected Count	48.0	31.0	79.0
$X^2 = 5.975$, degrees of freedom = 1, $\alpha = 0.015$					

level. Because there was only one degree of freedom the Yates Correction for Continuity was used to test the strength of the relationship. A value of 0.265 indicated that the relationship was weak. Interestingly, roughly the same number of respondents who owned their homes and rented their homes evacuated, while a greater number of respondents who owned their homes did not leave. This seems to be supported by the literature review in that respondents who own their homes may feel that the residence was strong enough to withstand hurricane damage or feel a need to protect their property.

The following variables were then altered using the mode or median: age, education, marital status, income, and race. Other variables that were modified included the persons in vehicle, trip purpose, trip destination, vehicle type and total trips made variables. After changing the variables, one non-random relationship between variables was discovered between evacuation behavior and the total trips made.

With regard to the age variable, no respondents who were under 18 years old reported making any trips during the evacuation for Hurricane Wilma. The categories of 60-74 years old and 75 years of age and older were combined, yet with a value of 2.003 no significant Chi-square value was calculated between age and evacuation. The age variable was then altered to reflect respondents who were between 18-44 years old and those 45 years old or older. Still no significant Chi-square value of 0.297 was determined after altering the variables (Table 23: Respondent Evacuation and Age Cross Tabulation).

Education was the next variable to be aggregated based on median. Education levels were regrouped to reflect two categories: a 2-year college degree or less and a 4-year college degree or more. Only one respondent reported having no high school diploma. At a value of 1.027, no statistically significant Chi-square was calculated. Though the literature review was

Table 23: Respondent Evacuation and Age Cross Tabulation					
			Age		Total
			18-44	45+	
Did the Respondent Evacuate?	Yes	Count	22	18	40
		Expected Count	22.7	17.3	40.0
	No	Count	24	17	41
		Expected Count	23.3	17.7	41.0
Total		Count	46	35	81
		Expected Count	46.0	35.0	81.0
$X^2 = 0.297$, degrees of freedom = 1, $\alpha = 0.586$					

inconclusive regarding education level and evacuation behavior, this data indicated that there was no statistical significance between educational level and evacuation behavior (Table 24: Respondent Evacuation and Education Level Cross Tabulation).

The lack of statistical significance continued even after modifying the marital status variable to reflect two categories: single, which included divorced and widowed, and married, which included respondents who were cohabitating (Table 25: Respondent Evacuation and Marital Status Cross Tabulation). However, the corresponding Chi-square value of 2.130 was not significant.

Income was the next variable to be aggregated. The income variable was changed to reflect two categories: Respondents who earned $49,999 or less and those who earned $50,000 or more. With a value of 0.376, no significant Chi-square value was calculated for the evacuation and income level variables. According to the literature review, respondents earning more than $40,000 are more likely to evacuate; the survey data does not support the literature review. Roughly the same number of respondents stayed behind as evacuated regardless of income level (Table 26: Respondent Evacuation and Income Level Cross Tabulation).

The race variable was regrouped into two categories: Non-Hispanic White and Other. With a Chi-square value of 0.102, a statistical significance was not found between race and

Table 24: Respondent Evacuation and Education Level Cross Tabulation					
			Education level		Total
			2-year degree or less	4-year degree or more	
Did the Respondent Evacuate?	Yes	Count	16	24	40
		Expected Count	17.8	22.2	40.0
	No	Count	20	21	41
		Expected Count	18.2	22.8	41.0
Total		Count	36	45	81
		Expected Count	36.0	45.0	81.0
$X^2 = 1.027$, degrees of freedom = 1, $\alpha = 0.311$					

Table 25: Respondent Evacuation and Marital Status Cross Tabulation					
			Marital		Total
			Single	Married	
Did the Respondent Evacuate?	Yes	Count	15	25	40
		Expected Count	18.3	21.7	40.0
	No	Count	22	19	41
		Expected Count	18.7	22.3	41.0
Total		Count	37	44	81
		Expected Count	37.0	44.0	81.0
$X^2 = 2.130$, degrees of freedom = 1, $\alpha = 0.144$					

Table 26: Respondent Evacuation and Income Level Cross Tabulation					
			Income Level		Total
			$49,999 or less	$50,000+	
Did the Respondent Evacuate?	Yes	Count	9	31	40
		Expected Count	8.4	31.6	40.0
	No	Count	8	33	41
		Expected Count	8.6	32.4	41.0
Total		Count	17	64	81
		Expected Count	17.0	64.0	81.0
$X^2 = 0.376$, degrees of freedom = 1, $\alpha = 0.540$					

Table 27: Respondent Evacuation and Race Cross Tabulation					
			Race		Total
			Non-Hispanic White	Other	
Did the Respondent Evacuate?	Yes	Count	29	11	40
		Expected Count	29.6	10.4	40.0
	No	Count	31	10	41
		Expected Count	30.4	10.6	41.0
Total		Count	60	21	81
		Expected Count	60.0	21.0	81.0
$X^2 = 0.102$, degrees of freedom = 1, $\alpha = 0.749$					

evacuation behavior. Nearly 75% of respondents who made pre-evacuation trips identified themselves as Non-Hispanic White. Though the literature review provided inconclusive results as to race and evacuation behavior, nearly the same number of respondents who considered themselves Non-Hispanic White evacuated as stayed behind. This holds true for people who considered themselves "Other" as well (Table 27: Respondent Evacuation and Race Cross Tabulation).

The persons in vehicle variable was categorized to reflect one person, two people and three or more people per vehicle, but because so few respondents indicated three or more people per vehicle, more than 30% of the categories contained an expected frequency of less than five. The variable was then altered to reflect vehicles occupied by one respondent, and vehicles occupied by more than one respondent. Interestingly, the same number of people evacuated alone as evacuated with others, but most respondents who did not evacuate took trips alone, and did not carpool with another. One respondent did not answer this question and was dropped from the pool. No significant Chi-square value at 2.026 was found (Table 28: Respondent Evacuation and Persons in Vehicle Cross Tabulation).

Table 28: Respondent Evacuation and Persons in Vehicle Cross Tabulation					
			Persons in Vehicle		Total
			1	2+	
Did the Respondent Evacuate?	Yes	Count	20	20	40
		Expected Count	22.7	17.3	40.0
	No	Count	25	15	40
		Expected Count	23.3	17.7	40.0
Total		Count	45	35	80
		Expected Count	45.0	35.0	80.0
$X^2 = 2.026$, degrees of freedom = 1, $\alpha = 0.363$					

The six trip purpose categories were combined to form two groups: pick-up, which included medications, money, property protection materials, and people, and work, which included trips to a job site or other. No statistically significant Chi-square value was calculated for the variables of evacuation and trip purpose at a value of 0.099. Surprisingly, nearly the same number of respondents who made trips to pick up medicines, money, property protection materials and people evacuated as stayed behind, and nearly twice as many respondents engaged in work or other trip purposes than pick-up purposes (Table 29: Respondent Evacuation and Trip Purpose).

Like trip purpose, the trip destination and evacuation variables were not found to be statistically significant even after the trip destination variable was modified. The original trip destination variable contained five categories: friend's home, store, work, other, and home. These were aggregated to reflect anyone's home, store, work, or other. Because there were no categories with an expected frequency of less than five, a reliable, but statistically insignificant Chi-square value of 3.537 was calculated (Table 30: Respondent Evacuation and Trip Destination Cross Tabulation). According to the survey data collected, more respondents who

Table 29: Respondent Evacuation and Trip Purpose					
			Trip Purpose		Total
			Pick-up	Work	
Did the Respondent Evacuate?	Yes	Count	14	26	40
		Expected Count	12.8	27.2	40.0
	No	Count	12	29	41
		Expected Count	13.2	27.8	41.0
Total		Count	26	55	81
		Expected Count	26.0	55.0	81.0
$X^2 = 0.099$, degrees of freedom = 1, $\alpha = 0.753$					

Table 30: Respondent Evacuation and Trip Destination Cross Tabulation							
			Trip Destination				Total
			Home	Store	Work	Other	
Did the Respondent Evacuate?	Yes	Count	10	9	10	11	40
		Expected Count	6.9	12.3	10.9	9.9	40.0
	No	Count	4	16	12	9	41
		Expected Count	7.1	12.7	11.1	10.1	41.0
Total		Count	14	25	22	20	81
		Expected Count	14.0	25.0	22.0	20.0	81.0
$X^2 = 3.537$, degrees of freedom = 1, $\alpha = 0.316$							

did not evacuate traveled to a store than those who did, and more respondents who evacuated traveled home than those who remained behind.

Vehicle type was tested against evacuation behavior. Unfortunately, only five of the 81 respondents reported using a bicycle or walking to make a trip. All other respondents used a car to make pre-evacuation trips. As a result of the concentration of vehicle type, a reliable Chi-square value could not be calculated, as half of the categories had expected frequencies of less than five.

The total number of vehicles available for pre-evacuation trips was tested against evacuation behavior. The number of vehicles available was changed to represent categories of one, two, and three or more vehicles. The Chi-square value of 2.272 was not significant (Table 31: Respondent Evacuation and Number of Vehicles Cross Tabulation).

Finally, the total number of trips made variable was altered to reflect three categories: one trip, two trips or three or more trips (Table 32: Respondent Evacuation and Total Trips Made Cross Tabulation). A relationship was found between the number of trips made and whether or not respondents evacuated. Twice as many respondents who evacuated made two trips than those who stayed behind, however, three times as many respondents who stayed

Table 31: Respondent Evacuation and Number of Vehicles Cross Tabulation

			Vehicles			Total
			1	2	3+	
Did the Respondent Evacuate?	Yes	Count	16	15	9	40
		Expected Count	12.8	17.3	9.9	40.0
	No	Count	10	20	11	41
		Expected Count	13.2	17.7	10.1	41.0
Total		Count	26	35	20	81
		Expected Count	26.0	35.0	20.0	81.0
$X^2 = 2.272$, degrees of freedom = 2, $\alpha = 0.321$						

Table 32: Respondent Evacuation and Total Trips Made Cross Tabulation						
			Total Trips			Total
			1	2	3 or more	
Evacuate	Yes	Count	20	18	2	40
		Expected Count	21.5	13.2	5.4	40.0
	No	Count	24	9	8	41
		Expected Count	22.5	13.8	5.6	41.0
Total		Count	44	27	10	81
		Expected Count	44.0	27.0	10.0	81.0
$X^2 = 7.653$, degrees of freedom = 2, $\alpha = 0.022$						

behind made three or more trips than those who evacuated. This could be explained by the number of trips required to purchase supplies to wait out the storm or find a safe place in the city to stay before the hurricane makes landfall. With two degrees of freedom, the Chi-square value of 7.653 was considered significant, but the Cramer's V statistic of 0.308 indicated that the relationship was weak.

No significant Chi-square value was found between evacuation behavior and most of the variables. This is counter to the literature review, which indicated that women were more likely to evacuate than men, and households with children were more likely to evacuate than those without children. Neither age, education, marital status nor income proved to be statistically significant with regards to evacuation behavior. The only two variables which were tested to have a non-random relationship with evacuation behavior were homeownership and total trips made. Overall, the survey results did not support the literature reviewed.

Binary Logistic Regression

In addition to the classification tables that were generated to indicate whether or not trip-making variables were associated with specific demographic characteristics, a stepwise binary logistic regression was used to predict the probability of a specific evacuation behavior based on

more than one variable. Though not a nonparametric statistical test per se, binary logistic regression assumes that the variables do not have a normal distribution or a linear relationship. The dependent variable in binary logistic regression takes the value of either 0 or 1. For this analysis, the independent variables were also assigned a value of 0 or 1. The dichotomous alteration of independent variables was done to tease out any possible relationship between an independent variable and evacuation behavior.

Respondents Not Reporting Pre-evacuation Trips and Respondents Who Did

A step wise binary logistic regression was run for respondents not reporting any trips and those who did. The variables were changed to reflect dichotomous values of either 0 or 1. Respondents who did not make any pre-evacuation trips were given a value of 0 and those who did were given a value of 1. This was considered the dependent variable. The independent variables that were modified included: gender, age, marital status, children, education level, income, housing type, and renter status (Table 33: Dichotomous Values of Variables). Variables

Table 33: Dichotomous Values of Variables

Group	Variable	Value	Variable	Value
Evacuation Behavior	No Trips Taken	1	Trips Taken	0
Gender	Female	1	Male	0
Age	18-44	1	45 or older	0
Marital Status	Married	1	Non-married	0
Race	White	1	Non-white	0
Children	No Children	1	Children	0
Education	2-year degree or less	1	4-year degree or more	0
Income	$49,999 or less	1	$50,000 or more	0
Housing Type	Single Family	1	Other	0
Renter Status	Rent	1	Own	0
Trip-making behavior	Stayed	1	Evacuated	0
Working Age	18-59	1	Under 18; 60+	0
Income 2	$99,999 or less	1	$100,000 or more	0
Education 2	No college	1	2-year degree or more	0

Table 34: Statistical Significance of Variables					
			Score	df	Sig.
Step 0	Variables	No Children	.982	1	.322
		Renter Status	.076	1	.782
		Gender	.051	1	.821
		Housing Type	2.158	1	.142
		Age	.691	1	.406
		Marital Status	.079	1	.778
		Race	2.101	1	.147
		Education Level	.039	1	.844
		Income Level	2.049	1	.152
		Working Age	1.188	1	.276
		Income $100,000+	1.947	1	.163
		No college	.067	1	.796
	Overall Statistics		11.037	12	.526

that had more than a dichotomous response were changed using the median or mode. Age was aggregated to reflect respondents 18-44 and 45 years and older; marital status was altered to reflect those respondents who were married or cohabitating and those who were single, divorced or widowed, and race was modified to reflect categories of Non-Hispanic White and Other. Education was changed to reflect those with a 2-year degree or less and respondents with a 4-year degree or more, and income was altered to reflect respondents earning $49,999 or less and those earning $50,000 or more.

Of the 287 respondents who answered the survey, 250 were included in the analysis because 37 responses contained missing values. Only one step was required to generate results; however the results indicated that no statistically significant coefficients were found among variables and evacuation behavior. That is, inclusion of the independent variables (e.g. renter status, gender, age, marital status, etc.) would not improve the model's ability to predict the probability that a respondent made any pre-evacuation trips based on respondent variables (Table 34: Statistical Significance of Variables). Transformations in the age, income and education

variables were made to reflect respondents of working age 18-59 years old, income of $100,000 or more and education level of 2-years college degree or more. Once again, no statistically significant result was generated, as all results were calculated at a value of 0.1 or higher, not the value of 0.05 or less to indicate statistical significance.

Trip Making Respondents Who Evacuated and Trip Making Respondents Who Did Not

When the analysis was limited to those who reported pre-evacuation trips, the step wise binary logistical mode proved to generate statistical significance between the respondents who evacuated and renter status and income. Respondents who waited out the storm were given a value of 1, while those who evacuated were given a value of 0. For this analysis, trip-making information was added to the variables being analyzed. These variables included passenger or driver status, number of passengers in vehicle, trip purpose, trip destination and total number of trips made. The variables were given dichotomous values (Table 35: Dichotomous Values of Variable for Trip Makers).

Of the 81 respondents who reported trip-making, 13 responses contained missing values. Two steps were needed to highlight the statistical significance of renter status in the first step, and income of $100,000 or more in the second step (Table 36: Statistical Significance of Variables for Trip-Makers). The coefficients on these variables were both negative. These

Table 35: Dichotomous Values of Variables for Trip Makers

Group	Variable	Value	Variable	Value
Evacuation Behavior	Stayed	1	Evacuated	0
Driver Passenger Status	Driver	1	Passenger	0
Number of Passengers	One	1	Two or more	0
Trip Purpose	Work	1	All other	0
Trip Destination	Work	1	All other	0
Total Trips Made	One	1	Two or more	0

Table 36: Statistical Significance of Variables for Trip-Makers							
		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1	Renter Status	-1.423	.566	6.316	1	.012	.241
	Constant	.442	.302	2.139	1	.144	1.556
Step 2	Renter Status	-1.978	.662	8.917	1	.003	.138
	Income $100,000+	-1.388	.605	5.267	1	.022	.250
	Constant	1.285	.509	6.383	1	.012	3.615

values indicate that renting decreases the probability of waiting out the storm. Put another way, homeownership increases the probability of waiting out the storm. Similarly, incomes greater than $100,000 make it less likely that a respondent will stay (more likely they will evacuate). The association between income and evacuation is supported by the literature reviewed in Chapter 2, as is the association between homeownership and waiting out the storm. The Chi-square statistic used to test for non-random relationships between evacuees and home ownership also revealed that more respondents who rented their homes than owned evacuated for Hurricane Wilma. Overall, the binary logistic regression model was used successfully to calculate the probability of evacuation with renter or homeownership status and income.

The -2 Log likelihood ratio was used to calculate how well the model fits data. In other words, the ratio was used to determine if the statistically significant results of the binary logistical regression indicated a strong probability that homeownership and income were related to evacuation behavior. Lower values of this statistic indicate a model that fits the data. The stepwise procedure was used to maximize the likelihood that the homeownership and income variables would be a significant predictor of evacuation behavior. In this case, the binary logistical regression model does not fit the data well; it does not predict very well the probability that homeownership and income have a strong relationship with evacuation behavior. In addition, two other statistics were used to explain the variability in the data. Because the number

Table 37: Binary Logistic Regression Model Summary			
Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	98.472	0.144	0.192

of respondents who made trips was small (<100) no true r-square, which measures the amount of variation in the data that can be explained by the model, could be calculated. Both the Cox & Snell R-square and the Nagelkerke R-square were used to calculate a pseudo r-square. The closer the r-square value is to 1.0, the more variability that can be explained by the model. In this case, the values indicated that very little of the variation in the data could be explained by the model (Table 37: Binary Logistic Regression Model Summary).

Prior Experience

Unfortunately, only a few respondents answered the questions involving prior hurricane experience. This was disappointing as a correlation between prior experience and evacuation behavior could not be adequately determined. However, of the 35 respondents who reported this information from the 206 respondents who did not report any trip-making, 94% reported having prior hurricane evacuation experience. Most waited out the storm, and only one respondent reported evacuating three times, but waiting out the storm for all other storms. Only six of the 81 respondents reporting trips provided previous hurricane experience – only four had previous experience. Yet, all but five of the 81 respondents providing trip-making data also reported whether or not they evacuated the city for the Hurricane Wilma mandatory evacuation. The lack of clear information about prior experience was puzzling as this was one of the internet pages that had to be completed before moving onto the portion of the survey that asked about trip-making.

Trips Taken

This portion of the research analyzes the pre-evacuation trips taken, including information about trip purpose, trip times and delays, traffic flows, the dispersion of trip origin and destination points, and the potential for traffic congestion on the roads used for travel. A total of 132 origin-destination pairs were reported for the 77 respondents who provided complete information about at least one origin and destination pair. Of these 77 respondents, a total of 35 respondents evacuated the city and 42 respondents waited out the storm (Table 38: Trips Made and Evacuation). Forty-two respondents only made one trip; of these, 18 respondents evacuated the city in their first trip, which means they left from an origin node in the city and either identified a destination node outside the city or identified a destination node inside the city, but reported that they evacuated. . Thirty-five of the 77 respondents made at least two trips. Of the 35 respondents who made at least two trips, twenty made two trips only. Of the respondents that only made two trips, twelve evacuated the city and eight waited out the storm. Fifteen respondents made at least three trips; with ten of these making three trips only. Of the ten

Table 38: Trips Made and Evacuation	
Respondents making at least one trip	77
Respondents who only made one trip	42
Respondents who evacuated on their 1st trip	18
Respondents who waited out the storm	24
Respondents making at least two trips	35
Respondents who only made two trips	20
Respondents who evacuated on their 2nd trip	12
Respondents who waited out the storm	8
Respondents making at least three trips	15
Respondents who only made three trips	10
Respondents who evacuated on their 3rd trip	4
Respondents who waited out the storm	6
Respondents making four or more trips	5
Respondents who evacuated on their 4th or more trip	1
Respondents who waited out the storm	4

respondents that made three trips, four evacuated the city in their third trip and six did not. The remaining five respondents made four or more trips, and one of those respondents evacuated, while the remainder waited out the storm. Thirty-five respondents engaged in trip-chaining.

With regard to the first trip taken, most residents reported making their first trip on Saturday, October 22, 2005 (Table 39: Date of First Trip). This was the date when the mandatory evacuation took place for all residents living in Key West irrespective of housing type. At this point, no trip-chaining had taken place, though there was some interesting information related to respondents making trips. Most of the respondents made their first trip at noon, irrespective of the day of their first trip. The start time for the various trips recorded varied from as early as 4 am to as late as 12 am. Not surprisingly, most trips occurred between 8 am and 8 pm. No trips were taken between midnight and 4 am (Table 40: Start Time of Trips). The mandatory evacuation was called for at noon on Wednesday, October 19, 2005 for people living in boats, recreational vehicles or travel trailers, and at 6 am and noon on Saturday, October 22, 2005 for all other residents. The 22% of trips taken on Wednesday, October 19 took place between 5 am and 9:30 pm, about half before the noon call for evacuation and half after 12 pm. Only 13% of the trips took place on Thursday between 7 am and 5 pm, slightly more than half of these trips took place before noon. Nineteen percent of trips took place on Friday between 6 am and 6 pm; half of these trips took place before noon and half after. Most of these trips took place between 10 am and 6 pm. Most trips were taken on Saturday (42%) when the mandatory evacuation was called for all residents. Slightly more trips were taken after 12 pm than before. Only four percent of trips were taken on Sunday.

Table 39: Date of First Trip		
Date	Number of Respondents	Percentage
Wednesday, October 19, 2005	17	22%
Thursday, October 20, 2005	10	13%
Friday, October 21, 2005	15	19%
Saturday, October 22, 2005	32	42%
Sunday, October 23, 2005	3	4%
Total	77	100%

Table 40: Start Time of Trips		
Start Time	Number of Trips	% of Total
4 am – 8 am	12	10%
8 am – 12 pm	33	27%
12 pm – 4 pm	35	29%
4 pm – 8 pm	34	28%
8 pm – 12 am	7	6%
Total	121	100%

For the first trip, almost 80% of respondents reported being the driver of the vehicle making the first trip, but approximately two out of every three respondents shared the ride with someone else. Only four respondents reported bicycling or walking instead of traveling by car. The various trip purposes seem to be concentrated on the "Other" category (Table 41: First Trip Purpose). Thirty-six percent of the respondents made trips to "purchase water and food . . . park a vehicle above the flood stage . . . take DVDs to Blockbuster . . . [leave] town after getting gas . . . [participate in a military] base evacuation . . . eat at a restaurant . . . go to dinner . . . catch a flight in Fort Lauderdale . . . [go to the] grocery store (Albertson's was mentioned by name), or . . . look around . . ." Going to work was listed by 34% of the respondents as the second most frequent trip purpose. Only 30% of the respondents took their first trip to perform tasks such as gathering medicines or money together, picking up others or protecting property. Trip destination differed from trip purpose in that the destination most frequently chosen was work and store at 27% each, which was closely followed by the "other" category at 26% of the respondents (Table 42: First Trip Destination). Other destinations included "P.T.'s Restaurant . . . bar . . . boat dock. . . parking garage, and . . . hotel."

A common assumption in evacuation modeling is that the traffic flow during the evacuation period follows the shortest path to a designated evacuation point. Further, the only trip purpose considered is that people want to evacuate the area as quickly as possible without making any stops along the way. Key West survey data for Hurricane Wilma does not support this assumption. In fact, six of the 77 respondents took their first trip to go to Home Depot. As seen in Figure 9. Origins and Destinations for Trip #1, of the 77 respondents who made their first trip, 38 traveled westbound toward the center of the city, 36 traveled eastbound toward US Highway #1 (the evacuation point), and three traveled north-south along the roadways or

Table 41: First Trip Purpose		
Trip Purpose	Number of Respondents	Percentage
Get Meds	6	8%
Get Money	3	4%
Other	28	36%
Pickup Person	11	14%
Get Property Protection Materials	3	4%
Go to Work	26	34%
Total	77	100%

Table 42: First Trip Destination		
Trip Destination	Number of Respondents	Percentage
Go to a Friend's House	14	18%
Go Home	1	2%
Go to a Store	21	27%
Go to Work	21	27%
Other	20	26%
Total	77	100%

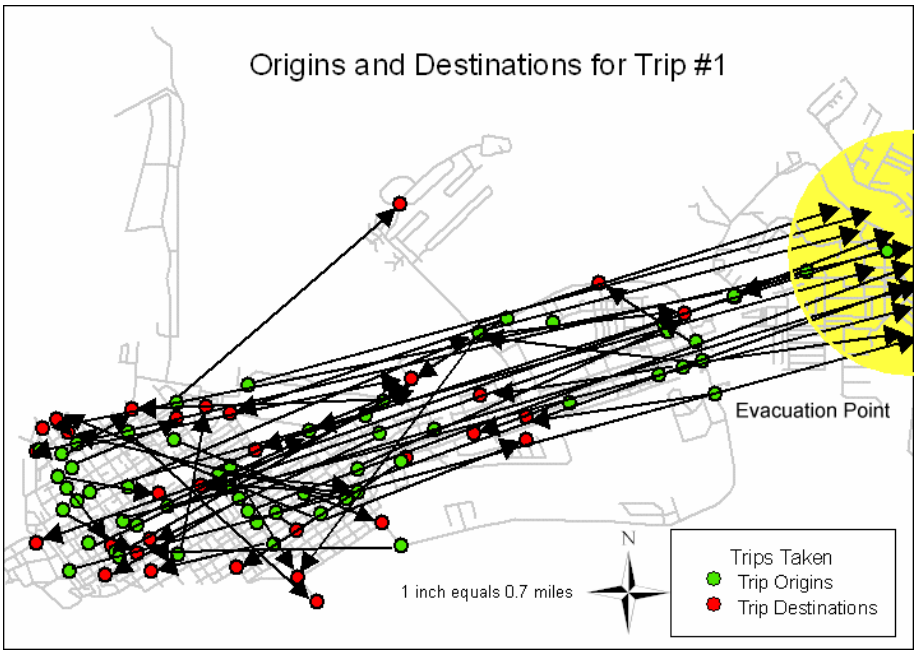

Figure 9: Origins and Destinations for Trip #1

remained in the same location for their first trip. Of those who traveled eastbound, two-thirds stopped at a destination short of the evacuation point. Thus, traffic flows in many directions, not just toward an evacuation point. The average travel time from origin to destination was about 16.5 minutes, and the average delay associated with trip purpose was 44 minutes. Though some evacuation models can mimic a delay in respondent evacuation by categorizing respondents into a specific group, and then coding each group to begin evacuation at different times during the simulation, the models do not take into account the delay caused by stopping to gather supplies or "Other" activities. Based on this research, most delays were caused by such trips.

A second trip was made by 35 of the respondents. Once again, most respondents made their second trip on the same day as their first (Saturday, October 22, 2005). Most respondents started their second trip at around 2:00 pm. All, but one of the respondents who made two trips traveled via car; one walked or used a bicycle, and almost 90% of the respondents were driving the vehicle. Just like the first trip, two out of every three respondents shared the ride with someone else. Like the first trip purpose, most of the respondents (39%) engaged in the "Other" trip purpose. This included such things as "[attending an] AA meeting . . . [moving] to a guest house . . . going to a friend's house to ride out the storm, and . . . [taking] a 13-mile ride on a bike around [the] island." However, unlike the first trip purpose, both getting money and going to work were listed as the second most popular trip purpose for the second trip (Table 43: Second Trip Purpose). Two of the respondents did not identify a second trip purpose. The trip destination for the second trip was different than the first trip, which identified travel to a store or work as equally the most frequently identified destination. For the second trip, more respondents traveled to a store (37%), than to work (28%). Interestingly, unlike the first trip when 3% of respondents traveled home, 23% of the respondents traveled home for the second trip (Table 44:

Table 43: Second Trip Purpose		
Trip Purpose	Number of Respondents	Percentage
Get Meds	4	12%
Get Money	6	17%
Other	14	39%
Pickup Person	4	12%
Get Property Protection Materials	1	3%
Go to Work	6	17%
Total	35	100%

Table 44: Second Trip Destination		
Trip Destination	Number of Respondents	Percentage
Go to a Friend's House	3	9%
Go Home	8	23%
Go to a Store	13	37%
Go to Work	10	28%
Other	1	3%
Total	35	100%

Second Trip Destination). The trip destination changed from first trip to second trip, which had an impact on the trip purpose delay. While 12 respondents evacuated on their second trip purpose, only 1 of the respondents used the second trip to travel to Home Depot. Unlike the first trip, the respondents who made at least two trips did not travel in nearly equal numbers eastbound and westbound. Three times as many respondents reported traveling eastbound toward US Highway #1 than westbound toward the city center. Twenty-four respondents traveled eastbound, eight respondents traveled westbound, and three respondents either traveled north-south or identified the same location for their origin and destination pair for the second trip (Figure 10: Origins and Destinations for Trip #2). Unlike the first trip, the average travel time from origin to destination for the second trip was about ten minutes longer at about 25.5 minutes, and the average delay associated with trip purpose was the same as the first trip at about 44 minutes.

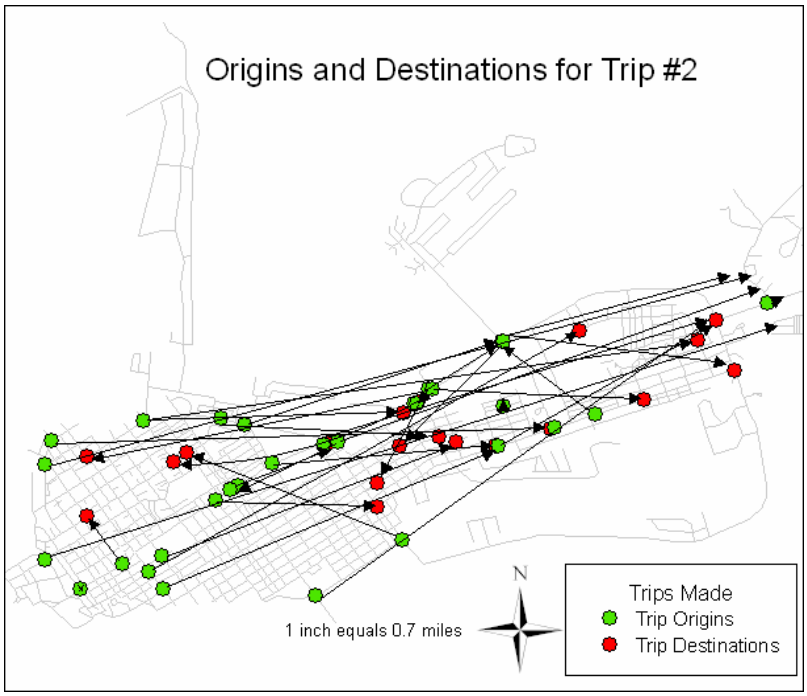

Figure 10: Origins and Destinations for Trip #2

Table 45: Third Trip Purpose		
Trip Purpose	Number of Respondents	Percentage
Get Meds	0	0%
Get Money	0	0%
Other	7	64%
Pickup Person	2	18%
Get Property Protection Materials	1	9%
Go to Work	1	9%
Total	11	100%

A third trip was taken by 15 of the respondents. Once again, most respondents made their third trip on the same day as their first and second trips, which was on Saturday, October 22, 2005. Most respondents started their third trip at around 6:00 pm. All of the respondents who made three trips traveled via a car, and only two of the respondents were passengers in the vehicle. Just like the first and second trips, most of the respondents traveled with more than one person. As seen in Table 45: Third Trip Purpose as in the first and second trip purposes, most of the respondents engaged in the "Other" trip purpose. The other trip purpose included "[dropping] the car off at above flood [level] . . . [going] golfing . . . [going] to dinner, and . . . [visiting] friends and [preparing] for the hurricane." Unlike the previous trip purpose, picking up a person was listed as the second most popular trip purpose for the third trip. Four of the respondents did not identify a third trip purpose, and none of the respondents traveled to get medicines or money. Trip destination was concentrated in the "Other" category for the 11 respondents who answered the question regarding generic trip end (Table 46: Third Trip Destination). Other included "golfing . . . going to the high school, and . . . [eating at a] restaurant." Four of the respondents evacuated on their third trip, and one respondent traveled to Home Depot. Like the first trip, the respondents making a third trip traveled nearly equally eastbound and westbound. Eight respondents traveled toward US Highway #1, and six

Table 46: Third Trip Destination		
Trip purpose	Number of Respondents	Percentage
Go to a Friend's House	2	18%
Go Home	1	9%
Go to a Store	3	28%
Go to Work	1	9%
Other	4	36%
Total	11	100%

respondents traveled toward the city. One respondent chose the same intersection as both the origin and destination node (Figure 11: Origins and Destinations for Trip #3). The average travel time from origin to destination for the third trip was about ten minutes long, and the average delay associated with trip purpose was longer than the first or second trip delay at slightly less than one hour.

Four or more trips were taken by five respondents. Most of respondents made their last trip on Saturday, October 22, 2005. Only one respondent evacuated on their fourth, fifth, or sixth trip. The average start time for the last trip was around 4:30 p.m. for most respondents. None of the respondents identified themselves as a passenger, but all but one driver traveled via car with a passenger. All the respondents chose "Other" as the trip purpose, except for one who chose getting medicines. The other trip purposes included "[going to my] mother's trailer . . . [going] to friends' house for dinner, and . . . [helping] a friend close up house." The trip destination for all remaining trips was either to a friend's house or to the store. The average travel time from origin to destination for the fourth, fifth, and sixth trips was about 8.5 minutes long, and the average delay associated with trip purpose was the longest of all trips at 74 minutes.

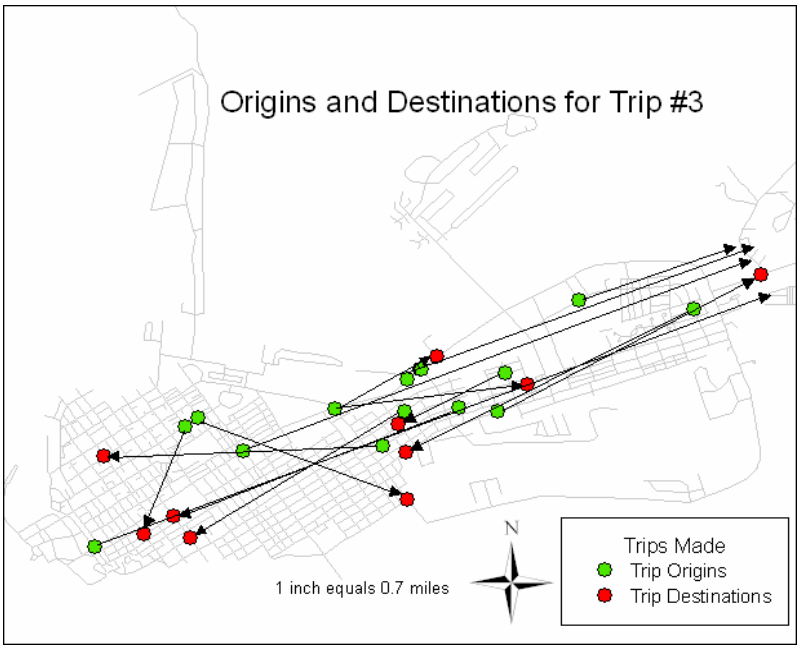

Figure 11: Origins and Destinations for Trip #3

Trip-chaining plays an important part in evacuation delay, and in the delay associated with reaching a safe place to wait out the storm. Of the 77 survey respondents reporting pre-evacuation trips, just under half (35) engaged in trip-chaining to accomplish their trip purposes. Though many respondents engaged in trip-chaining, one example provided by survey respondent #201 provides an illustration of trip purpose, destination, and delay (Table 47: Example of Trip Chaining). This particular respondent was a married, Hispanic, female, who was 60-74 years old, and was responsible for children or the caretaker for others. She was a high school graduate, with an income of $100,000 - $149,000, owned her single family home and had two cars at her disposal. At 12:00 PM on Saturday, October 22, 2007, she left somewhere around 15th and Flagler Avenues, traveled 15 minutes to somewhere around 10th and Flagler Avenues where she picked someone up. This took about one hour, so at 1:30 PM, she and her passenger traveled 20 minutes to Walgreens on Roosevelt Avenue to pick up some medications. It took her an hour to

Table 47: Example of Trip Chaining					
Trips for Survey # 201	Start Time	Trip Purpose	Destination	Travel Time	Purpose Time
15th and Flagler	12:00 PM	Pick-up	10th and Flagler	15 minutes	45 minutes
10th and Flagler	1:30 PM	Meds	Walgreens on Roosevelt	20 minutes	60 minutes

complete her task at Walgreens. At 2:50 PM she started her evacuation of the city; it took her 30 minutes to exit to U.S. Highway #1 at approximately 3:20 PM. Total travel delay due to trips taken was three hours and 20 minutes.

Residents living in Key West were asked to evacuate in stages based on housing type. For example, people who lived in boats, recreational vehicles (RV) or travel trailers were asked to evacuate by 12 p.m. on Wednesday, October 19, 2005; people who lived in a mobile home were asked to evacuate by 6 a.m. on Saturday, October 22, 2005, and those who lived in any other type of home were asked to evacuate by noon of the same day. The data collected for this research did not reflect this orderly evacuation. By Wednesday, three apartment dwellers, and 9 single family home dwellers had evacuated, but only 1 recreational vehicle dweller had left. The remaining three RV dwellers in the survey evacuated on Friday or Saturday. The difference between the RV dwellers is that the one who evacuated on Wednesday owned the RV and the others were renting. All other single family home or apartment dwellers left the city before or on Saturday, but four of these individuals evacuated later than noon - one at 3 p.m., and three at 6 p.m. The exception to this was the one apartment dweller who did not evacuate until 7 a.m. on Sunday, October 23, 2005.

Table 48: Origin Point Distribution			
Census Tract	Contained Within	Shared Border	Total
9719	9	1	10
9720	3	10	13
9721	11	1	12
9722	4	5	9
9723	1	9	10
9724	8	1	9
9725	8	1	9
9726	1	4	5
Total	45	32	77

The use of census tracts as a means to determine whether or not survey respondents were distributed throughout the City of Key West based on their choice of first origin location indicated that there was some clustering of more than nine respondents in most census tract. In order to ensure that the responses were spread throughout the city, each of the eight census tracts had to contain no fewer than nine origin points based on the sample size required. Seventy-seven origin points were identified, 45 of the points are fully contained within a census tract; 32 of these points shared the border with one other census tract, and one of these points shared the border with three census tracts. All of the census tracts, except for tract 9726, had at least nine origin points contained within the tract or sharing a border with some other tract (Table 48: Origin Point Distribution). Origin points that shared a border were randomly assigned to a census tract. Census tract 9726 contained slightly more than half of the responses needed to make sure respondents were spread throughout the city. This lack of responses could be due to two issues. First, census tract 9726 contained fewer residents than the other census tracts. Second, census tract 9726 also contained about 400 housing units less than the census tract with the next lowest level of housing units. Of the 710 housing units available, only 577 were occupied (Table 49: Census Tract Information). This means that the survey respondents did not

Table 49: Census Tract Information			
Census Tract	Population	Housing Units	Housing Units: Occupied
9719	5634	2305	2043
9720	4030	2202	1804
9721	4276	2002	1669
9722	3053	1371	1287
9723	2691	1620	1316
9724	3467	1958	1658
9725	1245	1139	663
9726	1065	710	577

identify their first origin intersection uniformly throughout the city; intersections contained within some census tracts were more frequently identified as the respondents starting point for their first trip. Of concern is the fact that this lack of equality in census tract representation could be a reflection of the data being more heavily drawn from residents in certain census tracts and not collected equally throughout the city from a sample of all residents.

A review of Figure 12: Dispersion of Origin Points, shows the dispersal of origin points across the city. The majority of respondents identified intersections with significant traffic counts as their points of trip origin. Though 81 respondents provided demographic information as well as information on whether or not they evacuated, only 77 respondents provided information about trips that could be used to plot origins on a map. Four respondents provided locations and intersections that could not be identified. The remaining respondents provided one or more trip origin and destination pairs; of these, 55 respondents identified heavily trafficked intersections as start locations for their trips. These intersections are worth noting because they have the potential to become congested areas during an evacuation. In order to create readable maps illustrating these locations, the City of Key West was divided into three sections: Old Town, Mid-Town, and New Town (Figure 13: Town Divisions). Based on personal observation,

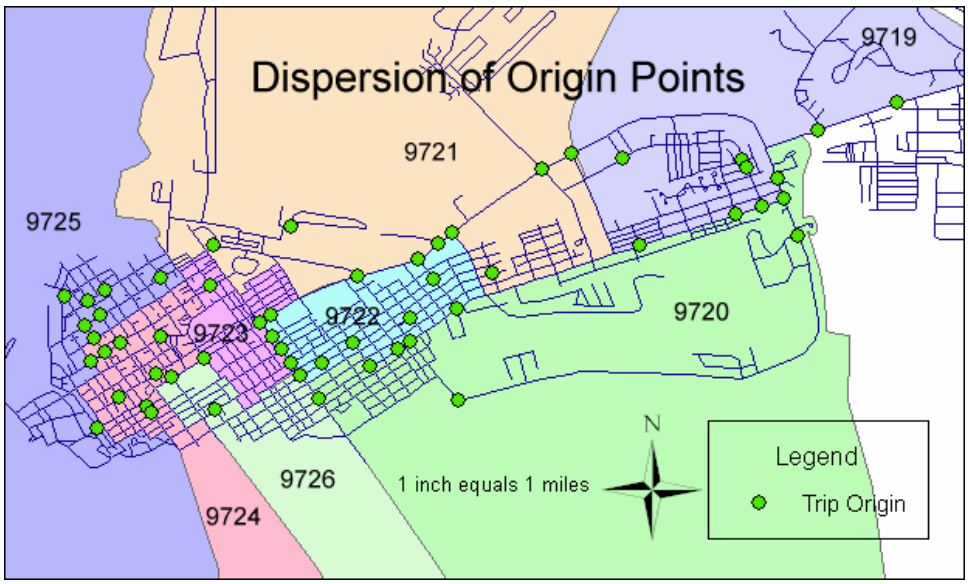

Figure 12: Dispersion of Origin Points

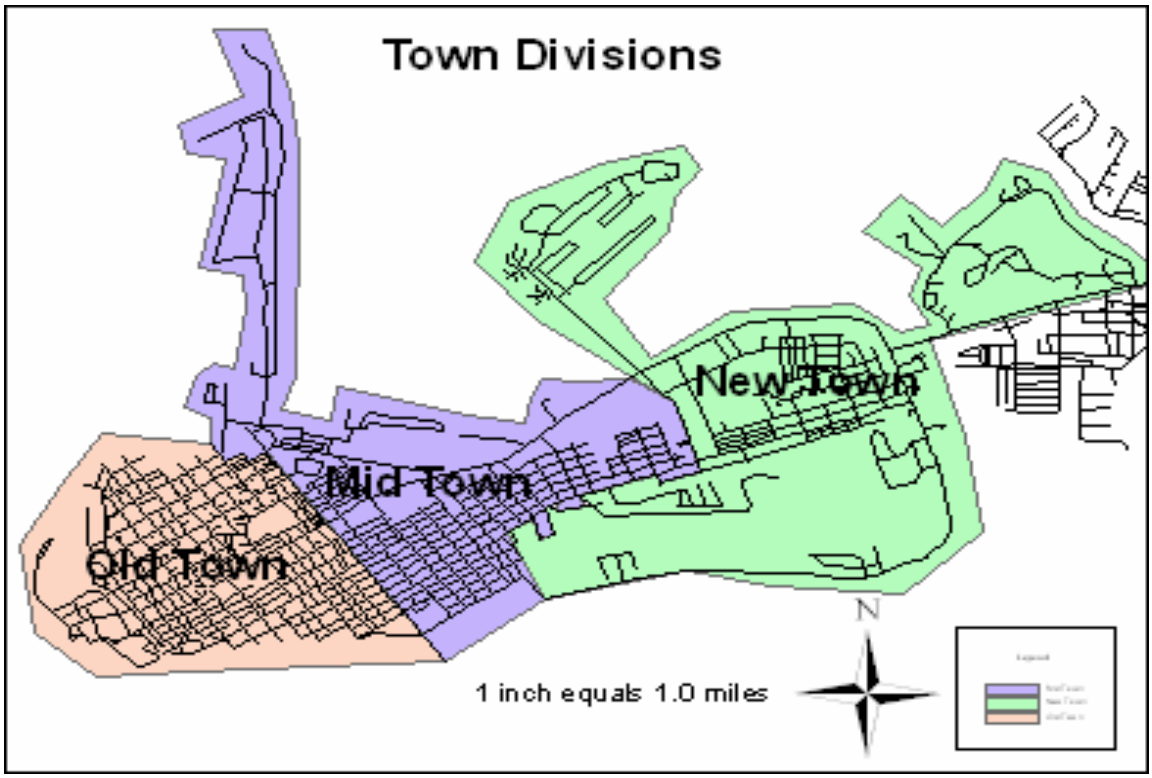

Figure 13: Town Divisions

the old town section of the city had the narrowest streets at about 10 feet per lane, most often there was only one lane to travel, and cars were parked along both sides of the streets. This is the section of the city that was first inhabited and is not really car friendly. Mid-town is to the east of old town; this was where the sprawl traveled when the population increased to the point where new places to live had to be found. Generally, there are two-way streets and homes were built with garages so that cars were not parked along the street. The newest section of town where the two shopping centers are located is called new town. In this section, the streets consist of two to five lanes with multiple traffic lights and turning lanes.

Twenty-six respondents reported the start of their first trip along heavily trafficked roads in New Town. The main focus was along Roosevelt Avenue, which loops around new town. This was not unusual because all sections of Roosevelt Avenue had high Average Annual Daily Traffic Counts (AADT) (FDOT 2005). Seven respondents specifically identified North Roosevelt and Kennedy Avenue as the initial trip making location. According to the Florida Department of Transportation, the AADT for this intersection was 9,900 vehicles per day with 5,400 vehicles traveling north and 4,500 traveling south along Kennedy Avenue. The intersection of Roosevelt Avenue and Flagler Street was mentioned twice as an origin location for trips. The AADT for the intersection at Roosevelt Avenue and Flagler Street was 12,700 vehicles per day; 5,900 vehicles traveling northbound on Roosevelt Avenue, and 6,800 vehicles traveling southbound on Roosevelt Avenue. Four respondents identified other intersections along Roosevelt Avenue as their origin locations, one at 14th Street, one at Duck Avenue, and two at Seaside Avenue. Four respondents identified origins along Flagler Avenue at 15th, 19th and 20th streets. No specific AADT counts are known for this section of Flagler Avenue. Three respondents identified their origin locations on interior residential streets within New Town.

Six respondents identified intersections along US Highway #1 as the origin point for their first trip. Four identified US Highway #1 and College Avenue as their trip origin location. This intersection is in Stork Island, which is located east of New Town. This was the only area of Stork Island that had been zoned as a part of the City of Key West. This area contains a private golf club in a gated community. The AADT for the intersection at US Highway #1 and College Avenue was 5,400 vehicles per day with 3,100 traveling northbound and 2,300 vehicles traveling southbound along College Avenue. The remaining two respondents identified the intersection at US Highway #1 and MacDonald Road, which had a red light, as their point for the first trip. The AADT for this intersection was 10,200 vehicles per day with 4,900 vehicles traveling northbound and 5,300 vehicles traveling southbound along MacDonald Avenue (Figure 14: New Town Trip Origins).

Twenty-seven respondents identified intersections in mid-town as their origin locations. Mid-town is located between White Avenue and 8th Avenue. One respondent chose Flagler and First Avenues as the origin point of their trip in mid-town. This intersection had an AADT of 15,700 vehicles per day; 7,700 vehicles traveling north and 8,000 vehicles traveling south along First Avenue. Three other respondents chose intersections along Flagler Avenue at Thompson, George and 5th Avenues as their starting point. Another respondent identified the intersection of Flagler and White Avenues as the origin point for their first trip. This intersection had 10,100 vehicles per day passing through it; 4,500 vehicles traveling north and 5,600 vehicles traveling south along White Avenue. Four other respondents also chose intersections along White Avenue as their trip origin location. Five respondents specifically chose the intersection of White Avenue and Truman Avenue as their first trip origin location. This intersection had a AADT of 14,000 vehicles per day; 7,500 vehicles traveling northbound and 6,500 vehicles traveling

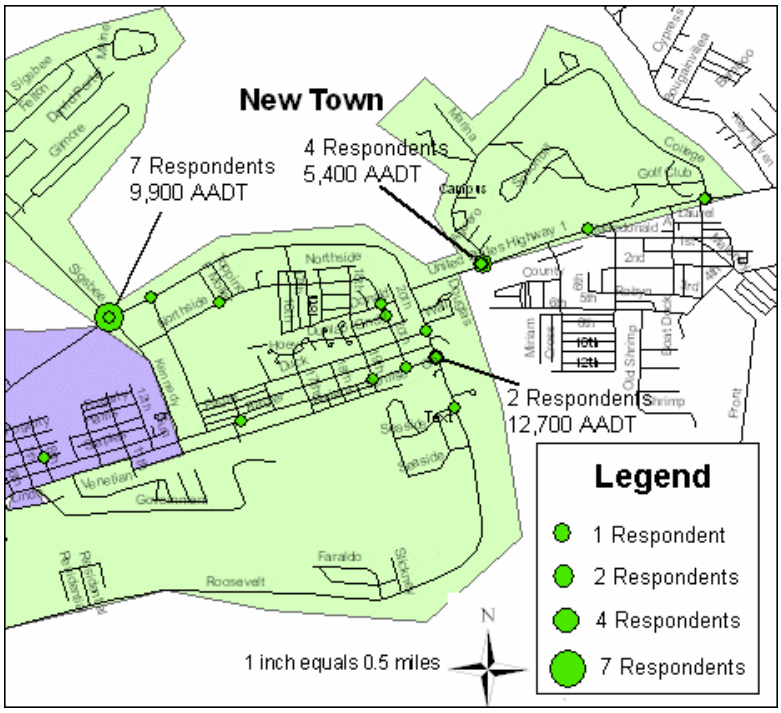

Figure 14: New Town Trip Origins

southbound along White Avenue. Two respondents identified South Roosevelt Avenue and Bertha Street as the origin location for their first trip. The AADT for the intersection at South Roosevelt Avenue and Bertha Street was 10,700 vehicles per day; 4,900 vehicles traveling eastbound on South Roosevelt Avenue and 5,800 vehicles traveling westbound on South Roosevelt Avenue. Four respondents identified intersections along North Roosevelt Avenue as their origin point, and two respondents identified intersections in the military housing section of the city north of Palm Avenue as their trip origin location. The remaining five respondents identified intersections inside mid-town in residential areas as the origin point for their first trip (Figure 15: Mid-Town Trip Origins).

Twenty-four respondents identified intersections in Old Town as the location for the origin point of their first trip. Two respondents chose intersections along Truman Avenue as their starting point at DeKalb and Simonton Avenues. Two other respondents chose the same

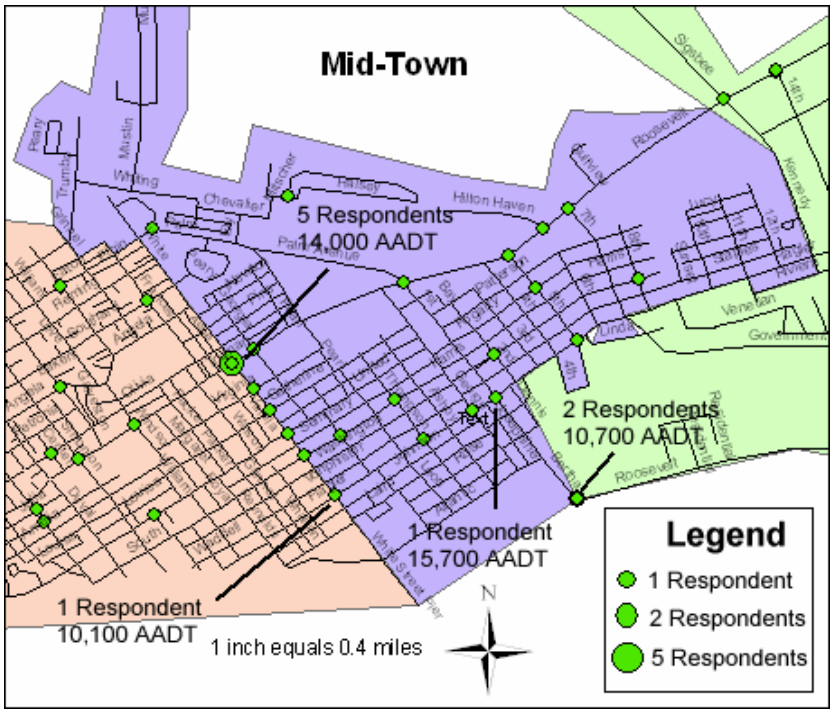

Figure 15: Mid-Town Trip Origins

intersection at Truman and Windsor Avenues as their start location. None of these intersections had specific traffic counts. Eight respondents identified intersections along Whitehead Avenue in the old city as the starting point for their initial trip. Two chose Whitehead Avenue and Eaton Street; two other respondents chose the intersection at Whitehead Avenue and Greene Street; the other 4 respondents chose intersections along Whitehead Avenue at Fleming Avenue, Southard Street, Virginia Avenue and Julia Street. The AADT for Whitehead Avenue and Julia Street was 6,700 vehicles per day; 3,100 vehicles traveling north and 3,600 vehicles traveling south along Whitehead Avenue. Five respondents identified the origin point for their first trip along Duval Street: two at Eaton Avenue, two at Southard Avenue and one at Margaret Street. The intersection of Duval Street and Eaton Avenue had an AADT of 5,500 vehicles; 2,200 traveling north and 3,300 traveling south along Duval Street. Two other respondents identified their origin

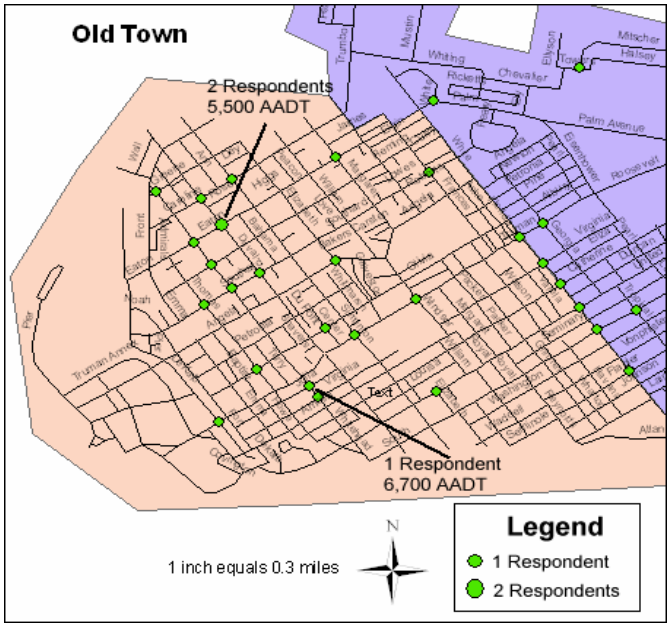

Figure 16: Old Town Trip Origins

locations along Southard Avenue at Frances and Thomas Streets, which did not have AADT counts. The remaining five respondents identified starting locations at intersections that had no traffic counts. These intersections included Caroline and Simonton Streets, Angela and Elizabeth Streets, Elizabeth and United Streets, Olivia and Center Streets, and Olivia and Thomas Streets (Figure 16: Old Town Trip Origins). Overall, 55 or the 77 respondents, who provided a usable origin-destination pair, identified an intersection along a road with at least 5,500 AADT as their origin location.

The Key West residents' choice of origin intersection suggests that in some evacuations residents could encounter congested areas when making pre-evacuation trips. At these heavily trafficked intersections, such as North Roosevelt and Kennedy, normally operating traffic signals may not be adequate. Law enforcement may need to monitor these intersections and direct traffic manually. The purpose of identifying the specific first trip origin intersections and

associating them with a traffic volume is to highlight the potential need for emergency managers to implement traffic management techniques at these intersections during a hurricane evacuation.

Survey Comments

More than 60 survey respondents relayed different comments regarding their experience with the Hurricane Wilma mandatory evacuation. In addition to demographic information analyzed earlier, a portion of the survey allowed respondents to write their own personal stories about their hurricane experience. These qualitative comments provided a glimpse into the thoughts and attitudes that directed respondent behavior during the hurricane crisis. Many respondents emailed their stories to the researcher; thus destroying a link between their demographic attributes and their accounts. This qualitative component of the research adds a valuable dimension to learning more about evacuation processes.

A few comments were fairly succinct and non-descript. One married male, aged 45-59 with a bachelor's degree and an income of $50,000-$99,000, who owned his single family home and had two vehicles to use, wrote that he had "never evacuated in the eleven years I have lived here." A younger and single male, aged 18-24, who had a high school education and an income of less than $24,000 wrote that he left his rented apartment and "only went from my house to a friend's." Neither of the male respondents evacuated nor had children or caretaker responsibilities.

Other comments provided a more intricate picture of what happened during the evacuation for Hurricane Wilma. Two married female respondents evacuated, while one divorced female respondent remained behind, and one male respondent evacuated. One 25-44 year old with a bachelor's degree and an income of $100,000-$149,000 wrote that she left her

owned single family "with my mother and two children." Another older female, aged 45-59, with the same income level, but with a graduate degree, and with no children or caretaker responsibilities, left her owned condominium or apartment to evacuate to Ft. Lauderdale. She wrote "My husband and I left Key West in two cars." Another woman of the same age, education, and income level as the previous respondent, but who owned her single family home and had caretaker responsibility for others simply "walked to a friend's house" to wait out the storm. Finally, one married male respondent, aged 45-59 with a high school diploma and an income of $100,000-$149,000 summarized his actions with "Put up shutters [on his owned condominium], put the pets in the car and left." One respondent evacuated with loved ones, one couple was willing to travel apart, and one respondent went to a friend's house to be with another during the storm.

Though evacuation response cannot be tied to one or more demographic attributes based on the data set, overall only about half of the respondents who made trips evacuated. However, according to *The Key West Citizen*, "only about 20 percent of the residents fled" (O'Hara 2005). The assumption that people stay or leave voluntarily is incorrect because some residents must either stay or leave based on their jobs. According to three respondents, there was no choice, but to stay behind, while two other respondents reported that their jobs required them to leave the area. Military personnel had to evacuate. The Naval Air Station Key West was closed at noon on Saturday [October 22, 2005], and "all families living in government housing were ordered to evacuate" (Bolen 2005).

- *As a military member, my wife and I were directed to evacuate base housing by 6:00 PM on Thursday [October 20, 2005]. We departed that day and drove directly to our designated safe haven location at Cocoa Beach, Florida. We remained there for 8 days. [This respondent was 45-59 years old, with a graduate degree and income of $100,000-*

$149,000. He rented his military housing, and had no children or caretaker responsibilities.]

- *I'm on the watch floor, so my team evacuates 64 hours from landfall in order to fall in on the "evac" watch floor in Orlando. Our last team departs 48 hours from landfall. It's going to take me awhile to get off the keys.*

In contrast, some respondents could not evacuate either because their jobs mandated they stay, or because there were economic opportunities to staying. Store owners, for example, stayed open as long as possible so that residents could prepare for the storm. Unfortunately, this also meant that store employees did not get time off ahead of the storm to prepare themselves. In spite of the good intentions, one grocery store employee noted that "most people walked past the storm display, aiming for the beer and wine" (Bolen 2005). One respondent wrote that some county officials must stay behind.

- *Since I've worked for the Key West Fire Department since 1983, I've not been able to evacuate. Also, my wife works for Monroe County School District. She's not evacuated since school attempts to re-open as soon as possible after an event.*

- *I cannot evacuate since my job is to facilitate the evacuation of all Special Needs Clients and facilitate their return to the keys after the ""all clear"" is given.[This single female respondent aged 25-44 had children, had a 2-year degree with an income of $25,000-$49,000. She owned her single family home.]*

- *I am the Emergency Coordinating Officer for all the courts in the Florida Keys. I'm probably not the best person to take your survey, because my position requires that I remain in the Keys during all hurricanes. I, however have lived along the coast of Texas, Louisiana and now Florida for 14 years, so I have seen my share of hurricanes and evacuated from many of them in the past.*

- *Most people don't know that irregardless of the emergency, a judge has to remain on duty 24/7 to handle first appearances by anyone charged with a crime. People accused of committing felonies have to be brought before a judge in this county within 24-48 hours, or they have to be released, no matter how serious the charge. Therefore the courts have to leave one judge, and a few support people on site even when the majority of the county is evacuating.*

Some families had previous hurricane experience and based their choice of evacuation or waiting out the storm on past history or the experience of people who had already witnessed a hurricane. According to *The Key West Citizen* one resident refused to leave because he wanted to "avoid all the confusion that [would] come with an evacuation on the mainland, and I think it's safer to stay home. We've had our hurricane supplies all season" (Bolen 2005). Hurricane experience could be passed down from generation to generation creating a family history where evacuation is considered unnecessary. Years of family experience could also help the younger generation understand the process of hurricane preparation. Respondent comments indicate that previous experience provided a rationale for staying behind based on the knowledge gained of post-hurricane trials. This knowledge included the expense of evacuation, and the difficulty of gaining permission to return home.

- *My family has been in Key West for five generations and two before that in the Bahamas. We as a rule do not evacuate. We do however, from family history and experience, know to have enough supplies to last around two weeks. We also plan to not expect assistance for some time. We as well recommend to friends who can't handle that sort of preparation and the duress after the storm to follow the evacuation advice from our city and county. [This respondent was a 25-44 year old single male with a graduate degree and an income of $50,000-$99,000. He owned his single family home and had no children or caretaker responsibilities.]*

- *Here in Key West storm tracking is so unpredictable. To leave for a hurricane, it has got to be a very large, looming and menacing one. Otherwise, ride it out. It is very expensive to stay in town, as no one is working or making money, but it is even more expensive to leave and spend money elsewhere on top of it. The two times we did evacuate, we found the storm heading in the direction to where we went. As we saw after Wilma, Miami-where most people evacuated to-was chaos. Happier to have stayed home and dealt with the flood aftermath.*

- *My husband and I did not evacuate for Wilma, but we did evacuate for Hurricane George in 1998. I didn't work for the courts then. Because only about half the people left the county there wasn't much traffic when we left, but coming back in was terrible. Law Enforcement was at the top of the Keys blocking the highway, and they were selecting the people that could get back in based on where they lived and how much damage had been done to their area. We sat at that road block for over 12 hours before we were allowed*

to return to our home. Our home was built on stilts and was OK, but we lost everything stored underneath.

- *What you need to know is that most people here do not go when ordered to go because history shows that it's pretty stupid to try to driver 150 miles to a shelter. Those who left here before Andrew drove right into it. A couple of years ago, when Miami was also ordered to evacuate the highways in South Florida became a parking lot. Many from Key West turned around and come back because it was safer there. Every hurricane I have experience here during the past 15 years have been just wind and rain storms. The power goes off, but buildings are not blown down. People don't die. It's just terribly inconvenient. Most of the people who leave don't leave because they are afraid; most of those who leave are government employees who get paid while they're gone and this is a good opportunity to visit Aunt Mary up in Georgia or affluent retirees who flit off to their second home up North. We also have a big military presence here and they are automatically evacuated by air.*

- *After helping some friends close up their homes for the hurricane, we returned to our home to finish closing up and to ride out the storm. Everyone in our neighborhood stayed, so there was a lot of last-minute preparations Sunday evening, but everyone basically shut their homes and waited until it was over.[This respondent was a single female aged 18-24 with no children or caretaker responsibilities. She had a bachelor's degree with an income of $100,000-$149,000, and she owned her single family home.]*

- *I have lived in Key West for seven years and have never evacuated. When I first moved here, I was told that common wisdom was never to evacuate because the County emergency managers call for evacuations so frivolously that if you evacuated every time they ordered an evacuation, you would spend more time off the Keys than on during hurricane season. Clearly an exaggeration, but telling of the mind set of residents. Additionally, the re-entry process is so clogged that if you evacuate even if there is no significant hurricane impact, you are likely to spend days trying to get back home.*

- *During Hurricane George, by the time we got all the "stuff" up from the ground level part of the house it was too late to evacuate. Truth be known, my husband would have sent me and the kids up the road if I felt the need to run and stayed with the house anyway (castle protecting), but we stayed and it was not something I ever want to experience again. I lost my husband about four years ago and have made the run when the evacuation order is given. I have two children and until this May, a large dog and we caravanned out, my son towing his boat, daughter and dog with me and went either to a hotel with a group of friends or to other friends on the main land. The plan varied with the projected path of the storm.*

Some residents were simply tired of evacuating the city. Hurricane Wilma was the fourth mandatory evacuation called for that season. Emergency managers had cried "Wolf" too

many times. Interestingly, a number of businesses stayed open to accommodate residents who stayed behind. In fact, "some Key West business owners, tired of losing money and waiting for bad weather created their own entertainment . . . and planned an old-fashioned pub crawl on Duval Street . . . starting at Hog's Breath Saloon and ending . . . at Atlantic Shores Resort" (Citizen Staff 2005). The Video to Go shop also stayed open as "customers were stocking up on movies to watch" (Bolen 2005). One respondent wrote "A certain percentage of the population [of Key West] will not leave." Another issue was Fantasy Fest. This festival was one of the city's biggest street parties and the most profitable. Apparently the storm was upgraded to a Category 3 rather quickly. As a result, a number of residents did not get the chance to evacuate. In fact, the "forecast guidance models used by the National Hurricane Center 'completely collapsed' on Wednesday" (October 19, 2005)(Iannotta 2005). Some residents moved to higher ground within the city to wait out the storm, and some residents simply chose not to evacuate.

- *We did not evacuate for Wilma. Because of the long "Wait" we had prior to the storms arrival, we vacillated between going and staying and eventually decided to stay. While waiting we made many trips to restaurants (that were still open), bars, grocery stores, friends homes, etc. Key West is a small island, so no trip is more than 7-8 miles round trip. We waited out the storm in our home. We had two different flooding occurrences, one while we were asleep and that one was minimal, and the second in the morning (around 6 – 8 am) and that was not so minimal, although we were very lucky compared to most on the island. [This respondent was a married female aged 18-24 with a bachelor's degree and an income of $50,000-$99,000. She had no children or caretaker responsibilities, and lived in her owned single family home.]*

- *Personally, my wife and I have gone through countless hurricanes . . . in 2004 and 2005, my wife and kids probably evacuated at least six times. I stayed probably two to three times, when they evacuated. By the time Wilma was here, we were tired of evacuating and it was originally projected to be a Category 1 storm. My house and business were flooded. Post Wilma, I anticipate that more locals and/or "Conchs" will evacuate. Most of the families I know, the wives and kids leave early. Some residents simply chose to stay in the city.*

- *I have no evacuation experience. I have not left for a storm yet. . . I only knew one person that evacuated for that storm [Hurricane Wilma]. The previous storms sent a lot of*

people scattering, but Fantasy Fest was coming at the end of October. . . One thing to remember about the evacuation before Wilma is that it was right before Fantasy Fest which is our island's biggest income event. We were informed by various news media that it was only going to be a category one. Most people stayed based on this information and the fact that they wanted to get things cleaned up as soon as possible so that Fantasy Fest could go on as scheduled. By the time we knew it was growing so dramatically, it was too late to leave. The overseas highway is the last place you want to be stuck when the high winds start.

- *The evacuation rate was very low for Wilma. I personally know of no one that evacuated. I believe this was for 2 reasons. The first is that it was a busy year with mis-forecasts and false alarms. The other is that the way it came around was a bit different and many felt that by the time they know to evacuate they would get caught up in it. Our church stays pretty tight knit during these things and I think everyone stayed because we were all checking up on each other afterwards.*

- *We have not had a Category 3-5 storm hit the Florida Keys since I have lived here, but most of the Category 2 storms are considered a "3" by our County Emergency Management people, because it takes too long to evacuate our county, if or when a "2" changes to a "3" in a matter of hours. We have a real problem getting all of our people to evacuate the Keys. Many want to stay and we consider it quite an accomplishment if 50% of the people leave the county. That might change if or when we have a Category 3-5 storm aiming right at us.*

- *I personally know no one in Key West who has ever evacuated, and the commonly held number of residents who do evacuate is less than 15%.*

- *Left home to stay at local guest house at a higher elevation. Our home is very low in elevation. With the expected storm surge this was the first time we left our home. [This respondent was a cohabitating female aged 25-44 with a 2-year college degree and an income of $100,000-$149,000. She had no children or caretaker responsibilities, and lived in her owned single family home.]*

- *Moved from Frances St. to Atlantic Blvd. location. Two trips. To friend's house at Atlantic/Thompson for dinner, then back home to the condo at Atlantic to wait out the storm.[This respondent was a single male 25-44 years old with a bachelor's degree and an income of $200,000 or more. He had no children or caretaker responsibilities, and owned his condominium.]*

- *From my experience, those who don't leave are have their minds made up that they're not leaving under any circumstances. The reasons they have for staying include "protecting the castle" or underestimating the potential of the storm. There are some who have no transportation, but that has been addressed by the county and busses pick up anybody and run them to shelters on the mainland.*

Some city residents simply chose not to evacuate. These people could have been concerned about protecting their property, or themselves. Others choose to evacuate because it was the "right" thing to do. One respondent wrote that a visitor was coming and that because of the mandatory evacuation, travel plans had to be changed to accommodate the hurricane. A few used the hurricane as an excuse to go somewhere for a vacation, and some had evacuated so often that the hurricane event was not very traumatic – A practice makes perfect approach.

- *Wife and I left taking our two cars. Roads were clear, mostly empty of traffic in lower and middle Keys with some moderate congestion in the upper keys (MM 78 - 88). We watched the eye of Wilma pass over us in Fort Lauderdale the next day, which killed all power and services in Broward County for weeks. [This respondent was a married male, aged 45-59, who had a graduate degree and earned $150,000-$199,000 per year. He had no children or caretaker responsibilities and owned his condominium or apartment.]*

- *I had a visitor coming from abroad who wanted to take her vacation with us in Key West. Arrival should have been exact on THAT day (19th October 2005), but they don't let her fly down anymore from Miami to Key West, so we had to rent a car and go to pick her up in a Miami Hotel and so, we used this Hurricane time to go with her around in Florida and to show her our sunshine state. It was an unexpected and very expensive trip. When we came back, everything was under water up to the hips, furniture floating around and our car filled with all our art work was filled with water up to the windows and all our masterpieces were gone!!! My visitor was shocked, she had never seen something like that before! This is our story! [This respondent was a married female, 45-59 years old with less than a high school education and an income of less than $24,000. She had no children or caretaker responsibilities and rented her single family home.]*

- *We, my partner and I, knew Wilma was going to hit Key West or at least very close so we got tickets to stay with friends in New York and wait out the storm. A little vacation sounded nice. [This respondent was a cohabitating male, 18-24 years old with a high school education and an income of $100,000-$149,000. He had no children or caretaker responsibilities and rented his condominium or apartment.]*

- *This is an issue dear to my heart. I evacuated four times in two years and have it down. It takes me four hours total. The last time I had time to break it down to two evenings of two hours each. Closed the house, cleared the refrigerator and freezer, packed the cooler and loaded the dog and we were on the road the next morning.*

- *My wife leaves with the two kids, dog, godmother and sometimes mother during the mandatory evacuation. If I leave it's late and traffic has never been an issue. After living in the Keys for 14 years, I have never experienced lengthy delays in evacuating.*

- *The only trouble I had was in trying to get gas on Thursday. [I had to go to the] shell station on 1st and N. Roosevelt because my usual was closed and I got stuck in a mess at the station so I got out and went to White St. and N. Roosevelt, the biggest intersection to the south of my home. Getting out was a breeze the next morning very early. [This respondent was a divorced female aged 60-74 with a bachelor's degree and an income of $25,000-$49,000. She had no children or caretaker responsibilities, and rented her condominium or apartment.]*

None of the survey respondents mentioned traffic laden roadways. In fact, all wrote about how easy it was to travel around or through the city. An article in *The Key West Citizen* reported that the "roads were mainly empty as of noon Saturday . . . Traffic is light and it's moving; we don't see any backups" (Bolen 2005). Noon Saturday, October 22, 2005 was the time and date for all Key West residents to evacuate. This countermanded the strong assumption that roadways become congested during a mandatory evacuation. However, traffic jams in other parts of Florida effected whether or not people evacuated Key West. One respondent wrote that "After seeing the huge lines of backed up traffic in Florida City on the TV, I am sure everyone still here said 'I'm glad I didn't go' and, unfortunately, that may cause many to not evacuate next time." Another respondent provided information on how to calculate the points along U.S. Highway #1 where congestion would occur.

- *Traffic was not heavy at all within the city of Key West after the evacuation orders were issued. The city cleared out and all was quiet. The residents who stayed were out biking, walking, visiting, and talking about what was to come. It is the same every time a storm comes. There was no traffic or delays within the city once the evacuation order was issued.*

- *The only major issue during this type of evacuation is to leave after the motor-homes and large vehicles. Therefore leaving early in the morning or 6 hours after the tourists are told gives you a little more freedom to drive the speed limit. Taking food with you and drinks with you provides the opportunity to only stop for gas on the turnpike. Stopping can take 25-60 minutes depending on availability of gas. [This respondent was a married female aged 25-44 with a graduate degree and an income of $25,000-$49,000. She had no children or caretaker responsibilities, and rented base housing. This is the only respondent who provided comments within the survey that identified "other" as her race. All other respondents who provided comments with demographic information were white.]*

- *There is no congestion here after an evacuation order because the tourists have already left. This is a 2-mile by 4-mile island with probably less than 25,000 permanent residents.*

- *That sounds like an interesting study. U.S. Highway #1 will ultimately become the bottleneck in the evacuation of Key West and you can do a quick computation on how long will it take to evacuate the city --in this case, and if no reverse lanes are used, it will be (population/vehicle occupancy)/4,000 vehicles per hour (vph), since Hwy 1 is a 4-lane divided highway and each lane can roughly carry 2,000 vph in the best conditions. However, congestion may (and I think will) develop upstream of the exit point (i.e., in places where the population tries to access Hwy 1) and it would be interesting to determine what these different evacuation simulation models predict.*

According to some residents the recovery efforts were impeded by the flood waters and the littering of damaged and disabled cars throughout the area. According to *The Key West Citizen* residents "lost 30 percent of their vehicles to flooding" (O'Hara 2005). However, not all areas of the city were severely flooded. City services took a while to recover. One married male respondent, aged 45-59, who owned his single family home and had an income of $100,000-$149,000, wrote "It took 4 days for the electric company to repair the lines to my home." Luckily he had no children or caretaker responsibilities.

- *For Wilma we lost our cars due to flooding, but our home was high enough that we didn't get water inside. Eighty percent of the cars in Key West were lost due to flooding. Waters reached at-least four feet over most of the lower Keys from Marathon on down.*

- *In the case of Wilma it seemed that nearly every car in the lower Keys was flooded. This was an unexpected twist by most of us who live here because in the 14 years I lived here the whole place never flooded. There was only minimal flooding with Georges which was my first significant storm. I heard one estimate that 15,000 cars were destroyed, but have no idea how accurate that is. Our local paper, the Key West Citizen, stated that "Flooded cars litter the Keys" on October 27. Obviously this makes post-event recovery a much more daunting task. These cars were often floated and many were in the middle of the streets when the water receded making it an enormous obstacle course for emergency services to get to those in need. It also makes it impossible for many to get any of the things they need on their own as well, even after the stores or emergency stations are opened.*

- *My family was in Maryland on vacation. My husband left early to go home to prepare for the storm. We followed and stayed in North Carolina until the coast was clear to come*

home. I drove both kids through the areas at the top of the Keys that we all knew so well not recognizing anything. Military all around, tents, etc. It was a nightmare.

- *Wilma was a real threat only due to its expected storm surge. Wind was not predicted, nor was is, severe. Personally, I live in a solid building well within the "X zone" where flooding has never happened, even with Wilma. Wilma itself passed well away from Key West and my neighborhood was not significantly threatened, very few evacuated, and there was absolutely no damage to any structure that was in good condition. Only a few roofs on poorly maintained nearby houses were slightly damaged; no worse than a typical thunderstorm in the Dallas, Texas area.*

Three respondents wrote comments about issues not related directly to the reasons why they stayed behind or evacuated. One respondent wrote about how changes in the estimated evacuation time would impact development in Key West. Another respondent mentioned Key West had no hurricane shelters, and another respondent commented on the number of things a resident needs to do before evacuating the city. According to an article in *The Key West Citizen* no shelters were open in the Keys (Bolen 2005).

- *Evacuation times have a direct effect on our building permits from the state, meaning developers and politicians are always trying to shave off the hours so they can build more condos. It's quite the heated debate!*

- *Sadly, in a category 4 or 5 storm there are no shelters open here in the Keys and I think, personally, that while it may encourage a small number to not evacuate, the benefits to those too hard-headed to leave far outweigh the added risks to the few who stay because of it.*

- *People do not evacuate when first asked to do so. Things that slow them down, picking up or tying down the stuff in their yards, boats, trailers, etc. and putting up the shutters. This is changing. The public housing projects no longer allow outdoor "stuff" by their residents, no grills, etc. and shutters are getting better in that more people have them, and they are easier to install. Less plywood, more accordions even in public housing.*

Finally, some insight as to why the bulk of respondents did not report any trips was identified based on some of the survey comments. "So hard to quantify all of those trips"; "Gosh can you remember the different "trips" you made on a certain date two years ago, even if it was punctuated by a big weather event?!"; "It is hard to remember the details at this point, I hope this

was helpful but we had so many storms and dealing with the problems from the storms causes people to forget the details of time," and "As far as the number of trips post evacuation notice, that is hard to remember (due to the number of recent hurricanes), but also many locals have numerous properties, vehicles and boats, and everyone is scrambling to secure everything." One respondent commented that he hoped the information gained by this research would not used to alter any of the evacuation models.

I certainly hope nobody adopts a model which factors in side or prep trips as it will only serve to cause the emergency management folks to trip the trigger unnecessarily even earlier than they do now. As a non-evacuating resident, I don't care much. As a business person, who see the Keys economy dry up for four or six or eight days when an evacuation is ordered and the tourists go home or stay away and nothing happens weather wise, I care a whole bunch.

Hurricane evacuation behavior is messy business; there was no "one" type of resident in Key West that evacuated for Hurricane Wilma, nor was there another type that remained behind. One respondent summed this ambiguity perfectly when he wrote:

Key West may be unique in the way we react to hurricanes. Most ignore evacuation orders because we know that evacuating may be more dangerous than staying. We prepare for the storm, or course, but as far as "Trips" after an evacuation order is concerned, it's usually business as usual until the storm is here and then we hunker down in a safe place until it's time to deal with the "After." Wilma, the storm, was not any worse than dozens of storms that have swept through here in recent years. What made it seem worse was the flooding. Many people lost cars and suffered damage to their homes, but nobody died.

Respondent commentary offered an enriched view of what happened during the evacuation for Hurricane Wilma. This aspect of the research was successful in documenting the multidimensionality of what respondents thought and did when the mandatory evacuation order was given. Respondents identified the fact that not all residents were allowed to evacuate, such as fire department personnel, emergency coordinators, and other facilitators, while military personnel and their families were ordered to evacuate in spite of any misgivings they may have had. Other respondents reported that previous experience was the determining factor in deciding

to evacuate or not. The respondents who did not evacuate had supplies at home, and the support of neighbors who stayed behind. Other respondents had previous experience and did not have confidence in the storm tracking and knew that the re-entry process into town was extremely difficult. One respondent had experienced a hurricane with devastating results, and evacuated by caravanning with her family. A few respondents left to take a mini-vacation while the storm traveled toward Key West. For the respondents who did evacuate by car, they reported that the roadways were not congested, and only one respondent reported that gasoline was difficult to obtain. However, many more respondents simply did not evacuate because they were tired of evacuating. Hurricane Wilma was the fourth mandatory evacuation issued in 2005. A few respondents traveled to homes on higher ground within city limits for protection, but did not evacuate. These comments illuminated the actuality of Key West resident response to the evacuation order for Hurricane Wilma.

Summary

Chapter 4 has analyzed the data to determine if demographic and other characteristics were associated with evacuation behavior. The Chi-square statistical test indicated that there was a non-random relationship between evacuation behavior and homeownership, and evacuation and the number of pre-evacuation trips made. Binary logistical regression indicated that homeownership and income were predictors of evacuation behavior for those making pre-evacuation trips. The literature review indicated that socio-demographic characteristics could be associated with specific evacuation behaviors; the sample for this study, however, indicated this to be true for only two characteristics. Pre-evacuation trips were then studied. Two interesting findings were discovered. First, respondents do not necessarily travel toward an exit point, but

instead may travel back and forth from an exit point toward the city. Second, most respondents did not experience the longest delay traveling, but had the longest delay in accomplishing the trip purpose. For example, one respondent spent 20 minutes traveling to Home Depot, but then spent four hours at the store accomplishing his trip purpose. Finally, respondent stories were categorized to illustrate the complexities associated with evacuation behavior. These findings are reviewed in light of the literature on evacuation and the assumptions made in evacuation modeling, and have implications for future evacuation models and policy. This is the focus of the next chapter.

Chapter 5: Conclusions and Future Research

This dissertation presents an empirical study of pre-evacuation trip making behavior. Based on statistical analysis of demographic and socio-economic variables, the inspection of pre-evacuation trip origins and destinations, and a review of personal stories, several key conclusions can be drawn.

1. Socio-demographic variables, which in previous research have been found to have some association with whether a person evacuates or stays, were found to have no association or very weak association with whether a person does or does not engage in pre-evacuation trip making. Though there was no statistically significant Chi-square calculated for respondents who made pre-evacuation trips and those who did not, there were two statistically significant Chi-squares calculated for respondents who evacuated or waited out the storm. These significant Chi-squares indicated a non-random relationship with homeownership and the number of trips made; however, these relationships were weak. The association between evacuation behavior and homeownership was supported by Mei's research, which indicated that a smaller percentage of homeowners than renters evacuated for Hurricane Andrew (2002). The relationship between evacuation behavior and the number of trips made constituted a new finding as there were no readily available studies researching this particular variable.

2. When considering only those who engage in pre-evacuation trip making, two socio-demographic variables are associated in predicting if one evacuates or stays after making pre-evacuation trips. Binary logistic regression was used to test the variables for their ability to predict pre-evacuation trip behavior. Once again, no statistically significant results were calculated for those who reported making pre-evacuation trips and respondents who did not. The

binary logistic regression statistic did, however, find a significant relationship between respondents who evacuated and homeownership and income. In this case, respondents who rented and those earning $100,000 or more increased the probability of evacuating rather than waiting out the storm. This result is directly supported by Mei's finding regarding evacuation and homeownership (2002). The association between evacuation behavior and income was also supported by the existing literature. According to Howell (2006), almost 55% of the households with an income over $80,000 evacuated for Hurricane Georges. The positive link between income level and evacuation for Hurricane Bonnie was also supported by Smith (1999) whose research indicated that evacuations increase as income increases.

3. The main component of pre-evacuation trip delays is delays at stops, not along links. This runs counter to evacuation models, discussed below, that focus on route congestion. According to the research for the respondents living in Key West, the delay for completing a trip purpose could be up to six times longer than the travel time from origin to destination. For example, the average travel time from origin to destination for the first trip was about 16.5 minutes, but the average delay associated with completing an activity was 44 minutes. For the second trip, the average travel time was about 25 minutes with the trip purpose delay of 44 minutes; however, for respondents who made a third trip, the travel time was approximately 10 minutes long with a trip purpose delay of one hour. Though some evacuation models can impose evacuation delay based on a category of agents, the models do not take into account the delay caused by trip purpose. Based on this research, most delays were caused by completing tasks at destinations.

4. Related to the previous finding, trip delays are associated with completing tasks at stops. This, too, runs counter to evacuation models that only allow one trip purpose—to evacuate

the area. Respondents answered two categories for trip purpose most frequently: To travel to work or other. Forty-two of the respondents reported making trips to complete "Other" tasks; these included returning DVDs to a store, attending an AA meeting and golfing. Of the 81 respondents who made pre-evacuation trips, only 15 evacuated in their first trip.

5. The spatial pattern of pre-evacuation trips did not reflect an orderly or single spatial orientation toward evacuation points. A number of pre-evacuation trips made by both residents who evacuated and those who did not displayed movements away from the evacuation routes. Interesting traffic flow pattern began to emerge after the first trip where it becomes clear that destination points flow both into and out of the city. By the second trip, seven of the 32 respondents traveled away from the evacuation destination at U.S. Highway #1 and toward the center of town. By the third trip, more than half of the respondents traveled toward the city, indicating that evacuation is not an orderly procession of agents traveling toward evacuation destinations, but a mix of incoming and outgoing traffic flows.

6. The Key West mandatory evacuation for Hurricane Wilma consisted of a phased evacuation based on housing types. Residents living in recreational vehicles were asked to evacuate by noon on October 19, 2005; mobile home dwellers were asked to evacuate before dawn on October 22, 2005, and those who lived in any other type of home (single family, apartment, condominium, etc.) were asked to evacuate by noon of the same day. The Key West data did not reflect a staged evacuation. By October 19, three apartment dwellers, and nine single family home dwellers had evacuated, but only one of the four recreational vehicle dwellers had left. All respondents who lived in any other type home evacuated before or on October 22, but not all by the noon deadline. Of those who did evacuate for the hurricane, many

did not participate in the phased evacuation process, but left when convenient for them. Evacuation models do not reflect this real, but disorganized evacuation progression.

7. The personal stories offered by respondents indicate that not evacuating is often related to job requirements, economic opportunity, previous evacuation experience, and evacuation "burnout." For example, one judge must remain in the city to handle within 24 hours first appearances by people charged with any crime. On the other hand, military personnel and their families are required to evacuate. Navy personnel must take their ships out to sea to protect them, and their families are required to report to another naval station in the state. Store owners try to stay open as long as possible, even through the mandatory evacuation, in order to make as much money as possible before residents and visitors leave the city and to accommodate pre-evacuation trip makers. Some respondents who cited previous experience with mandatory evacuations did not leave because they had a family history of waiting out the storm or were more afraid of being caught unprotected along U.S. Highway #1 in the middle of a mis-projected hurricane than staying behind in their homes. Finally, some residents did not evacuate because the Hurricane Wilma evacuation represented the fourth time they were told to leave the city without any hurricane making landfall; they were simply tired of evacuating.

Of the major findings, points 3 through 6 have direct implications for modeling evacuation behavior. To assess the current state-of-the-art in such models, and to indicate if they currently have the capability to incorporate the empirical findings of this dissertation, a brief review of evacuation models is presented.

Implications for Evacuation Modeling

The evacuation models used to calculate ETEs do not inherently include an option to incorporate various pre-evacuation trips and time delays into the ETE calculation. The models also do not provide options for traveling toward an evacuation zone and pausing to complete a trip. The focus of these models is on delays associated with congested links, not on delays associated with stops and trip purpose. Evacuation models assume that residents evacuate directly from origin to exit point at a particular time and, though there may be delays based on link congestion, the evacuees are not assumed to make other trips. One of the reasons that models do not accurately reflect pre-evacuation trip delays may be that pre-evacuation trip data is not readily available; another reason may be that the calculation of ETE becomes more complex and computationally demanding when the delays associated with trip purpose are incorporated. Furthermore, evacuation models inherently assume that evacuees always choose the shortest travel path from origin to destination.

The limitations of some of the evacuation models are reviewed to understand more fully their model inputs and to determine if those models can be extended to incorporate pre-evacuation trips and delays. The models reviewed for this study include nuclear evacuation models as well as hurricane evacuation models. This provides a basis for further research into the extension of model attributes to allow for the incorporation of pre-evacuation trips and delays made before evacuating an area or returning home to wait out the storm.

In order to understand evacuation models, a quick review is provided. One method for depicting evacuation scenarios is through simulation (Axelrod 1997). Simulation models incorporate the actions of agents, which can either represent a single element (one vehicle) or an aggregated number of elements (more than one vehicle). The traffic movements on the road

network are simulated through a series of behavior rules linked with each agent's attributes (Axtell 2000). Unfortunately, current evacuation models limit the types of behavior each agent can reflect. For example, some models allow for agents to be categorized, and then each category is allowed to evacuate at different times to reflect a staged evacuation. However, the number of categories identified is limited, and each agent is assumed to act in the same way. None of the agents can stop mid-way in the evacuation process, for example, to perform a trip purpose as was the case with many of the Key West residents who had been ordered to evacuate from Hurricane Wilma in 2005.

Some models can assign each agent a route, a speed, and the probability of a vehicular break-down. Each agent then moves in the traffic stream with one car following another in an orderly fashion (Mei 2002). In disaggregate models, the large numbers of agents make the processing of each evacuation computationally demanding and time-consuming (Pidd 1993). This problem can be addressed through advances in computer hardware and software, and in the use of high performance computing clusters. On the other hand, in aggregated models, individual agents are not represented, and traffic flow is composed of each agent representing a platoon of vehicles where movement is guided through speed, flow and density (Mei 2002). This prohibits the simulation of individual agent delay based on trip purpose, where one vehicle leaves at a different time to travel to a location and then waits for the trip purpose to be completed. As a result, the resulting ETE values in aggregated models are more unreliable than in disaggregated models (Chen 2006). This is also because in the aggregate approach, when each aggregated agent passes an exit point it is assumed that two, three, four or even more vehicles pass that exit point at exactly the same time; a phenomenon that does not occur.

In addition to the disaggregate and aggregate differences in models, evacuation models can be differentiated based on those that use dynamic versus static road network assignment. In the dynamic models, road demand changes at each time interval. This allows the agents entering the network to chose a link to the exit point based on updated travel times and congestion. However, these models assume that agents always choose a different path when congestion occurs, and will take the shortest path to travel to the nearest exit point. Agents are also assumed to have perfect knowledge of the road network, which is unlikely to occur during an evacuation. On the other hand, static assignment models assume that road capacity is constant. Agents do not change routes nor are they affected by other agents (Wilmot 2004).

In order to gain a fuller understanding of evacuation models with regards to conducting future research, a few of the currently used hurricane and nuclear evacuation models were reviewed. The purpose was to gather information regarding the specific inputs of these models to evaluate the limitations each model has with regards to integrating pre-evacuation trips in the calculation of the ETE.

Though the WITNESS evacuation model provides evacuation times that take into account delays based on either bi-directional or unidirectional traffic flows, evacuation times are calculated on the accident rate, and evacuation start time (Farahmand 1997). Evacuation times are based on the aggregated agents being assigned as a "resident" or "tourist." Only two different start times are allowed based on category designation. Additional categories would allow for many more groups to be represented. Different links on the road network are assigned different road capacities, and there are three road types: primary, secondary, and other. As the model is run, demand decreases as road capacity is met (Farahmand 1997). However, no agent category allows for delay based on trip purpose or allows an agent to travel toward the

evacuation zone. Agents that do not participate in evacuation are assumed to remain stationary and do not make any trips. Furthermore, WITNESS results have been known to calculate that higher demand, delays and late evacuees do not affect ETEs when 100% of residents are evacuated (Farahmand 1997).

Unlike WITNESS, the Configurable Emergency Management and Planning System (CEMPS) model, which was developed by faculty at the Department of Management Science at Lancaster University, so that emergency planners could experiment with different emergency evacuation plans, allows for multiple evacuation destinations to be created, and the geographic region is divided in zones, which dictate the phasing of the evacuation (Pidd 1993). Link choice is based on link capacity (Alsnih 2004), which also assumes perfect knowledge of the network. Evacuation times incorporate not only population evacuation, but the time needed to get relief vehicles into the affected area. The model can include delays and congestion based vehicle break down, and re-routing based on link capacity (Pidd 1993). However, the model assumes that all agents that are activated at the beginning of the evacuation are constantly active throughout the calculation of the ETE. No agents are allowed to "wait" in order to simulate the time it takes to complete a trip task, and no vehicles are allowed to travel and then stop without evacuating in order to mimic an evacuee making an inner city pre-evacuation trip (Pidd 1993).

The Network Emergency Evacuation Model (NETVAC), created by researchers from the Massachusetts Institute of Technology to model evacuation from areas in the vicinity of nuclear power plants following the Three Mile Island accident in 1979, uses a GIS platform to display the movement of vehicles, and estimate network clearance times. Agents can replicate behaviors of three different categories: resident, transient and special facility populations. These evacuees are assigned to the evacuation network at varying times based on a particular category (Earth

Tech 2006). Each of the three categories is given attributes pertaining to evacuation notification; preparation and mobilization times. Different traffic flows are simulated based on road type (rural, residential, or city) and each road type is assigned a lane width, speed limit and traffic control device (stop sign, signal light, etc.) (Earth Tech 2006). Each agent's route choice is determined at each node based on the shortest path to the exit point and link congestion. When run in the normal mode, the model assumes that agents have delays based on existing traffic control devices. When in the override mode, the model does not. However, the model will only calculate the time needed for 100% evacuation. The model does not incorporate the concept that some residents will made trips without evacuating, nor does the model allow for delays at nodes in order to simulate trip purpose completion times. In addition, the model has some inherent difficulty in calculating accurate evacuation times for hurricane evacuation because it moves agents away from one single point of danger (Stopher 2006), and though the model can track from a single origin point to a single destination point, the model cannot track multiple origins to multiple destinations (Southworth 1991).

Finally, the Oak Ridge Evacuation Modeling System (OREMS) is a disaggregate model that simulates traffic demand, response and flow in a staged evacuation. The geographic region is divided into three types of evacuation zones: Immediate Response Zone, which is the area closest to the disaster; Protective Action Zone, which is an area slightly farther away, and the Precautionary Zone, which is the area where no adverse effect can be expected. Links represent unidirectional roadways, which do not allow for the agents to backtrack or travel away from the exit node using the same link; however, parallel unidirectional links can be incorporated to represent roadways leading away from the exit. Nodes represent entry or exit points along the network. Unlike the other models, entry into the network can take place at either links or nodes.

Characteristics are assigned to each link and node, including road capacity and traffic controls. Agents are assigned entry onto a link or node, at each node turn percentages forces agents onto certain links, and road closures and signal timings add evacuation delay. Evacuation start delays are based on household characteristics, the time-of-day, and the evacuee's location (Franzese 2003). The assumption for this model and the others is that evacuation will take place using personal vehicles, as none of the models consider public transit. OREMS also assumes the agent chooses the shortest route to evacuate (Franzese 2003).

Overall the evacuation models now used to calculate ETEs lack the ability to fully integrate the delays in the start of an evacuation, the unique travel patterns of different agents based on numerous characteristics, the time it takes to travel back and forth along the network, not necessarily toward the evacuation exit, and the delays associated with performing a task. Nodes that act as the loading points in an evacuation model do not allow agents to enter and then exit at varied rates.

This research demonstrates that ETE behavior is both impotent and complex, but should be incorporated into some of these evacuation models to improve their accuracy. My empirical research is just a start for further research into extending our existing models to incorporate pre-evacuation trips for those who do evacuate and those who do not or creating new models that do so to reflect more accurate traffic congestion and delays in evacuation.

Concluding Remarks

Events of recent years, and in particular the plight of the Gulf Coast during Hurricane Katrina, have made it clear that a fuller understanding of human responses to evacuation orders is needed. While their have been advances in agent-based evacuation models (e.g., Axlerod,

1997; Ben-Akiva et al. 1998; Chen, 2008; Chen and Zhan, 2008; Cova and Johnson, 2002), this dissertation is, I believe, the first empirically based study of pre-evacuation trip making behavior. The findings listed at the beginning of this chapter have implications for evacuation planners, evacuation modelers, and social scientists wanting to better understand how individuals and communities will react to impending natural disasters. This research offers insights into how the respondents from Key West, Florida, reacted to the evacuation orders for Hurricane Wilma. It remains to be seen if these results can be replicated in other areas, and if the findings here can lead to more realistic models of the evacuation process.

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Appendices

Appendix One: Online Survey Questionnaire

Welcome to the Key West Evacuation Survey
*This is the main page of www.keywestevacuation.com

Thank you for your interest in this study! My name is Melany Noltenius, and the purpose of my project is to understand more about the trips taken after a mandatory evacuation order has been issued.

By answering questions about the trips you took after the mandatory evacuation was ordered for Hurricane Wilma, you will help me in determining evacuation delays associated with these trips.

Currently, evacuation models are used to calculate the time it takes for residents to leave an area. Unfortunately, these models do not include the time it takes for residents to make trips before leaving an area or going back home or to a shelter, etc.

Participation will help me apply these trip delays to an evacuation model to calculate a more realistic evacuation time.

You will also be helping me to fulfill one of the requirements to earn a Ph.D. degree in Geography, with a major in Transportation and Geographic Information Science (GIS) from the University of Tennessee, Knoxville.

If at all possible, please invite other people to respond to the survey. Just forward the www.keywestevacuation.com website link to friends and family. Please choose one person per household to answer the survey; I only need one response per household.
For more information about the study, click here.

Thank You!

Start Survey

Information about the Study
*Information found using "click here".

I want to thank you for your help in filling out this survey.

I am studying evacuation modeling and the methods used to determine clearance time for residents of a city. In my review of current models, I noticed that clearance times do not include the delays associated with pre-evacuation trips.

The models calculate evacuation times with the underlying assumption that 1) all residents evacuate (none return home or go to a shelter), and 2) no one makes trips before evacuating. This provides an under-calculation of evacuation times, which are used to determine when to issue a mandatory evacuation order.

One example of a severe miscalculation includes New Orleans, where Mayor Nagin issued a mandatory evacuation order only 20 hours before Katrina hit.

I will use the survey information to study trips made after a mandatory evacuation order has been issued. I chose the city of Key West because city residents have first hand experience and knowledge about trips made after the mandatory evacuation order was issued for Hurricane Wilma.

By submitting responses, you are indicating your consent to participate.
Survey requires approximately 20 minutes to complete.
Should you receive multiple invitations, ***please complete the survey only once.***

Risks

There are no known risks. Your identity will remain anonymous. Please do **NOT** submit your name, contact information or email address in any blanks found in the survey.

Benefits

By participating, you will be contributing to a body of knowledge focused on the issuing of a mandatory evacuation order. The time to declare a mandatory evacuation is based upon the approximation of hurricane landfall/storm surge and the estimated time for evacuation (ETE). Evacuation models are used to determine ETE. Currently, the time it takes to make pre-evacuation trips are not calculated into the ETE, leading to its underestimation.

Confidentiality

Your responses will remain anonymous and confidential. Only this researcher and my Dissertation Committee will have access to the raw data, which does **NOT** identify respondents.

Contact

If you have questions at any time about the study or the procedures, please contact me at:
Melany Noltenius
University of Tennessee, Knoxville
Department of Geography
Burchfiel Geography Building
Room 304
Knoxville, TN 37996-0925
Email: mnolteni@utk.edu

Participation

Your participation in this study is voluntary, you may decline to participate or may withdraw from the study at any time by not proceeding further or closing down your browser.

If you agree to participate, press the "Take Survey" button below to begin.
When completing this survey online, you will need to start and finish the survey in one sitting. If you close the survey's window before finishing, your responses will be lost, requiring you to start at the beginning.

Take Survey

Online Survey Questionnaire
* This section is found by clicking either on the "Start Survey" or "Take Survey" buttons

Part One: Introduction

The purpose of this survey is to gather data about the trips you took after the mandatory evacuation order was issued for Hurricane Wilma in October 2005. In this context, trips are defined as "going from one place, an origin, to another place, a destination, using any type of transportation, including public transit and walking."

For example, if you walked or drove from your home to the grocery store before leaving the city or returning home to wait out the storm, this is considered a trip.
However, before you continue to the next part, I need to ask you two important questions:

Were you living in the City of Key West Florida on October 19, 2005?
Yes
No

Are you currently at least 18 years old?
Yes
No

Next Reset

* This section is found by responding "No" to either one of the previous questions, and clicking on the "Next" button
Thank you for your interest in this study but since you did not live in the City of Key West, Florida on October 19, 2005 and/or you are not currently at least 18 years old, you cannot continue the survey.

For more information please contact me at: Melany Noltenius at mnolteni@utk.edu

Online Survey Questionnaire
* This section is found by responding "Yes" to both previous question, and clicking on the "Next" button

Part Two: Demographic Characteristics

This part of the survey asks you demographic questions in order to associate a specific characteristic, like age or gender, with trip-making. Please answer the following to the best of your ability:

General Demographic Questions
What is your gender?
Male
Female

How old were you on October 19, 2005?
Under 18
18-24
25-44
45-59
60-74
75 and older

What was your marital status on October 19, 2005?
Single
Married Couple
Non-married Couple
Divorced
Widowed

To which racial or ethnic group do you most identify?
African-American (Non-Hispanic)
Caucasian (Non-Hispanic)
Latino or Hispanic
Other

In October 2005, did you have any child under 18 years old living at your home?
Yes
No

In October 2005, were you the care-taker for other adult relatives living in your home, such as a parent or sibling, etc.?
Yes
No

Next Reset

Online Survey Questionnaire
* This section is found by clicking on the "Next" button

Part Two: Demographic Characteristics (continued)

What is the highest degree or level of school you have completed?
Did Not Finish High School
High School Graduate or GED Recipient
Associate Degree or Trade School
Bachelor's Degree
Graduate or Professional Degree

What was your total gross household income in 2005?
Under $25,000
$25,000 - $49,999
$50,000 - $99,999
$100,000 - $149,999
$150,000 - $199,999
$200,000 and above

Which best describes the building you lived in October 2005?
Single-Family Home
Townhouse or Apartment/Condominium
Mobile Home, Recreational Vehicle or Boat
Other

If you selected "Other", please specify:

Do you own or rent?
Own
Rent

In October 2005, how many vehicles (cars, vans, pickup trucks, motorcycles, etc.) were available for use by the members of your household?

Next Reset

Online Survey Questionnaire
* This section is found by clicking on the "Next" button

Evacuation Experience:

By October 2005, how many years had you lived in the City of Key West?

Prior to October 2005, had you had hurricane experience?
Yes
No

If you selected "Yes", please specify:

How many hurricanes had you experienced?
How many times did you evacuate the area?
How many times did you wait out the storm?

Next Reset

Online Survey Questionnaire
* This section is found by clicking on the "Next" button

Did you make any trips?

This part of the survey asks if you made any trips after the mandatory evacuation was issued for Hurricane Wilma in October 2005.
Depending on your housing type, this means any trips made after:

- 12 p.m. on Wednesday, October 19, 2005 if you lived in a boat, recreational vehicle or travel trailer
- 6 a.m. on Saturday, October 22, 2005 if you lived in a mobile home or are considered a special needs resident
- 12 p.m. on Saturday, October 22, 2005 if you lived in any other type of home

If you made any trips, please continue the survey by clicking on the "Next" button.
If you **did not** make any trips after the mandatory evacuation was issued, please click here.

Next

*Information found using "click here".
Thank you for your interest in this study but since you made no pre-evacuation trips the next section will not apply.

For more information please contact me at: Melany Noltenius at mnolteni@utk.edu

Please provide any additional comments h

Submit Survey Reset

* This section is found by clicking on the "Submit Survey" button
Thank you for responding to this survey. I really appreciate your help in learning more about the evacuation of Key West, Florida.

Online Survey Questionnaire

* This section is found by clicking on the "Next" button

Part Three - Trips Made
This part of the survey asks for information regarding the specific trips you took.
Please click here for a street map of key west.

The mandatory evacuation for Hurricane Wilma was issued on October 22, 2005 to mobile home dwellers and special needs residents. Remaining residents were ordered to evacuate by noon of the same day.

Residents who lived in boats, recreational vehicles or travel trailers were issued a mandatory evacuation order three days before.

Depending on the type of household you lived in, I am interested in recording the specific trips you made:

Date of your first trip after the evacuation order was issued:
Wednesday, October 19, 2005
Thursday, October 20, 2005
Friday, October 21, 2005
Saturday, October 22, 2005
Sunday, October 23, 2005

Start Time of your first trip (Please identify Hours: Minutes and AM or PM):

Please provide the name of the nearest intersection to the Start location of your first trip (Examples include: Truman & White, College & Highway #1, etc.):

What type of transportation did you use to make this trip?
Car/Van or Truck
Bicycle or Walked
Public Transit
Other

Were you a driver or passenger?
Driver
Passenger

Number of persons in the vehicle, please include yourself:

What was the purpose of your trip (For example, if you traveled to Home Depot for wood, you would select "Purchase property protection materials"):
Work/Job Related
Pick-up or Meet-up with People
Purchase Medicines, Travel Supplies, etc.

Purchase Property Protection Materials
Obtain Money
Other

If you selected "Other", please specify:

Please provide the generic destination of your trip (For example, if you traveled to Home Depot, you would select "Store"):
Home
Workplace
Store
Friend/Relative's House
Other

If you selected "Other", please specify:

Please provide the name of the nearest intersection to the end location of your first trip (One example is Roosevelt & Gulfview for Home Depot):

How long did it take to travel from the Starting point to the ending point of your first trip (in minutes)?
How long did it take you to complete this trip purpose (in minutes)?

After this trip, did you make more trips?
Yes
No

Next Reset

Online Survey Questionnaire
*This section is found by responding "Yes" when asked about making more trips, and then clicking on the "Next" button
**Multiple legs of multiple trips can be entered; at this point, the survey automatically supplies the date and destination location intersection from the previous page as the origin point for the next trip.

Part Three - Trips Continued
Date of trip number **2:**
Information Supplied

Start time for this trip (Please identify Hours: Minutes and AM or PM):

Name of nearest intersection to the start location of this trip:
Information Supplied

What type of transportation did you use to make this trip?
Car/Van or Truck
Bicycle or Walked
Public Transit
Other

Were you a driver or passenger?
Driver
Passenger

Number of persons in the vehicle, please include yourself:

What was the purpose of this trip:
Work/Job Related
Pick-up or Meet-up with People
Purchase Medicines, Travel Supplies, etc.
Purchase Property Protection Materials
Obtain Money
Other

If you selected "Other", please specify:

Please provide the generic destination of this trip:
Home
Workplace
Store
Friend/Relative's House
Other

If you selected "Other", please specify:

Please provide the name of the nearest intersection to the end location of this trip:

How long did it take to travel from the starting point to the ending point of this trip (in minutes)?

How long did it take you to complete this trip purpose (in minutes)?

After this trip, did you make more trips?
Yes
No
Next Reset

Online Survey Questionnaire
*This section is found by responding "No" when asked about making more trips, and then clicking on the "Next" button

Did you evacuate the city?
Yes
No

OR

Did you travel somewhere, such as your home or a shelter, to wait out the storm?
Yes
No

At what time did you leave to either evacuate the city or travel somewhere to wait out the storm (Please answer with Hours: Minutes and AM or PM)?

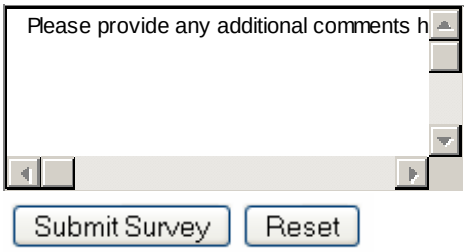
Name of same intersection cited as the end location of your trip from the last page:

What type of transportation did you use to make this trip?
Car/Van or Truck
Bicycle or Walked
Public Transit
Other

Number of persons in vehicle, please include yourself.

Name of nearest intersection to the end location of this last trip. (Residents who evacuated, can fill in "Passed the Southernmost Shell Station on U.S. Highway #1"):

How long did it take to travel from the Start location to the end location of this trip (in minutes):



* This section is found by clicking on the "Submit Survey" button
Thank you for responding to this survey. I really appreciate your help in learning more about the evacuation of Key West, Florida.

Appendix Two: Email Solicitation

Dear Sir or Ma'am,

My name is Melany Noltenius, and I am a Ph.D. student studying hurricane evacuation models used for Key West.

Part of my research involves calculating the time delays associated with trips made after a mandatory evacuation order has been issued, but before evacuating the city or returning someplace to wait out the storm.

I am asking for people who live in the City of Key West to help me by filling out a survey.

Could you please fill out my survey?

The survey is found at: http://www.keywestevacuation.com/

Also, if you know of anyone else who could fill out the survey, please forward this email to them.

I appreciate any help you can provide!

Sincerely,

Melany Noltenius

Melany Noltenius, M.S.P.
Ph.D. Candidate
University of Tennessee, Knoxville
Transportation Geography and GIS
Phone: 865 974-2418
Email: mnolteni@utk.edu

Appendix Three: Chi-square Analysis Between Variables

This appendix was developed to analyze the association among the socio-demographic variables themselves and not necessarily with evacuation behavior, to examine if the variables in the four groups share statistical significance. For example, to see if both respondents who made trips and those who did not have an association between marital status and income. Chi-square statistical significance tests were calculated between the socio-demographic variables within the four groups studied:

- Respondents did not report making any trips (206)
- Respondents who reported making at least one trip (81)
- Respondents who made at least one trip and evacuated (40)
- Respondents who made at least one trip and did not evacuate (41)

The Chi-square nonparametric test was run on the data to determine whether the variables contained within each group were not just randomly related.

At first, the Chi-square test was run for all data as reported in the original database, but later the data were altered for those categories with expected frequencies of less than five. In the cases where there was an expected frequency problem, the data were aggregated using the mode and/or median to determine the cut-off point.

For respondents not reporting any trips, statistical significance was found between age and marital status. The age variable was changed because two of the age categories had expected frequencies of less than five. Respondents who reported being under 18 years old during the evacuation were added to the 24 years or younger category, and respondents who reported being older than 75 were added to the 60-74 years old category to form a 60-plus grouping. The marital status variable was altered into categories of single, which included widowed and divorced respondents, and married, which included couples cohabitating (Table One: Age and Marital

Table One: Age and Marital Status Cross Tabulation					
			Marital Status		Total
			Single	Married	
Age	24 or younger	Count	17	4	21
		Expected Count	8.9	12.1	21.0
	25-44	Count	32	52	84
		Expected Count	35.5	48.5	84.0
	45-59	Count	32	55	87
		Expected Count	36.7	50.3	87.0
	60+	Count	6	8	14
		Expected Count	5.9	8.1	14.0
Total		Count	87	119	206
		Expected Count	87.0	119.0	206.0
$X^2 = 14.556$, degrees of freedom = 3, $\alpha = 0.002$					

Status Cross Tabulation). The Chi-square value of 14.556 was considered statistically significant; however, the Cramer's V result of 0.266 indicated that the relationship between age and marital status was weak.

The regrouped age variable was also tested against the income category, which was changed to reflect incomes of less than $49,999 or $50,000 plus. Two of the respondents, who identified themselves as being 24 years old or younger, did not answer the income question, and were dropped from the pool (Table Two: Age and Income Cross Tabulation). The Chi-square value was considered statistically significant at the 0.000 level, but the strength of the relationship between the two variables was weak with a Cramer's V of 0.314.

The gender and education variables were tested next. Ten of the respondents did not identify a gender and were removed from the pool, and one respondent did not identify an education level and was removed. For the remaining 195 respondents, significance was found between gender and education. This significance was found after the education variable was changed to reflect four categories: Respondents with a high school diploma/General Education Degree (GED) or less; respondents with a 2-year degree; respondents with a 4-year degree, and

Table Two: Age and Income Cross Tabulation					
			Income		Total
			$49,999 or less	$50,000+	
Age	24 or younger	Count	13	6	19
		Expected Count	5.9	13.1	19.0
	25-44	Count	28	56	84
		Expected Count	25.9	58.1	84.0
	45-59	Count	16	71	87
		Expected Count	26.9	60.1	87.0
	60+	Count	6	8	14
		Expected Count	4.3	9.7	14.0
Total		Count	63	141	204
		Expected Count	63.0	141.0	204.0
$X^2 = 20.080$, degrees of freedom = 3, $\alpha = 0.000$					

respondents with a graduate degree or more (Table Three**:** Gender and Education Cross Tabulation). The Chi-square value of 13.077 was significant, but once again the Cramer's V statistic indicated a weak relationship between the two variables (0.259).

The marital status variable was then aggregated to reflect categories of respondents who identified themselves as single, married/cohabitating, and widowed/divorced. After this transformation, a significant Chi-square value was found between marital status and children present in the household and/or caretaker status (Table Four: Marital Status and Children/Caretaker Status Cross Tabulation). The Chi-square value of 6.124 was statistically significant at the 0.047 level. The Cramer's V statistic tested the relationship between the two variables as being very weak (0.176). Eight respondents did not provide information regarding the presence of children in the home or caretaker status and were removed from the pool.

Marital status and income were also shown to have a statistically significant relationship. Two respondents did not report an income and were removed from the pool (Table Five: Marital Status and Income Cross Tabulation). The Chi-square value of 19.242 was statistically significant, but the Cramer's V identified the relationship as weak at 0.307. In this case, the

Table Three: Gender and Education Cross Tabulation							
			Education				Total
			High School/GED or less	2-year degree	4-year degree	Graduate degree	
Gender	Male	Count	27	13	25	32	97
		Expected Count	20.9	19.9	30.3	25.9	97.0
	Female	Count	15	27	36	20	98
		Expected Count	21.1	20.1	30.7	26.1	98.0
Total		Count	42	40	61	52	195
		Expected Count	42.0	40.0	61.0	52.0	195
$X^2 = 13.077$, degrees of freedom = 3, $\alpha = 0.004$							

Table Four: Marital Status and Children/Caretaker Status Cross Tabulation					
			Children/Caretaker		Total
			Yes	No	
Marital	Single	Count	9	55	64
		Expected Count	15.2	48.8	64.0
	Married/Cohabitating	Count	35	82	117
		Expected Count	27.8	89.2	117.0
	Widowed or Divorced	Count	3	14	17
		Expected Count	4.0	13.0	17.0
Total		Count	47	151	198
		Expected Count	47.0	151.0	198.0
$X^2 = 6.124$, degrees of freedom = 2, $\alpha = 0.047$					

Table Five: Marital Status and Income Cross Tabulation					
			Income		Total
			$49,999 or less	$50,000 +	
Marital	Single	Count	34	34	68
		Expected Count	21.0	47.0	68.0
	Married/Cohabitating	Count	23	96	119
		Expected Count	36.8	82.3	119.0
	Widowed/Divorced	Count	6	11	17
		Expected Count	5.3	11.8	17.0
Total		Count	63	141	204
		Expected Count	63.0	141.0	204.0
$X^2 = 19.242$, degrees of freedom = 2, $\alpha = 0.000$					

same number of single respondents indicated an income of less than $49,999 and more than $50,000. Nearly twice as many widowed/divorced respondents indicated an income of $50,000 or more than $49,999 or less. However, most married/cohabitating couples did earn more than $50,000.

Race and marital status generated a statistically significant Chi-square after the race variable was altered to the categories of Non-Hispanic White, Black, and Other. The marital status variables was changed to reflect single and married respondents (Table Six: Race and Marital Status). The Chi-square value of 10.582 was significant, and the Cramer's V of 0.160 indicated a very weak relationship.

Education was also statistically significant with regards to income. Considering that education level can impact income, the statistically significant relationship makes sense (Table Seven: Education Level and Income Cross Tabulation). Two respondents did not identify an education level and were removed from the pool. The Chi-square value of 11.593 was considered statistically significant; however, the Cramer's V statistic of 0.238 indicated that the relationship was weak.

Income level and homeownership also report a statistically significant Chi-square. Ten of the respondents did not identify a homeownership status and were dropped from the pool. The Chi-square value of 28.266 indicated a non-random relationship between the two variables, but the Yates correction for continuity indicated that the relationship was weak (0.355). Because the dichotomous data had one degree of freedom, the Yates correction for continuity was used to test the strength of the relationship. The expected frequencies in all categories were five or more (Table Eight: Income Level and Homeownership Cross Tabulation).

Table Six: Race and Marital Status Cross Tabulation					
			Marital		Total
			Single	Married	
Race	Non-Hispanic White	Count	66	99	165
		Expected Count	69.7	95.3	165.0
	Black	Count	12	5	17
		Expected Count	7.2	9.8	17.0
	Other	Count	9	15	24
		Expected Count	10.1	13.9	24.0
Total		Count	87	119	206
		Expected Count	87.0	119.0	206.0
$X^2 = 10.582$, degrees of freedom = 2, $\alpha = 0.036$					

Table Seven: Education Level and Income Cross Tabulation					
			Income		Total
			$49,999 or less	$50,000+	
Education	High School/GED or less	Count	23	24	47
		Expected Count	14.5	32.5	47.0
	2-year degree	Count	10	31	41
		Expected Count	12.7	28.3	41.0
	4-year degree	Count	20	43	63
		Expected Count	19.5	43.5	63.0
	Graduate degree	Count	10	43	53
		Expected Count	16.4	36.6	53.0
Total		Count	63	141	204
		Expected Count	63.0	141.0	204.0
$X^2 = 11.593$, degrees of freedom = 3, $\alpha = 0.009$					

Table Eight: Income Level and Homeownership Cross Tabulation					
			Homeownership		Total
			Own	Rent	
Income	$49,999 or less	Count	20	35	55
		Expected Count	35.9	19.1	55.0
	$50,000 or more	Count	108	33	141
		Expected Count	92.1	48.9	141.0
Total		Count	128	68	196
		Expected Count	128.0	68.0	196.0
$X^2 = 28.266$, degrees of freedom = 1, $\alpha = 0.000$					

Table Nine: Homeownership and Housing Type Cross Tabulation						
			housing			Total
			Single-family	Apartment	Other	
Homeownership	Own	Count	95	24	9	128
		Expected Count	84.2	34.0	9.8	128.0
	Rent	Count	34	28	6	68
		Expected Count	44.8	18.0	5.2	68.0
Total		Count	129	52	15	196
		Expected Count	129.0	52.0	15.0	196.0
$X^2 = 12.563$, degrees of freedom = 2, $\alpha = 0.002$						

Finally a significant Chi-square was found between homeownership and housing type. Housing type was modified to only include single-family, apartment, and other categories. The other category combined mobile home, recreational vehicle, houseboat and any other categories (Table Nine: Homeownership and Housing Type Cross Tabulation). The Chi-square value of 12.563 indicated a non-random relationship between the two variables; however, the Cramer's V statistic indicated that the relationship was weak (0.253).

For respondents not reporting any trips, Chi-square significance was found between the following variable pairs; however, all of the relationships were either weak or very weak:

- Age and Marital Status
- Age and Income
- Marital Status and Children
- Marital Status and Income
- Marital Status and Race
- Education Level and Income
- Education Level and Gender
- Homeownership and Income Level
- Homeownership and Housing Type

A number of the variable pairs that had a significant Chi-square were expected, such as the non-random relationship between homeownership and income or income and education level. However, the statistically significant relationship between gender and education level and race

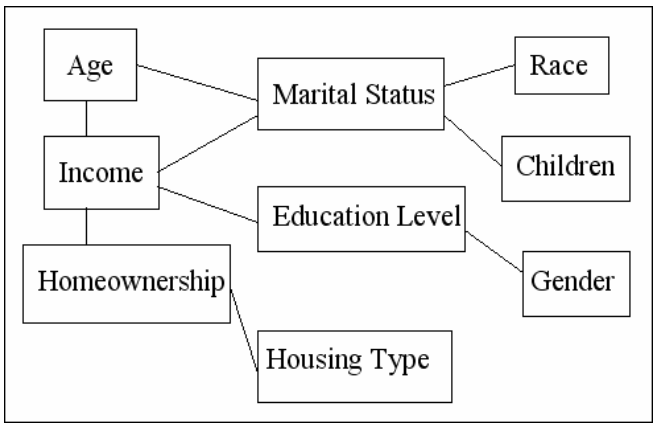


Figure One: Variable Relationships for Respondents Not Reporting Trips

and marital status were unexpected (Figure One: Variable Relationships for Respondents Not Reporting Trips).

For those who made trips, the variables were extended to include, not only socio-demographic attributes, such as gender, age, marital status, race, etc., but also the variables identifying those who evacuated and those who waited out the storm, trip purpose, origin and destination, and number of persons in the vehicle. There were 81 respondents who made pre-evacuation trips and provided information about whether they evacuated or not.

Without transforming any of the variables, no statistically significant Chi-square could be calculated; however, after transforming the variables, two non-random relationships were uncovered. Statistical significance was discovered between the variables of income and homeownership when the income categories were regrouped to reflect three categories ($49,999 or less, $50,000-$99,999 or $100,000 plus). The number of respondents who own their homes increased as income increased (Table Ten: Income and Homeownership Cross Tabulation). The Chi-square value of 13.603 indicated statistical significance, and the Cramer's V statistic of 0.418 indicated that the relationship was moderate in strength.

Table Ten: Income and Homeownership Cross Tabulation					
			Homeownership		Total
			Own	Rent	
Income	$49,999 or less	Count	4	12	16
		Expected Count	9.9	6.1	16.0
	$50,000-$99,999	Count	18	12	30
		Expected Count	18.5	11.5	30.0
	$100,000 plus	Count	28	7	35
		Expected Count	21.6	13.4	35.0
Total		Count	50	31	81
		Expected Count	50.0	31.0	81.0
$X^2 = 13.603$, degrees of freedom = 2, $\alpha = 0.001$					

Statistical significance could also be found between homeownership and the number of vehicles available for making trips when the number of vehicles was changed into categories of one vehicle, two vehicles or three or more vehicles. Overall those respondents who owned their own homes had more vehicles at their disposal (Table Eleven: Homeownership and Available Vehicles Cross Tabulation). With a Chi-square value of 18.648, statistical significant was shown between homeownership and available vehicles, and the Cramer's V statistic of 0.489 showed that this relationship had moderate strength.

In order to ensure that statistical significance between variables was tested thoroughly, the variables were categorized again. This would expose any non-random relationships, but the variables would lose their granularity. The age variable was reduced to two categories based on the mode: those respondents 18-44 years old, and those 45 and older. As a result three significant Chi-square values were discovered between age and gender, age and income, and age and marital status. The Chi-square value of 4.744 showed significance between age and gender; however, the Yates contingency coefficient indicated that the relationship was weak at 0.224. Nearly twice as many men 45 years old or older reported making trips than women of the same

Table Eleven: Homeownership and Available Vehicles Cross Tabulation						
			Vehicles			Total
			1	2	3 or more	
Homeownership	Own	Count	8	22	20	
		Expected Count	15.4	21.6	13.0	50.0
	Rent	Count	17	13	1	31
		Expected Count	9.6	13.4	8.0	31.0
Total		Count	25	35	21	81
		Expected Count	25.0	35.0	21.0	81.0
$X^2 = 18.648$, degrees of freedom = 2, $\alpha = 0.000$						

age (Table Twelve: Age and Gender Cross Tabulation). A significant Chi-square value of 6.473 was found between age and income; the Cramer's V statistic of 0.285 indicated the relationship was weak. According to Table Thirteen: Age and Income Cross Tabulation, more than three times the number of respondents less than 45 years old reported earning $49,999 or less, while nearly twice the number of respondents less than 45 years old reported earning more than $100,000. Finally, a statistically significant Chi-square value of 15.781 indicated a non-random relationship between age and marital status; however, the Cramer's V statistic of 0.437 indicated that the relationship was moderate in strength. Almost four times as many respondents identified themselves as single in the under 45 age group as the over 45 age group, though about the same number of respondents in both age groups identified themselves as married or cohabitating. Most who were divorced or widowed identified themselves as being 45 years old or older (Table Fourteen: Age and Marital Status Cross Tabulation).

Marital status was altered to reflect two categories: Single, which included divorced and widowed respondents, and married, which included respondents cohabitating. Two significant Chi-squares emerged after the transformation: marital status and income, and marital status and number of vehicles available. With a Chi-square value of 8.103, marital status and income were

Table Twelve: Age and Gender Cross Tabulation					
			Gender		Total
			Male	Female	
Age	18-44 years	Count	20	27	47
		Expected Count	24.6	22.4	47.0
	45 plus years	Count	23	11	34
		Expected Count	18.4	16.6	34.0
Total		Count	43	38	81
		Expected Count	43.0	38.0	81.0
$X^2 = 4.744$, degrees of freedom = 1, $\alpha = 0.029$					

Table Thirteen: Age and Income Cross Tabulation						
			Income			Total
			$49,999 or less	$50,000-$99,999	$100,000+	
Age	18-44	Count	13	12	22	47
		Expected Count	9.7	17.2	20.1	47.0
	45+	Count	4	18	12	34
		Expected Count	7.3	12.8	14.9	34.0
Total		Count	17	30	34	81
		Expected Count	17.0	30.0	34.0	81.0
$X^2 = 6.473$, degrees of freedom = 2, $\alpha = 0.036$						

Table Fourteen: Age and Marital Status Cross Tabulation						
			Marital			Total
			Single	Married/Cohabitating	Widow/Divorced	
Age	18-44	Count	21	24	2	47
		Expected Count	14.3	25.8	6.9	47.0
	45+	Count	4	21	9	34
		Expected Count	10.7	19.2	5.1	34.0
Total		Count	25	45	11	81
		Expected Count	25.0	45.0	11.0	81.0
$X^2 = 15.781$, degrees of freedom = 2, $\alpha = 0.000$						

statistically significant at the 0.017 level, but the Cramer's V statistic of 0.350 indicated that the relationship was weak. More than five times the respondents who considered themselves married earned $100,000+ than $49,999 or less, but the same number of respondents who considered themselves married as single earned in the mid-range of $50,000-$99,999 (Table Fifteen: Marital Status and Income Cross Tabulation).

A significant Chi-square value was also found between marital status and the number of vehicles available for respondents to use for trip-making during the Hurricane Wilma evacuation. Almost three times as many respondents who identified themselves as single had one vehicle to use when compared to respondents who considered themselves married. Nearly twice as many married respondents had two or more vehicles to use than single respondents (Table Sixteen: Marital Status and Available Vehicles Cross Tabulation). The Chi-square value of 11.649 was statistically significant, but the Cramer's V statistic of 0.378 indicated that the relationship was weak.

The next variable to be changed into dichotomous categories was race. This variable was modified to identify two categories of respondents: Non-Hispanic White and Other. A statistically significant Chi-square value was found between race and gender. Twice as many "Other" females as males participated in pre-evacuation trip-making (Table Seventeen: Race and Gender Cross Tabulation). A Chi-square value of 3.894 was statistically significant, and the Yates contingency coefficient of 0.214 indicated that the relationship between race and gender was weak at best.

The education variable was aggregated from the four categories of High School/GED or less, 2-year degree, 4-year degree, or Graduate degree to two categories based on the mode: 2-year degree or less and 4-year degree or more. A statistically significant Chi-square value

Table Fifteen: Marital Status and Income Cross Tabulation						
			Income			Total
			$49,999 or less	$50,000-$99,999	$100,000 +	
Marital	Single	Count	12	15	10	37
		Expected Count	7.3	13.7	16.0	37.0
	Married	Count	4	15	25	44
		Expected Count	8.7	16.3	19.0	44.0
Total		Count	16	30	35	81
		Expected Count	16.0	30.0	35.0	81.0
$X^2 = 8.103$, degrees of freedom = 2, $\alpha = 0.017$						

Table Sixteen: Marital Status and Available Vehicles Cross Tabulation						
			Vehicles			Total
			1	2	3 or more	
Marital	Single	Count	19	11	7	37
		Expected Count	11.9	15.5	9.6	37.0
	Married	Count	7	23	14	44
		Expected Count	14.1	18.5	11.4	44.0
Total		Count	26	34	21	81
		Expected Count	26.0	34.0	21.0	81.0
$X^2 = 11.649$, degrees of freedom = 2, $\alpha = 0.003$						

Table Seventeen: Race and Gender Cross Tabulation					
			Gender		Total
			Male	Female	
Race	Non-Hispanic White	Count	35	25	60
		Expected Count	31.1	28.9	60.0
	Other	Count	7	14	21
		Expected Count	10.9	10.1	21.0
Total		Count	42	39	81
		Expected Count	42.0	39.0	81.0
$X^2 = 3.894$, degrees of freedom = 1, $\alpha = 0.048$					

Table Eighteen: Education Level and Income Cross Tabulation					
			Income		Total
			$49,999 or less	$50,000 or more	
Education	2-year degree or less	Count	12	25	37
		Expected Count	7.3	29.7	37.0
	4-year degree or more	Count	4	40	44
		Expected Count	8.7	35.3	44.0
Total		Count	16	65	81
		Expected Count	16.0	65.0	81.0
$X^2 = 21.219$, degrees of freedom = 1, $\alpha = 0.009$					

surfaced between education level and income. The Chi-square value of 21.219 indicated statistical significance, but the Yates contingency coefficient of 0.280 indicated that the relationship was weak. Nearly ten times as many respondents who had a 4-year degree rather than a 2-year degree earned $50,000 or more (Table Eighteen: Education Level and Income Cross Tabulation).

Overall, the respondents who made trips had a statistically significant Chi-square between the following variables after the first data transformation:

- Homeownership and Income
- Homeownership and Available Vehicles

Homeownership and income Level was also significant in the group not reporting any trips. However, homeownership and available vehicles was unique to the group reporting trips. After the second data transformation, more significant Chi-square relationships became apparent at the expense of the granularity of data. The following variables were found to have a non-random relationship when at least one of the variables was converted to dichotomous categories:

- Age and Gender
- Age and Income
- Age and Marital Status

- Marital Status and Income
- Marital Status and Available Vehicles
- Race and Gender
- Education Level and Income

Four of the variable relationships were also found in the group of respondents not reporting any trips; the exceptions were age and gender, race and gender, and marital status and available vehicles (Figure Two: Variable Relationships for All Respondents Reporting Trips).

Of the 81 total respondents who reported trips, 40 evacuated and 41 waited out the storm. Because of the small sample sizes, a significant Chi-square was difficult to calculate because the expected frequencies often fell below five in each cell or more than 20% of the cells contained expected frequencies of less than five. Only one significant Chi-square value was calculated for those respondents who evacuated the city. This occurred after the data was altered to represent races of Non-Hispanic White or Other. The Chi-square value of 6.144 indicated statistical significance between race and gender, but the Yates contingency coefficient statistic of 0.365 indicated that the non-random relationship was weak. Of the respondents who evacuated, half were female and half male, but nearly four times as many "Other" females than males evacuated, and more Non-Hispanic White males than females evacuated (Table Nineteen: Gender and Race Cross Tabulation).

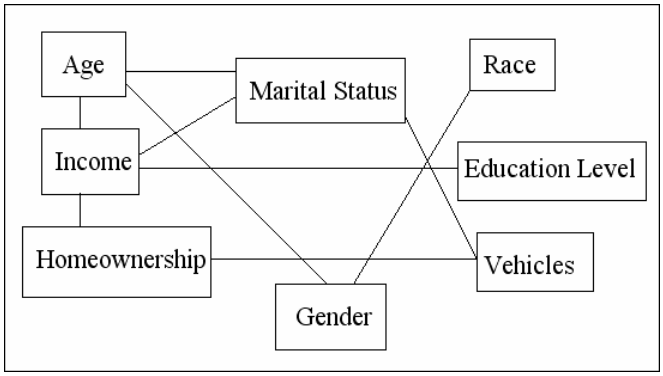


Figure Two: Variable Relationships for All Respondents Reporting Trips.

Table Nineteen: Gender and Race Cross Tabulation					
			Race		Total
			Non-Hispanic White	Other	
Gender	Male	Count	18	2	20
		Expected Count	14.5	5.5	20.0
	Female	Count	11	9	20
		Expected Count	14.5	5.5	20.0
Total		Count	29	11	40
		Expected Count	29.0	11.0	40.0
$X^2 = 6.144$, degrees of freedom = 1, $\alpha = 0.013$					

For the respondents who waited out the storm, two significant Chi-square values emerged after the data were regrouped into dichotomous categories: age and gender, and education and marital status. The age category contained either respondents who identified themselves as being 44 years old or younger, and those 45 years old or older. Interestingly, more young females 18-44 years old than males of the same age range waited out the storm (Table Twenty: Age and Gender Cross Tabulation). Whereas, more males 45 years or older waited out the storm than females of the same age range. A Chi-square value of 6.078 indicated statistical significance, and the Yates contingency coefficient of 0.324 indicated that the relationship was weak.

Education and marital status was the only other significant Chi-square found in the group of respondents who made trips, but did not evacuate for Hurricane Wilma. Education level was broken into two categories: 2-year college degree or less, which included respondents who both did and did not graduate from high school, and 4-year college degree or more, which included respondents with a graduate degree. Marital status was consolidated into two categories: single and married. More than twice as many single respondents as married respondents with a 2-year degree waited out the storm, and nearly twice as many married respondents as single respondents with a 4-year degree waited out the storm (Table Twenty-One: Education Level and Marital

Table Twenty: Age and Gender Cross Tabulation					
			Gender		Total
			Male	Female	
Age	18-44	Count	10	15	25
		Expected Count	13.4	11.6	25.0
	45+	Count	12	4	16
		Expected Count	8.6	7.4	16.0
Total		Count	22	19	41
		Expected Count	22.0	19.0	41.0
$X^2 = 6.078$, degrees of freedom = 1, $\alpha = 0.028$					

Table Twenty-One: Education Level and Marital Status Cross Tabulation					
			Marital		Total
			Single	Married	
Education	2-year degree or less	Count	15	6	21
		Expected Count	11.3	9.7	21.0
	4-year degree or more	Count	7	13	20
		Expected Count	10.7	9.3	20.0
Total		Count	22	19	41
		Expected Count	22.0	19.0	41.0
$X^2 = 7.152$, degrees of freedom = 1, $\alpha = 0.07$					

Status Cross Tabulation). The Chi-square value of 7.152 indicated statistical significance; the Yates contingency coefficient of 0.418 indicated that the relationship was moderate.

The Chi-square test statistic was used to highlight relationships between variables within each of the four groups in order to examine the differences and similarities between groups. For example, there was a significant Chi-square value between age and income found in the group that did not report any trips, as well as the group that did. For both groups age was also non-randomly related to marital status, but only for those who made pre-evacuation trips and respondents who made pre-evacuation trips and stayed behind did the age variable have statistical significance with gender. Marital status was also related to race and the presence of children in the home for respondents not reporting any trips. This association was not found in respondents who made trips, but an association between marital status and number of available vehicles was found. For the respondents who evacuated the city, statistical significance was found between race and gender.

A statistically significant Chi-square value was found between education level and income for both groups, as well as education level and gender for respondents not reporting any trips. For respondents who made trips but did not evacuate, a non-random relationship was found between education level and marital status. Finally, homeownership had statistical significance with income for both groups, but only those who did not report any pre-evacuation trips had a relationship between homeownership and housing type, and only those who did report making trips had a relationship between homeownership and the number of vehicles available.

Vita

Melany Noltenius was born the same year the Beatles came over the Big Pond to see what the revolutionaries had done with their little nation's former colonies. After completing high school the same year Ronald Reagan took his oath of office as the 40th President of the United States of America, she began her bachelors degree at the University of Tennessee, Knoxville. Nine years later, after marriage and the birth of a beautifully intelligent daughter, she received her Bachelor of Science degree in Communications. Twelve years later, still married, but permanently scarred by the raising of a teenage daughter, she received her Masters degree in Planning, specifically in Transportation Planning from UTK. She continued studying, knowing full-well that, as a terribly talented, but tired middle-aged woman, if she stopped after her M.S.P. she would never earn her doctorate. She received her Doctorate in Philosophy in Transportation Geography and Geographic Information Science in 2008, and hopes to actually find employment . . . sometime after getting a good night's sleep.