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16. Abstract

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Development of a Time-Dependent Hurricane Evacuation Model for the New Orleans Area

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ABSTRACT

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IMPLEMENTATION STATEMENT

The research in this study developed a novel method to collect hurricane evacuation behavior data. The new method can be used to collect time-sensitive evacuation behavior data without having to wait for an actual event to occur. The data collected using the new method can be used in multiple ways: to build evacuation demand models, to test alternative evacuation strategies, and also as an input to evacuation simulation.

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INTRODUCTION

Background

Hurricanes wreak havoc in coastal areas around the world. In the United States, over 1300 people died when Hurricane Katrina struck the city of New Orleans in 2005. Given the challenge of evacuating large populations within a stipulated amount of time, public officials face several challenges when hurricanes threaten coastal regions.

Although evacuation has traditionally been the responsibility of emergency management officials, they are increasingly seeking the help of transportation officials in planning evacuations *[1]*. In response to this, transportation officials are investigating alternative ways to plan and manage hurricane evacuation. For example, a staged evacuation, where evacuation is conducted by sequentially evacuating portions of a geographical area under threat to establish optimal use of the transportation network, has been suggested as one means of improving the efficiency of the evacuation process *[2]*. Other tactics include the use of contraflow operations or directing traffic onto specific routes *[1]*. To evaluate such alternative policies and strategies, one must be able to model human behavior under these conditions. To establish models that are capable of doing that, data is required on evacuation behavior under different conditions.

Surveys are the traditional method of collecting data on human behavior. In the past, post-event behavioral studies were conducted to record the reported behavior of individuals during an emergency event, like an approaching hurricane. Post-event behavioral studies recorded the revealed behavior of respondents, among other things.

A large number of post-event hurricane evacuation surveys have been conducted in the past *[3]*. However, very few of these surveys were conducted by transportation professionals. As a result, data in these surveys tends to be inadequate in transportation terms. For instance, most surveys neither record the time of departure of those evacuating, nor the time of arrival at the place of destination. Additionally, no information is collected on time-sensitive features of the storm under study, or the actions taken by emergency managers in response to developing storm conditions. This limits use of the data in predicting human behavior over time. In the past, time-sensitive features of the storm were added manually by supplementing static data with time-dependent information obtained from other sources *[4]*. That is, static information from evacuation surveys, such as the evacuee's socio-demographic characteristics, were supplemented with time-dependent information, such as distance to the hurricane, its path, its forward speed, and intensity, from sources such as the archives at the National Hurricane Center *[4]*. Dynamic information on actions taken by emergency managers, such as the type and timing of evacuation orders, were obtained from official records or media reports *[4]*.

In order to assess how evacuation policies and strategies can influence a decision made by an evacuee, evacuation travel demand models should include policy variables and operational strategies such as the type and timing of evacuation order issued, the imposition of contraflow, and the possibility of road closures *[2]*. For example, if variables that reflect operational strategies, such as contraflow and its timing, are included in evacuation demand models, they allow estimation of the consequences of various contraflow strategies in terms of their impact on evacuation time, volume of people evacuated, levels of congestion experienced, and flow patterns in the network. Thus, the idea is to include as many of the factors that influence the evacuation decision as possible in the model, so that by manipulating these key variables, the model is able to estimate the impact of changes in their values on the system.

A major limitation of post-event behavioral studies is that many emergency events, like hurricanes, are rare occurrences. This limits the opportunity to conduct post-event surveys because one has to wait until an event occurs before a survey can be conducted. Another disadvantage is the inability to alter event characteristics. For instance, hurricane characteristics such as category of the storm, projected path, and forward speed usually vary very little for a given event. This makes it impossible to observe the impact of variation in these variables on evacuation behavior. To solve this problem, either data from multiple events has to be combined or stated choice with multiple storm scenarios has to be used.

Stated choice data collection enables one to record evacuation behavior without the event actually occurring. In this method, potential respondents are presented with hypothetical choice scenarios and are asked to state their expected behavior. The approach enables one to construct choice scenarios which reflect a wide range of conditions, thus addressing one of the shortcomings of the post-event approach. One such data collection approach was used to record expected evacuation behavior information in New Orleans *[2]*. The respondents were presented with different storm scenarios, each one depicting a storm with different characteristics. However, aside from asking when the respondent would evacuate if the decision to evacuate was made, the survey remained static in nature.

Previous research has suggested that the decision to evacuate or not is influenced by the characteristics of the hurricane, the conditions in which the potential evacuee resides, and the characteristics of the household *[3], [4]*. Several of these conditions change over time, and it is these conditions, or the anticipation of how they will develop, that play a major role in the evacuation decision. In order to capture the temporal behavior of these conditions, static stated choice should be adapted, to enable collection of temporal behavior and temporal conditions. This can be done by introducing the dimension of time into the data collection process, producing dynamic or time-dependent stated choice data collection. Since it is not feasible to collect data continuously, we have collected data at discrete intervals of time in this study. Consequently, rather than refer to it as dynamic data collection, we have chosen to refer to it as time-dependent data collection.

In the time-dependent stated choice method, a hypothetical storm is represented as a set of conditions that change in discrete steps over time. For example, at a particular time before a hurricane is expected to make landfall, the conditions prevailing at that time are presented to the respondent and the decision to evacuate or not is recorded. The process is then repeated at each time interval as the storm progressively gets closer until the respondent either evacuates or the hurricane makes landfall, whichever occurs first. For a given respondent, the socio-demographic characteristics of a household are fixed, but the characteristics of the approaching hurricane, the conditions surrounding the respondent, and the evacuation strategies implemented by emergency managers can change over time. For example, the projected path, storm intensity, and forward speed of a hurricane can change. In addition, the respondent's home could become vulnerable to flooding or storm surge, evacuation routes could become congested, and emergency managers could introduce contraflow, close roads, or implement staged evacuation. By changing the contextual conditions of a household in discrete steps over time, and obtaining the respondents stated choice in each time interval, time-dependent stated choice data can be captured. Respondents can be asked to respond to multiple scenarios, thereby capturing the behavior that would result from a wide range of storm and contextual conditions.

One of the challenges in implementing time-dependent stated choice is enabling respondents to visualize the developing storm, thereby helping the respondent make realistic decisions regarding whether and when to evacuate. Still pictures have been used to enhance verbal descriptions of a hypothetical scenario in face-to-face stated choice interviews *[5]*. However, the full impact and urgency of an emergency might not be adequately captured in a still photo. One possibility would be to establish audio-visual scenarios on a DVD to depict the storm scenario as a short movie for each time interval considered. Each time interval could present storm conditions as presented in a storm update on TV. For example, a map showing the animation of the expected path of the storm, storm surge, rainfall intensity, and so on, in each time interval could be presented. The video could be compiled in a TV studio using archive video material, and actors acting out fictional scenes.

OBJECTIVE

The objectives of this study are to:

- To design a time-dependent, audio-visually based stated choice questionnaire.
- To design a conventional static revealed preference self-administered questionnaire to be administered jointly with the time-dependent, audio-visually based stated choice questionnaire.
- Subcontract the joint surveys out to a travel survey agency with instructions to monitor the time and cost of each survey separately. The revealed preference survey should use Hurricane Gustav as the event surveyed.
- Enhance the revealed preference data with time-dependent storm data from official sources.
- Estimate two time-dependent sequential logit models (TDSLM) of evacuation demand; one on the enhanced revealed preference data, and the other on joint data formed by combining the enhanced revealed preference data and time-dependent stated choice data.
- Apply each model to conditions reflecting Hurricane Georges.
- Compare each model's prediction of time-dependent evacuation demand with the reported values from the post-Georges survey conducted by the University of New Orleans Survey Research Center in November 1998.
- Specify and derive a new model, time-dependent nested logit model (TDNLM) to relax the restrictive assumptions imposed by the TDSLM.
- Estimate a TDNLM using Hurricane Gustav data and compare the model's prediction with the prediction from the TDSLM on the same data.
- Compare the cost and predictive performance of each survey method.

SCOPE

The research reported in this document is restricted to the development and evaluation of a new method to collect hurricane evacuation behavior. As such, it is a proof-of-concept study to determine the effectiveness and relative cost of collecting data using the new method in contrast to conventional post-event revealed preference data collection. The method was tested using data collected in the New Orleans metropolitan area, and resulted in completed surveys from the relatively small sample of 300 households. The results of the study are not necessarily generalizable and the results of the comparison of revealed preference data with that from stated choice are restricted to evacuation behavior during Hurricane Gustav. Assessment of the new data collection procedure is limited to comparison of the relative cost of data collection with each procedure and the performance of the data in producing evacuation demand models that reproduce observed behavior.

LITERATURE REVIEW

Stated Choice Methods

Stated choice methods use experiments that present sampled respondents with a number of hypothetical choice situations, consisting of a universal but finite number of alternatives that differ on a number of attribute dimensions. The respondents are asked to specify their preferred alternative from the options within each choice situation shown. The responses are then pooled, over hypothetical choice scenarios and respondents, before being used to estimate models that predict choice behavior in response to attribute values on each alternative.

Experimental Design

Experimental design is an important building block in the use of stated choice methods. Given the objective of presenting a respondent with hypothetical choice situations, the researcher's main task is to develop choice situations that achieve certain desired features in the collected data. Traditionally, researchers have relied upon the use of orthogonal experimental designs to establish hypothetical choice situations in which variable values vary independently of each other. Louviere, Hensher, and Swait present a good review of orthogonal designs *[6]*. However, more recently, Huber and Zwerina, Kanninen, Kessels, Goos, and Vanderbrook, and Sándor and Wedel have begun to question the relevance of orthogonal designs when applied to stated choice experiments *[7], [8], [9], [10], [11], [12]*. They argue that orthogonality as a design criterion in the construction process is unrelated to the desirable properties of econometric models, (e.g. logit and probit models) which use the data.

The idea of using orthogonality as a design criterion to construct a stated choice experiment was borrowed from statistical linear theory *[13]*. Thus, orthogonality is realized between design attributes only when statistical linear models are used to analyze the resulting data from the experiment. However, the predominant form of models used to analyze stated choice experiments are statistical non-linear models like probit and logit. Huber and Zwerina relate the statistical properties of stated choice experiments to econometric models estimated on stated choice data *[7]*. They show that designs with relaxed orthogonality as a consideration in generating stated choice experiments, and instead reduce the asymptotic standard errors of the parameter estimates, generally result in designs that either (a) improve the reliability of the parameters estimated from stated choice data at a fixed sample size or (b) reduce the sample size required to produce a fixed level of reliability in the parameter estimates with a given experimental design *[14]*. The linking of experimental design to reduction of the asymptotic standard errors of the parameter estimates has resulted in a class of designs known as 'efficient designs'.

In order to calculate the asymptotic variance-covariance matrix (AVC) for a stated choice design, the analyst requires *a priori* knowledge of the utility functions for that design. This is because the values of the AVC matrix are directly dependent upon both the attribute levels and the choice probabilities of the alternatives contained within each of the design choice situations. The choice probabilities for a given design are in turn a function of the attribute levels of the alternatives, as well as the parameter weights associated with each of these attributes. Thus, the parameter values play a key role in determining the level of efficiency of a design. Unfortunately, the exact parameter values are unlikely to be known at the design construction phase, and as such, the researcher may have to make certain assumptions as to what values (priors) these will be in order to generate an efficient design.

Three different approaches have been used in the past regarding the parameter priors assumed in generating efficient stated choice experiments. In the first approach, researchers make the strong assumption that all parameter priors for the design are simultaneously equal to zero *[15], [7], [16], [17]*. While such an assumption is able to estimate an efficient design, optimality will only exist if parameter estimates are indeed zero. The assumption of zero parameter priors is unlikely to hold in reality, and if it does, then there are significant implications in terms of the attributes and/or levels used in the stated choice study. Thus, the efficiency of a design generated under such an assumption is unlikely to be meaningful. A second approach that has sometimes been used is to assume that the parameter priors are non-zero and known with certainty *[20, 18]*. In such an approach, a single fixed prior is assumed for each attribute. While the assumption of certainty is a strong one, the design generation process is such that researchers are able to test its impact on a design's efficiency, assuming misspecification of the priors. A third approach, introduced by Sándor and Wedel, relaxes the assumption of perfect *a priori* knowledge of the parameter priors by adopting a Bayesian approach to the design generation process *[11]*. Rather than assume a single fixed prior for each attribute, the efficiency of a design is now determined over a number of draws taken from prior parameter distributions assumed by the researcher.

Constrained Designs

Certain combinations of attribute levels in a choice situation can be unrealistic or infeasible and these unrealistic choice situations can be avoided by imposing constraints. For example, in a route choice experiment, one could think of route alternatives in terms of their different departure times, free-flow travel times and arrival times. In reality, arrival times are always later than departure times and free-flow travel times are equal to or less than the difference between arrival and departure times. To deal with this reality, researchers impose constraints on the choice sets generated using either orthogonal or efficient designs.

Pivot Designs

Pivot designs are stated choice experiments that are developed on the basis of a respondent's revealed preference choice. For example, in a route choice study conducted by Rose et al., they first asked the respondent to describe a recent trip *[19]*. Hypothetical choice sets containing different routes were then constructed with travel times and costs higher or lower than that of the recent trip, and respondents were asked to choose among the hypothetical routes. The practice of constructing hypothetical choice sets in which attributes of a hypothetical choice are created by changing the attributes of an RP alternative is called "pivoting". Applications of pivoting are discussed in Hensher and Greene, Hensher, and Caussade et al. *[21]*, *[22]*, *[23]*, *[24]*.

Current State-of-Practice in Stated Choice Design

Even though the field of designing stated choice experiments has advanced theoretically, the state-of-practice has not. Several researchers and practitioners still continue to use orthogonal designs or its variants to design stated choice experiments *[25]*. This is because several of the newly developed methods require a great deal of technical expertise and people who can train or educate others are few and not easily accessible. In addition, considering the novelty of the new methods, practitioners have not gained enough confidence to replace existing orthogonal methods with new methods. Apart from the factors mentioned above, others dependent on the objectives of the study undertaken by a researcher also play a role in choice of design method.

Past Studies That Used Stated Choice to Study Hurricane Evacuation Behavior

Numerous stated choice surveys have been conducted on evacuation behavior but none of them have included all the factors commonly believed to influence evacuation behavior. Baker conducted a study in which he manipulated several of the key variables known to influence evacuation behavior *[26]*. He presented sets of hypothetical hurricane threats to 400 residents of Pinellas County, Florida, to assess the effect of hurricane probability forecasts and other risk indicators on public response to the threats. Results showed that evacuation notices from local officials were more important than other threat variables, and hurricane probability did little to modify their effect.

Whitehead conducted a predictive validity test on hurricane evacuation behavior using revealed and stated behavior data from a panel survey on North Carolina coastal households *[27]*. Data was initially collected after Hurricane Bonnie led to hurricane evacuations in North Carolina in 1998. Then respondents were asked for their behavioral intentions if a hurricane threatened the North Carolina coast during the 1999 hurricane season. Following Hurricanes Dennis and Floyd in 1999, a follow-up survey was conducted to see if respondents behaved as they intended. A jointly estimated revealed and stated behavior model indicated that similar decisions are made in hypothetical and real evacuation situations. Their results also suggest that stated behavior data has a degree of predictive validity.

Kang, Lindell, and Prater also compared respondent's expected evacuation behavior with actual behavior *[28]*. In their study, they compared respondents' stated hurricane evacuation response with their actual behavior two years later during Hurricane Lili. Respondents were found to have accurate expectations about their actual evacuation behavior, information sources, evacuation transportation modes, number of vehicles taken, and evacuation shelter types. In addition, they also found that respondents had generally accurate expectations about the time it would take them to implement some, but not all, evacuation preparation tasks.

Main Factors Influencing Evacuation Behavior

Baker reviewed fifteen post-event surveys conducted between 1963 and 1990 to identify common information among them *[3]***.** From this review he suggests that five factors play a major role in influencing evacuation behavior. The factors are:

1. Prior perception of personal risk
2. Storm specific threat factors (example: hurricane intensity, storm surge, path)
3. Action taken by public authorities (example: type and timing of evacuation orders)
4. Risk level of the area in which household resides (example: flooding potential)
5. Type of housing in which one resides (example: mobile home, permanent structure)

Whitehead also investigated the main factors influencing evacuation behavior *[29]*. He conducted a study to assess the determinants of hurricane evacuation behavior of North Carolina coastal households during Hurricane Bonnie and a hypothetical hurricane. He used a telephone survey to establish evacuation behavior following Hurricane Bonnie, and to assess whether respondents would evacuate and where they would evacuate to in the case of hypothetical hurricanes with varying intensities. His findings suggest that the evacuation decision of a household depends on 1) type of evacuation order 2) social factors 3) economic factors 4) objective and subjective risk factors. Although expressed differently, these findings are in agreement with those of Baker.

Peacock, Broody, and Highfield, examined factors contributing to hurricane risk perceptions of single family homeowners in Florida *[30]*. They also examined the influence of location on shaping homeowner perceptions, along with factors such as knowledge of hurricanes, previous hurricane experience, and socio-economic and demographic characteristics. Their findings suggest that there is a good deal of consistency between residing in locations identified by experts as being high hurricane wind risk areas and homeowner risk perceptions.

Dow and Cutter examined the relationship between the household evacuation decision and official emergency management practice in the light of an increase in the availability and diversity of hurricane-related information *[31]*. While the focus of study was on Hurricane Floyd in South Carolina, they also incorporated findings of their longitudinal research effort covering four years and six post-1995 hurricane threats to the state. They also reported that individual assessment is more influential than official orders in making evacuation decisions in that greater weight is given to household circumstances and preferences, the diligent monitoring of a variety of information sources, and the incorporation of past experiences into the decision-making process than to evacuation orders. Surveys also indicated differences between the general public and officials in terms of priorities and preferences about hurricane evacuations.

Time-dependent, Audio-Visual, Data Collection Methods Used in the Past

Based on the review of literature review published up to 2010, the authors did not find any study that used a time-dependent, audio-visual, stated choice survey to collect time-dependent stated choice data, either for evacuation or any other activity.

Medium Used to Present Stated Choice Experiments

A written description of hypothetical scenarios has been the preferred method of conducting stated choice experiments in the past. Many of these studies were conducted during the seventies and eighties in the field of marketing. However, the use of graphics or photographic material in stated choice experiments gained popularity with the advent of new, cheap, ubiquitous technology, such as personal computers. Studies in the late eighties and throughout the nineties started to use more photographic material and graphics to aid respondents in understanding the proposed scenario and improving the realism of it. Several studies were conducted in the past decade and spread across several fields, such as marketing, agricultural economics, and econometrics in which animation or videos were used to present hypothetical scenarios as part of stated choice experiments. In the transportation field, several studies have used photographic or video material to present stated choice experiments *[5]*, *[32]*, *[33]*, *[34]*.

There is a general consensus among practitioners of stated choice experiments that the use of animation helps survey respondents visualize a hypothetical scenario in a cognitively favorable manner and, consequently, results in more accurate responses. For example, Richarme and Colias used 3 D animation to present a hypothetical scenario in a marketing study and found that the amount of work and level of frustration to be higher among respondents who used the traditional approach rather than the 3 D animation procedure *[35]*. In addition, the study also found that participants preferred 3 D animation over the traditional approach in terms of respondent burden and in presenting a more realistic presentation of the scenario.

Conclusions Drawn from the Literature Review

The literature review showed that stated choice surveys can produce useful and meaningful information and practitioners have used graphics and, particularly, animation to enhance surveys. In addition, the literature review revealed that time-dependent, audio-visually enhanced stated choice data collection has, apparently, not been used before. Considering the need for time-dependent data in hurricane evacuation demand modeling, and the fact that stated choice data collection is particularly suited to collecting data on rare events, extending current practice to include audio presentation, as well as introducing the collection of dynamic information, appears to be a worthwhile area of investigation.

METHODOLOGY

Preliminary Planning of Survey

During the preliminary planning phase, important decisions regarding the choice of a survey agency, time needed to finish the survey, and the budget required for conducting the survey were made. Furthermore, a review of the existing sources of evacuation behavior was conducted to gain an understanding of the type and amount of data available. Some of the surveys conducted in the past also served as a guide in designing the questionnaires.

The Public Policy Research Lab (PPRL) located on the LSU Campus was chosen as the agency responsible for conducting the survey. The choice of the agency was influenced by the ease of access, having a common administrative process, and the ability to effect payment without having to initiate a contract.

A series of meetings were arranged between the authors and the PPRL personnel to discuss time and money requirements for accomplishing the desired goals of the study. While it is theoretically desirable to have enough resources to accomplish a desired set of goals, in reality it is not always practically achievable. Since only a limited budget was allotted to the current study, certain trade-offs were made to accomplish important objectives. It was decided in the meetings that the PPRL would be responsible for conducting the focus groups, recruitment of participants for pre-testing survey instruments, sending out advance letters, making reminder calls, retrieving the completed questionnaires, entering data retrieved from questionnaires into a database, and sending out a letter indicating the completion of the main survey. At the same time, it was agreed that the primary investigators would supply the material required for the survey, including the printed questionnaires, envelopes, letterheads, and other paraphernalia.

Based on the budget and personnel availability, the PPRL established a time line of seven months to conduct the focus groups, pre-test the survey questionnaires, conduct a pilot survey, complete the main survey, and prepare a database of the collected survey data.

Survey Design

Sample Design

In the sample design portion of the survey, the target population was defined and decisions regarding the type of sampling units, sources for compiling the sampling frame, size of sample, and type of sampling procedure employed were made.

The target population depends on the goals of the study. One of the objectives of the current study was to compare data obtained from time-dependent stated choice survey with that obtained from the revealed preference survey. As the study required data on revealed behavior of evacuees in a recent evacuation, the target population had to include people who resided in the selected geographical region at the time of the hurricane selected in this study. We chose Hurricane Gustav as the event on which revealed behavior would be collected, and the New Orleans area as the location in which the survey would be conducted.

The target population for this survey was defined as all people living in the parishes of St. Bernard, Orleans, Jefferson, St. Charles, St. John the Baptist, Terrebonne, Plaquemine, Tangipahoa, Lafourche, and St. Tammany since these were the areas affected by Hurricane Gustav. Households were selected as the sampling units in this study. The geographical region is shown in Figure 1.

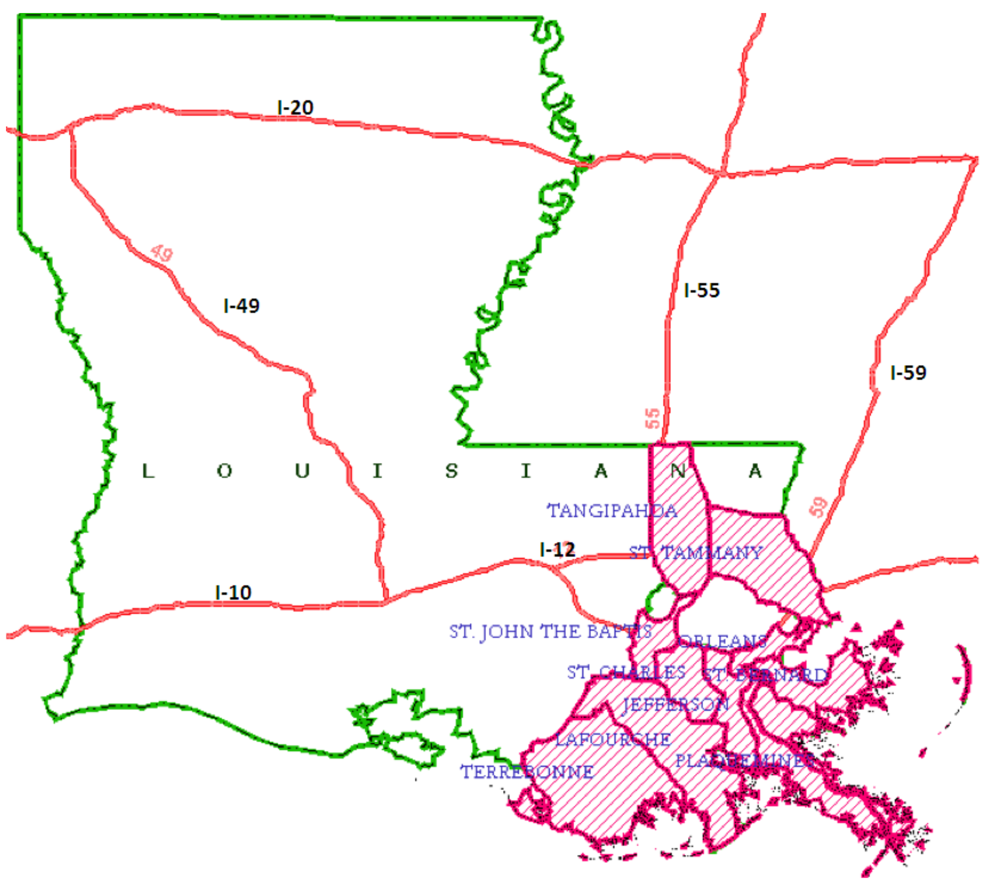

Figure 1
Parishes sampled for this study

Sample design also deals with the calculation of required sample size. Theoretically, sample size is calculated based on the equation that relates accuracy of the estimate of a quantitative variable under investigation to sample size. But, because of budget and resource constraints in this study, sample size was decided *a priori* at 300 households.

Design of Revealed Preference Survey

The main objective in designing the Revealed Preference (RP) survey was to collect information regarding the recent past evacuation experience during Hurricane Gustav. Questions were included on the evacuation decision, and, if they evacuated, the day and time they evacuated, and the city and state to which they evacuated. In addition, information on the number of vehicles used, trailers pulled, the socio-economic characteristics of the household, and whether the household had members with special needs, were collected.

The questionnaire was designed with the objective of limiting the amount of time a household would spend completing the survey. To make things easier for households that did not evacuate, skip patterns were used in the questionnaire. A total of 27 questions were included in the questionnaire. A typical household that evacuated filled in 23 questions, whereas a household that did not participate in evacuation had to fill out less than 15 questions. Additionally, the physical form of the questionnaire was made as aesthetically pleasing as possible to keep interest alive in the survey. The questionnaire used to collect the RP information is shown in Appendix D.

Design of the Time-Dependent, Audio-Visual, Stated Choice Survey

Time–Dependent and Static Stated Choice Surveys. Time-dependent stated choice surveys are an adapted form of static stated choice surveys. The variation is best explained by an example. Consider a scenario in which a hypothetical hurricane is expected to make landfall near a respondent's home in 75 hours. Given the conditions prevailing at the time, the respondent is asked whether their household will evacuate or not. Since they are probably not sure whether the hurricane will really pose a danger in the area in 75 hours time, they are likely to decide not to evacuate in the first time period, but will continue to monitor the hurricane on television or some other media. At this point, current conditions and the respondent household's decision to not evacuate will be recorded. If this process is repeated at successive discrete time intervals in the remaining period, each time noting the prevailing conditions and the decision of the respondent, this represents time-dependent stated choice. In contrast, static stated choice surveys ignore the temporal properties of data and report only on total or average values of variables in the data set.

Nomenclature. Stated choice methods question respondents on hypothetical choices, rather than actual choices. In the choice process, we use the following nomenclature: objects of choice are called alternatives, the characteristics of alternatives are called attributes, and the agent who makes the choice is called the respondent or subject. In a hurricane evacuation scenario, the evacuee will be the agent and the choice will be to evacuate or not. The choice set, or list of alternatives, will be the choice to evacuate or not in each time period. The attributes in this case will be the time–dependent characteristics of the hurricane, the policies and strategies of emergency managers, and the conditions prevailing in each time period.

Attribute and Attribute Level Identification. Attributes needed for setting up choice experiments are identified based on the results that have been listed in the literature as important in affecting an evacuee's behavior *[2], [3], [4]*. Table 1 shows a list of the potential attributes that were considered in this study. The list of the attributes stated here are limited because an increase in the number of attribute increases the complexity of the choice experiment considerably. For example, the total number of combinations arising out of the attributes considered in Table 1 is 3x2x3x2 = 36. Thus, adding attributes or attribute levels increases the number of combinations by the product of the numbers of attributes and their levels. On the other hand, ignoring certain attributes, such as traffic conditions in Table1, reduces the total number of combinations to 18, which is something that was considered. It must be noted that some of the combinations are implausible in reality. For example, the combination of attributes of a Category 1 hurricane, a storm surge greater than 15 ft., and a mandatory evacuation order are unlikely to occur in reality. Plausible combinations of attributes are referred to as treatment combinations or hypothetical storms in further discussion.

Table 1
Attribute and attribute levels

Attributes	Attribute Levels
Hurricane Category	1, 3,5 (3 levels)
Storm surge	>15 ft, < 15 ft (2 levels)
Evacuation ordered	None, Mandatory, Voluntary (3 levels)
Traffic conditions	Free flow, congested (2 levels)

Experimental Design Considerations. The objective in designing an experiment is to make use of accumulated knowledge in the area of hurricane evacuation behavior to design a choice experiment that is cognitively sensible to respondents. Furthermore, the choice experiment should allow one to estimate a statistical model on the data as efficiently as possible. The process used to accomplish these objectives is described in this and following sections.

One of the important points that need to be addressed in designing a hypothetical time-dependent scenario is the number of discrete time steps that should be used. There is no hard and fast rule that the number of discrete time steps should be limited to any particular number. However, practical considerations do bring some guidance on the issue. For example, it can be argued that in real life people are informed about a developing hurricane in six-hour time intervals, as the National Weather Service updates its forecasts every six hours. However, people do not listen to every forecast when the storm is distant, and it is important to limit the number of time intervals a respondent is asked to consider, if respondent burden is taken into account. Considering that people are less likely to evacuate when a hurricane is far away than when it is close, it makes sense to observe evacuation behavior more closely in times close to landfall. At the same time, early evacuations should be observed to capture early evacuation behavior. To accommodate both these needs, one time period was scheduled long before hurricane landfall while the others were scheduled with increasing frequency as time to landfall decreased. Since respondent burden is directly related to the number of time periods, the minimum number of time periods should be used, and we felt that a number less than four would be undesirable. Thus we adopted an experimental design with four time periods. However, rather than have fixed time periods for all observations we allowed the variable time periods to center around 72, 48, 24, and 12 hours before landfall as shown in Figure 2 below. This allowed a better discernment between the impact of time to landfall and the evacuation decision.

If all treatment combinations in Table 1, excluding traffic conditions, were arranged in four discrete steps of time, it would result in 18^{4} or 104,976 different permutations of hypothetical storms. However, not each sequence of attribute levels are feasible over time, since there is a temporal dependency among attribute levels, and a limit on the rate at which attribute levels can change. Unfortunately, even if only feasible sequences of treatment combinations are retained, there are still likely to be many more treatment sequences than can be handled in a stated choice experiment. This gives rise to the problem of selecting a feasible number of treatment sequences that can be handled in a survey. To solve this problem, researchers working in the field of stated choice designs have made use of a method rooted in statistical experimental design theory. The method involves randomly selecting a sample of treatment combinations from the total possible number of combinations. This can be administered to respondents by implicitly assuming that each treatment combination is formed by combining various attributes which are independent of each other. If the attributes are independent of each other, each treatment combination is equally likely and a random sample of the treatment combinations would be representative of all treatment combinations. However, this assumption poses a problem when applied to the current situation because attribute levels cannot change independently of each other over time, as discussed previously; therefore, treatment combinations are not independent of each other. A practical solution to this problem is discussed in the following section.

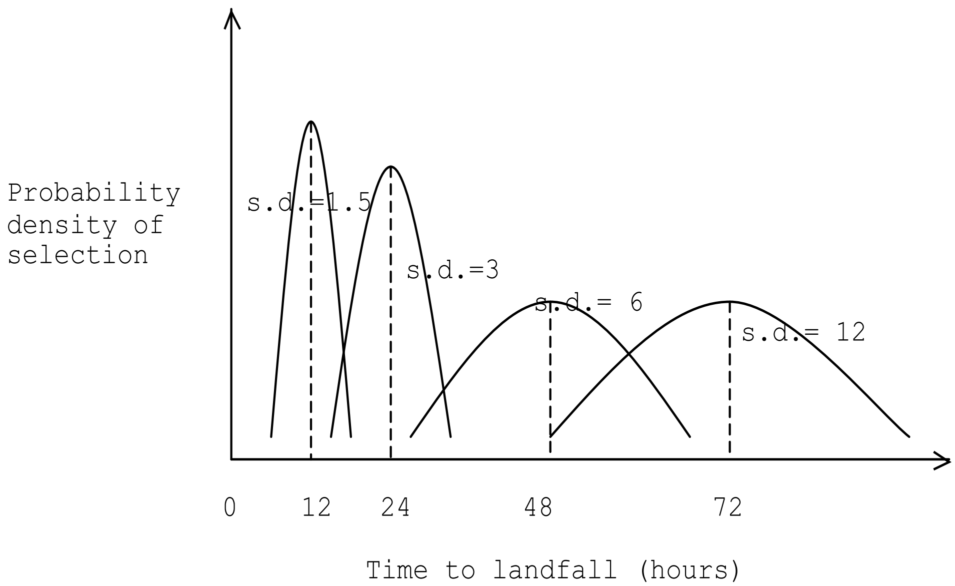

Figure 2
Schematic of probablity distribution of attribute time to landfall

Reducing the Number of Hypothetical Storms. In the absence of a method that offers a solution to reduce the number of hypothetical storms, it is appropriate to take a practical approach. There are two questions that need to be answered in order to provide a practical solution. First, how many hypothetical storms should be considered and, second, which hypothetical storms should be considered? The number of hypothetical storms that should be considered for this study would be a function of resources available, the amount of effort that will be required to develop a video of each storm, and the number of storms each respondent could reasonably be expected to handle. There is some evidence in the literature that respondents are willing to answer 8 to 16 static stated choice questions before they start to show signs of fatigue *[6]*. If each scenario takes two minutes to present and answer, this implies that we can expect a respondent to be prepared to take up to half an hour in answering a set of stated choice scenarios. However, we expect the video to make the presentation of each time-dependent scenario more interesting than a narrative-based questionnaires used in conventional stated choice. Thus, a total time of 40 to 45 minutes was suggested as a reasonable duration of the survey based on the following assumptions:

1. Each sequence of treatments (i.e. hypothetical storm) takes a respondent approximately 10 minutes to view and answer (based on four treatments, each taking two minutes to audio-visually present and half a minute to answer in terms of whether they would evacuate or not, and if they do, what vehicles they would use, when they would leave, where they would go, and what route they would take)
2. Each respondent is asked to respond to three time-dependent scenarios, which together with the revealed preference survey, takes approximately 45 minutes (3x10 + 15 minutes for revealed preference survey)
3. A total of nine time-dependent scenarios were developed (given the above assumptions, three sample groups, each responding to three time-dependent scenarios, results in nine time-dependent scenarios).

When considering which hypothetical storms should be included in the analysis, it is necessary to recognize that while it is advantageous to provide the greatest variation in attribute values as possible in stated choice scenarios, attribute values also have to be consistent among each other. For example, as mentioned earlier, it is unlikely that a Category 1 storm will be accompanied by a large storm surge or a mandatory evacuation order. Also, attributes in one time interval are likely to be similar in the next time interval. One way in which realistic scenarios can be obtained is to look at past hurricanes. In doing so, hypothetical storms are entirely realistic. One more advantage of using past storms comes in the form of psychological behavior of human beings. Since it is well known that future expected human behavior more closely correlates to past behavior under similar circumstances, it can be safely assumed that the responses to hypothetical storms would be more realistic in nature.

A history of past hurricanes available on the National Hurricane Center website was retrieved. Retrieved history contained information on the path of a hurricane and other time-dependent characteristics, such as storm category, storm location, and time of landfall. From this retrieved hurricane history, nine hurricanes were randomly chosen. However, the attributes of the hurricanes were reviewed and new samples drawn to allow a wide variation on all attributes among the selected hurricanes. For example, storms were selected to ensure that hurricanes of Categories 1, 3, and 5 are included in the sample. It was arranged that one of the sampled hurricanes was Hurricane Gustav. Two variations of each of the nine hypothetical storms were then obtained by varying the attribute time to expected landfall, by one and two hours. This resulted in a total of 27 (9 × 3) hypothetical storms that were used in this study. Table 2 below shows the final nine hypothetical storms and their respective time-dependent characteristics.

Although this practical approach solves the problem of selecting a feasible sample, at the same time it introduces the problem of choosing a biased sample from the total number of past hurricanes. The biased sample arises due to the act of intentionally selecting hurricanes of preferred choice rather than a random sample. However, the problem of bias is of no consequence because the biased sample will not bias the model parameters, but only the constant associated in the model. Thus, one can safely afford to select a biased sample without much harm being done to the model.

Construction of the Time-Dependent Audio-Visual Survey Instrument

The survey instrument consists of two components. The first part of the instrument is a DVD which contains videos depicting hypothetical storms. The second part of the instrument is a paper-based response sheet that is complementary to the video shown to respondents. The following sections describe details about the video and the response sheet.

Developing Videos for Presentation of Time-dependent Stated Choice Survey. A given hypothetical storm is presented as a video clip, comprising four time-dependent forecasts. The video clip starts off by showing Forecast 1 in terms of attribute levels in the first time period, and then continuing with subsequent Forecasts 2, 3, and 4. Each forecast presents a background geographical map, location of storm at that time, the projected track of the storm from its current location, and attributes of the storm, such as hurricane category, expected time to landfall, and whether evacuation orders were issued. A narrator's voice describing the hurricane characteristics was also added to the forecast. Commercially available software, Adobe Flash, was used to develop graphics and animate the projected path. For illustration purposes, a graphic from the video presentation is shown in Figure 3. Three hypothetical storms, along with instructions on how to fill out the response sheet, were compiled into one DVD. This resulted in a total of nine DVDs with each DVD containing three unique hypothetical storms.

Table 2
Hypothetical storms and their attributes

Storm Name	Hurricane Characteristics	Forecast 1	Forecast 2	Forecast 3	Forecast 4
Storm 1	H C* EO* TOD* TTEL* DOW*	4 None 10:15 am 70 Wednesday	4 Voluntary 6:15 am 50 Thursday	4 Mandatory 12:15 am 32 Thursday	3 Mandatory 2:15 pm 18 Friday
Storm 2	H C EO TOD TTEL DOW	5 Voluntary 12:30 pm 72 Monday	4 Mandatory 2:30 pm 45 Tuesday	3 Mandatory 4:00 pm 19 Wednesday	2 Voluntary 1:00 am 8 Thursday
Storm 3	H C EO TOD TTEL DOW	3 None 6:30 am 68 Saturday	4 Voluntary 6:30 am 44 Sunday	3 Mandatory 8:30 am 18 Monday	3 Mandatory 3:30 pm 11 Monday
Storm 4	H C EO TOD TTEL DOW	5 None 12:30 pm 69 Wednesday	3 Voluntary 1:30 pm 44 Thursday	2 Voluntary 12:30 pm 21 Friday	2 Voluntary 1:30 am 8 Saturday
Storm 5	H C EO TOD TTEL DOW	3 None 9:30 am 76 Tuesday	5 Voluntary 12:30pm 49 Wednesday	2 None 11:30 am 26 Thursday	1 None 11:30 pm 14 Thursday
Storm 6	H C EO TOD TTEL DOW	5 None 9:30 am 75 Wednesday	3 Voluntary 3:30 pm 45 Thursday	2 Voluntary 4:30 pm 20 Friday	1 Voluntary 3:30 am 9 Saturday
Storm 7	H C EO TOD TTEL DOW	1 None 11:30 am 74 Friday	3 Voluntary 9:30 am 52 Saturday	2 Mandatory 9:30 am 28 Sunday	2 Mandatory 8:30 pm 13 Monday
Storm 8	H C EO TOD TTEL DOW	4 None 12:30 pm 67 Sunday	3 Voluntary 9:30 am 46 Monday	3 Mandatory 8:30 am 23 Tuesday	3 Mandatory 8:30 pm 11 Tuesday
Storm 9	H C EO TOD TTEL DOW	5 None 6:30 am 75 Saturday	3 Voluntary 10:30 am 47 Sunday	2 Voluntary 6:30 am 27 Monday	1 Voluntary 10:30 pm 11 Monday

HC* = Hurricane Category, EO* = Evacuation Order, TOD* = Time of Day,
TTEL* = Time to expected landfall (in hours), DOW* = Day of the Week

For the narration included in the video, a prewritten script was read and recorded, then added to a video as background narration. Software developed by Apple, Sound Track Pro, was used to record and edit the soundtrack before adding it to the animation of each hypothetical storm.

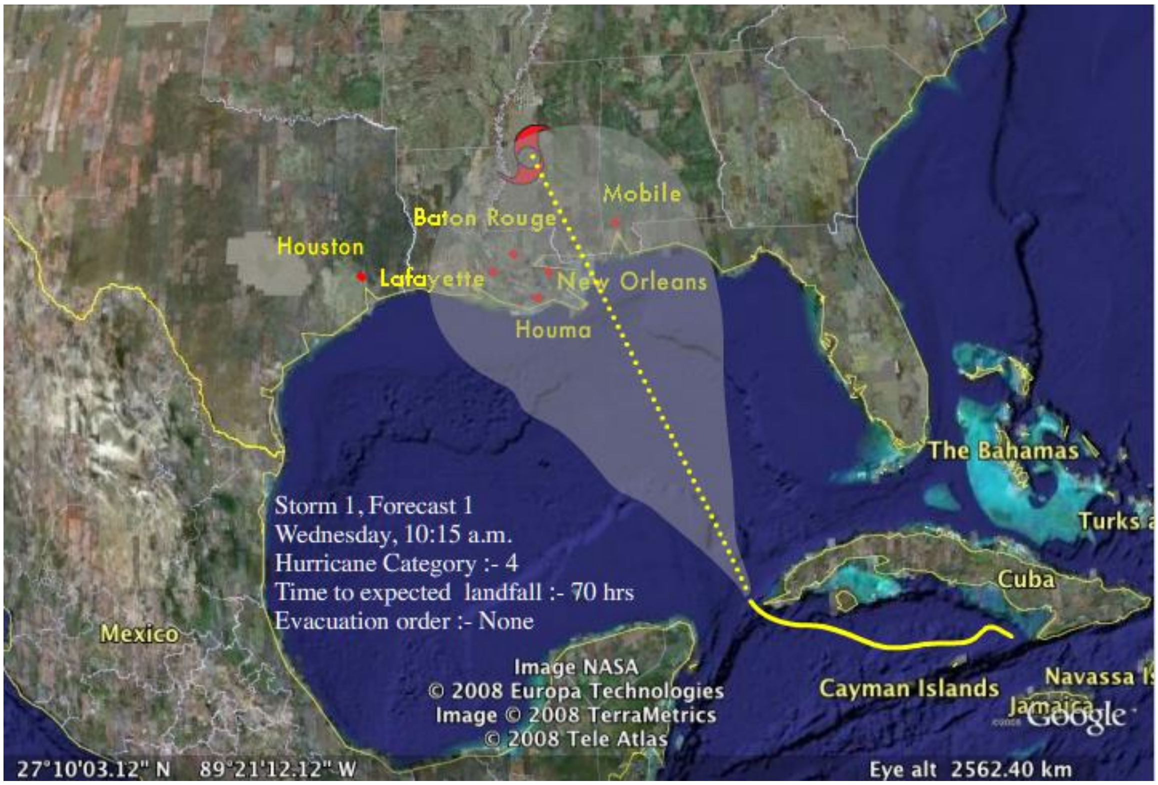

Figure 3
Illustration of a single forecast

DVD Authoring. Authoring of a DVD allows one to control the flow of the content present on the DVD. For example, while watching a movie on a DVD, a menu showing choices of sections of a movie will appear at the beginning. After the appearance of the sections, one can then select to either play the entire movie or go to a particular section. DVD Studio Pro was the software used to build navigational controls of the DVD after copying the videos of hypothetical storms into it.

The task of authoring a DVD was an important part in making cognitively sensible scenarios. DVD navigation included a stop at the end of each forecast to wait for a participant's response. Additionally, to avoid inadvertent skipping from one part of animation to another part, the fast-forward functionality was disabled. To reduce the time spent by a survey participant in completing the survey, skip patterns were incorporated into the navigation. For example, if a survey participant chose to evacuate before reaching the final forecast, then subsequent forecasts of the storm were automatically skipped to reach the next storm on a DVD.

Design of Dynamic Response Sheet. The dynamic response sheet, a complement to the DVD, was designed with the objective of making it easy to fill out the responses after watching a video of the forecast animation. The responses that were to be filled out were: intended day and time of evacuation, mode of evacuation, number of vehicles to be used for evacuation, type of refuge, city and state of intended destination, and route planned to use. A set of instructions on how to play the DVD was also included in the response sheet. The response sheet is shown in Appendix E.

Selection of Survey Method

Four types of survey method were considered for administering the survey.

- Telephone recruitment with an internet-based survey,
- Telephone recruitment, with mail-out questionnaire and telephone retrieval,
- Telephone recruitment with mail-out, mail-back questionnaires, and
- Telephone recruitment and telephone interviews.

Telephone recruitment with mail-out, mail-back questionnaire was chosen to conduct the survey because it was the only economical method (within available methods) that offered the advantage of having survey participants watch a video of hypothetical storm stored on a DVD while simultaneously recording response on a survey booklet.

Survey Administration

It is considered unwise to conduct a full-fledged survey unless its basic components, such as sampling method, recruitment, and survey instruments, are subjected to a set of checks like pre-testing and pilot testing. The following discussion will describe various procedures and tests that were used as checks prior to conducting the main survey.

Focus Groups

After designing the survey instruments it was important to follow a rigorous testing regime to gain more confidence in the correct functioning of the instrument and also to reduce errors arising from poor instrument design. In an effort to improve the design of survey instruments, two focus groups were used. What follows is a discussion of both the informal and formal groups that were used to refine the survey instruments that were developed in the preceding tasks.

Informal Focus Group. An informal focus group was conducted before the formal focus group study. The main purpose was to assess the design and appeal of the stated choice survey, to know its ease of use, to know how well the response sheet and videos on the DVD complement each other, to find any technical difficulties in playing DVD on different media, and to get a critical review of the audio-visual, stated choice survey holistically. The focus group participants were graduate students who worked in the transportation lab at LSU at the time when the study was in progress. It is of particular importance to note that all the participants were highly educated and well-informed about the research goals, which would generally not be the case when a survey is sent out to the general population.

The majority of the participants found it easy and convenient to use and fill out the survey, but they were not happy with the instructions provided in the video on how to play the DVD and record responses to the stated choice survey. Consequently, a major effort was made to improve the video part of the survey based on the critical reviews of the participants.

Formal Focus Group. A plan was formed to conduct a focus group with 16 participants drawn from the general public. The main objective was to gauge an understanding of the performance of the survey material when sent to the field, and also to pick up vocabulary that is used by general population during hurricane evacuation.

The PPRL advertised in local newspapers asking for volunteers to participate in the study. A $50 incentive was offered to all the participants. Volunteers were enrolled in the focus group based on a first-come, first-serve basis.

Conducting the focus group involved using a moderator capable of guiding the discussion and eliciting appropriate responses from the group in a skilled and objective manner. The moderator was hired by PPRL for the job.

All the participants of the focus group received an envelope containing a DVD, a stated choice response sheet, a revealed preference survey booklet, and instructions on how to fill out the survey. All the materials were sent to participants one week in advance of the focus group meeting and they were also informed of the time and place of the meeting.

The focus group was held on June 24th, 2009, at the Journalism building on the LSU campus.

The meeting lasted approximately an hour. For convenience, the focus group was divided into two groups established on the basis of income reported by the participants. The first group was the high-income group with seven participants and their meeting started at 5:30 pm and lasted for an hour. The second group, the low-income group, with nine participants, commenced at 6:30 pm and lasted for one hour as well. All the discussion was concentrated on the audio-visual stated choice survey. Each participant was given a choice to comment on the survey and suggest improvements for the survey to make it easier to comprehend and complete.

Collectively, participants suggested they would like to see changes in the:

1. Navigational capabilities of the DVD menu
2. Audio instructions on how to play and fill out the stated choice survey at the beginning of the DVD, and possibly an example
3. More storm information
4. An estimate of the total time taken to fill out the survey in the cover letter.

Out of all the suggestions made by the focus group only two, the second and fourth of those listed, were practically feasible to be implemented. This was because more sophisticated navigational possibilities were not available in the software used, and additional storm information was considered redundant. Based on the recommendations of the focus group, changes were made in the instruction sheet and a two minute set of instructions on how to fill out the stated choice survey were added at beginning of the video presentation.

Pilot Testing

After completing the focus group, a pilot test was conducted involving a complete application of the survey process. The pilot test was conducted on 50 households with the object of

- Testing the influence of paying monetary incentives on response rate,
- Testing the adequacy of the sampling frame,
- Estimating the non-response rate,
- Testing the efficacy of the questionnaire in recording desired data,
- Testing the efficacy of data entry, editing and analysis procedures in recording responses from completed questionnaires and, finally,
- To get an estimate of the cost and duration of the survey

An advance letter, shown in Appendix B, was sent to a sample of 350 respondents before making recruiting phone calls for the pilot survey. The basic premise behind sending an advance letter was that people who get notices in advance show more willingness to participate in the survey than people who have never been told about the impending recruitment phone call.

The pilot survey was conducted between 08/01/2009 and 08/20/2009. Recruitment calls were made between 5 pm and 9:30 pm on week days. Only two personnel worked on recruitment. One person recruited people for the incentive study and another for the non-incentive study. Incentive group people were recruited from a sample of 100 households and the non-incentive group from a sample of 200 households. A total of 25 households agreed to participate from the incentive sample and a total of 26 from non-incentive sample. This resulted in a recruitment rate of 12.5 percent for non-incentive group and 25 percent recruitment rate for incentive group.

Out of the 25 from the incentive group only 11 households sent back their completed questionnaires. Surprisingly, 14 out of 26 households from the non-incentive group sent back their completed questionnaires, but only 11 of the 14 provided meaningful information. Thus, the effective retrieval rate was similar between the incentive and non-incentive groups. Contrary to popular belief that incentives increase retrieval rate, this was not observed in this study, although it did seem to influence the recruitment rate. The main reason for the low retrieval in the incentive group is believed to be the requirement of filling out a W-9 form by participants in order to receive a twenty-dollar incentive. Completion of the W-9 form requires providing your social security number, and many respondents were reluctant to provide it. Because of this influence and the counter influence of an improved recruitment rate, the effect of an incentive on response rate could not be determined objectively.

A telephone help line was made available to the pilot survey participants. It was expected that when people are provided with a help line for a survey they would be more inclined to want to complete the survey with help from a person who will walk them through the process. However, during the period of the pilot survey only five calls were received, and most related to the requirement that incentive-receiving participants had to fill out a W-9 form. Out of the five calls received, two calls were regarding technical difficulties that were faced by participants in playing the DVD.

A total of three reminder calls were made to households who failed to send back their questionnaires within the time frame allotted to them. Most of the calls were made in the evenings after 5 pm and before 9:30 pm. No significant improvement in response was observed after making reminder calls. This might be due to most participants of pilot study being reluctant to discuss the W-9 issue any further.

Some of the important information gained by conducting the pilot survey was an estimate of the recruitment rate, an indication of the effect of an incentive on recruitment rate, an estimate of the questionnaire retrieval rate, and the technical difficulties experienced by survey respondents using the DVD. In moving forward, several measures were taken to minimize the complaints about the DVD and also to improve the retrieval rate of questionnaires. While the need to complete a W-9 form to receive the incentive detracted from participation, the incentive also seemed to improve response.

Main Survey

Based on the recruitment and retrieval rate from the pilot survey, it was decided to recruit approximately 650 to 700 households in order to end up with a sample of approximately 300 households. Furthermore, based on the past recruiting experience of PPRL and results of the pilot survey, it was decided that incentives would be paid to survey participants in the main survey.

Before the commencement of the recruitment process, advance letters, were sent to 3500 potential survey participants. The advance letter informed survey participants about the impending phone call, the objectives of the survey, dates the survey would be conducted, the amount of incentive offered, and the time it would take to complete the survey. To improve the appeal of the advance letter, it was printed on Louisiana State University's Civil Engineering department's letterhead. The letter was sent five days in advance of the recruitment start date.

One of the problems that were encountered initially was lack of accurate addresses. This was due to erroneous addresses present in the sampling frame that was purchased from a commercial vendor. About 180 advance letters were sent back due to incorrect addresses.

The main survey was conducted between 9/23/2009 and 12/11/2009. Recruitment of the households started on 9/27/2009. The PPRL appointed approximately 10 people to recruit 650 households for the survey. Most of the people working were either transient workers or students enrolled at LSU. Recruiting started every day around 5:00 pm and lasted until 9:00 pm. During the weekends, recruiting was conducted between 12:00 pm and 4:00 pm.

Survey material was sent out within three days of recruiting a household. Survey material comprised of a pre-paid return envelope, a cover letter (shown in Appendix C), a DVD, a stated choice survey questionnaire, and a revealed preference survey questionnaire. Each participant was told to return the survey questionnaires within 10 days from the date of reception of the material. Survey material was sent in two waves to a total of 665 households. In the first wave 300 survey packages were mailed to recruited households and 365 in the second wave.

As explained earlier in the pilot survey section, a telephone help line was made available to all the participants. The helpline was a cell phone purchased specifically for the purpose of providing round the clock service and was carried by the lead author at all the times. The service was available 24 hours a day throughout the survey period. A total of 23 calls, amounting to 60 minutes of airtime, were received during the active period of survey. However, most of the calls were related to the confidentiality issue of supplying a social security number in the W-9 form, which was required to receive the twenty-dollar incentive, rather than any difficulties experienced in filling out the survey.

A major problem with self-completion surveys is that very often the response rate is low, and therefore the opportunity for sampling bias to occur is quite high. One reasonably effective strategy to combat this is to use reminder calls.

Three reminder calls were made to all households who failed to return their completed questionnaires within the allotted time frame. Four-day time intervals were maintained between each successive reminder call. One interesting aspect of the survey was that after initiation of the reminder calls retrieval rate of the completed questionnaires improved from 20 percent to 49 percent; a situation quite different to that experienced in the pilot survey

The response rate is often used to gauge the success or failure of a survey. Nonetheless, a poor response rate does not always translate into a poor quality survey. There might be several reasons for poor response rate that at the time of executing the survey are not clear and only emerge at the end of a survey. For the present survey, out of 666 households that were recruited only 331 households sent back a completed survey questionnaire. This resulted in a retrieval rate of approximately 50 percent. But out of the 331 returned questionnaires, only 288 provided all information requested while the remaining 43 contained missing data.

In the opinion of the authors, the reason for the poor retrieval rate was the requirement placed on survey participants to fill out a W-9 form to receive the incentive. The requirement might have deterred several potential responders from sending their completed questionnaires.

Even after successful retrieval of the completed questionnaires, it is not uncommon for researchers to find some of the information provided by survey respondents is completely ambiguous, incorrect, or missing. While some of the information can be deduced from other inter-related information provided by respondents, it is impossible to deduce the answer on items that are unrelated. For example, one of the pieces of information requested in the revealed preference questionnaire was the date of evacuation and the date of arrival at the destination; information that cannot be deduced from any other reported data. Around 30 to 35 households failed to provide such information. In order to retrieve this important and crucial information three call-back attempts were made to contact the households before categorizing the questionnaires as incomplete.

At the end of the study period a letter, shown in Appendix F, was sent to households that were never contacted by phone notifying them of the termination of the study. This action was taken out of courtesy and in an effort to maintain trust between the conducting agency and future potential participants. If the letter was not sent, then all the people who were expecting to receive a call would have perceived the advance letter as a farce and consequently it would have diminished the effect of using the advance letter strategy in the future.

Data Entry, Data Correction, Weighting and Expansion

Data Entry

Retrieved survey questionnaires were directed by the PPRL to the lead author for editing purposes before the data was entered into an Excel database. All completed questionnaires were checked for illogical entries, inconsistent information, and missing data before forwarding them for data entry by the personnel working at PPRL. Two data entry personnel manually entered all the information into an Excel database designed for recording the responses from both the RP and SP survey. The data was rechecked after it was transcribed into the Excel database.

Data Correction/ Missing Data/Data Cleaning

Despite the best efforts expended in preparing a survey instrument, there are always issues that hinder a researcher from collecting all the desired information in an accurate fashion from a survey respondent. This happens because when designing the survey instrument, the researcher makes certain assumptions about the real world situation and, using these assumptions, designs the survey instrument hoping that all assumptions will hold true. As often happens during the development of a new procedure, all of the assumptions may not prove to be true. One such assumption that did not hold true related to the method used to collect the date and time of departure and the date and time of arrival at a destination. At least 5 percent of the survey respondents reported either their time of departure or time of arrival inconsistently particularly with respect to confusion between 12 am and 12 pm This was detected very early when researchers were retrieving the questionnaires and running data checks for errors in the questionnaires. Wherever possible, call backs were used to retrieve missing information but where that failed, deduction was first attempted followed by hot deck imputation. This applied particularly to missing information on household income, education level, and number of vehicles owned.

For certain data items, an example being the length of residency at a current home, it is not possible to use inference or imputation to arrive at a reasonable value. When this situation arose, three attempts were made to reach respondent on the phone and if respondents responded and provided the required information then information was recorded and if contact was not established then the comment "missing data" was made against the observation corresponding to the household in the comment sections of the database.

Weighting and Expansion

Non-response, non-reporting, and inaccurate reporting often occurs in self-administered surveys and they introduce bias in the sample due to over representation or under representation of certain groups within the sample. The remedy for this is to weight the observations in the sample to account for the bias in the sample.

Expansion factors scale up the sample so as to represent the entire population and are the inverse of the sampling rate. Weighting is employed to remedy bias in data sets, and weighting factors and expansion factors are often combined into a single weighting and expansion factor. Calculation of weighting and expansion factors requires a secondary source of data collected independently from the survey. In addition, the secondary data sources need to have information on the same socio-economic data items describing the population as present in the sample.

The socio-economic data from the year 2000 census and the year 2009 American Community Survey (ACS) was retrieved from the Census Bureau website. The socio-economic data were combined into a single data set for the target area. Household size, ethnicity, and number of vehicles owned by a household were identified as common variables between the retrieved data and the sample data. Household size and ethnicity were retrieved from ACS survey, while vehicle ownership was retrieved from the year 2000 census. Because one variable, vehicle ownership, came from a different source, the total number of households when summed over all levels for the variable vehicle ownership did not equal the total number of households when summed over all the levels of either ethnicity or household size variables. To remedy this discrepancy, a proportional correcting factor was applied to the total number of households that existed in each level of the variables ethnicity and household size to bring them to the number of households in the study area in 2009.

Iterative proportional fitting (IPF) is commonly employed in surveys to compute weighting and expansion factors. Simply described, IPF is a procedure used to adjust cells of an n-dimensional table so that they add up to pre-determined totals on each dimension of the table. The starting values or initial values of the table that are adjusted are referred to as *seed values* and the pre-determined totals on each dimension are referred to as *marginals*.

For application of the IPF procedure in the current study, the seed values were the sample data values cross-classified by household size, vehicles owned and ethnicity. As shown in the table, this involved the use of five levels of household size, three levels of vehicles ownership, and two levels of ethnicity. After establishing the sample data seed values and gathering the required marginals from the census and ACS data, a 3-dimensional IPF procedure was applied. After five iterations the values in the table converged to the marginals. The resulting cell values after the fifth iteration were then divided by the original seed values to get the combined weighting and expansion factors shown in Table 3.

Table 3

Weighting and expansion factors

		Household Size						
		1	2	3	4	5+		
Ethnicity	White	5545	3296	3023	3109	3268	0	Vehicles Owned
		2956	1757	1612	1658	1743	1	
		1861	1106	1015	1044	1097	2+	
	Non-White	13354	7939	7281	7489	7872	0	
		7120	4233	3882	3993	4197	1	
		4482	2664	2444	2513	2642	2+	

Enhancement of the Revealed Preference Data

Adding Storm Specific Data

As stated earlier, one of the objectives of this study was to add time-dependent characteristics of Hurricane Gustav to the RP data. To accomplish this, the time-dependent path taken by Gustav and the time-dependent category of the storm were retrieved from the National Hurricane Center website. Action taken by public officials, such as whether or not evacuation orders were given and what type of evacuation order was issued, was retrieved from archives of newspapers and Wikipedia.

Potential Flooding of Each Household

Another important piece of information added to the RP data was related to the storm surge zone in which a household was located. To do so, all households were geocoded in TransCAD by using the address provided. A geographic file containing the information of the maximum elevation of water level, downloaded from the National Hurricane Center website, was overlayed on the geocoded layer to extract the water elevation level for each household for several hurricane categories. Then the ground elevation level for each household was extracted by overlaying the geocoded households on a geographical layer, downloaded from USGS website, containing ground elevation information. Finally, the net storm surge height was computed as the difference between the storm surge height and the ground elevation level. If the net storm surge level was greater than 10 feet, then it was coded as one or else it was coded as zero. The value of 10 feet was used because the home sites in the New Orleans area are often raised above mean ground level due to the construction of retention ponds or lakes, depressed roads, and raised foundations.

Adding Time-dependent Distance for Each Household

Time-dependent distance between the geographical location of a household and the center of a hurricane was considered an important variable. To measure the distance between a household and the center of a storm, a geographic point layer was created in TransCAD using latitude and longitude information of households and the path of the hurricane from data available at the National Hurricane Center website. The shortest distance matrix utility available in TransCAD was then used to measure time-dependent distance between households and the position of the storm in each time interval.

ANALYSIS AND RESULTS

Results from the Revealed Preference Survey

Introduction

Hurricane Gustav developed into a tropical storm southeast of Port-au-Prince, Haiti, on August 25, 2008 and then rapidly strengthened into a hurricane on August 26. It made landfall on the island of Haiti, inundated Jamaica, and ravaged Western Cuba. After moving into the Gulf, Gustav gradually weakened to a Category 2 hurricane late on August 31 and remained at that intensity until landfall on the morning of September 1 near Cocodrie, Louisiana. While Hurricane Gustav was looming in the Gulf, it threatened New Orleans and triggered mass evacuation from the area, thus providing the opportunity to study evacuation behavior and use it for the current study.

Socio-Economic Characteristics of the Survey Sample

As stated elsewhere, the sample size of the data collected in this study was 300 households. The data included the socio-economic characteristics of the household, RP evacuation behavior data from Hurricane Gustav, and dynamic SC data from three hypothetical hurricanes for each household. While the socio-economic data was collected using both the recruitment script, shown in Appendix A, and the RP questionnaire, dynamic SC data was collected using the SC response sheet/questionnaire. The data thus collected was synthesized into a single Excel database with the data from each household being presented on a single row and several columns. The codebook describing the variables, their formatting, and their coding is shown in Appendix H.

The response rate for the study was 12 percent. The method used to calculate response rate is described in the metadata to the survey in Appendix G. Other information, such as the time period in which the survey was administered and other details of the survey which might be of interest to researchers intending to either use the data or replicate the procedure, is also provided in the metadata.

The sampled households that participated in this study came from 10 parishes as shown in Figure 1. The size of the sample for each parish is shown in Table 4 below. As can be seen from the sample distribution, parishes which have higher population had correspondingly larger sample sizes. It should be noted that it was not the purpose of the study to collect a specific size sample in each parish, but rather the sample sizes were the consequence of using simple random sampling.

Table 4
Geographical distribution of the sample

Parish Name	Sample Size[1]
Jefferson	90
Lafourche	18
Orleans	29
Plaquemines	3
St. Bernard	4
St. Charles	10
St. John the Baptist	9
St. Tammany	64
Terrebonne	36
Tangipahoa	25

The socio-economic characteristics of the sample such as type of house, vehicle ownership, household size distribution, number of household members less than 17 years age, pet ownership, length of residence and household income are summarized in the following pages. The data summarized here is weighted data; the sample data weighted by using the combined weighting and expansion factors in Table 3.

One of the important variables known to influence evacuation behavior is the type of house in which a household resides. At the recruitment stage of the survey, every participating household was asked about the type of house they live in. The majority of survey participants, about 80 percent as shown in Figure 4, reported that they live in a permanent house. The other 20 percent of survey participants answered that they live in a mobile home, apartment, or other dwelling type. Previous research has shown that mobile homes are more vulnerable to storm damage than other structures and residents of mobile homes evacuate more readily. However, there were insufficient respondents living in mobile homes in this sample to be able to capture the impact of mobile homes on evacuation behavior.

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1 The individual samples add up to 288 households even though data was collected from 300 households. This is because the addresses of 12 households were not available and thus their location could not be identifiable geographically.

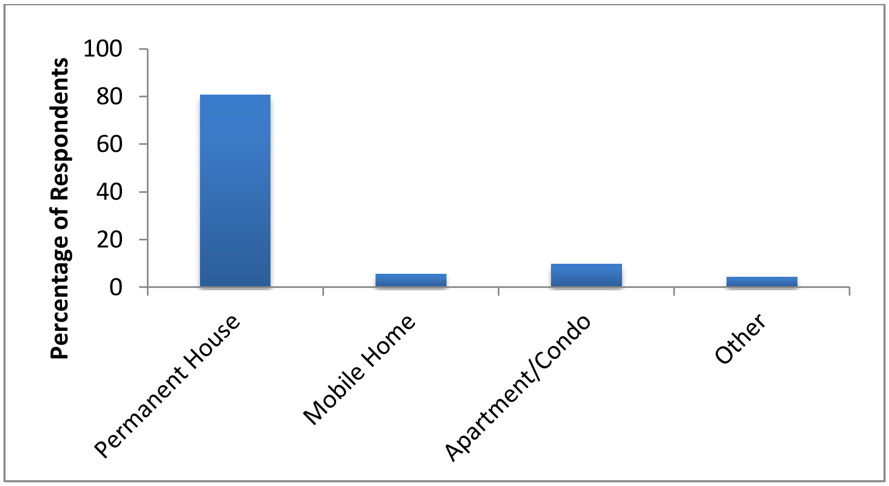

Figure 4
Distribution of type of house

The number of vehicles owned by a household is not known to have a direct impact on the decision whether to evacuate or not, but having no vehicle at all is likely to inhibit evacuation. As shown in Figure 5, 15 percent of households reported that they do not own any vehicles, while the remaining households predominantly have one or two vehicles. Most zero car-owning respondents come from the more centrally located parishes of Orleans and Jefferson.

Information on the number of members living in a household was also collected from survey respondents along with the other socio-economic data. Approximately 70 percent of the households as shown in Figure 6, reported having two or more members in their household and the average household size was estimated to be 2.5 persons. This information was useful in moving from households to people when estimating the total number of people who participated in evacuation during Hurricane Gustav.

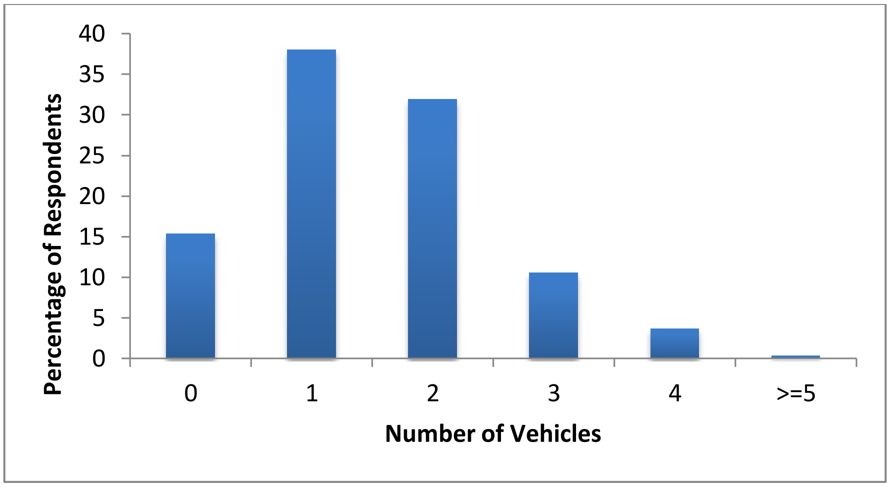

Figure 5
Vehicle ownership among respondents

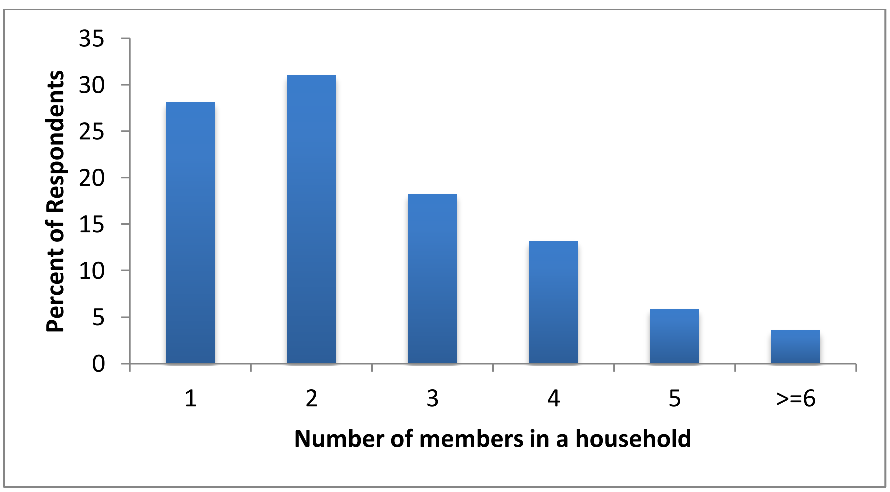

Figure 6
Household size distribution

One of the socio-economic characteristics of a household that is believed to influence their evacuation behavior is the presence of children who are younger than 17. As shown in Figure 7, 70 percent of households reported that they do not have any children younger than 17 in their household.

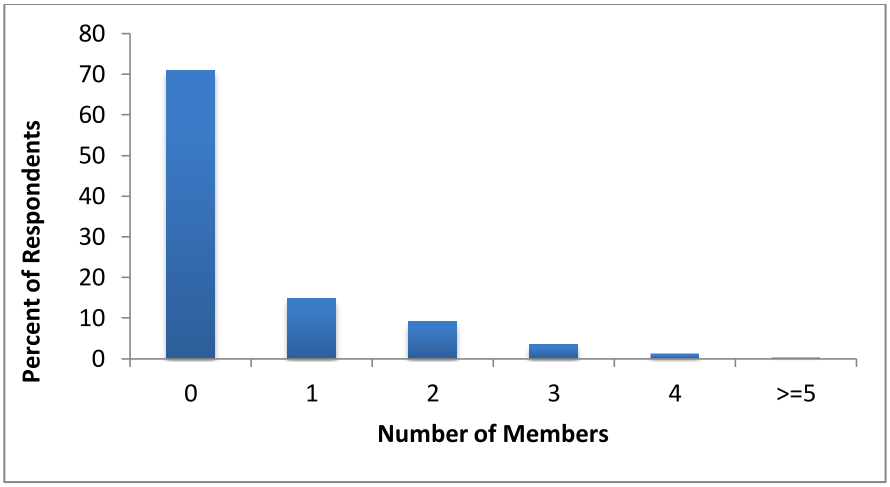

Figure 7
Households with members younger than 17

Pet ownership is yet another socio-economic characteristic that is believed to influence a household's behavior during hurricane evacuation. Past research has suggested that households that own pets are less likely to participate in evacuation because places of accommodation (hotels, motels, and shelters) may forbid pets. Thus, to make use of this finding, information on pet ownership was collected. Forty-six percent of the households in the sample reported that they own a pet.

Believing that the length of residence at a particular residence may also influence how a household behaves when threatened by a hurricane, survey participants were asked the length of time they lived in their current residence. Based on the reported length of time, the households were then categorized into three periods: 0 to 5 years, 6 to 10 years, and greater than 10 years. Fifty percent of households reported that they have been living at their current residence for 10 years or more, 25 percent of households reported that they have been living at their current residence for greater than 5 years, but less than 10 and the remaining 25 percent reported that they have been living at their current residence for five years or less.

Household income is believed to have a higher influence on a household's decision on evacuation than other socio-economic characteristics. In accordance with this belief, and with the intent of using it for further analysis, all sampled households were asked to report their income. Figure 8 shows the reported income distribution of households that participated in this study. The weighted household median income of the sample is $ 45,000.

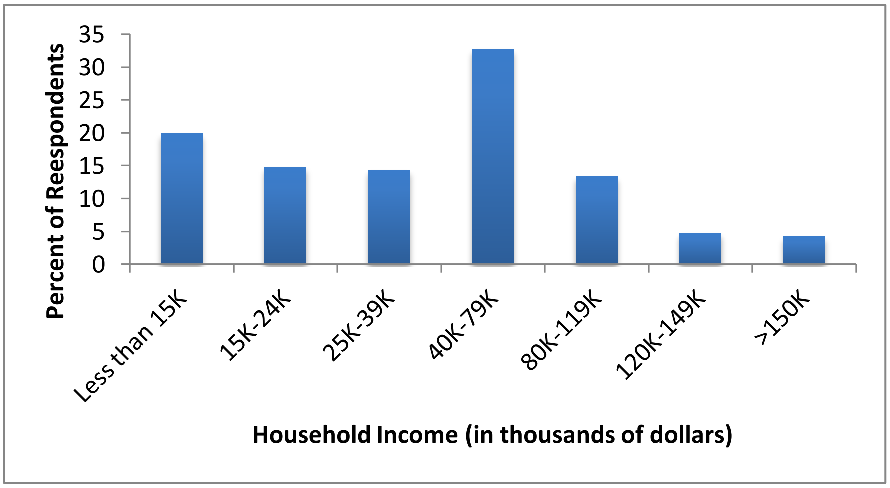

Figure 8
Weighted household income distribution

Evacuation Behavior for Hurricane Gustav

Apart from socio-economic characteristics, the RP questionnaire also collected hurricane evacuation behavior for Hurricane Gustav from the sampled respondents. The evacuation behavior is summarized in the following paragraphs.

Hurricane Gustav was a relatively weak storm heading south of New Orleans area by the time it made landfall. However, it was as high as a Category 4 at one stage and triggered mass evacuation in Orleans and surrounding parishes, in that 67 percent of the households in the weighted sample reported evacuating for Hurricane Gustav. This high rate of participation is likely due to the experience with Hurricane Katrina in New Orleans just three years earlier.

Figure 9 shows the cumulative percent of evacuating households with date and time. As seen in the figure, 15 percent of evacuating households evacuated spontaneously without any evacuation order, 25 percent of evacuating households evacuated while a voluntary evacuation order was in effect, and the remaining 60 percent evacuated after issuance of a mandatory evacuation order.

Respondents were also asked about the reasons behind their evacuation decisions, whether they evacuated or did not evacuate, and were given a choice of selecting more than one reason. Among those that chose to evacuate, the majority cited that they were either concerned about flooding or they heeded advice to evacuate. There were other reasons cited by evacuees as shown in Table 5, but these were not as significant. For example, very few households cited that advice or an order from police officer as the reason because they were never used.

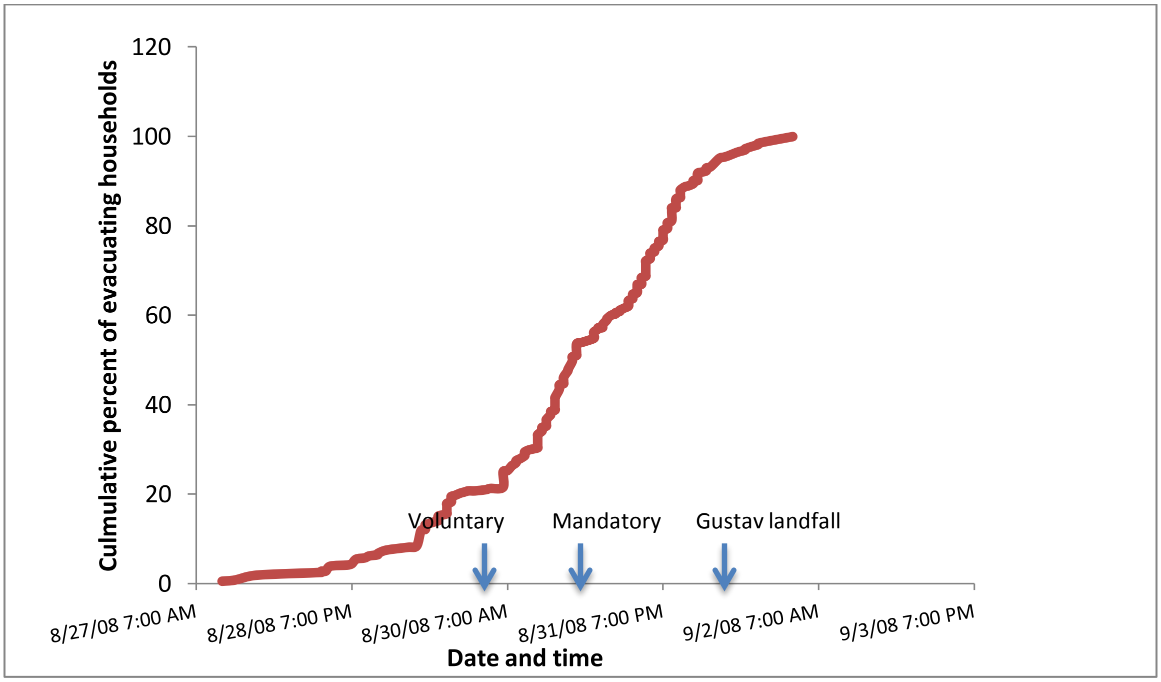

Figure 9
Evacuation timing for hurricane gustav

From a researcher's perspective, it is always interesting to learn the reasons behind evacuating. However, it is often difficult to use these reasons in a model predicting future behavior because most reasons cited are subjective, temporal, and difficult to predict. For example, it would be difficult to predict the advice that family, friends, or neighbors would give, and even predicting the advice the weather service would give would be difficult. On the other hand, many of the factors quoted as influencing the evacuation decision in Table 5 are probably correlated (e.g. advice factors and evacuation orders) so that capturing the influence of one variable is likely to lead to capture of part of the influence of others.

Table 5
Reasons for evacuating

Reason for evacuating	Percent of evacuating households
Advice from weather service	55
Evacuation orders from emergency /elected officials	48
Concerned flooding would flood home/ cutoff roads	46
Advice from family/friends/neighbor	45
Concerned strong winds would damage house	41
Advice from media	27
Other	23
Storm got stronger	13
Advice or order from police officer/firefighter	5

When asked about the reason for not evacuating, the majority of the non-evacuees responded that they believed their house was adequate for protection from the storm. While the reason behind their belief is unknown, this behavior was consistent with what is reported in the literature *[3]*. As with the reason for evacuating, the reason for not evacuating is purely subjective and so cannot be used in modeling evacuating behavior. Table 6 shows the list of reasons and their corresponding percentages.

Table 6
Reasons for not evacuating

Reasons for not evacuating	Percent of non-evacuating households
Storm not severe or house adequate	55
Wanted to protect property from storm	23
Traffic too bad	18
Left unnecessarily in past storms	17
Forecasts indicated low chance of hit	15
Wanted to protect property from looters	15
Other	14
Could not afford it	13
Waited too long to leave	9

Reasons for not evacuating	Percent of non-evacuating households
Had no transportation	8
Job required staying	8
Officials did not say to evacuate	6
Friend or relative said evacuation unnecessary	5
Tried to leave – traffic too bad	5
Shelter would not accept pets	5
Too dangerous - might get caught in storm	3
Required special medical care	3
Don’t know	1

As shown in Table 7, approximately 96 percent of the evacuees stated that they either used car or van to evacuate. Other modes of transportation, like bus, train, or sharing ride with someone else, were used sparsely. This does not suggest that nobody used train or bus to evacuate but that among people who participated in the study, very few used modes of transportation other than car. From the researcher’s perspective this information is useful in predicting future evacuation mode use.

Table 7
Evacuation mode for evacuating households

Evacuation Mode	Percent Evacuation Households
Car/Suv/Truck	96.1
RV	0.3
Bus	0.8
Train	0
Walk	0
Ride with someone else	2.8

The number of vehicles used by evacuees is important information in estimating vehicular flow on the network and, ultimately, in estimating clearance time. As shown in Figure 10, 35 percent of evacuees used two or more vehicles to evacuate.

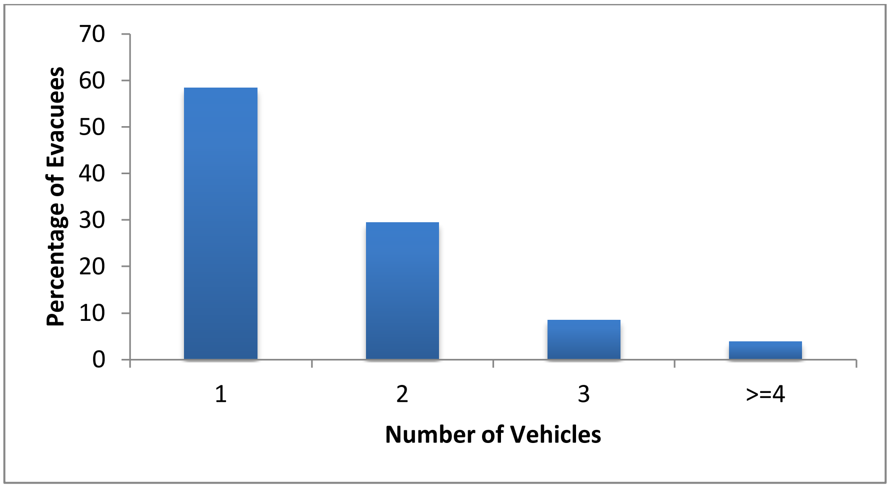

Figure 10
Number of vehicles used in evacuation

Vehicle occupancy, which is defined as the number of people present in a vehicle, was also collected along with the number of vehicles used by evacuating-households. From the evacuation research perspective, occupancy helps in estimating the number of people who evacuate from a hurricane threatened area in a fixed amount of time, if traffic counts are available, and also to test alternative policies, like testing introduction of managed lanes. With the expectation of more application of vehicle occupancy in future research, vehicle occupancy data was also collected along with the vehicle usage data. Average weighted occupancy for the households that used one vehicle was two persons/vehicle, for the households that used two vehicles it was 2.65 person/vehicle and for the household that used three or more vehicles it was 2.83 persons/vehicle.

Some evacuating households tow their trailers or boats while evacuating. The higher the number of households that tow trailers/boats the more time it will take to evacuate an area. This is because a single trailer occupies more road space and thus lowers the capacity of the roads.

As shown in Table 8 below, five percent of evacuating households reported that they towed trailers while evacuating. This implies that approximately 20,000 of the evacuating households towed a trailer and thus increased the traffic on the evacuation routes accordingly.

Table 8

Number of trailers/boats pulled by evacuating households

Number of Trailers Pulled	Percent of Evacuating Households
0	94.3
1	4.7
2	1.0

Evacuees were also asked about the type of refuge they sought for shelter. As shown in Table 9, 44 percent of households answered that they went to the homes of friends or relatives and 46 percent of the evacuees answered that they stayed at a hotel or motel. Less than 15 percent of the evacuees said that they stayed at a public shelter, church, work place, or other type of shelter. These results are consistent with the results reported in the study jointly conducted by U.S. Army Corps of Engineers and Federal Emergency Management in 1999 *[36]*. In their study they reported that 45 percent of evacuating households used friend or relative's homes as a place of refuge while 30 percent used a hotel or motel. The trend of low public shelter usage as a type of refuge is common when a higher percentage of people evacuate significant distances inland.

Table 9

Type of refuge

Type of Refuge	Percent of Evacuating Households
Hotel/Motel	46.4
Friend/Relative	43.7
Other	7.0
Church	1.6
Public Shelter	1.5
Work Place	0.6

Along with the type of refuge, evacuees were also asked about the state where the refuge was located. As indicated in Figure 11, about 73 percent of evacuees traveled to states other than Louisiana, of which about 10 percent traveled to states other than the ones shown in the chart. The reasons for a substantial number of evacuees seeking refuge outside Louisiana might be 1) destination region's close proximity to Louisiana (particularly Mississippi) and also 2) due to presence of major metropolitan areas in the states like Texas and Georgia that are capable of providing refuge in the form of hotels/motels.

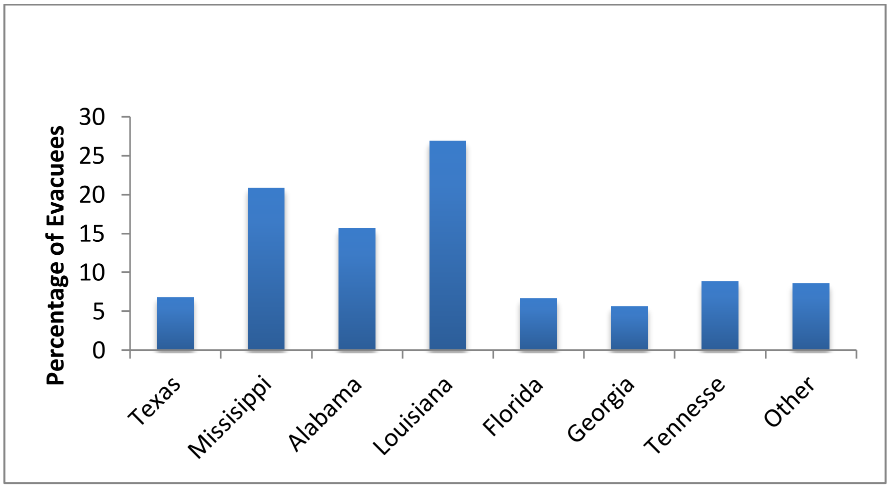

Figure 11
Evacuation destination

Most post-event hurricane evacuation studies don't collect data about time of departure from an origin and the time of arrival at a destination. Even though this information is not of any significance to social scientists, it provides valuable information for transportation modeling purposes.

Evacuees participating in this study were asked to provide information on time of departure and time of arrival. The information was then used to compute travel times for all evacuating households. As shown in Figure 12, 70 percent of households took less than 16 hours to reach their respective destinations. However, a few households reported evacuating as far as Wisconsin and thus took 24 hours or more to reach their destinations. Additionally, a few households also reported seeking temporary refuge at RV parks and other rest areas before proceeding on to their final choice of destination. These factors might have contributed to the relatively high percentage of respondents in the group taking 24 to 28 hours traveling. Travel time can be used as a variable to measure the effectiveness of different policies initiated by emergency management officials while managing evacuation and thus plays a crucial role in testing alternative policies.

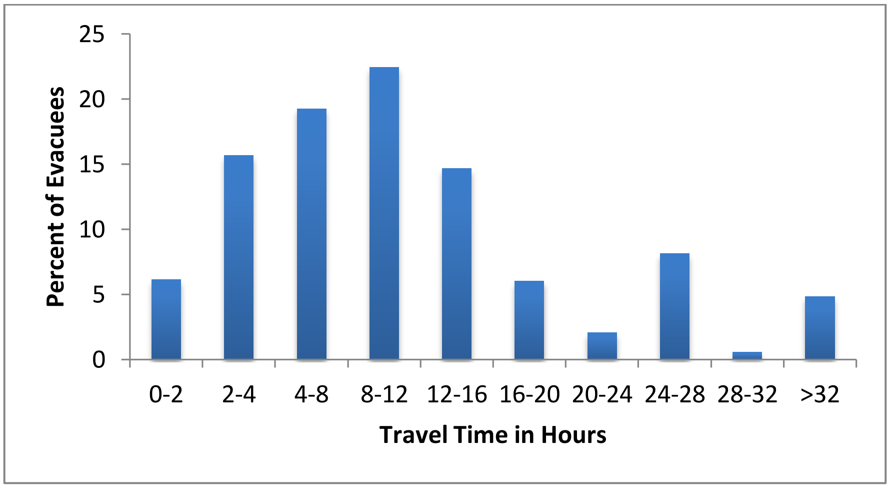

Figure 12
Travel time distribution for evacuees

New Orleans has a city-assisted evacuation plan to evacuate people who are transportation-disabled. To implement the city-assisted evacuation plan, it is important to plan for resources based on the evacuation demand. Thus, with the idea of helping emergency planners, a question was included in the RP questionnaire that asked respondents if anyone in their household required any assistance while evacuating. Ten percent of evacuating households responded that they required some kind of assistance while evacuating for Hurricane Gustav.

An important characteristic of a household that is thought to influence evacuation behavior is whether the head of a household is required to stay as part of their job. For example, a policeman or a bus driver might be required to stay to perform essential services. When a respondent was asked whether or not their job required them to stay, 10 percent answered in the affirmative (see Figure 13). However, if this is broken down among those that evacuated and those that did not, 8.5 percent of evacuees said yes while 12.5 percent of non-evacuees said no. Thus, a job requiring a member of the household to stay in the area seems to inhibit evacuating but it does not prevent it. Clearly, the rest of the household evacuates while the person required to remain does so.

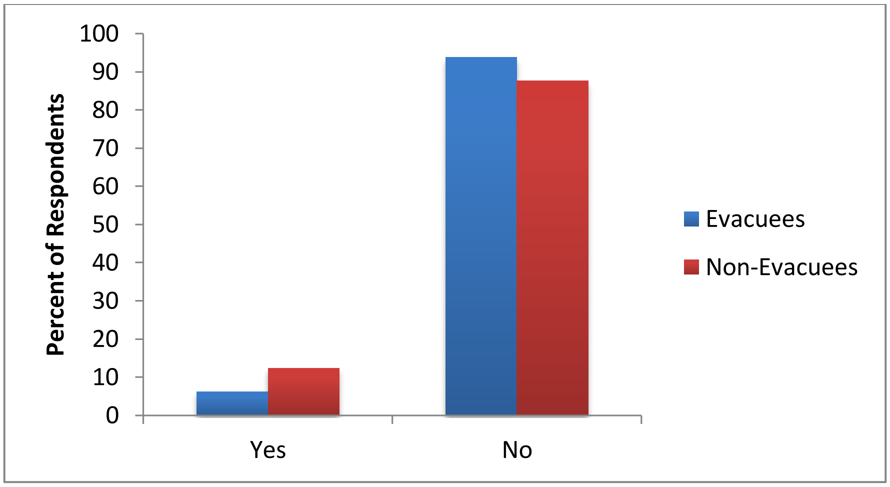

Figure 13
Job requires staying during an evacuation

Results from the Time-Dependent, Audio-Visual, Stated Choice Survey

As discussed earlier, survey respondents were shown a total of nine hypothetical storms. The following sections present the evacuation behavioral results from the Time-Dependent, Audio-Visual Stated Choice Survey (TDAVSCS).

Validity of the newly collected data is a central issue when establishing a new method like TDAVCS. There are several ways to validate the data collected. One can either compare the newly collected data with the data collected using the traditional method or look for the presence of general patterns in the new data. For example, a general trend that is observed in evacuation behavior when an impending hurricane threatens a geographical area is that a lower proportion of people evacuate when a hurricane is 75 hours or more from making landfall, followed by a peak in percentage of people evacuating between 40 and 24 hours, before dropping to low values when the hurricane is less than 20 hours from making landfall. Yet another trend that is very prominent and consistently observed across all hurricanes is that a higher percentage of people evacuate when an evacuation order is in effect as compared to no evacuation order at all. In an effort to validate the stated choice data collected from the sampled respondents, the data was investigated for general trends by plotting stated evacuation intentions against variables like time to expected landfall, hurricane category, evacuation orders, and time-of-day. In addition, the stated behavior for

Hypothetical Storm 7 (which was identical to Hurricane Gustav) was compared with the actual behavior of respondents to Hurricane Gustav as recorded in the RP data.

Hypothetical Storm 1

Storm1 was presented to survey respondents as a storm that was initially positioned in the Gulf of Mexico as a Category 4 hurricane. In forecasts following the first forecast (Forecast 2 and Forecast 3), the hurricane category was kept at 4 and the evacuation order was upgraded to a Mandatory from None as the storm advanced towards Louisiana. Storm 1 can generally be considered to represent a strong hurricane since it remained at Category 3 or above throughout its travel through the Caribbean and the Gulf.

While presentations of the forecasts were in progress, respondents were asked about their expected behavior and 77 percent stated they would evacuate. Of all households intending to evacuate, 60 percent reported they would evacuate before the storm was 25 hours from making landfall (see Figure 14). This pattern of relatively early evacuation was probably affected by the high intensity of the storm: Category 4, while the storm was 32 hours or more from landfall, but weakening to Category 3 at 18 hours to landfall. This seems to be verified by the fact that 97 percent of respondents who intended to leave stated they would leave when the hurricane was at its peak strength of Category 4. This behavior is consistent with observed behavior in other storms, such as Hurricane Gustav. The evacuation orders issued at 50 hours to landfall complemented the motivation to evacuate generated by the intensity of the storm up to 32 hours before landfall, but then there is a relatively rapid dropoff in evacuation rate as the storm weakens to a Category 3 at 18 hours to landfall.

Generally, people prefer to evacuate during the day rather than at night and, particularly, they prefer to evacuate during the daylight morning hours *[4]*. This is shown to be the case in the reported values for storm 1 as shown in Figure 15. However, almost 30 percent of the respondents evacuated in the early hours of the morning (12 am to 6 am) which is not entirely typical if there are not external influences affecting their behavior. In this case, the change from a voluntary to mandatory evacuation order at 12:15 am and the persistence of the storm at Category 4 resulted in the relatively large proportion of evacuation in the early hours of the morning.

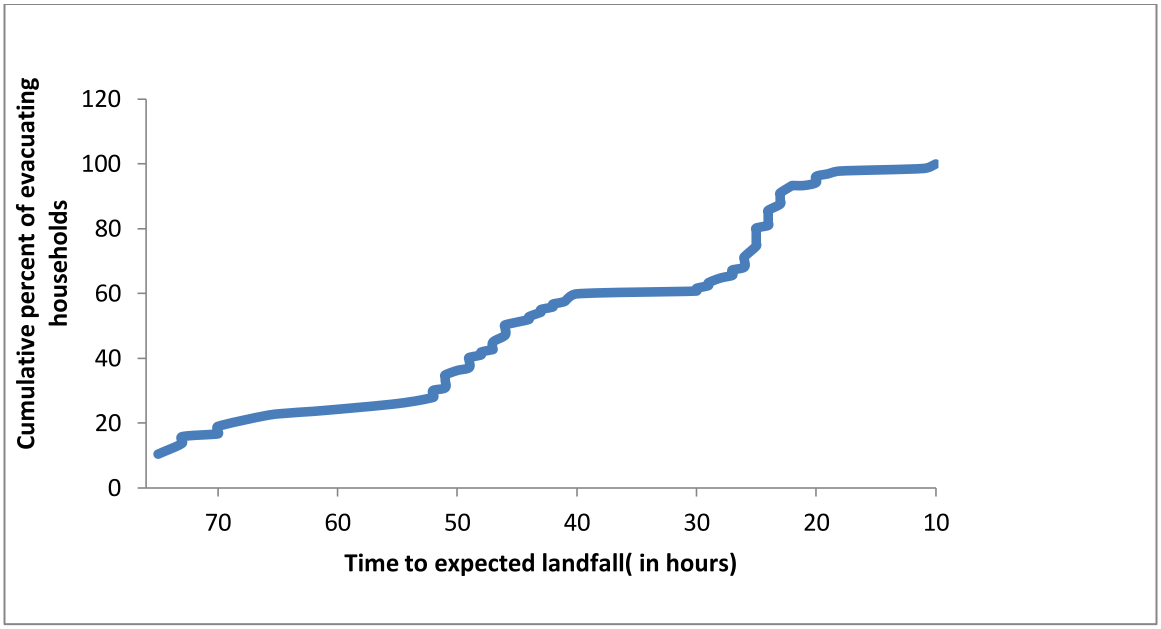

Figure 14
Influence of time to expected landfall on evacuation behavior for Storm 1

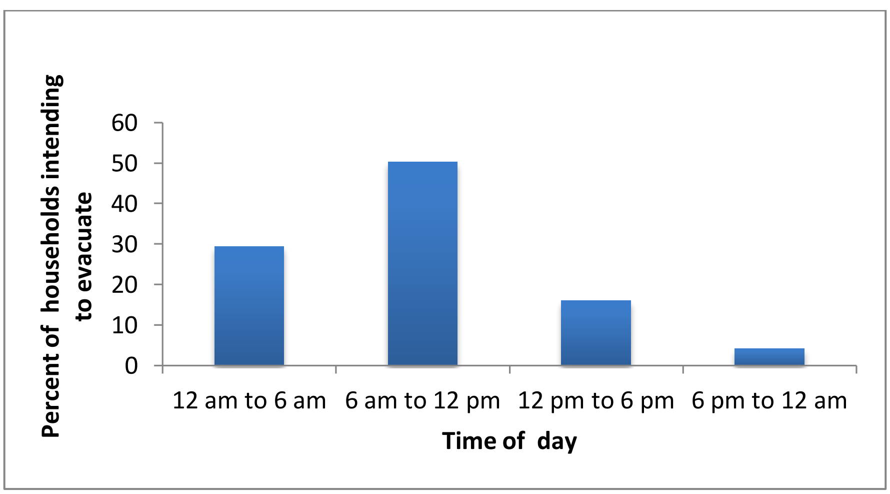

Figure 15
Influence of time-of-day on evacuation behavior for Storm 1

Taken as whole, the stated evacuation response for Storm 1 was very consistent with expected behavior. That is, the stated intentions of the respondents to the portrayed conditions appear to generate very plausible and realistic responses. Nonetheless, the evidence is not complete enough to establish confidence in the new method. Therefore, a further investigation was carried out to identify general evacuation patterns.

Hypothetical Storm 2

While Storm 1 was presented as a storm that did not vary its strength a great deal over time, Storm 2, in contrast varied its strength considerably from one period to another. Storm 2's strength varied from a high of Category 5 to a low of Category 2. The change in storm intensity over time can be observed in Table 2.

Of households who watched the videos of Storm 2, 79 percent reported their intention to evacuate. As shown in Figure 16, 70 percent of all households intending to evacuate stated that they would like to evacuate before the storm is 20 hours away from making landfall. Interestingly, this is considerably less than the 32 hours when the majority of households stated they would evacuate in Storm 1. This could be due to the sustained strength of the hurricane in Storm 1, and the weakening intensity of the storm in Storm 2. It is also interesting that more households expressed an interest in evacuating when the hurricane strength was Category 4 or 5 earlier in its approach.

As shown in Figure 17, 43 percent of evacuating households stated that they would evacuate when hurricane strength reaches category 4 and 51 percent when hurricane strength reaches Category 5. This behavior is both expected and observed in reality.

Evacuating households, as shown in Figure 18, showed a strong tendency to evacuate during the daytime between 6 am and 12 pm followed by a second preference to evacuate between 12 pm and 6 pm. It should be noted though that storm 2 had a projected time of landfall of 72, 45, 19, and 8 hours, which allowed proximity of the storm to reinforce the preference to evacuate during daylight hours.

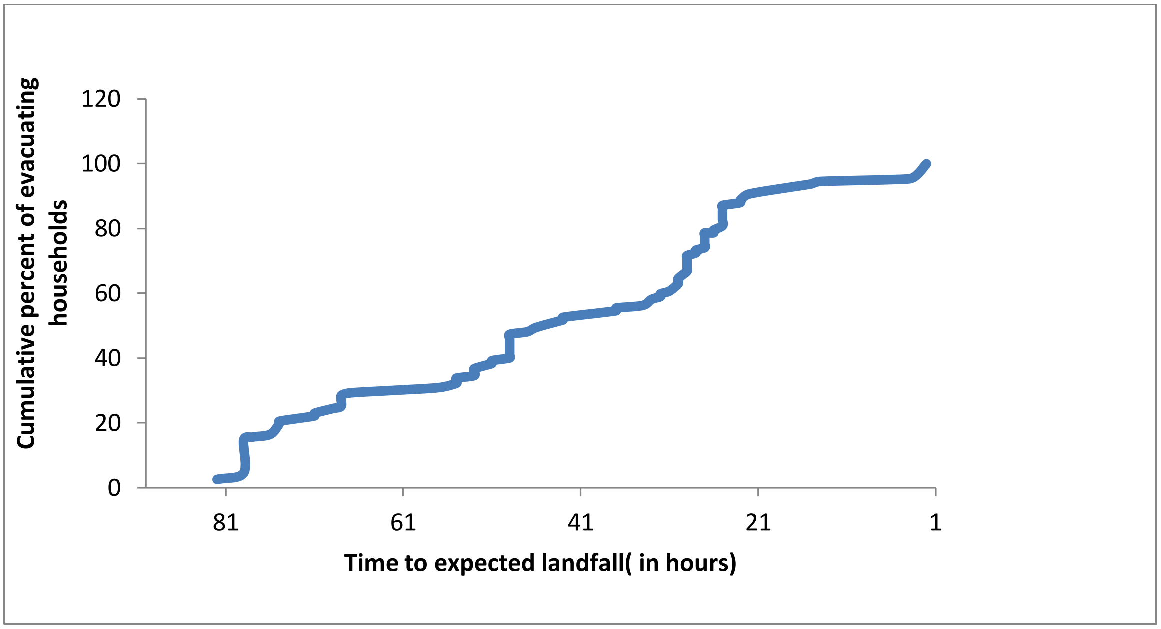

Figure 16
Influence of time to expected landfall on evacuation behavior for Storm 2

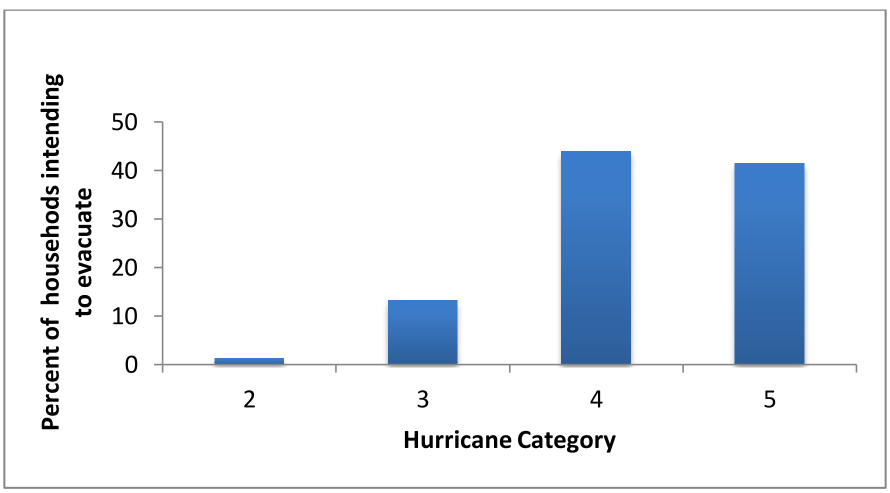

Figure 17
Influence of hurricane category on evacuation behavior for Storm 2

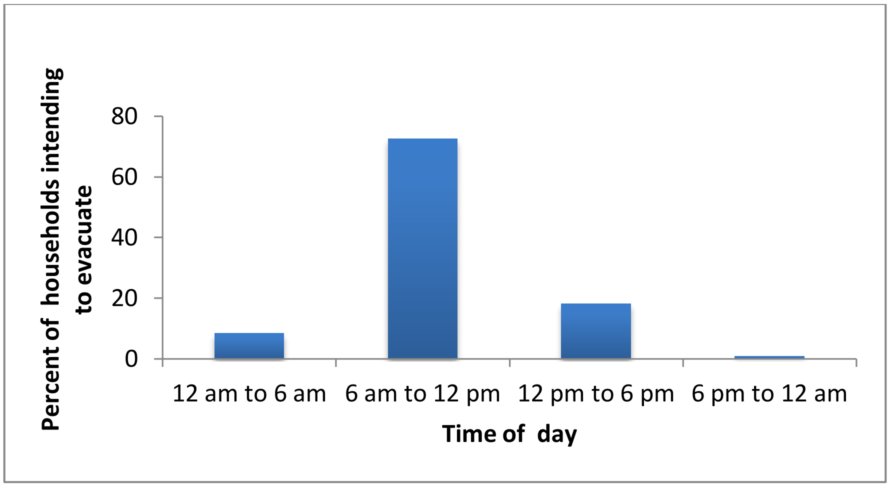

Figure 18
Influence of time-of-day on evacuation behavior for Storm 2

Hypothetical Storm 3

Hypothetical Storm 3 was portrayed as a storm that was active during the weekend (i.e. Saturday through Monday). This was made to actively engage survey participants in the question of evacuating over the weekend and how it may differ from evacuating during the week. For example, most households have a different set of activities over weekends compared to weekdays, such as going to work or school versus household members being together over the weekend. The time-to-expected landfall varied between 68 hours and 11 hours and the hurricane category alternated between three and four.

For Storm 3, 73 percent of households stated they would evacuate. As shown in Figure 19, the majority (40 percent) of those who would evacuate stated they would want to evacuate when the storm is 33 hours away from making landfall, although the steep drop-off of evacuees occurs at approximately 20 hours from landfall as in the case of Storm 2.

Hurricane category combined with evacuation orders elicited more response than hurricane category alone. As shown in Figure 20, the majority of households (66 percent) stated they would evacuate when hurricane strength reached Category 3. Normally, one would expect a higher evacuation response for a higher category storm but Storm 3 reached Category 4 for only one time period (time period 2, when the storm was still 44 hours from expected landfall) and therefore did not elicit a strong response from risk-taking individuals who wanted to wait until the storm got closer.

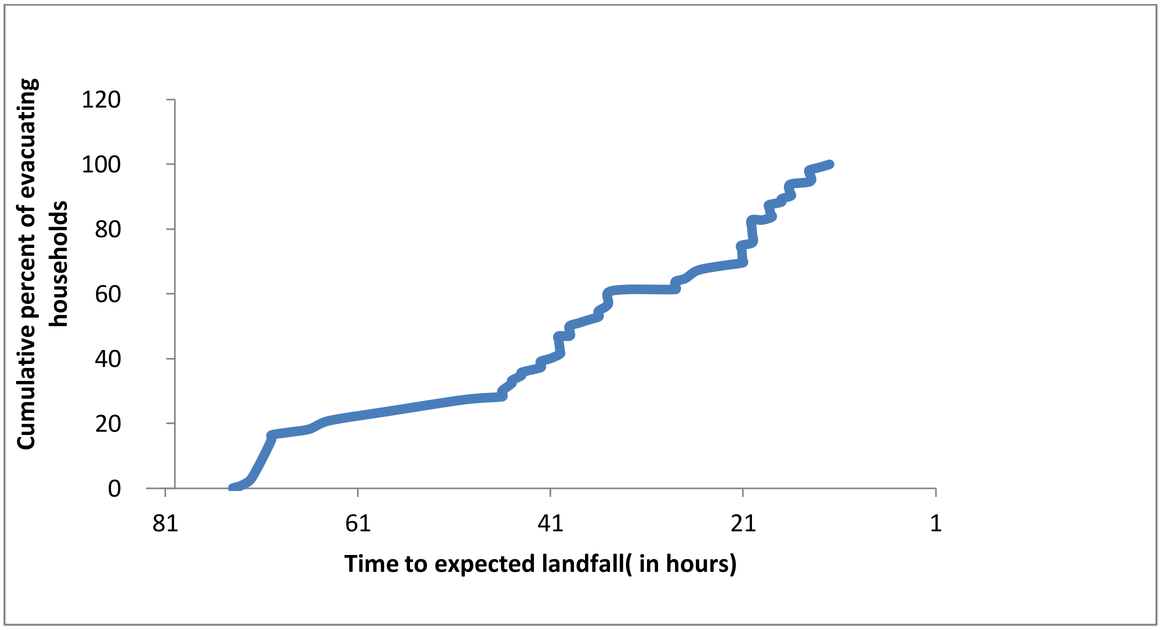

Figure 19
Influence of time to expected landfall on evacuation behavior for Storm 3

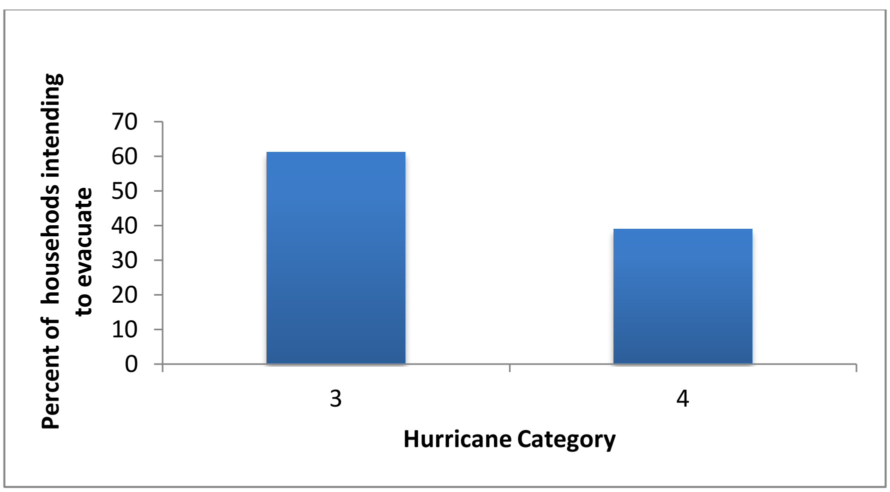

Figure 20
Influence of hurricane category on evacuation behavior for Storm 3

The influence of evacuation orders and time-of-day was as expected and is shown in Figure 21 and Figure 22 Of the households that did evacuate, 94 percent stated they would do so when either a voluntary or mandatory evacuation order was issued. Of the households who stated they would evacuate, 38 percent wanted to do so between 6 am and 12 pm.

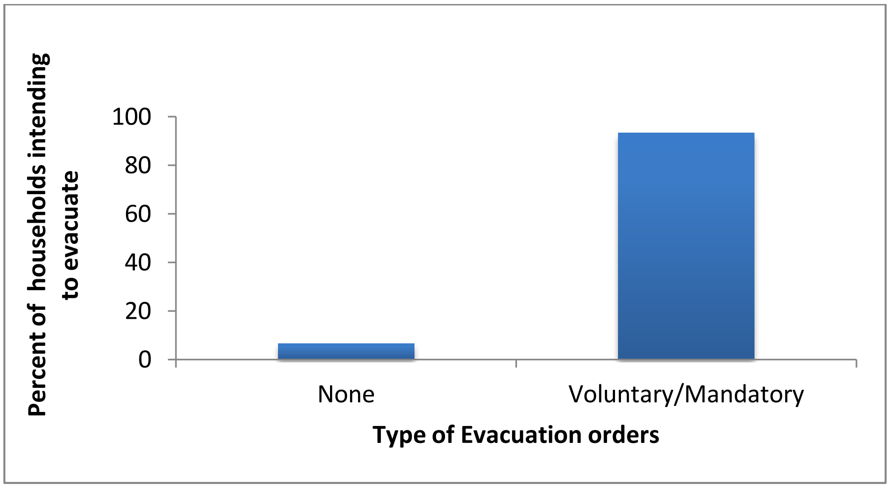

Figure 21
Influence of evacuation orders on evacuation behavior for Storm 3

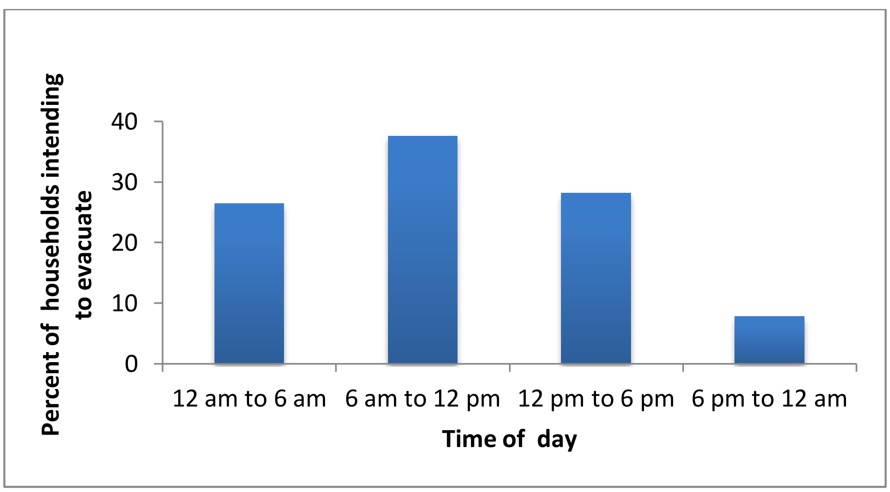

Figure 22
Influence of time-of-day on evacuation behavior for Storm 3

Hypothetical Storm 4

Hypothetical Storm 4 was a storm that started out strong but quickly weakened. Its was downgraded from Category 5 in Forecast 1 to Category 3 in Forecast 2, and then to Category 2 in Forecast 3, where it stayed till landfall. The evacuation order was never upgraded above voluntary and stayed at that level for Forecasts 2, 3, and 4.

Because of the mild nature of Storm 4 in its later stages, it elicited fewer evacuations than Storms 1, 2, and 3. Seventy percent of households reported that they would evacuate and of those evacuating, the majority (70 percent) wanted to evacuate before the storm was 45 hours away from making landfall as shown in Figure 23. This is because the respondents perceived only a small threat from a Category 2 hurricane and gave little credence to the voluntary evacuation order that was in effect from Forecast 1.

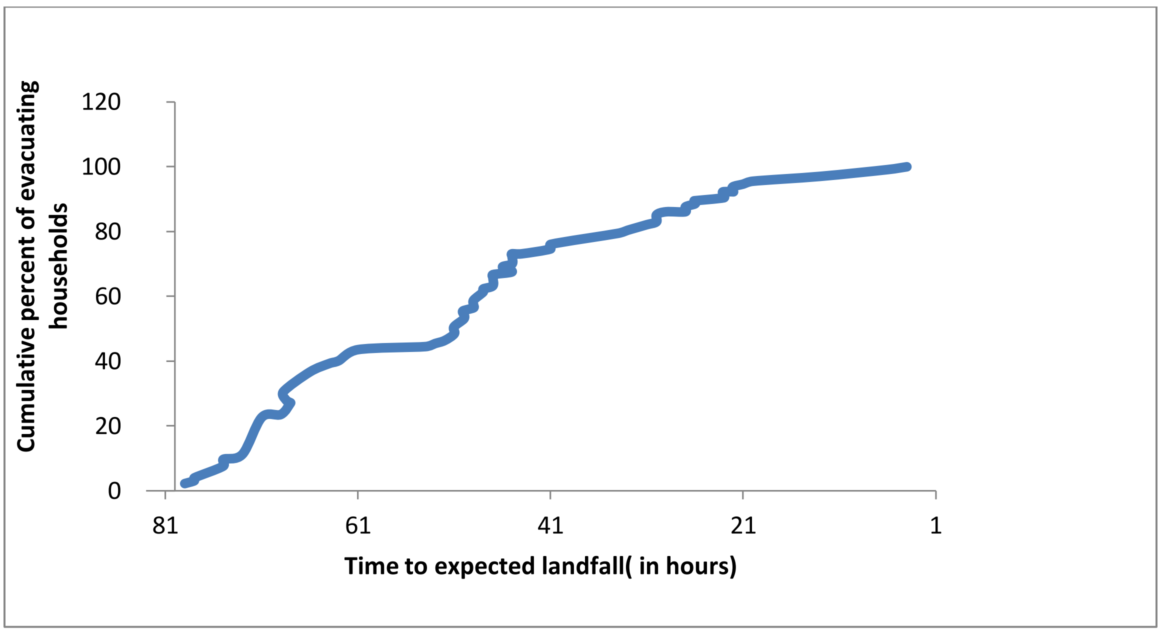

Figure 23

Influence of time to expected landfall on evacuation behavior for Storm 4

The influence of hurricane category on evacuation rate was as expected, as shown in Figure 24 where more households (70 percent) chose to evacuate when the storm was a Category 5 than when it weakened.

As the case with other storms, more households showed an interest in evacuating during the daytime than nighttime, as illustrated in Figure 25. Storm 4 was at its most intense during the first reporting period, which was 12:30 pm during a weekday (Wednesday). Thus, the general preference for daytime evacuation could be easily satisfied during the time when storm was most threatening.

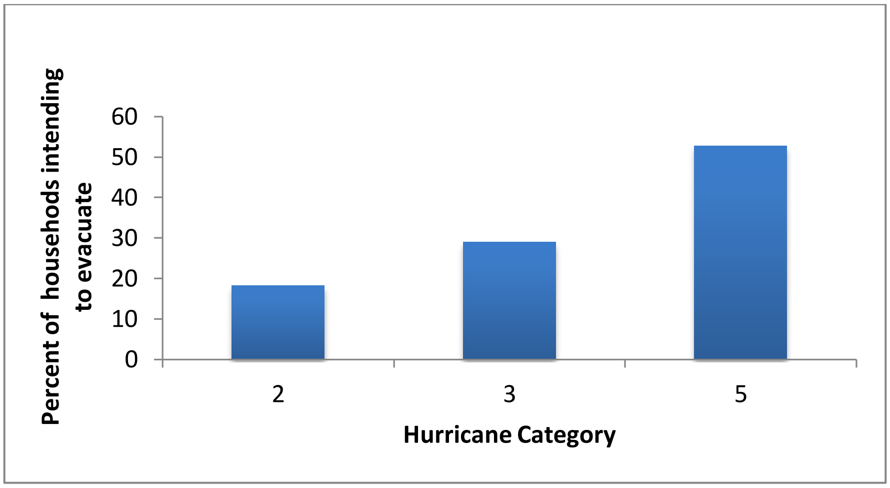

Figure 24
Influence of hurricane category on evacuation behavior for Storm 4

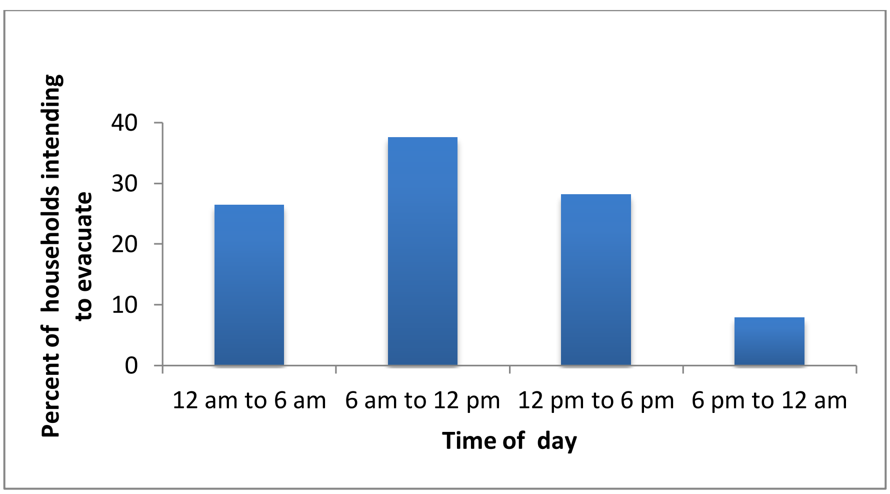

Figure 25
Influence of time-of-day on evacuation behavior for Storm 4

Hypothetical Storm 5

Hypothetical Storm 5 was one of the weak storms included in the study, although there was a brief period when it became a Category 5 before dropping precipitously to a Category 1 at landfall. Hypothetical Storm 5 was a Category 5 during the second forecast (49 hours from projected landfall), but dropped to a Category 2 in Forecast 3 and a Category 1 in Forecast 4. Storm 5 was not threatening enough to draw a strong response from the survey participants. Therefore, only 57 percent of households, as compared to 77 percent for Storm 1, stated that they intended to evacuate. As displayed in Figure 26, 68 percent of evacuating households wanted to evacuate when the storm was 34 hours away from making landfall. This early response was the result of the storm intensity being a Category 5 at this time, and a voluntary evacuation order being in effect. The drop-off in evacuation rate in later time periods was due to the fact that the storm intensity dropped from 5 to 2 to 1, and the voluntary evacuation order was withdrawn.

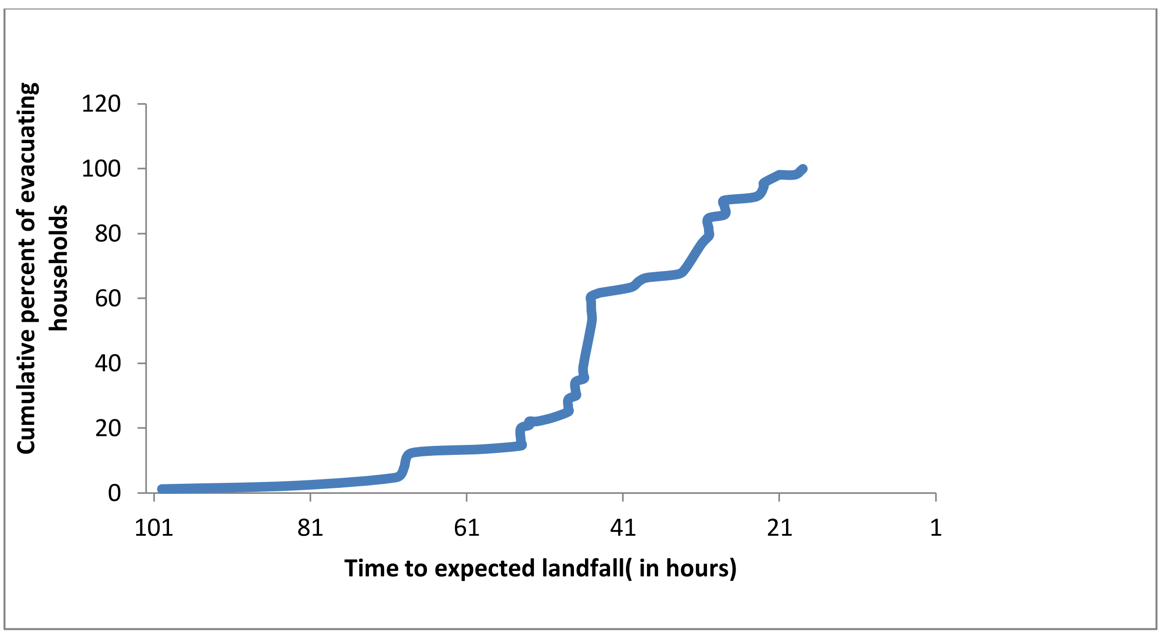

Figure 26

Influence of time to expected landfall on evacuation behavior for Storm 5

It is interesting to note in Figure 27 that in Storm 5, 50 percent of the evacuating households stated they would evacuate between 12 pm and 6 pm rather than between 6 am and 12 pm, which is usually the preferred time. This behavior is the result of portraying Storm 5 as a

Category 5 storm in Forecast 2 at 12:30 pm, which falls in the 12 pm to 6 pm time-of-day category. Thus, once again, rational behavior of the respondents to conditions portrayed in the audio-visual presentation is evident in their responses.

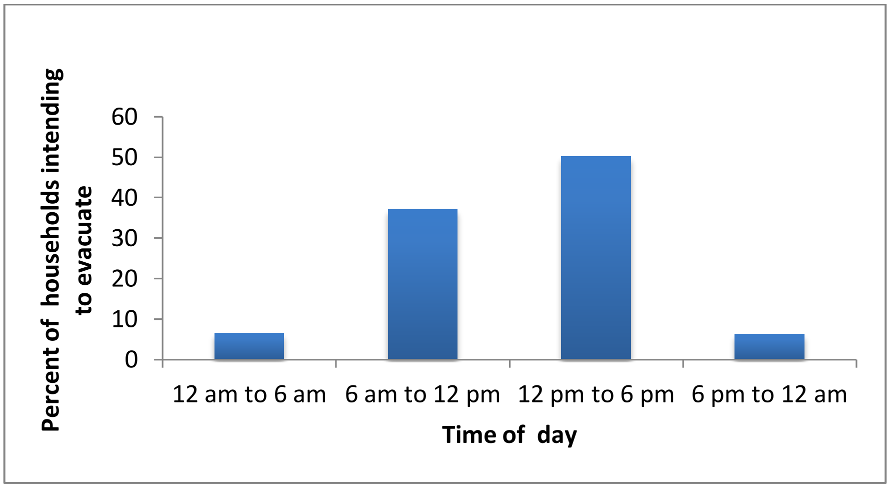

Figure 27
Influence of time-of-day on evacuation behavior for Storm 5

Hypothetical Storm 6

Hypothetical Storm 6 was another storm that elicited relatively few evacuations from survey respondents. This was because it weakened steadily from a high category hurricane in the first forecast to a low category hurricane in the final forecast. The evacuation order was kept at the voluntary level from the second until the final forecast.

Of the households that viewed Storm 6, 51 percent stated they would evacuate. The rapid rate of evacuation occurs at 54-50 hours before landfall on Thursday morning when the prevailing hurricane intensity was still a Category 5. At 3.30 pm on Thursday the storm was downgraded to a Category 3. Of the total households that intended to evacuate, 80 percent reported they would evacuate before the storm was 20 hours from making landfall (see Figure 28). As can be seen in Table 2, up to 20 hours before landfall, the hurricane was a Category 3 and it dropped to a Category 2 at the third scenario at 20 hours to landfall. Also, the time was 4.30 pm. Thus, the reducing storm intensity and the lateness in the day reduced further evacuation.

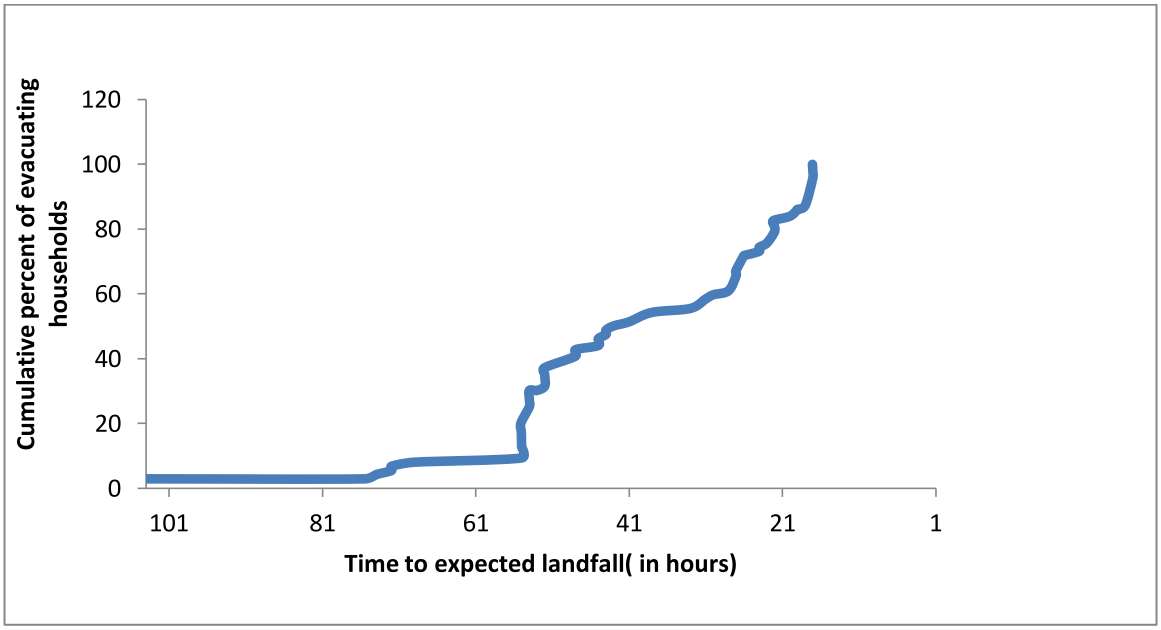

Figure 28
Influence of time to expected landfall on evacuation behavior for Storm 6

The influence of hurricane category is shown in Figure 29. The counterintuitive larger evacuation with Category 2 and 3 hurricanes than a Category 5 hurricane is the result of the decreasing storm intensity as the storm got closer to landfall.

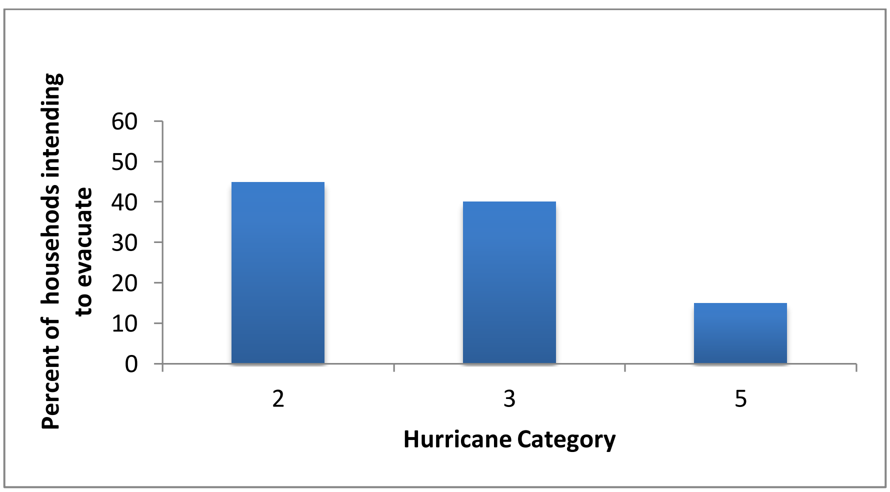

Figure 29
Influence of hurricane category on evacuation behavior for Storm 6

The impact of time-of-day on evacuation behavior is consistent with reality, as illustrated in Figure 30. Households prefer to evacuate during the day rather than at night, and all else being equal, the morning is preferred over the afternoon.

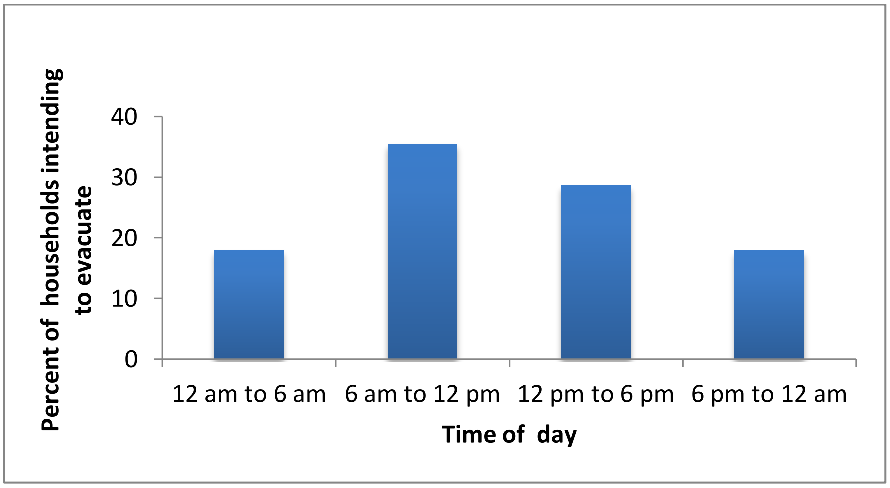

Figure 30
Influence of time-of-day on evacuation behavior for Storm 6

Hypothetical Storm 7/Hypothetical Gustav

Researchers often express skepticism of stated choice data because of its obvious limitations. In particular, the major criticism is that what respondents say they will do is often not what they do. Moreover, respondents stated intentions might be influenced by factors that do not exist in the real world, such as stating what they think the person asking the questions wants to hear. Therefore, to gain confidence in the stated choice data collected in this study, a hypothetical storm, identical to Hurricane Gustav, was created and used to elicit stated intentions from survey respondents without identifying it as Hurricane Gustav to the respondents. The purpose of doing this was to compare stated intentions on Hurricane Gustav from the stated choice survey with the actual behavior of the same households in the revealed preference survey.

The time-dependent characteristics of hypothetical Gustav or synonymously, Storm 7, are presented in Table 2. Even though hypothetical Gustav was made identical to real Gustav there are some notable differences between the hypothetical presentation of the storm and its actual occurrence. Real Hurricane Gustav occurred in real time and was perceived by survey respondents as a continuous event whereas hypothetical Gustav was presented as a sampling of hurricane conditions at four discrete points in time. Thus, the perception of hypothetical Gustav in the mind of the respondent might not have been the same as the same respondent's perception of real Hurricane Gustav.

In the stated choice survey, Storm 7 was generally perceived as a weak storm and thus elicited weak evacuation response even though it was a Category 3 hurricane 52 hours from landfall and remained a Category 2 thereafter. Only 51 percent of households stated that they would evacuate and 80 percent of evacuating households, as displayed in Figure 31, stated they would evacuate before the storm was 32 hours away from making landfall. This is likely due to the Category 3 storm 52 hours from landfall and the voluntary evacuation order in effect.

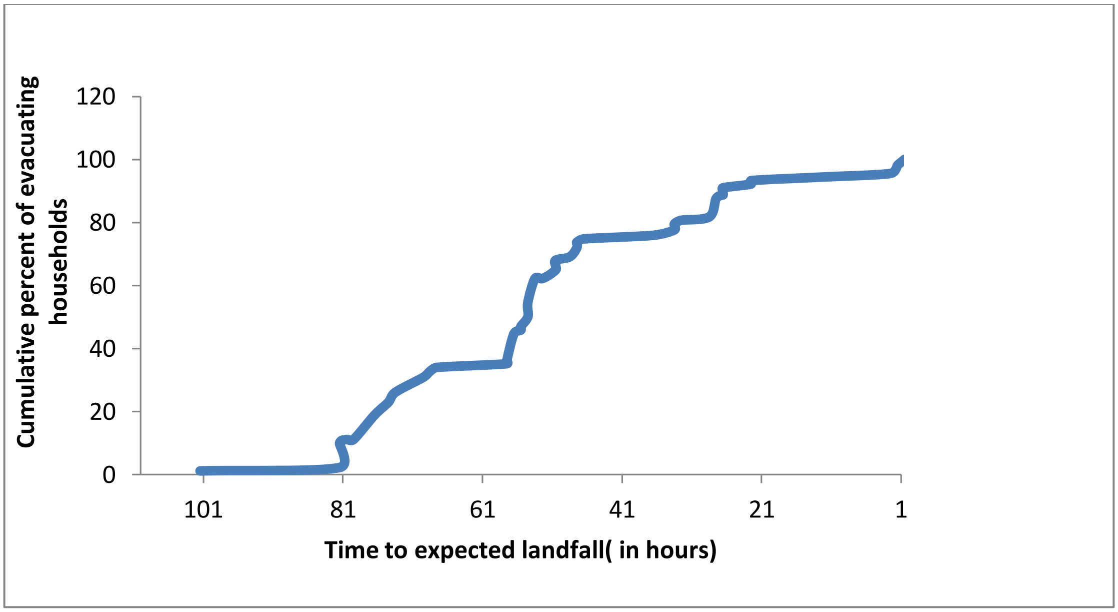

Figure 31
Influence of time to expected landfall on evacuation behavior for Storm 7

The influence of time-of-day is shown in Figure 32. The most popular time to evacuate of 20-32 hours before landfall occurred during the day in this case. Thus, the clear preference for a daytime morning evacuation is shown in the results.

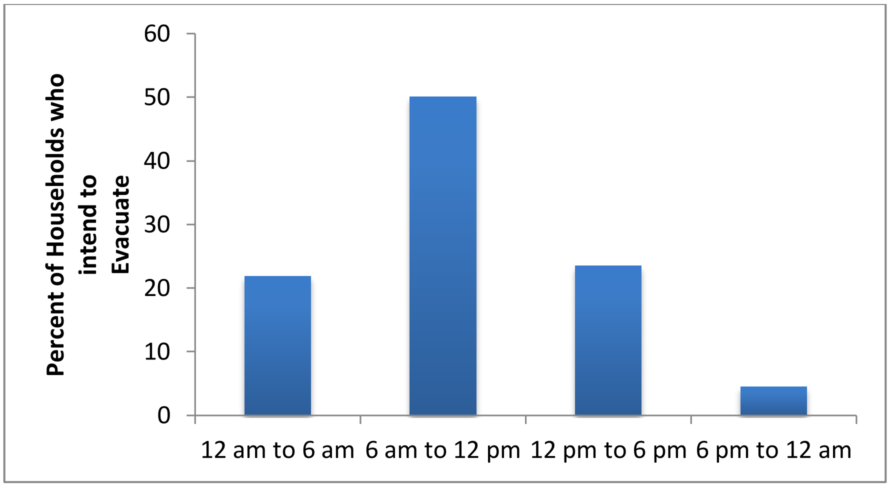

Figure 32
Influence of time of day on evacuation behavior for hypothetical Gustav

Comparison of Hypothetical Gustav (HG) with Real Gustav(RG). To test whether stated responses were similar to actual behavior, the responses to the hypothetical Gustav were compared with the responses to Hurricane Gustav on an individual basis. Table 10 shows the comparison. Sixty-eight percent of the households were consistent in their decision to either evacuate or stay for Hurricane Gustav. Of those who were inconsistent in their actual and stated behavior, more displayed greater risk taking by saying they would stay when their actual behavior revealed they evacuated (25 percent), rather than those that were less risk taking in their stated behavior (8 percent).

Table 10
Comparison of Responses between Hypothetical Gustav and Real Gustav

	Evacuated in Real Gustav	Stayed in Real Gustav
Stated would evacuate for hypothetical Gustav	43	8
Stated would stay for hypothetical Gustav	24	25

Cumulative evacuation rates between hypothetical Gustav and real Gustav are shown in Figure 33. For hypothetical Gustav, respondents stated that they would evacuate immediately. However, in real life people cannot evacuate as soon they wish to leave because they have to perform several preparatory activities before departing. Without giving attention to such impediments in the hypothetical scenario, people stated they would evacuate immediately without giving much thought to evacuation preparations they had to perform. Consequently, this resulted in a steeper cumulative evacuation curve for hypothetical Gustav between 8/29/08-9:00 am and 8/30/08-4:00 pm as shown in Figure 33. However, the cumulative evacuation curve of real Gustav became much steeper than hypothetical Gustav after 8/30/08-4:00 pm. This might be because evacuating households might have made their evacuation decisions based on prevailing environmental cues, whereas in hypothetical Gustav there were no such cues and households evacuated at lesser rate. However, overall the evacuation patterns are similar.

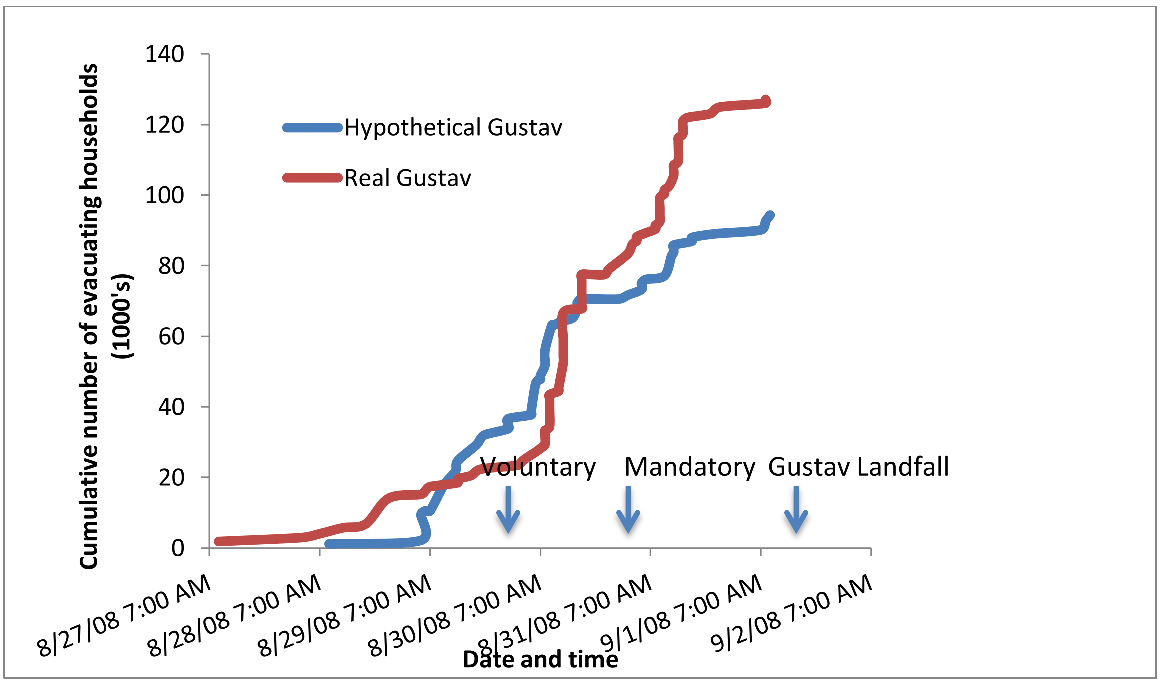

Figure 33

Comparison of cumulative evacuation rate for hypothetical Gustav and real Gustav

Figure 34 shows comparison of evacuation rates between hypothetical Gustav and real Gustav for different evacuation orders. The evacuation percentages for voluntary and mandatory evacuation orders are less distinguishable for real Gustav than for hypothetical

Gustav. When the actual event happened there is a high likelihood that as many as half of them did not hear the order *[37]*. In contrast, with hypothetical Gustav, all respondents are aware of the evacuation order in effect as it is presented in both visual and verbal form in the presentation of the scenario.

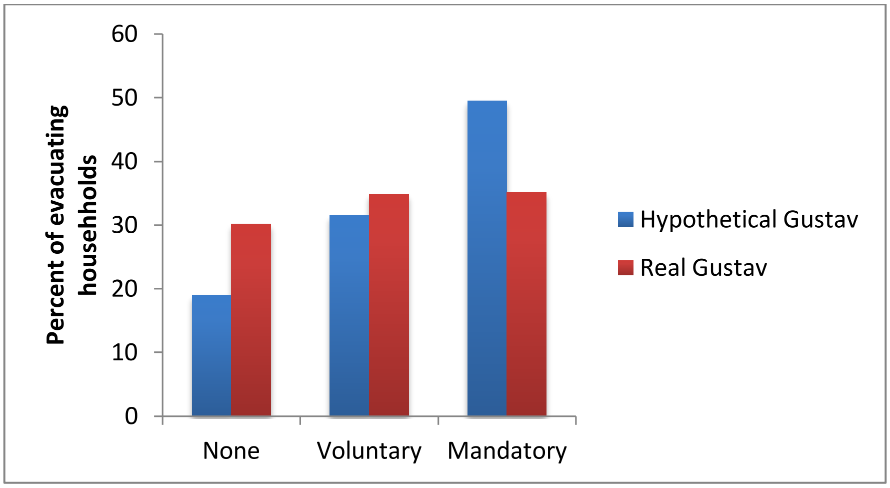

Figure 34
Influence of evacuation orders on hypothetical Gustav and real Gustav

As shown in Figure 35, there was greater correspondence between hypothetical Gustav and real Gustav for the choice of transportation mode although even a higher percentage of respondents want to evacuate using a car in real Gustav than hypothetical Gustav. Very few people want to or do evacuate using a transportation mode other than car.

Similar to the case with evacuation mode, a high correspondence between hypothetical Gustav and real Gustav results were observed for the type of refuge sought. The results are shown in Figure 36. A high percentage of households reported that they prefer seeking refuge at a hotel or motel followed by the friend/relative destination type. Very few indicated that they would go to a public shelter. Less than 15 percentage point difference exists between the hypothetical and real results regarding destination type.

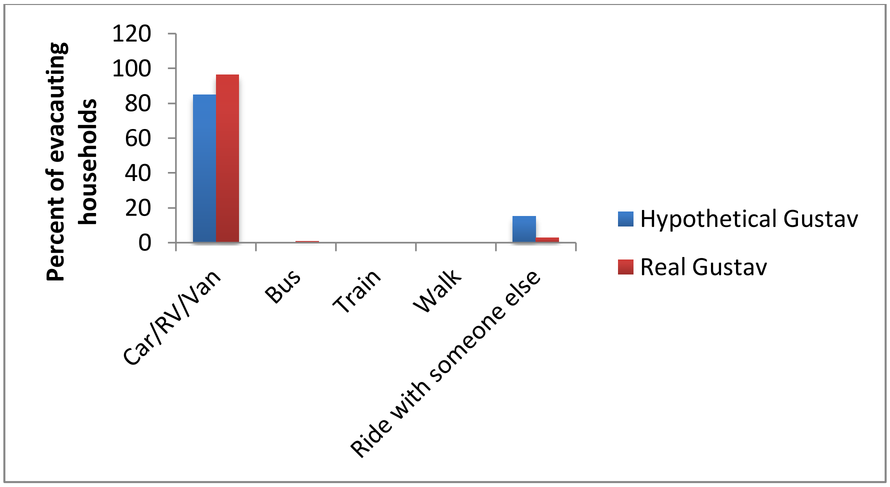

Figure 35
Comparison of evacuation mode for hypothetical Gustav and real Gustav

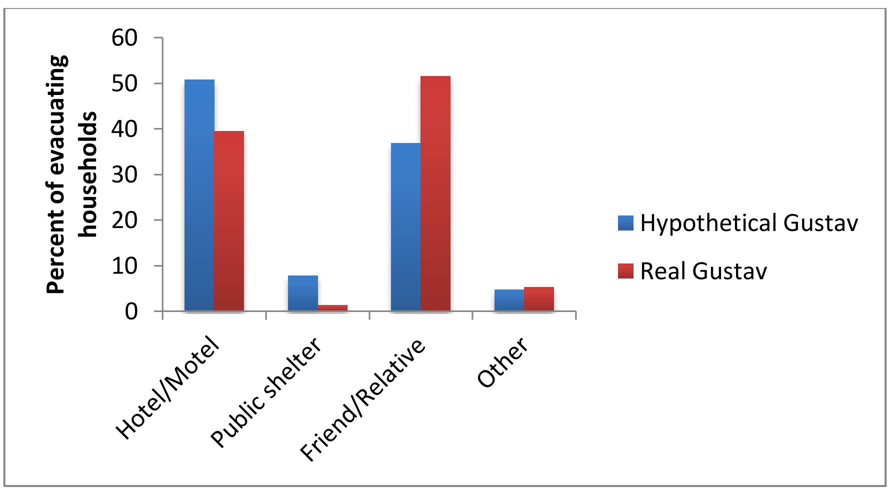

Figure 36
Comparison of type of refuge for hypothetical Gustav and real Gustav

While comparing actual and stated behavior, it is natural to get curious about the reasons behind the existence of discrepancies between observed and stated behavior and in the author's opinion there are multiple reasons for such differences. The theory proposed by Fishbein and Ajzen and empirical research done by Kang, Lindell and Prater, cite that lack of information about the consequences of chosen behavior, the probabilities of these consequences, normative beliefs, situational constraints, and facilitating conditions contribute to discrepancies *[38]*, *[27]*. In addition, they pointed out that parity between behavioral intentions and actual behavior is strongest when the behavior to be predicted is performed repeatedly, and parity is weakest when there is a long interval between the measurement of intentions and the opportunity to exhibit the behavior. All the above-mentioned reasons are certainly valid explanations of the discrepancies observed between evacuation behavior in hypothetical Gustav and real Gustav. However, there is a striking similarity between stated and actual behavior in this study, as demonstrated in the comparison of the results.

Hypothetical Storm 8

Hypothetical Storm 8 can be considered a strong storm. The hurricane category never dropped below 3 and the evacuation order was maintained at mandatory for two forecasts. As a result, Storm 8 elicited a strong evacuation response in that 78 percent of the households stated their intention to evacuate.

As displayed in Figure 37, of all the households who responded to Storm 8, 60 percent of evacuating households stated they would evacuate before the storm was 30 hours away from making landfall. However, the majority of evacuating households (71 percent, as displayed in Figure 38) would evacuate when the hurricane is Category 3. This response may be thought as counterintuitive because fewer households indicated they would evacuate for Category 4 in comparison to category 3. However, the reason for more evacuations for Category 3 becomes clear if one considers the interaction effect of hurricane category and evacuation orders, as well as storm proximity. In all the forecasts shown during Storm 8, hurricane Category 3 appeared three times and was always associated with either voluntary or mandatory evacuation orders, but hurricane Category 4 was not accompanied by any order and occurred when the storm was still 67 hours from landfall. Thus, association of hurricane category with evacuation order and storm proximity had more impact than just the hurricane category alone.

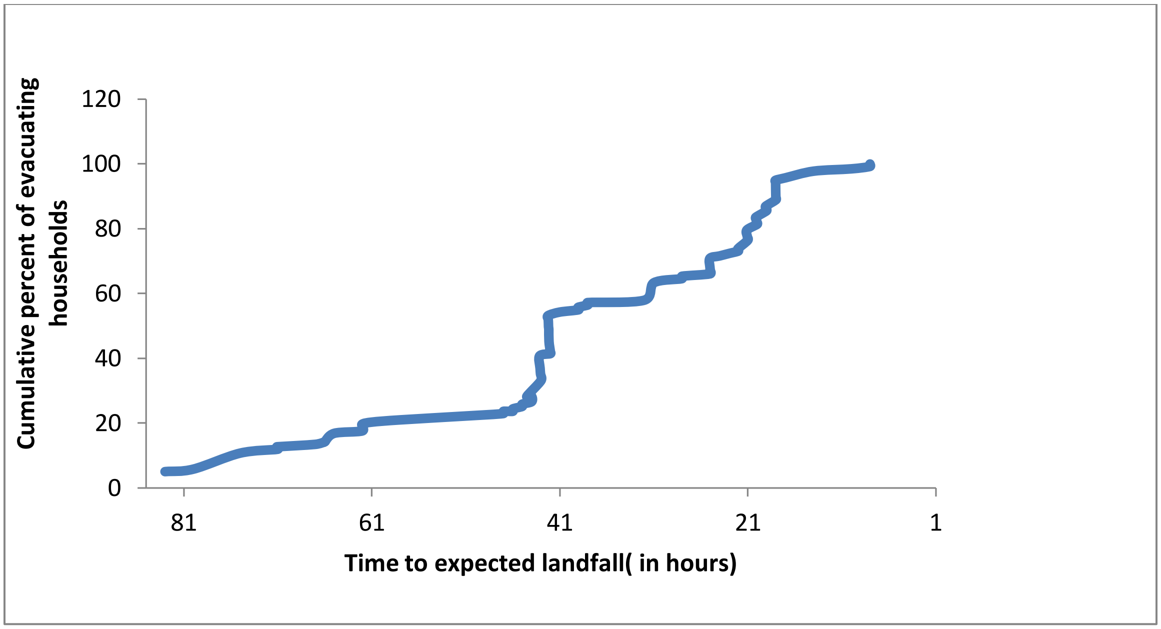

Figure 37

Influence of time to expected landfall on evacuation behavior for Storm 8

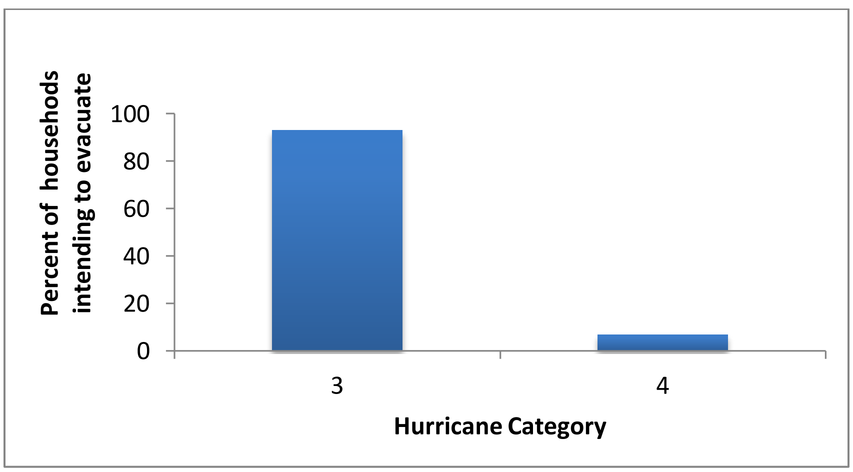

Figure 38

Influence of hurricane category on evacuation behavior for Storm 8

The influence of time-of-day is presented in Figure 39. As with all other hypothetical storms, the preference for daytime evacuation is evident, particularly in the morning with the prospect of making the entire, or at least the majority, of the evacuation trip in daylight.

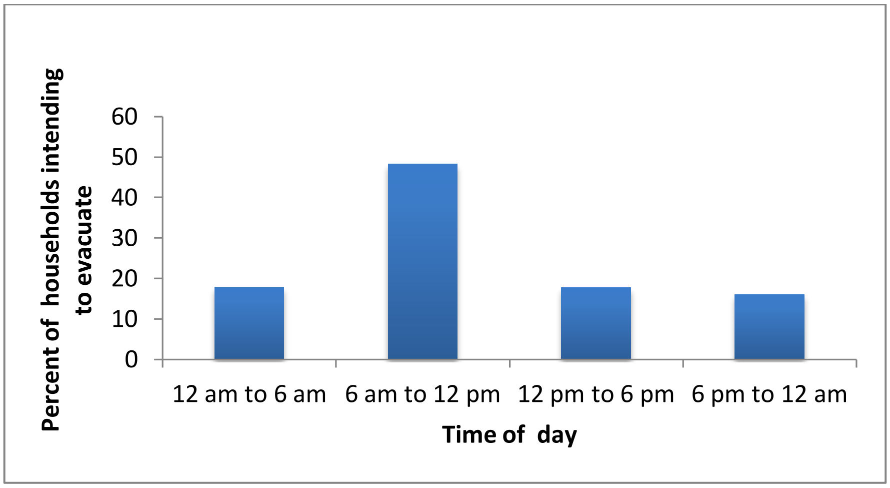

Figure 39
Influence of time-of-day on evacuation behavior for Storm 8

Hypothetical Storm 9

Like Storms 5, 6, and 7, Storm 9 was a weak storm. Thus, Storm 9 elicited a weak response from survey respondents. An evacuation order was never upgraded beyond voluntary and the hurricane was downgraded from Category 5 in Forecast 1 to Category 1 in Forecast 4. Consequently, only 53 percent households stated that they would evacuate for storm 9.

As shown in Figure 40, most (70 percent) evacuating households stated they would evacuate before the storm approaches too close (i.e. at 35 hours or less to landfall). This is primarily due to the high storm intensity in the early stages of the storm followed by a steady decline in intensity to Category 1 at 11 hours from landfall. The stated behavior appears totally plausible and logical.

The influence of hurricane category is also shown in Figure 41, where most households want to evacuate at Category 3, when the storm is beginning to get close enough to pose a threat (47 hours from landfall), rather than at Category 5 while the storm was 75 hours from landfall.

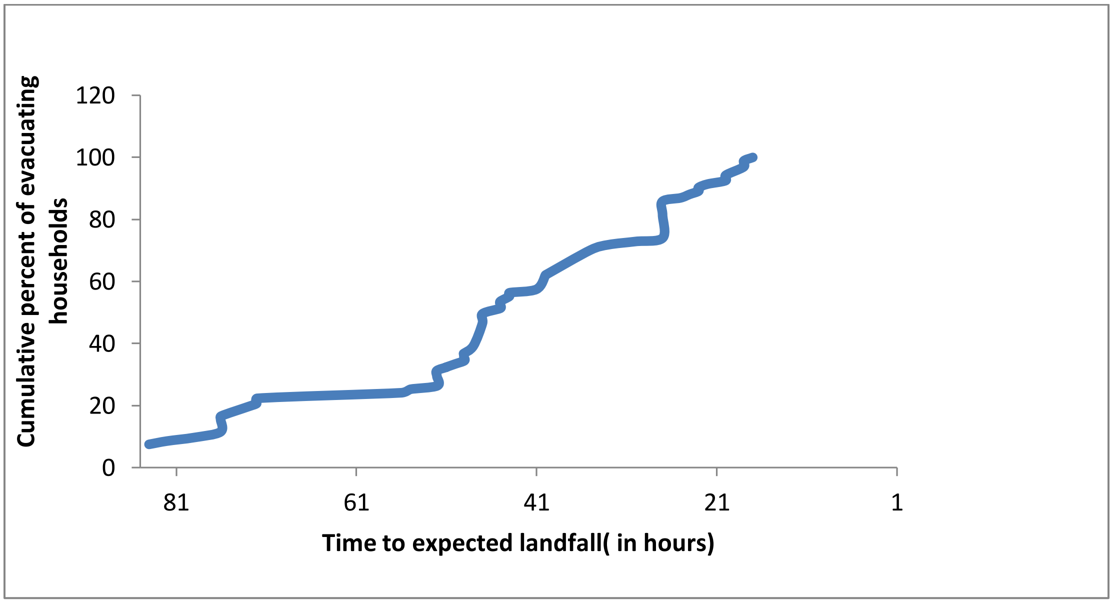

Figure 40
Influence of time to expected landfall on evacuation behavior for Storm 9

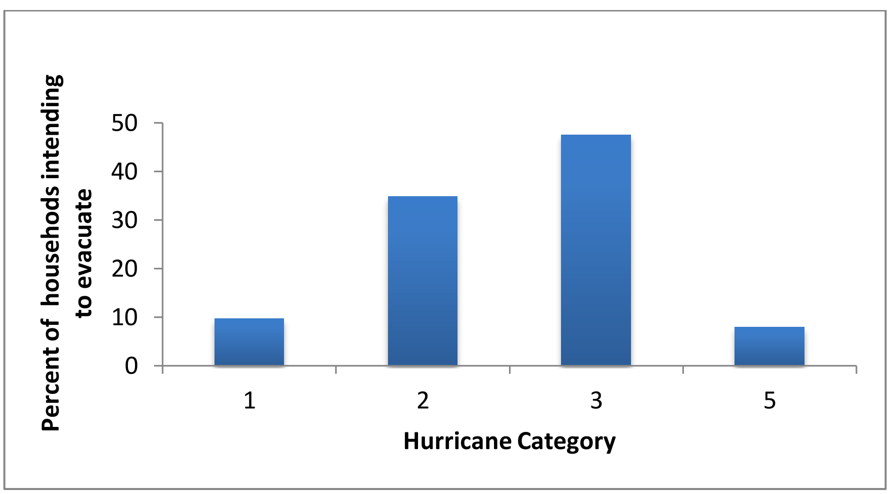

Figure 41
Influence of hurricane category on evacuation behavior for Storm 9

To summarize, evacuation response from the stated choice survey displayed behavior that was consistent with what is expected in reality. The evidence of consistency was clear when evacuation response was measured against the evacuation causative variables like hurricane category, evacuation orders, time to expected landfall and time-of-day. More people were responsive to hurricane category followed by evacuation orders. Generally, this is what is observed in reality. Nonetheless, to further validate the SC data, hurricane evacuation demand models were developed and tested for predictive validity. The topic of estimation is taken up in the following sections.

Estimation of Hurricane Evacuation Demand Models on Collected Data

To evaluate the performance of the new data collection method, it was required to estimate two time-dependent hurricane evacuation demand models on the data - one on the RP data and one on the combined RP/SC. Two hurricane evacuation demand models were considered in this process; the time-dependent sequential logit model (TDSLM) first suggested by Fu, and the time-dependent nested logit model (TDNLM) developed by Gudishala *[4]*, *[46]*. The topic of estimation is taken up in this section and the procedure used to estimate models is described in the following sections.

Background to the TDSLM

The time-dependent sequential logit model assumes that the decision making process of a household facing the threat of an approaching hurricane can be modeled as a series of sequential binary choices over discrete time periods until either the household evacuates or the hurricane passes without evacuation occurring. The equation for TDSLM and the method used to estimate it is explained in greater detail by Fu *[4]*.

The TDSLM is given by the following equation:

$$P_n(i) = Pr(u^s_{n1} \geq u^e_{n1} \cap u^s_{n2} \geq u^e_{n2} \cap \dots\dots u^s_{ni-1} \geq u^e_{ni-1} \cap u^e_{ni} \geq u^s_{ni}) \qquad (1)$$

where,

$P_n(i)$ = probability household n evacuates in time interval i
u^s_{ni} = utility of household n to stay (not evacuate) in time interval i
u^e_{ni} = utility of household n to evacuate in time interval i

If it assumed that the utility assessments made by household *n* in each time period *i* are independent of each other, *P(i)* can be rewritten as:

$$P_n(i) = P_n(1)_{s/e}.P_n(2)_{s/e} \ldots\ldots P_n(i-1)_{s/e}.P_n(i)_{e/s} = P_n(i)_{e/s}\prod_{j=1}^{i-1}[1 - P_n(j)_{e/s}] \qquad (2)$$

where,

$P_n(i)_{s/e}$ = probability that the utility of household *n* to not evacuate is greater than the utility of the household to evacuate in time interval *i*

$\mathrm{P_n(i)}_{e/s}$ = probability that the utility of household *n* to evacuate is greater than the utility of the household to not evacuate in time interval *i*

If the probability of household *n* evacuating in time interval *i* is a binary logit function of the utilities of evacuating or staying in time interval i, then :

$$P_n(i)_{e/s} = \ e^{u_{ni}^e}/(e^{u_{ni}^e} + \ e^{u_{ni}^s}) \qquad (3)$$

If the evacuation decision of a household in a particular time period is entirely dependent on the utility difference between evacuating and not evacuating in that time period and nothing else, then the probability of the household evacuating in time interval *i* is accurately described by equation (3). However, each momentary assessment in time period *i* is preceded by (*i*-1) decisions to not evacuate in previous time periods. Therefore, once the momentary (or conditional) logit model described in equation (3) is established, it's estimate of evacuation for each household in each time interval is substituted into (2) to estimate the actual (or true) probability of each household evacuating in each time interval.

If it is assumed that choices made by individual households regarding the evacuation decision are independent of each other, and that decisions made by the same household are independent of each other among the time periods, then a common model in equation (3) (i.e. a model with the same specification and the same parameter values for all households and all time periods) can be estimated. Making this assumption allows data of observed time-dependent evacuation decisions under varying conditions to be used to estimate a common model.

As stated above, the TDSLM assumes that choices are independent over households and over time. That choices are independent over households is a common assumption in choice modeling where households are unrelated and randomly drawn from the population. However, in the context of this study, evacuation decisions within the same household are likely to be correlated over time. For example, storm conditions anticipated in the next time period may affect the current choice, or unobserved factors affecting choice in one period may influence the decision in the next time period in the same manner. The issue of choice dependency over time is taken into consideration in deriving the time-dependent nested logit model in the next section.

Specification and Derivation of the Time-Dependent Nested Logit Model

The sequential choice paradigm described earlier is used in this section with a slight modification; the assumption that the evacuation decision of each household in each time period is a set of independent sequential binary decisions is relaxed and the sequential binary decisions are treated as interdependent over time. This is accomplished by modeling the sequential binary decisions as a nested logit model with each nest representing a time period and the expected conditions in the next period entering the decision of the current period through the so-called "logsum" term as described below.

The description of the time-dependent nested logit is described, for convenience, in the context of three sequential time periods: i =1, i = 2, and i = 3. Assume that the decision-making process of a household proceeds in sequential fashion as shown in Figure 42. In the first time period, the household either chooses to "evacuate" or "stay". However, it is intuitively plausible that a household will take current conditions as well as anticipated future conditions into account when making a decision to evacuate or not. To accommodate the impact of future conditions into current decisions we employ the concept of the maximum utility of lower nest entering the utility of the upper nest through the so-called logsum expression. Doing this in the context of time-dependent decisions, we call the model a time-dependent nested logit model (TDNLM).

The following assumptions are made in deriving the TDNLM: The utility that household n obtains from choosing to evacuate, e in time period i is expressed as $U_{nei} = \beta_n x_{nei} + \varepsilon_{nei}$, and from the choice to stay in time period i is $U_{nsi} = \beta_n x_{nsi} + \varepsilon_{nsi}$, where x_{nei} and x_{nsi} are vectors of observed variables relating to household n in time period i, β is a vector of parameters and ε_{nei} and ε_{nsi} are unobserved random error terms that are assumed to be independently and identically Gumbel distributed.

Let the portion of the utility that can be measured from conditions in time period i, $\beta_n x_{nei}$ and

$\beta_n x_{nsi}$, be rewritten, for convenience, as V_{nei} and V_{nsi}, respectively. Assume that in time period 1 a household decomposes its utility into a known part V, and unknown part, γ e.g., $U_{ne1} = V_{ne1} + \gamma_{ne1} + \varepsilon_{ne1}$, $U_{ns1} = V_{ns1} + \gamma_{ns1} + \varepsilon_{ns1}$ and assume that γ follows a Gumbel distribution. If γ measures the conditions expected in the next time period and they influence current utilities, then being able to estimate γ provides a means of accommodating at least a portion of the dependence among time periods. Since the Gumbel distribution is stable under maximization, the maximum of the two Gumbel distributed parameters, γ_{ne2} and γ_{ns2} are again Gumbel distributed with a mean and standard deviation of $1/\mu \ln(\exp(\mu\eta_1) + \exp(\mu\eta_2))$ and μ, where η is a location parameter and μ a scale parameter defining the distribution *[39]*. Thus, the expected value of the distribution of $\max(\gamma_{ne2}, \gamma_{ns2})$ is equal to $(1/\mu \ln(\exp(\mu\eta_1) + \exp(\mu\eta_2)))$. This expected value is the log sum term used in the nested logit model linking upper and lower nests *[40]*. This observation was first noted and used by Rust *[41]*. (For exposition purposes the log sum term is labeled *LS* in further discussion).

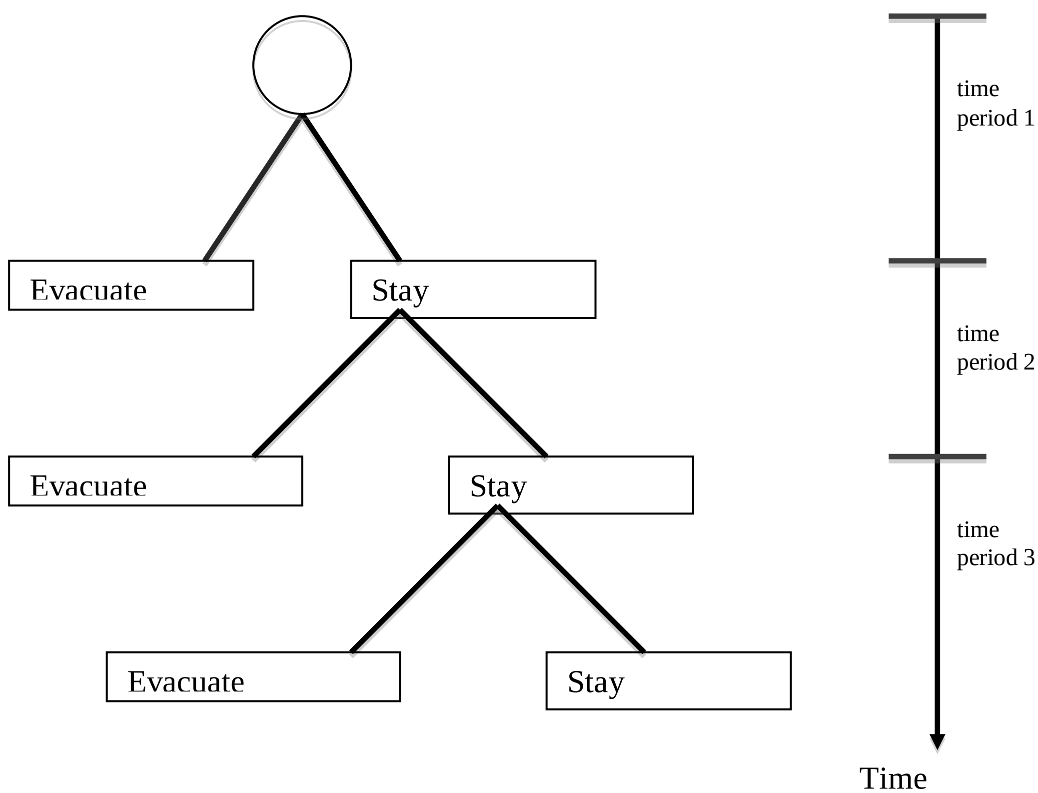

Figure 42

Conceptual representation of the sequential decision-making process

When applied in the context of the current discussion, this feature can be used to incorporate the utility of the best alternative from a future time period (i.e. the alternative with the maximum utility in the next time period) into the assessment of the utilities of the present. Therefore, the utility of household *n* evacuating in time period 1, U_{ne1} , becomes $V_{ne1} + \varepsilon_{ne1}$ and U_{ns1} becomes $V_{ns1} + \varepsilon_{ns1} + LS_2$. Here, *LS2* is defined as log sum of the denominator of the binary logit model in time period 2 and is given by:

$$LS_2 = \lambda \ln\left(\exp(V_{ne2}) + \exp(V_{ns2} + LS_3)\right) \qquad (4)$$

where *1-λ* represents the correlation between time period 1 and time period 2. Note that the log sum term LS2 takes into account the utility of staying in both time period 2 and time period 3. This can be verified by the fact that:

$$LS_3 = \lambda \ln\left(\exp(V_{ne3}) + \exp(V_{ns3})\right) \qquad (5)$$

So that substituting (5) into (4), the value of L_2 becomes:

$$LS_2 = \lambda \ln\left(\exp(V_{ne2}) + \exp(V_{ns2} + \lambda \ln\left(\exp(V_{ne3}) + \exp(V_{ns3})\right))\right) \qquad (6)$$

Since LS_2 is a part of the utility to stay in time period 1, this shows that conditions in time periods 2 and 3 influence the decision in time period 1.

The values of λ and the other parameters in the utility functions can be estimated using maximum likelihood, as described later, thereby providing estimates of log sum expressions. This allows estimation of the probability of "evacuating" or "staying" in each time period. For example, in time period 1, the probability that household *n* evacuates in time interval 1 can be written as:

$$P_{ne1} = Prob(U_{ne1} \geq U_{ns1})$$

$$= Prob(V_{ne1} + \varepsilon_{ne1} \geq V_{ns1} + \varepsilon_{ns1} + LS_2) \qquad (7)$$

Since ε_{ne1} and ε_{ns1} are assumed to be Gumbel distributed, the difference between them is logistic distributed and the above equation can be expressed as a binary logit model of the following form.

$$P_{ne1} = \frac{exp^{V_{ne1}}}{exp^{V_{ne1}} + exp^{V_{ns1} + LS_2}} \qquad (8)$$

If the household did not evacuate in time interval 1, the process will be repeated in time interval 2, taking into account the expected utility from time period 3 in evaluating the choices available in time period 2. Based on the argument made in the previous paragraph, the marginal probability that the household evacuates in time interval 2 can be written as

$$P_{ne2} = \frac{exp^{V_{ne2}}}{exp^{V_{ne2}} + exp^{V_{ns2} + LS}{}_3} \qquad (9)$$

and the conditional probability that the household evacuates in time interval 2 is:

$$P_{ne2} = (1 - P_{ne1}) * P_{ne2}$$

$$P_{ne2} = \left(1 - \frac{exp^{V_{ne1}}}{exp^{V_{ne1}} + exp^{V_{ns1} + LS_2}}\right) * \left(\frac{exp^{V_{ne2}}}{exp^{V_{ne2}} + exp^{V_{ns2} + LS_3}}\right) \qquad (10)$$

Similarly, the marginal probability that household *n* evacuates in time interval 3 is:

$$P_{ne3} = \frac{exp^{V_{ne3}}}{exp^{V_{ne3}} + exp^{V_{ns3}}} \qquad (11)$$

Notice that there is no log sum term in the above equation because it is the final time period.

The conditional probability that the household evacuates in time interval 3 is:

$$P_{ne3} = (1 - P_{ne1}) * (1 - P_{ne2}) * P_{ne3} \qquad (12)$$

The derivation shown in this section with three levels of nests, can be extended to any number of time periods or levels. However, adding more levels adds to the complexity of the estimation process and may demand more resources and sample data. To give an example, estimation of a three level nested logit model typically involves estimation of coefficients of explanatory variables, estimation of alternative specific constants, estimation of two correlation coefficients, and finally estimation of two log sum terms. Given the highly nonbehavioral nature of the nested logit model, and the added burden of many parameters, most estimation routines require an analytical second derivative for producing a reliable set of estimates. Adding many levels to an already complex problem compounds the estimation problem considerably.

Most of the popular estimation packages, like SAS, STATA, and LIMDEP do not allow users to specify levels beyond 4 while estimating a nested logit model. Therefore, to estimate a nested logit model with more than 4 levels, special programs that have the capability of employing sophisticated optimization routines are needed. Examples of such software include TOMLAB, GAMS, and AMPL.

For a sample of N households, the vector of parameters β can be estimated by applying maximum likelihood to the following log likelihood expression

$$L(\beta) = \prod_{n=1}^{n=N} \prod_t P_{net}^{y_{ni}} \qquad (13)$$

where y_{ni} = 1 if household n chose to evacuate in time interval i and zero otherwise, and P_{net} is the conditional probability of household n evacuating in time interval i.

Data Preparation for Estimating TDSLM and TDNLM

Data preparation is an integral part of estimating the TDSLM. To begin with, data required for estimation is arranged in a row and column format, with each row representing the time dependent conditions for each household and each column representing the time-dependent and time-invariant attributes of the households and their exposure to a hurricane.

Decisions That Went into Arranging Data

One of the major decisions that needed to be made before embarking on data arrangement was the length of the time-dependent period over which evacuation behavior of a household was to be analyzed. A preliminary investigation of departure time during Hurricane Gustav found that some households evacuated very late, while other households evacuated very early. To accommodate all households, the time of analysis should be made equal to the earliest time-to-expected landfall point at which a household is likely to evacuate. In this data, the earliest a household evacuated when time-to-expected landfall was 126 hours away.

Consequently, the length of time over which the analysis was performed was made equal to 132 hours to allow the first evacuation to occur after the limit of the analysis period.

After deciding on the length of the analysis period, the next decision to be made was the number of discrete time steps the total 132 hours should be divided into. Even though it is desirable to have more discrete time intervals, for practical reasons it may not be wise to do so. For example, if the total analysis time period is divided into two hour discrete time intervals then there would be 66 discrete time intervals. Using 66 time intervals becomes computationally burdensome, and some of the discrete time intervals might also contain too few evacuations or become otherwise redundant. Redundancy can result from the fact that time-dependent conditions of a hurricane change very little from time period to time period if short time intervals of say two hours are used. But in some instances where time-dependent conditions change very rapidly, it may be justified to use shorter time intervals. Based on the preceding argument to achieve a balance between the two arguments, and also because of very gradual changes to time-dependent conditions of Hurricane Gustav, it was decided that six hour time intervals would be used. Consequently, this resulted in a total of 132/6 = 22 time intervals.

The total number of rows in the dataset for a given household depended on when a household evacuated. For example, if the household evacuated in time interval 10 then the data related to that particular household would only have 10 rows. On the other hand if a household did not evacuate at all then the total number of time intervals for that household was 22.

Selection of Independent Variables for Inclusion into the TDSLM

The first step in developing a model is to choose the independent variables that will be included in the model. The choice of independent variables is influenced by formal theories and informal judgment that represents an analyst's best *a priori* knowledge of the phenomenon being modeled.

Based on the past research done by Fu and Baker, it is clear that the most important variables influencing evacuation behavior are storm-specific factors like hurricane category, type of risk area (i.e. flood prone or not), type of house, prior perception of personal risk, and management actions taken by public officials. Given the difficulty of quantifying a variable like perception of personal risk, a decision was made to include all other variables but exclude the variable perception of personal risk *[4]*, *[3]*.

With the preceding ideas and discussion in mind, several models were estimated using a progressive elimination or addition of variables based on three criteria.

- An explanatory variable was retained in the model if the sign associated with the model did not violate *a priori* assumptions about its influence on evacuation behavior.
- An explanatory variable was retained in the model if it was statistically significant.
- An explanatory was retained if it was believed it was a contributing factor even if it was not entirely statistically significant.

Assumptions Regarding the Influence of Explanatory Variables on Evacuation Behavior

It was assumed that a direct relationship exists between the variable hurricane category and number of evacuations. Figure 43, shows the relationship between percent of evacuees and hurricane category for Hurricane Gustav. Intuitively, one would expect to see an increase in the proportion of evacuees with an increase in hurricane category. However, what one sees here is an increase in the proportion of evacuees from Category 1 through Category 2 but a drop in the percent for Category 3 and Category 4. This is because there are several other factors like time of a day, evacuation orders, the length of the time for which hurricane stayed at Category 4, and time to expected landfall that are interacting with hurricane category simultaneously and affecting the evacuation behavior apart from hurricane category. However, category of storm clearly will influence evacuation behavior and, subsequently, it was included in the candidate variables for inclusion in the model.

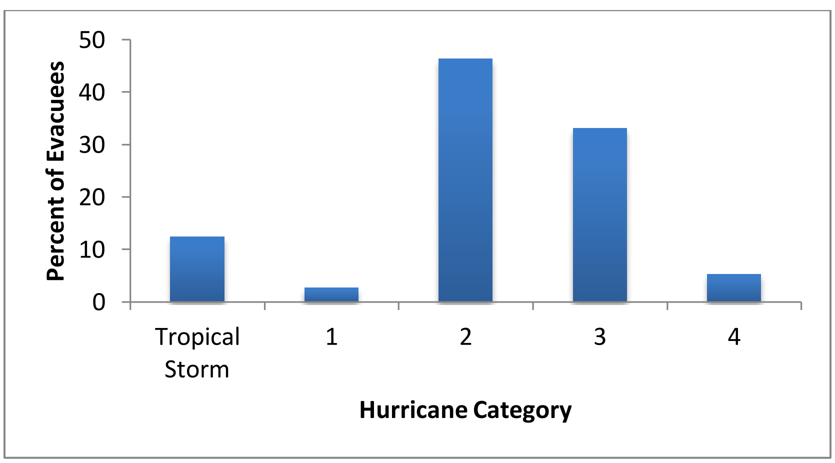

Figure 43
Hurricane Gustav- influence of hurricane category on evacuation

Another important explanatory variable that is expected to influence evacuation participation in a direct manner is evacuation order. As one would expect, and as shown in Figure 44, the evacuation rate during Hurricane Gustav increased when public officials issued voluntary evacuation orders and reached a peak when the voluntary evacuation order was followed by a mandatory evacuation order.

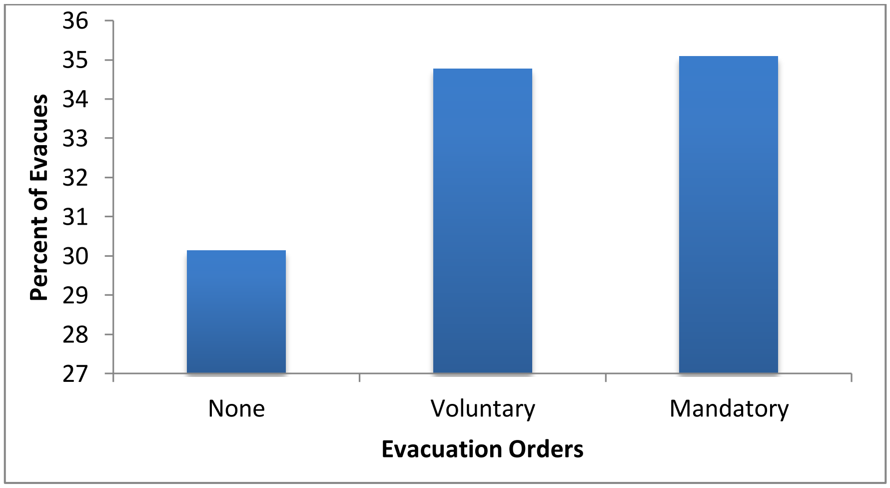

Figure 44
Hurricane Gustav influence of evacuation orders on evacuation

For analysis purposes time of a day was divided into four parts. First, 12 am-6am is considered as Time Of Day (TOD) 1, 6 am to 12 pm as TOD 2, 12 pm to 6 pm as TOD 3, and 6 pm to 12 am as TOD 4. It is expected that fewer people evacuate during the night because it would be inconvenient and, as shown in Figure 45, it is clear that lowest evacuation rates occurred between 6 pm and 12 am followed by 12 am and 6 am, whereas the highest evacuation rate occurred for time period 6 am to 12 pm.

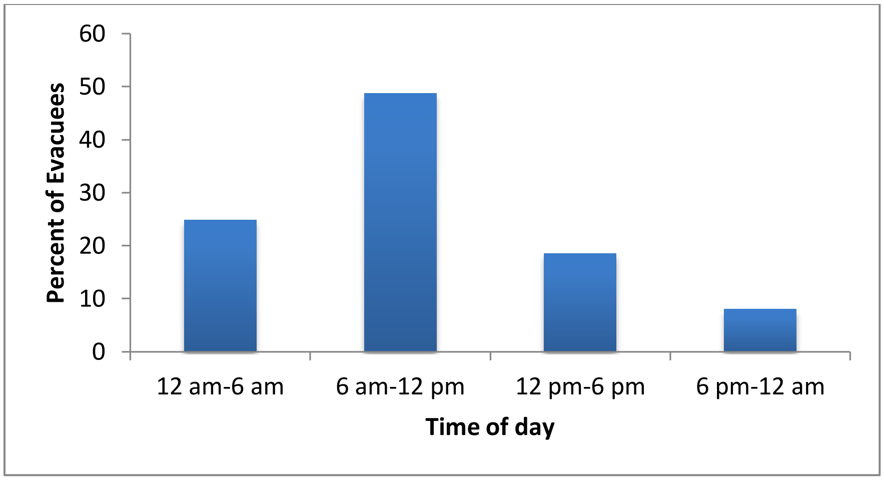

Figure 45
Hurricane Gustav - influence of time-of-day on evacuation

Another variable that is expected to influence evacuation behavior is the time-dependent distance between a household's geographical location and the storm *[4]*. That is, the proximity of the storm is expected to affect evacuation behavior. However, the relationship between the probability of evacuating and time-dependent distance is not expected to be linear but rather to follow a probability distribution curve, as shown in Figure 46. That is, a household's probability of evacuating when facing a threat from an impending hurricane is expected to be of a bell shape rather than a straight line. This is because when a hurricane is far away the household is not immediately threatened and the probability of evacuating is low. On the other hand, when a hurricane is too close, say less than100 miles from making landfall, there is typically not enough time for a household to leave and safely reach a destination before they are subjected to the full force of the storm. In between these distances, however, there is a period in which the probability of a household evacuating is high when just considering storm proximity. To incorporate this relationship into the model the time-dependent distance was transformed using a lognormal probability distribution function, as shown in Figure 46. The location parameter of the distribution, μ, was 6 and the scale of the distribution σ was = 0.6.

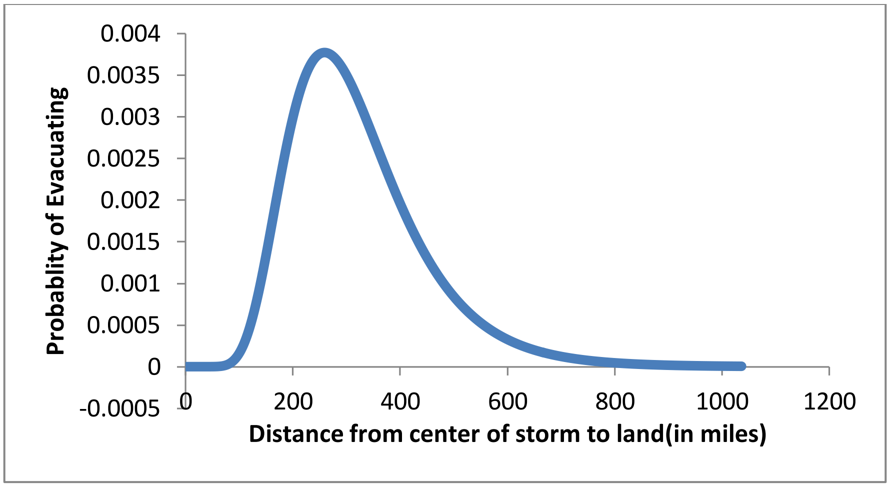

Figure 46
Transformation of distance using lognormal distribution

Vulnerability to flooding is another variable that is known to influence evacuation behavior. It is expected that households that live in a zone vulnerable to flooding will leave more promptly than households that live in a levee-protected zone or are otherwise not vulnerable to storm surge.

Coding of Variables for Estimation Purpose

Not all the variables that are used in estimating TDSLM were quantitative and this led to the requirement of coding variables as categorical variables for estimation purposes. The variables that needed category codes were type of evacuation order, storm surge, and time of day. Storm category, while not a true numeric variable, has ordinal scale properties and was assumed to be a numeric variable with ratio scale properties for the purposes of this study. The variable evacuation order was coded using two levels. When no evacuation order was issued, it was coded as zero and when an evacuation order of either voluntary or mandatory nature had been issued, it was coded as one. Storm surge was coded using two levels. When the storm surge was greater than 10 ft it was coded as one whereas when it was less than 10 feet it was coded as zero. Time of day (TOD) was coded into four time periods of six hours each as described earlier. Using the fourth time period as base case, three binary dummy variables TOD 1, TOD 2 and TOD 3 were created for the remaining three time periods, respectively. The binary variables attained the value of one when the corresponding time period was in existence and had the value of zero otherwise.

Estimation Results

Using hurricane Gustav behavioral RP data, several combinations of explanatory variables were tried to estimate a model. The model with explanatory variables and its corresponding t-statistics shown in Table 11 was considered the best model. It is a binary logit model estimating the probability of a household evacuating in each time period (equation (3)).

Table 11

Time-dependent sequential logit model estimation results for RP data

Variable	Estimate	Standard Error	t- statistic
Voluntary/Mandatory Evacuation Order	0.66	0.22	2.99
Hurricane Category	0.47	0.07	6.57
Time of Day 1(TOD1)	1.23	0.29	4.19
Time of Day 2 (TOD2)	1.92	0.29	6.63
Time of Day 3 (TOD3)	0.83	0.30	2.71
Time dependent distance	760.15	179.84	4.22
Storm Surge	0.91	0.377	2.41
Constant	-5.91	0.32	-18.01
Number of Observations = 4774 Number of Cases = 288 Log Likelihood at zero L(0)= -3309.46 Log Likelihood when only constant is used L(c) = -1225.04 Log Likelihood at convergence L(β) = -722.43 Rho Square/Log Likelihood Ratio Index = 0.41			

All the signs associated with the explanatory variables were as expected and were also significant at the 95 percent significance level. The likelihood ratio index of the model was estimated as 0.41, which indicates a good fit.

Coefficient estimates shown in Table 11 were then used to compute the probability of evacuating in different time intervals using the TDSLM shown in equation 2. The resulting probabilities were then used to predict the total number of evacuations for each time period. Figure 47 shows a comparison between the total observed and predicted evacuations in each time period.

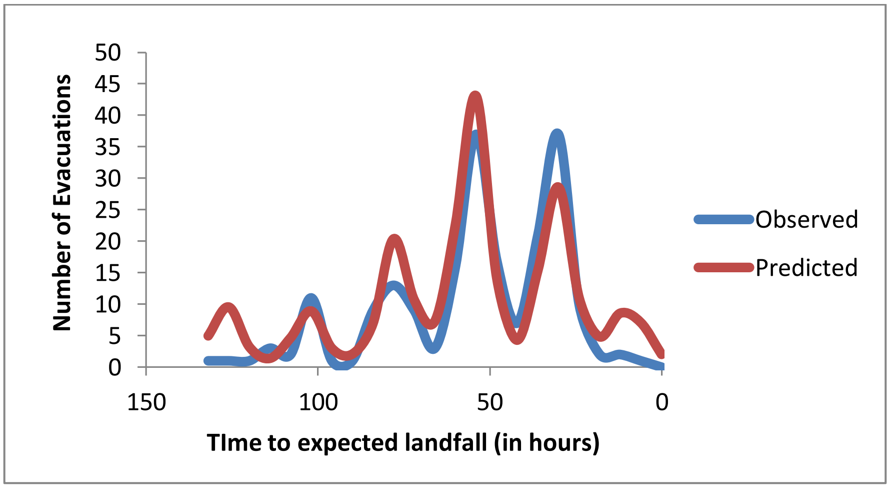

Figure 47
Comparison of observed versus predicted evacuations

Model Estimation for Comparison of TDSLM and TDNLM

To compare the TDSLM's performance against that of a TDNLM, a new TDSLM model was estimated with additional explanatory variables as compared to the old TDSLM model estimated in the previous section. A new TDSLM model was estimated because the comparison-data set did not have all the data that old model required as input. The results of the estimation are shown in the Table 12. All parameters have the correct sign and, with the exception of the parameter for the variable vehicles owned, all were found to be significant at the 95 percent significance level. The variable vehicles owned was retained within the model because it is considered a relevant variable in the decision to evacuate or not.

Table 12
Estimation result for new TDSLM

Explanatory Variable Name	Estimate	Standard Error	t-statistic
Lognormal (Time Dependent Distance)	769.52	18.58	4.26
Hurricane Category	0.47	0.07	6.58
Evacuation Order	0.68	0.22	3.08
TOD1	1.23	0.29	4.20
TOD2	1.92	0.29	6.62
TOD3	0.84	0.30	2.72
Storm Surge	0.91	0.377	2.43
Income	0.0028	0.0014	2.05
Vehicles Owned	0.0798	0.0682	1.16
Constant	-6.29	0.36	-17.07
L(0)	-3309		
L(C)	-1299		
L(β)	-718.94		
ρ^2	0.44		
Number of Cases	288		
Number of Observations	6224		

Among the time of day explanatory variables, the variables TOD 2 and TOD 3 are positive and large, suggesting that a household is more likely to evacuate during the daytime as compared to evening, and particularly in preference to the early hours of the morning as represented by the base case from 12 am to 6 am. The coefficient of the transformed time-dependent distance is large due to the transformation used.

Among the dummy variables, storm surge has the second largest parameter value after time-of-day. Its value is higher than for the variable evacuation order. This implies that a household living in high potential storm surge area is more sensitive to flooding than they are even to evacuation orders from officials, although the time when they will evacuate is still strongly affected by the time of day.

The variable income is normally expected to have a direct relationship to the evacuation decision. That is, a household with higher income is expected to evacuate more readily than a household with a low income, and as expected the parameter associated with the variable income has a positive value. Similarly, a household which owns a vehicle is more likely to evacuate than a household with no vehicle. This is reflected in the sign of the parameter associated with the variable vehicles owned.

The time dependent nested logit model (TDNLM) was estimated using equation 13. A full information maximum likelihood procedure programmed in Matlab's custom environment TOMLAB was used to maximize equation 13. It is important to note that the TDNLM applied on Hurricane Gustav data used 22 time intervals or levels. Each level represented a six hour time-period. In estimating the model, it was assumed that λ, the factor representing the correlation among time intervals, is constant across all the time periods and only one constant was used in the representative portion of the utility for all levels. If a unique constant is used in each time period, the model is over specified and the constants ensure that the observed evacuations are reproduced in each cell without any contribution from the remaining variables. The results from the estimation of the model are shown in Table 13.

All the parameter estimates have the right signs, and the majority of the parameters are significant. The model specification used for the TDSLM was retained in the TDNLM for comparison purposes (parameter values, parameter significance) but it is possible that a different specification in the TDNLM could produce better estimation results. The parameter values for corresponding explanatory variables in the two models are different. Some variables appear to be more influential in one model than the other. For example, time-dependent distance, hurricane category, time of day, income, and vehicles owned appear to have a greater impact in the TDNLM than in the TDSLM. In contrast, storm surge seemed to have a greater impact in the TDSLM.

Table 13

Estimation results for time-dependent nested logit

Explanatory Variable Name	Estimate	Standard Error	t-statistic
Lognormal (Time Dependent Distance)	1402.96	400.56	3.56
Hurricane Category	0.73	0.17	4.24
Evacuation Order	1.87	0.43	4.36
TOD1	2.34	1.06	2.21
TOD2	2.81	1.16	2.41
TOD3	1.26	0.93	1.34

Explanatory Variable Name	Estimate	Standard Error	t-statistic
Storm Surge	0.26	0.34	0.766
Income	0.01	0.00	1.89
Vehicles Owned	0.16	0.15	1.07
Constant	-9.39	2.46	-3.82
Lambda	0.644	0.12	5.5
L(0)	-2067		
L(C)	-1960		
L(β)	-704		
ρ^2	0.64		
Number of Cases	288		
Number of Observations	6224		

The parameter that is not estimated in TDSLM but estimated in the TDNLM is the parameter λ. As explained elsewhere, the parameter when subtracted from 1 indicates the correlation between two successive time-periods. Since it was assumed that λ is constant across all time periods, 1-λ = 1-0.64 = 0.36, is the estimated correlation coefficient between all time periods among all households.

Prediction and Comparison

To compare the relative performance of TDNLM and TDSLM, the estimated model parameters from both models were used to predict the observed hurricane evacuation demand. Figure 49 shows the results from the comparison. The predictions from both models were similar in almost all time intervals, except in time intervals 3, 10, and 21, where the TDSLM over-predicted the number of evacuations. Both models over-predicted in time interval 14 and under-predicted in time interval 18. Two factors, the Root Mean Square Error (RMSE) and the likelihood ratio index (ρ^2) were used for objective comparison purposes. The RMSE for the TDNLM was 3.16 and for the TDSLM it was 4.63, showing a 32 percent better predictive performance of the TDNLM over the TDSLM. The likelihood ratio index shown in Table 12 and Table 13 uses the log likelihood of the models with constants as the base, and suggest good fits for both models although a ρ^2 value of 0.64 for the TDNLM is considerably better than the 0.44 obtained with the TDSLM. It is also worthwhile to note here that the number of TDNLM predicted evacuations when summed over all 22 time intervals matched the sum of observation evacuations; whereas the sum of

TDSLM predicted evacuations exceeded the observed evacuations by 40. Thus, it appears that the TDNLM is better than the TDSLM in predicting hurricane evacuation demand.

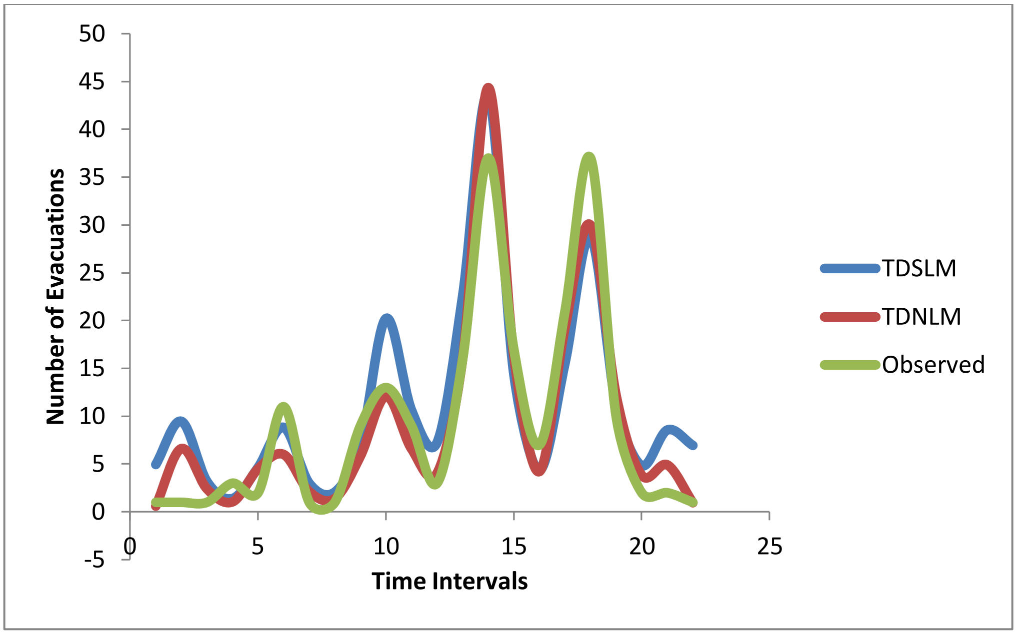

Figure 48

Comparison of predictions from TDSLM and TDNLM with observed evacuations

TDSLM Model from Combined Stated Choice and Revealed Preference Data

A joint model was estimated on a combination of RP and SC data. The RP data source is the Hurricane Gustav evacuation behavior data and the SC data is the data collected using the new data collection method from all 9 hypothetical storms.

It is common to pool RP and SC data because SC data is not necessarily expected to produce realistic results. This is because what people say they will do while responding to an SC experiment may not be the same as what they actually do in reality. At the same time, SC data offers a rich variability in attributes, which is generally deficient in RP data. On the other hand, RP data enjoys high credibility on actual behavior because it is based on revealed choices in real life. Therefore, SC and RP choice data pooled together can secure advantages of each method while mitigating their limitations.

To estimate a joint model, an estimation procedure is needed that allows the ratio of coefficients to be estimated primarily from the stated-preference data while the alternative-specific constants and overall scale of the parameters are estimated from the revealed preference data *[40], [42], [43], [44]*. The most predominant issue when pooling RP and SC data is that the unobserved factors are generally different for the two types of data *[40]*. A procedure that is used to handle this issue is described in the following paragraphs.

According to the TDSLM paradigm, the utility that household *n* obtains from the alternative "evacuate" in time period *i* is specified as $U_{nei} = \beta x_{nei} + e_{nei} + C_e$, where x_{nei} is a vector of variables that relate to the alternative "evacuate" as faced by household n in time period i, **β** are coefficients of these variables, C_e is a constant that captures the average effect on utility of all factors that are not included in the model, and e_{nei} represents the effect of factors that are not observed by the researcher but incorporated by the household in the utility function. The constant C_e has a mean and distribution. For a standard logit model, the distribution of the error term is extreme value with variance $\lambda^2\pi^2/6$. As described by Train, the scale of the utility is set by normalizing the variance of the unobserved portion of utility *[*40*]*. After normalization, the utility function in the TDSLM becomes $U_{nei} = (\beta/\lambda)x_{nei} + \mathcal{E}_{nei} + c_e/\lambda$, where the normalized error $\mathcal{E}_{nei} = (e_{nei} - c_e)/\lambda$ is independent and identically distributed extreme value with variance $\pi^2/6$. The parameters that are estimated by regular logit estimation routines are the original parameters divided by the scale factor λ. One should note here that scale factors are confounded with the coefficient estimates and not separately identifiable per se.

There is no reason to expect that the alternative-specific constant and the scale factor will be the same for the RP and SC data *[40]*. This is because the parameters reflect the effects of unobserved factors which are unavoidably different in real and hypothetical situations. In a stated choice experiment, a household is asked to assume that all unobserved factors are identical for alternatives "evacuate" and "do not evacuate" in each time period. However, in making a choice in a real evacuation, several factors affect a household's choice that are not observed by the researcher. In contrast, in a stated choice experiment, if a respondent strictly obliges the request of the researcher then unobserved factors do not exist at all by definition. However, the respondent does bring in some concepts or perceptions of his own in responding to hypothetical choices. Thus, it is reasonable to assume that the alternative-specific constant and the scale factor are distinct for RP and SC data.

To reflect the differences, separate constants and scale parameters are specified and estimated for SC and for RP. Let c_e^{RP} and c_e^{SC} represent the mean effect of unobserved factors for alternative “evacuate” in time interval i for revealed preference choices, and stated-choice experiments, respectively. Also, let λ^{RP} and λ^{SC} represent the scales of the distributions of the unobserved factors around the means in revealed and stated preference contexts respectively. Normalizing either of the scale parameters to one sets the overall scale of the utility. Traditionally, λ^{RP} is normalized to one so that λ^{SC} reflects the variance of unobserved factors in stated choice situations relative to that in revealed preference situations. After normalizing, the utility for RP observations becomes $U_{nei} = \beta x_{nei} + c_e^{RP} + \mathcal{E}_{nei}$ for each time period i and $U_{nei} = (\beta/\lambda^{SC})x_{nei} + c_e^{SC}/\lambda^{SC} + \mathcal{E}_{nei}$ for each stated choice observation i.

After accounting for difference in scale factors and alternative specific constants, the model is estimated on data from both the RP and SC data. Both groups of observations are stacked together as input to a log likelihood optimization routine. Most importantly, the coefficients in the model are divided by a parameter $1/\lambda^{SC}$ for the stated choice observations. Then the joint log likelihood, shown below in Equation 14, is maximized with respect to η, the vector of all parameters to be estimated. Standard binary estimation packages lack the functionality of estimating a joint model. Hence, a custom script was written in Matlab to estimate the parameter vector using the standard optimization procedures available in Matlab.

The parameters estimated using the procedure described above allow estimation of vector **β,** the coefficients of the explanatory variables. The alternative-specific constants are estimated separately for the two types of data. This distinction allows the researcher to avoid the biases that SC data might contain. When forecasting with the model, the estimated **β** values and the constant from the RP data are used to avoid any bias the constant from the SC data might carry.

$$L(\eta) = \sum_{n \in R} \sum_{P_i \in C_n{}^{RP}} y_{in} \ln P_{in}^{RP}\left(X_{in}^{\mathrm{RP}} \middle| c^{RP}, \beta\right) + \sum_{n \in S} \sum_{P_i \in C_n{}^{SP}} y_{in} \ln P_{in}^{SC}\left(X_{in}^{SC} \middle| c^{SP}, \beta, \lambda^{SC}\right) \quad (14)$$

Where η = **β**, λ, c_s^{RP}, and c_s^{SC}

y_{in} = 1 if household n chooses to evacuate, and = 0 otherwise ,

P_i^{RP} = the conditional probability that a household evacuates in time interval i for the RP data

$P_i^{SC} =$ the conditional probability that a household evacuates in time interval i for the SC data

where, as described by equation (3)

$$P_i^{RP} = \frac{\exp\,(\mathrm{c_i^{RP}} + \boldsymbol{\beta} X_i^{RP})}{(1 + \exp\,((\mathrm{c_i^{RP}} + \boldsymbol{\beta} X_i^{RP}))} \qquad (15)$$

$$P_i^{SC} = \frac{\exp\,(\lambda^{SC}(\mathrm{c_i^{SC}} + \boldsymbol{\beta} X_i^{SC}\,)}{(1 + \exp\,(\lambda^{SC}(\mathrm{c_i^{SC}} + \boldsymbol{\beta} X_i^{SC}))} \qquad (16)$$

Arrangement of SC Data for Estimation Purposes

The data collected from SC survey was arranged in a row and column format identical to the RP data arrangement explained in section *Data Preparation for estimating TDSLM and TDNLM*. However, a major difference between RP data and SC data arrangement arose because of the manner in which data was collected. Because the SC method used only four forecasts in each hypothetical storm it resulted in a maximum of four observations per household if a household did not evacuate. On the other hand the RP data resulted in 22 observations for a single non-evacuating household as explained earlier.

Results from Estimation of Joint Model

To facilitate comparison among the two models, the model from the RP data and the model from the joint data, the specification of both the models were made identical. Variables that proved to be logical and significant in explaining evacuation behavior in the RP model were used in the estimation of the joint model. The coefficient estimates and their corresponding statistics are shown in Table 14.

The signs associated with all the coefficient estimates were as expected and all the coefficients were significant at the 95 percent confidence level. The log likelihood ratio index was estimated as 0.39 indicating that the joint model was a good fit to the joint data.

Table 14
Time-dependent sequential logit model estimation results for joint data

Variable Name	Estimate	Standard Error	t-statistic
Voluntary/Mandatory	1.06	0.15	6.78
Hurricane Category	0.35	0.05	6.91
Time of Day 1	1.14	0.255	4.47
Time of Day 2	1.55	0.24	6.3
Time of Day3	1.17	0.23	4.93
Time dep dist	555.61	126.75	4.38
Surge	0.60	0.14	4.11
Constant RP	-5.67	0.29	-19.21
Constant SP	-6.16	0.56	-10.85
λ^{SC}	0.83	0.11	7.24
Number of Observations = 7355 Number of Cases = 1136 Log Likelihood at zero L(0) = -5098.09 Log Likelihood when only constant is used L(c) = -3062.35 Log Likelihood at convergence L(β) = -1845.31 Log Likelihood Ratio Index/ Rho Square = 0.39			

Evaluation of the Time-Dependent, Audio-Visual, Stated Choice Data Collection Method

To determine if the new data collection method constituted an improvement over the old method, it was compared with old method in two ways. First, predictions from the TDSLM developed using data collected from the old method were compared to predictions from the TDSLM model developed from the joint data and, second, the cost of the two methods were compared.

Comparison of Predictions from Application of TDSLM Model on Hurricane Georges
To test the accuracy of prediction of the TDSLM models in practice, data from Hurricane Georges was used. The use of an independent data set to validate the models allows one to remove the advantage that the models might have if prediction is tested on the estimation data set.

Hurricane Georges was a major hurricane that threatened New Orleans and surrounding parishes in 1998. The University of New Orleans (UNO) Survey Research Center conducted a post-evacuation behavioral study of Hurricane Georges *[45]*. The data collected in the survey was used to evaluate the performance of the two TDSLM models developed in this study by comparing their predictions with the observed values from the data.

Preparation of the Hurricane Georges Data for the RP and the Joint Model Prediction
The UNO data was cleaned and arranged in a format required by the models. To arrange the data, the following procedure was used. The Georges data was first appended with time-dependent features of Hurricane Georges. For example, information such as hurricane category, time-dependent path of the storm, and actions taken by public officials were added to the data set. The single row of data for each household in the original data set was altered into rows for each time period over which evacuation behavior of the household was observed. In this case, the total number of rows for each household was equal to 22. The columns in the row and column format hold time-dependent characteristics of the storm along with time-invariant socio-economic characteristics.

Recalibration of the Constants from the RP-data- TDSLM Model and Joint-data-TDSLM Model Alternative-specific constants are incorporated in discrete choice models to capture the average effect of unobserved factors. In forecasting or predicting, it is often useful to adjust these constants, to reflect the fact that unobserved factors are different in the predicted context than in the context in which the model was estimated. For these reasons, constants from the RP-data TDSLM model and the joint-data TDSLM model were adjusted using the procedure explained in the following paragraph.

Let C^0 be the estimated alternative specific constant for the estimation data set and let E denote the total number of evacuations observed for Hurricane Georges and $\hat{E}^0$ denote the predicted number of evacuations using the estimated constant. Using the TDSLM with its original values of C^0, the total number of evacuations was predicted using the estimated model. If the actual number of observed evacuations were lower than the predicted number than the alternative specific constant was lowered using an adjustment factor computed as:

$$C^1 = C^0 + \ln\left({}^{E}/_{\hat{E}^0}\right) \qquad (17)$$

With the new constant, C^1, total number of evacuations were predicted again and compared with the observed. The process of adjusting was repeated until predicted evacuations were sufficiently close to the observed. The recalibrated constant for the RP-data TDSLM changed from -5.9 to -6.76 and for the joint-data TDSLM it changed from -5.6 to -6.46.

Application of the RP-data-TDSLM and Joint-data-TDSLM on Hurricane Georges

Both the RP-data TDSLM and joint-data TDSLM were used to predict time-dependent evacuations for Hurricane Georges. The results from both the predictions are shown in Figure 49. The results suggest that the model from the joint data performed slightly better than the model using the RP data in predicting time-dependent evacuations of Hurricane Georges.

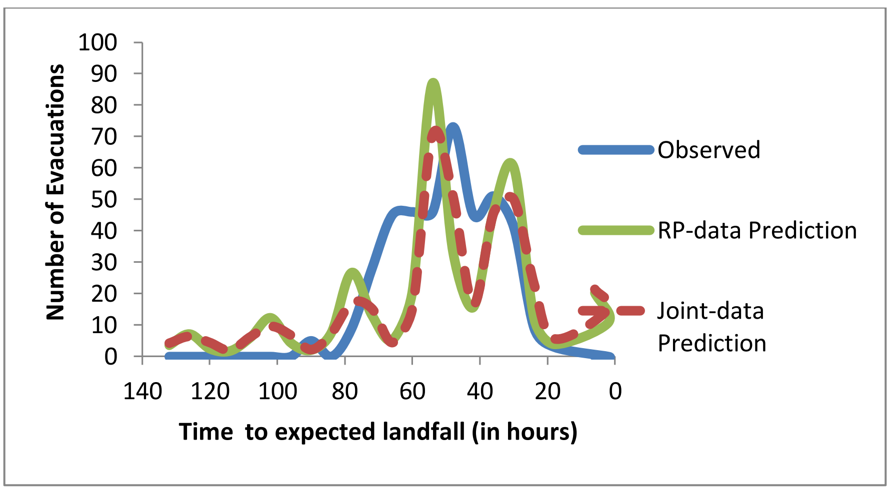

Figure 49

Comparison of observed versus predicted for RP-Data-TDSLM And Joint-Data-TDSLM

To objectively evaluate the performance of the two models, a Chi square statistic was computed for the predictions resulting from the application of two models. The chi square statistic was calculated as shown below

$$\sum_{22}^{1} \frac{(Observed-Predicted)^2}{Predicted} \quad (18)$$

The Chi square statistic was then used to test the null hypothesis that the models were a good fit for the observed time-dependent evacuations from Hurricane Georges. The null hypothesis was tested for each model independently. At the 95 percent significance level, the null hypothesis for both the models were rejected in favor of the alternative hypothesis that the models were not a good fit to the observed evacuations from Hurricane Georges.

Because the chi square test was unable to distinguish the relative performance of each model a root mean square error (RMSE) was computed for the predictions from both the models. The RMSE for the RP data model was 19.2 evacuations per six hour period while the RMSE for the joint data model was 16.5, thus suggesting a slightly better prediction from the joint data model.

Cost Comparison of the RP and the SC Method

As stated earlier, to fulfill the objectives of this study the task of comparing the costs for the RP and the SC method was considered. The following paragraphs describe the method used to compare the costs.

The costs incurred in collecting data using the two methods were divided into eight categories: Material Costs, Labor Costs, Printing Costs, Mailing Costs, Incentives, Management Costs, Recruitment Costs, Development Costs, and Data Entry Costs. Table 15 shows all the categories and the associated costs for the two methods. The detailed list of items that fall into each category are shown in Appendix I.

The RP and the SC methods both had their own exclusive costs as well as shared costs. Some of shared costs were divided proportionately between them, while other shared costs were divided disproportionately depending on the situation. An example of a shared cost that was divided proportionately between the RP and the SC method is recruitment cost. Since it would have cost the same regardless of what survey method was used, the cost was shared equally between the two methods. An example of the cost that was shared disproportionately between the two methods is development cost. The items that were categorized into development cost were expenses related to development of survey instruments, expense for conducting the focus groups, and other paraphernalia that were unique to the RP and the SC surveys. Since most of the focus group discussion was devoted towards the development of new survey instrument for the SC method, 96 percent of the costs associated with the conduct of the focus groups were listed under the SC method. Yet another example of cost that was shared unequally is data entry cost. Since the amount of data gathered in the RP survey instrument was more than the SC survey instrument, it took more time for data entry personnel to enter data from the RP survey instrument into database and consequently the RP data entry incurred more cost than the SC data.

The total costs associated with the RP and the SC methods are shown in Table 10. The RP survey cost $39,386 while the SC survey cost $49,086 suggesting that the new method cost approximately 25 percent more than the traditional RP method.

Table 15
Cost comparisons of the RP and the SC Method

Category	**Cost in dollars**	
	RP	**SC**
Materials	1354	2417
Printing	1637	1584
Development	509	8473
Recruitment	8229	8229
Mailing	4832	4831
Labor	950	1100
Management	17834	17834
Data Entry	402	256
Incentives	3640	4360
Total	39386	49086

CONCLUSIONS

The new method that was evaluated in this research costs approximately 25 percent more than conventional data collection method. However, at least part of this increased cost can be attributed to the extra effort expended in developing the new method. The authors expect the cost will decrease in subsequent developments because of prior investments of time and effort made in learning and establishing the methodology.

All survey participants perceived the hypothetical storms used in this study as realistic and consequently their reported stated behavior was very consistent with what is observed in reality.

One of the limitations of the new method is that stated responses of survey respondents cannot to be taken at face value because people will not always do what they say will do. Therefore, the stated choice data should be used along with the RP data when predicting time-dependent evacuation demand or testing alternative evacuation policies.

The new method appears to have the potential to replace the existing method but there are certain issues that should be improved to increase its attractiveness as a replacement method. For example, in the new method that was tested in this study, every survey participant was requested to consider his or her own dynamic contextual conditions while responding to a hypothetical storm. Nonetheless, the author did not find any evidence that survey participants obliged in adhering to this request. Therefore, in order to make survey participants actively think about their contextual conditions they should be incorporated into animations of forecasts via a virtual reality environment.

Enhanced RP data alone can be sufficient for post analysis of a hurricane evacuation event. However, when it comes to evaluating new policies or strategies collecting SC data in conjunction with RP data would be more beneficial and insightful and help in devising new policies that will improve the efficiency of evacuations.

Considering the fact that most of survey participants took only 10 to 15 minutes to fill out the new survey, more scenarios could have been included without incurring respondent burden.

Paying incentives when conducting survey through university-based research centers should be approached cautiously. This is because bureaucratic requirements that require survey participants to share confidential information will deter potential participants from participating in a survey.

If possible, survey responses should be recorded interactively within the survey instrument to allow on-the-fly data checking, provide help menus to participants, and reduce errors in recording responses.

Very favorable and positive feedback was received from survey participants for the new methodology and the majority of them, inferred from comments provided while filling our survey questionnaire, seemed to enjoy the survey experience. Given that the general population were more receptive to the survey conducted using new technology than was initially expected, this fact should be exploited to develop new survey instruments to collect more data efficiently and without compromising accuracy.

A scenario should present an approaching storm as a continuous event rather than as several discrete events to reduce the confusion caused by interference of logistical design and discrete time steps.

For researchers who are modeling transportation evacuation behavior to evaluate potential evacuation policies or strategies, the time-dependent stated-choice data collection method can serve as a source of information for inputs like dynamic demand estimation, destination choice, and route choice.

The time-dependent stated-choice method along with RP survey appears to have the potential of evolving into a new survey instrument to collect important time-sensitive, policy-sensitive, and behavioral response for wide variety of conditions thus enabling researchers to build behavioral models to predict responses to new policies.

The joint model estimated by using newly collected data slightly enhanced the predictive capability of TDSLM. The authors think this is due to addition of the time-dependent SC data that had considerable variability on variables such as time-dependent distance, hurricane category, and evacuation orders.

A new hurricane evacuation demand model, the time-dependent nested logit model, was successful in predicting evacuation demand by overcoming some of limitations imposed by time-dependent sequential logit model.

RECOMMENDATIONS

Electronic equipment should be developed with a capability to both present hypothetical scenarios and simultaneously record responses to hypothetical scenarios. Detailed animation of contextual activities related to a potential survey participant should be included in the hypothetical conditions presented to a survey participant. The aim should be to develop a total immersive virtual environment that helps a survey participant virtually experience hurricane evacuation and thereby help him make realistic choices.

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APPENDIX A: RECRUITMENT SCRIPT

Travel Related to Hurricane Gustav
Recruitment Script

Households will be recruited by RDD eliminating those telephone numbers that are on "do not call" lists or are registered business numbers. The script includes screening questions to determine whether or not the household is to be recruited.

The telephone number to be dialed should appear on-screen, along with an opening question and response codes. Call dispositions, as shown below, should be recorded on the screen.

01 Busy

02 Answering machine

03 No answer

04 Household refuses to continue and insists do not call back (hard refusal)

05 Disconnected number

06 "No call" listed

07 Fax machine – remove from further consideration

08 Household refuses to continue (soft refusal) – ask "Can we call you later at a more convenient time?"

09 Call back (at specific time)

10 Call back (no specific time)

11 Language barrier

12 New number recording (note new number)

13 Successful contact (GO TO Q1)

14 All other reasons

1. Hello, this is yyyy and I' m calling from Louisiana State University. (Instruction to operator: If respondent sounds like a young child ask them if you can speak with an adult) Are you 18 years of age or older ?

1 YES (CONTINUE)

2 No (GO TO Q4)

3 Refused (DO NOT READ)

2. We are doing a study of travel related to hurricane evacuation in and around the New Orleans area. We are offering $ 20 as an incentive for the participants. This is not a telephone survey. We will ask you few questions on the telephone to check your eligibility for participation in the survey and then we will mail a DVD that you can watch at your leisure and fill out the survey booklet accompanying the DVD. I would like to ask you some questions about your household. Whatever you tell me will be kept STRICTLY CONFIDENTIAL. Is this a good time for me to proceed ?

1 YES (GO TO Q5)

2 No (CONTINUE)

3 Refused (END CALL. RETAIN NUMBER AND ARRANGE CALL BACK)

3. When would be a good time for me to call back?

(ARRANGE A CALL BACK TIME OR GIVE THE RESPONDENT THE CHOICE OF CALLING THE INTERVIEWER ON THEIR PERSONAL CELL PHONE AT ANY TIME THEY WISH TO CALL)

I will be your personal survey person. Again, my name is XXXXX

4. Is there an adult who lives there I can speak with ?

1 Yes (GO BACK TO Q1 WITH NEW RESPONDENT)

2 No (IF AN ADULT WHO LIVES HERE IS NOT CURRENTLY PRESENT, RETAIN NUMBER AND ARRANGE A CALLBACK)

5. Do you own a DVD player ?

1 Yes (Go to question 7)

2 No (Go to question 7)

6. Do you own a desktop computer or laptop that has the ability to play DVD's ?

1 Yes (continue)

2 No (If answer is no do not recruit the household)

7. Is this where you LIVE ? (Quote address from reverse phone listing, including zip)

1 Yes (Continue)

4 No, I don't live here (Continue)

5 No, this is not a residence. Say: I' m sorry, this study is for residents only. Thank you for your time. (TERMINATE)

8 Refused (Continue)

9 Don't Know (Continue)

8. We would like to send you a questionnaire regarding your response to hurricane

Gustav and other storms. The whole survey will take less than 30 minutes to complete. Can we send it to the above address?
1**.**Yes (Continue)
2. No (get new address)

9. Were you residing in the area, when HURRICANE GUSTAV made landfall in September of 2008 ?
1 Yes (Continue)
2 No (THANK AND TERMINATE)
4 Other (THANK AND TERMINATE)
IF "NO," TERMINATE THE INTERVIEW BY RESPONDING "THANK YOU FOR YOUR TIME, BUT WE ARE LOOKING FOR PEOPLE WHO WERE RESIDING IN THIS AREA AT AT THAT TIME. THANK YOU AGAIN. GOODBYE."

10. What type of house do you live in ? (read out the choices)
1 Permanent house
2 Mobile home
3 Apartment/ Condo
4 Other (specify)

11. How many vehicles do you own ?
______ Number

(This is the end of the recruitment script)

APPENDIX B: ADVANCE LETTER

Date: - September 21, 2009

Dear «FIRSTNAME» «LASTNAME»,

A study is being conducted by Louisiana State University into hurricane evacuation behavior. You have been randomly selected from a group of qualified households to participate in the survey. Your participation is of course voluntary but we are writing to you in advance to tell you that we will be calling you in a few days time to invite you to participate in this survey. A 20-dollar incentive will be paid upon completion of the survey.

The Public Policy Research Lab of Louisiana State University will conduct the survey. Part of the data will be used in a doctoral research project that focuses on modeling evacuation behavior.

We are writing in advance because we have found people like to know ahead of time that they will be contacted

The Public Policy Research Lab will call you between 09/24/09 and 10/01/09 to invite you to participate in the survey. We assure you that all the information collected from you will be kept strictly confidential.

The study is an important one that will help government agencies in Louisiana manage evacuations better. Thank you for your time and consideration. It's only with the generous help of people like you that our research can be successful.

Sincerely,

Ravindra Gudishala
Doctoral Candidate,
Department of Civil and Environmental Engineering,
Louisiana State University.

Chester Wilmot
Professor and Advisor to the Doctoral Candidate,
Department of Civil and Environmental Engineering,
Louisiana State University.

APPENDIX C: COVER LETTER

Dear XXXXX,

Thank you for agreeing to take part in this study aimed at developing a new survey procedure to . You will help us develop a questionnaire that will get information on hurricane evacuation behavior. To participate in this study it is not required for you to be a hurricane Gustav evacuee.

This envelope contains a green colored booklet, a violet colored booklet, DVD, W-9 form and a pre-paid postage envelope. The DVD complements the violet colored booklet as described in greater detail below.

Start the survey by filling out the green colored booklet followed by the violet colored booklet. In order to fill the violet colored booklet you have to play the DVD and watch the videos included in the DVD. If you have any difficulty filling out the details on booklets or playing the DVD please call us at 225-678-8695, at any time.

Send the two booklets, W-9 form and the DVD to us by November 7th 2009, using the pre-paid postage envelope provided to you.

You will be paid $ 20 by check once we receive your completed survey questionnaires. It is important that you fill out the W-9 forms included in this package to receive your $ 20. Federal regulations require that LSU have a completed W-9 form for any payment it makes. Please be assured that all documentation associated with this survey is treated with the greatest confidentiality.

Thank you once again for your time and willingness to participate in this research project.

Yours truly,

Ravindra Gudishala
Doctoral Candidate,
Department of Civil and Environmental Engineering,
Louisiana State University.

Chester G.Wilmot-Professor,
Department of Civil and Environmental Engineering,
Louisiana State University .

Public Policy Research Lab-Louisiana State University.

Telephone Enquiry No-225-678-8695.

APPENDIX D: REVEALED PREFERENCE SURVEY INSTRUMENT

2008 Hurricane Evacuation Survey

Questionnaire
For
Hurricane Gustav

Household : ____________________

Month and year of Survey_____/_____

Survey conducted by Public Policy Research Lab at LSU

Thank You!

For agreeing to take part in this important study

Your information counts!

By completing this questionnaire, you will be providing important information that will help understand evacuation behavior during hurricanes.

QUESTIONS ?
Call us at
225-678-8695

Consent Form

Study title : "Development of Time-dependent, audio-visual, stated choice method of data collection of hurricane evacuation behavior."

Conducted by: Public policy research lab located on the campus of Louisiana State University, Baton Rouge.

Investigators: The following investigators are available to answer your questions about this study
M-F 9:30 am-4:30 pm
Dr. Chester G. Wilmot 225-578-4697
Ravindra Gudishala 225-578-5266

Purpose of the Study: The purpose of this research project is to develop a new method for collecting hurricane evacuation behavior data and compare its efficiency with traditional method.

Subject Inclusion: Individuals, 18 years or older, who live in households located in New Orleans area and were present when hurricane Gustav made landfall in September 2008.

Number of subjects: 300 households

Study Procedures: The study will be conducted by using two questionnaires. First questionnaire, green color booklet, will collect information both on evacuation behavior during hurricane Gustav and demographics. Second questionnaire, violet color booklet along with a DVD, will collect information about expected evacuation behavior if threatened by a hurricane in future. It will take approximately 20 minutes to complete two questionnaires.

Benefits: Subjects will be paid $20 to participate in the study. Additionally, the study may yield valuable information about hurricane evacuation behavior that would help Louisiana Department of Transportation to manage hurricane evacuations in an efficient manner.

Risks: The only study risk is the inadvertent release of sensitive information found in the two questionnaires. However, every effort will be made to maintain the confidentiality of your study records. Files will be kept in secure cabinets to which only the investigator has access.

Right to Refuse: Subjects may choose not to participate or to withdraw from the study at any time without penalty or loss of any benefit to which they might otherwise be entitled.

Privacy: Results of the study may be published, but no names or identifying information will be included in the publication. Subject identity will remain confidential unless disclosure is required by law.

Signatures: The study has been discussed with me and all my questions have been answered. I may direct additional questions regarding study specifics to the investigators. If I have questions about subjects' rights or other concerns, I can contact Robert C. Mathews, Institutional Review Board,(225) 578-8692, irb@lsu.edu, www.lsu.edu/irb. I agree to participate in the study described above and acknowledge the investigator's obligation to provide me with a signed copy of this consent form.
Signature____________________Date________________

Questions related to Evacuation decision

1. **Did you evacuate for Hurricane Gustav ?**
   - ☐ Yes (If yes, go to question 3)
   - ☐ No
   - ☐ Don't know

2. **What made you decide *not* to evacuate ? (mark all boxes that are relevant. Circle the box that is the most important reason for not evacuating)**

   - ☐ Storm not severe/house adequate
   - ☐ Forecasts indicated low chance of a hit
   - ☐ Friend/relative said evacuation unnecessary
   - ☐ Officials didn't say to evacuate
   - ☐ Had no transportation
   - ☐ Had no place to go
   - ☐ Wanted to protect property from looters
   - ☐ Wanted to protect property from storm
   - ☐ Left unnecessarily in past storms
   - ☐ Job required staying
   - ☐ Waited too long to leave
   - ☐ Traffic too bad
   - ☐ Tried to leave, but returned home because of traffic
   - ☐ Too dangerous to evacuate because we might get caught on road in storm
   - ☐ No place to take pets/Shelter would not accept pets
   - ☐ Required special medical care
   - ☐ Could not afford it
   - ☐ Other, specify:__________
   - ☐ Don't know

   Go to Q 23 After answering Q 2

3. **What convinced you to leave your home to go someplace safer ? (mark all boxes that are relevant.**
   Circle the box that is the most important reason for evacuating)

   - ☐ Evacuation order from emergency or elected officials
   - ☐ Advice from Weather Service
   - ☐ Advice/order from police officer or fire fighter
   - ☐ Advice from media
   - ☐ Advice from family/friends/neighbor
   - ☐ Concerned strong winds would make house unsafe
   - ☐ Concerned flooding would cut off roads or flood home
   - ☐ Storm got stronger
   - ☐ Other; specify:___________

☐ Don’t know

Questions related to evacuation travel

4. Hurricane Gustav made landfall at 9:20 am on Monday, September 1, 2008. On which date and at what time did you leave ?

Date_____ / 08 / 2008 Time____________(am/p.m)

5. How did you travel ?

- ☐ Car / Van/ SUV/ Truck
- ☐ RV
- ☐ Bus (Go to question 10)
- ☐ Train (Go to question 10)
- ☐ Walk (Go to question 10)
- ☐ Got a ride with someone else (Go to question 10)

6. How many vehicles were used?

______ Number

7. How many vehicles were available in your household that you could have used to evacuate?

_____ Number of vehicles

8. How many people were in each vehicle ?

____ Vehicle 1
____ Vehicle 2
____ Vehicle 3

9. Number of trailers/boats/ vehicles pulled

_______Number

10. Where did you evacuate to ?

- ☐ Public shelter
- ☐ Church
- ☐ Friend/relative (Go to question 12)
- ☐ Hotel / Motel (Go to question 12)
- ☐ Workplace (Go to question 12)
- ☐ Other, specify:_____________ (Go to question 12)

11. Why did you go to a public shelter or church rather than going someplace else?

- ☐ Close to home
- ☐ Safer than home or other places
- ☐ Not enough time to get to anyplace else

☐ Couldn't find motel with vacancy
☐ Got tired of driving
☐ Couldn't afford hotel/motel
☐ Had no place else to go
☐ Officials recommended going to public shelter or church
☐ Media recommended going to public shelter
☐ Friend/relative recommended going to public shelter
☐ Other, specify:_________
☐ Don't Know

12. In which city or county is that located?

____

13. In which state is that located?

☐ Texas
☐ Mississippi
☐ Alabama
☐ Other, (specify)_______________
☐ Don't know

15. Was that your original destination when you set out to evacuate, or did you change your mind about where to go after leaving home?

☐ Changed destination (Go to question 17)
☐ Reached original destination
☐ Don't Know

16. Did you end up going farther from home than you had planned or not as far?

☐ Farther
☐ Not as far
☐ About the same distance (Go to question 18)
☐ Don't Know (Go to question 18)

17. What caused you to change your mind about where to go? (mark all boxes that are relevant. Circle the one box that was the most important reason to change your mind)

☐ Traffic congestion
☐ Information about better routes
☐ Information about available shelter or lodging
☐ Ran out of gasoline
☐ Tired of being on road
☐ Hungry
☐ Storm getting too close to continue

18. While on the road during the evacuation, did you experience any difficulties such as running out of gasoline, your vehicle breaking down, or needing food, water, or a restroom? (mark all boxes that are relevant. Circle the box next to the greatest difficulty)

☐ Yes, ran out of gasoline
☐ Yes, car broke down/overheated

☐ Yes, needed water
☐ Yes, needed food
☐Yes, needed restroom
☐ No
☐ Other,________________________________
☐ Don't Know

19. At what time did you reach your destination?

Date____/____/2008 Time____________(am/pm)

20. Did you or anyone in your household require assistance in evacuating?

☐ Yes
☐ No (go to question 23)
☐ Not sure (go to question 23)

21. Did the person just need transportation, or did they have a disability or medical problem that required special assistance?

☐ Transportation only
☐ Special need (disability or medical problem)
☐ Both
☐ Other, specify:_______________

22. Was that assistance provided by someone within your household, or by an outside agency, or by a friend or relative outside your household?

☐ Someone in our household
☐ Outside agency
☐ friend / relatives outside our household
☐ Others (specify)______________

Questions related to the household

23. Does your job require you, or any individual in your household, to remain in the area during an evacuation ?

☐ Yes
☐ No

24. How many people live in your household, including yourself ?

________ Number

25. How many of these are 17 years of age or younger ?

________Number

26. Do you have any pets ?

□ Yes
□ No
□ Refuse to disclose

27. What is the highest level of schooling you have COMPLETED ?

□ No school completed
□ Preschool/nursery school
□ Kindergarten-4 th grade
□ 5^{th}-8^{th} grade
□ 9^{th}- 12 th grade
(no high school diploma)
□ High school graduate
□ Some college, but no degree
□ Associate degree in college
□ Bachelor's degree
□ Some graduate school
□ Master's degree
□ Professional school degree
□ Doctorate degree

28. How long have you lived in the home, in which you were present when hurricane Gustav made landfall?

_______Years _________Months _______Days

29. Which one of the following races best describes you ?

□ Asian/Pacific
□ Black/African American
□ Indian (American)
□ Mixed Race
□ White
□ Other

30. Which of the following ranges best describes your total household income for 2008?

___ Less than $15,000
___ $15,000 to $24,999
___ $25,000 to $39,999
___ $40,000 to $79,999
___ $80,000 to 119,000
___ $120, 000 to 149,000
___ Over $150,000
___ Refused

Comments

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____

Thank you !

This is the end of your Hurricane Gustav questionnaire

☐ Please go back over your Questionnaire to be sure that you answered all your questions

Please place all of your questionnaires in the envelope provided and put in the mail. No postage is required.

This study is being conducted by Louisiana State University under funding from Louisiana Department of Transportation and Development

Fill out the response sheet and hurricane Gustav questionnaire

Mail back your response sheet and hurricane Gustav questionnaire in the envelope provided

Your opinion counts !

Use the last page of the questionnaire to tell us how you felt about the traffic congestion on evacuation routes during hurricane evacuation. Also make any comments about the quality of preparations made by government to evacuate people.

Thank You

APPENDIX E: DYNAMIC STATED CHOICE SURVEY INSTRUMENT

Response sheet
For the Dynamic Stated Choice Survey

Household ：____________________

Month and year of Survey_____/_____

Survey conducted by Public Policy Research Lab at LSU

To Play DVD.

1) Insert the DVD in a DVD player and wait for the title menu to appear.
2) Press ▷ on your remote control to play
3) Use the buttons on your remote to navigate the DVD backwards if you feel it necessary to review information.
4) Follow instructions on screen.

Instructions for playing the DVD in a desktop/laptop computer.

1. Insert the DVD in the DVD drive and wait for the initial screen to appear.
2. Press enter to start playing the DVD after the appearance of initial welcome screen.
3. Use the DVD player software's navigation tools to navigate the DVD.
4. Use the mouse pointer to make selections on the screen whenever you are required to.

Response Sheet for use with the supplied DVD

Storm Number	***I would evacuate on*** ***Day (circle one)*** ***Time (fill in time)***	***Evacuate by (circle one)***	***Evacuate to (circle one)***	***Evacuation Destination***	***Route (circle one)***
Storm 1	Wednesday _____ am/pm Thursday _____ am/pm Friday _____am/pm Do not evacuate	Private vehicle no. of vehicles___ no. of people____ Bus Train Walk Ride with friend Other (specify) _____________	Motel Public shelter Friend/Relative Work Place Other (specify) _____________	City/town _____________ State________	I-10 Airline hwy I-190 I-55 Other (specify) _____________
Storm 2	Monday _____ am/pm Tuesday _____ am/pm Wednesday _____ am/pm Thursday _____ am/pm Do not evacuate	Private vehicle no. of vehicles___ no. of people____ Bus Train Walk Ride with friend Other (specify) _____________	Motel Public shelter Friend/Relative Work Place Other (specify) _____________	City/town _____________ State________	I-10 Airline hwy I-190 I-55 Other (specify) _____________
Storm 3	Saturday _____ am/pm Sunday _____ am/pm Monday _____am/pm Do not evacuate	Private vehicle no. of vehicles___ no. of people____ Bus Train Walk Ride with friend Other (specify) _____________	Motel Public shelter Friend/Relative Work Place Other (specify) _____________	City/town _____________ State________	I-10 Airline hwy I-190 I-55 Other(specify) _____________

Feed Back on the Dynamic State Choice Survey

Please comment about your experience conducting this survey

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Please fill out the response sheet and mail it back, along with Hurricane Gustav questionnaire and DVD, in the envelope provided.

Thank You !

APPENDIX F: TERMINATION LETTER

Dear XXXX,

We wrote to you in September this year saying we planned to call you and ask for your participation in an evacuation survey. Since we have reached our goal of recruiting 665 households for the study we no longer need your participation and are terminating our study.

We appreciate being able to call upon you and thank you for your time and consideration.

Sincerely,

Ravindra Gudishala
Doctoral Candidate,
Department of Civil and Environmental Engineering,
Louisiana State University,
Baton Rouge, Louisiana-70803.

Chester Wilmot
Professor,
Department of Civil and Environmental Engineering,
Louisiana State University,
Baton Rouge, Louisiana-70803.

Public Policy Research Lab
Louisiana State University,
Baton Rouge, Louisiana-70803.

APPENDIX G: METADATA
Metadata for the 2009 LSU Hurricane Evacuation Survey

1. *Sponsorship for the survey*: The Louisiana Transportation Research Center (LTRC) sponsored the survey. The Public Policy Research Lab, located on the LSU campus, collected the data for LTRC

2. *Survey purpose and objectives:* The purpose of the survey was to test a new survey methodology to collect time-dependent, hurricane evacuation behavior. The specific objectives of the survey were to jointly administer a revealed preference survey instrument and a new time-dependent, audio-visual, stated choice instrument and then compare the effectiveness and cost of the two methods.

A focus group study was conducted before the main survey. The purpose of the focus group was specifically to gauge the understanding of the general population about the survey and the new survey methodology, which was the main focus of the survey. Following the focus group a pilot study was also conducted to test the influence of post-incentive payment on the response rate.

Survey period: The pilot survey was conducted from July 23, 2009, through August 13, 2009. The main survey was conducted between September 23, 2009, and October 20th 2009. The recruitment calls were made mostly during the evenings between 5:00 pm and 9:00 pm

3. *Questionnaire and other survey documents:*The revealed preference questionnaire and the response sheet for the dynamic stated choice survey used in this study are presented in Appendix D and Appendix E, respectively. The recruitment script used for the survey is presented in Appendix A. The instructions mailed to respondents are provided in Appendix C. The advance letter is included in Appendix B

4. *Other survey materials:*Codes used to code the survey results and its meaning are provided in the codebook, attached as Appendix H.

5 *Incentive*: An incentive of twenty dollars was paid in the form of a check to respondents who successfully completed the survey. Respondents had to fill out a W-9 form to receive the check - a requirement that turned out to be very unpopular with many respondents because they had to furnish their Social Security number on the form. This was not picked up in the pilot survey because respondents were paid in cash in the pilot survey, but the University insisted on completion of W-9 forms and payment by check for the full survey.

6. *Population and sampling frame:*Households from ten parishes in the vicinity of New Orleans were targeted for the survey. These parishes were considered because survey objectives required households to have experienced Hurricane Gustav and these parishes experienced Hurricane Gustav when it made landfall in September 2008. The parishes of Tangipahoa, St. John the Baptist, Plaquemines, Jefferson, Orleans, St. Tammanny, Lafourche, St. Charles, Terrebonne, and St. Bernard were included in the population sampled. The sampling frame consisted of 10,000 randomly generated telephone numbers and their corresponding addresses purchased

from a commercial firm.

7. *Sample selection:* The targeted sample size was 300 households. To participate in the survey a household had to have experienced Hurricane Gustav and own a DVD player. Households were screened for these required characteristics during the recruitment process.

Because the survey was a mail-out-mail-back survey, it was assumed that the head of a household would fill out the survey. There was no criterion on tolerance of proxy reporting. However, it was acceptable that any member of household who was above 18 years would fill out the questionnaires.

Households that did not report anything for certain questions on the survey were contacted by phone in an attempt to get missing information. Three call back attempts were made for establishing contact with the households before dropping the households from the call back list. Approximately, 30 households were contacted for missing information.

Three reminder calls were made to all households that failed to send in their questionnaires past their assigned due date. Reminder calls proved to be very effective in improving the response rate.

A completed household was considered to be a household that provided all socio-economic data, their decision on evacuation for Hurricane Gustav, and filled out information regarding their intended response for at least one hypothetical storm.

9. *Sample disposition:* A table showing refusals, terminations, ineligibles, and noncontacts is shown in Table 1.

The survey was conducted in two stages. In the first stage, households were recruited through telephone; in the second stage, survey questionnaires were sent out to all households that agreed to participate in the survey. Table 1 represents the dispositions from the first stage.

Table 1
Sample disposition

DISPOSITION CODE	DESCRIPTION	RECORDS	ELIGIBILITY
1	Hard Refusal	311	Eligibility unknown
2	No eligible respondent	30	Ineligible
3	Business	31	Ineligible
4	Busy	62	Eligibility unknown
5	No Answer	1571	Eligibility unknown
6	Callback later	60	Eligibility unknown
7	Disconnected	410	Ineligible
8	Fax	64	Ineligible
9	Soft Refusal	120	Eligibility unknown
10	Partially Complete	2	Eligible
11	Language Barrier	11	Ineligible
12	Not Qualified	12	Ineligible
13	Don't have a DVD player	59	Ineligible
20	Complete	706	Eligible
21	Never Call	44	Ineligible

A high level of item non-response was observed for the variable evacuation time. This was because a great amount of time passed between the conduct of survey and Hurricane Gustav's landfall.

10. *Response rates:* Response rate for the survey was 12 percent. The eligibility rate was computed using the CASRO method shown here:

RR = RH / (E+ e* U) * SR/RH where

RR = response rate
RH = recruited households (665)
E = eligible households (706)
e = eligibility rate (eligible units divided by sum of the eligible and ineligible units)

(706/(706+207)) = 706/913.
U = Unknown sample units (2531) (Eligibility Unknown)
SR = Completed interviews (312)

RR = 665/(706 + ((706/913)* 2536) * 312/665 = 0.11 = 11.69 percent

11. *Processing description:* The data was edited for accuracy and consistency by manually checking each and every questionnaire returned by households. When needed, deduction was first used followed by hot deck imputation to replace missing data.

12. *Weighting and Expansion*: The weighting and expansion factors were computed using the iterative proportional fitting method. The variables used for estimation were household size, vehicle ownership- vehicles/household and ethnicity. The input needed for computation was retrieved from both 2000 census data and 2009 American Community Survey for the geographical region of interest. Sample data was cross-classified using the three variables. The variable vehicle ownership was divided into 0, 1, and greater than or equal to 2 vehicles per household. The variable household size was divided into five levels 1,2,3,4 and greater than or equal to 5. Finally, the variable ethnicity was divided into two categories: White and Non-White. The expansion factors were based on an estimate of 527,430 households in the study area and a sample size of 288 households.

13. *Data-collection methods:* Telephone recruitment, with self-administered mail-out, mail-back questionnaires were used to collect evacuation behavior data. For the stated choice portion of the survey, recruited households were required to watch animations of hypothetical hurricanes and then fill out a questionnaire describing their expected response. Additionally, households were required to complete a revealed preference questionnaire regarding their evacuation behavior during Hurricane Gustav. Hypothetical storm 7 had the same storm characteristics as Hurricane Gustav but respondents were not made aware of that fact.

14. *Interviewer characteristics:* Most of the workers or staff working at PPRL were either master's or Ph.D. students enrolled at LSU. There were also other personnel at PPRL who worked full time as telephone interviewers and they had at least two or more years of experience working as an interviewer.

15. *Geocoding of household location:* All households were geocoded using the home address, provided by respective participants, and employing the transportation GIS software package called TransCAD. All the addresses were found in the GIS database with zero unmatched records.

16. *Supplementation of Hurricane Gustav's data with time-dependent data*.

The Revealed Preference data was enhanced with Hurricane Gustav's storm-related information by retrieving information from the archives of the National Hurricane Center. Dynamic information such as hurricane category at every time interval, actions taken by public officials, the predicted path of the storm, and the potential storm surge for the surveyed area was appended to the collected data. The procedure used to add the data is described in the following paragraphs.

Data collected from the RP study was rearranged for the estimation of hurricane evacuation demand models. Each row of observations from a single household was expanded into 22 rows. In the expanded data, each row represented a time-period of six hours and the value of dynamic variables varied between these time periods. The 22 rows represented a total duration of 22 x 6 = 132 hours, which was the total length of the analysis period considered.

Dynamic variables values were entered in columns in the data set. The intersection of each row and column was populated with the value taken by a particular dynamic variable for a household in the corresponding time interval. Thus, the data presented time-dependent conditions experienced by the sampled households during Hurricane Gustav. When a household reported evacuating in a certain time period, no further rows of data were included in the data set for that household. For example, if a household reported evacuating in time period 13, then only 13 rows of data would appear for that household. If a household did not evacuate at all, all 22 rows of data were present in the data set.

16.1 Time-Dependent Distance: Time-dependent distance here is defined as the distance from the center of the hurricane to the geographical location of the household at a particular time. To calculate the distance, the latitude and longitude of the Hurricane Gustav's time-dependent track were first retrieved from NHC's website. Retrieved track and geographical location of the sampled households was then geocoded manually into a geographical map using Trans CAD. Then the distance between the track, time-dependent individual points, and geographical locations of the sampled households were calculated using the distance measuring tool available in the Trans CAD.

16.2 Hurricane Category: The variable hurricane category was entered as a variable with potentially five values corresponding to the five categories of hurricanes in the Saffir-Simpson scale. For Hurricane Gustav, the storm category ranged from a maximum of 4 to minimum of 2 as it approached the coastline, and these dynamic values were entered into the data.

16.3 Evacuation Order: An evacuation order refers to the action taken by public officials specifying the type and timing of an evacuation order issued. This variable was entered as a dummy variable acquiring the value of zero or one. A mandatory or voluntary order was represented by one and no evacuation order was represented by zero. The type of evacuation order in effect at any particular time-interval was retrieved using newspaper archives and Wikipedia.

16.4 TOD : The variable time-of-day(TOD) was represented using three dummy variables, TOD1, TOD2, and TOD3. If the time-of-day was between 12 am and 6 am then the TOD1 was coded as one and zero otherwise. If the time-of-day was between 6 am and 12 pm then TOD2 was coded as one and zero otherwise. TOD3, represented time between 12 pm to 6 pm and was coded as one if time of day fell in that category and zero otherwise. The time between 6 pm and 12 am was used as the base and was represented in the data with zeros on TOD1, TOD2, and TOD3.

16.5 Storm Surge: The variable storm surge represents the threat of flooding a household may face and enters the models as a dummy variable. Whenever the storm surge from Hurricane Gustav resulted in an estimated inundation depth greater than 10 feet above ground level at a household's geographical location, the variable storm surge was coded as one and zero when it was less than 10 feet. The value of 10 feet was used because the home sites are often raised above mean ground level due to the construction of retention ponds or lakes, depressed roads, and raised foundations.

16.6 Estimation of projected storm surge levels.

1. The storm surge, in the form of a GIS map, for the geographical region of interest for various hurricane categories was downloaded from the National Hurricane Centers website.

2. The land elevation level for the Geographical regions, in the form of a GIS map, was retrieved from the United States Geographical Society website.

3. A new geographical map was created in Trans CAD using the storm surge map, land elevation map and geocoded locations of the sampled households. Using the overlay procedure available in Trans CAD the storms surge levels and land elevation levels of the sampled households was then estimated. The land elevations were then deducted from the projected storm surge levels to get net storm surge level for the geocoded households locations.

4. Since Hurricane Gustav was a Category 2 hurricane when it made landfall, net storm surge associated with that category was used and coded into the data set as a categorical variable.

APPENDIX H: CODE BOOK

The survey was conducted by the Public Policy Research Lab with the sponsorship from the Louisiana Transportation Research Center

6/29/2010
LSU
Ravindra Gudishala

Variable type	Variable name	Variable description	Code	Question number	Frequency	Additional comments
Numeric	ID	Identification number	Number	-	-	Id assigned to a household
Numeric	Long	Longitude	-	-		Longitude of household's residential location
Numeric	Lat	Latitude	-	-	-	Latitude of household's residential location
Character	City	City	Name	-		City in which household resides
Character	State	State	LA = Louisiana	-	-	State in which household resides
Numeric	Zip	Zip Code	Five-digit ZIP code	-	-	Zip code of area where household resides
Alpha-numeric	HYPSU	Hypothetical storms used	1 = Storm 1,2,3 2 = Storm 1,2,3 Var1 3 = Storm 1,2,3 Var2 4 = Storm 4,5,6 5 = Storm 4,5,6 Var1 6 = Storm 4,5,6 Var2 7 = Storm 7,8,9 8 = Storm 7,8,9 Var1 9 = Storm 7,8,9 Var2	-	1 = 34 2 = 39 3 = 34 4 = 40 5 = 26 6 = 31 7 = 39 8 = 36 9 = 31	Labels in the code column are names of individual DVDs. Each household watched a DVD from the list of nine DVD's. Each DVD contained animations of three hypothetical storms
Character	PN	Parish Name	Name -96 = Not available	-	Orleans = 29 St.Tammany = 64 Jefferson = 90 Terrebonne = 36 Tangipahoa = 25 Lafourche = 18 Plaquemines = 3 St.Bernanrd = 4 St.Charles = 10 St.John the Baptist = 9 -96 = 22	
Numeric	FL_ZONE	Flood zoning of respondent residence	1 = house in flood zone 0 = house not in flood zone -96 = Not available		1 = 236 0 = 52 -96 = 22	

Variable type	Variable name	Variable description	Code	Question number	Frequency	Additional comments
Character	TY_HO_GUS	Type of house the household was living in when Gustav made landfall	1 = Permanent house 2 =Mobile home 3 = Apartment/Condo 4= Other -96 = Not available	-	1= 277 2 = 8 3 = 13 4 = 5 -96 = 7	
Character	TY_HO_CURR	Type of house currently living in	1 = Permanent house 2 =Mobile home 3 = Apartment/Condo 4= Other -96= Not Available	-	1= 240 2 = 5 3 = 10 4 = 5 -96 = 50	
Numeric	NO_VEH_OWN	No. of vehicles owned	-96 = Not available	-	0 = 12 1 = 84 2 = 148 3 = 36 4 = 17 ≥5 = 6 -96 = 7	Open ended question
Numeric	TI_RP_DATA	Time taken to enter RP data	Number of minutes	-	-	Time taken to enter a single household's information from the revealed preference survey into the database
Character	EVAC_YES_NO	Evacuated for hurricane Gustav or not?	1= Evacuated 2 = Did not evacuate	Q1 Revealed Preference questionnaire	1 = 223 2 = 87	Only respondents who experienced hurricane Gustav were surveyed
Character	RFNE	Reason for not evacuating	1= Storm not severe/house adequate 2 = Forecasts indicated low chance of hit 3 =Friend/relative said evacuation unnecessary 4 =Officials did not say to evacuate 5 = Had no transportation 6 = Had no place to go 7 = Wanted to protect property from looters 8 = Wanted to protect property from storm 9 = Left unnecessarily in past storms 10 = Job required staying	Q2 Revealed Preference questionnaire	1 = 13 2 = 1 3 = 1 4 = 0 5 = 1 6 = 1 7 = 0 8 = 1 9 = 0 10 =3 16=1 17=1 18=7 19=1 1_10 = 2 1_15 = 1 1_17 = 3	For this question a respondent had a choice of selecting more than one option. Therefore a format that allowed coding of multiple choices is used. For example a code 1_2_3 indicates that a respondent choose options 1,2 and 3.

Variable type	Variable name	Variable description	Code	Question number	Frequency	Additional comments
			11 = Waited too long to leave 12 = Traffic too bad 13 = Tried to leave but returned home because of traffic 14 = Too dangerous to leave because we might get caught in storm 15 = No place to take pets/Shelter would not accept pets 16 = Required special medical care 17 = Could not afford it 18 = Other 19 = Don't know -96 = No response -97 = legitimate skip/question not applicable		1_2 = 3 1_2_12 = 1 1_2_18 = 1 1_2_9 = 1 1_3_5_9_11_12_13_14 = 1 1_5_12_13 = 1 1_5_6_7_8_9_17_18 = 1 1_7 = 2 1_7_8 = 1 1_7_8_9 =1 1_7_8_9_12 = 1 1_7_9_12_14_15 16_17 = 1 1_8 = 3 1_8_10 = 1 1_8_12 = 1 1_8_15 = 1 1_8_18 = 1 1_8_9 = 2 1_9 =1 1_9_12_7 = 1 1_9_18 =2 11_12 = 2 16_18 =1 3_5_6_16 =1 3_9_11 = 1 3_9_11_12 = 1 6_10 =1 6_15_17 = 1 6_7_8_12_13 =1 6_7_8_17 = 1 6_7_8_9_14_17 =1 7_8_11 =1 7_8_11_12_13 =1 7_8_12 = 1 -96 = 8 -97 = 223	
Character	RFE	Reason for evacuating	1= Evacuation orders from emergency/elected officials 2 = Advice from weather service 3=Advice/order from police officer/fire fighter	Q3 Revealed Preference questionnaire	1 = 10 2 = 6 3 = 1 4 = 1 5 = 10 6 = 4 7 = 4	For this question a respondent had a choice of selecting more than one option. Therefore a format that allowed coding of multiple choices is used. For example a code 1_2_3

Variable type	Variable name	Variable description	Code	Question number	Frequency	Additional comments
			4 = Advice from media 5 = Advice from family/friends/neighbor 6 = Concerned strong winds would make house unsafe 7 = Concerned flooding would flood home/cutoff roads 8 =Storm got stronger 9 = Other 10 = Don't know -96 = No response -97= legitimate skip/question not applicable		8 = 1 9 =14 1_2 = 4 1_2_3_4_5_6_7 = 2 1_2_3_4_5_6_7_9 = 1 1_2_3_4_6_7 = 1 1_2_3_5_6_7 =1 1_2_3_6_7 = 1 1_2_4_5 = 4 1_2_4_5_6 = 1 1_2_4_5_6_7 = 4 1_2_4_5_6_7_8_9 = 1 1_2_4_5_6_8 =1 1_2_4_5_8 = 1 1_2_4_6 = 2 1_2_4_6_7 = 3 1_2_4_6_8_9 = 1 1_2_4_7 = 3 1_2_4_7_9 = 1 1_2_4_8 = 1 1_2_4_9 = 2 1_2_5 = 1 1_2_5_6 = 1 1_2_5_6_7 = 1 1_2_5_6_7_8 = 1 1_2_5_6_8 = 2 1_2_5_6_9 = 1 1_2_5_8 = 1 1_2_6 = 2 1_2_6_7 = 4 1_2_6_8 = 1 1_2_7 = 6 1_2_7_8 = 2 1_2_7_9 =1 1_2_8 = 2 1_3_4_6 = 1 1_4 = 4 1_4_5_6_7 = 1 1_4_5_7 =2 1_4_6_7 = 1 1_5 = 2 1_5_6_7 = 2 1_5_6_7_9 = 1 1_5_7 = 1 1_5_7_8 =1	indicates that a respondent chose options 1,2 and 3.

Variable type	Variable name	Variable description	Code	Question number	Frequency	Additional comments
					1_5_7_9 = 2 1_5_9 =1 1_6 = 1 1_6_7 = 3 1_6_8 =1 1_6_9 =1 1_7 = 2 1_7_8 = 2 1_7_9 =1 1_8 = 1 1_9 = 5 2_4 = 4 2_4_5 = 2 2_4_5_6 = 1 2_4_5_6_7 =1 2_4_5_7 =2 2_4_5_9 =1 2_4_6_7 =1 2_4_7 = 2 2_4_7_8 =1 2_4_9 = 1 2_5_6 = 1 2_5_6_7 = 2 2_5_6_7_9 = 2 2_5_6_9 = 1 2_5_7 = 3 2_5_7_8 = 1 2_5_8 = 3 2_6 = 2 2_6_7_8 = 2 2_6_8 = 1 2_6_9 = 1 2_7 = 4 2_7_8 = 1 2_7_9 = 1 2_8_9 = 2 2_9 = 2 3_5_6_7_9 = 1 3_6_8 = 1 3_7 = 1 4_5_6_7 = 1 4_5_7_9 = 1 4_6 = 1 4_6_7_8 = 1 4_9 = 1 5_6 = 1 5_6_7 = 1	

Variable type	Variable name	Variable description	Code	Question number	Frequency	Additional comments
					5_7 = 3 5_8_9 = 1 5_9 = 3 6_7 = 6 6_7_8_9 =3 6_7_9 = 2 6_9 =1 7_8_9 = 1 7_9 = 1 8_9 = 1 -96 = 0 -97 = 87	
Numeric	DTE	Date and time of evacuation	Date in MM\DD\YY Time in HH:MM AM\PM -96 = No response -97 = legitimate skip	Q4 Revealed Preference questionnaire	-96 = 1 -97 = 87	Open ended question
Numeric	EM	Evacuation mode	1= Car/Van/Suv/Truck 2 = RV 3 = Bus 4 = Train 5= Walk 6 = Got ride with someone else -96 = No response -97 = legitimate skip	Q5 Revealed Preference questionnaire	1 = 213 2 =1 3 =1 4 = 0 5 = 0 6 = 6 -96 = 2 -97 = 87	
Numeric	NO_VEH_EVAC	Number of vehicles used for evacuation	Number -96 = No response -97 = legitimate skip	Q6 Revealed Preference questionnaire	1 = 123 2 = 70 3 = 11 4 = 6 ≥5 = 2 -96 = 5 -97 = 93	Open ended question
Numeric	NO_VEH_AVAI	Number of vehicles available	Number -96 = No response -97 = legitimate skip	Q7 Revealed Preference questionnaire	1 = 47 2 = 114 3 = 40 4 = 6 ≥5 = 1 -96 = 5 -97 = 94	Open ended question

Variable type	Variable name	Variable description	Code	Question number	Frequency	Additional comments
Numeric	NO_PEOP_VEH1	Number of people in vehicle 1	Number -96 = No response -97 = legitimate skip	Q8 Revealed Preference questionnaire	1 = 48 2 = 87 3 = 36 4 = 18 ≥5 = 5 -96 = 9 -97 = 94	Open ended question
Numeric	NO_PEOP_VEH2	No. of people in vehicle 2	-96 = No response -97 = legitimate skip	Q8 Revealed Preference questionnaire	1 = 34 2 = 29 3 = 9 4 = 10 ≥5 = 1 -96 = 5 -97 = 209	Open ended question
Numeric	NO_PEOP_VEH3	No. of people in vehicle 3	-96 = No response -97 = legitimate skip	Q8 Revealed Preference questionnaire	1 = 4 2 = 5 3 = 5 4 = 2 ≥5 = 1 -96 = 4 -97 = 279	Open ended question
Numeric	NO_OF_TRAIL	No. of trailers	Number -96 = No response -97 = legitimate skip	Q9 Revealed Preference questionnaire	0 = 163 1 = 11 ≥2 = 2 -96 = 40 -97 = 94	Open ended question. Number of trailers used for evacuation
Character	TYOFREF	Type of Refuge	1= Public Shelter 2 = Church 3 = Friend/Relative 4 = Hotel/Motel 5 = Work place 6 = Other -96 = No response -97 = legitimate skip	Q10 Revealed Preference questionnaire	1 = 3 2 = 2 3 = 114 4 = 80 5 = 3 6 = 20 -96 = 1 -97 = 87	
Character	TYOFREF_OTH	Description of "other" type of refuge in question above	Description 1 = Hunting Camp /Camp Ground/ Camp 2 = Group Condo or	Q10 Revealed Preference questionnaire	1 = 4 2 = 4 3 = 8 4 = 1 5 = 1	Open ended question

Variable type	Variable name	Variable description	Code	Question number	Frequency	Additional comments
			Condo/Rental Home 3 = Home/2nd Home /2nd Home bought for this purpose /beach house 4 = Military base 5 = RV Park 6 = Relative of a friend 7 = Evacuation House purchased after hurricane Katrina owned by Parents -96 = missing -97 = legitimate skip		6 =1 7 = 1 -97 = 287 -96 = 3	
Character	RE_PS_CHU	Reason for choosing public shelter or church as refuge	1 = Close to home 2 = Safer than home or other places 3 = Not enough time to get any place else 4 = Could not find motel with vacancy 5 = Got tired of driving 6 = Could not afford hotel/motel 7 = Had no place to go 8= Officials recommended going to public shelter/church 9 = Media recommended going to public shelter 10 = Friend/Relative recommended going to public shelter 11 = Other 12 = Don't know -96 = No response -97 = Legitimate skip	Q11 Revealed Preference questionnaire	1 = 0 2 = 0 3 = 1 4 = 1 5 = 1 6 = 1 7 = 0 8 = 0 9 = 0 10 = 0 11 = 0 12 = 0 -96 = 1 -97 = 305	
Character	RE_PS_CHU_OT	Explanation for "other" reason for choosing public shelter or church as refuge in question above	-97 = legitimate skip	Q11 Revealed Preference questionnaire	-97 = 310	Open ended question
Character	CITY_REF	City/ County in which refuge is located	City or county name 1 = Abita Springs	Q12 Revealed Preference questionnaire	1 = 2 2 = 1 3 = 1	Open ended question

Variable type	Variable name	Variable description	Code	Question number	Frequency	Additional comments
			2 = Addis 3 = “Do not remember” 4 = Alexandria 5 = Amite 6 = Atlanta 7 = Baldwin 8 = Batesville 9 = Baton Rouge 10 = Birmingham 11 = Booneville 12 = Bossier City 13 = Brentwood 14 = Bunkie 15 = Bush 16 = Canton 17 = Carthage 18 = Chattanooga 19 = Coldwater 20 = Collins 21 = Cookeville 22 = Cook station 23 = Covington 24 = Dallas 25 = Daphne 26 = Deridder 27 = Demopolis 28 = DeQueen 29 = Destin 30 = Dothan		4 = 2 5 = 2 6 = 9 7 = 1 8 = 1 9 = 19 10 = 3 11 = 2 12 = 1 13 = 1 14 = 1 15 = 2 16 = 1 17 = 1 18 = 1 19 = 1 20 = 1 21 = 1 22 = 1 23 = 2 24 = 4 25 = 1 26 = 1 27 = 1 28 =1 29 = 9 30 = 2 31 = 2 32 = 1 33 = 1 34 = 1 35 = 2 36 = 2 37 = 2 38 = 2 39 = 1 40 = 1 41 = 1 42 = 2 43 = 4 44 = 1 45 = 1 46 = 4 47 = 2 48 = 1 49 = 1 50 = 1 51 = 6	

Variable type	Variable name	Variable description	Code	Question number	Frequency	Additional comments
			31 = Fair Play 32 = Florida 33 = Folsom 34 = Forest 35 = Fort Walton 36 = Gatlinburg 37 = Gonzalez 38 = Grand Parish 39 = Granda 40 = Gulfport 41 = Gulfport Lawrenceville 42 = Hammond 43 = Hattiesburg 44 = Hodgenville 45 = Hoover 46 = Houston 47 = Hot Springs 48 = Houma 49 = Huntsville 50 = Independence 51 = Jackson 52 = Jacksonville 53 = Jasper 54 = Jayess 55 = Kankakee 56 = Karnack 57 = Knoxville 58 = Krellen		52 = 1 53 = 1 54 = 1 55 = 1 56 = 1 57 = 1 58 = 1 59 = 1 60 = 1 61 = 1 62 = 1 63 = 1 64 = 1 65 = 1 66 = 4 67 = 1 68 = 1 69 = 1 70 = 8 71 = 2 72 = 5 73 = 1 74 = 1 75 = 1 76 = 1 77 = 1 78 = 3 79 = 1 80=1 81 = 1 82 = 1 83 = 1 84 = 2 85 = 1 86 = 1 87 =1 88 = 4 89= 1 90= 1 91= 1 92 = 1 93 = 1 94 = 1 95 = 1 96 = 1 97 = 2 98 =2	

Variable type	Variable name	Variable description	Code	Question number	Frequency	Additional comments
			59 = Lafayette 60 = Lafourche 61 = Lake Ozark 62 = Lamar County 63 = LaSalle 64 = Laurel 65 = Lebanon 66 = Little Rock 67 = Madison 68 = Mandeville 69 = Mansura 70 = Memphis 71 = Mobile 72 = Monroe 73 = Montgomery 74 = Moreauville 75 = Mosspoint 76 = Naples 77 = Nashville 78 = Natchez 79 = Natchy 80 = Navarre Beach 81 = Neertunie 82 = Norcross 83 = Orange Beach 84 = Oxford 85 = Panama City Beach 86 = Pasadena 87 = Pass Christian		99 = 1 100 = 1 101 = 1 102 = 1 103 = 1 104 = 1 105 =1 106 = 1 107 = 3 108 = 2 109 = 2 110 = 1 111 = 2 112 = 1 113 = 1 114 = 1 115 = 1 116 = 1 117 = 1 118 = 1 119 = 1	

Variable type	Variable name	Variable description	Code	Question number	Frequency	Additional comments
			88 = Pensacola			
			89 = Philadelphia			
			90 = Phoenix city			
			91 = Pinola			
			92 = Plaquemines			
			93 = Pollock			
			94 = Pontotoc			
			95 = Prairieville			
			96 = Richland			
			97 = Ruston			
			98 = San Antonio			
			99 = Santa Rosa Beach			
			100 = Saratoga Springs			
			101 = Sharpco			
			102 = Shreveport			
			103 = Sparta			
			104 = St.Francisville			
			105 = Sulphur			
			106 = Tallahassee			
			107 = Texarkana		-96 = 15 -97 = 87	
			108 = Tifton			
			109 = Tylertown			
			110 = Val burg			
			111 = Vicksburg			
			112 = Vivian			
			113 = Wake Forest			
			114 = Warner Robins			
			115 = West Monroe			
			116 = Wiggins			

Variable type	Variable name	Variable description	Code	Question number	Frequency	Additional comments
			117 = Winnsboro 118 = Winona 119 = Zachary -96 = No response -97 = legitimate skip			
Character	STATE_REF	State in which refuge is located	1 = Texas 2=Mississippi 3=Alabama 4=Other 5=Don't know -96 = No response -97 = Legitimate skip	Q13 Revealed Preference questionnaire	1 = 15 2 = 46 3 = 20 4 = 133 5 = 0 -96 = 7 -97 = 89	
Character	STA_REF_OTH	Specification of "other" state in which refuge is located	State name 1 = Arkansas 2 = Florida 3 = Georgia 4 = Illinois 5= Kentucky 6 = Louisiana 7 = Missouri 8 = North Carolina 9 = New York 10 = South Carolina 11 = Tennessee 12 = Wisconsin -97 = legitimate skip	Q13 Revealed Preference questionnaire	1 = 10 2 = 23 3 = 13 4 = 1 5 = 1 6 = 65 7 = 3 8 = 2 9 = 1 10 = 1 11 = 17 12 = 1 -96 = 3 -97 =169	Open ended question
Character	CHAN_MIND_LH	Did you change your mind about where to go after leaving home?	1 = Changed destination 2 = Reached original destination 3 = Don't know -96 = No response -97 = legitimate skip	Q15 Revealed Preference questionnaire	1 = 14 2 = 201 3 = 5 -96 = 3 -97 = 87	
Character	ENDUP_FARTH	Did you ended up going farther from home than you had planned or not so far?	1 = Farther 2 = Not as far 3 = About the same distance 4= Don't know -96 = No response -97 = legitimate skip	Q16 Revealed Preference questionnaire	1 = 15 2 = 8 3 = 167 4 = 7 -96 = 26 -97 = 87	

Variable type	Variable name	Variable description	Code	Question number	Frequency	Additional comments
Character	RFCM	Reason for changing mind	1=Traffic congestion 2 = Information about better routes 3 = Information about available lodging or shelter 4 = Ran out of gasoline 5 = Tired of being on road 6 = Hungry 7 = Storm getting too close to continue -97= legitimate skip -96 = No response/missing	Q17 Revealed Preference questionnaire	1 = 2 2 = 1 3 = 2 4 = 0 5 = 2 6 = 0 1_2= 1 3_7 = 1 -96 = 14 -97 = 287	For this question a respondent had the choice of selecting more than one option. Therefore a format that allowed coding of multiple choices is used. For example a code 1_2_3 indicates that a respondent choose options 1,2 and 3.
Character	DIF_EXP_EVAC	Difficulties experienced while evacuating	1 = Yes, ran out of gasoline 2 = Yes, car broke down/overheated 3 =Yes, needed water 4 = Yes, needed food 5 = Yes, needed rest room 6 = No 7 = Other -97 = legitimate skip -96 = No response/missing	Q18 Revealed Preference questionnaire	1 = 0 2 = 1 3 = 1 4 = 0 5 = 31 6= 128 7= 10 1_2_3_4_5 = 1 1_3_4_5 = 1 1_4_5 = 1 2_4_5 = 1 3_4_5 = 14 3_4_5_7 = 1 3_4_7 = 2 3_5 = 1 4_5 = 20 4_5_7 = 1 4_7 = 1 5_6 = 1 5_7 =4 6_7 =1 -96 = 0 -97 = 89	For this question a respondent had a choice of selecting more than one option. Therefore a format that allowed coding of multiple choices is used.
Numeric	DTA	Date and time of arrival at destination	Date in MM\DD\YY Time in HH:MM AM\PM -96 = No response/missing -97 = legitimate skip	Q19 Revealed Preference questionnaire	-96 = 7 -97 =87	Open ended question
Character	ASSI_EVAC	Anyone in your household required assistance in evacuating ?	1=Yes 2 = No 3 = Not sure -96 = No response -97 = Legitimate skip	Q20 Revealed Preference questionnaire	1 = 23 2 = 195 3 = 3 -96 = 2 -97 = 87	

Variable type	Variable name	Variable description	Code	Question number	Frequency	Additional comments
Character	ASSI_TRANS	Type of assistance needed	1= Transportation only 2 = Special need(disability or medical problem) 3 = Both 4= Other -96 = No response -97 = Legitimate skip	Q21 Revealed Preference questionnaire	1 = 6 2 = 9 3 = 5 4 = 2 -96 = 3 -97 = 285	
Character	ASSI_TRANS_OT	Explanation of "other" assistance needed in question above	Description of assistance needed 1 = Walker 2 = Muscular Dystrophy -96 = No response/Missing data -97 = legitimate skip	Q21 Revealed Preference questionnaire	1 = 1 2 = 1 -96 = 22 -97 = 286	Open ended question
Character	ASSI_PROV	Was the assistance provided by household member or outside agency?	1 = Someone in our household 2 = Outside agency 3 = friend/relative outside our household 4 = Others -96 = No response -97 = Legitimate skip	Q22 Revealed Preference questionnaire	1 = 15 2 = 0 3 = 5 4 = 0 -96 = 5 -97 = 285	
Character	ASSI_PROV_OT	Explanation of "others" provided assistance in question above	Description of others providing assistance -97 = legitimate skip	Q22 Revealed Preference questionnaire	-96 = 4 -97 = 306	Open ended question
Character	JOB_STAY_EVA	Does your job require you stay in the area during evacuation ?	1 = Yes 2 =No -96 = No response	Q23 Revealed Preference questionnaire	1 =30 2 = 275 -96 = 5	
Numeric	HHSIZE	Household size	Number in household -96 = No response	Q24 Revealed Preference questionnaire	1 = 43 2 = 130 3 = 54 4 = 52 5 = 18 6 = 8 ≥7 = 3 -96 = 2	Open ended question
Numeric	≤17	No_ of people who are 17 or younger living in household	Number in household -96 = No response	Q25 Revealed Preference questionnaire	0 = 195 1 = 49 2 = 37 3 = 8 4 = 3 5 = 3 -96 = 15	Open ended question

Variable type	Variable name	Variable description	Code	Question number	Frequency	Additional comments
Character	HAV_PETS	Have pets ?	1= Yes 2 = No 3 =Refuse to disclose -96 = No response	Q26 Revealed Preference questionnaire	1 = 164 2 = 139 3 = 2 -96 = 5	
Character	LEVEL_SCH	Highest level of schooling	1 = No school completed 2 = Pre school/Nursery school 3 = Kindergarten-4th grade 4 = 5th to 8th grade 5 =9th to 12th grade 6= High school graduate 7= Some college but no degree 8 = Associate degree in college 9= Bachelor's degree 10 = Some graduate school 11 = Master's degree 12 = Professional school degree 13 = Doctorate degree -96 = No response	Q27 Revealed Preference questionnaire	1 = 0 2 = 0 3 = 0 4 = 1 5 = 25 6 = 77 7 = 63 8 = 20 9 = 58 10 = 22 11 = 29 12 = 7 13 = 6 -96 = 2	
Numeric	LEN_RES_YRS	Number of years resided at current residence	Number of years	Q28 Revealed Preference questionnaire	<5 = 76 5-10=54 >10 =177 -96 = 3	Open ended question
Character	ETHNICITY	Ethnicity	1 = Asian/Pacific 2 = Black African/American 3 = Indian(American) 4 = Mixed race 5 = White 6 = Other -96 = No response	Q29 Revealed Preference questionnaire	1 = 1 2 = 32 3 = 1 4 = 6 5 = 251 6 = 2 -96 = 17	
Numeric	HHINC	Total household income per year($)	1= Less than 15000 2 = 15,000 to 24,999 3 = 25000 to 39,999 4 = 40,000 to 79,999 5 = 80,000 to 119,000 6 = 120,000 to 149,000 7 = Over 150,000 8 = Refused -96 = No response	Q30 Revealed Preference questionnaire	1 = 28 2 = 35 3 = 41 4 = 82 5 = 53 6 = 18 7 = 18 8 = 32 -96 = 3	

Variable type	Variable name	Variable description	Code	Question number	Frequency	Additional comments
Character	COMMENTS	Comments	-	-		Open ended question
Numeric	TIME_SC_DATA	Time taken to enter the SC data (in minutes)	Number per respondent			Open ended question
Alpha-numeric	HSL1	Hypothetical storm label	11 = Storm 1 in DVD 'Storm 1,2,3' 21 = Storm 1 in DVD Storm 1,2,3 Var1 31 = Storm 1 in DVD Storm 1,2,3 Var2 44 = Storm 4 in DVD Storm 4,5,6 54= Storm 4 in DVD Storm 4,5,6 Var1 64= Storm 4 in DVD Storm 4,5,6 Var2 77= Storm 7 in DVD Storm 7,8,9 87=Storm 7 in DVD Storm 7,8,9 Var1 97 = Storm 7 in DVD Storm 7,8,9 Var2	-	11 = 33 21 = 38 31 = 34 44 = 37 54 = 25 64 = 31 77 = 38 87 = 36 97 = 30	
Numeric	INTDOFEV1	Intended day of evacuation for hypothetical storm1	1 =Monday 2 = Tuesday 3 = Wednesday 4 = Thursday 5 = Friday 6 = Saturday 7 = Sunday 8 = Do not evacuate -96 = No response/missing	Q1 Dynamic Stated Choice questionnaire	1 = 4 2= 2 3 = 24 4 = 55 5 = 67 6 = 20 7 = 14 8 = 116 -96 = 6	
Numeric	INTEVTIME1	Intended evacuation time for hypothetical storm1	Time in HH:MM AM/PM -96 = No response -97 = legitimate skip	Q1 Dynamic Stated Choice questionnaire	-96 = 7 -97 = 115	Open ended question
Numeric	INTEVMOD1	Intended evacuation mode for hypothetical storm1	1= Private Vehicle 2 = Bus 3 = Train 4 = Walk 5 = Get ride with someone else 6 = Other -96 = No response -97 = legitimate skip	Q2 Dynamic Stated Choice questionnaire	1 = 179 2 = 1 3 = 0 4 = 0 5 = 5 6 = 1 -96 = 7 -97 = 115	
Numeric	INTEVMOD_OTH	Description of "other" intended evacuation mode	Description of "other" mode	Q2 Dynamic Stated Choice questionnaire	-97 = 298	Open ended question

Variable type	Variable name	Variable description	Code	Question number	Frequency	Additional comments
		above	-97 = legitimate skip			
Numeric	INT_NO_VEH1	Intended number of vehicles that will be used to evacuate in storm1	Number -96 = No response -97 = legitimate skip	Q3 Dynamic Stated Choice questionnaire	1 = 116 2 = 51 3 = 6 ≥4 = 1 -96 = 8 -97 = 119	Open ended question
Numeric	INT_OCCUP1	Number of people evacuating for hypothetical_storm1	Number -96 = No response -97 = legitimate skip	Q3 Dynamic Stated Choice questionnaire	-96 = 12 -97 = 119	Open ended question
Numeric	INT_EVA_DEST 1	Intended evacuation destination type for hypothetical storm1	1 = Motel 2 = Public Shelter 3 = Friend/Relative 4 = Work Place 5 = Other -96 = No response/missing -97 = legitimate skip	Q4 Dynamic Stated Choice questionnaire	1 = 80 2 = 2 3 = 90 4 = 1 5 = 12 -96 = 6 -9 = 114	
Numeric	INT_EVA_DEST OT1	Description of "other" destination type above	Description of "other" destination type -96 = No response -97 = legitimate skip	Q4 Dynamic Stated Choice questionnaire	-96= 5 -97 = 287	Open ended question
Character	INT_EVA_CITY 1	Intended evacuation destination location for hypothetical storm 1_City	-96 = No response -97 = legitimate skip	Q4 Dynamic Stated Choice questionnaire	-96 = 114 -97 = 11	Open ended question
Character	INT_EVA_STAT E1	Intended evacuation destination location for hypothetical storm1-State	-96 = No response -97 = legitimate skip	Q5 Dynamic Stated Choice questionnaire	-96 = 7 -97 = 114	Open ended question
Numeric	INT_EVA_RT1	Intended evacuation route for hypothetical storm1	1 = I-10 2 = Airline Hwy 3= US90 4= I-55 5= Other -96 = No response/missing -97 = legitimate skip	Q6 Dynamic Stated Choice questionnaire	1 = 91 2 = 6 3 = 4 4 = 44 5 = 35 -96 = 11 -9 = 115	
Numeric	INT_EVA_RT_O T1	Description of "other" intended evacuation route above	Description of "other" evacuation route -97 = legitimate skip -96 = No response	Q6 Dynamic Stated Choice questionnaire	-96 = 11 -97 = 259	Open ended question

Variable type	Variable name	Variable description	Code	Question number	Frequency	Additional comments
Alpha-numeric	HSL2	Hypothetical Storm label	12 = Storm 2 in DVD Storm 1,2,3 22 = Storm 2 in DVD Storm 1,2,3 Var1 32 = Storm 2 in DVD Storm 1,2,3 Var2 45 = Storm 5 in DVD Storm 4,5,6 55= Storm 5 in DVD Storm 4,5,6 Var1 65= Storm 5 in DVD Storm 4,5,6 Var2 78= Storm 8 in DVD Storm 7,8,9 88=Storm 8 in DVD Storm 7,8,9 Var1 98 = Storm 8 in DVD Storm 7,8,9 Var2	-	12 =33 22 = 38 32 = 34 45 = 37 55 = 26 65 = 31 78= 38 88 = 36 98 = 30	
Numeric	INTDOFEV2	Intended day of evacuation for hypothetical storm2	1 =Monday 2 = Tuesday 3 = Wednesday 4 = Thursday 5 = Friday 6 = Saturday 7 = Sunday 8 = Do not evacuate -96 = No response/missing	Q7 Dynamic Stated Choice questionnaire	1 = 45 2= 58 3 = 64 4 = 22 5 = 0 6 = 1 7 = 13 8 = 100 -96 = 5	
Numeric	INEVTIME2	Intended evacuation time for hypothetical storm2	Time in HH:MM AM/PM -96 = No response -97 = legitimate skip	Q7 Dynamic Stated Choice questionnaire	-96 = 5 -97 = 100	Open ended question
Numeric	INTEVMOD2	Intended evacuation mode for hypothetical storm2	1= Private Vehicle 2 = Bus 3 = Train 4 = Walk 5 = Got ride with someone else 6 = Other -96 = No response -97 = legitimate skip	Q8 Dynamic Stated Choice questionnaire	1 = 193 2 = 1 3 = 0 4 = 0 5 = 7 6 = 1 -96 = 4 -97 = 100	
Numeric	INTEVMOD_OTH2	Description of "other" evacuation mode above	Description of "other" evacuation mode -96 = No response -97 = legitimate skip	Q8 Dynamic Stated Choice questionnaire	-96 = 4 -97 = 299	Open ended question
Numeric	INT_NO_VEH2	Intended number of vehicles that will be used	-96 = No response -97 = legitimate skip	Q9 Dynamic Stated Choice questionnaire	1 = 130 2 = 50	Open ended question

Variable type	Variable name	Variable description	Code	Question number	Frequency	Additional comments
		for evacuating in hypothetical storm2			3 = 4 ≥4 = 3 -96 = 4 -97 = 105	
Numeric	INT_OCCUP2	Occupancy while evacuating for a hypothetical_storm2	-96 = No response -97 = legitimate skip	Q9 Dynamic Stated Choice questionnaire	-96 = 6 -97 = 104	Open ended question
Numeric	INT_EVA_DEST 2	Evacuation destination for hypothetical storm2	1 = Motel 2 = Public Shelter 3 = Friend/Relative 4 = Work Place 5 = Other -96 = No response/missing -97 = legitimate skip	Q10 Dynamic Stated Choice questionnaire	1 = 81 2 = 2 3 = 101 4 = 1 5 = 14 -96 = 3 -97 = 100	
Numeric	INT_EVA_DEST OT2	Description of "other" evacuation destination above	Description of "other" evacuation destination 96 = No response -97 = legitimate skip	Q10 Dynamic Stated Choice questionnaire	-96 = 4 -97 = 284	Open ended question
Character	INT_EVA_CITY 2	Intended evacuation Location for hypothetical storm 2_City	-96 = No response -97 = legitimate skip	Q10 Dynamic Stated Choice questionnaire	-96 = 7 -97 = 101	Open ended question
Character	INT_EVA_STAT E2	Intended evacuation location for hypothetical storm2-State	-96 = No response -97 = legitimate skip	Q11 Dynamic Stated Choice questionnaire	-96 = 3 -97 = 100	Open ended question
Numeric	INT_EVA_RT2	Intended evacuation route for hypothetical storm2	1 = I-10 2 = Airline Hwy 3= I-190 4= I-55 5= Other -96 = No response/missing -97 = legitimate skip	Q12 Dynamic Stated Choice questionnaire	1 = 84 2 = 3 3 = 7 4 = 46 5 = 54 -96 = 9 -97 = 100	
Numeric	INT_EVA_RT_O T2	Description of "other" intended evacuation route above	Description of "other" evacuation route -96 = No response -97 = legitimate skip	Q12 Dynamic Stated Choice questionnaire	-96 = 9 -97 = 240	Open ended question

Variable type	Variable name	Variable description	Code	Question number	Frequency	Additional comments
Alpha-numeric	HSL3	Hypothetical storm label	13 = Storm 3 in DVD Storm 1,2,3 23 = Storm 3 in DVD Storm 1,2,3 Var1 33 = Storm 3 in DVD Storm 1,2,3 Var2 46 = Storm 6 in DVD Storm 4,5,6 56= Storm 6 in DVD Storm 4,5,6 Var1 66= Storm 6 in DVD Storm 4,5,6 Var2 79= Storm 9 in DVD Storm 7,8,9 89=Storm 9 in DVD Storm 7,8,9 Var1 99 = Storm 9 in DVD Storm 7,8,9 Var2		13 = 33 23 = 38 33 = 34 46 = 37 56 = 26 66 = 31 79 = 38 89 = 36 99 = 30	
Numeric	INTDOFEV3	Intended day of evacuation for hypothetical storm3	1 =Monday 2 = Tuesday 3 = Wednesday 4 = Thursday 5 = Friday 6 = Saturday 7 = Sunday 8 = Do not evacuate -96 = No response/missing	Q13 Dynamic Stated Choice questionnaire	1 = 44 2= 1 3 = 6 4 = 22 5 = 24 6 = 18 7 = 58 8 = 126 -96 = 9	
Numeric	INTEVTIME3	Intended evacuation time for hypothetical storm3	Time in HH:MM AM/PM -96 = No response -97 = legitimate skip	Q13 Dynamic Stated Choice questionnaire	-96 = 9 -97 = 126	Open ended question
Numeric	INTEVMOD3	Intended evacuation mode for hypothetical storm3	1= Private Vehicle 2 = Bus 3 = Train 4 = Walk 5 = Get ride with someone else 6 = Other -96 = No response -97 = legitimate skip	Q13 Dynamic Stated Choice questionnaire	1 = 160 2 = 1 3 = 0 4 = 0 5 = 5 6 = 1 -96 = 10 -97 = 126	
Numeric	INTEVMOD_OTH3	Description of "other" mode of evacuation above	Description of "other" mode of evacuation -96 = No response -97 = legitimate skip	Q13 Dynamic Stated Choice questionnaire	-96 = 10 -97 = 291	Open ended question
Numeric	INT_NO_VEH3	Intended number of vehicles that will be used	-96 = No response -97 = legitimate skip	Q14 Dynamic Stated Choice questionnaire	1 = 101 2 = 47	Open ended question

Variable type	Variable name	Variable description	Code	Question number	Frequency	Additional comments
		for hypothetical storm3			3 = 5 ≥4 = 1 -96 = 10 -97 = 130	
Numeric	INT_OCCUP3	Occupancy while evacuating for hypothetical_storm3	-96 = No response -97 = legitimate skip	Q14 Dynamic Stated Choice questionnaire	-96 = 13 -97 = 132	Open ended question
Numeric	INT_EVA_DEST 3	Evacuation destination for hypothetical storm3	1 = Motel 2 = Public Shelter 3 = Friend/Relative 4 = Work Place 5 = Other -96 = No response/missing -97 = legitimate skip	Q14 Dynamic Stated Choice questionnaire	1 = 74 2 = 2 3 = 85 4 = 0 5 = 10 -96 = 9 -97 =126	
Numeric	INT_EVA_DEST OT3	Description of "other" destination above	Description of "other" destination -96 = No response -97 = legitimate skip	Q15 Dynamic Stated Choice questionnaire	-96 = 10 -97 = 285	Open ended question
Character	INT_EVA_CITY 3	Intended evacuation Location for hypothetical storm 3_City	-96 = No response -97 = legitimate skip	Q16 Dynamic Stated Choice questionnaire	-96 = 11 -97 = 126	Open ended question
Character	INT_EVA_STAT E3	Intended evacuation location for hypothetical storm3-State1	-96 = No response -97 = legitimate skip	Q17 Dynamic Stated Choice questionnaire	-96 = 8 -97 = 126	Open ended question
Numeric	INT_EVA_RT3	Intended evacuation route for hypothetical storm3	1 = I-10 2 = Airline Hwy 3= US90 4= I-55 5= Other -96 = No response/missing -97 = legitimate skip	Q18 Dynamic Stated Choice questionnaire	1 = 77 2 = 3 3 = 2 4 = 45 5 = 37 -96 = 13 -97 = 126	
Numeric	INT_EVA_RT_O T3	Description of "other" evacuation route above	Description of "other" evacuation route above -96 = No response -97 = legitimate skip	Q18 Dynamic Stated Choice questionnaire	-96 = 14 -97 = 252	Open ended question
Character	SP_COMM	SP_Comments	-	-	-	Open ended question
Character	MI	Missing information	-	-		This columns tells about the missing information in a retrieved questionnaire

Variable type	Variable name	Variable description	Code	Question number	Frequency	Additional comments
Character	IMU	Imputation method/Inference method used	-	-	-	This column indicates the method used to fill in the missing information
Numeric	Imputed hh Income	Imputed values of the variable household income	1= Less than 15000 2 = 15,000 to 24,999 3 = 25000 to 39,999 4 = 40,000 to 79,999 5 = 80,000 to 119,000 6 = 120,000 to 149,000 7 = Over 150,000 8 = Refused -96 = No response	-	1 = 25 2 = 39 3 = 39 4 = 83 5 = 55 6 = 22 7 = 25 8 = 0 -96 = 22	This column contains imputed values of the variable household income which were imputed using variables education level and number of vehicles owned. When data was insufficient for imputation the value is coded as -96
Numeric	Imputed no of vehicles owned	Imputed value of the variable number of vehicles owned	-96 = No response	-	0=13 1 = 76 2 = 141 3 = 35 4 = 17 5 = 4 10 = 1 14 =1 -96 = 22	This column contains imputed values of the variable vehicles owned which were imputed using variables education level and household income. When data was insufficient for imputation the value is coded as -96
Numeric	Weights	Weighting and Expansion Factors needed to make sample representative of the population	-96 = No weight	-	5544.69 = 2 3296.23 = 2 3022.96 = 3 3109.33 = 0 3268.42 = 0 2956.31 = 24 1757.48 = 21 1611.78 = 6 1657.83 = 9 1742.65 = 4 1860.90 = 6 1106.27 = 80 1014.56 = 30 1043.55 = 40 1096.94 = 18 13354.23 = 2 7938.87 = 0 7280.72 = 2 7488.72 =2 7871.89 = 1 7120.20 = 3 4232.84 = 5	Weighting and Expansion Factors calculated using tri proportional iterative fitting method. Three variables , household size, number of vehicles owned and ethnicity were used in estimating the factors.

Variable type	Variable name	Variable description	Code	Question number	Frequency	Additional comments
					3881.93 = 2 3992.83 = 2 4197.13 = 1 4481.92 = 1 2664.43 = 6 2443.54 = 9 2513.35 = 2 2641.95 = 4 0 = 25	

APPENDIX I: COSTS ASSOCIATED WITH THE RP AND THE SC SURVEYS

Item	Number or quantity or hours spent		Expense	RP	SP	Category
Incentives for focus group participants	16 participant		800	40	760	Incentives
Incentives for pilot survey participants	11 participants		220	220	220	Incentives
Charges for printing survey booklets for pilot survey	green 50		235.06	235.06	0	Printing
Charges for printing survey booklets for pilot survey	purple color booklets		159.78	0	159.78	Printing
Charges for DVD clam shel for pilot surveyl		100	81.62	0	81.62	Materials
Charges for DVD for pilot survey		50	69.68	0	69.68	Materials
Brown and White Envelopes for main survey	750 each		328.72	328.72	328.72	Materials
Mailing labels	250 sheets		160.21	160.21	160.21	Materials
Letter heads		9000	540	540	540	Materials
Window envelopes		7500	324.83	324.83	324.83	Materials
Survey Instrument for SC method		750	1014.52	0	1014.52	Printing
Survey Instrument for RP method		750	991.51	991.51	0	Printing
DVDs and Printer Cartridge for SC method	5 color ink and 300 dvds		456.84	0	456.84	Materials
DVD inkjet printable		15	455.40	0	455.4	Materials
DVD imation		10	288.96	0	288.96	Materials
DVD cases	clam shells = 600		314.54	0	314.54	Materials
Incentives for main survey		169	3380	3380	3380	Incentives
Focus Gourp			7050	352.5	6697.5	Development Costs
Project Management (thouta)		7000	7000	7000	7000	Management
Reminder call script		1000	1000	1000	1000	Management
thouta and Kathryn management cost		4000	4000	4000	4000	Management
Advance letters	stamps=3500		1700	1700	1700	Recruitment Costs
Mailing survey Envelopes		670	1005	1005	1005	Mailing
Payment for received envelopes		292	438	438	438	Mailing
Payment for mailing envelopes for pilot		50	75	75	75	Mailing
Payment for receiving envelopes for pilot		25	37.50	37.5	37.5	Mailing
Printing on cover letters			350	350	350	Printing
Mail folding			750	300	450	Labor
Student labor- Manual Stamping			650	650	650	Labor

Item	Number or quantity or hours spent	Expense	RP	SP	Category
Cover letter printing		60	60	60	Printing
Manual data Entry		2400			Data Entry
Telephone expense		1469	1469	1469	Recruitment Costs
Telephone sample		1400	1400	1400	Recruitment Costs
sample generation		1600	1600	1600	Recruitment Costs
Tech support		4000	4000	4000	Management
Supervisor GA s		450	450	450	Management
Number of hours spent on programming in Wincati	14	60	1384.488	1384.488	Management
Number of calling hours on the Incentive pilot study	13.72	9	151.88	151.88	Recruitment Costs
Number of calling hours on the Non-Incentive pilot study	9.2	9	101.84	101.84	Recruitment Costs
Number of calling hours on the recruitment for main survey	161.86	9	1806.3576	1806.3576	Recruitment Costs
Number of hours spent on mailing	273	12	3276	3276	Mailing
Number of hours spent on data entry for RP survey	33.5	12	402	0	Data Entry
Number of hours spent on data entry for SC survey	21.3	12	0	255.6	Data Entry
Number of hours spent for developing animation	30	12	0	360	Development Costs
Number of hours spent for recording narration and animation in DVD Pro	50	12	0	600	Development Costs
Number of hours spent for replicating DVDs	60	12	0	720	Development Costs
Number of hours spent for preparing RP booklet	10	12	120	0	Development Costs
Number of hours spent for preparing SC booklet	5	12	0	60	Development Costs
Number of hours spent for preparing advance letter	2	12	24	24	Development Costs
Number of hours spent for preparing cover letter	1	12	12	12	Development