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Survey Analysis for Evacuee Preferences on Real-Time Traffic Monitoring Systems in Texas

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Survey Analysis for Evacuee Preferences on Real-Time Traffic Monitoring Systems in Texas

by

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Dedication

This thesis is dedicated to my beloved family for their unwavering love, support, and inspiration in all my endeavors. I couldn't get this far without your endless support. Your belief in me has kept me going during the toughest moments and has been a constant source of motivation and strength.

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Lastly, I would like to acknowledge the Texas Department of Transportation for providing funding for the project on which this thesis is based and thank those individuals who provided valuable input to the project.

Abstract

Survey Analysis for Evacuee Preferences on Real-Time Traffic Monitoring Systems in Texas

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The University of Texas at Austin, 2023

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Relocating large populations from at-risk locations to safe areas using existing road networks in a timely manner is a challenge faced by many transportation agencies in regions exposed to hurricanes. Residents may react disparately to evacuation orders based on their past experiences and the information that they receive. Real-time traffic monitoring devices may assist with evacuations by alerting operators to traffic congestion or roadway incidents such as disabled vehicles, which may block evacuation routes and impact the safety and efficiency of the evacuation event. Evacuees may rely on real-time traffic information to make evacuation decisions and select their routes and destinations. To better understand their perceptions and usage of traffic monitoring devices during past hurricane evacuations, an online survey was distributed via email and social media, targeting Texas residents who were exposed to previous hurricane events in the state. Survey questions were designed to learn about the demographics of evacuees, common issues encountered during past Texas hurricane evacuations, the usage of traffic monitoring devices, and suggestions for traffic monitoring system improvements. A total of 1,398 valid responses

were received, and the results indicate that certain demographic groups may be more likely to evacuate compared to other groups. The results also suggest that improved traffic data quality and accessibility may increase the likelihood for residents to evacuate and improve evacuation efficiency.

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Chapter 1: Introduction

1.1 Research Motivation

With an extensive coastline along the Gulf of Mexico, Texas has faced numerous major hurricane events that caused substantial damage and loss of life over the many years. Since 1851, Texas has been frequently struck by hurricanes, second only to Florida (LaurenC, 2012). In the last two decades, Hurricanes Rita (2005), Ike (2008), Harvey (2017), and Laura (2020) all made landfall in or near Texas and resulted in the temporary displacement of hundreds of thousands of residents, through both mandatory and voluntary evacuations.

Evacuations typically occur in advance of cyclonic events to mitigate potential losses of life or injuries. It is critical to ensure that transportation networks operate safely and efficiently during evacuations as the sheer number of people trying to leave at the same time can overwhelm the transportation infrastructure, leading to traffic jams and delays. The surge in traffic volume can put a strain on highways and other key transportation arteries, potentially resulting in gridlock and even accidents. In addition, emergency response vehicles such as ambulances and fire trucks may have difficulty navigating through the congested roads, hindering their ability to reach those in need of assistance.

Traffic counting and vehicle surveillance technologies offer a great deal of promise in emergency management (Southworth, 1991). Since the 1990s, Intelligent Transportation Systems (ITS) have been under development and implementation in the United States. ITS primarily consist of a sensing system, a communication system, roadside units (RSUs) made up of different types of sensors, a traffic signal control system, and a notification system that includes car navigation and alerts (Khalid et al., 2016). In an effort to perform

real-time traffic monitoring, all of the systems should work seamlessly to direct people away from the disaster site efficiently and safely.

Due to the substantial societal and economic costs of hurricane evacuations, officials responsible for coordinating evacuations require assistance from technology to direct people away from the disaster site efficiently and safely in a timely manner. However, a state transportation agency often faces a challenge of limited resources and funding to completely improve statewide real-time traffic monitoring. State transportation agencies typically develop a methodology to prioritize projects that are most urgent. To make informed decisions and strategic investments, it is essential to have a thorough understanding of the needs of evacuees by gaining insights into their background and previous experiences.

1.2 Research Objectives

This study seeks to explore factors that may influence an individual's decision-making during their past hurricane evacuation experiences with a focus on real-time traffic monitoring devices through an online survey distributed to residents in Texas. The study has the following research objectives:

1. Identify current practices for using real-time traffic monitoring devices in hurricane evacuations.
2. Understand the support and needs that evacuees require from real-time traffic monitoring devices.
3. Explore the relationship between an evacuee's demographic status and their decision-making.

1.3 STRUCTURE OF THE THESIS

The reminder of this thesis is structured into subsequent chapters as follows: Chapter 2 provides key background information on fundamental concepts and terminology related to hurricane evacuation in Texas, including major hurricanes that have struck Texas, current hurricane evacuation plans, and types of monitoring devices. Chapter 3 presents a review of current practices on public involvement and previous studies on factors that may influence evacuee's decision-making. Chapter 4 proposes a methodology for survey design, data collection and survey analysis. Chapter 5 demonstrates the results and discussion. Chapter 6 summarizes conclusions, highlights key findings, discusses study limitations, and concludes recommendations for future exploration in the field of hurricane evacuation.

Chapter 2: Background

All Gulf Coast states are required by U.S. Congress to develop and assess their evacuation plans for enhancing evacuation safety and other elements of preparedness (USDOT & USDHS, 2006). Every evacuation plan must have designated evacuation routes and address strategies and responsibilities for maintaining route capacity and safety. Roadway networks are of utmost importance among the major critical infrastructure systems in disaster management as they play a crucial role in evacuation and emergency response (Balakrishnan et al., 2020). Real-time traffic monitoring systems can help officials identify areas of congestion and potential obstacles that could slow down the evacuation process. By having surveillance on roads, officials can quickly re-route people to routes that have been underutilized and dispatch emergency response teams to areas where assistance is needed so that people can reach safety as quickly as possible.

2.1 Major Hurricanes in Texas

Hurricane Rita, which made landfall in east Texas in August of 2005, was the most powerful tropical cyclone ever recorded in the Gulf of Mexico. An estimated 2.5 million people along the Texas gulf coast fled inland to cities such as Austin, Dallas, and San Antonio in the days prior to Rita's landfall, resulting in the largest evacuation event in US history. In Texas, a total of 111 deaths were recorded. Among the 111 deaths, only three were directly attributed to the storm; the other deaths primarily occurred during the mass evacuation process (Zachria & Patel, 2006). Evacuation orders were also issued for Hurricane Ike in Galveston, Texas in 2008 with over one million residents estimated to have evacuated (NPR, 2008).

Hurricane Harvey brought large amounts of rainfall to the Texas coastal region in 2017 resulting in severe damage. Locations near Corpus Christi, Texas were placed under

a mandatory evacuation order. However, mandatory evacuation orders were not issued farther north in Houston as officials, wary from the disaster that occurred during Hurricane Rita in 2005, did not wish to create more hazardous conditions that may result from mass volumes of people trying to evacuate (Domonoske, 2017).

Hurricane Laura, which made landfall on August 27, 2020, was the most recent major hurricane to impact Texas, reaching a destructive Category 4 severity and striking Louisiana, close to the Texas border. Approximately 385,000 residents evacuated under a mandatory evacuation order which was declared for parts of Chambers, Jefferson, Galveston, and all of Orange counties. Laura was directly responsible for 15 deaths in the United States (CBS, 2020).

2.2 Methods Used by Texas Department of Transportation

To fully understand the current state of evacuation monitoring processes and technologies, a thorough review of existing resources and methods employed by the Texas Department of Transportation (TxDOT) and other agencies in the country was conducted. In addition, the author also examines how emerging technologies may be incorporated into the existing evacuation traffic monitoring systems.

Following Hurricane Rita in 2005, the Texas Office of Homeland Security issued a report with specific suggestions for enhancing evacuation procedures and other elements of preparedness. To improve traffic control and management during a mass evacuation, former Governor Rick Perry directed TxDOT to coordinate with other emergency management agencies to develop several traffic control and management strategies, including developing contraflow plans, implementing solutions to reduce congestion, and prioritizing infrastructure projects along evacuation routes (USDOT & USDHS, 2006).

TxDOT is responsible for maintaining major evacuation routes for the five districts along the Gulf of Mexico coast, including Beaumont District, Corpus Christi District, Houston District, Pharr District, and Yoakum District (TxDOT, 2023a). Figure 2-1 shows major evacuation routes, potential contraflow that allows vehicles to travel in the opposite direction of a lane's normal traffic flow, and Evaculane routes for emergency outside shoulder use planned in the five districts along the coast.

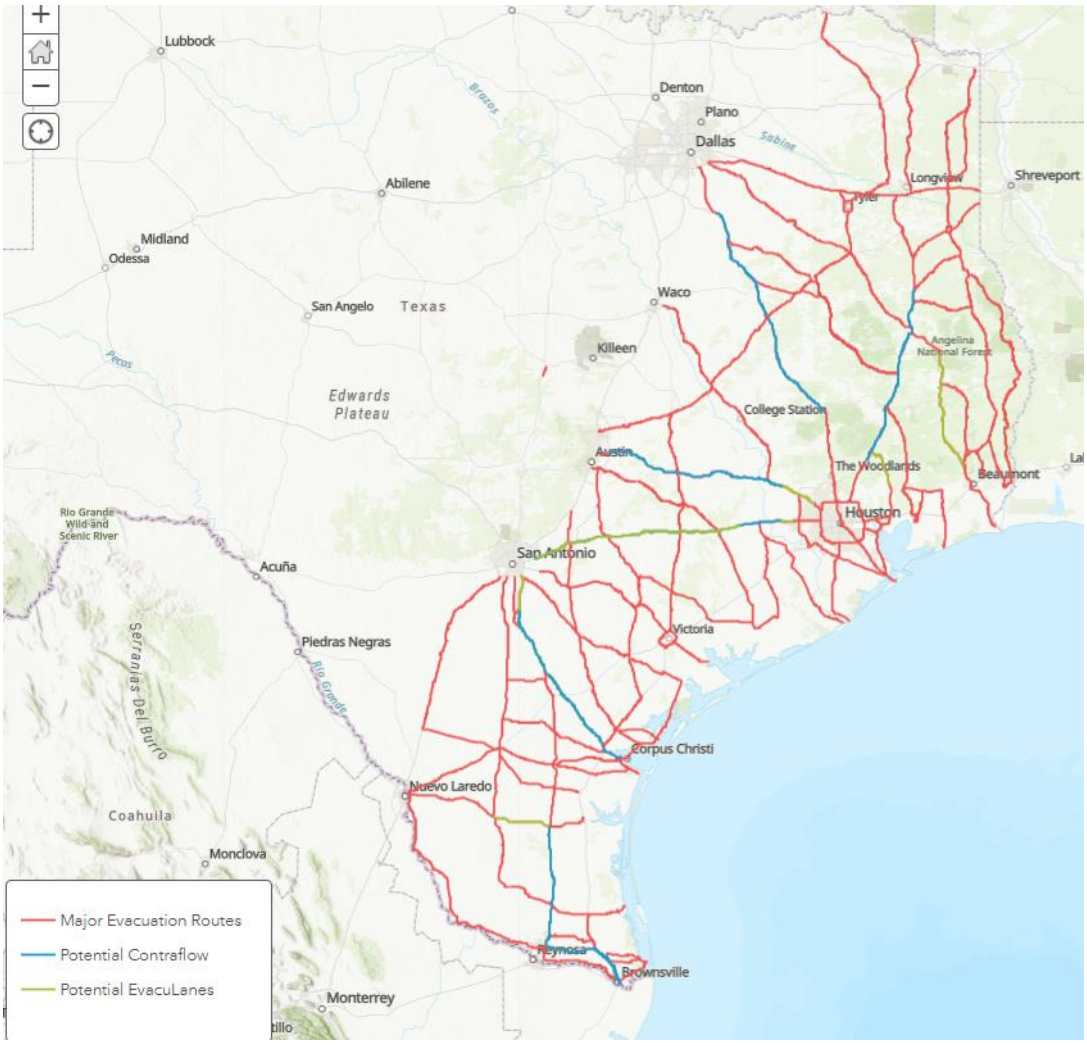

Figure 2-1. Map of major evacuation routes, potential contraflow, and Evaculane routes within Texas (TxDOT, 2023c).

After the historic 2005 hurricane season, TxDOT conducted a research project to investigate traffic operation recommendations for hurricane evacuation regarding the development of contraflow, emergency shoulder lanes, traffic signals, ITS, and motorist information systems (Ballard & Borchardt, 2006). Following the 2006 report, Ballard et al. (2008) inventoried various ITS strategies that have been used and whose implementation was planned for four of the districts (Beaumont, Corpus Christi, Houston, and Yoakum District) by interviewing and surveying the public officials who had experienced hurricane evacuations before. Table 2-1 presents a summary of plans and ITS deployments that have been developed and implemented.

Table 2-1. Summary of strategies used by districts.

Districts	Beaumont District	Corpus Christi District	Houston District	Yoakum District
Planning and Management Strategy				
ITS Implementation Plan	No	Yes	Yes	No
Traffic Management Center (TMC)	No	No	Yes	No
Existing Communication with Other State Agencies	No	Yes	Yes	Yes
Traffic Monitoring Strategy				
Automated Vehicle Identification	No	No	Yes	No
Vehicle Sensors	No	No	Yes	No
Closed Circuit Television (CCTV) Cameras	Yes	Yes	Yes	Yes
Traffic Flow Control Strategy				
Contraflow Lanes/Evaculane	Yes	Yes	Yes	Yes
Lane Control Signals	No	No	No	No
Ramps Meters	No	No	Yes	No
Information Disseminating Strategy				

Dynamic Message Signs (DMS)	Yes	Yes	Yes	Yes
Highway Advisory Radio (HAR)	No	No	Yes	No

It is crucial to achieve efficient and accurate real-time data collection and transmission during hurricane evacuations. TxDOT's Traffic Monitoring System collects traffic volume data through both short-term traffic counting (such as pneumatic tube counts) and continuous traffic counting programs and is obligated to report data to the Federal Highway Administration (FHWA, 2023a). Most of the sensors currently in use for long-term traffic counting are intrusive, including induction loop, quartz sensor, bending plate, and piezoelectric sensors. TxDOT also uses High Definition (HD) radar length-based technology for vehicle classification. Figure 2-2 shows the locations of permanent count stations in the state of Texas.

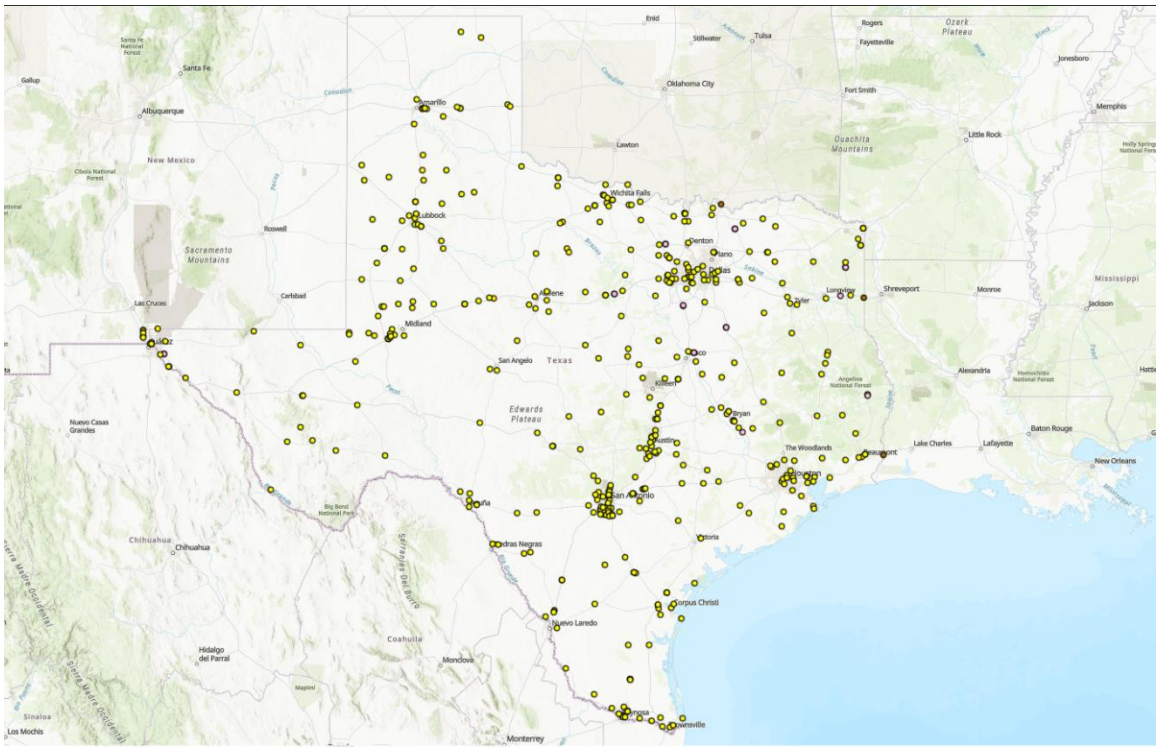

Figure 2-2. Map of TxDOT permanent count stations (TxDOT, 2023d).

In addition to vehicle detection technologies, the video surveillance system is another effective tool that TxDOT has been using to monitor traffic. The Traffic Management Centers (TMC) in Texas commonly use Pan-Tilt-Zoom (PTZ) Closed Circuit Television (CCTV) cameras to monitor the traffic conditions throughout the roadway network in real time. One of the TxDOT ITS websites maintains a map of traffic cameras installed along major corridors for each district. Figure 2-3 is a representative map of cameras installed along major corridors in the Houston District.

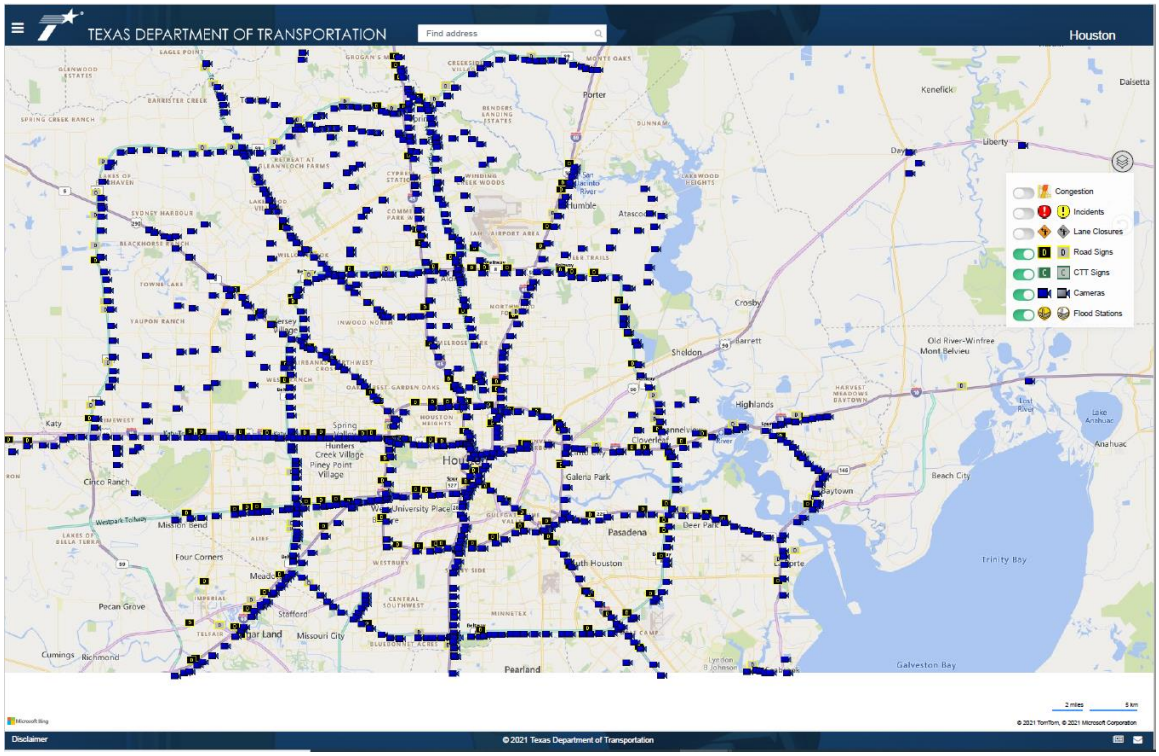

Figure 2-3. ITS field devices in Houston District (TxDOT, 2023b).

Texas has a long history of incorporating innovative ITS solutions into the TMCs of the state. STAR II, a cloud-based application used by Transportation Planning and

Programming (TPP) Traffic Analysis, is the official traffic data source for TxDOT and the State of Texas to store, analyze, report, and publish traffic data (TxDOT, 2022). However, the state needs to expand video and traffic monitoring capabilities beyond the urban areas to allow for better traffic management in response to evacuations as well as normal traffic operations. The report prepared by Borchardt and Puckett (2008) provided a list of additional recommended deployments of video and sensor detection stations to allow for improved monitoring and managing of traffic during evacuation events. However, the limited available resources and the expanded network size present several technical and economic difficulties, especially in rural areas. Intrusive vehicle sensors must be embedded in the road pavement and are often large, expensive, and power-hungry, while video surveillance technologies can be mounted on existing transportation infrastructures on roadways or roadsides, but their performance can be affected by weather conditions (Balid et al., 2018).

2.3 Methods Used in the Other U.S. States

Many Departments of Transportation (DOTs) collect real-time traffic data through vehicle sensors and cameras to determine road conditions and the best route for evacuation. DOTs also offer real-time roadway conditions and incident updates to the general public through online service and radio systems.

In addition to these common practices, individual states have been investing in a variety of technologies that are suitable for their particular situations. The Florida Department of Transportation (FDOT) (Haas et al., 2009) developed a model deployment called "*i*Florida" to examine how "widespread availability of real-time transportation information would enhance the security and reliability of the surface transportation system," especially during a hurricane evacuation. The North Carolina Department of

Transportation (NCDOT) Division of Aviation (2018) has conducted experiments using Unmanned Aircraft Systems in emergencies. FDOT and NCDOT also started working with private companies to incorporate data gathered from connected vehicles into emergency response. The Louisiana Department of Transportation and Development (DOTD), the United States Geological Survey (USGS), Louisiana State University (LSU), and private-sector companies joined forces to create traffic, weather, flood, and bridge scour monitoring systems for critical routes within the state (Wolshon & Levitan, 2002). The South Carolina Department of Transportation (SCDOT) tested a video-based traffic monitoring system that used vehicle tracking to more accurately and effectively identify and count motorcycles traveling side by side or close behind one another (Kanhere et al., 2010).

2.4 EMERGING TECHNOLOGIES

Extensive studies (Aljehani & Inoue, 2016; Elloumi et al., 2018; Kanistras et al., 2013; Liu et al., 2019) have proven that Unmanned Aerial Systems (UASs) are a viable and less-time-consuming alternative to real-time traffic monitoring and management. Employing UASs in the field of natural disaster evacuation is valuable because of their advantages in mobility, low cost, and broad view range. However, there are concerns regarding the surveillance capability of UASs in inclement weather. Cloudy conditions and high humidity climates can distort the imagery (Haddal & Gertler, 2010) and daylight constraints create barriers to time-sensitive applications (Gao et al., 2021). A typical hurricane brings at least 6 to 12 inches (152 to 304 millimeters) of rainfall and 74 to 95 (33 to 42) mph (m/s) winds (National Hurricane Center, 2005). Although weather-resistant drones have higher tolerances in temperature (-20 °C to 46 °C), wind speed (31 mph), and precipitation (50 mm/h) (Gao et al., 2021), they are more likely to be employed before or

after a storm, when weather conditions permit. A typical UAS deployment for civil applications must follow regulations from the Federal Aviation Administration and other regulatory agencies. Therefore, issues with flying UAS in civil airspace must be addressed before UASs can widely be used in real-life evacuations (Kanistras et al., 2013).

Even though public agencies have been planning to expand their networks of traffic monitoring systems over the years, gaps in data coverage remain, and public agencies have considered filling the gaps using data from the private sector. The rapid advancement of Connected Vehicle technology offers a promising platform for traffic monitoring and data collection, particularly in urban environments. Vehicles equipped with wireless communication devices in a network of connected vehicles can transmit vehicle safety messages to other connected vehicles (Xu, 2017). Private companies have teamed with Departments of Transportation across from the United States to collect traffic data from a network of connected vehicles on roads. TMCs are able to know how to avoid congestion on major escape routes and make critical decisions during an evacuation with the live traffic data collected by driving connected vehicles within minutes (Wejo, 2020).

Chapter 3: Literature Review

This chapter aims to document resources in the research community regarding how transportation agencies identify the need for improving the public hurricane evacuation experience, compare different approaches to determine the most effective way to engage the public, and evacuees' behavioral responses to evacuation that may influence decision makers to assess the needs of prioritizing hurricane evacuations.

3.1 Agency's Projects Planning Process

One component of a successful evacuation effort is to safely and efficiently move people out of hazardous zones while traveling along evacuation routes. The state of Texas has developed and improved hurricane evacuation routes and various tools in order to enhance evacuation operations for its coastal regions (Ballard & Borchardt, 2006). Nonetheless, there are instances when the resources available may be insufficient for accomplishing all objectives set forth by an organization. A process for project identification and prioritization is typically developed to identify and allocate funding to the most urgently required projects.

TxDOT's Project Development Process Manual (2019) outlines various stages for transportation engineering professionals to initiate a project concept and progress towards its completion. The initial step in developing a project entails the identify and document needs through the engagement of internal personnel and collaborative efforts with external entities, such as Governor's Office, legislators, Metropolitan Planning Organization (MPO), counties, cities, transportation stakeholders and the public (TxDOT, 2022). The objective of public involvement is to cultivate a communication channel between the public and government agencies so that the perspectives, concerns, and issues of the public can be incorporated into creating a more efficient and transparent decision-making process.

3.2 Public Engagement Approaches

Public engagement can yield a lasting impact on the planning and advancement of a project. Without it, there is a potential for making poor decisions (FHWA, 2004). Traditionally, conducting in-person public meetings is one of the methods of engaging the public. Technology advancements have led to use the emergence of innovative techniques to inform the public and collect feedback through public social media, telephone town halls, online meetings, crowdsourcing, survey tools and real-time polling tools (FHWA, 2023b).

Survey tools are often at a lower cost than traditional public engagement methods, and appeal to stakeholders who may not participate in conventional public engagement approaches. It has been widely employed as a means to efficiently and cost-effectively engage a larger demographic in numerous fields within the transportation research community. For instance, Wong et al. (2020) developed an online survey to offer policy recommendations for agencies to enhance hurricane evacuate efforts by utilizing advanced methods grounded in discrete choice theory. Jin & Gambatese (2018) conducted a study to assess the impacts and effectiveness of temporary construction signage in relation to sign characteristics using an online questionnaire. Majumdar (2017) designed a survey to evaluate the extent of social media usage in transportation planning among local governments in Texas.

3.3 Evacuation Decision-Making and Behavioral Responses

As daily users of the transportation system, the public possesses valuable opinions, insights and observations to share with agencies on the performance and needs of the transportation system. Especially during emergency situations, learning their experiences and gaining a comprehensive understanding of the factors that influence their decision are

even more valuable so that public officials can make better preparation and provide constructive guidance.

However, a household's decision-making process in the face of a hurricane threat is complex and can be affected by numerous factors (Hasan et al., 2011). Several research efforts have identified multiple factors that impact the potential hurricane evacuation residents' behavior at different regions where hurricanes have posed a challenge.

Researchers have examined a wide array of factors that may potentially affect evacuation decisions after individuals receive hurricane forecasts and other related information. Information sources, consistent information across media, and emphasis on hurricane damages can heighten an individual's sense of risk and make them more likely to evacuate (Burnside et al., 2007; Huang et al., 2012) since people usually were not motivated to evacuate by warnings, rather they must perceive risk (Dash & Gladwin, 2007). Similarly, studies have shown and supported that risks posed by hurricanes are a major determinant. Storm strength and vulnerability of the housing unit had a significant positive effect on evacuation behavior using logistic regression analysis (Smith & McCarty, 2009). Furthermore, this study also revealed that factors such as sex, household structure, and homeownership had a either positive or negative impact on people's decision.

Hasan et al. (2011) introduced a mixed logit model to account for the heterogeneous behavior of household in decision making. Several key factors, including the household's location, evacuation notice sources, work obligations, number of children, housing type and ownership status, evacuation notice type (mandatory or voluntary) issued, previous hurricane experience, and income or educational attainment, were found to significantly influence a household's decision to shelter in place or evacuate. Age and race, on the other hand, had either minor or inconsistent effects on the behavior.

In a more recent study, a research team investigated evacuation behavior from a different angle. The study captured a joint preferences for early-nighttime and early-highway evacuations by developing a portfolio choice model (PCM) with data from surveying individuals impacted by Hurricane Irma (Wong et al., 2020).

As suggested by Lindell et al. (2007), a series of large-scale surveys should be conducted on hurricane evacuations that encompass diverse storm and community characteristics, targeting areas adjacent to evacuation zones. Specifically, data interested would include evacuation decision criteria, distribution of evacuation departure and preparation time, evacuation logistics, and costs incurred during the evacuation process.

Chapter 4: Methodology

In order to comprehensively understand stakeholder perceptions about real-time traffic monitoring during hurricane evacuation events, efforts were directed toward obtaining insights from end users who utilized data generated from these devices during actual evacuation events in Texas. The survey method was chosen considering the research questions and the desired source of information.

4.1 Survey Design and Collection

An online survey was developed to solicit information from Texas residents who reside or resided in coastal regions as well as those inhabiting areas susceptible to evacuation events during an ongoing project funded by TxDOT. Gaining insight into the experiences of these individuals is a crucial aspect of the stakeholder outreach process, as it allows for a comprehensive understanding of the challenges and concerns faced by those directly affected by such natural disasters.

The questions were designed with a particular interest to elicit the participant's views regarding real-time traffic monitoring systems, their assessment of service satisfaction while evacuating from a hurricane and determine commonly observed deficiencies within the existing network and identify feasible improvements. The survey was approved by the author's Institutional Review Board (IRB) before publishing in Qualtrics. It was then distributed through TxDOT's Nextdoor account and statewide email accounts obtained from Department of Public Safety (DPS) in an attempt to gain a greater number of responses from a variety of users to determine common factors present within the general population. Nextdoor is a hyper local social networking service. It can help reach residents in specific regions or neighborhoods. Unfortunately, there was no location indication from the email accounts received.

The survey was constructed to ensure that respondents would find it easy to engage with the questions presented by incorporating concise, easy-to-understand and straightforward-to-answer questions. The number of questions was kept to a minimum and the primary response style was multiple choice or multiple selection questions. The main sections of questions desired to be answered by the survey were:

1. What demographic characteristics were associated to evacuees and non-evacuees at the time of a hurricane evacuation?
2. How soon did evacuees leave prior to landfall, what types of vehicles did they use, how far did they travel, and where did they go?
3. Did evacuees use real-time traffic data during past evacuations? Which platforms were used to access the data and what issues did evacuees encounter while using it? What suggestions do evacuees and non-evacuees have to improve the real-time traffic information services?

The survey was created with four parts and with a total of 32 possible questions with an emphasis on the role of real-time traffic information systems in hurricane evacuations. The first part of the survey includes a brief introduction of the project and a consent page where respondents agreed to participate in the survey. A question was then presented asking if the respondent had previously participated in a hurricane evacuation in Texas. Those who responded "Yes" were taken to the full survey. A "No" response brought the respondent to a different set of survey questions that asked for the reasons why the individual did not evacuate and if improved traffic monitoring capabilities would have altered their decision. Demographic information from all respondents was collected to help understand evacuee's behaviors during an evacuation, regardless of their prior experience in participating in an evacuation. Since survey takers may not wish to respond to

demographic questions, these questions were optional and written such that values were represented within a range.

4.2 Data Cleaning and Analysis

4.2.1 Aggregate Data

A total of 2,933 responses were received from August 30, 2022, to February 22, 2023. Sporadic responses were received after, but they were not included in this analysis due to time constraints. In order to ensure that the survey response is reliable and accurately reflects the perspectives of the participants, uncompleted survey responses were deleted and removed from analyses. After removing uncompleted responses, 1550 responses were obtained to continue with further analysis.

The survey provides some freedom for participants to provide their comments on the text questions. These questions were uniformly formatted in order to keep the data concise and consistent. For example, any zip code provided were only kept with 5 digits. During this process, several entries were found to be irrelevant to the purpose of this study. The primary survey participants were residents in Texas who have experienced a hurricane before, whether they evacuated or not. However, since the emails obtained from DPS were statewide, residents who lived in inland regions also received and completed the survey. Given that they have not been and likely will not be under the threat of hurricanes, their responses were removed from further analyses. In summary, a total of 1,398 responses were used for statistical analysis.

4.2.2 Discrete Choice and Variables

A simple binary logit model was used to explore the possible influence of demographic variables on choice behavior. To prepare the aggregate data for this model, it

was further refined and coded. Given the individuals below the age of 18 are less likely to independently make decisions in the context of evacuation without a legal guardian; therefore, such individuals were excluded from the model. Dummy variables were created to represent the numeric attributes of each independent variable. The refined dataset ultimately consisted of 1,042 observations to be used for testing binary logit model. Table 4-1 presents the descriptions of dummy variables created for the model.

Table 4-1. Description of variables.

Group	Variable	Description
General Variables	PERSID	Observation number
	DECISION	The chosen alternative (1 = evacuate, 2 = not evacuate)
Demographic Variables	AGE	1 if individual is under 54 years old, 0 otherwise
	HOUSEHOLD SIZE	Number of persons in a household
	WHITE	1 if race is white, 0 otherwise
	INCOME	1 if income is higher or equal to $50,000, 0 otherwise
	FEMALE	1 if individual is female, 0 otherwise
	EDUCATION	1 if individual has bachelor's degree or higher degree, 0 otherwise
	HOUSETYPE	1 if individual owns a house, 0 otherwise

Chapter 5: Results and Discussion

Out of the 1,398 valid responses as the aggregate data, 871 respondents (62.3%) indicated that they participated in a mandatory or voluntary evacuation in Texas before, while 527 (37.7%) respondents indicated they chose not to evacuate. For those who participated in a past hurricane evacuation, it was observed in Figure 5-1 that the majority of respondents had participated in the evacuation for Hurricane Rita, with Hurricane Ike being the second most evacuated storm, followed by Hurricane Harvey and Hurricane Laura. The four hurricanes were considered as major hurricanes in Texas for the remaining discussions due to the combination of their storm severity, the issuance of mandatory evacuation orders, and the substantial number of individuals affected by their impact.

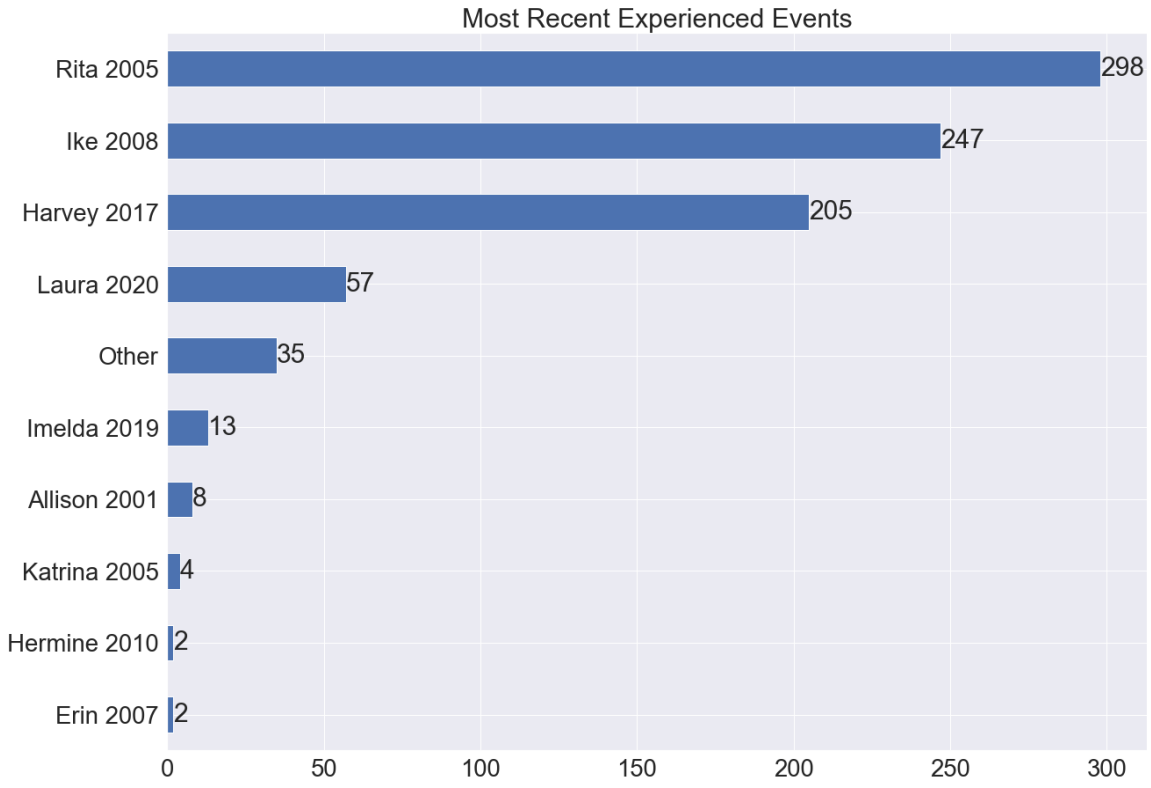

Figure 5-1. Most current hurricane evacuation events respondents participated.

5.1 Survey Participants' Demographic Characteristic

5.1.1 Aggregate Data

Survey participants were asked to voluntarily disclose their demographic information before responding to questions regarding their experiences with hurricane evacuation traffic monitoring devices. They had the option to either skip these questions or select an option indicating that they preferred not to provide an answer. The demographic questions incorporated in the survey included respondents' age, household size, race, income, gender, education level, and housing arrangements at the time of a hurricane event. In cases where respondents experienced more than one hurricane, they were instructed to provide responses pertaining only to the most recent hurricane evacuation they could recall. The results are presented in the subsequent graphs.

Figure 5-2 illustrates the distribution of reported ages at the time of most recently experienced hurricane for individuals who did and did not evacuate.

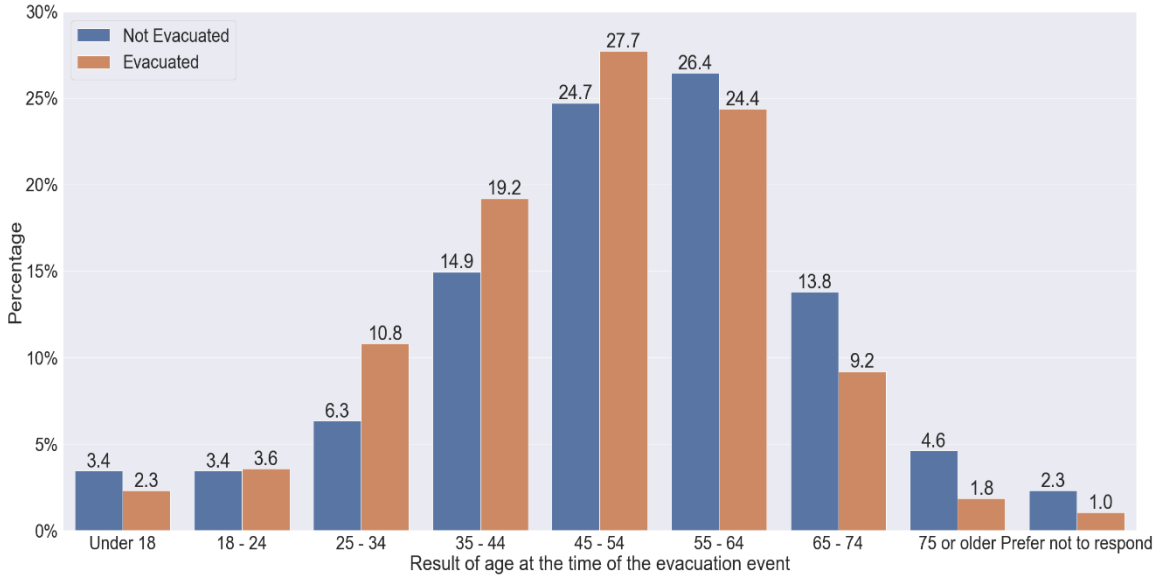

Figure 5-2. Distributions of reported age at time of most-recently experienced hurricane.

In both groups – those who evacuated and those who did not – the most frequently reported age ranges were 45-54 and 55-64. Except for the group under 18 years old, more people chose to evacuate from the groups younger than the age of 54 and more people chose not to evacuate for the groups older than 54.

Household size was also collected in the survey, with results shown in Figure 5-3. The most common household represented in the survey was a two-person household for both people evacuated and did not evacuate. The mean household size of evacuees was 3.1 and those who did not evacuate was 2.9. These numbers are consistent with the average family size being 3.13 according to the 2021 U.S. Census Bureau statistics (Duffin, 2022). The standard deviation of the reported household size was both 1.4. It was observed that households with more than two people tend not to evacuate.

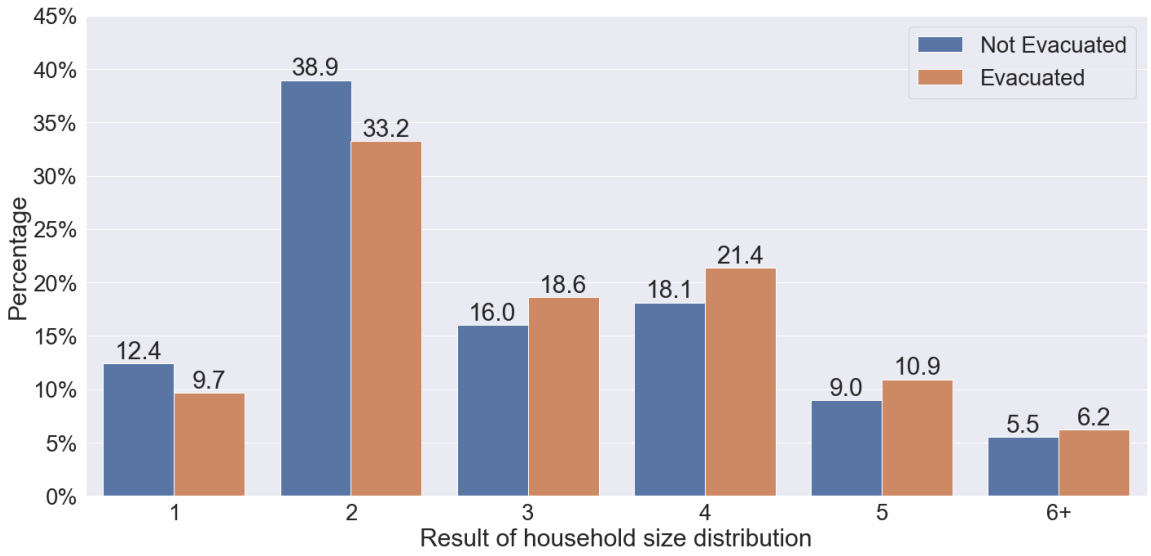

Figure 5-3. Reported household size at time of most-recently experienced hurricane.

The recorded racial composition of the survey participants was presented in Figure 5-4. The racial demographics of the respondents help to understand how various ethnic groups might react to hurricane evacuation orders.

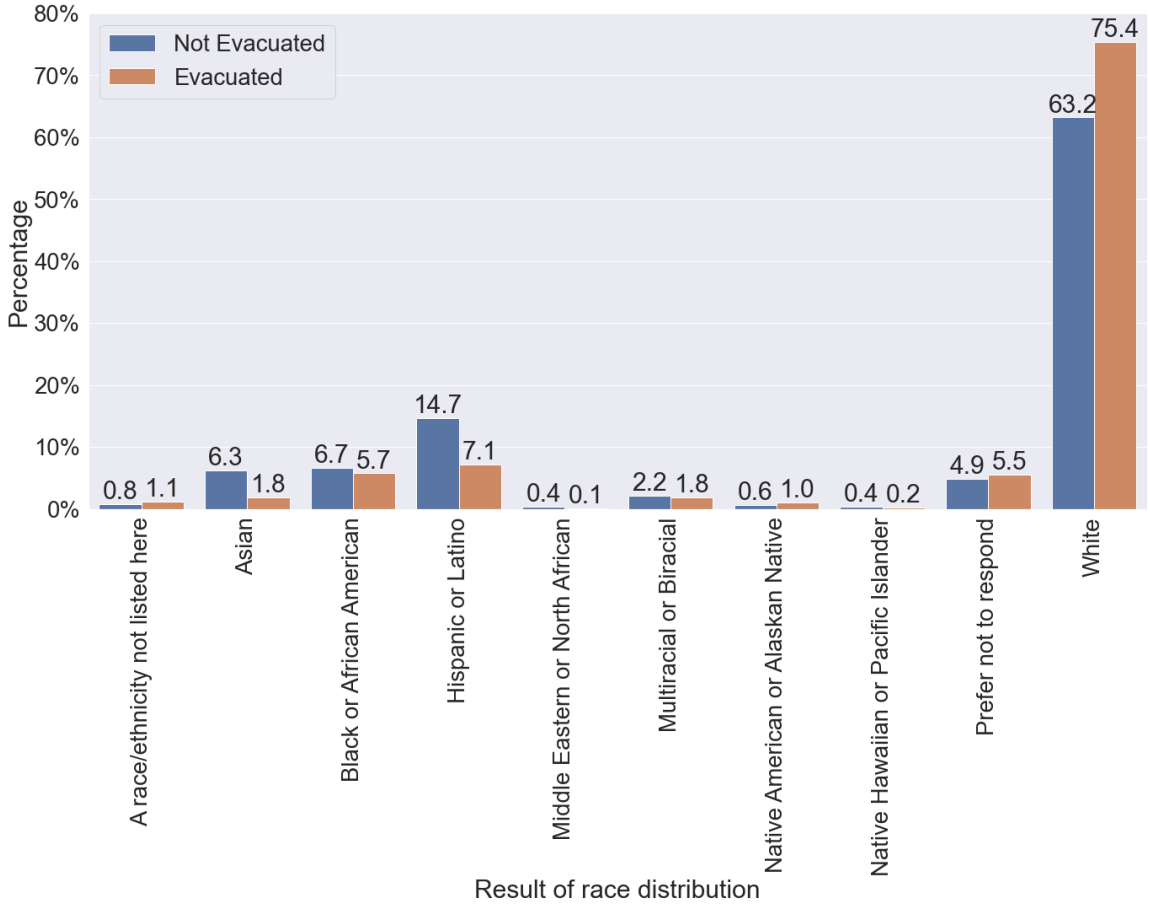

Figure 5-4. Distributions of reported race.

In both groups, a majority of respondents identified themselves as “White”, while smaller portions of “Hispanic or Latino”, “Black or African American”, and “Asian” were reported. The percentage of people who chose to evacuate and not evacuate among each ethnic group is very close, except people identifying them as Hispanic or Asian. A higher percentage of respondents from the Hispanic or Asian group reported that they did not

evacuate compared to those who reported evacuating, while a higher percentage of respondents from the White group reported they evacuated. This discrepancy may indicate some underlying disparities in the capability of specific demographic groups to evacuate during disaster situations, potentially due to factors such as socioeconomic status, access to resources, or cultural differences.

Figure 5-5 presents the distribution of respondent's annual household income. The majority of income data fell within the range of $50,000 and $199,000. It was observed that individuals with an income under $99,999 had a slightly higher possibility to shelter in place at the time of a hurricane evacuation, while the percentage of evacuating was higher for individuals with an annual income above $100,000.

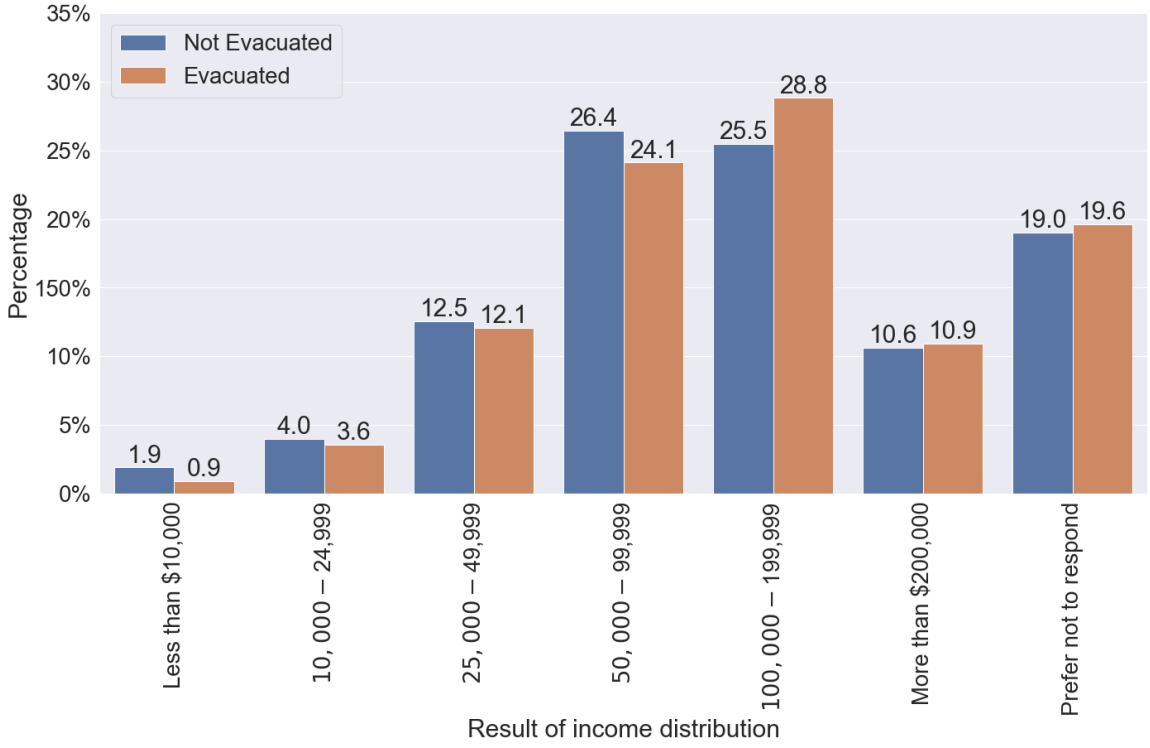

Figure 5-5. Distributions of reported income.

Over 20% of the participants opted not to disclose their income information. This is significantly higher than other demographic questions. Literature found that survey data on income can be missing up to one-third of respondents in general (Kim et al., 2007). Data missing could be random or it could be biased if there are additional unobserved predictors contributed to respondents' decision to not disclose income (Chen et al., 2008).

The results of inquiry into the respondents' gender were demonstrated in Figure 5-6. A higher proportion of male reported not evacuating as opposed to female, and conversely, more female indicated that they evacuated in comparison to male. This is likely because males and females sometime exhibit varying degrees of risk-acceptance.

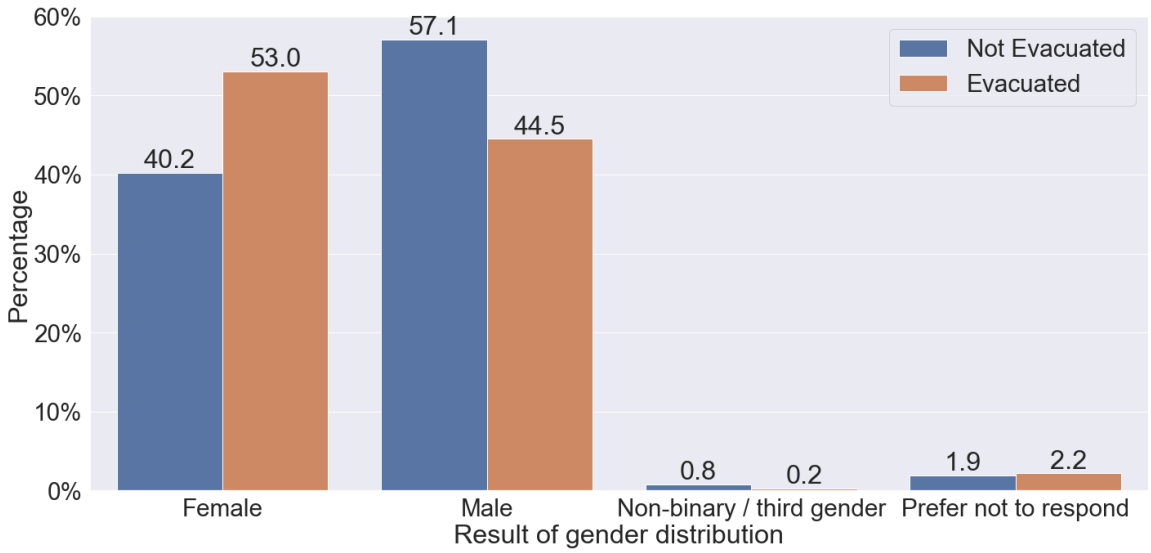

Figure 5-6. Distributions of reported gender.

Figure 5-7 displays the distribution of the highest education attained by the respondents. Over one-third of respondents possess a bachelor's degree and approximately 20% either have some college credit without obtaining a degree or have a Master's degree. The remaining respondents have diverse educational backgrounds, which constitute a

smaller proportion of the sample. The results appear relatively consistent between those who chose to evacuate and those who did not.

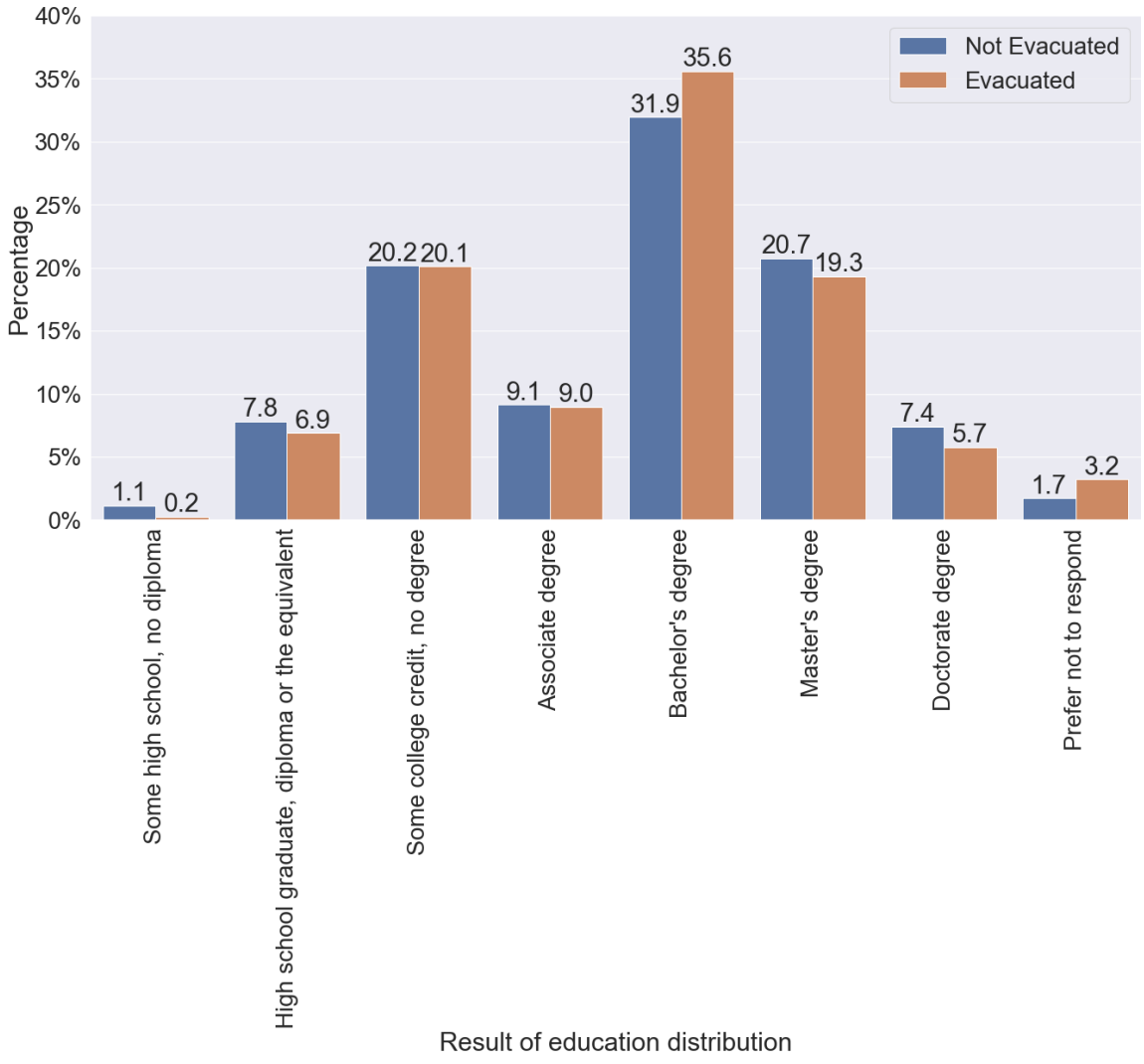

Figure 5-7. Distributions of reported education.

The last demographic inquiry pertained to the housing arrangements of potential evacuees. As shown in Figure 5-8, an overwhelming majority of respondents reported being homeowners. Renting emerged as the second most prevalent housing arrangement,

while the remaining alternatives collectively constituted approximately 10% of the total sample. While some of the demographic data matches with the general population in the United States, it is still necessary to consider that some of the results might be biased because of the distribution methods.

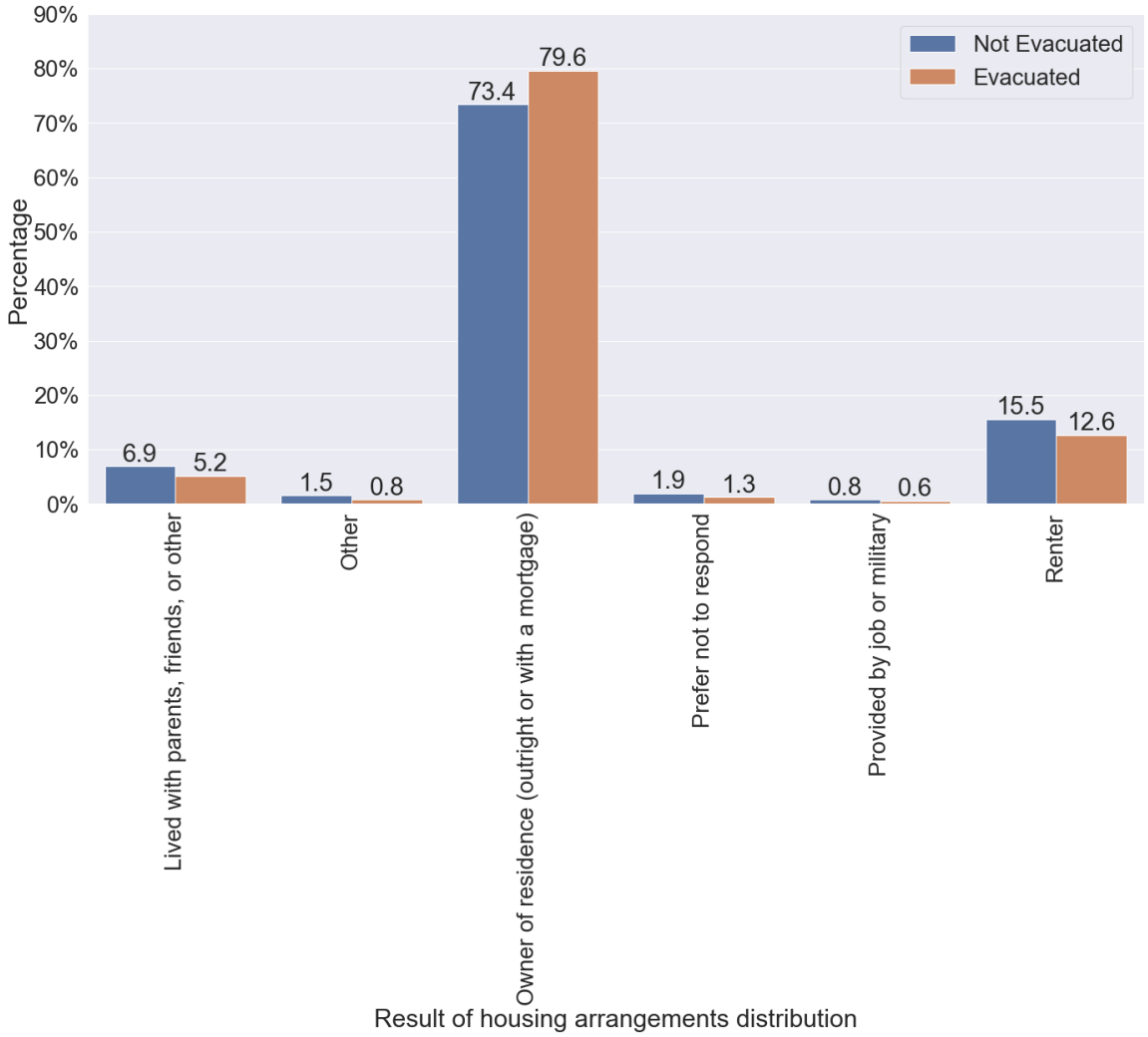

Figure 5-8. Distributions of reported housing arrangements.

5.1.2 Binary Logit Model

A binary logit model was used to examine if any of the demographic variables have potential impact on evacuees' decision making, in the context of whether or not to evacuate from a storm. Table 5-1 summarizes key statistics generated from the model.

Table 5-1. Binary logit model of the decision to evacuate or not.

Explanatory Variable	Estimate Coefficient	t-stat (95% confidence)
CONSTANT		
Yes (Base)	0.00	NA
No	1.43	4.96
AGE		
Yes (Base)	0.00	NA
No	-0.49	-3.25
HOUSEHOLD SIZE		
Yes (Base)	0.00	NA
No	-0.13	-2.45
WHITE		
Yes (Base)	0.00	NA
No	-1.00	-6.25
INCOME		
Yes (Base)	0.00	NA
No	-0.07	-0.37
FEMALE		
Yes (Base)	0.00	NA
No	-0.66	-4.79
EDUCATION		
Yes (Base)	0.00	NA
No	0.05	0.32
HOUSETYPE		
Yes (Base)	0.00	NA
No	-0.29	-1.65
Number of Observations	1042	
Rho-Squared	0.10	
Adjusted Rho-Squared	0.09	
Loglikelihood at constant	-686.88	
Loglikelihood at convergence	-647.43	

As illustrated in Table 5-1, all demographic variables are found to be statistically significant at a 95% level of confidence as evidenced by their absolute t-value being greater than 1, with the exception of the education indicator. A higher t-value suggests increased confidence in the variable's true impact on choice behavior. The possession of a bachelor's degree or a higher diploma does not exhibit a statistically significant influence on an individual's decision to stay or leave during a hurricane event.

Notably, all significant variables negatively affect the utility of opting not to evacuate. This suggests that if an individual is below the age of 54, their likelihood of choosing not to evacuate decreases, thus making decision to evacuate is more probable for individuals under 54. Likewise, individuals who identify themselves as "White" and those with a household income exceeding $50,000 are more inclined to evacuate. This observation potentially highlights that vulnerable road users and underserved communities may face limited access to pertinent information and resources necessary to facilitate their evacuation.

Moreover, female respondents demonstrated a higher likelihood of evacuating compared to males, which could be attributed to differing risk perceptions between the genders. Additionally, an increase in the number of household members positively correlates with the likelihood of a household opting to evacuate. Homeowners also exhibit a greater tendency to evacuate during such events.

5.2 Survey Participants' Past Experience in Evacuation

Following the section of collecting demographic information, the survey questions shifted focus to delve deeper into exploring the time and spatial information related to evacuation. Respondents were requested to provide their zip code of residence at the time of a hurricane event, for both people who evacuated and did not evacuate. This information

was gathered with the intention of identifying the regions in Texas that had the highest rates of evacuation participation. The zip codes were transformed into counties and the percentage of individuals who evacuated and did not evacuate was computed for each respective county. Respondents who did not evacuate before were not asked about which storm event they did not evacuate; therefore, these results are not specific for different storm events. Table 5-2 represents a summary of the evacuation rates for the top seven most frequently reported counties of residence.

It was observed that residents from Galveston County, Jefferson County, and Brazoria County were utmost likely to evacuate, as these coastal counties are the most exposed and vulnerable to hurricane impacts. Conversely, for counties that are not directly adjacent to the coastline or are located further west of Texas, the probability of residents evacuating decreases to approximately 60% to 70%. This highlights the varying degrees of evacuation participation based on the geographical location and perceived risk of hurricane impact among the different counties in Texas.

Table 5-2. Survey results for percentage of people evacuated by county.

County	% of total response	% Evacuated	% Not evacuated
Harris	41.2	72.3	27.7
Galveston	8.2	89.8	10.2
Fort Bend	6.4	62.3	37.7
Jefferson	4.1	95.5	4.5
Brazoria	4.0	90.7	9.3
Montgomery	3.7	55.0	45.0
Nueces	3.6	71.1	28.9

Figure 5-9 and Figure 5-10 show the timeframe before hurricane landfall in which evacuees reported departing from their homes or workplace. The number of responses varied across different storms. Predicted landfall location, advance warnings from the officials, affected population, job responsibility can all potentially affect people's desire on when to evacuate. In most instances, evacuees reported leaving 12-24 hours prior to the hurricane's landfall. Notably, during particularly severe storms like Hurricanes Rita and Ike, respondents indicated that they evacuated 24-36 hours before the storm's arrival. This finding suggests that heightened storm severity prompts evacuees to adopt a more cautious approach, prompting them to leave earlier than they would for less severe storms.

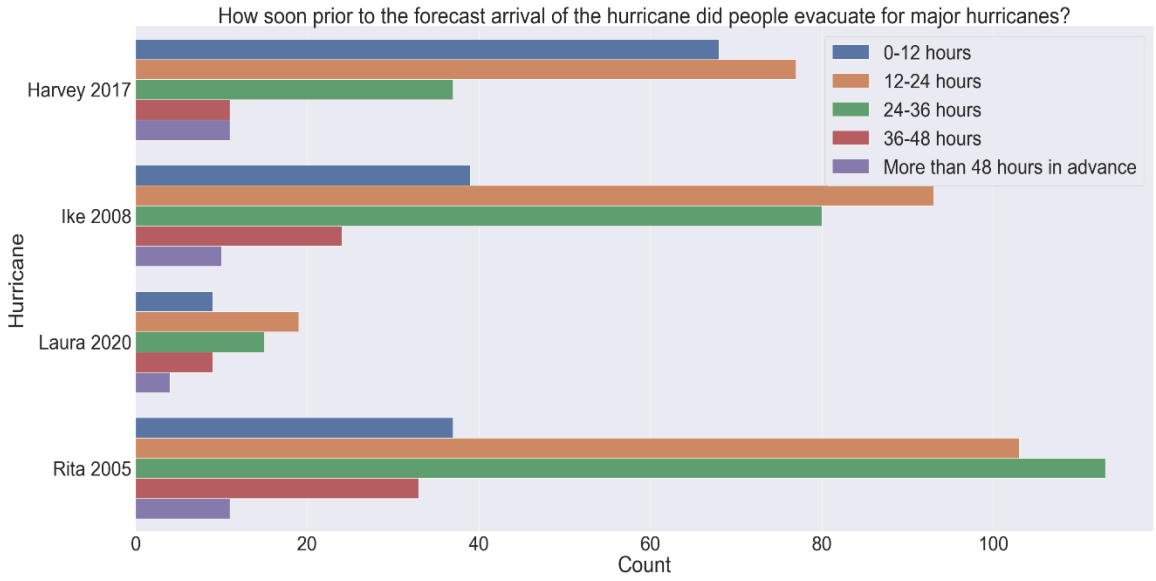

Figure 5-9. Survey results for how soon evacuees departed prior to the forecast arrival for major hurricanes.

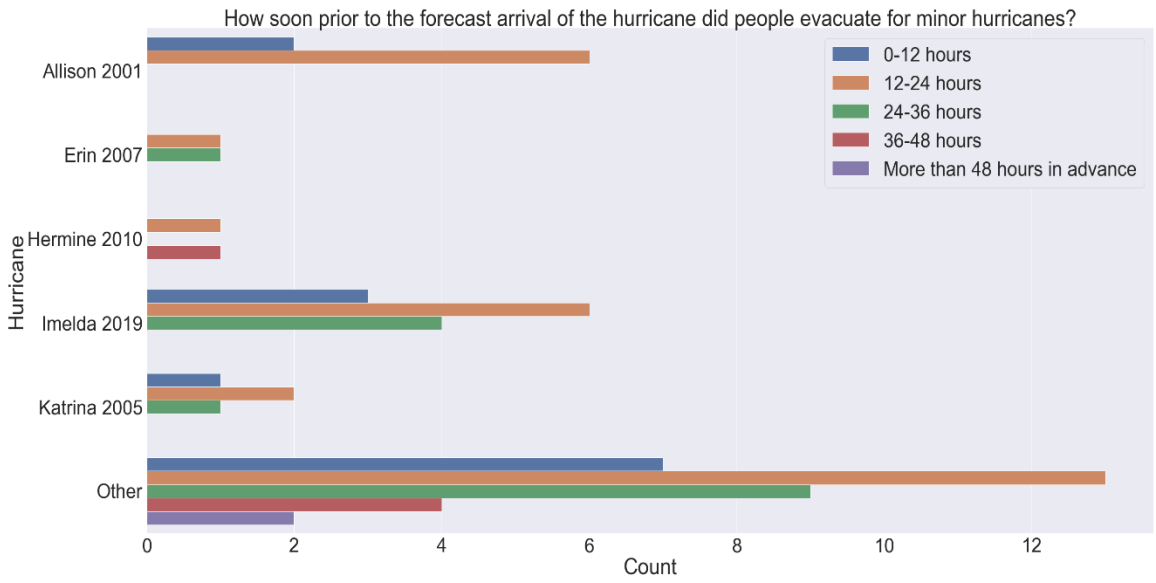

Figure 5-10. Survey results for how soon evacuees departed prior to the forecast arrival for minor hurricanes.

Upon identifying the origins of evacuate traffic, the survey also inquired about evacuees' destination cities and states. This information was subsequently transformed into counties. The top five most common destinations included Travis County (Austin), Harris County (Houston), Dallas County (Dallas), Bexar County (San Antonio), Tarrant County (Fort Worth) and Brazos County (College Station). All of these destinations, with the exception of Harris County, are major metropolitan areas situated along inland state highways.

Further analysis revealed that Houston was a popular destination for evacuees during Hurricane Harvey, Imelda, and Rita. Hurricanes Harvey (at initial landfall) and Imelda were considerably farther away from Houston so it makes sense that evacuees may choose it as a destination. Many respondents indicated they were unable to travel too far for Hurricane Rita due to significant congestion. As a result, they traveled as far as they could to the northwest of Harris County before running out of gas.

Figure 5-11 and Figure 5-12 present the findings on the distances that respondents traveled to reach their destination. Although the results differ depending on the specific storm, the most frequently reported distances traveled by evacuees ranged from 101 to 200 miles and 201 to 300 miles. These insights are crucial for evacuation planning and coordination, as they enable government officials to better comprehend the likely destinations and lengths of evacuation routes. By understanding these patterns, officials can develop more effective strategies for managing evacuation traffic and ensuring adequate resources such as placing more shelters and providing fuel to support evacuees within these evacuation lengths.

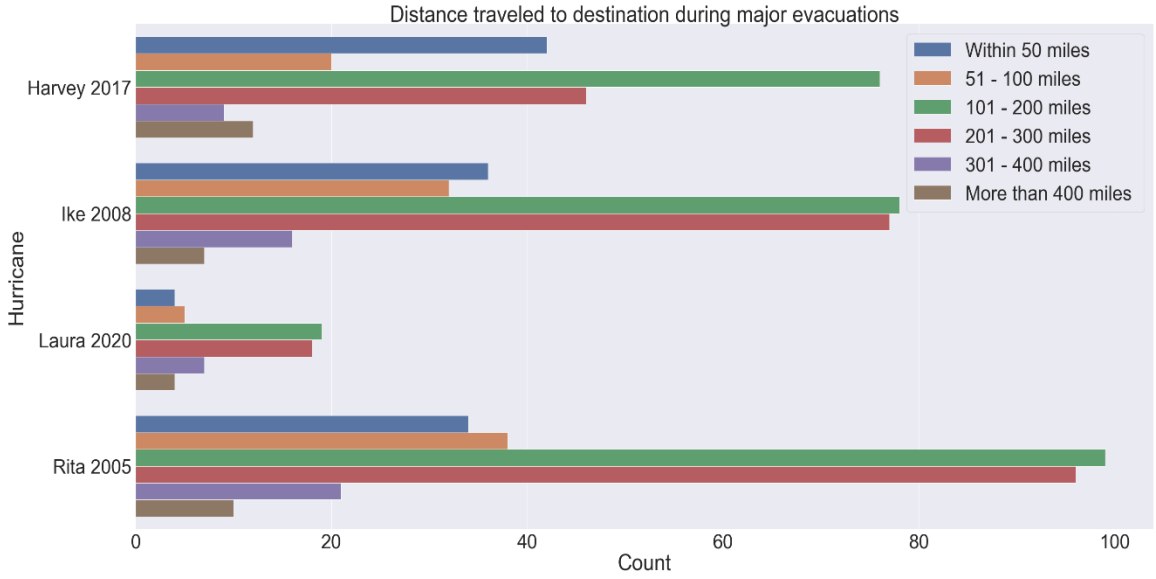

Figure 5-11. Survey results for how far evacuees traveled to reach a safe destination for major evacuations.

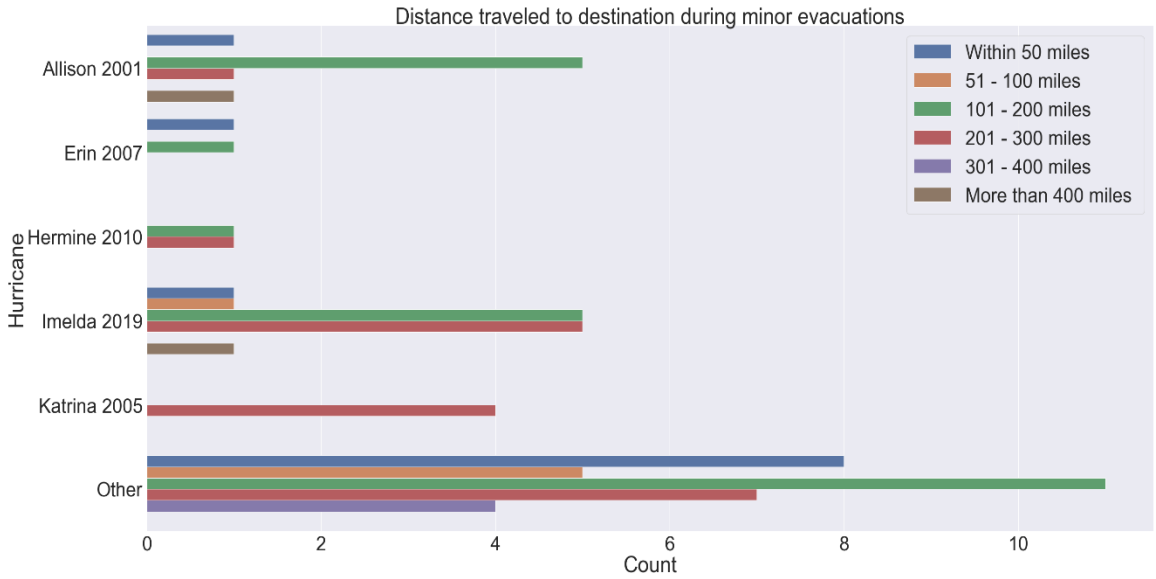

Figure 5-12. Survey results for how far evacuees traveled to reach a safe destination for minor evacuations.

Once evacuees reached their destination, the majority were able to stay with their family or friends in locations that were not threatened by the hurricane as shown in Figure 5-13. The second most common recommendation choice for evacuees was staying in hotels. On the other hand, shelters were not the top choice for evacuees.

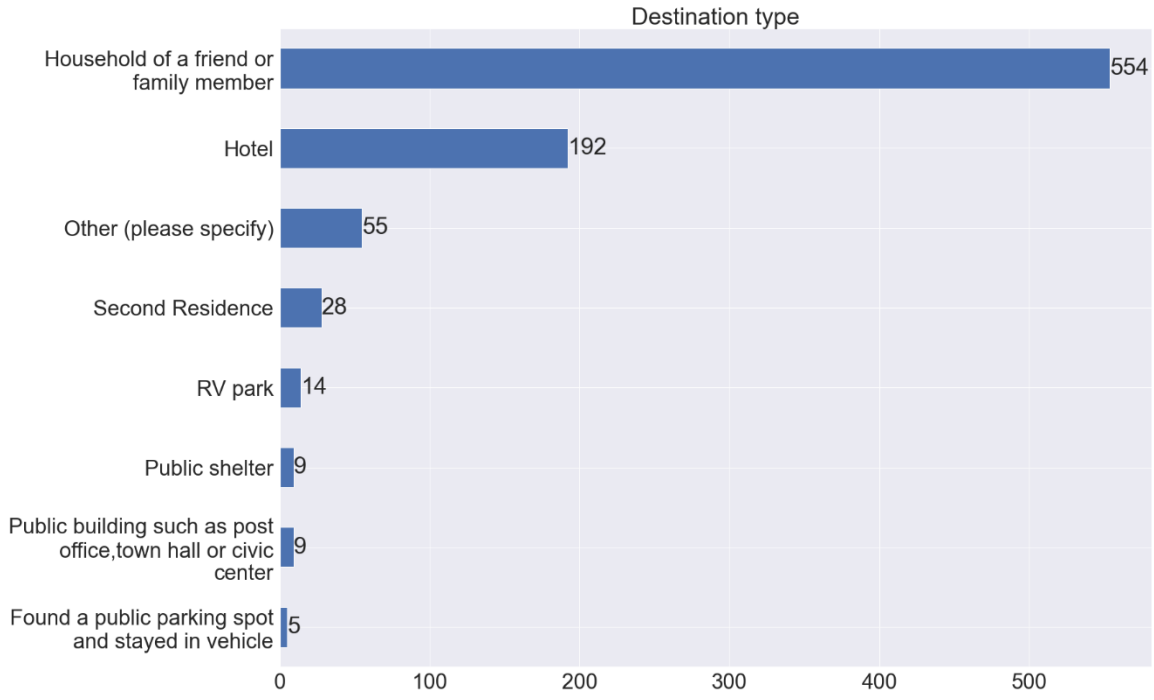

Figure 5-13. Popular types of destination for evacuees.

5.3 Survey Participants' Perceptions of Traffic Monitoring Systems

After understanding evacuees' general behavior during an evacuation, the next section of the survey asked them about issues they encountered while driving and their perceptions of traffic monitoring system. Results for the general issues that encountered during the evacuation were summarized in Figure 5-14. Respondents were directed to select multiple options, such that any of the listed issues that they encountered would be recorded. The results show that traffic congestion was overwhelming the most commonly occurring issue during past Texas hurricane evacuations (32.7%), followed by gas shortages (20.2%), road closures (10.8%), and road rage/other driver's behavior (8.5%). Other factors were also reported, but to a lesser extent.

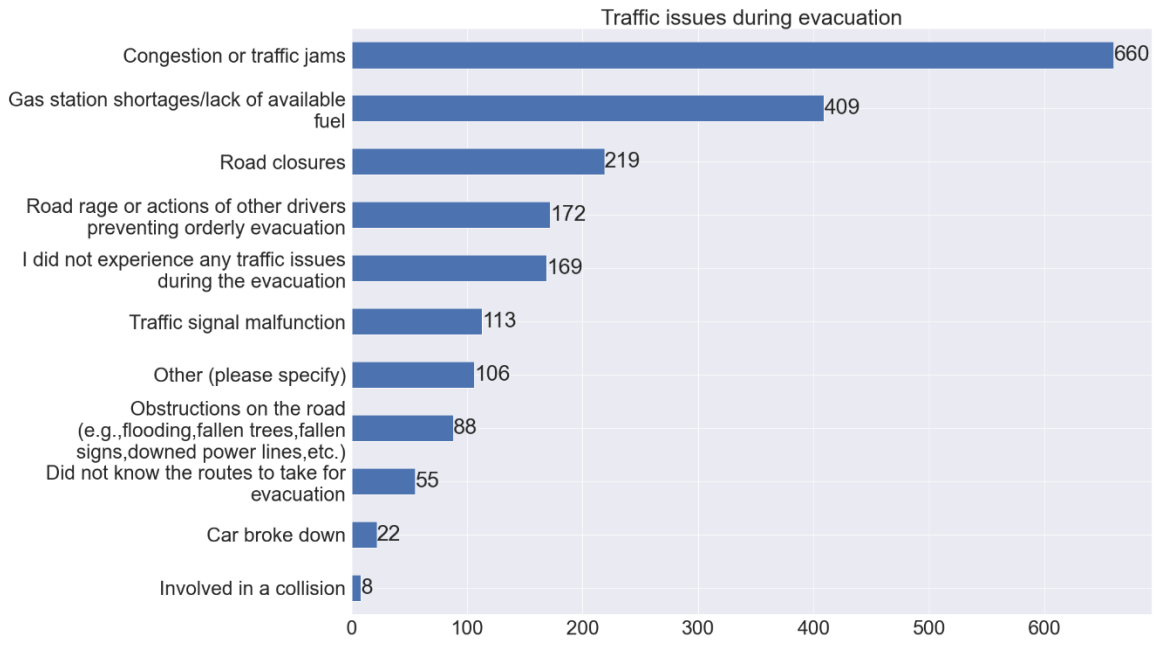

Figure 5-14. General issues encountered during evacuation.

Among the respondents who evacuated for their most recently experienced hurricane event, 50.2% people used real-time traffic data to aid in their route and destination selection during the evacuation while 49.8% people did not use real-time traffic data. As shown in Figure 5-15, for evacuees who used real-time traffic data, radio (25.7%), TV channels (23.2%), and navigation apps (15.1%) are three commonly used platforms to access such data.

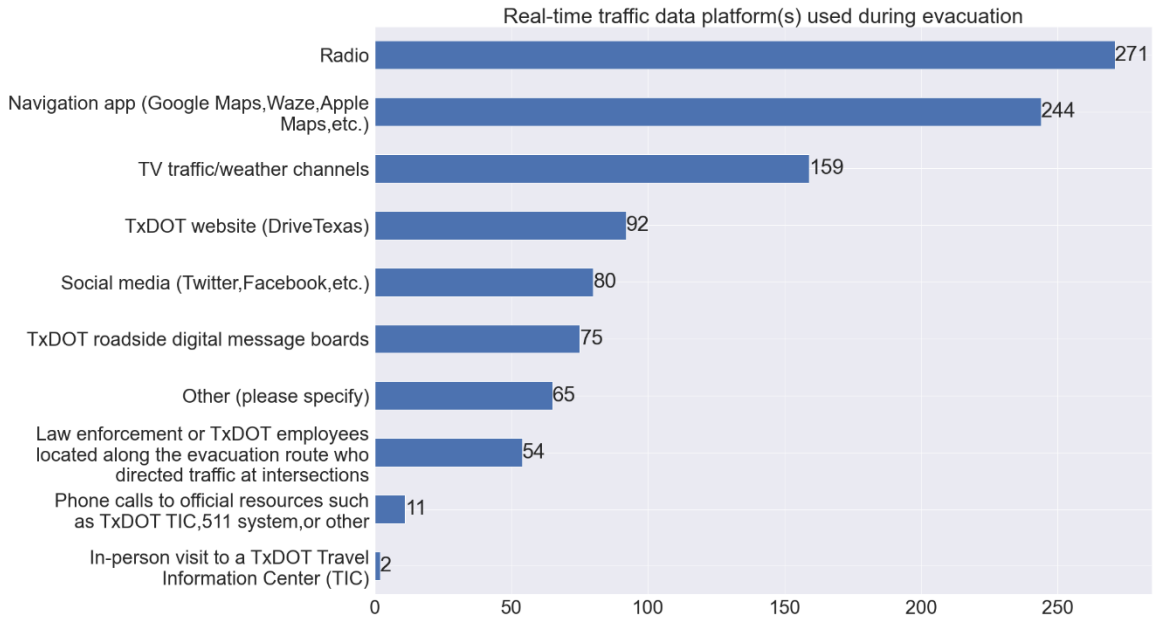

Figure 5-15. Summary of real-time traffic data provider used by evacuees.

According to the report prepared by Ballard & Borchardt (2006), access to any real-time traffic data beyond large metropolitan areas remained scarce in Texas prior to the 2006 hurricane season. Therefore, questions regarding the utilization of real-time traffic data and associated issues were presented in separate figures, enabling a comparative analysis of the results for hurricanes occurring before and after the year of 2006.

For hurricane events occurring before 2006, radio emerged as the predominant medium for obtaining real-time traffic information, as shown in Figure 5-16. Television channels and navigation applications followed as the second and third most prevalent platforms, respectively. However, the reliance on radio and television channels experienced a decline in popularity post-2008, as navigation applications ascended to the forefront as the primary source for traffic data in Figure 5-17.

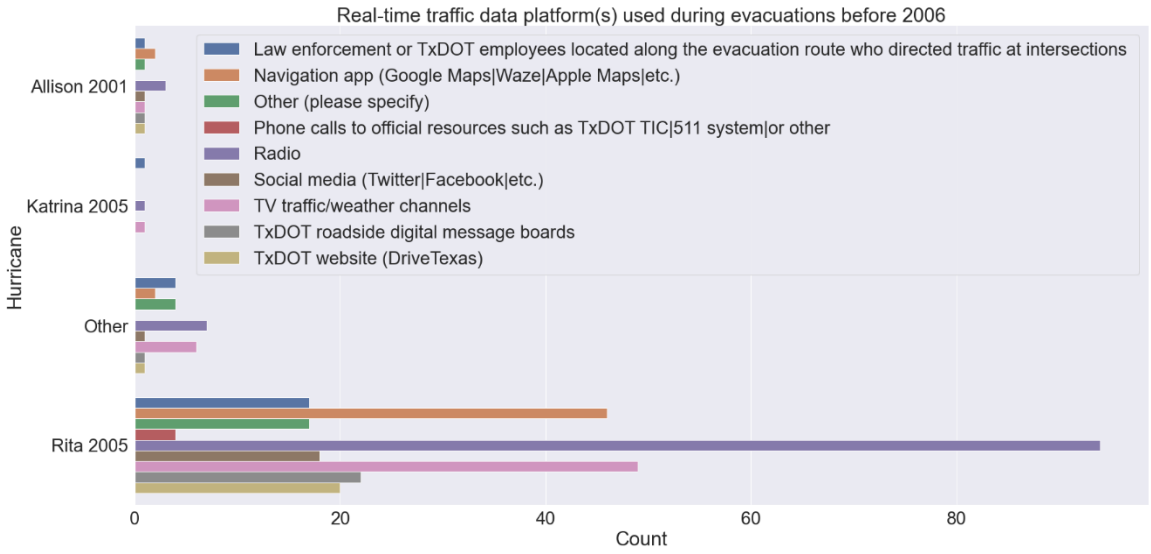

Figure 5-16. Summary of real-time traffic data provider used by evacuees before 2006.

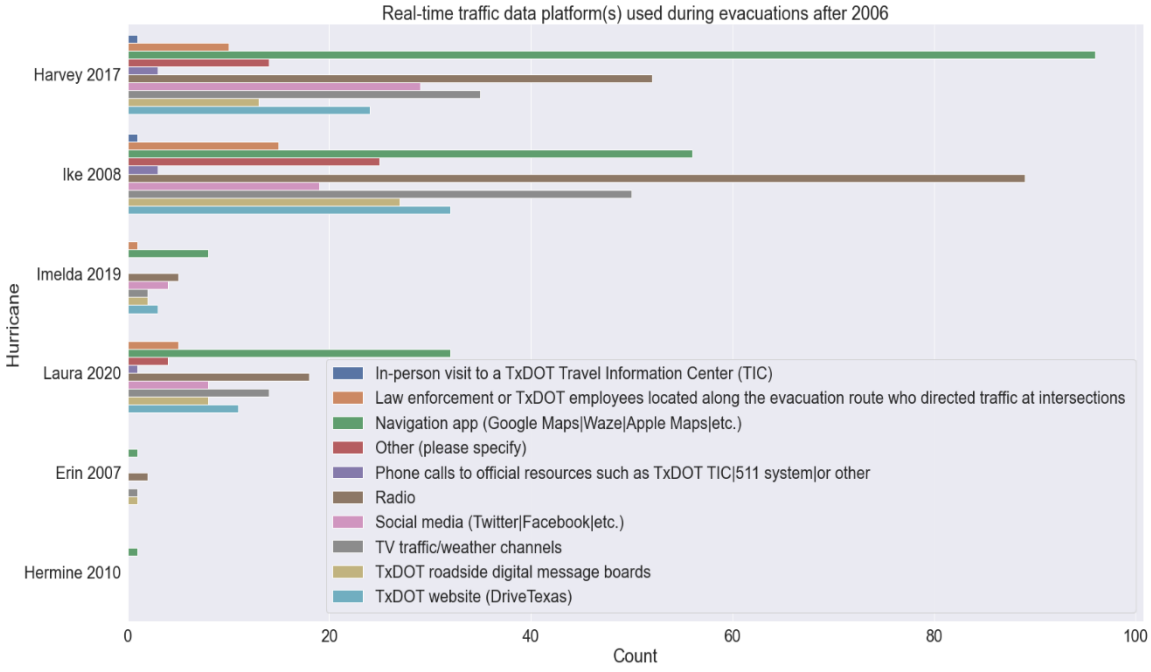

Figure 5-17. Summary of real-time traffic data provider used by evacuees after 2006.

After knowing the common platforms that evacuees used for accessing real-time traffic data during an evacuation, it is needed to understand why they chose those particular

platforms so that potential suggestions can be made to better serve evacuees for future events. From the responses in Figure 5-18, evacuees were inclined to select a service that was available, easy to use, and accessible during an evacuation. Familiarity, accuracy, and the information source are also important contributing factors to evacuees' selection. The cost of a service does not weigh in significantly compared to other reasons.

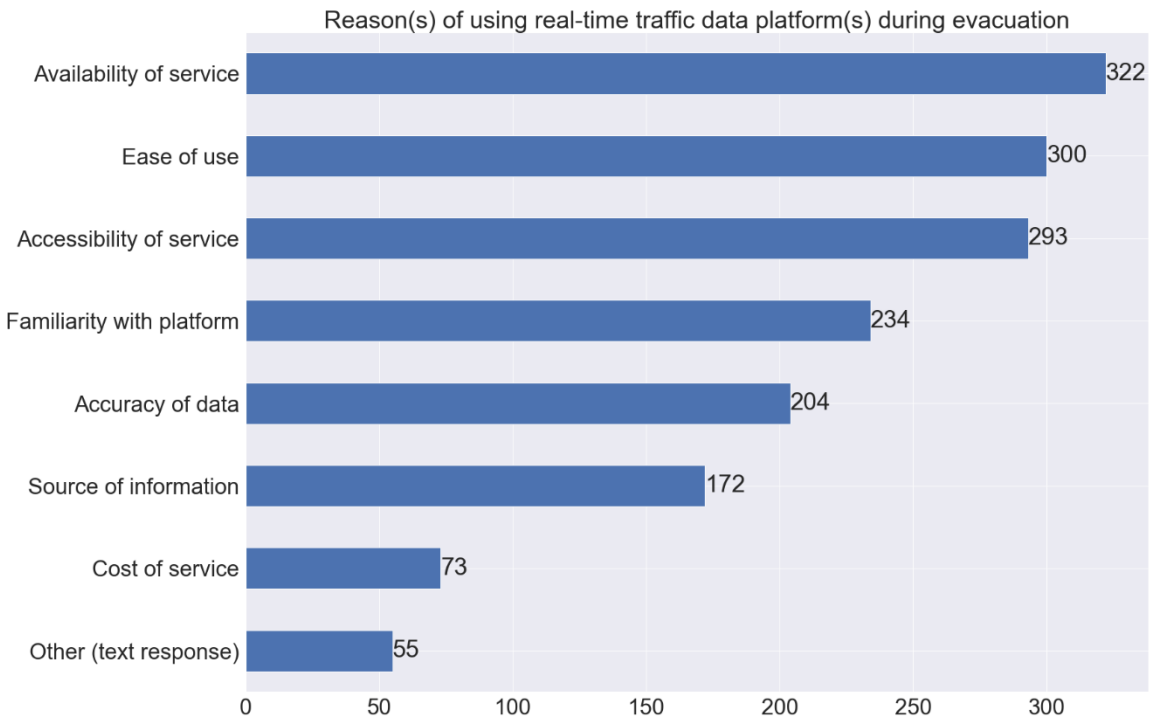

Figure 5-18. Reasons for choosing a real-time data platform.

Among the individuals who used any services to aid in their evacuation, 24.9% of evacuees used real-time traffic data for route selection when they were planning for evacuating to a safe destination, with the second most being using it to adjust route or destination during the evacuation process, followed by monitoring traffic congestion and incidents along routes. A number of people also utilize these platforms to determine

destination, departure time, and other essential services along routes according to Figure 5-19.

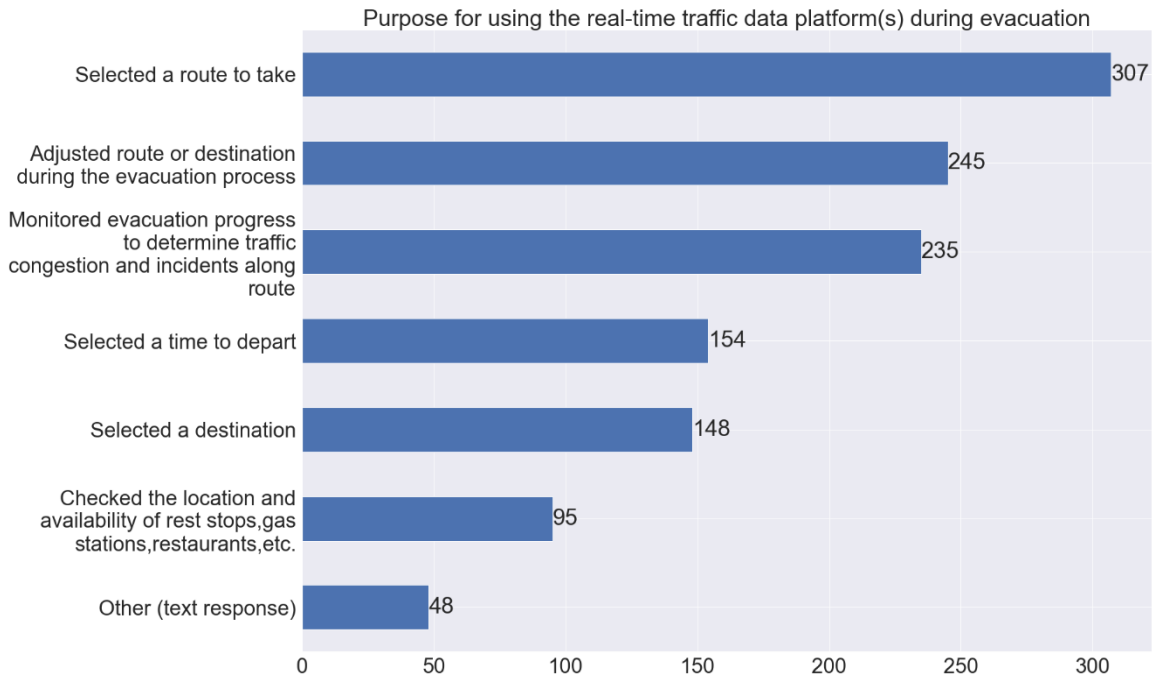

Figure 5-19. Purpose for using the real-time traffic data platform(s).

For respondents who used real-time traffic data, 147 out of 627 (23.4%) said they did not encounter any issues regarding the reliability or accuracy of the systems across all hurricane events, as shown in Figure 5-20. It was approximately evenly distributed among individuals who encountered lost cell phone or internet service, inaccurate real-time travel information, or were unable to access traffic condition information. It was less common for people to experience inoperative or dysfunctional message board systems or a loss of power services.

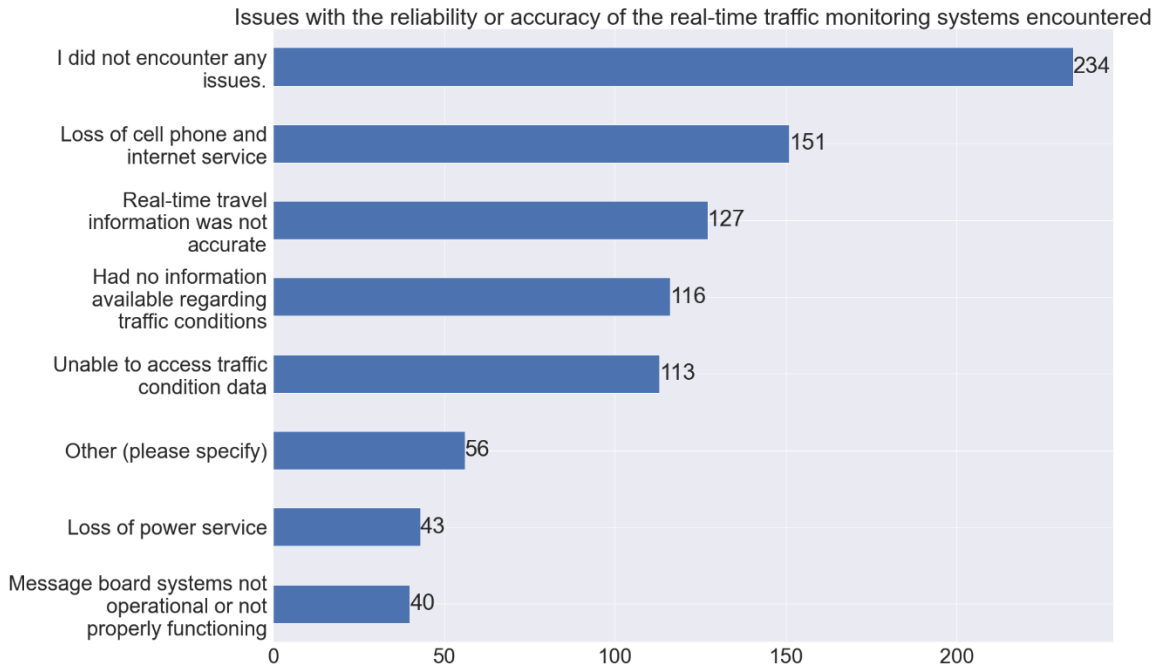

Figure 5-20. Issues encountered when using real-time traffic data.

Upon investigating the issues related to the reliability and accuracy of real-time traffic monitoring systems for each individual hurricane in Figure 5-21 and 5-22, it was discovered that most of the evacuees faced difficulties in getting accurate real-time travel information and accessing stable cell phone and internet services during Hurricane Rita. Moreover, the issues arising from Rita were predominantly related to the limited availability of real-time traffic information services. The advancements in real-time traffic monitoring systems have led to enhanced accessibility, reliability, and accuracy over the years, as evidenced by the diminishing number of evacuees reporting issues during the events of Hurricanes Ike, Harvey, and Laura, as shown in Figure 5-22.

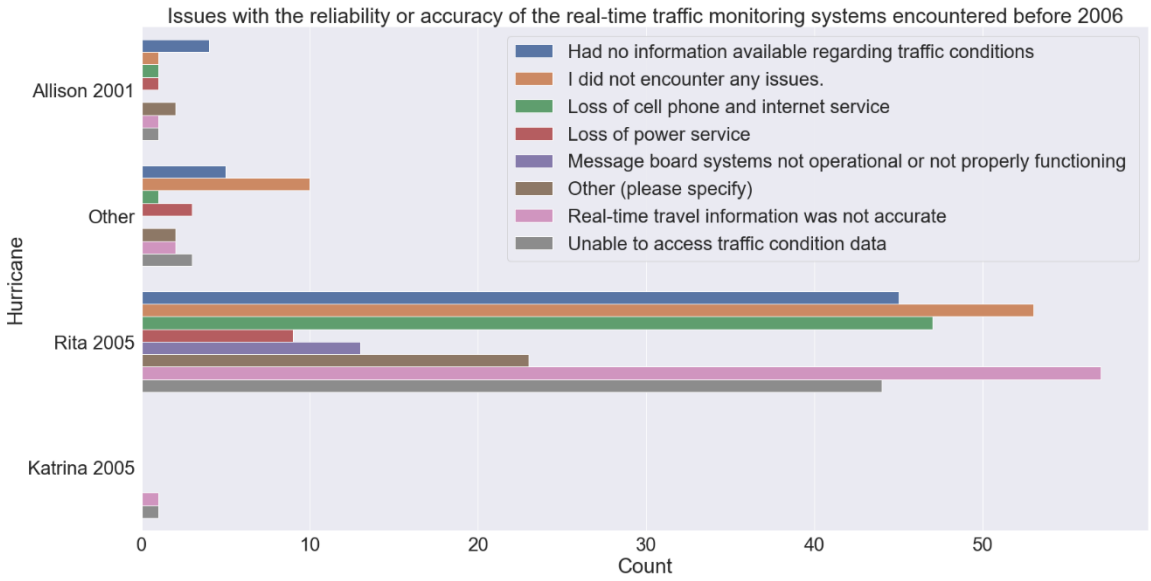

Figure 5-21. Issues encountered when using real-time traffic data before 2006.

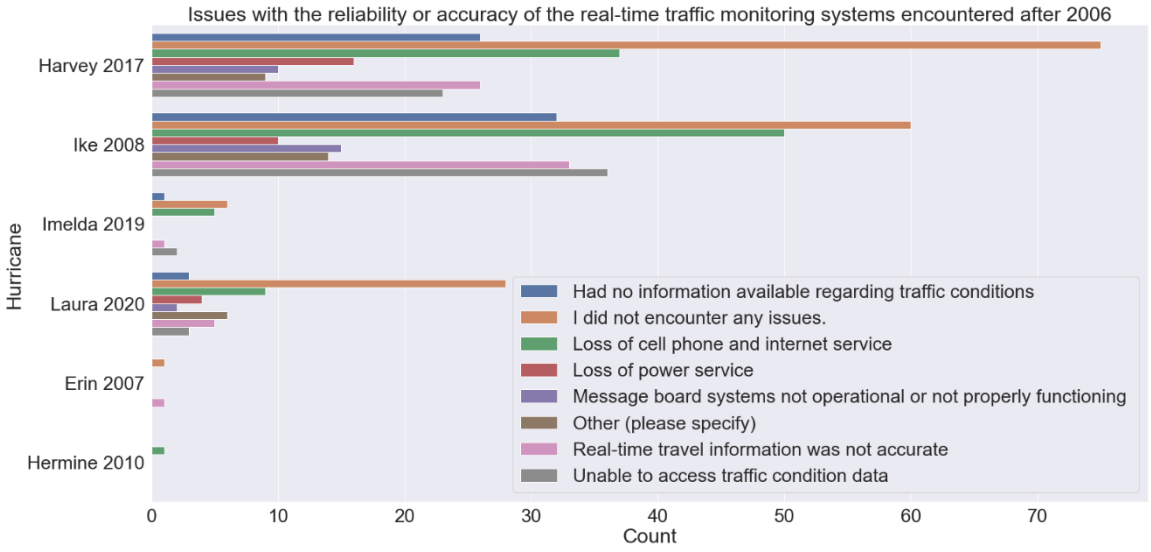

Figure 5-22. Issues encountered when using real-time traffic data after 2006.

Since many respondents evacuated during hurricanes that occurred before 2006, it was frequently mentioned that there were not many services available, or they were

unreliable at the time of the evacuation. Cell phones and internet connectivity were not as widespread as today, so real-time traffic data was not widely available and accessible. Most of the evacuees were unable to receive real-time traffic updates due to service availability. Some of the respondents explained in the "Others (please specified)" field that they mostly relied on radios, news channels, and phone calls with family members and friends who lived in a safe area to inquire such information.

However, these services had their own limitations. For example, people mentioned that radio service was only available along major roads and was unreliable because of the storm. Therefore, availability and accessibility were two important factors of selecting a platform from their point of view. With the advancement of technology, more services have become available, and people are able to choose between a variety of services based on their familiarity with a platform, data accuracy, and the source of the information.

The survey also asked respondents about their experiences with real-time traffic information when they were returning to their residence after the storm threat passed. From Table 5-3, most of the evacuees, constituting over 50%, reported that the quality of post-storm real-time traffic information remained the same as the initial evacuation across all hurricanes. Approximately 32.4% of the respondents perceived an improvement in the quality of the data service, while a smaller fraction of 8.3% expressed that the quality had deteriorated in comparison to their initial evacuation experience.

Table 5-3. Summary of real-time traffic data quality during return compared to initial evacuation.

Result of Quality Comparison	Count	Percentage
The Same	366	59.3%
Better	200	32.4%
Worse	51	8.3%

Although most of the evacuees did not encounter any issues with real-time traffic data during their return from the evacuation across all hurricanes in Figure 5-23, the issues that were reported were disparate across different hurricanes from Figure 5-24 and Figure 5-25.

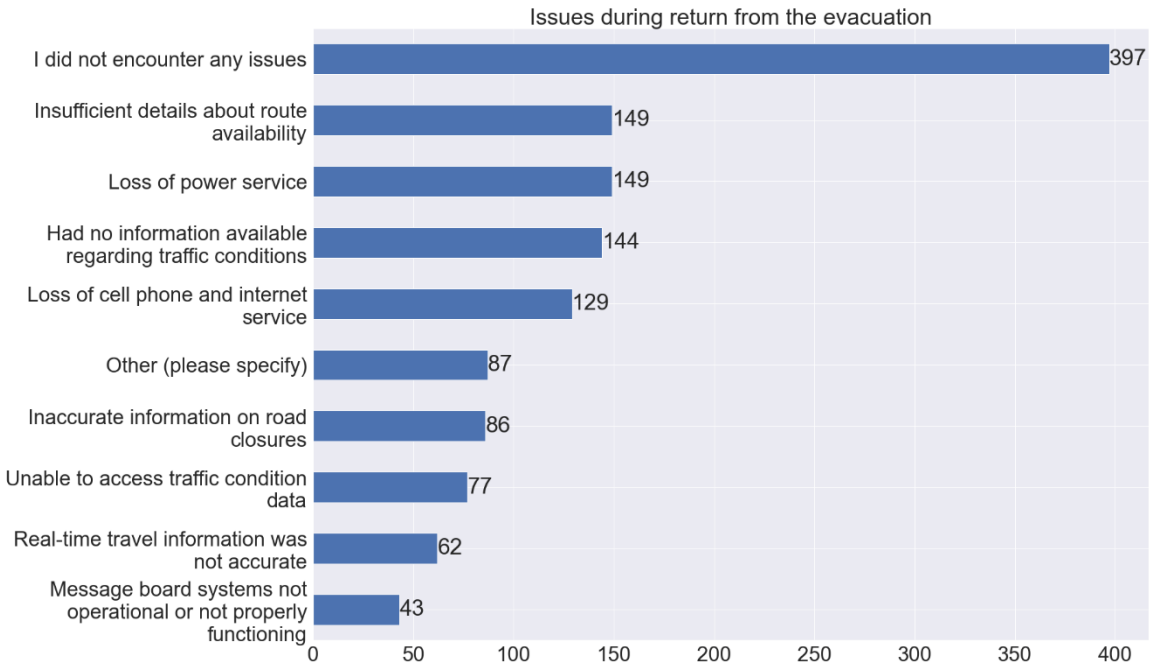

Figure 5-23. Data issues encountered during return from the evacuation.

The most common and specific issue experienced during Rita was that no traffic data was available at the time, followed by insufficient details about route availability. This was because the service was not widely available due to limitations in technology.

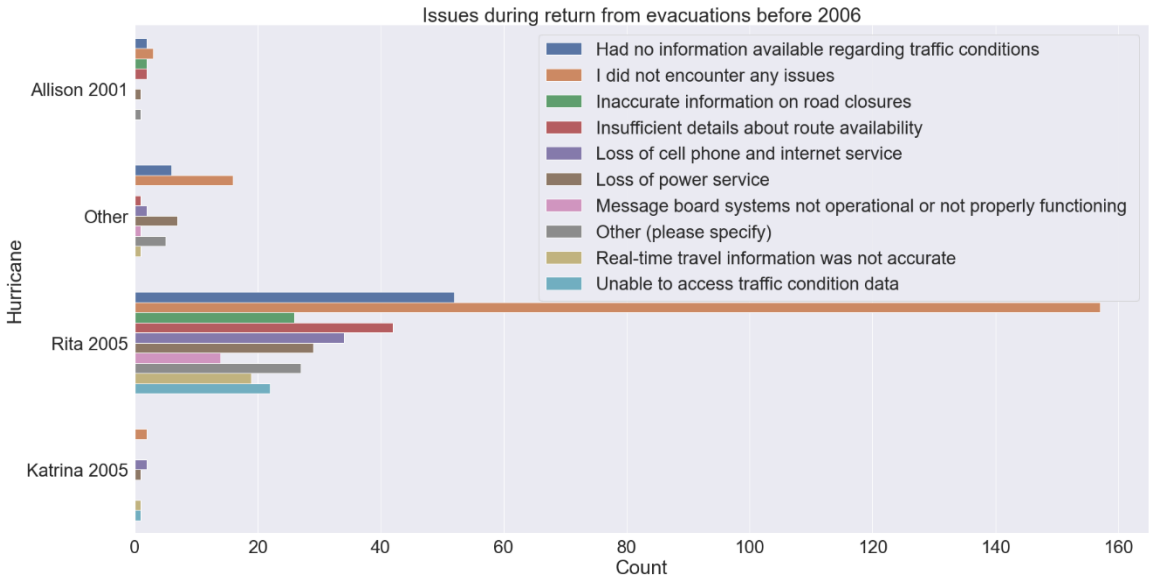

Figure 5-24. Data issues encountered during return from the evacuation before 2006.

In the case of Hurricane Ike, the primary concerns reported by evacuees included a lack of sufficient information pertaining to route availability and widespread loss of power services. During Hurricane Harvey, similar issues were encountered, such as inadequate route availability data and power outages; however, the magnitude of these occurrences was not as prominent as compared to Ike. With the most recent Hurricane Laura, evacuees primarily experienced loss of power, cell phone service, and internet connectivity as their top concerns.

Interestingly, the availability of detailed information and service accessibility no longer appeared to be a significant issue for the majority of evacuees in the last six years in Figure 5-25. The current challenge lies in ensuring stable access to these services and obtaining continuous traffic information. To achieve this, it is crucial to invest in resilient and reliable infrastructure capable of providing essential utilities during extreme weather events, thereby enabling individuals to consistently access the vital information they require.

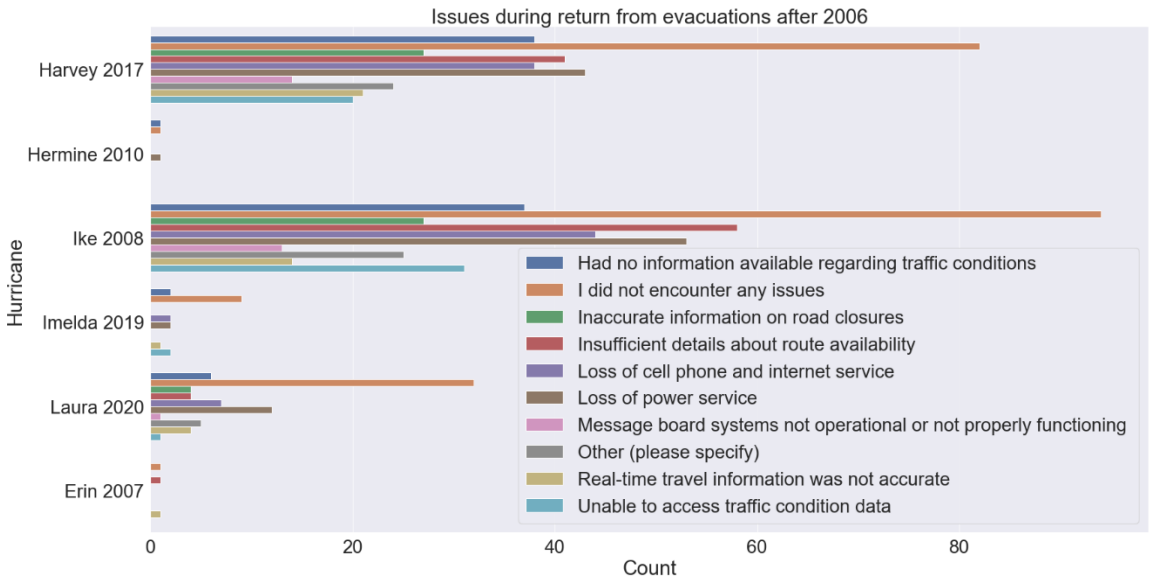

Figure 5-25. Data issues encountered during return from the evacuation after 2006.

Survey participants were asked about their opinions on if the real-time traffic monitoring system was sufficient to provide the data needed to support their decision-making during evacuations. 62.4% participants thought the current system was sufficient while 37.6% participants did not think it was sufficient. Following this question, participants were asked about the most important factor they would like to see addressed to improve the current real-time traffic monitoring system to make future evacuations better. The text responses for this question can be summarized and organized into three groups:

- Emergency Planning: which requires the government to develop a thorough evacuation plan and routes, better communicate information to the public, and organize emergency management responses during an evacuation process.

- Traffic Operations: which requires state agencies to install adequate devices on evacuation routes, ensure routes are clear to use, and ensure infrastructure devices are well maintained and functioning.
- Traffic Information: which involves providing more detailed and accurate data to the public and improving the methods of delivering such information.

In particular, most residents would like to have more accurate traffic data from provided services to improve the existing evacuation real-time monitoring system, followed by providing educational resources to increase awareness of existing resources and how to use them.

A different and short set of questions were given to participants who did not evacuate from hurricane events to gain insights into their reasons for not evacuating. Approximately 33.6% of participants believed it was safe to stay put or felt confident in their ability to manage the situation without fleeing. A similar proportion of individuals (31.3%) reported not evacuating due to the absence of a mandatory evacuation order. The results are shown in Figure 5-26.

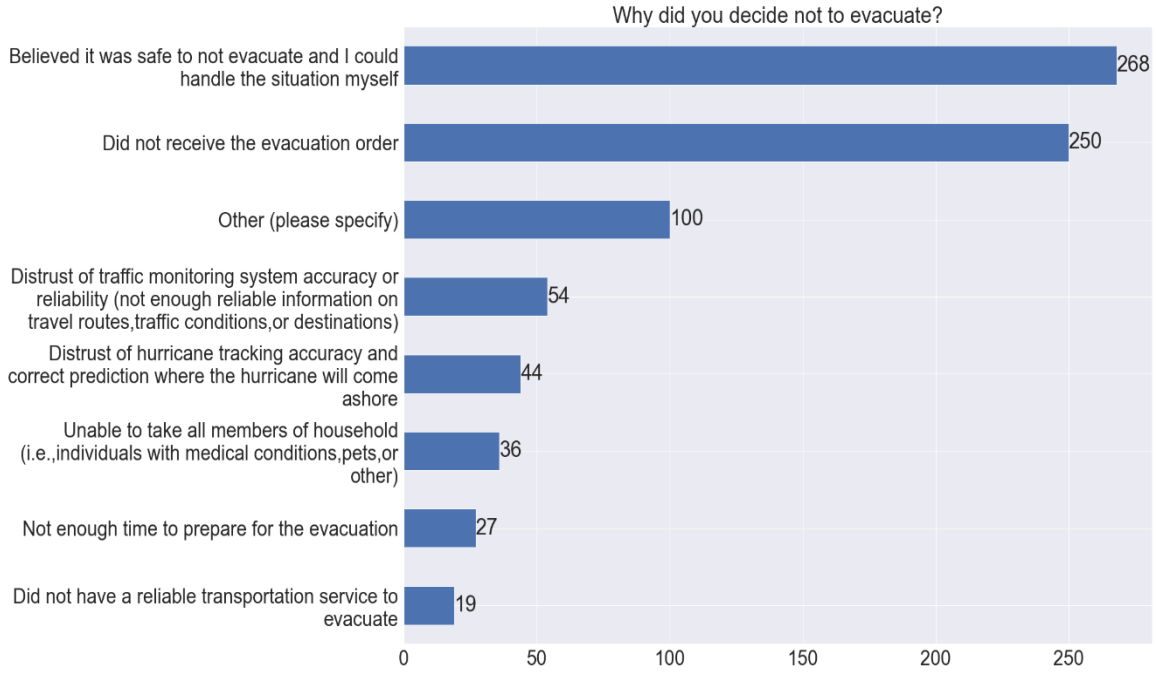

Figure 5-26. Reason(s) for choosing not to evacuate.

About 40% of the participants indicated that, if better traffic monitoring data were available, they would reconsider their decision and opt to evacuate. For those who indicated they would reconsider their evacuation decisions, the survey further inquired about the factors they believed should be addressed to enhance their likelihood of evacuating, with the aim of improving the current real-time traffic monitoring system for evacuations. The outcomes are presented in Figure 5-27. Over 80% of participants identified accessibility and ease of use of existing services, education about the current service, accuracy of the data provided by the service, and service expansion as essential factors. In contrast, only 8% of respondents chose the cost of service as a significant concern. These findings suggest that during an evacuation event, there is a strong demand for improved service quality, while evacuees appear to be less concerned about the potential costs associated with these services. By augmenting service availability and quality of real-time traffic monitoring

systems along evacuation routes, public confidence in evacuation safety and efficiency may be increased, thereby motivating more individuals to evacuate during future hurricane events.

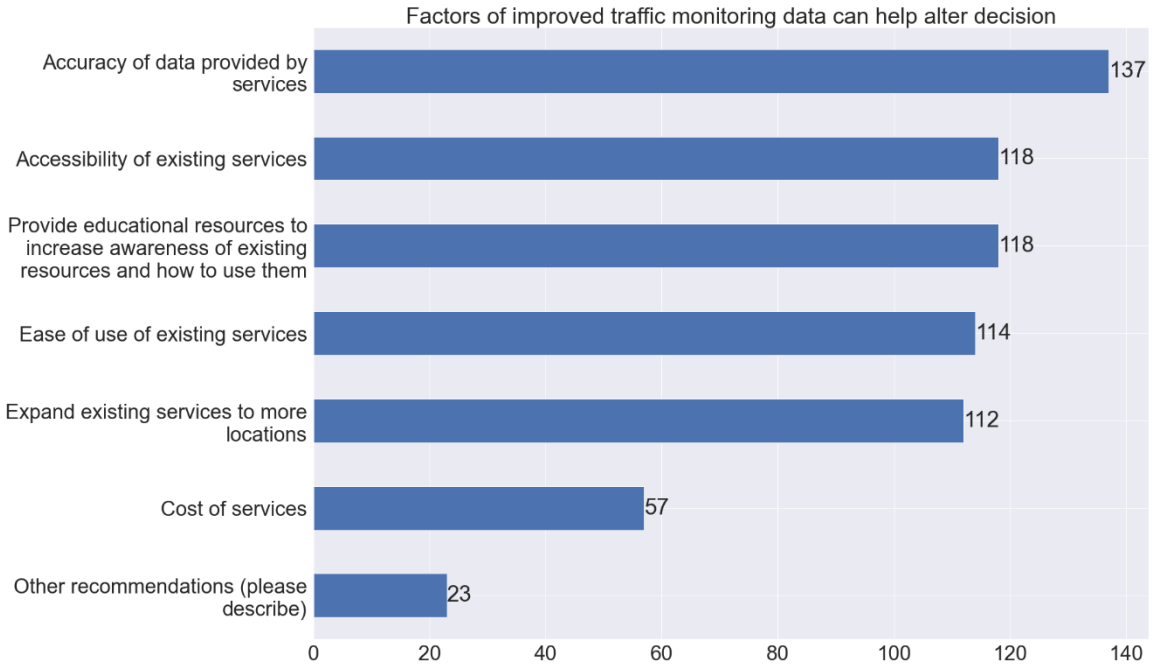

Figure 5-27. Factors with improved traffic monitoring data to help people alter evacuation decision.

5.4 Miscellaneous Comments Received

In addition to the survey responses, individuals who follow the TxDOT Nextdoor account were actively engaged with the survey post. There were 188 comments under the post, some of which were valuable to the research. A multitude of commenters shared their experience with Hurricane Rita. Many mentioned that it was not a smooth evacuation, and it took over 10 hours to get to a safe destination, where it is usually reachable within four hours during normal operation. During the evacuation, there were also issues of congestion, flooded roads, and gas scarcity. Because of these issues, many individuals decided not to

evacuate for any future evacuations as they think that evacuations are riskier than staying at home and riding out the storm. A few comments mentioned that traffic was better during voluntary evacuations. Individuals also commented that they were concerned about future hurricane evacuations as more electric vehicles on Texas roads may lead to issues if there are not enough EV charging stations installed along evacuation routes.

Chapter 6: Summary and Conclusions

With the increasing threats and challenges posed by recent hurricanes in Texas, it is crucial to understand current perceptions, common issues, and potential improvements of the real-time traffic monitoring systems within the state. Efficient roadway networks are indispensable for relocating large populations from danger zones in a timely manner. Enhanced ability to surveillant road conditions can significantly assist officials in managing evacuations. A survey was designed to examine the perceptions and preferences of Texas coastal region residents who had experienced past hurricane events, specifically regarding real-time traffic monitoring systems operating during evacuations. Thorough statistical analyses of the survey data also unveiled trends and correlations in evacuation behavior.

Over 1,300 valid responses were analyzed, with approximately 62.3% of respondents having participated in a past hurricane evacuation in Texas. The survey included numerous demographic questions for both evacuees and non-evacuees, encompassing age, household size, gender, race, education, income, and housing arrangements at time of a hurricane event. A basic binary logit model was employed to examine the potential relationship between individuals' decision-making process and their demographic characteristics. The findings indicated that the propensity to evacuate increased for individuals under 54 years old, with larger household sizes, annual incomes above $50,000, and who identified themselves as female, white, and homeowners. This may imply that vulnerable road users and underserved communities may pose challenges to evacuate due to limited access to information and not enough resources to support evacuation. Although the majority of the demographic distribution corresponded to the

general population, certain aspects may have been biased due to the survey's distribution methods.

The study also investigated the temporal and spatial aspects of evacuations. Most individuals evacuated from counties located along the Gulf of Mexico, which are directly threatened by hurricanes. Typically, they traveled 101 to 300 miles to reach large metropolitan areas along the I-35 corridor, such as Austin, San Antonio, and the Dallas-Fort Worth region. Evacuees often stayed with family or friends, though some opted for hotel accommodation.

Real-time traffic information was often used by evacuees to determine routes, make mid-trip adjustments to routes and destinations, and monitor traffic congestion. Service availability and accessibility emerged as crucial factors influencing platform choice. While most respondents did not encounter any issues with data reliability or accuracy when using a service, issues with a lack of service, unreliable or inaccurate information, and loss of cell phone or internet service still exists for a considerable number of individuals. To improve existing real-time traffic monitoring systems, the public desires enhanced traffic information accuracy and increased awareness of available resources. Improving service availability and quality may also influence the decisions of individuals who initially chose not to evacuate.

Despite offering valuable insights, this study possesses certain limitations that could be addressed to improve its findings in future studies. The problem of recall is a common obstacle that is likely to be encountered in evacuation research. The most current hurricane event recorded in the survey was Hurricane Laura in 2020, while the majority of respondents indicated they had experience in Hurricane Rita, which occurred nearly two decades ago. As time elapses after a hurricane, respondents may not accurately remember all the details of their evacuation experience or may possess false memories. Additionally,

technological advancements, such as cellphones and the internet, were not as widespread 20 years ago, limiting the scope of services provided and individuals' access to vital information. Future surveys could focus on more recent hurricanes to obtain a more accurate representation of the issues being investigated. Additionally, demographic information obtained for this survey may result in biased relationships and an inadequate explanation of the underlying causes for each variable. To better understand the relationship between individuals' decision-making process and the availability of real-time traffic data services, the model could incorporate a wider range of variables related to the accessibility, quality, and reliability of real-time traffic information.

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