FLORIDA STATE UNIVERSITY

Assessment of Transportation Systems Resilience for Vulnerable Communities and Populations

Task #6 Deliverable: Final Report

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16. Abstract Florida Department of Transportation identified resilience as a critical priority in its Florida Transportation Plan (FTP). Resilient transportation systems are assets that can withstand disruptions, adapt to changing conditions, perform effectively, and recover rapidly. Historically, disruptions from natural hazards are more consequential, with more negative, disproportionate impacts for older adults, ethnic minority groups, and rural populations. These vulnerable populations are disproportionately represented among people failing to evacuate as well as those injured or killed during hurricanes. This project aimed to investigate and develop policy and planning recommendations for transportation systems pertaining to vulnerable populations. Vulnerable populations in this study included: (i) older adults, (ii) ethnic minority groups, and (iii) rural populations in the state of Florida. Natural hazards affecting these populations will include hurricanes and storm surges. The overall goal of this project was to provide methodologies and recommendations for FDOT to develop transportation systems resilience policy and planning guidelines to improve the outcomes for vulnerable communities and populations, especially regarding resilience to natural hazards events.			
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Executive Summary

Recently, there have been increase in the severity and frequency of natural disasters. Transportation agencies nationwide have begun to prioritize the incorporation of resilience into transportation planning. This is an essential practice given the vital role transportation systems play during and after natural hazards for mobility, emergency response, access to essential services, and the overall socioeconomic and health well-being of communities. The Florida Department of Transportation identified resilience as a critical priority in its overarching policy documents, including the Florida Transportation Plan (FTP) Vision Element and Policy Elements. A stated objective found in these documents is for the state to ensure that it has an "*agile, resilient, and quality transportation infrastructure*".

For transportation systems, to be considered resilient, they must be able to withstand disruptions from natural hazard events, adapt to changing conditions, perform effectively, and recover rapidly. Resilience, however, must also encompass the people who use and rely upon transportation systems. While state-level resilience policies tend to focus on mitigating the impact of natural hazards on physical assets (critical infrastructure and the built and natural environment), to a lesser extent they address system users, particularly socially vulnerable populations, those individuals who, for a range of socioeconomic factors, are less able to anticipate, respond to and recover from the impacts of natural hazards than the general population. This study examines transportation system resilience through the lens of these vulnerable population groups.

The goal of *Assessment of Transportation Systems Resilience for Vulnerable Communities and Populations* is to develop decision support tools for transportation systems resilience planning pertaining to vulnerable populations, as well as to provide resilience policy and planning recommendations for transportation systems in support of the goals of state-level policy plans, especially as related to vulnerable populations. Vulnerable populations in this study included older adults, ethnic minority groups, and rural populations in the state of Florida. Natural hazards affecting vulnerable populations include hurricanes and storm surges. Consistent with this goal, this project achieved five objectives, including;

Objective 1: Provide resilience policy and planning recommendations to FDOT by developing broad policy recommendations with actionable strategies as well as detailed actionable planning recommendations

Objective 2: Provide and facilitate methodologies for resilience assessment pertaining to vulnerable populations through surveys, statistical analysis, GIS mapping, and economic impact analysis

Objective 3: Advance discovery and understanding of resilience for vulnerable populations using surveys and statistical analysis.

Objective 4: Broaden FDOT outreach and diversity by providing policy, planning, and communications recommendations pertaining to underrepresented populations

Objective 5: Achieve the overarching goal of transportation equity by defining recommendations pertaining to vulnerable populations

To achieve these objectives, the project was subdivided into four main tasks, each of which included a terminal report. Key findings of each task are listed as broad outcomes outlined below:

Outcome 1: Literature Review. A comprehensive review of academic literature and planning documents was conducted. Key findings, including those listed below, helped to guide the development of subsequent research steps.

- Current resilience and emergency management planning processes identify the actions that agencies take to mitigate the impacts of natural hazards on transportation systems, but to a lesser extent, they include means to protect people, especially those belonging to vulnerable groups.
- More studies must be conducted to understand the relationships between the social vulnerability attributes and the geophysical factors that result in increased levels of vulnerabilities to natural hazards.

Outcome 2: Experts and Vulnerable Populations Surveys. Two survey instruments were developed: one targeting planning professionals working with vulnerable populations and another targeting members of socially vulnerable population groups. Relevant observations were based only on perceptions and opinions of populations and experts surveyed. These observations included, but were not limited to:

- The quality of infrastructure elements (e.g., the drainage system) is of high concern among the surveyed experts. This indicates that the transportation system has high levels of vulnerability during natural hazards.
- In both surveys, the functionality of the transportation system (i.e., provision of basic mobility) during natural hazards is an issue of high concern and should be prioritized.
- There are consistent levels of high concern about the safety of the transportation system during natural hazards (as reported by the three groups of vulnerable populations).
- The experts survey indicated that the disruptions of the transportation system due to natural hazards lead to negative social and economic impacts on vulnerable populations. This finding was further validated by the vulnerable populations survey, as the majority of the respondents reported suffering socioeconomic impacts due to transportation related issues.

Outcome 3: Assessment of Transportation Systems Resilience for Vulnerable Populations. Using the survey results as a guide, this task conducted statistical, geospatial, and economic analyses to provide insight into enhancing system resilience, including;

- Development of ranking of importance (prioritization) of resilience issues using statistical analysis of the surveys' results.
- Development of vulnerability hotspot maps to identify the locations of vulnerable populations along the I-4 corridor (the study area) using Census Tract, Social Vulnerability Index (SoVi), and Composite Index (CI) developed by the research team.
- The developed economic impact analysis supports the main hypothesis, as areas with high concentrations of vulnerable populations suffer higher impacts than other areas. These

impacts are both technical (cost damages to the roads) and social (suffered by the populations in terms of loss of employment, loss of income, loss of economic output, and loss of tax revenues).

Outcome 4: Policy and Planning Recommendations. Based on the findings of the research and with input garnered at an April 20, 2022, workshop with FDOT staff, policy and planning recommendations were developed. Some of the key highlights of those collaboratively reviewed data-driven recommendations include;

- Policy recommendations are broad in nature and are based on synthesis of all the previous project tasks outcomes. The policy recommendations also include corresponding implementation strategies. The policy recommendations include:
    a. Incorporate and integrate vulnerable populations resilience considerations across FDOT offices.
    b. Identify and prioritize multimodal transportation system improvements that enhance system's performance and reliability in vulnerable population hot spot areas.
    c. Promote community-based resilience approaches that improve transportation systems resilience for vulnerable populations.
- The planning recommendations are based on the experts and vulnerable populations survey responses, as well as statistical analysis to determine priorities of issues and concerns. The key planning recommendations are categorized and summarized as follows:
    a. Physical conditions
        i. Engage with and provide guidance to local agencies.
        ii. Prioritize finding and guidance for areas with high concentration of vulnerable populations.
        iii. Explore using technologies such as drones, sensors, and cameras to monitor conditions during and after natural hazards.
    b. System functionality
        i. Formulate evacuation guidelines specific for vulnerable populations.
        ii. Prioritize and expedite road-related restoration services for vulnerable population areas.
    c. System recovery
        i. Prioritize and expedite debris clearance after hazard in vulnerable populations areas.
        ii. Ensure adequate transportation access to post-hazard services in vulnerable population areas.
        iii. Develop or improve plans to utilize public transit services to connect vulnerable populations to essential services.
    d. Communications and outreach
        i. Streamline hazard-related communications with vulnerable populations through different media.

FDOT has a long-standing commitment to improving the resiliency of the state transportation system to support the safety, mobility, quality of life, and economic prosperity of Florida, while preserving the quality of our environment and communities. Years of extreme weather events have led FDOT to improve the system's resiliency including better preparation for storms and well as quicker recovery in the event of extreme weather. To solidify this commitment, FDOT enacted a Resiliency Policy to consider the resiliency of the State's transportation system. This study proposes building on the existing resilience policy and developing a complimentary resilience policy pertaining to vulnerable populations.

This report provides a description of these research tasks, research conclusions, recommendations for future research, and supporting appendices.

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Chapter 1: Introduction

Transportation systems have a critical role in the functioning of societies as they facilitate the mobility of users and freight, provision of essential services, and achievement of economic prosperity. However, these systems are under continuous pressure to perform with the increasing intensities and frequencies of natural and technical risks. The stress on the capital required to manage the infrastructure after the occurrence of a disruptive event calls for a shift in the traditional practices of planning and managing transportation systems. The Florida Department of Transportation (FDOT) has vision policies directed to ensure that infrastructure assets are adequate to meet the future needs of Florida's residents; this vision includes the provision of infrastructure resilience. The FDOT Policy 000-525-053, Resiliency of State Transportation Infrastructure, mandates the department to consider and incorporate resiliency into their business practices. As per the policy, resiliency must be implemented throughout FDOT's long-range and modal plans, work program, and asset management plans (i.e., Florida Transportation Plan, and Transportation and Asset Management Plan)[1]. Current resilience practices focus on mitigating the impacts of threats on the physical components of the transportation system; they rarely include guidelines to reduce the negative consequences on users of the system, especially vulnerable populations users. Existing resilience guidelines are mostly designed based on the assumption that individuals can adequately respond to and apply instructions, thereby, failing to reflect the reality that a considerable percentage of the population can be deemed vulnerable to disasters due to their existing demographic and social conditions. As Florida is the state with the highest percentage of older population nationally and has large number of minority residents, FDOT needs to enhance considerations for the resilience of the transportation systems pertaining to the needs of vulnerable populations.

The World Health Organization defines vulnerability as: "*the degree to which populations, an individual, or an organization is unable to anticipate, cope with, resist and recover from the impacts of disasters*" (Wisner et al. 2002). The Centers for Disease Control and Prevention (CDC) define vulnerable populations as those who (1) have difficulty communicating, (2) have difficulty accessing medical care, (3) may need help maintaining independence, (4) require constant supervision, and (5) may need help accessing transportation. The aforementioned characteristics are what define vulnerable populations in the general context; however, specific guidelines are needed to identify these populations in the context of mobility, especially in case of natural hazards. It is critical to consider these aspects of vulnerability because they define the needs of the groups that require special attention in transportation planning. Understanding the interactions between the social and technical components of the transportation system, especially as pertaining to vulnerable populations, is critical for the efficient and equitable allocation of investments and resources to improve the state of resilience of the transportation system.

The socio-ecological and technical nature of transportation systems often leads to added complexities in the management of these assets. Despite this nature, current resilience practices

[1] FDOT: Resilience, https://www.fdot.gov/planning/policy/resilience/default.shtm

mainly focus on the technical (physical) aspects of resilience, such as evaluating and strengthening roadway pavements, bridges, rails, etc. The historical data shows that the disruptions of transportation-related services from natural hazards are more consequential, with more negative disproportionate impacts for a specific segment of the population, this includes older adults (those of 65 years and older), ethnic minority groups (non-white populations), and rural groups (populations living in areas classified as rurality). These groups are represented among the people who fail to evacuate, get injured or killed at higher rates, and fail to recover in a timely manner after a natural hazard event. For effective implementation of the Florida Transportation Plan's (FTP) resiliency vision, the FDOT needs to develop special planning and policy guidelines pertaining to these vulnerable populations.

To make investments decisions that lead to better transportation resilience outcomes, this project seeks to investigate, understand, model, and develop innovative solutions for risks and vulnerabilities (to natural hazards) of vulnerable populations pertaining to the transportation system. Vulnerable populations in this project are (i) older adults, (ii) ethnic minority groups, and (iii) rural populations, in the state of Florida. The natural hazards affecting vulnerable populations include hurricanes and storm surges. The overall goal of the project is to provide tools and resources for FDOT to develop transportation systems resilience policy and guidelines to improve the outcomes for vulnerable communities and populations, especially regarding resilience to natural hazard events (specifically hurricanes and storm surges). Consistent with this goal, the specific objectives of this project are:

Objective 1: Provide resilience policy and planning recommendations – Develop and provide resilience policy recommendations pertaining to transportation systems to satisfy FTP Vision and Policy resilience objectives specifically, as related to vulnerable population groups.

Objective 2: Provide and facilitate tools for transportation systems resilience assessment – Develop and provide transportation systems decision support tools pertaining to vulnerable populations to improve their socioeconomic wellbeing outcomes.

Objective 3: Advance discovery and understanding – Advance the knowledge base in the area of transportation systems resilience for vulnerable populations with concomitant promotion of research, education, and training in collaboration with FDOT and appropriate local agencies.

Objective 4: Broaden FDOT outreach and diversity – Broaden FDOT outreach and diversity programs and initiatives by catering for and participation of underrepresented vulnerable groups (through surveys) and improving information dissemination and communication with vulnerable population before, during, and after natural hazards.

Objective 5: Achieve the overarching goal of transportation equity – Assist in FDOT efforts to achieve transportation equity by improving outcomes for vulnerable communities and populations through policy and planning guidelines and recommendations and future implementation.

To achieve the five objectives, the project was divided into four main tasks:

Task 1: Literature Review: Understanding transportation system resilience considerations for vulnerable populations.

Task 2: Surveys: Understanding the special resilience needs of vulnerable populations.

Task 3: Assessment of Transportation Systems Resilience: Assessing the current transportation systems capabilities in meeting the special needs of vulnerable populations.

Task 4: Policy and Planning Recommendations: Developing policy and planning guidelines to bridge the gap between the system capabilities and the vulnerable populations' needs.

The first task involves a comprehensive literature review that aims to (1) identify the social vulnerability characteristics that create mobility vulnerability, and (2) identify current resilience practices and outline their shortcomings in addressing the vulnerabilities of the focus groups of the project. The knowledge gathered from the literature review reveals that in the context of mobility, there needs to be a deep consideration of the complex problems related to the issues of residence, resilience, and resources availability for communities to determine the population groups that can be deemed as vulnerable (Stanton & Duran-Stanton, 2019). These groups may differ from those defined by using the existing social vulnerability indices, such as the Social Vulnerability Index (SoVI) (Cutter et al. 2003). For effective resilience planning practices, agencies should place special emphasis on understanding the issues of residence, resilience, and resources availability, and evaluate how these issues impact the current resilience practices and determine if there needs to be a special resilience plan to deal with the needs of special vulnerable groups. The results of the literature review also show that there is an uncertainty of how to incorporate resilience into the planning process, especially as it relates to the vulnerable groups. This was found to be, largely, a conceptual problem, as planners direct too much effort into measuring the resilience in a phase-related manner (usually around hazard events; immediately before, during, and immediately after), this results in fragmented thinking about resilience, and results in practices that are as effective as the predictive capacity of future events (Wall et al. 2015). With the deep uncertainties in future challenges, such as climate change, such planning methods are becoming less effective in preserving infrastructure assets against natural hazards.

The second task involves the deployment of surveys to understand the perception of the transportation system's users (the three vulnerable population groups) about the current state of the system performance. The survey was launched to understand the experiences and concerns of Florida's residents about the performance of transportation systems during natural hazards (mainly hurricanes/tropical storms, and flooding). These concerns were used to determine the special mobility needs of vulnerable populations. The perceptions of experts about the current state of the transportation system's resilience in Florida were gathered through a survey designed to understand the practitioners' experiences, perceptions, and concerns about the performance of the system (including the practices of the agencies and the stakeholders involved in the management practices) during the identified natural hazards. The findings of the surveys are beneficial to transportation planners as they highlight some of the major concerns related to functionality (system's capacity in providing basic mobility) and the serviceability (system's capacity in providing safe mobility and meeting the socioeconomic needs of the users it serves). The results of the task provide insights to achieve the FDOT's statewide objectives by enhancing incorporating the needs and priorities of vulnerable populations in the analysis of transportation system resilience.

The third task involves conducting statistical analyses on the surveys' results to determine and prioritize the resilience requirements of the transportation system in Florida. The analyses results were used to evaluate the current state of system performance to provide a reference point from which efforts can be directed towards improving the overall system's resilience. A hierarchical system-performance evaluation framework was developed based on this evaluation, and users' needs, and concerns were utilized as performance-measures to allow agencies to evaluate the system's resilience for the needs of vulnerable populations. The literature review showed that the issue of mobility-related vulnerability is a complex issue with no clear indicators to evaluate the degree of this vulnerability. Therefore, it was critical to validate the hypothesis of the research − age, ethnic minority, and rurality are the three main characteristics that derive mobility-vulnerability for individuals and/or groups − and provide more insight into mobility-related vulnerability. The third task involves geographic analysis, based on the mobility-vulnerability characteristics, to determine the locations of the vulnerable in the I-4 corridor in central Florida ((Hillsborough, Lake, Orange, Osceola, Pinellas, Polk, Seminole, Volusia counties); this analysis was used as a platform to conduct an economic impacts analysis and prove that the three determined groups (and the areas in which they are highly concentrated) disproportionately suffer more impacts than other segments of the society. The analysis also highlighted the gaps in the literature and highlighted potential future opportunities for mobility-related vulnerability research and resilience planning.

Based on the information gathered from the first three tasks, task four focused on developing proposed planning and policy recommendations pertaining to vulnerable communities and populations for consideration by the FDOT to be integrated in the FTP and other FDOT plans. The policy recommendations are developed to incorporate and integrate the vulnerable populations' resilience considerations into the transportation planning and decision-making process. Broad policy recommendations, along with their respective implementation strategies, were developed to assist the FDOT in making better investment decisions to improve the system resilience to meet the needs of vulnerable populations. The planning recommendations were developed to target the specific transportation system issues pertaining to the specific needs of vulnerable populations (determined in the second task). The planning recommendations are categorized into four categories: (1) Physical conditions, (2) System functionality, (3) System recovery, and (4) Communication and outreach. These recommendations tie back to the broader resiliency objectives of the FTP, specifically: Complete transportation networks, transform major elements, identify and mitigate risks, expand transportation infrastructure, update statewide emergency evacuation plans, and define strategies for preparing/responding to transportation threats.

Chapter 2: Transportation Systems Resilience for Vulnerable Populations

In order to efficiently improve the resilience of the transportation system and understand the attributes that contribute to its vulnerabilities, it is important to first understand the socioeconomic factors that lead to the increased level of risks among different segments of the society. An extensive literature review was conducted to gather information on two fronts: (1) the social vulnerability characteristics that create mobility vulnerability, (2) identify the current resilience practices and outline their shortcomings in addressing the vulnerabilities of the focus groups of the study.

To achieve the two objectives, the research team examined peer-reviewed journal papers and conference papers, transportation planning and engineering handbooks, as well as relevant project reports from transportation agencies across the United States. The team queried various online databases and search engines such as: ScienceDirect, Google Scholar, Wiley Online Library, TRIS, TRID, Springer Nature, and NTIS. The covered literature discussed various concepts critical to the scope of the project, such as the concepts of social vulnerabilities, transportation system vulnerabilities, communities' resilience, transportation system resilience, current resilience planning approaches, and shortcomings in current resilience practices. Several keywords were used to cover a wide range of materials, these keywords included, but were not limited to, the following: *transportation resilience, engineering resilience, ecological resilience*, *adaptive resilience*, *transportation vulnerabilities, social vulnerabilities, social vulnerability index, communities' resilience, resilience to natural disasters, resilience planning,* and *resilience policies*.

The literature review was a two-phased task. The first phase focused on answering the following question: *what defines social vulnerabilities? What are the characteristics that define vulnerability in the context of mobility (especially in the events of hurricanes and tropical storms)?* The information provided in this phase highlights the main issues that need to be studied more extensively in order to effectively evaluate the mobility-related vulnerabilities in specific groups and communities. The second phase focused on answering the following question: *how is the concept of resilience deployed in transportation systems management, and what are the shortcomings of the current practices in addressing the needs of vulnerable populations?* The information gathered through this phase highlights the gaps that needs to be filled in order to improve the state of resilience practices within any agency to meet the specific needs of vulnerable populations.

2.1 Vulnerability and Socially Vulnerable Groups

The World Health Organization defines vulnerability as: "the degree to which population, an individual or an organization is unable to anticipate, cope with, resist and recover from the impact of disasters" (Wisner et al., 2002). According to the Centers for Disease Control and Prevention

(CDC), vulnerable populations are the following: (1) have difficulty communicating, (2) difficulty accessing medical care (3) may need help maintaining independence, (4) require constant supervision, and (5) may need help accessing transportation. The aforementioned characteristics are what define vulnerable populations for medical professionals, specifically for healthcare analysis purposes; however, they are less efficient in evaluating the mobility-related vulnerability of populations, especially in the context of natural hazards. To understand what defines mobility-related vulnerability, it is essential to look at social vulnerability beyond the concepts of hazards and risks – and expand the consideration to include complex problems related to the issues of residence, resilience, and the resources available for the community (Stanton & Duran-Stanton, 2019) . Each of these factors influences the vulnerability of an individual or a group in a number of ways. Considerations should be given to these factors when there are attempts to determine vulnerable populations in the context of mobility, especially those who suffer more negative consequences due to natural hazards.

2.1.1 Residence

According to Stanton and Duran-Stanton (2019), when conducting spatial analysis to visualize the distribution of vulnerable populations across a specific region, residence can be considered in two ways: as a habitat, and as a state of power. The consideration of residence as a habitat –the physical location where someone resides– entails the following variables:

- The physical and environmental hazards specific to the location.
- The quality of infrastructure present in the location and the level of service it provides, especially during hazards, as well as other services that define the level of community's preparedness.
- The differential access to the resources available in the area under consideration (city, county, state, etc.).

These variables (when considered individually and collectively) result in different distributions of vulnerable groups. The vulnerabilities to, along with the probabilities of occurrence of, geophysical risks (such as hurricanes and floods) will show different variations of vulnerable groups across the state. Thereby, the variables used for vulnerability analysis make a difference, and can yield considerably different results. This finding is also supported by Chakraborty et al. (2005) who combined various geophysical risks and social vulnerability indicators to determine the spatial distribution of vulnerability levels in Hillsborough County, Florida. Depending on the measures selected for the analysis, between 4% and 15% of the population of the county were considered in highly vulnerable areas. The considerable length (the absolute value) of this interval (11%) reflects the importance of the appropriate selections of variables used to determine the levels of vulnerabilities.

The second consideration of residence, the state of power, is usually linked to the post-hazard planning considerations. For instance, someone may reside in the United States physically but lacks legal status, resulting in increased difficulties in accessing the appropriate needed resources, such as healthcare and disaster relief benefits, when a hazard occurs; rendering them more vulnerable than their counterparts who do have the exact same geophysical and social circumstances but do not face this particular challenge. Moreover, there is also the vulnerability to cognitive and semiotic factors linked to social inequalities, as well as psychological and emotional factors of not having a support network to cope with stresses after hazards.

2.1.2 Resilience

Resilience in this context is taken as a construct that denotes to the capability of individuals to respond to problems through a hierarchy of response mechanisms. Resilience here, as discussed by Stanton and Duran-Stanton (2019), is taken as one of the attributes of vulnerability – which is the overall measure of the level of exposure to hazardous conditions. The resilience of a person or a group in this context is measured on their abilities to own or manage a number of attributes that facilitate their response to hazards (Buckle, 2006). Examples of such attributes are: efficient use of information and advice from emergency communications, efficient use of resources, and the individual's own management capacity. The lack of this resilience in a group would increase their level of vulnerability, even if the other attributes are similar (e.g., a person with college degree is less vulnerable than an illiterate person, even if they have the exact amount of resources, due to the former's ability in utilizing the available information to mitigate the impacts of risks). It is worth mentioning that the use of term 'resilience' here slightly differs than the concepts that will be discussed later on this document, the terminology examined here is directly linked to the concept of vulnerability, and it was necessary to report it in this chapter to highlight the fact that there are attributes unique to the individual (or the population group) that result in increased levels of vulnerability but are not related to the geophysical threats or the availability of resources.

2.1.3 Resources

In many frameworks, accessibility to resources is an attribute that indicates the level of social resilience of a society; however, some academic opinions argue that the resources attribute should be kept separate because it can be considered as a unique measure for the level of social vulnerability which is different than the measures discussed in the resilience subsection above (which are related to the ability of an individual/group to respond to hazards, and not the preexisting conditions that lead to increased levels of exposure). This distinction stems from the fact that, unlike the preexisting conditions, the accessibility of resources can be managed to reduce the level vulnerability.

The three aforementioned attributes, along with a number of pre-existing conditions (Table 1). contribute to the levels of social vulnerabilities of a society. Vulnerability is not a static trait, it changes with time depending on factors such as the level of community preparedness and allocated resources, it also changes with location as there are substantial differences in how the same hazard affects urban and rural communities. Therefore, there is a need to address the issue of vulnerability in a way that conceptualizes the unique and compounding vulnerabilities of a specific community and enable capacity building processes (Jurjonas & Seekamp, 2018). These compounding vulnerabilities include the preexisting social conditions and the attributes of residence, resilience, and the available resources. The need is for a framework that approaches vulnerability as a continuous spectrum and reflects an understanding of the risks threatening the livelihood of the community, as well as their future development.

There have been various efforts by researchers to provide frameworks to determine social vulnerabilities (see for example: Adger, 2006; Barnett et al., 2008; Cutter et al., 2003; Webster, 2014; and Wisner et al., 2002). The definitions found in the literature depend on the context of the study, but are related, nevertheless, in some sense. The underlying element of all definitions is the increased level of exposure to risks and threats. Therefore, the metrics that measure the level of social vulnerability are the characteristics and circumstances that result in the disproportionate exposures of individuals and groups to risks. These characteristics are shown in Figure 1.

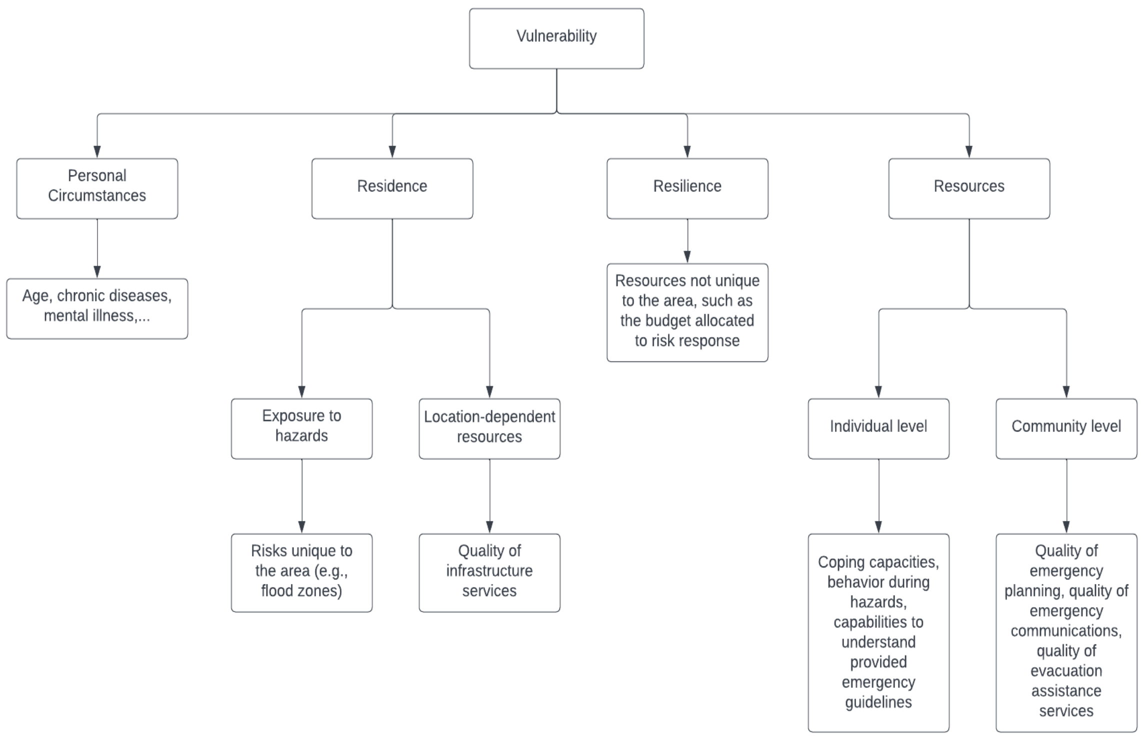


Figure 1. Social Vulnerability Characteristics

All the social vulnerability definitions found in the literature share the following common ground: vulnerability is a metric that measures the potential losses from an adverse event and their severity. There are many available categorizations for the metrics used in measuring social vulnerabilities. Some efforts include providing named groups (e.g., aged population, physically disabled, mentally challenged, etc.) to determine who is considered vulnerable, while others provide a list of circumstances and social factors that contribute to the level of vulnerability.

Measuring social vulnerability is challenging because even in a close proximity in a community, an individual or a group can have any or all of the above attributes, increasing their level of vulnerability when compared to others. Therefore, it is crucial to carefully analyze these attributes to provide the appropriate mechanisms for the development of risk management strategies that target the needs of these specific individuals or groups. Evidence from the literature shows that the existence of these attributes together does not always amplify the level of vulnerability for the community (Miller et al. 1999; Saegert, 1989). While these considerations suggest additional attention, the studies indicate a need to account for the possibility that the same attribute can act to exacerbate or ameliorate the levels of vulnerability based on the relationships with the environmental and hazard characteristics (Paton & Johnston, 2001).

The results of the literature review suggest the fact that the contextual nature of social vulnerability imposes a challenge to developing a robust framework, and that the complexities associated with the concept result in different sets of indicators across the research community. Studying the attributes and estimating the social vulnerabilities of subpopulations have the potential of helping agencies and policy makers in optimizing the resources used in disaster management, and the research team suggest that the recommendations provided in this report are merely support tools, not a strict measuring tool by which the exact level of exposure of the socially vulnerable groups can be determined. Table 1 summarizes the main attributes that leads to enhanced levels of exposure to risks and threats. These attributes are relevant to measure vulnerability in the context of mobility; therefore, it is useful for transportation agencies to study these attributes and utilize them in assessing the level of vulnerability to natural hazards in their respective areas.

It is important to underline that the concepts of vulnerabilities and social vulnerabilities are complex, and their meanings slightly differ among researchers and stakeholders. Therefore, it is somewhat difficult to find empirical evidence for social vulnerability and establish viable measures for determining social vulnerability (Cutter & Finch, 2008). The lack of consensus on what social vulnerability means may result in uncertainty for agencies' resilience planning (in the scope of this project the social (mobility-related) vulnerability is derived by age, ethnic minority, and rurality). While we acknowledge the complexity of providing a definite framework for social vulnerability, we provide a 2-step approach recommended by Paton and Johnston (2001) that can aid in providing resilience and emergency plans that account for the needs of vulnerable populations:

1. Identify the social vulnerability factors relative to the context: vulnerability or resilience) is not an inherent characteristic of a particular individual or a group. It is a context-specific concept (dependent on both time and space) that should be treated as such. The recommendation is that a list of hazards should be available (hazards unique to the area under consideration) and then the social vulnerability attributes that increase the level of exposure of populations to that set of hazards can be selected to determine the populations that require special attention.

2. Define the relationships between the social factors identified and the hazard effects: since vulnerability is time-dependent, it is important to understand the interrelationships between the social factors and the effects of hazards. The literature indicates that vulnerabilities exist based on pre-incident circumstances, but there are also special types of vulnerabilities experienced after a disaster. Understanding when each attribute is most crucial along a timeline of before, during, and after a disaster is important because it can tell us which groups require special attention during what times. A framework of such nature was constructed by Martin (2015) and implemented in the city of Boston and is believed that it has the potential to improve the emergency planning process.

Table 1. Social vulnerability attributes, vulnerable groups, and related circumstances

Attribute(s)	Vulnerable Group(s)	Circumstance(s) - Mobility Attributes
Age	Young children. Senior citizens.	Less mobile. Dependent. Need help accessing transportation
Physical, mental, cognitive and emotional status	Disabled. Suffering from chronic physical and/or mental illness. Socially isolated. Individuals with limited coping capacities.	Less mobile. Have difficulties communicating. Dependent. Require constant supervision. Need help accessing transportation. May depend on technology-based life support.
Culture, ethnicity, language, religion, citizenship, and other socioeconomic statuses	The poor (or low-income individuals). Minority groups. Migrants. Socially marginalized. Socially isolated. Low-literacy and illiterate individuals. Non-English speakers.	Scarcity of resources. Have difficulties communicating. Need help accessing transportation.

Finally, Social vulnerability assessment is closely related to the concept of 'place.' The social vulnerability hazards-of-place model established by Cutter (1996), sets the significance of the place in the assessment. Modern GIS-based spatial vulnerability analysis is a very useful tool in vulnerability assessment that follows the hazards-of-place model approach. GIS-based social vulnerability analysis is becoming more and more diversified and is expanding in scope, leading to efforts to examine the spatial relationships between social vulnerability and broader hazard risks. GIS-based assessment offers a valuable tool to evaluate social vulnerability. Appendix A summarizes case studies to identify GIS-based assessment, its implications, and limitations.

2.2 Resilience in Transportation Systems

2.2.1 The Concept of Resilience

To this date, there is not a widely agreed upon definition for the concept of resilience. Resilience in infrastructure systems is viewed as a multidimensional concept, and in many infrastructure-related implementations, the concept is defined as the ability of a system to prepare for, absorb, recover from, and adapt to disturbances (Linkov et al., 2014). The concept has its roots in many scientific areas, including physics and mathematics, where it refers to the ability of a system or a material to recover its shape following a displacement or disturbance (Norris et al., 2008) . The concept can be traced back to the field of ecology where it was defined as the capacity of an ecosystem to absorb shocks and keep functioning (Folke, 2006; Walker et al., 2004) . A number of subsequent applications has emerged in many fields, including the built environment, where resiliency has been defined as the ability of a system to react to tremors, shocks, and catastrophes (Linkov et al., 2014). Some other definitions of resiliency as found in the literature include the following (Wakemann et al., 2017):

- The capacity of the system to function in spite of external drivers (both shocks and directed change)
- The capacity to sustain a shock, recover, and continue to function and, more generally, cope with change
- The ability of a system to absorb disturbance and still retain its basic function and structure
- The ability of households, communities, and nations to absorb and recover from shocks, while positively adapting and transforming their structures and means for living in the face of long-term stresses, change, and uncertainty

Despite the lack of unified definition, the concept always revolves around two main ideas: ‘absorbing the shocks’ and ‘bouncing back or recovering’ after a shock or disturbance has taken place. The issue with identifying resilience is not associated with the lack of a unified definition, but rather originates from the lack of clear measures that can help the decision makers in knowing the degree or level of resilience of their assets. Often times, stakeholders do not know how resilient their system or asset is until an adverse event takes place. To address this issue, part of the literature suggests that when studying the resilience of a system (or a component of a system), three main themes should be analyzed: (1) the ability to absorb or resist a shock with the aim of enhancing this ability, (2) maintaining an acceptable performance level during adverse events and working to increase the adaptability of a system, and (3) reducing the recovery time after adverse events while working to improve the performance level from its pre-disaster state (Weilant et al., 2019). Norris et al. (2008) states that the three themes translate into three capacities at the community level which are essential to achieve community resilience: (1) Absorptive Capacity, (2) Adaptive Capacity, and (3) Restorative Capacity. These capacities are the core of many conceptual frameworks found in the literature to identify the resilience level of a community.

One of the misconceptions arises from the confusion between what a resilient system and a stable system are. Therefore, it is equally important to know what resilience is not to be able to effectively measure it (Wakemann et al., 2017). Meadows, a leader in systems thinking, was clear in defining what resilience is not in her book "Thinking in Systems: A Primer (Norris et al., 2008)":

"Resilience is not the same as stability, which we can define here as relative consistency over time. Resilient systems can be very unstable. Short-term oscillations, or periodic outbreaks, or long cycles of succession, climax, and collapse may in fact be the normal unstable condition, which resilience acts to restore!

And conversely stable systems can be un-resilient. The distinction between stability and resilience is important, because stability is something you can see; it's the measurable variation in the condition of a system week-by-week or year-by-year.

There are limits to resilience.

Resilience is something that may be very hard to see, unless you exceed it, and the system breaks down. Because resilience is not obvious without a whole-system view, people sacrifice resilience for stability, or for productivity, or for some other more immediately recognized system property."

As stated by (Wakemann et al., 2017), this distinction is of particular interest to transportation professionals. Resilience, unlike stability, is difficult to capture in equations and quantities. Many factors are involved in measuring resiliency, and by not considering all factors a simple answer may be found but may not be beneficial for the entire system. Furthermore, the system is constantly changing as it responds to feedback, internally and externally, thus taking a singular perspective in the pursuit of a complex problem may result in counterintuitive outcomes.

2.2.2 Resilience in Transportation Systems

The importance of a robust and reliable transportation system to the economic vitality and the social wellbeing of a society has resulted in a considerable amount of research to understand what creates the vulnerabilities of transportation systems to find practical ways to enhance their robustness and resilience, as well as to mitigate the impacts of any disturbances and disruptions.

Similar to the general concept of resilience, there are no commonly accepted definitions of transportation systems vulnerability and resilience. The definition provided by Berdica (2002) is often cited and representative of part of the literature: "*Vulnerability in the road transportation system is a susceptibility to incidents that can result in considerable reductions in road network serviceability*." This definition is valid for other modes of transportation (Mattsson & Jenelius, 2015). The definition, in its core, emphasizes that the vulnerability of the system stems from the likelihood of a disruptive event that has the potential to negatively impact the performance of the system and its ability to provide its intended services to users. Thereby, the concept of vulnerability is associated with the idea of a potential risk. As noted Mattsson and Jenelius (2015), risk in this context can be perceived in accordance with Kaplan and Garrick (1981) who suggest that risk analysis should answer the questions of: What can happen? How likely is it to happen? What are the consequences? for every conceivable risk scenario. Establishing clear guidelines based on these questions is crucial for effective risk management and resilience planning processes.

There are different kinds of disruptions to transportation systems, different kinds of disruptions may require different tools of analysis and different courses of actions. Therefore, to understand the vulnerabilities of transportation systems, understanding of the different kinds of adverse events is required. The disruptions can generally be categorized into internal and external disruptions or threats. Internal threats are those associated with mistakes and/or accidents caused by staff or users, as well as technical and structural failures of one or more of the system's components. The external threats, on the other hand, are those associated with natural phenomenon such as storms, hurricanes, tornadoes, and floods, etc. External threats also include deliberate sabotage and antagonistic actions such terrorist attacks and acts of war (Mattsson & Jenelius, 2015). While all of these events result in different disruptions in the performance and the service provided by the system, and they all ultimately contribute to the vulnerability of the transportation system, making a clear distinction between them is essential in order to define what makes the resilience of the system as whole. In light of these points, we find that it is not important to establish a strictly worded definition for the term 'resilience' as it is to understand its meaning and its relevance to the transportation community. In fact, the definition of resilience varies across transportation entities, but it mostly reflects the ability to adapt to, recover from, and respond to a variety of threats to the physical infrastructure (Weilant *et al.*, 2019). The Federal Highway Administration defines resilience in its Order 5520 as: "the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions" (U.S. Department of Transportation, FHWA, 2014). Many State DOTs have similar definitions for the concept of resilience; thus, the focus should be on how to address the three resilience capacities (absorptive, adaptive and restorative) in the context of pre-defined hazards, rather than focusing on defining the word itself.

Providing a resilient infrastructure is one of the seven goals of The Florida Transportation Plan (FTP). The vision is to provide: Agile, Resilient and Quality Transportation Infrastructure. The question guiding the vision is "how do we prepare our transportation system for, and recover from, weather, environmental, economic, and operational disruptions?". In this context, planning is focusing on the following:

- Extreme weather events.
- Emergency evacuation and emergency response.
- Sea level rise and flooding.
- Economic and societal changes.

The connection between the concept of resilience in the covered literature, and the concept in the FTP is apparent. In terms of the vulnerabilities, the plan is focused on the external threats (i.e. natural phenomenon and adverse weather), while also including the impacts of climate change, which is a specific long-term threat that is considered to be in-between the internal and external threats because it is partially a consequence of human activities in the transport sector (Koetse &

Rietveld, 2009). Again, clearly determining these vulnerabilities is crucial for establishing effective performance and resilience metrics for the network at the end of the project. The justification for this is found in the literature presented by Ganin et al. (2017) who argue that the concepts of 'resilience' and 'efficiency', despite often being used interchangeably in some of the literature, are not correlated and they should be considered as complementary characteristics for roadway networks. The characteristic differences between the two concepts stem from the nature of the disturbances. Efficiency is often associated with the performance of urban transportation systems under normal conditions; it is usually measured with quantitative metrics such as the average annual delay per peak hours. Resilience, on the other hand, is usually operationalized through the change of performance relative to stresses. Ganin et al. (2017) also states that there are differences in the characteristics of resilience of different urban areas, and these differences are persistent at different levels of stresses. Therefore, the consideration of different vulnerabilities allows for a clear distinction between the two concepts.

There is substantial literature on transportation systems vulnerability. An overview of the research efforts in identifying the vulnerability and resilience of transportation systems is provided by Mattsson & Jenelius (2015): There are two distinct traditions in identifying the vulnerabilities of a transportation system. The first tradition is characterized as 'topological vulnerability analysis of transport networks' and the second one is known as 'system-based vulnerability analysis of transport networks. The two distinctions have limited interactions and they both have their unique strengths and weaknesses. The topological vulnerability analysis is based on the concept of the graph theory, where a transport network is considered to be a connected network (G) and its features are represented as nodes and links (e.g. in urban road networks the intersections are most commonly represented as nodes while the street segments are represented as links), then a natural efficiency indicator would be used to represent the vulnerability of the network (most commonly the efficiency is the average distance between node pairs which represents the shortest distance among possible routes in the network).

The main advantage of the topological approach is that it requires few data, as well as it is very simple to model. This simplicity allows the stakeholder to simulate different vulnerability scenarios by removing nodes or links randomly or according to a modeled attack strategy or threat possibility. The performance of the network after the removal of links/nodes is then evaluated (often times as the change in the network efficiency; the average of the reciprocals of the shortest distance between pairs of nodes). There are also alternative performance indicators associated with this method. The straightforwardness and the limited need for data of the method make it realistic to study the performance of transport networks under the successive removal of nodes/links, making it possible for the modeler to test different vulnerability scenarios based on the perceived risk. Another benefit is that this method allows for comparisons of different transport networks (real or theoretical), comparing different scenarios would allow the decision makers to test the effectiveness of different resilience policies that are already in place.

Despite the apparent advantages of this method, the simplistic modeling of the transport system as an abstract network does not provide a realistic representation of the behavioral responses of the users to different disturbances and threats. In reality consequences of threats depend on their duration, the number of individuals impacted by the threat and their coping capacities, as well as the emergency management in place. With the topological modeling, it is not possible to capture the dynamic effects associated with threats (the increased congestion on detour routes, the behavior and responses of individuals, etc.) as the method implicitly assumes that all segments of the network continue to function normally after the disturbance (i.e., removal of links/nodes). This shortcoming makes the method too simplistic to be useful in assessing actual policy actions in a specific transport system.

The second approach, the system-based transport vulnerability analysis, represents more features of the structure of the real transport network via the use of demand and supply models in the analysis process. The network is still represented as an abstract network (graph), but it is usually weighted with link weights that represent the actual lengths, travel times, costs or combinations of these. Moreover, the supply-demand interactions are simulated using comprehensive transport system models (Cascetta, 2009). In this method, travel demand is usually modeled in terms of trip generation, destination choice and mode choice. Route choice may also be modeled taking the congestion and delays into account. This somewhat sophisticated modeling can overcome the shortcomings of the topological modeling but comes at a price of requiring much more data and calibrated behavioral models, meaning that the methodology is less uniform and depends on the case under investigation, and what can be studied depends on the availability of data and appropriate models. Nevertheless, compared to the topological modeling, the system-based modeling allows for more intuitive impact measures, and allows the modeler to capture more consequences of threats.

Vulnerability analysis tells us primarily about what to expect (the potential risks and their possible consequences). Resilience, on the other hand, is a socio-technical perspective that focuses on how the knowledge gained from the vulnerability analysis (anticipating ability) must interact with monitoring (what to look for), responding (what to do) and learning (what happened) abilities in order to provide a more resilient system (Mattsson & Jeneilus, 2015). There is a lack of literature on the specific topic of Transportation Systems Resilience and Disaster Management, and most of the available literature focuses on the pre-disaster phase of mitigating and preparing for a threat. The covered literature highlights some of the shortcomings of the current resilience planning approaches; the following section discusses some of the major criticism that has the potential to improve the resilience practice in the sector.

2.2.3 A Critique of Current Resilience Practices

As discussed by MacKinnon, D. in his critique of current resilience policies, the main issue with the current resilience planning practices is that they privilege existing social relations. The core of this problem is that the concept of urban resilience is an extension of the ecological resilience thinking to the social sphere. Cities are conceived as social-ecological systems in which biophysical and social factors are linked by multiple feedback loops which share common characteristics of resilience and complexity (Folke, 2006). The product of this thinking is to view cities as self-contained systems and stripping them from the wider determinants of urban form such as the flow of capital and modes of state regulations (Gandy, 2002; 8). Since resilience is fundamentally about maintaining the function of an existing system in the face of disruptions, this way of resilience thinking results in prevalence of social divisions and inequalities. Ecological models of resilience are fundamentally anti-political, when these models are extended to society, existing social networks and relations are taken as ‘natural’ and harmonious. Swanstorm (2008: 16) argues that the privileging of existing social networks makes the ecological models ‘profoundly conservative’ when imported into social contexts. This conservatism results in an inability of disadvantaged groups and communities to access the levers of social change; thus, this direction of resilience thinking creates a problem of resource distribution and strips the concept from the recognition of a resourceful community (MacKinnon, D., 2012).

Chapter 3: The Surveys

3.1 Methodology

The first step in developing policy and planning recommendations to improve the resilience of transportation systems for vulnerable populations was characterizing the current state of system performance and evaluating its capacity of meeting the needs of the populations. To do this, two surveys were deployed with the following objectives:

(i) Three vulnerable populations (VP) surveys (age group, minority group, and rural group) were deployed to capture the perception of the transportation system's users about the performance of the system. The surveys intended to capture the experiences and concerns of the three vulnerable groups in Florida about the performance of the transportation system during natural hazards (mainly hurricanes and storm surges).

(ii) Experts surveys were deployed to understand the perceptions of transportation professionals about the current state of transportation system's resilience in Florida. The surveys intended to understand the practitioners' experiences, perceptions, and concerns about the performance of the system, including the management practices of an agency.

The survey instruments were developed to better understand the ramifications that natural hazards may have on vulnerable populations due to the adequacy of the transportation system. The surveys were similarly structured, and consisted of four main sections:

1. Previous Disaster Experiences
2. Mobility and Resilience
3. Economic Impacts
4. Social Impacts

The expert group was selected based on their professional expertise within organizations that focus on vulnerable populations relevant to the study, including directors of senior organizations, directors of Black and Hispanic organizations, emergency managers, Title IV coordinators at different FDOT offices, and planners from different offices across the state of Florida. The three population groups were sampled based on the vulnerability characteristics set by the research hypothesis. The three characteristics that define mobility-related vulnerability are:

1. Age (those of 65 years of age or older)
2. Ethnic and racial minorities (non-white populations)
3. Rural populations

In collaboration with FDOT staff, the surveys were deployed in a study area roughly corresponding with the I-4 corridor. To ensure that the rural populations were adequately sampled, the study area included counties in the East Central Florida Regional Planning Council, the Central Florida Regional Planning Council, and the Tampa Bay Regional Planning Council.

Description of the sections of the surveys and the survey questions are presented in Appendix B.

3.2 The Experts Survey

3.2.1 Target Group

A total of 79 potential respondents were identified to take the survey. The selection of respondents was based on their professional expertise within select organizations or roles within affinity groups related to vulnerable populations and the geographic scope of the services offered. The four main areas of focus were Affinity Groups, Emergency Management, Agencies, and Planning Groups. Table 2 below specifies the organizations represented within each group.

Table 2. List of specific organizations targeted for the Experts survey

Type of Organization	Specific Organizations Identified
Affinity Groups	Senior Resource Alliance, Senior Connection Center, Hispanic Chamber of Commerce, National Association for the Advancement of Colored People (NAACP), Council on Aging of Volusia.
Emergency Management	FDOT Central Office, County Emergency Management Offices for Brevard, Citrus, DeSoto, Hardee, Herndando, Highlands, Hillsborough, Lake, Okeechobee, Orange, Osceoloa, Pasco, Pinellas, Polk, Seminole, Sumter, and Volusia.
Agencies	Title VI Coordinators at FDOT Central office, FDOT district offices, Central Florida Regional Planning Council, Pinellas MPO, Heartland Regional TPO, Hillsborough MPO, Lake Sumter MPO, MetroPlan Orlando, Pasco County MPO, Polk TPO, River to Sea TPO, Sarasota Manatee MPO, Space Coast TPO.
Planning	Tampa Bay RPC, Central Florida RPC, City of Tampa, City of Lakeland, City of Plant City, City of Davenport, City of Kissimmee, City of Sanford, Orange City, City of DeLand, City of Daytona Beach, Hillsborough County, Polk County, Osceola County, Orange County, Seminole County and Volusia County and County Board of Commissioners for DeSoto, Hardee, Highlands, Okeechobee.

3.2.2 Survey Administration

The Qualtrics online survey platform was used to manage the survey. The survey was initially distributed on January 15, 2021. The survey was concluded March 31, 2021. The survey administration timeline is outlined in Table 3.

Table 3. The outline of the key activities in the rollout plan of the Experts survey

Date	Step
November 15 – January 14 2021	Survey design and preparation
January 15, 2021	Initial survey deployment
March 31, 2021	Survey closed.

3.2.3 Survey Results

In this subsection, a summary of the results of the six survey sections will be presented.

<u>Response Rate:</u>

Out of the 79 individuals that received the survey, 40 individuals participated and completed the survey, resulting in a response rate of 51%. Table 4 represents the breakdown of the response rate by professional grouping. The highest level of response came from the 'Emergency Management Group'. The lowest response rate corresponds to the 'Planning Group' as shown in the table.

Table 4. Survey response rate by professional grouping.

Type of Organization	**Affinity Group**	**Emergency Management**	**Agency**	**Planning**	**Total**
Target Respondents	10	23	24	22	79
Responses Received	5	15	14	6	40
Response Rate	50%	65.22%	58.33%	27.27%	50.63%

<u>Respondent Data:</u>

In terms of occupation, 35% of respondents identified their professional backgrounds as part of the 'Other' group, reporting backgrounds other than engineering, emergency management, and public administration. The second largest group were individuals with planning backgrounds, 32.5% of the total respondents.

In terms of years of experience, 35% of the respondents reported having work experience of 15 - 24 years in their respective fields, while 27.5% reported having experience of 25 years or more. The other 37.5% were as follows: 17.5% reported having experience of less than 5 years, 10% reported having an experience of 5 - 9 years, and 10% reported having an experience of 10 - 14 years.

The respondent pool reflects a high level of specialization within all areas of interest (see Table 5). In the context of transportation systems and their related issues, the results show that almost two-thirds of the respondents deal with transportation issues (either frequently, or as their primary focus), and more than half of the respondents have transportation infrastructure-related duties, as well as resilience and/or hazard mitigation duties. In the context of working with vulnerable populations, 41% of respondents reported that they work frequently with vulnerable populations, while 35.9% reported that this area is their primary focus. Figure 2 shows the distribution of occupational specialization in key areas among the respondents.

Table 5. Degree of occupational specialization with respect to the survey four interest areas

Specialization	Degree of Involvement			
	Not at all	Somewhat	Frequently	Primary Focus
Transportation Infrastructure	15.8%	31.6%	36.8%	15.8%
Transportation Issues	10.5%	23.7%	31.6%	34.2%
Resilience and/or Hazard Mitigation	15.4%	30.8%	38.5%	15.4%
Vulnerable Populations	5.1%	18%	41%	35.9%

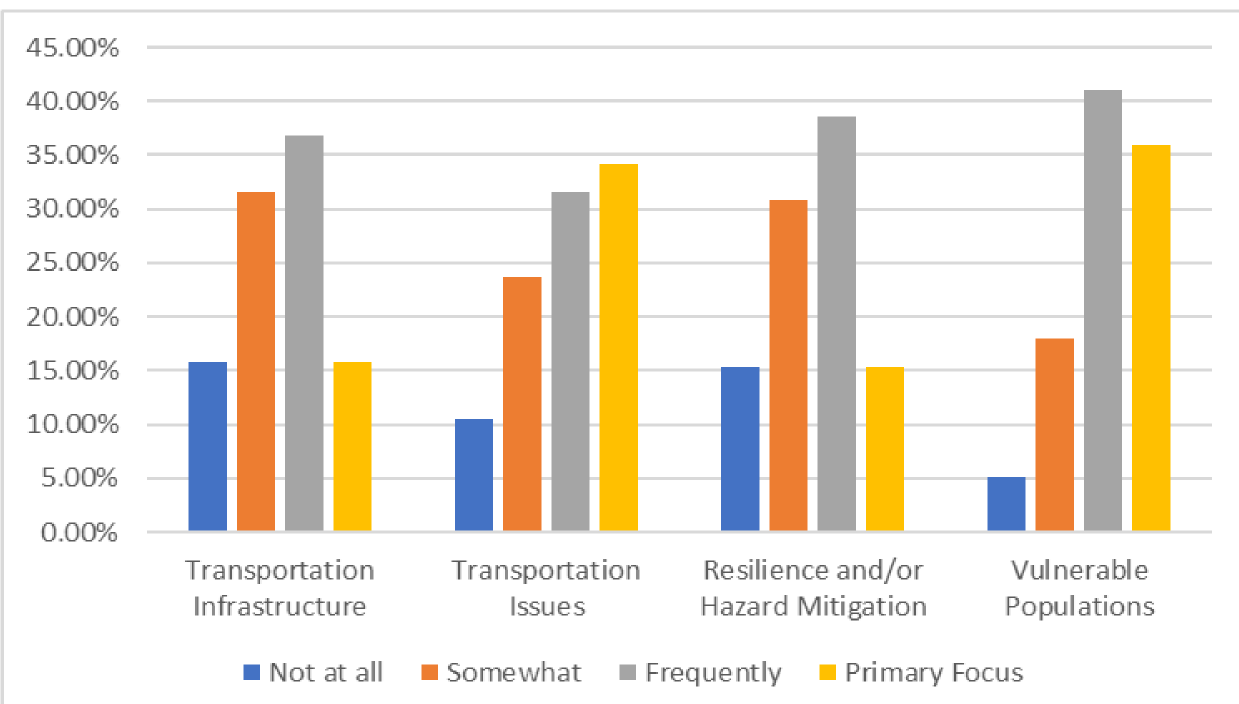


Figure 2. Degree of occupational specialization in key areas

Moreover, respondents indicated working with a wide-cross section of vulnerable populations. The different types of vulnerable populations served by the professionals were distributed as follows: racial or ethnic minorities (20.0%), people who speak English as a second language (17.4%), people with disabilities (17%), populations older than 65 years (16.8%), people with no access to vehicles (15.8%) and rural populations (11.0%). Figure 3 summarizes the breakdown of these percentages.

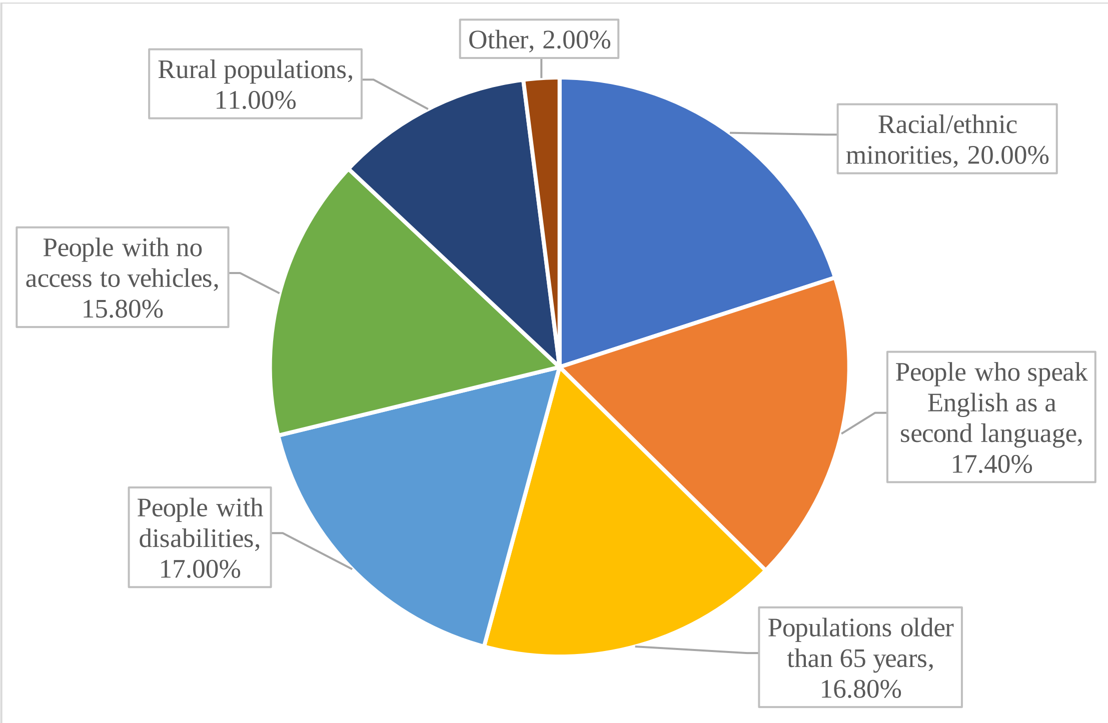


Figure 3. Composition of vulnerable populations served by experts

<u>Previous Disaster Experiences:</u>

Of the respondents, 60% resided in Florida for 25 years or more and almost three-quarters of the experts have worked on natural-hazard events and related issues in Florida. The top three natural hazards personally experienced by the respondents coincided with the top three natural hazards experienced by them in a professional capacity. Table 6 represents the percentage of experts who experienced specific natural hazards (in both personal and professional capacity). Figures 4, 5 and 6 summarize the results of this section.

Table 6. Percentage of respondents who experienced specific natural hazards

Rank	Natural hazard	Percentage of respondents	
		Personal	**Professional**
1	Hurricane	23.49%	22.22%
2	Severe weather	21.08%	17.65%
3	Flooding	16.87%	16.34%
4	Tornado	13.86%	11.11%
5	Wildfire	8.43%	8.50%
6	Coastal erosion	7.83%	8.50%
7	Sinkholes	6.02%	7.84%
8	Other	1.81%	3.92%
9	None	0.60%	3.92%

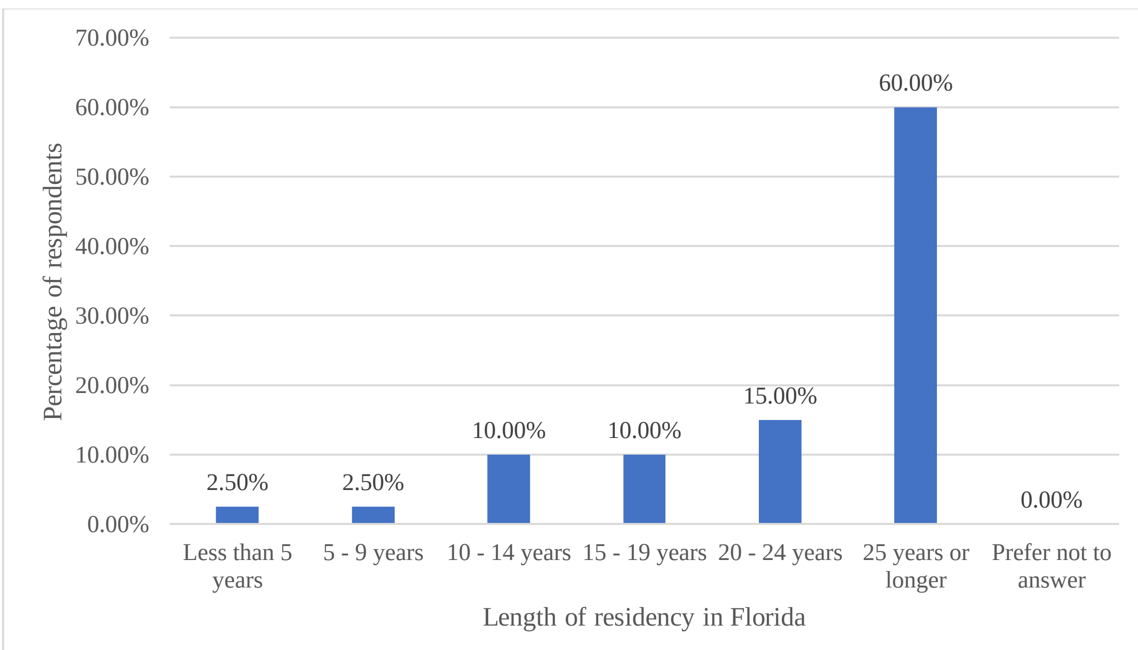


Figure 4. Length of residency in Florida

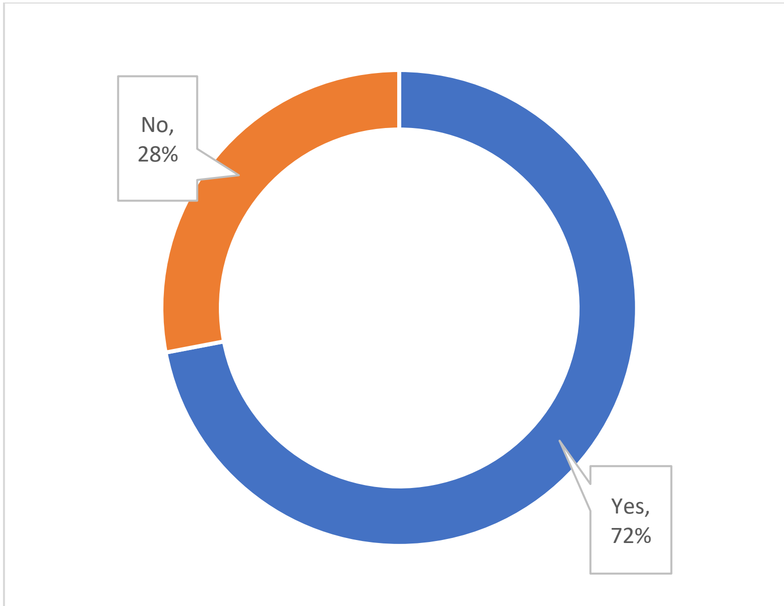
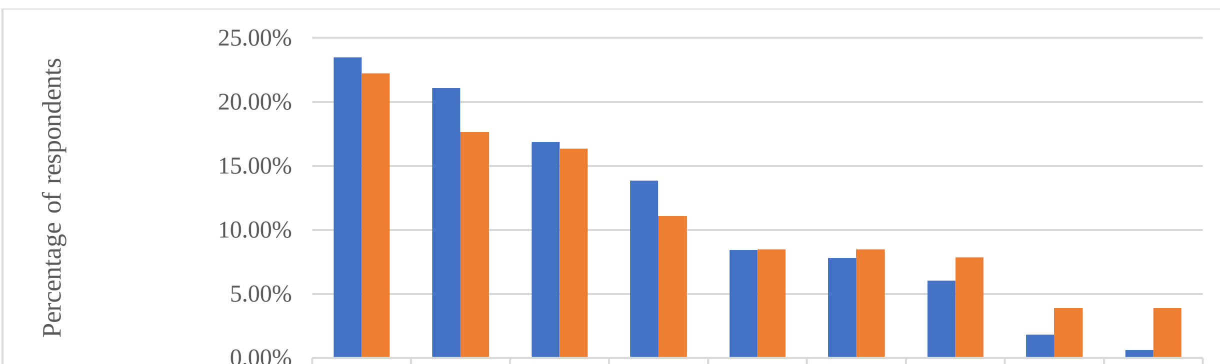


Figure 5. Share of respondents who have work experience related to natural hazard events in Florida



	Hurricane	Severe weather	Flooding	Tornado	Wildfire	Coastal errosion	Sinkholes	Other	None
Personal Experience	23.49%	21.08%	16.87%	13.86%	8.43%	7.83%	6.02%	1.81%	0.60%
Professional Experience	22.22%	17.65%	16.34%	11.11%	8.50%	8.50%	7.84%	3.92%	3.92%

Figure 6. Percentage of respondents who experienced specific natural hazards

Mobility and Resilience:

This section of the survey was designed to understand the perceptions of experts on the performance and health of transportation infrastructure during natural hazards, as well as assessing the level of concern for the serviceability of the system. Additionally, this section was developed to gain insight on how the needs of vulnerable populations are being addressed within specific organizations. With regards to the vulnerability of the system, the experts indicated that drainage-related issues are of highest concern, followed by power/communication related issues, and then the condition of local roads. Table 7 and Figure 7 summarizes the level of concern (reported on a scale from 0 to 5, with 5 being the maximum level of concern) for the main elements of the transportation infrastructure during natural hazards (in descending order).

Table 7. Levels of concerns for infrastructure elements vulnerability to natural hazards

Rank	Transportation Infrastructure Element	Level of concern
1	Drainage	4.19
2	Power/communications	4.13
3	Local roads	4.09
4	Public shelters	3.78
5	Federal and/or state highway system	3.56
6	Medical facilities	3.55
7	Bridges	3.44
8	Critical emergency response facilities	3.21
9	Ports/airports	2.72
10	Rail	2.47

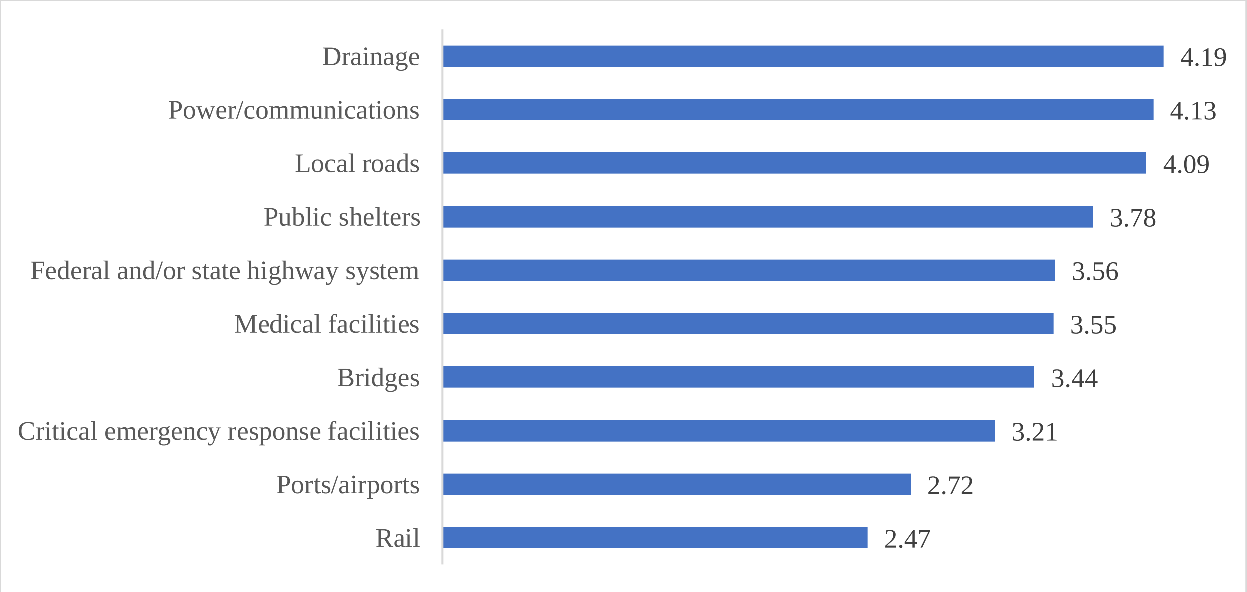


Figure 7. Levels of concerns for infrastructure elements vulnerability to natural hazards

With regards to the concerns related to the serviceability of transportation systems during hazards, the experts reported that fuel accessibility issues are of highest concern, followed by evacuation concerns, and temporary road closures. Table 8 and Figure 8 summarize the findings in descending order.

Table 8. Levels of concerns for infrastructure issues with the context of residents' needs

Rank	Transportation Infrastructure Element	Level of concern
1	Fuel accessibility	4.03
2	Evacuation	4
3	Temporary road closures	3.91
4	Disruption to public transportation	3.75
5	Long-term road closures	3.75
6	Re-entry	3.56
7	Lack of service at airports or ports	2.83
8	Long term disruption to airports or ports	2.74

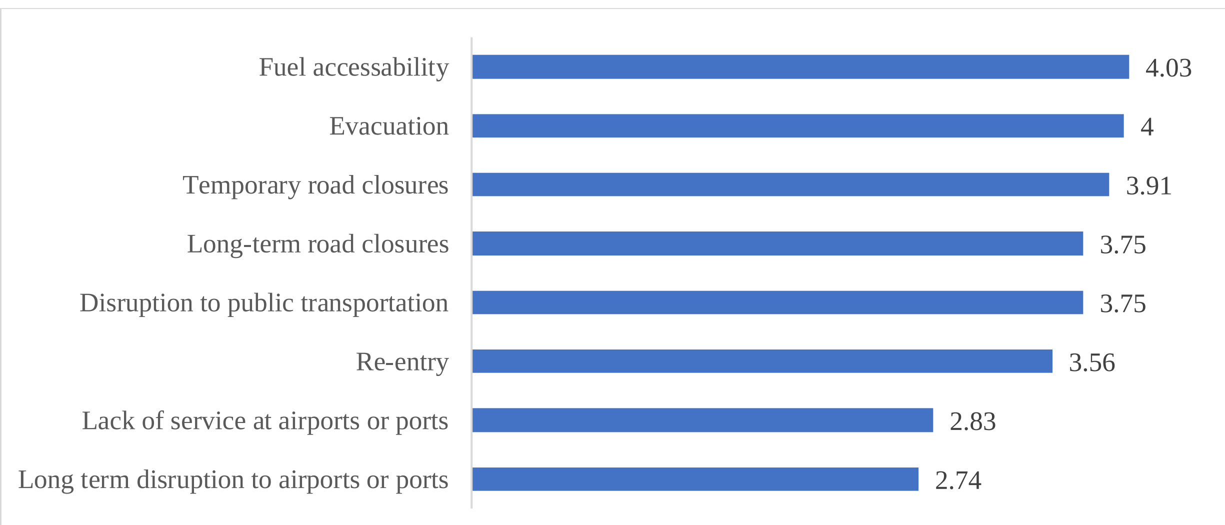


Figure 8. Levels of concerns for infrastructure issues with the context of residents' needs

In terms of monitoring and addressing the needs of vulnerable populations, 62.5% of respondents indicated that their organizations had plans and/or measures in place to address issues outside of the context of natural disasters (see Table 9). Similarly, 60% of the respondents stated that additional measures were in place to monitor and address the resilience needs of vulnerable populations. Furthermore, these plans addressed the following issues: evacuation (32%), re-entry (21%), post-disaster access to medical services and amenities (26%) and special subsidies for public transit (14%). Figure 9 summarizes the breakdown of the specific issues addressed in different organizations' plans.

Table 9. Share of respondents whose organizations have plans and measures in place to monitor and address selected issues

Organizations with plans and measures in place to monitor	Yes	No	No Response
Access needs of special or vulnerable populations outside the context of a natural disaster	62.5%	22.5%	22.5%
The resilience needs of vulnerable populations	22.5%	22.5%	22.5%

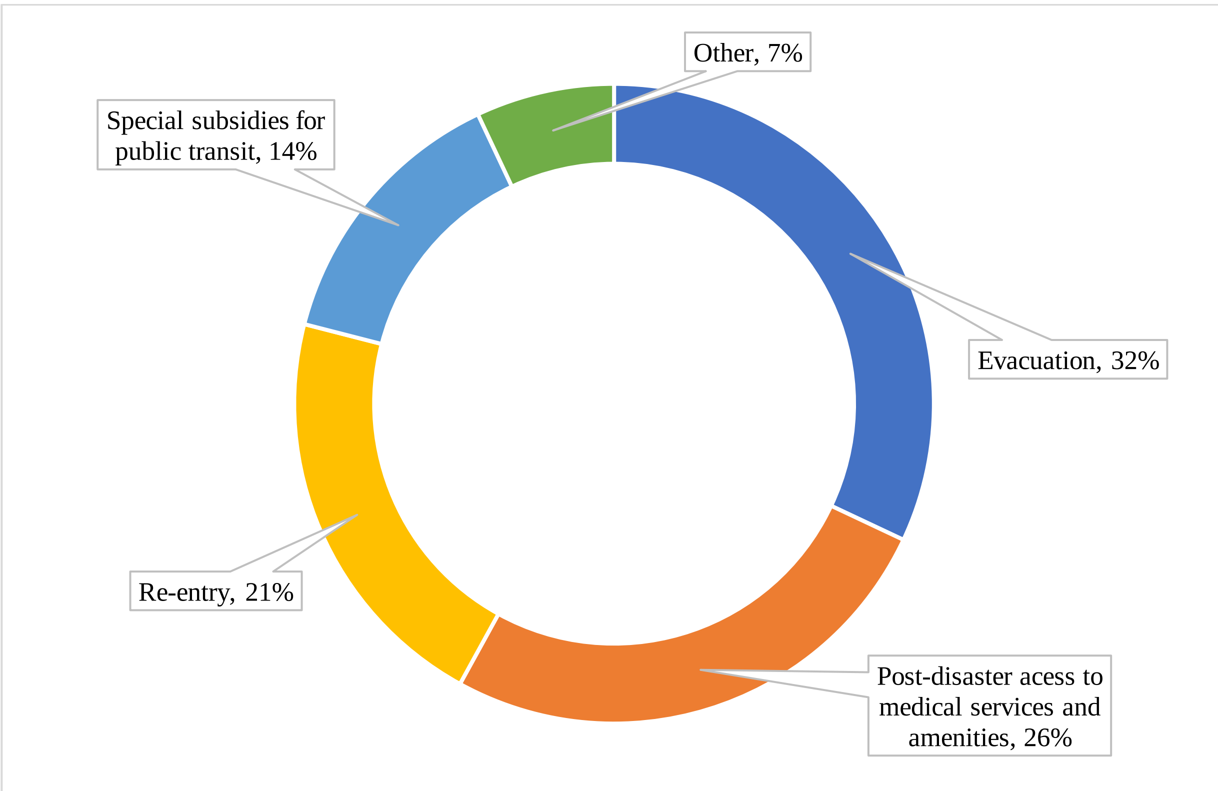


Figure 9. Categories of issues addressed in different organizations' plans

Economic Impacts:

In terms of monitoring economic impact, 50% of the respondents indicated that their organization has plans or measures in place to monitor and address hazard-related economic needs of vulnerable populations. Of the remaining respondents, 25% indicated that no such plans or measures were in place, while 25% did not respond.

At the group summary level, high concerns (a mean score of 3.9 in a scale of 1 (no concern) to 5 (highest concern)) were expressed by respondents for the hazard-related economic needs of the vulnerable populations within their agency's geographic scope. Similarly, the group expressed that there was a high extent (a mean score of 4.1) to which the potential economic needs of these populations are (or could be related) to their transportation needs (Figure 10).

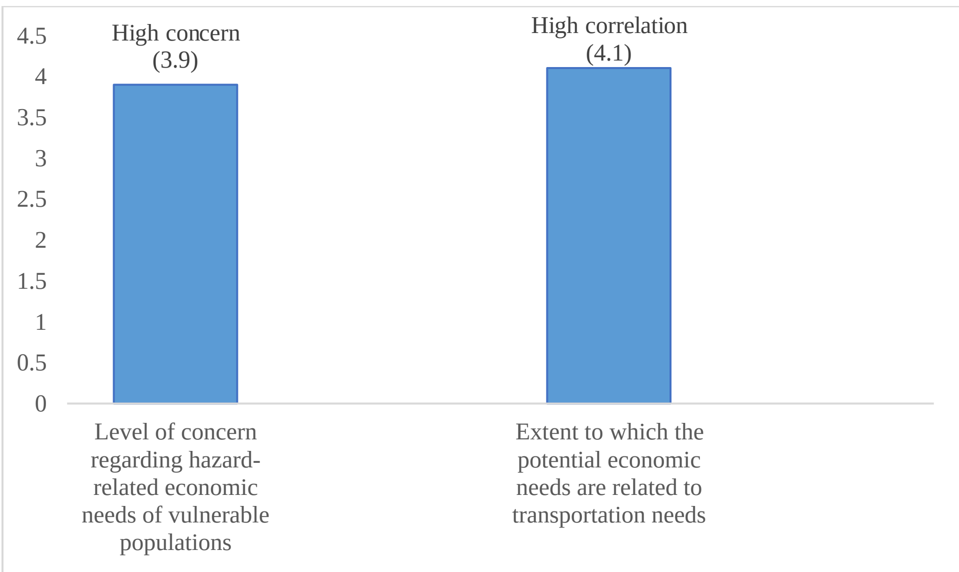


Figure 10. Relationship between the level of concern of economic needs and transportation needs

Social Impacts:

With respect to the social impacts (physical and mental health impacts, access to government services, and isolation) 37.5% of the respondents indicated that their organizations have plans or measures in place to monitor and address the hazard-related social needs of vulnerable populations within their geographic scope. Of the remaining respondents, 37.5% indicated that no such plans or measures were in place, while 10% did not respond. At the group summary level, high concern was expressed by respondents for hazard-related social impacts to vulnerable populations within their agency's geographic scope. Similarly, the group expressed there was a high extent to which the potential social impacts of this population are/or could be related to their access or transportation needs (see Figure 10).

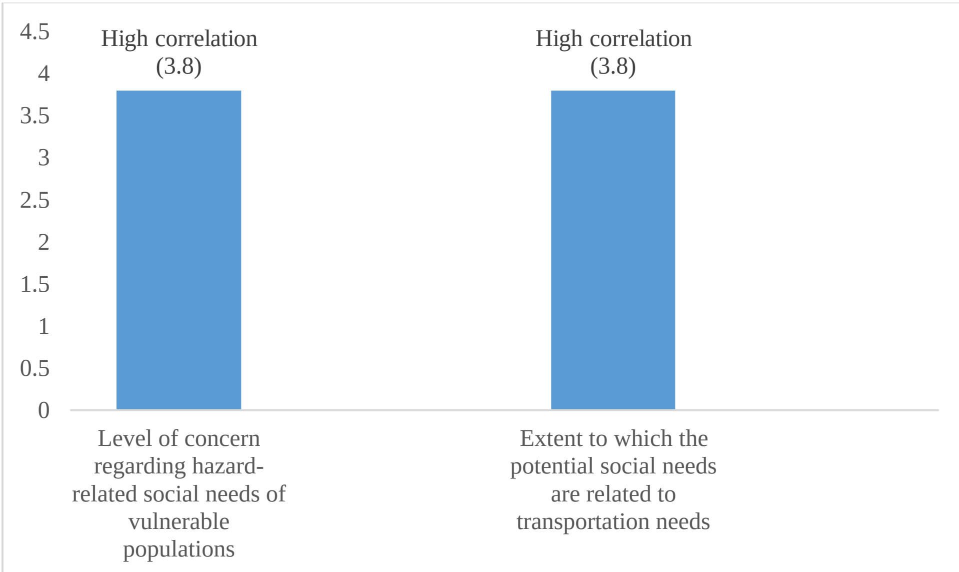


Figure 11. Relationship between the level of concern of social impacts and transportation needs

3.3 The Vulnerable Populations Survey

3.3.1 Target Group

The vulnerable population surveys were implemented to target three different groups that represent the desired characteristics of social vulnerability for the purpose of this study. The groups were as follows:

(1) All rural population respondents (irrespective of their age and/or racial and ethnic backgrounds).

(2) Age, i.e., all populations ≥ 65 years old, irrespective of socioeconomic status and/or racial/ethnic background.

(3) People who identified as racial/ethnic minorities (focusing on black and Hispanic/Latino populations).

3.3.2 Definition of Rurality in the Scope of the Project

The definition of rurality varies across agencies. The U.S. Census Bureau definition has classified Urbanized Areas (UAs) as areas populated by 50,000 or more people, and Urban Clusters (UCs) as areas populated by at least 2,500 and less than 50,000 people. Since the Census does not define 'rural' areas, rural areas have been identified as areas that are not included in the definitions of urban areas (UAs or UCs). Another definition is used by the Office of Management and Budget (OMB), which divides counties into metropolitan, micropolitan, or Neither. According to the OMB definition, a metropolitan area includes a core urban area of 50,000 inhabitants or more, and a micropolitan area contains an urban core of at least 10,000 inhabitants (but less than 50,000). All the other counties that do not meet the definition of either metropolitan or micropolitan requirements are considered 'rural' areas.

There are some measurement challenges between the two definitions. The Census Bureau overestimates rural areas, and the OMB underestimates rural areas. Filling this gap, the Federal Office of Rural Health Policy (FORHP) determines rural areas by registering all the non-metro counties as rural, via Rural-Urban Commuting Area (RUCA) codes. By doing so, the FORHP enables the identification of rural census tracts in metropolitan counties. With the 2010 Census, the FORHP definition identified 84% of the area of the U.S. as rural.

Florida statutes define rural communities with the following four criteria (s. 288.0656(2)(e), F.S.): Firstly, a county with a population of 75,000 or fewer: Secondly, a county with a population of 125,000 or fewer, which is contiguous to a county with a population of 75,000 or fewer: Thirdly, any municipality within a county as described above: Lastly, an unincorporated federal enterprise community or an incorporated rural city with a population of 25,000 or fewer and an employment base focused on traditional agricultural or resource-based industries, located in a county not defined as rural, which has at least three or more the economic distress factors as identified in Florida statutes, Section 288.0656 Paragraph (c), and verified by the Department of Economic Opportunity (DEO). Following these criteria, the Florida Department of Transportation Office of Policy Planning (FDOT OPP) provides the list of counties, municipalities, and communities that meet the state definition. Using this list, we identified rural zip codes that intersect with rural counties and municipalities as defined by FDOT OPP.

Identification of Rural Zip Codes

Using both the federal and the state definitions of rurality, the team identified the rural zip codes in Florida, using the definition of rurality provided by FDOT OPP and the FORHP. The FORHP's zip code files were produced based on the Census Bureau files, and the Census Bureau's 2018 American Community Survey (ASC) Zip Code Geography was used to find the rural zip codes in Florida. After that, a spatial analysis was implemented to find the zip codes of the areas that intersect with the rural counties defined by the FDOT OPP. In summary, the following steps were followed to identify the rural zip codes for the study:

1. Using a spatial intersection analysis, zip code areas that intersect with rural counties from the FDOT OPP list were gathered (in the analysis, if the center of a zip code area is located within a rural county, the zip code area is defined as a rural zip code).
2. Zip codes of municipalities located in rural counties (as defined by the FDOP OPP) were gathered.
3. Zip codes of rural areas in Florida were gathered from the FORHP lists.
4. The obtained zip codes from steps 1,2, and 3 were combined.

As a result, 201 rural zip codes (refer to the end of Appendix B2 for the complete lists of rural zip codes) and 807 urban zip codes were identified in total. Rural zip codes identified are shown in

Figure 12. The left side of Figure 12 shows the locations of rural areas in Florida, while the right side of the figure shows the area along the Interstate 4 (which is the study area of the project).

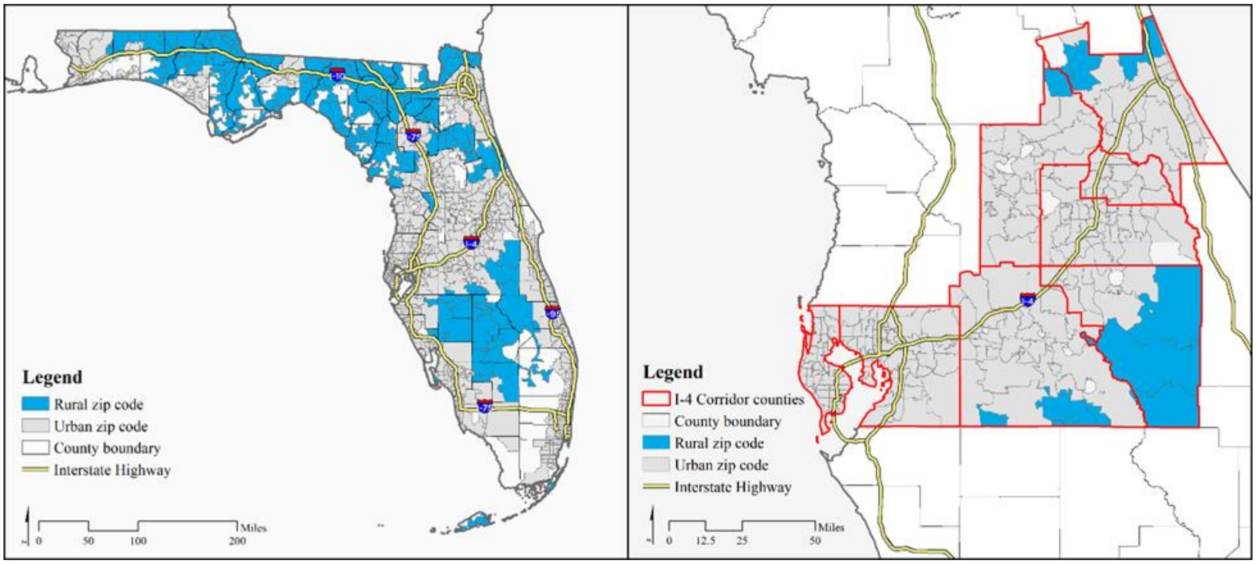


Figure 12. Rural Zip Codes in Florida

3.3.3 Survey Administration

The Pollfish survey platform was used to manage the vulnerable populations' surveys. Pollfish is a platform that allows a researcher to target respondents by specifying potential respondents' locations, and socioeconomic and/or demographic characteristics. To deploy the surveys through Pollfish, the three surveys used different filters to target the following groups:

- The age survey targeted older populations (those of 65 years of age, or older).
- The minority survey targeted the racial/ethnic minority groups (i.e., Black, Hispanic, Asian, and Multiracial groups).
- The rural survey targeted people who live in areas identified as rural (section 3.2.2 above) based on zip codes (out of the 201 identified rural zip codes, the Pollfish platform accepted only 185).

The surveys were deployed in April 2021. Table 10 summarizes the timeline of the execution of the three surveys.

Table 10. The timeline of the execution of the vulnerable populations' survey

Date	Survey executed
April 15 - April 18, 2021	The Age survey
April 23 - April 24, 2021	The Minority Group survey
April 20 - April 28, 2021	The Rural survey

3.3.4 Survey Results

Response Rate:

The total number of targeted respondents was 630. The three surveys were executed independently, leading to duplicate respondents in some of the surveys. After eliminating the duplicates, a total of 608 unique samples were collected, giving an overall response rate of 96.51%.

Location Data & The Demographics:

Each of the 608 unique respondents belonged to one of the targeted vulnerable population groups. The following summarizes the percentage of respondents based on their socio-demographics characteristics:

- The age group (65 years and older) made up 38% of the total respondents.
- The racial/ethnic minorities (non-white population) were 39.5% of the total respondents, while the black and Hispanic populations (focus of the minorities group) are 31.1% of the total respondents.
- The rural populations (those who identified their living conditions as rural within the rural zip codes initially identified) made up 18.3% of the total respondents.

Tables 11, 12, 13 summarize the percentage of respondents based on the three main targeted groups.

Table 11. Percentages of respondents based on age

Socio-demographic characteristic	Category	Percentage of respondents
Age group	Under 18	2.00%
	18 - 29	16.40%
	30 - 45	16.10%
	45 - 64	29.40%
	65 - 74	8.60%
	75 years and older	28.30%

Table 12. Percentages of respondents based on the rurality of the area

Socio-demographic characteristic	Category	Percentage of respondents
Area development	Urban	28.30%
	Suburban	50.50%
	Rural	18.30%

Table 13. Percentages of respondents based on their race/ethnicity

Socio-demographic characteristic	Category	Percentage of respondents
Race/Ethnicity	White	58.70%
	Black	17.60%
	Hispanic	13.50%
	Asian	4.60%
	Native American	0.50%
	Pacific Islander	0.20%
	Some other race	0.30%
	Two or more races	3.80%
	Prefer not to say	0.8%

In terms of the level of education of the respondents (62.8%) obtained a bachelor's degree or completed a higher level of education, while 37.2% of respondents had completed a high school education only. Figure 13 shows the percentage of respondents corresponding to each level of education in the survey.

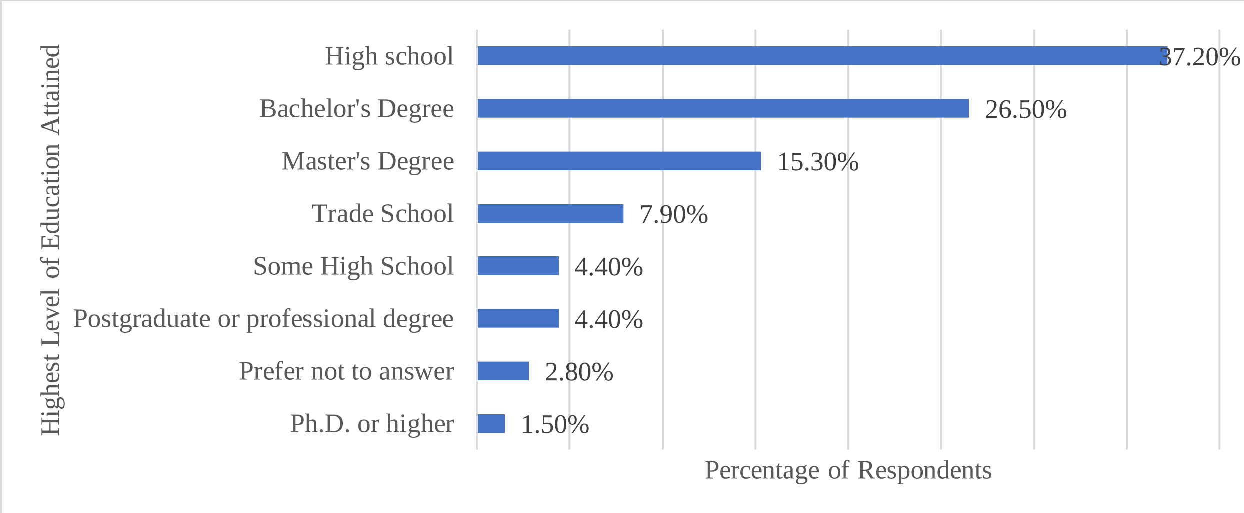


Figure 13. Percentage of respondents corresponding to specific levels of educations

Previous Disaster Experiences:

Of the respondents, 40% resided in Florida for 25 years or more. Overall, 75.7% of respondents have experienced a natural hazard while living in Florida. Among the different types of natural hazards listed in the survey, hurricanes were the most experienced, accounting for 33.6% of the total experiences. Table 14 summarizes the list of natural hazards and the overall percentages of experiences. The vulnerable populations were also asked to indicate their major concerns during hazardous events (reported on a scale of 1 to 5, with 5 being their highest concern). The results show that the issue of highest concern was the personal safety of the respondent and their family, followed by 'utilities' concerns. Table 15 summarizes respondents' concerns and the level of concern (in a descending order). Figures 14, 15, 16, and 17 summarize the results of this section.

Table 14. Percentage of respondents who experienced specific natural hazards

Rank	Natural hazard	Percentage of respondents
1	Hurricane	33.60%
2	Severe weather	27.90%
3	Flooding	14.00%
4	Tornado	10.50%
5	Wildfire	6.40%
6	Coastal erosion	4.10%
7	Sinkholes	3.40%
8	Other	0.20%

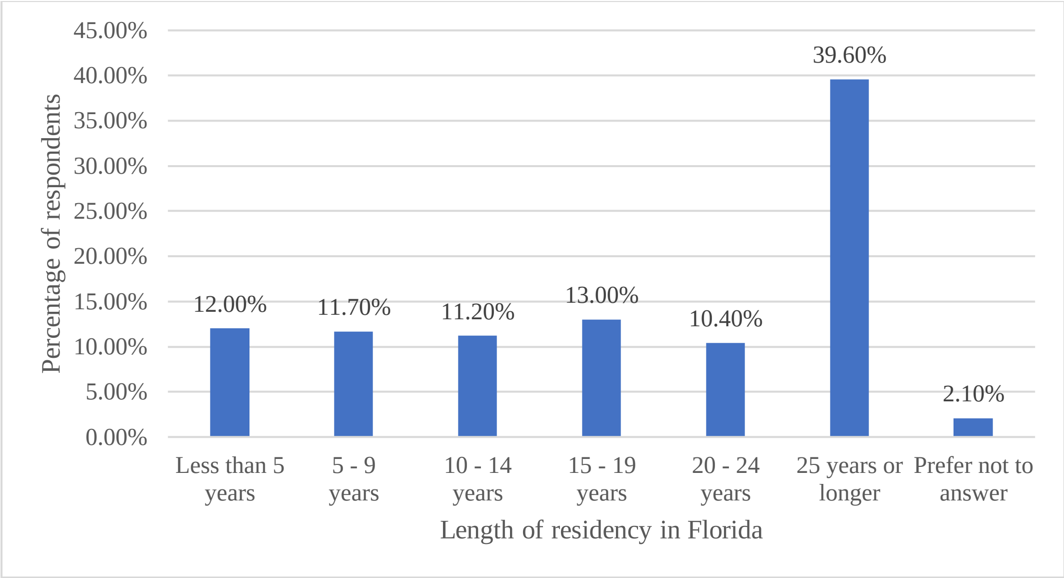


Figure 14. Length of Residency in Florida

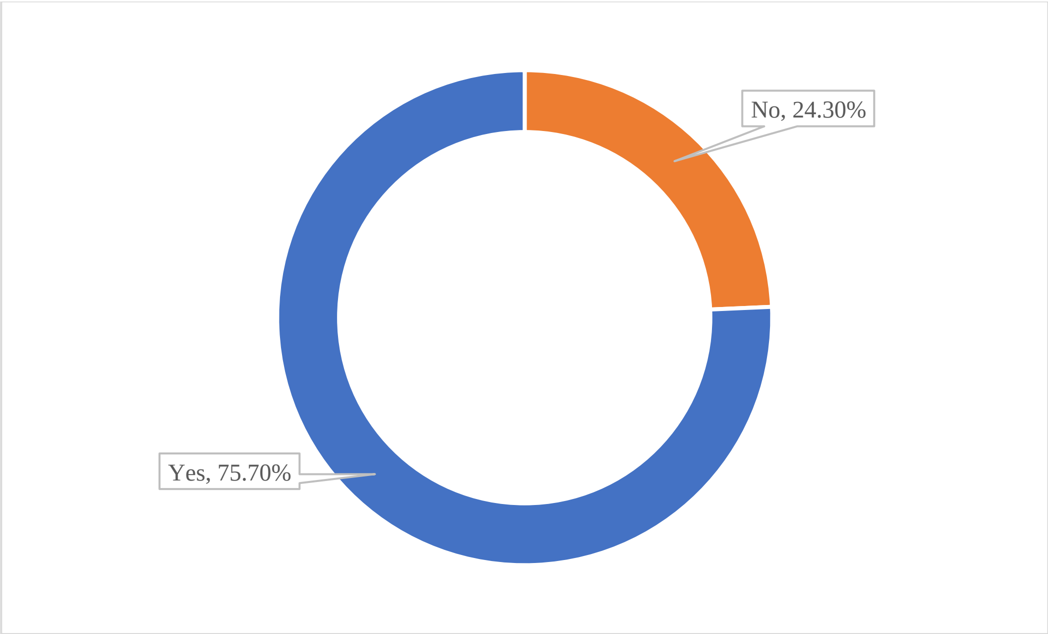


Figure 15. Share of respondents who experienced natural hazards in Florida

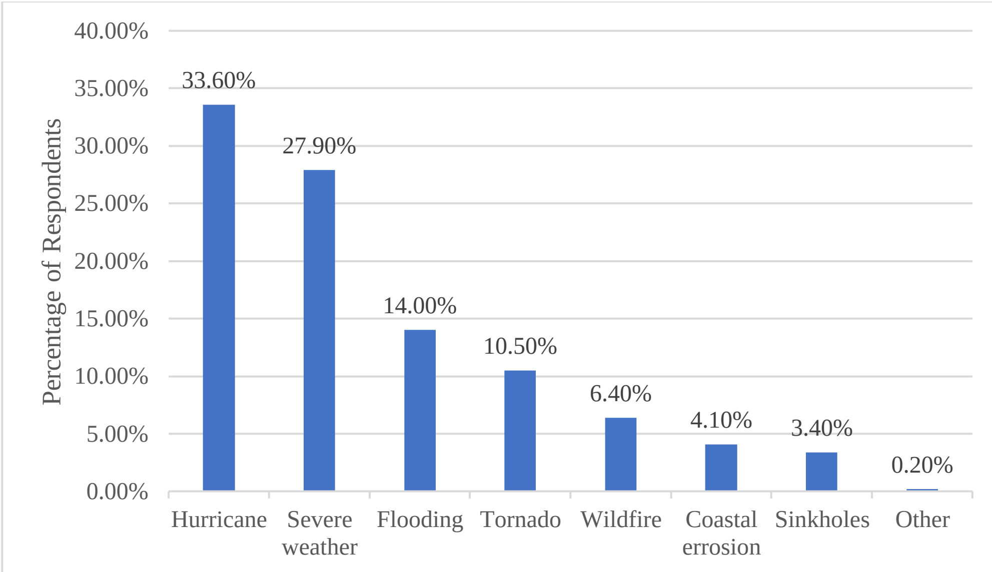


Figure 16. Percentage of respondents who experienced specific natural hazards

Table 15. Main concerns of respondents during natural hazards (descending order)

Rank	Concern	Score
1	My personal safety and/or that of my family members	3.95
2	Utilities	3.9
3	Potential damage to my home or apartment	3.78
4	Food and supplies	3.66
5	Disaster debris	3.47
6	Damage to roads and/or bridges	3.43
7	Traffic congestion on roads	3.4
8	A place to go	3.26
9	My access to transportation	3.24
10	Length of time away from home	3.15
11	Other	2.65

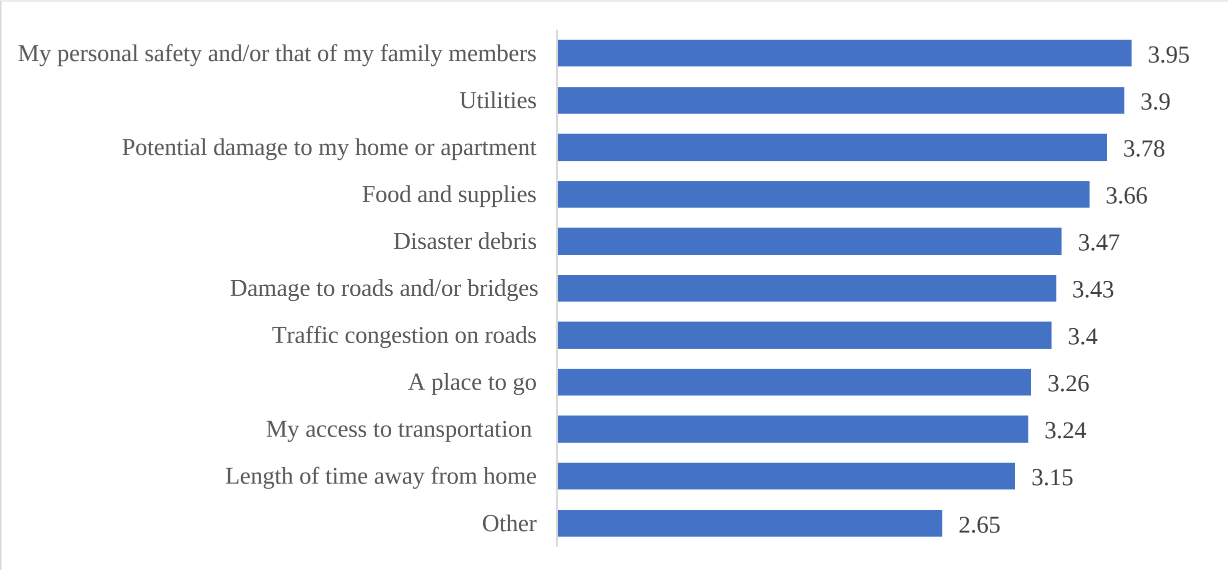


Figure 17. The main concerns of respondents during natural hazards

Mobility and Resilience:

This section of the survey intended to understand the mobility and the resilience of respondents in the context of transportation infrastructure, during hazardous events. The respondents' behaviors can be understood by analyzing their evacuation experiences, whether or not they felt safe while evacuating, the difficulty of the experience, and their major concerns.

Of those who experienced natural hazards, 53.2% reported having an evacuation experience, therefore the results are the personal assessment of these respondents to their respective experiences. In terms of safety, 56.6% of the respondents felt safe during their evacuation (on a scale of 1 to 5, a safe experience is a one that is rated 4 or 5, a neutral experience is 3 and an unsafe experience is a 1 or 2), while only 11.1% reported an unsafe experience. Table 16 shows the breakdown of the assessment of the respondents.

Table 16. Safety assessment of the evacuation experiences

Evacuation experience rating	Percentage of respondents
5 (very safe)	34.70%
4 (safe)	21.90%
3 (neutral)	32.20%
2 (unsafe)	6.60%
1 (very unsafe)	4.50%

In terms of major concerns while evacuating, most of the respondents (irrespective of their socioeconomic statuses) reported having major concerns about the well-being of their family, friends and/or pets. With respect to infrastructure and its related services, most of the respondents had major concerns about the availability of fuel and excessive traffic congestion while evacuating. Table 17 represents a summary of the severe concerns of each of the target groups, classified by the rurality of their locations (on a scale of 1 to 5: a severe concern is a concern rated 4, with 5 being extreme concern). Concerns about the well-being of family, friends, and/or pets as well as concerns about the availability of fuel and amenities remain high during return experiences. However, an overview of the results shows that there is increased concern about excessive disaster debris during return experiences. Table 18 shows an overview of the results.

Table 17. The top three concerns (while evacuating) of each of the three target groups

Focus group	Major concerns (concerns with 4 and 5 ratings)		
	Urban areas	Suburban areas	Rural areas
Minority	Well-being of family/friends	Well-being of family/friends	Well-being of family/friends
	Quality of roads	Uncertainty about return	Availability of fuel
	Availability of fuel	Well-being of pets	Excessive traffic congestion
Rural	Presence of standing water	Well-being of family/friends	Well-being of family/friends
	Well-being of pets	Well-being of pets	Well-being of pets
	Lack of communication	Availability of fuel	Availability of fuel
Age	Well-being of family/friends	Excessive traffic congestion	Uncertainty about return
	Well-being of pets	Availability of fuel	Excessive traffic congestion
	Availability of fuel & food, traffic congestion, excessive debris, presence of standing water	Well-being of family/friends	Well-being of family/friends

Table 18. The top three concerns (while returning) of each of the three target groups

Focus group	Major concerns (concerns with 4 and 5 ratings)		
	Urban areas	Suburban areas	Rural areas
Minority	Well-being of family/friends	Presence of standing water	Well-being of pets
	Quality of roads	Availability of fuel	Availability of food
	Availability of food	Excessive debris	Availability of fuel/ traffic debris
Rural	Excessive debris	Well-being of family/friends	Well-being of family/friends
	Well-being of family/friends	Availability of fuel	Well-being of pets
	Well-being of pets	Well-being of pets	Excessive debris
Age	Well-being of pets	Availability of fuel	Well-being of family/friends
	Well-being of family/friends	Well-being of family/friends	Availability of fuel
	Availability of fuel	Excessive traffic congestion	Excessive traffic congestion

Furthermore, respondents were asked about their choice of transportation should they have to evacuate an area in the future (see Figure 18). Unsurprisingly, 63.4% of the respondents said they would prefer a “Personal vehicle" or "A private vehicle driven by a friend or relative", while only 4.7% of respondents selected “Public transit”.

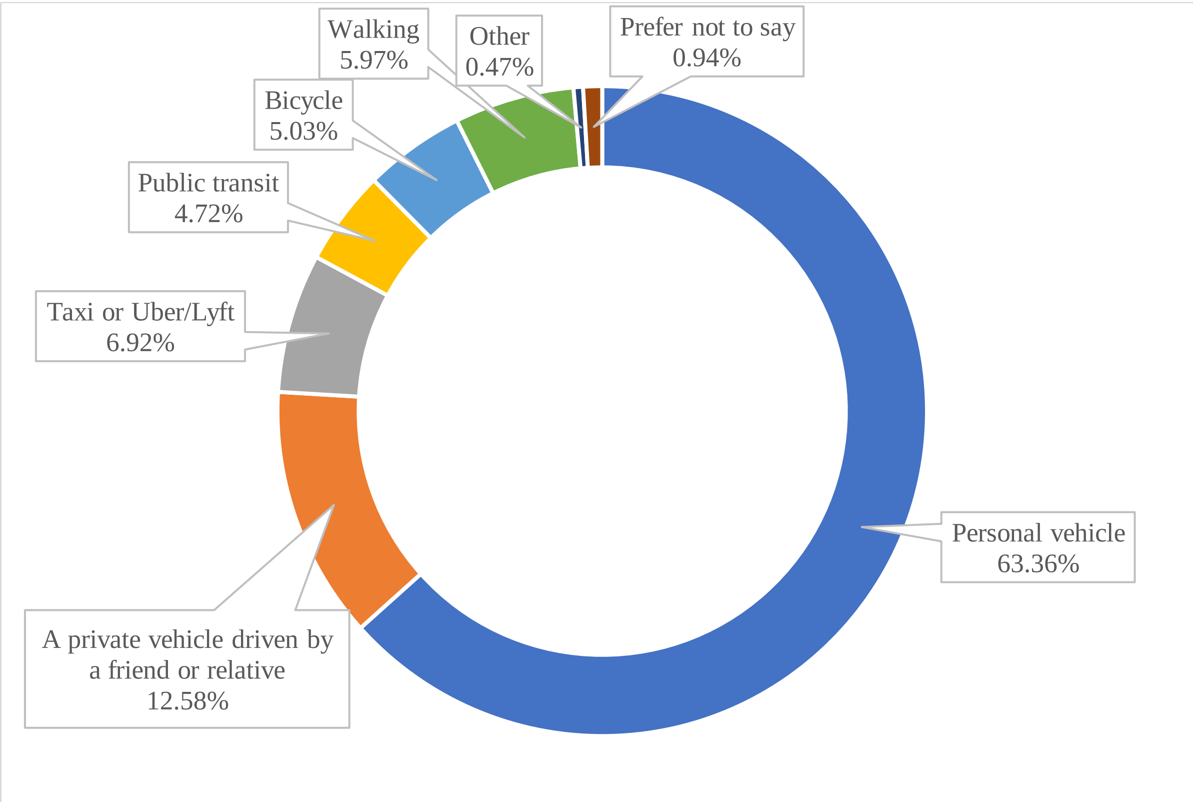


Figure 18. Mode choices of respondents in a case of a future natural hazard

Economic Impacts:

The fourth section of the survey studied the related-economic impacts of natural disasters. Overall, the majority of the respondents (28.9%) have experienced some form of damage to their properties, while 13.7% have experienced damage to their vehicles. Table 19 displays the list of impacts along with the percentage of respondents who experienced them. It was found that 34.3% of respondents received government assistance. The impacts of hazard events on the employment of individuals were also evaluated. The results show that the "Closure of workplace" is the primary reason for unemployment during such events (18.6%). Reasons such as damage to personal vehicle and damaged or closed travel routes were also high among the list of reasons for unemployment. Table 20 shows the reasons leading to unemployment after natural hazard events.

Table 19. Percentage of respondents who experienced specific economic impacts

Impact	Percentage of respondents
Housing damage	28.90%
Isolation	14.80%
Damage to vehicle	13.70%
None of the above	13.30%
Interruption or changes to commute (to work)	11.50%
Relocation to temporary housing	6.00%
Loss of employment	5.30%
Physical injury to self or a family member	5.20%
Other	1.30%

Table 20. Reasons leading to unemployment after natural hazard events

Rank	Reason	Percentage of respondents
1	None of the listed reasons	34.90%
2	Closure of workplace	18.60%
3	Damage to personal vehicle	11.50%
4	Damaged or closed travel routes	10.70%
5	Personal health issues	8.10%
6	Relocation from home	7.80%
7	Disruption of transit services	7.80%
8	Other	0.70%

Social Impacts:

The last section of the survey aimed to investigate the personal, social, and mental impacts caused by natural hazards on vulnerable populations. Out of those who experienced natural hazards, 28.5% have reported experiencing physical or mental health impacts due to the hazard, out of this percentage, 38.2% reported that *'Damage to their vehicle'* was the most impactful factor on their recovery. Table 21 (and Figure 19) summarizes the list of impacts along with the percentages of respondents who experienced them. In terms of post-disaster aids, almost 68% of the respondents reported having adequate access to the social services during and after natural hazard events, while 17% of the respondents responded such services were lacking. The section also investigated if the lack of social services was due to transportation-related issues. Table 22 (and Figure 20) shows a ranking of the potential transportation-related issues compromising access to social services.

Table 21. Percentage of respondents who experienced specific social impacts

Rank	Impact	Percentage of respondents
1	Damage to vehicle	38.20%
2	Availability of fuel	26.50%
3	Damage or closed roads	12.50%
4	Cost of fuel	10.30%
5	None of the above	8.80%
6	Disruption to public transportation routes or services	3.70%

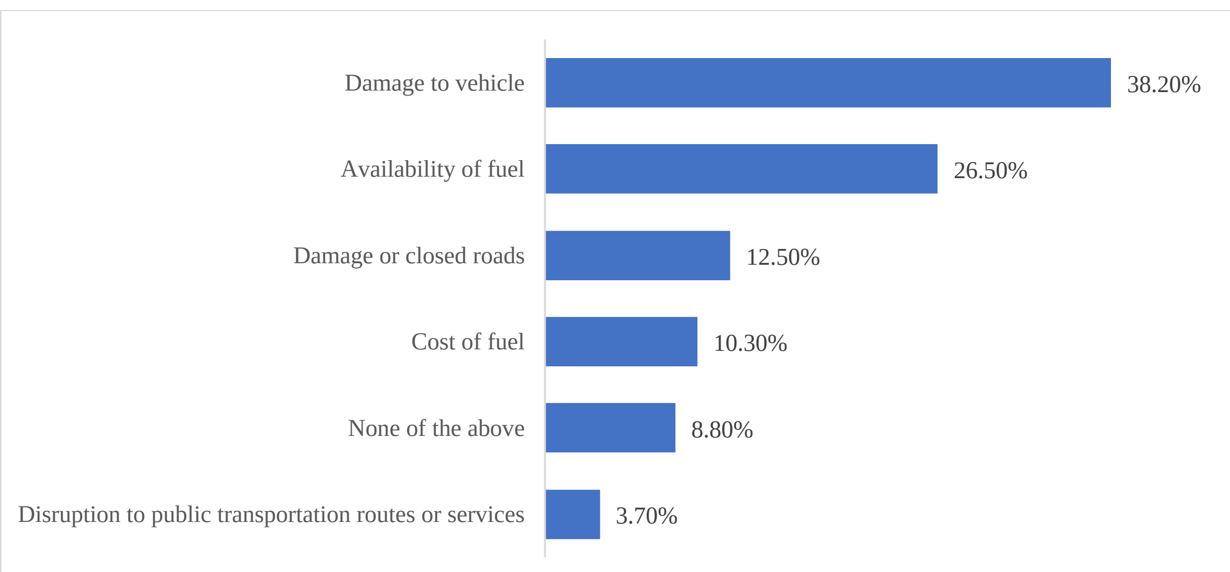


Figure 19. Percentage of respondents who experienced specific social impacts

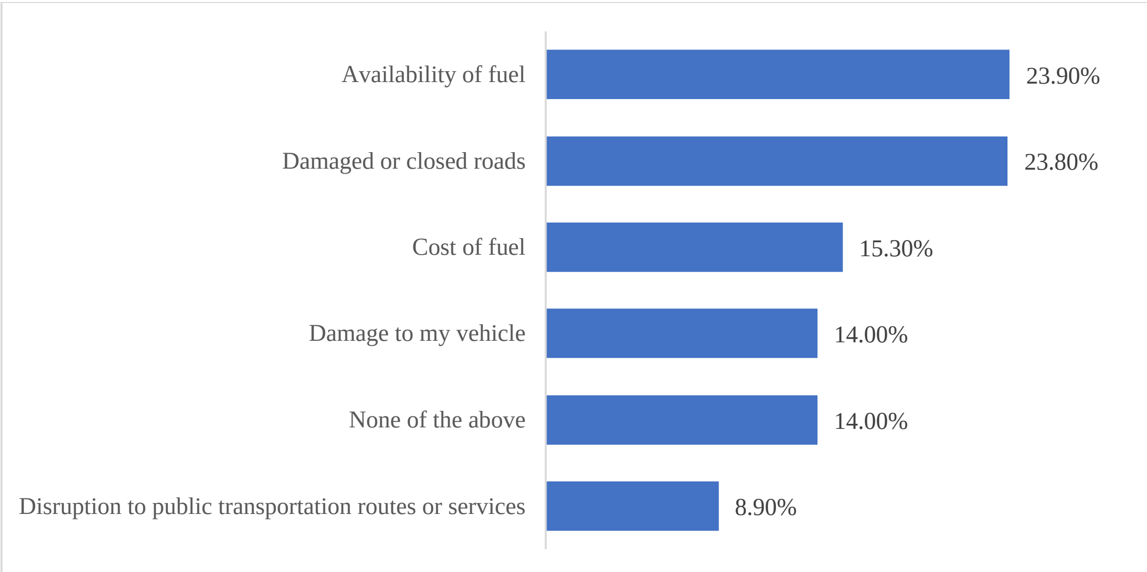


Figure 20. Transportation system related issues that impacted access to social services after hazard events

Table 22. Transportation system related issues that impacted access to social services after hazard events

Rank	**Reason**	**Percentage of respondents**
1	Availability of fuel	23.90%
2	Damaged or closed roads	23.80%
3	Cost of fuel	15.30%
4	None of the above	14.00%
5	Damage to my vehicle	14.00%
6	Disruption to public transportation routes or services	8.90%

Chapter 4: Assessment of Transportation Systems Resilience for Vulnerable Populations

Before developing the policy and planning recommendations, it is crucial to prioritize the resilience requirements of the users (demands), and the resilience capacity of the transportation system in Florida (supply). To achieve this, the following activities were conducted:

(i) A system-performance evaluation framework was developed to guide the assessment process of system resilience. The framework provides a decision-support tool to formally incorporate the needs of vulnerable populations into the FTP objectives.

(ii) The results obtained from the surveys (shown in Chapter 3) were analyzed to evaluate the transportation system's capacity in meeting the users' needs. The hierarchical system-performance evaluation framework was used as a reference point from which efforts can be made to improve the system's resilience.

(iii) A list of transportation system's resilience capabilities was compiled from the literature and refined to characterize the system's resilience based on the needs of the vulnerable populations, as obtained from the survey.

(iv) The literature review (Chapter 2) shows that the issue of mobility-related vulnerability is a complex matter, with no clear methodologies on how to evaluate the degree of vulnerability of societies. Therefore, it was important to validate the main research hypothesis: that age, ethnic minority, and rurality are the three main characteristics that define mobility-related vulnerability. Vulnerability areas were mapped using GIS to determine the locations of vulnerable populations at a fine-grained scale. This step provided an analysis platform to conduct economic impacts analyses to validate the research hypothesis and determine the system's components that require improvements to serve the needs of the vulnerable populations.

4.1 Resilience Assessment Framework

Infrastructure systems are complex social and technical systems that have constant interactions with the surrounding environments, e.g., *open-loop* systems (Blanchard, 2004). This dual nature (socio-technical) makes pure engineering approaches (e.g., structural health monitoring) weak in producing effective decisions related to fostering resilient and sustainable infrastructure systems (Cascetta at al., 2015). For an effective decision-making process, it is important to understand the social component of transportation systems and incorporate user needs in the investment decisions to foster a more resilient system. Overall, the needs of the populations can be categorized into four categories: basic needs, safety needs, social and economic needs, and sustainability and equity needs. Table 23 describes the categories of mobility needs of vulnerable populations. The survey instruments developed in Task 2 of the project were used to better understand the ramifications of natural hazards on vulnerable populations within the context of the performance of transportation systems. In this regard, the perceptions of vulnerable populations obtained from the surveys are grouped by the natural hazard's timeline. The vulnerable populations were asked about their concerns pre-, during, and post (short-term) natural hazards. The timeline of the needs is highlighted in Table 23. The scope of the survey did not include questions about the long-term needs (sustainability, long-term resilience, and equity) as the survey was administrated in the context of natural hazards; however, such needs are incorporated into the conceptual framework from the literature (including a review of the FTP Policy Element) to address the full scope of resiliency for vulnerable populations.

Table 23. Categories of mobility-related needs of vulnerable populations

Needs	Description	Disaster Timeline
Basic	Capacity of the transportation system to mobilize the vulnerable populations safely during normal conditions.	Pre
Safety	Capacity of the transportation system to mobilize the vulnerable populations during hazard events (e.g., facilitate the evacuation needs).	During
Social and Economic	Capacity of the transportation system to provide vulnerable populations with accessibility to medical healthcare and jobs.	Post
Sustainability and Equity	Capacity of the transportation system to strengthen the regional economy, enhance the environmental conditions, and support community livability for vulnerable populations.	Long-term

To characterize the needs of the vulnerable populations according to the categorization provided in Table 23 above, the team developed a portfolio of needs based on the timeline of the hazard. For example, concerns about the quality of roads pre-disasters are characterized as basic needs, while concerns about the quality of roads during and post-disasters are characterized as safety needs. The portfolio shown in Table 24 is used to answer and determine the mobility-related needs of vulnerable populations.

The vulnerable populations survey results were used along with a review of the literature of resilience measures (e.g., Bhamra at al. (2011); Martin-Breen and Anderies (2011); Sun et al. (2020); Wang (2015)) to compile the list of mobility-related needs of vulnerable populations. The list is shown in Table 25.

Table 24. Portfolio of vulnerable population needs (obtained from the survey results)

Survey questions category	Needs category
Physical condition of infrastructure pre-hazard events	Basic
Concerns during hazard event - Physical condition of infrastructure	Basic and Safety
Concerns during hazard event - Hazard impacts	Safety
Concerns while returning - Physical condition of infrastructure	Safety
Concerns while returning - Hazard ramifications	Safety
Post-disaster impacts	Social and Economics

Table 25. List of mobility-related needs of vulnerable populations

Needs Category	**Needs (Technical Performance)**	**Needs (Management Process)**
Basic	Condition of local roads (pre), quality of drainage systems (pre).	Traffic conditions (pre), availability of services, e.g., fuel (pre), clear communications about future hazards.
Safety	Condition of local roads (during and post), quality of drainage systems (during and post), robustness of drainage systems (capacity during hazards), robustness of transportation system, redundancy of transportation network.	Traffic congestion (during and post), availability of services (during and post), emergency management processes, evacuation resourcefulness.
Social and Economics	Degree of recoverability of the system, ability to meet the socioeconomic needs post-disasters (access to jobs and medical support).	Rapidity of debris management process, adaptability of organizations to future events.

The Sustainability and Equity needs category is not included in the assessment of the resilience capabilities because there were no specific questions in the survey to investigate such long-term needs. However, as previously mentioned, these needs are included in the conceptual framework because the framework will serve as a platform for the analysis of planning guidelines to enhance system resilience. Moreover, focusing on the vulnerable population needs as related to transportation resilience does contribute to the equity needs category. This research project and other similar efforts will help understand, analyze, and provide recommendations to address these equity needs. Additionally, for the analysis to be comprehensive and align with the FTP objectives, the sustainability component is crucial to consider in the analysis.

4.1.1 The Hierarchical Needs of the Transportation System

A review of the history and future prospects of transportation systems (Rodrigue, 2020) offer a way for the performance of transportation systems, from a systems' perspective with four classes of needs, to meet current and future demands while adapting to and mitigating the impacts of modern day challenges (e.g., natural disasters and climate change). Through this lens (the transportation systems are systems with needs that must be fulfilled to be capable of meeting the population demands), the team offers a conceptual framework to the level of maturity of the transportation systems. The developed framework determines that there are four levels of maturity (four classes of needs) for the system performance: functionality, safety and short-term resilience, social and economic equity, sustainability and long-term resilience. Figure 21 shows the framework.

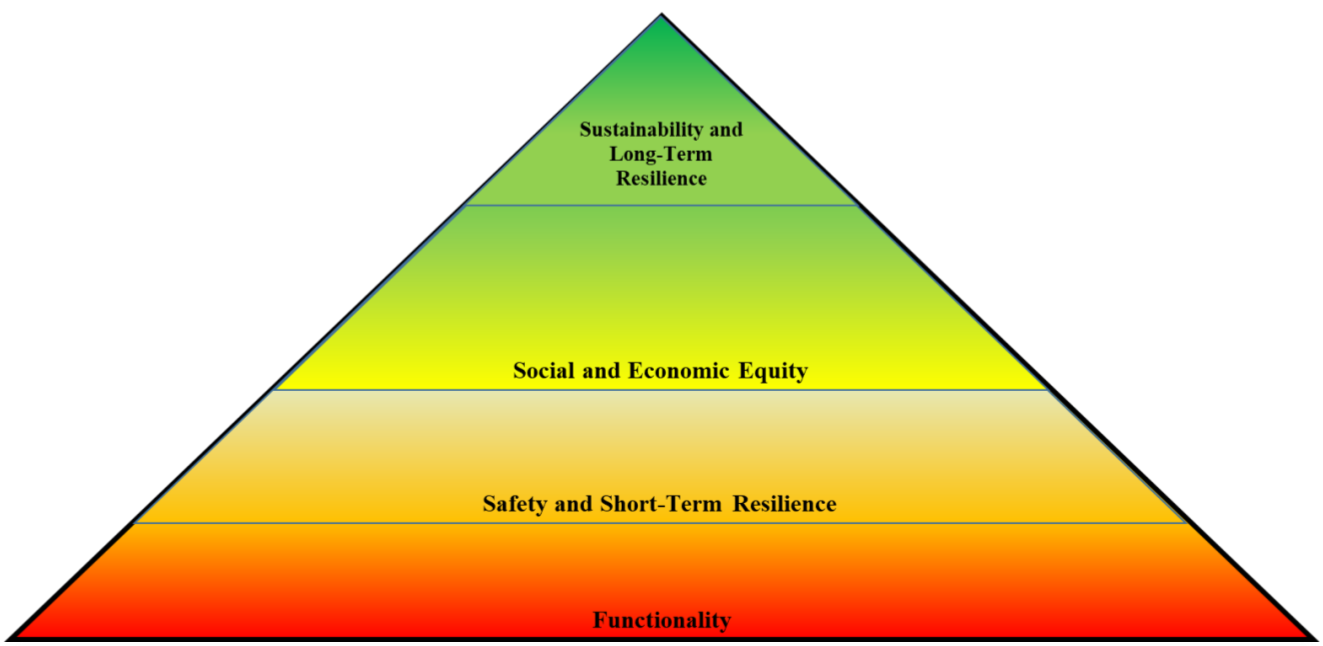


Figure 21. Hierarchical transportation system performance evaluation framework

From the standpoint of system-performance, and in the context of resilience and sustainability objectives listed in the FTP Policy Element, the maturity levels can be described as follow:

1. **Functionality**: this is the basic level of performance; the system should meet all the basic needs of stakeholders to deem it as *functional*. This level includes basic resilience parameters such as connectivity and the structural condition of local roads.
2. **Safety & Short-Term Resilience:** this level assesses the safety level of the transportation systems and its capability to provide services beyond the normal conditions (i.e., during and post-disaster events). The performance measures of this level include the level of traffic congestion during evacuations, the quality of drainage systems, the disaster debris management processes, and the damages to roads/bridges.
3. **Social & Economic Equity**: systems at this level are at good (beyond-average) performance levels. They exhibit the capabilities of providing more than the basic levels of serviceability and safety. Goals such as 'Accessibility and Equity' and 'Economy' and 'Agile, Resilient, and Quality Transportation' in the Florida Transportation Plan are realized once the system reaches this level.
4. **Sustainability & Long-Term Resilience:** At this level, the system (technical and institutional) should exhibit the adaptive characteristic of resilience and environmental sustainability. Goals such as 'Environment' and 'Communities' in the Florida Transportation Plan are realized once the system reaches this top level.

From the standpoint of FDOT, and in the context of fostering resilient systems for vulnerable populations, the following questions are relevant:

- What is the current maturity level of the statewide transportation systems in the general context (not specific to vulnerable populations)?
- What is the current maturity level of the statewide transportation systems for the specific needs of vulnerable populations?
- What are the resilience parameters/system performance measures (if any) that result in different maturity levels for vulnerable populations?
- Where are the different regions within the states where the system exhibits different maturity levels for vulnerable populations? And what are the parameters that need to be addressed to improve the system resilience in these regions?
- What are the priority investment tradeoffs that must be made to enhance the statewide transportation systems resilience and specific locations systems resilience in areas with high concentrations of vulnerable populations?

While the ultimate goal is to reach the fourth level of maturity (Sustainability & Long-Term Resilience) at a statewide level, understanding that strengthening the resilience of the system in only specific locations with high concentrations of vulnerable populations may contradict achieving the statewide goals; in such cases, the emphasis is on achieving co-benefits with respect to regional priorities (vulnerable populations) and statewide priorities (overarching FTP goals).

The framework shown in Figure 21 offers a hierarchical view of transportation systems performance. In the context of resilience, it is important to realize that the system cannot reach the next maturity level until all the conditions of the preceding step are met. For example, a system cannot be characterized as safe if it does not fulfill the mobility needs of the users. Similarly, a system is not sustainable if it does not provide social equity for the vulnerable populations using it. Such views suggest that the basic levels of mobility and safety are the foundation for a resilient transportation system.

To develop effective policies and planning guidelines to upgrade the system performance for vulnerable populations, evaluating the current maturity level of the system is necessary. Quantitative analysis of the survey results is used, and the results of such analysis are related to the system-performance framework to estimate the performance level of the system for vulnerable populations.

The lists of needs compiled from the survey (see Table 25) are translated into measures that can be used to evaluate the state of resilience of the transportation systems, specifically for the needs of vulnerable populations.

4.1.2 Transportation Systems Resilience Capabilities for Vulnerable Populations

To determine appropriate performance measures for the transportation systems' resilience for vulnerable populations, the results of the surveys administrated in Task 2 of the project were analyzed to achieve the following:

1. Understand how the needs of different segments of the vulnerable populations vary (e.g., minority, rural, and older), prioritize these needs, and determine the appropriate resilience capabilities and performance measures that relate to these needs
2. Characterize the concerns of experts about the performance of the system and validate the resilience capabilities determined from the populations' surveys

The first step of analyses was conducting a correlation analysis to help understand what defines resilience within the context of mobility during natural hazards. The main focus of this analysis was the *Mobility & Resilience* section of the survey. Spearman's nonparametric correlation coefficients were calculated to measure the linear relationship between the resilience parameter, and the concerns of the populations. The statistical significance is also calculated to ensure that the obtained results are not due to a chance in response. Four different sets of analysis were conducted as follows:

1- The correlations between the concerns of the populations during natural hazards (Q10 of the surveys).
2- The correlations between the concerns of the populations while evacuating (Q13 of the surveys).
3- The correlations between the concerns of the populations while returning (Q15 of the surveys).

4- The correlations between the concerns of the populations while evacuating and the corresponding concerns while returning.

Table 26 reports presents the main mobility concerns of the populations.

Table 26. Vulnerable populations' concerns related to the transportation systems management and operations

Q #	Code	Concern
Q10	A1	My personal safety and/or that of my family members
Q10	A3	My access to transportation (my car or other ways I would normally get around)
Q10	A4	Damage to roads and/or bridges
Q10	A5	Traffic congestion on roads
Q10	A9	Disaster debris
Q13, Q15	A1, B1	Lack of official communications or directions
Q13, Q15	A3, B3	Quality of the roads
Q13, Q15	A4, B4	Excessive traffic congestion
Q13, Q15	A5, B5	Availability of fuel
Q13, Q15	A7, B7	Presence of standing water
Q13, Q15	A8, B8	Excessive disaster debris

The correlation coefficients between the responses of the populations (related to the concerns shown in Table 26) indicate strong correlations between concerns (greater than 0.8). This observation is consistent for all three populations (i.e., minority, rural, and older groups). In Appendix D, it can be observed that there are some variables with moderate correlation coefficients (around 0.6). These variables are not significant for FDOT as they relate to personal concerns, such as concerns about the safety of a pet during natural hazards. While it was a valid concern reported by the respondents, it does not relate to the operations of the FDOT, and thus, such concerns are disregarded in further analysis steps. The importance scores method was used to prioritize the concerns reported Table 27. Inspecting the importance scores of the responses of the populations provides insights into which concerns are the most important and which are the least, based on the surveys' responses, providing an arithmetic mean value for each concern, allowing the capacity of ranking the needs quantitatively. The importance scores analysis results are shown in Task 3 document of this project. The rankings of the concerns of the three population groups (ranked from most to least) are shown in tables 27, 28, and 29.

Observations of the results indicate that the safety of the populations during hazards, the availability of fuel during evacuation and while returning, the capacity of the network, as well as the reliability of the network are among the greatest concerns among all three groups of vulnerable populations.

Table 27. Ranking of the concerns of the minority populations (most concerning to least concerning issues)

Minority Population Group			
Rank	**Concern**	**Timeline**	**Emergency Management Phases**
1	Safety	during hazard	Preparedness
2	Fuel availability	during evacuation	Preparedness and Response
3	Fuel availability	during return	Preparedness, Response, and Recovery
4	Quality (functionality) of network	during evacuation	Preparedness and Response
5	Quality of network	during return	Preparedness, Response, and Recovery
6	Quality (functionality) of network	during hazard	Preparedness
7	Capacity of the network	during hazard	Preparedness and Mitigation
8	Network clearance (debris)	during evacuation	Response and Recovery
9	Quality of drainage systems	during evacuation	Preparedness and Response
10	Capacity of the network	during evacuation	Preparedness and Mitigation
11	Quality of drainage systems	during return	Preparedness, Response, and Recovery
12	Network clearance (debris)	during return	Response and Recovery
13	Capacity of the network	during return	Preparedness, Response, and Recovery
14	Accessibility to transportation	during hazard	Preparedness and Mitigation
15	Clear communication/directions	during evacuation	Preparedness and Response
16	Clear communication/directions	during return	Response and Recovery
17	Safety	during evacuation	Preparedness and Response
18	Safety	during return	Preparedness, Response, and Recovery

Table 28. Ranking of the concerns of the rural populations (most concerning to least concerning)

Rural Population Group			
Rank	**Concern**	**Timeline**	**Emergency Management Phases**
1	Fuel availability	during evacuation	Preparedness and Response
2	Safety	during hazard	Preparedness
3	Capacity of the network	during evacuation	Preparedness and Mitigation
4	Fuel availability	during return	Preparedness, Response, and Recovery
5	Network clearance (debris)	during return	Response and Recovery
6	Quality of drainage systems	during evacuation	Preparedness and Response
7	Network clearance (debris)	during evacuation	Response and Recovery
8	Quality of drainage systems	during return	Preparedness, Response, and Recovery
9	Quality (functionality) of network	during hazard	Preparedness
10	Quality of network	during return	Preparedness, Response, and Recovery
11	Quality (functionality) of network	during evacuation	Preparedness and Response
12	Clear communication/directions	during evacuation	Preparedness and Response
13	Capacity of the network	during return	Preparedness and Mitigation
14	Clear communication/directions	during return	Response and Recovery
15	Capacity of the network	during hazard	Preparedness and Mitigation
16	Accessibility to transportation	during hazard	Preparedness and Mitigation
17	Safety	during evacuation	Preparedness and Response
18	Safety	during return	Preparedness, Response, and Recovery

Table 29. Ranking of the concerns of the older populations (most concerning to least concerning)

Older Population Group			
Rank	**Concern**	**Timeline**	**Emergency Management Phases**
1	Fuel availability	during evacuation	Preparedness and Response
2	Safety	during hazard	Preparedness
3	Capacity of the network	during evacuation	Preparedness and Mitigation
4	Fuel availability	during return	Preparedness, Response, and Recovery
5	Capacity of the network	during return	Preparedness and Mitigation
6	Capacity of the network	during hazard	Preparedness and Mitigation
7	Network clearance (debris)	during return	Response and Recovery
8	Quality of drainage systems	during evacuation	Preparedness and Response
9	Network clearance (debris)	during evacuation	Response and Recovery
10	Quality of drainage systems	during return	Preparedness, Response, and Recovery
11	Quality (functionality) of network	during hazard	Preparedness
12	Accessibility to transportation	during hazard	Preparedness and Mitigation
13	Clear communication/directions	during return	Response and Recovery
14	Quality of network	during return	Preparedness, Response, and Recovery
15	Quality (functionality) of network	during evacuation	Preparedness and Response
16	Clear communication/directions	during evacuation	Preparedness and Response
17	Safety	during evacuation	Preparedness and Response
18	Safety	during return	Preparedness, Response, and Recovery

Similar analyses are conducted on the experts' survey to characterize the system's performance. The focus of the analysis of the experts' survey was on two fronts:

1- Characterizing the performance of the transportation systems based on the level of concern(s) about the quality of infrastructure elements during hazards.

2- Understanding the transportation issues relative to the needs of the vulnerable populations.

The experts reported concerns about ten specific infrastructure elements during hazards, five of which are more relevant to the needs of vulnerable populations (see Table 25). Four of these elements are within FDOT management capacity. These elements are summarized in Table 30.

Table 30. Infrastructure Elements subject to hazards vulnerability as obtained from the experts' surveys

Element	Mobility-related needs during hazards	FDOT management capacity
Critical emergency response facilities like police and fire stations		
Medical facilities like hospitals and clinics		
The federal and/or state highway system	√	√
Local roads	√	√
Public shelters		
Power / communications infrastructure	√	
Drainage	√	
Ports/ airports		
Rail		√
Bridges	√	√
Other		

The correlation analysis results indicate a strong positive correlation between all the responses regarding concerns about the vulnerability of infrastructure elements. Only three variables indicated moderate association; however, they are not related to the mobility needs of the vulnerable populations.

Importance scores are used to rank the concerns about the infrastructure elements (most concerning to least concerning). A summary of the results is shown in table 31.

Table 31. Ranking of concerns about the vulnerability of infrastructure elements (most to least)

Rank	Concern
1	Drainage
2	Power / communications infrastructure
3	Local roads
4	Public shelters
5	The federal and/or state highway system
6	Medical facilities like hospitals and clinics
7	Other
8	Critical emergency response facilities like police and fire stations
9	Ports/ airports
10	Bridges
11	Rail

Referring to the Transportation Systems Performance-Evaluation Framework (see Figure 21), the results of the experts' survey suggest that the performance of the system is at *a basic functionality* level, and resilience concerns exist during natural hazards. This validates the vulnerable population surveys results, who indicated being worried about their safety and the reliability, and the efficiency of the system during hazards. It should be noted, however, that these surveys are perceptions of the individuals surveyed and no technical assessment was performed by the research team or the experts surveyed. Moreover, these perceptions do not provide comprehensive assessment of the safety and reliability of the system.

4.1.3 Transportation Issues Relative to the Needs of Residents

Table 32 below summarizes the results of the importance scores analysis for the transportation issues variables in the experts' survey.

Table 32. Ranking of concerns about the transportation issues

Rank	Concern
1	Fuel accessibility
2	Evacuation
3	Temporary road closures due to flooding or debris
4	Long-term road closures due to disasters damage
5	Disruptions to public transportation routes or schedules
6	Re-entry
7	Lack of service at airports or ports
8	Long-term disruptions to airports or ports

The results of the analysis of this section indicate that the top three transportation issues relative to the needs of vulnerable populations are:

1- Fuel accessibility.
2- Evacuation.
3- Temporary closure of roads due to flooding or debris.

The results align with the perceptions of the surveyed populations who expressed high levels of concerns about the availability of fuel, system reliability during evacuation (e.g., damage to roads and bridges and the quality of roads), and disaster debris.

Based on the concerns of the surveyed populations, the perceptions of the experts regarding the vulnerability of the infrastructure elements, and the transportation issues related to the vulnerable populations, a number of resilience capabilities are determined for each maturity-level in the constructed framework (Figure 21). The resilience capabilities for the needs of vulnerable populations are shown in Figure 22. These resilience capabilities (performance metrics) were used in Task 4 of the project when the planning guidelines were proposed, and a proposal of their relevancy was made.

Functionality	Safety and Short-Term Resilience	Social and Economic Equity	Sustainability & Long-Term Resilience
Condition of local roads (pre)	Condition of roads (during & post)	Degree of recoverability of the system	Community Livability
Quality of infrastructure elements (pre)	Quality of infrastructure elements (during & post)	Capacity of meeting the socio-economic needs post hazards	Support of Regional Economy
Serviceability of network	Robustness of drainage system	Rapidity of debris management process	Environmental Sustainability
Availability road related services for vulnerable populations (pre)	Robustness of network	Adaptability of organizations to future events	
Clear communications before hazards	Redundancy of transportation network		
	Emergency management process		

Figure 22. Resilience capabilities of the transportation system

4.2 Vulnerability Mapping

To identify areas vulnerable to natural disasters by virtue of their local population characteristics, social vulnerability indices are widely used by public health officials, local planners, practitioners, and emergency managers (Cutter and Morath, 2013;). There are two prominent indices. One of the indices is the social vulnerability index (SoVI) developed by Cutter et al. (2003) and another metric is the CDC/ATSDR social vulnerability index (SVI) introduced by Flanagan et al. (2011). Detailed reviews of these and many other related social vulnerability indices can be found elsewhere (Fatemi et al., 2017).

The SoVI is based on the concept of the hazards-of-place model (Cutter, 1996). The initial model had 11 normalized factors that were derived from 42 vulnerability variables, but a recent version of the model had 7 factors from 29 variables. Some of the variables used in the SoVI include items such as race and ethnicity, poverty, age, and wealth. The 11 normalized factors are transformed to z-scores, and then all the factors are summed to quantify the relative vulnerability of a county or census tract, or potentially any geographical unit given data availability. Officially, the SoVI 2010-2014 version has been released (www.sovius.org), and the SoVI 2017 for Florida has been shared by Emrich via an ArcGIS online platform.

A second popular index, the SVI, first appeared via Flanagan et al. (2011) and is computed based on 15 census variables derived from the American Community Survey within four social vulnerability categories: socioeconomic status, household composition & disability, minority status & language, and housing type & transportation. Unlike the SoVI, the SVI is calculated based on the census tract's percentile ranks. Table 33 shows the list of SVI variables. To date, the 2000, 2010, 2014, 2016, and 2018 SVI have been released.

Table 33. A list of variables used for the SVI

Vulnerability Categories	ACS variables
Socioeconomic Status	Below Poverty
	Unemployed
	Income
	No High School Diploma
Household Composition & Disability	Aged 65 or Older
	Aged 17 or Younger
	Civilian with a Disability
	Single-Parent Households
Minority Status & Language	Minority
	Aged 5 or Older who speaks English "Less than Well"
Housing Type & Transportation	Multi-Unit Structures
	Mobile Homes
	Crowding
	No vehicle
	Group Quarters

Source: Flanagan et al. (2011)

There have been efforts to evaluate the validity of the two indices; however, their validity is inconclusive. For example, Rufat et al. (2019) found a weak or insignificant relationship between the two indices with the effects of Hurricane Sandy, but Bakkensen et al. (2017) reported that the two indices perform differently in accounting for damages, fatalities, or disaster declarations from a disaster. In this regard, taking account of the benefits and challenges inherent to each index into account is suggested (Bakkensen et al., 2017).

In the analysis conducted here, the SVI is utilized as a baseline to assess and identify vulnerable locations with the three vulnerable populations groups (i.e., older, minority, and rural population groups). As can be seen from the table above, the SVI considers numerous characteristics that lead to social vulnerability that may not necessarily lead to vulnerability in the context of mobility (e.g., the level of education). For this reason, a composite index is developed to look at population groups that are assumed to be specifically vulnerable in a mobility-related capacity. Given that the SVI has been released and updated recently (2018). Every index that reduces data in an effort to simplify difficult concepts suffers from weaknesses. Even so, the research team determined that the SVI is a reasonable approach to adopt, given the range of available alternatives in the literature.

4.2.1 Summary of the Analysis

This analysis aims to:

1. Identify vulnerable locations from our selected study area (Hillsborough, Lake, Orange, Osceola, Pinellas, Polk, Seminole, Volusia counties), using the three vulnerable population groups; and
2. Present statistical comparisons of responses between population groups.

These two objectives are divided into two parts. The first part is mapping SVI and the three vulnerable population groups to identify areas that have (a) high SVI and the three population groups and areas that have (b) high three population groups but not high SVI.

The second part of this analysis is to compare surveys responses regarding the concerns or experiences of respondents about transportation and mobility during or after a natural hazard event. We compare different population groups to understand their potential divergent behaviors and concerns. We thus divide and combine a set of combinations of populations, for instance, older vs. younger, minority vs. white, rural vs. urban, older in rural vs. younger in rural, older in urban vs. older in urban, minority in rural vs. white in rural, and so on for more in-depth assessment.

The remaining part of this chapter is constructed as follows. First, we illustrate a series of maps depicting SVI and our three population groups and look for vulnerable areas based on a comparison between them. Second, statistical assessments are presented based on analysis of the Pollfish survey. Lastly, we briefly discuss vulnerable areas and list a few policy implications based on the vulnerability mapping and initial statistical analysis.

4.2.2 Methods

The objective of the vulnerability mapping is to identify vulnerable populations areas, using the three vulnerable population groups parameters and the SVI data. To identify the locations of vulnerable populations along the I-4 corridor, the social vulnerability index SVI was used as a baseline, then a Composite Index (CI), based on the assumed demographic characteristics defined for this project, was developed to identify the population groups who are vulnerable in the context of mobility (the research hypothesis was that: racial and ethnic minority, rurality, and older groups are disproportionately vulnerable to natural hazards in the context of mobility). The census tract level, which is collected from the American Community Survey 2014-2018, is used to directly compare metrics between the SVI (2018) and our three vulnerable population groups. The comparison is performed following three steps:

1. First, a score of 0 or 1 is given to the specific area if there is a considerable concentration of a particular vulnerable group (elderly (65+), minority, or rural) as follows: the census tracts within the 5th quintile of aging population density and minor population density will have a point; otherwise, zero point. Here, 'density' means the number of people concentrated in a census tract (the number of people per mile^2). Likewise, rural census tracts have a point and other census tracts have zero point.
2. Second, a composite score of the three population groups is computed by summing the individual scores (i.e., 5th quintile of aging population (1) + 5th quintile of minority population (1) + rural census tract (1)), meaning the composite score will range from zero to three. The conceptual illustration is presented in Figure 23.
3. Third, by making comparisons between the composite score and the SVI score, we identify areas where both scores are high (high SVI-high CI) which means the areas are vulnerable in terms of density of the three population groups and SVI and areas that the composite score is high but not the SVI (low SVI-high CI). This second group is particularly of

interest because it represents the areas that contain people we have prioritized as 'vulnerable' based on this project, which the SVI would have missed.

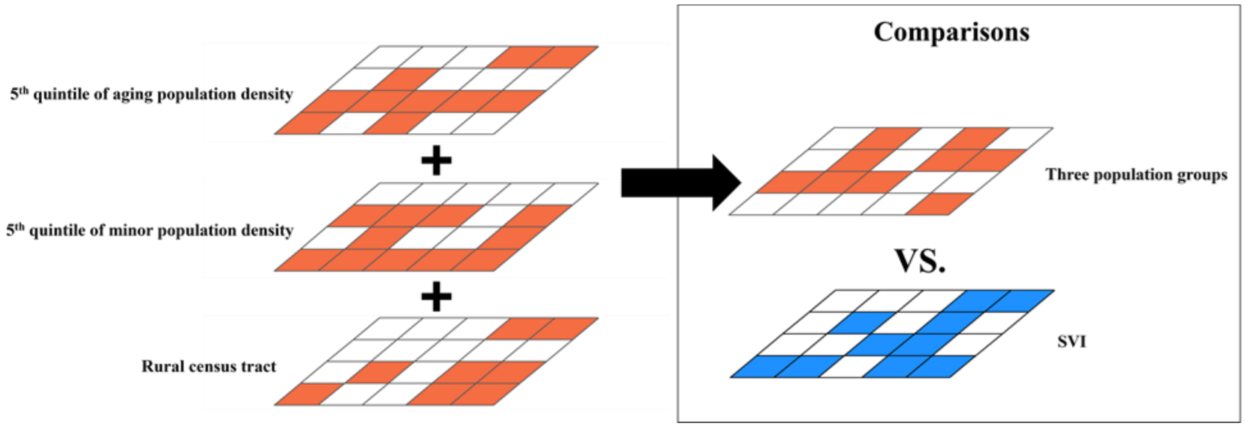


Figure 23. Conceptual illustration of calculating a composite score and the way of comparing SVI and the composite index (CI)

In this analysis, the SVI score is recalculated to account for the relative vulnerability of a given census tract in our study area. Since the SVI score provided by the CDC is computed based on the whole state of Florida, the SVI score in our study area would be relatively high or low compared to other regions in Florida. In this regard, we recalculated the percentile ranks of the SVI score within our study area in order to consider the relative vulnerability of a given census tract in our study area even though the difference between the original SVI score and the recalculated SVI score is small. Through this recalculation, we can directly interpret the SVI score as on a quintile's basis. For example, if the SVI score is greater than 0.8, the SVI score would be understood as the score being within the 5th quintile. Likewise, the SVI score that is less than 0.2 could be thought of as within 1st quintile. Based on this interpretation, areas with high SVI score (SVI greater than 0.8) and high composite index (at least one) (high SVI-high CI) and with low SVI score (SVI less than 0.8) and high composite index (at least one) (low SVI-high CI) are identified.

4.2.3 Results

Figure 24 shows the choropleth maps for the SVI score and the population groups in our study area. Since census tracts colored as yellow mean a high SVI score, 5th quintile of aging and minor population densities, and rural census tracts, the census tracts can be thought of as vulnerable, and these areas are highlighted by red circles.

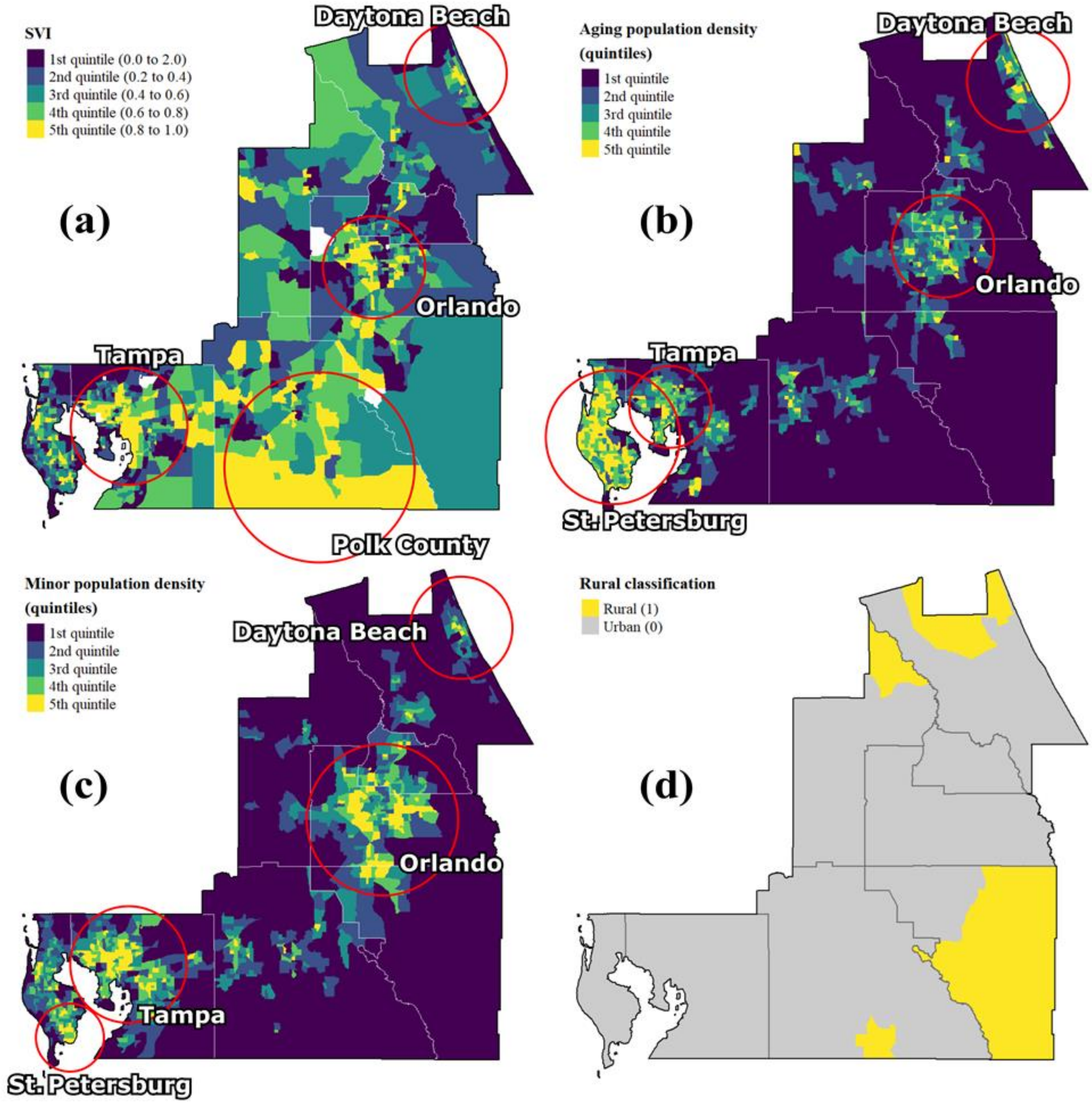


Figure 24. Composite index results. High value of the score means high concentration of selected population groups

Finally, Figure 25 illustrates the comparison between the SVI and the composite index. The red color indicates census tracts where both scores on the indices are high. Most red-colored census tracts are found in the city of Orlando and the Tampa Bay area. On the other hand, blue-colored census tracts are those areas where the SVI is low, but the composite index is high. This means that these areas are less vulnerable, although they have concentrations of vulnerable populations. We identified instances of these tracts along the gulf coast in the city of Clearwater, Sun City Center around southern Hillsborough County, and northern Volusia County. When referring to

Figure 24.b, we can tell that the blue-colored census tracts in the city of Clearwater and the Sun City Center are within the 5th quintile of the aging population, and the other tracts in northern Volusia County are the rural census tracts. It should be noted that the SVI considers a wider range of socioeconomic factors while the Composite Index (CI) considers only mobility related factors.

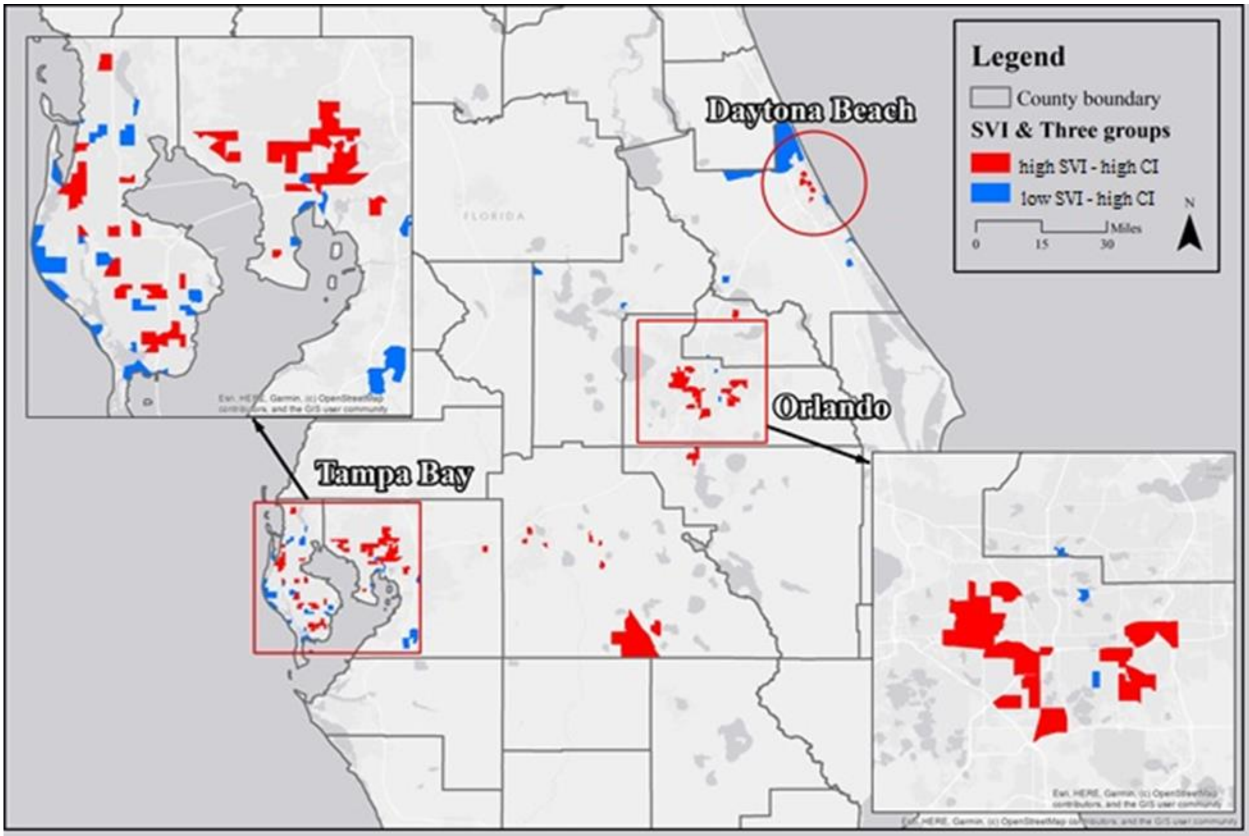


Figure 25. The comparison between the SVI and the composite index (CI)

4.3 Economic Impacts Analyses

From the literature review in task 1, the research team outlined the reported increased economic damage to vulnerable populations during and after natural hazards. Hurricanes typically impact the coast of Florida each year. The compounded effects of climate change-related sea-level rise and hurricane storm surge have drastic ramifications on the physical environment, emergency services, and local communities. The magnitude of exposure to a storm event, such as the maximum water elevation, helps model storm surge inundation (Bloetscher et al., 2014 and Shen et al., 2016). Bloetscher et al. (2016) indicate that the bathtub model approach is valid when analyzing permanent roadbed inundation associated with sea-level rise (SLR). Likewise, the bathtub model can be used to quantify temporal events such as storm surge. Alternatively, the transportation network will return to normal post-storm event conditions if there has been no significant over-top wave action, debris loading, or prolonged saturation of the roadbed (Shen et al. 2016).

Per Cowe et al. (2004), value is a fair monetary representation of the desire to own an asset. Engineering value measures services and life expectancy guided by expert knowledge. There are five primary models for valuing transportation infrastructure: the book value, replacement cost, written down replacement cost, net salvage value, and Government Accounting Standards Board Summary of Statement No. 34[1]. For this analysis, the replacement value of the transportation network will be used to estimate the total potential damage cost of replacing or rebuilding roads via the new construction cost (Cowe et al., 2004). The new construction costs for the inundated FDOT transportation network features will be derived by associating each road segment with one FDOT Cost per Mile Model for Long-Range Estimating (LRE) for the Low SVI-High CI and High SVI-High CI vulnerable census tracts in Pinellas County, Florida.

4.3.1 Data

The data for the FDOT transportation network analysis were compiled from four primary sources (Table 34): The vulnerability mapping results (see section 4.2), the FDOT ArcGIS Online data portal, the National Hurricane Center (NHC) Storm Surge Inundation Texas to Maine Interactive Map Viewer (Zachry et al., 2015), and the Census Bureau 2020 Census Demographic Data Map Viewer (U.S. Census Bureau, 2021).

4.3.2 Methods

The spatial analysis of the FDOT transportation network was performed in ArcGIS Pro Version 2.9.0 (Esri, 2021). Microsoft Excel for Microsoft 365 MSO Version 2110 (Build 16.0.14527.20270) 64-bit (Microsoft, 2021) was used to calculate road attribute fields and community makeup characteristics and to produce data visualizations.

Firstly, the composite score Low SVI-High CI and High SVI-High CI tracts were used to define the area of interest in Pinellas County, Florida. The composite score High SVI-High CI locations represent census tracts with a high transportation vulnerability. Conversely, the composite score Low SVI-high CI areas have higher levels of transport-related vulnerabilities.

Furthermore, for the storm surge inundation locations, per Zachry et al. (2015), the U.S. Gulf and East Coast Categories for Storm Surge Inundation (SLOSH Maximum of MEOWs) (Figure 1) were used to bathtub model impacted locations in Pinellas County. The Esri (2021) intersect geoprocessing tool was used to identify the overlap between the hurricane storm surge inundation classes, composite score locations, and the FDOT transportation network features. As S. Tewari et al. (2019) demonstrated, inundation areas can be overlayed with topographic data to determine the potential extent of the impact associated with seawater encroachment.

[1]Governmental Accounting Standards Board – GASB 34: https://www.gasb.org/cs/ContentServer?c=Document_C&cid=1176160029121&d=&pagename=GASB%2FDocument_C%2FGASBDocumentPage

Table 34. Data sources, titles, fields names, and file formats for the data used in the FDOT transportation network total potential damage cost estimates

Data Source	Title	Fields Used	Format
AdbelRazig. Y., et al	comparescore	Name; compareScores	CSV
NOAA	US Gulf and East Coast Category 1 Storm Surge Inundation (SLOSH Maximum of MEOWs)	-	Esri Tile Layer
NOAA	US Gulf and East Coast Category 3 Storm Surge Inundation (SLOSH Maximum of MEOWs)	-	Esri Tile Layer
NOAA	US Gulf and East Coast Category 5 Storm Surge Inundation (SLOSH Maximum of MEOWs)	-	Esri Tile Layer
FDOT	Functional Classification TDA	FUNCLASS	Shapefile
FDOT	Divided Roads TDA	ROAD_TYPE	Shapefile
FDOT	Number of Lanes TDA	LANE_CNT	Shapefile
FDOT	Bike Lane TDA	LNCD	Shapefile
FDOT	Inside Shoulder Type TDA	ISLDTYPE	Shapefile
FDOT	Inside Shoulder Width TDA	WIDTH	Shapefile
FDOT	Outside Shoulder Type TDA	OSLDTYPE	Shapefile
FDOT	Outside Shoulder Width TDA	WIDTH	Shapefile
FDOT	Median Type TDA	MEDIAN_TYP	Shapefile
FDOT	Median Width TDA	WIDTH	Shapefile
FDOT	Cost Per Mile Models for Long Range Estimating	Model; Cost per Mile	HTML Table
US Census Bureau	2020 Census Demographic Data Map Viewer	Census Tract; Total Population	Web Map App

Many datasets needed to be aggregated to evaluate the road network in areas vulnerable to storm surge in Pinellas County. The Add Join data management tool joined multiple FDOT shapefiles into one feature class (Esri, 2021). The FDOT Functional Classification TDA shapefile features were used to join all subsequent FDOT shapefiles using the ROADWAY field to add attribute data to the road network. The shapefiles were chosen because the data points aligned with the Cost Per Mile Models.

Value data was needed to interpret the potential for economic loss due to storm surge. Sixty-one FDOT Cost Per Mile Models were analyzed and considered. Afterward, only four primary cost models matched the attributes from the FDOT shapefile features in the Low SVI-high CI and High SVI-high CI vulnerability areas in Pinellas County. The models used to obtain the replacement value were: New Construction 2 Lane Undivided Urban Arterial with 4' Bike Lanes: U01; New Construction 3 Lane Undivided Urban Arterial with Center Lane and 4' Bike Lanes: U02; New Construction Undivided Urban Arterial with 4' Bike Lanes: U03; and New Construction 4 Lane Divided Urban Interstate, Closed 22' Median with Barrier Wall, 10' Shoulders Inside and Out U06. An attempt was made to assign a conservative value from the Cost Per Mile Models to the road segments via the Functional Classification, Lane Count, and Road Type fields.

Community makeup information was used to estimate the population and land area totals in each Low SVI-high CI and High SVI-high CI census tract (U.S. Census Bureau, 2021). Population and land area data are necessary to normalize raw number findings from the analysis. In addition, the per capita, per land area, and road segment lengths were used to account for disparities between census tracts in Pinellas County (Dougherty & Ilyankou, 2021).

4.3.3 Results

The results of the analysis were follows. First, the total new construction cost of the transportation network in the (Low SVI-high CI) regions is $315 MM, and the High SVI-high CI new construction value is $284 MM (Table 35). Second, the total population of the Low SVI-high CI locations is 78,120 people, and 75,894 people for High SVI-high CI areas. Third, the length of the FDOT features in miles in the Low SVI-high CI regions is 59.7 mi and over 52 mi in High SVI-high CI vulnerability tracts, with a new construction cost of nearly $2M per mile (Table 36). Fourthly, the most impacted areas are Category 5 storm surge inundation for Low SVI-high CI vulnerability populations with a potential replacement value based on new construction costs of $185 MM and a cost per capita (1000 people) of $2.6 MM. In contrast, the least affected areas are the Category 1 inundation for High SVI-high CI vulnerability census tracts, and the potential replacement new construction cost is $25 MM with a cost per capita (1000 people) of $865 K, and $3 MM cost per capita for the associated Low SVI-high CI regions. Lastly, the total Low SVI-high CI new construction cost per capita (1000 people) is $4 MM and $3.7 MM for High SVI-high CI areas (Table 37).

In terms of the impacts to the infrastructure, the results indicate that areas with high concentrations of populations exhibiting transport-related vulnerability characteristics (ethnic & racial minority, older, & rurality) are more impacted by disasters, and higher investments are made in such areas after disaster events. This finding indicates that the infrastructure in areas with high concentrations of vulnerable populations require strengthening, and the technical measures should be placed to respond to the technical needs of the vulnerable populations, such as the quality of roads and the capacity of the network.

The map in Figure 26 shows storm surge inundated FDOT features in the Low SVI-high CI and High SVI-high CI locations. The bar graph shows the total new construction value and potential total new construction value of flooded roads.

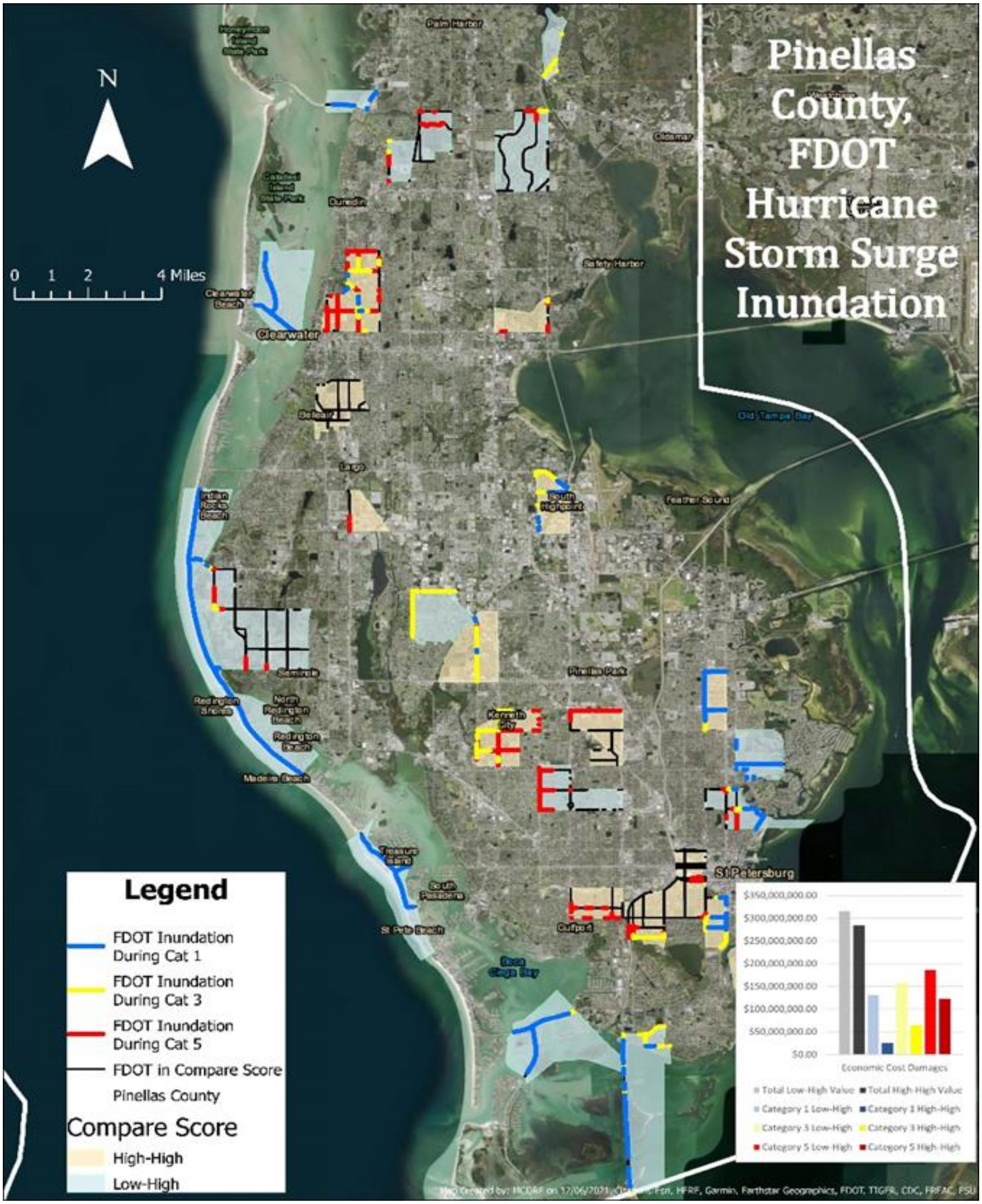


Figure 26. Pinellas County, FDOT Hurricane Storm Surge Inundation Map

Table 35. Total potential economic cost damages

Total Categories	Economic Cost Damage
Total (Low SVI – High CI) FDOT Network Value	$315,539,461.00
Total (High SVI – High CI) FDOT Network Value	$284,383,256.00
Category 1 Inundation (Low SVI – High CI)	$131,319,615.00
Category 1 Inundation (High SVI – High CI)	$25,291,805.00
Category 3 Inundation (Low SVI – High CI)	$158,319,928.00
Category 3 Inundation (High SVI – High CI)	$64,330,152.00
Category 5 Inundation (Low SVI – High CI)	$185,727,934.00
Category 5 Inundation (High SVI – High CI)	$123,331,342.00

Table 35 shows the inundation categories and the total potential new construction replacement value of impacted roads.

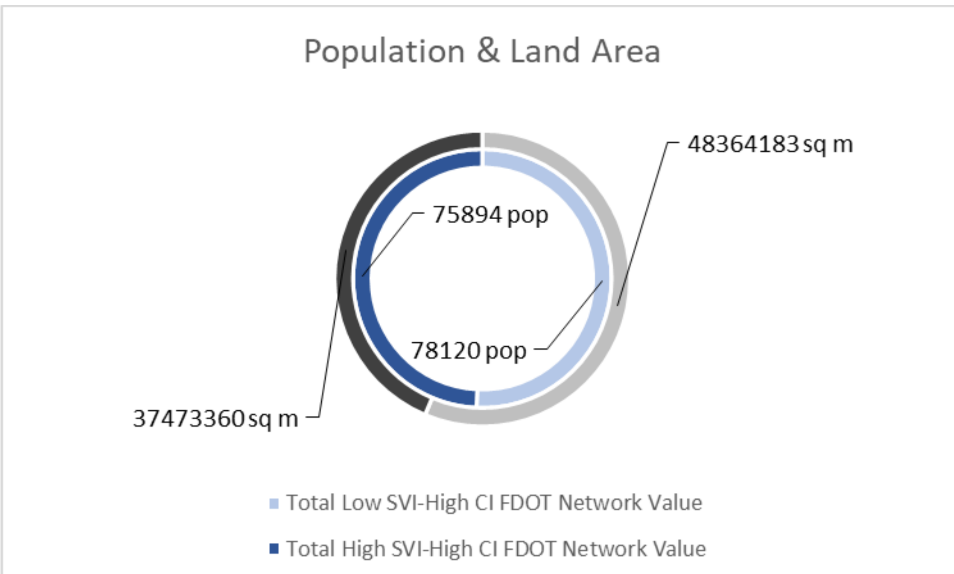


Figure 27. Population and transportation network length

The pie chart in Figure 27 shows the total population and transportation network length in Low SVI-high CI and High SVI-high CI vulnerability tracts.

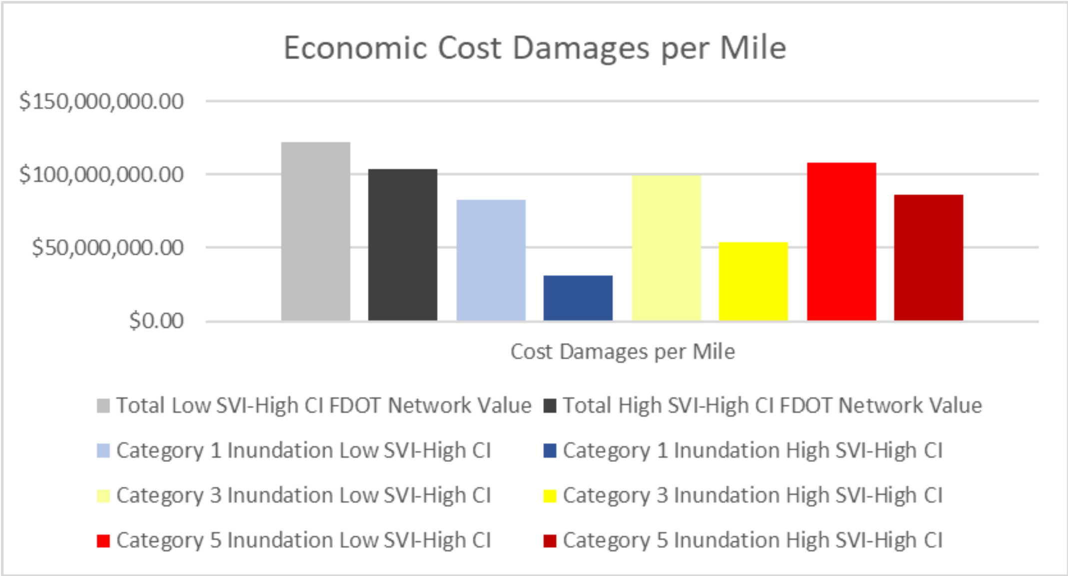


Figure 28. Transportation network lengths in miles and cost damages per mile

Table 36 shows the comprehensive transportation network in Low SVI-high CI, High SVI-high CI, Hurricane Category-One, -Three, and -Five Storm Surge Inundation classes. The table also shows the potential replacement cost from damages per mile.

Table 36. Transportation network lengths in miles and cost damages per mile

Total Categories	Cost Damages (per mile)	Transportation Network (miles)
Total (Low SVI – High CI) FDOT Network Value	$2,053,492.00	59.70
Total (High SVI – High CI) FDOT Network Value	$1,995,663.00	52.20
Category 1 Inundation (Low SVI – High CI)	$3,456,295.00	23.20
Category 1 Inundation (High SVI – High CI)	$6,362,281.00	4.90
Category 3 Inundation (Low SVI – High CI)	$3,525,018.00	28.20
Category 3 Inundation (High SVI – High CI)	$4,149,050.00	12.90
Category 5 Inundation (Low SVI – High CI)	$3,211,019.00	33.80
Category 5 Inundation (High SVI – High CI)	$3,496,583.00	2.47

Table 37 shows the potential total replacement value of the road network in each inundation category per capita.

Table 37. Cost Damages per Capita (1000 people)

Total Categories	Cost Damages per capita (1000 people)
Total (Low SVI – High CI) FDOT Network Value	$4,039,164.00
Total (High SVI – High CI) FDOT Network Value	$3,747,111.00
Category 1 Inundation (Low SVI – High CI)	$3,106,025.00
Category 1 Inundation (High SVI – High CI)	$865,062.00
Category 3 Inundation (Low SVI – High CI)	$2,621,321.00
Category 3 Inundation (High SVI – High CI)	$1,429,527.00
Category 5 Inundation (Low SVI – High CI)	$2,666,934.00
Category 5 Inundation (High SVI – High CI)	$1,860,650.00

4.3.4 Limitations

During the economic impact analysis phase, several limitations to the analysis process were discovered. Unfortunately, the FDOT Cost per Mile Models R01-O05 do not account for the numerous combinations of road feature attributes found in Pinellas County, Florida. Thus, an extensive list of Cost per Mile Models should be generated from the FDOT LRE Tool (FDOT, 2021b) or obtained from FDOT. Likewise, the AASHTOW Project Webgate Exporting Application for Historical Average Reports (FDOT, 2021a) may offer information for valuing road assets, but special permission must be granted via FDOT before login.

Likewise, the FDOT transportation network data, the Pinellas County Commissioners data, and Property Appraisers GIS portal data were incomplete. For example, there are virtually no feature polygons, construction dates, milling and resurfacing dates, condition indicators, materials field (paved, dirt, or grass), and indeed no values. However, the original construction date and the milling and resurfacing dates could aid in calculating depreciation (Cowe et al., 2004).

4.3.5 Discussion and Conclusions

The estimates produced by this analysis represent the replacement value of the roads inundated by storm surge, based on the total potential for new construction costs. This study helped to highlight the differences in the replacement value for road segments in composite score Low SVI-high CI and High SVI-high CI transportation vulnerability populations impacted by hurricane storm surge in Pinellas County, Florida. Many other variables can gauge the economic impact of storm surge interacting with a road network. For example, resilience and vulnerability cost modeling related to storm surge considers the temporal loss of access to critical community and emergency facilities (Shen et al., 2016). Estimating the volume and duration of debris removal needed to get the transportation network operational after a hurricane could improve vulnerability and resilience cost estimates.

Likewise, more road features are needed to analyze each area in Pinellas County. The street features can be estimated based on street-sized gaps in the county parcel layer or remotely sensing the transportation network roads using an aerial or satellite product to generate road polygons from pixel classification. In the future, FDOT should be brought on board in the project's planning phase to provide enriched data with values.

Indeed, a rigorous study needs to be done on the transportation network in Florida. First, accurate and near-complete transportation network data must be generated. Then, the cost/value of the roads should be estimated with the help of FDOT. Furthermore, the potential for debris crossing the street during a storm needs to be analyzed. Afterward, the predicted debris results should be compared to historical post-storm debris removal operations. Lastly, the dollar amount for loss of access to critical assets, critical community and emergency facilities, and evacuation routes should be quantified.

4.3.6 Economic Impacts Analysis for Social Impacts on the Vulnerable Populations

The Center for Economic Forecasting & Analysis (CEFA) at Florida State University conducted the social economic impact analysis for the project. CEFA used a well-established analytical tool known as the Impact Analysis for Planning, or IMPLAN® model. IMPLAN is a widely accepted integrated input-output model that is used extensively by state and local government agencies to measure proposed legislative and other program and policy economic impacts across the private and public sectors. There are several advantages to using IMPLAN:

- It is calibrated to local conditions using a relatively large amount of county level and State of Florida specific data;
- It is based on a strong theoretical foundation, and;
- It uses a well-researched and accepted applied economics impact assessment methodology supported by many years of use across all regions of the U.S.

The economic impact model used for this analysis was specifically developed for the counties of Florida, which includes 534 sectors, 25 institutional sectors, and latest dataset – year 2019 data. IMPLAN's principal advantage is that it may be used to estimate direct, indirect and induced economic impacts for any static (point-in-time) economic stimulus. Consistent with standard practice, the direct impact economic losses, based on FDOT historical cost damages[1], associated with the two vulnerable populations, as well as the indirect and induced impacts are calculated for the Pinellas County area's two vulnerable case study areas (high SVI-high CI and low SVI-high CI) as described earlier in the narrative. The proposed project's broader economic losses were evaluated, measured in terms of economic output (the value of industry production), local employment or jobs, and income or wages. The loss from total economic impacts of the two case studies vulnerable populations areas (high SVI-high CI and low SVI-high CI) is the summation of the direct, indirect and induced economic cost damages[2] associated with baseline, CAT 1, 3, and 5 hurricane conditions. For the following economic impact results, the economic project team selected historical cost damages associated with an average CAT 3 hurricane for the two High SVI-high CI and Low SVI-high CI vulnerable populations.

The analysis generated the following types of multiplier effects, or economic impact losses, in the Pinellas County economy:

- Direct Impact Losses. Direct impacts relate to the short-term business activities associated with the roadway cost damages.
- Indirect Impact Losses. Indirect impacts will arise when local firms directly impacted by the cost damages in turn purchase materials, supplies, or services from other firms.
- Induced Impact Losses. Induced impacts relate to the consumption and spending of employees of firms that are directly or indirectly affected in the project area. These would include all of the goods and services normally associated with household consumption (i.e., housing, retail purchases, local services, etc.).

4.3.7 Summary of the Total Economic Impacts Losses

The total economic impacts are estimated to be 640 jobs, about $33 million in income or wages, and about $103.2 million in total economic output. Estimated total tax losses (federal, state & local) are $10,133,745. The Low SVI-high CI Cost Estimates: The total economic impacts are estimated to be 1,554 jobs, about $81.1 million in income or wages, and nearly $254 million in total economic output. Estimated total tax losses (federal, state & local) are $24,939,686. The results are summarized in Table 38.

Table 38. Summary of the total economic impact's losses on vulnerable populations in Pinellas County

Project FDOT (CAT 3) Economic Measure	Economic Output (Sales/Revenues)	Employment or Jobs	Income or Wages
High SVI-High CI Cost Estimates	$103,206,936	640	$32,967,629
Low SVI-High CI Cost Estimates	$253,997,766	1,554	$81,135,092

*** in 2021 $**

Chapter 5: Policy and Planning Recommendations

5.1 Summary

FDOT has a long-standing commitment to improving the resiliency of the state transportation system to support the safety, mobility, quality of life, and economic prosperity of Florida, while preserving the quality of our environment and communities. Years of extreme weather events have led FDOT to improve the system's resiliency including better preparation for storms and well as quicker recovery in the event of extreme weather. Use of design techniques such as pavement markings, roundabouts, high mast lighting, and planning tools such as the Sea Level Rise Sketch Planning Tool which provides roadways impact data for a range of climate and flooding scenarios has helped make Florida's transportation system inherently resilient. To solidify this commitment, FDOT enacted a Resiliency Policy to consider the resiliency of the State's transportation system. This study proposes building on the existing resilience policy and developing a complimentary resilience policy pertaining to vulnerable populations. The recommendations proposed in this chapter can provide a foundation for this complimentary vulnerable populations resilience policy.

The research team developed policy and planning recommendations to assist FDOT to improve resilience outcomes for vulnerable populations. The policy recommendations are broad in nature and are based on synthesis of all the previous project task outcomes. The policy recommendations also include corresponding implementation strategies. The planning recommendations are based on the experts and vulnerable populations survey responses, as well as statistical analysis to determine priorities of issues and concerns. Additionally, a presentation/workshop with Florida Department of Transportation (FDOT) staff was conducted to discuss and refine these planning and policy recommendations. The resilience communications guidelines are based on literature review and best-practice methods of various transportation agencies.

Efforts presented in the previous chapters focused on analyzing the transportation system's performance pertaining to the needs of vulnerable populations identified in the surveys conducted in Task 2. The four surveys (three vulnerable populations' surveys and one experts survey) were used to determine the perceptions and concerns of the vulnerable populations, and observations were made based on the perceptions of surveyed groups about the state of performance of the transportation system based on the surveys' outcomes. The concerns of the populations, as obtained from the surveys were categorized based on the timeline of the natural hazard into the following three categories:

(1) *Pre-hazard concerns:* These are the concerns of the populations during the timespan of the natural hazard and before evacuation. These concerns are used to draw conclusions about the pre-hazard system's condition because the system is not stressed from the evacuation processes.

(2) *During-hazard concerns:* These are the concerns during evacuation processes, used to draw conclusions about the system's performance when it is stressed due to traffic loads from evacuations.

(3) *Post-hazard concerns:* These are the concerns while returning from an evacuation experience (re-entry concerns), used to draw conclusions about the system's performance post-hazard. These concerns entail the short-term resilience of the system, system recovery, and adaptation to future hazards.

The concerns of the vulnerable populations and the experts obtained from the surveys and the analyses were translated into issues that are used to develop the policy and planning recommendations to improve the state of the transportation system's resilience for these vulnerable groups. The issues are summarized in Table 35.

To facilitate FDOT efforts in addressing these needs, the research team has developed two sets of recommendations: policy recommendations and planning recommendations. The policy recommendations were developed to incorporate and integrate the vulnerable populations' resilience considerations into the transportation planning and decision-making process. The planning recommendations were developed to target the specific transportation system issues pertaining to the needs of vulnerable populations (Table 39). The planning recommendations were categorized into four categories:

1. Physical conditions
2. System functionality
3. System recovery
4. Communication and outreach

The planning recommendations developed in this project tie back to the broader FTP resiliency objectives, specifically the elements of the FTP that relate to the system functionality (i.e., Complete Transportation Networks, Transform Major Elements) and system recovery & short term-resilience (i.e., Identify and Mitigate Risks, Expand Transportation Infrastructure, Update the statewide emergency evacuation plans, *and* Define strategies for preparing/responding to transportation threats).

Table 39. Transportation system issues pertaining to the concerns of the vulnerable populations

#	Issue	Groups Involved				Questions from the Surveys	
		Rural	***Minority***	***Elderly***	***Experts***	***VP***	***Experts***
1	Concerns about the condition of local roads during and post hazards (evacuation and re-entry)	Y	Y	N	Y	Q10, 13, 14, 16	Q17 to Q22
2	Concerns about the supporting elements of the system (power and communication elements) during & post hazards	Y	Y	N	Y	Q10, 13, 14, 16	Q17 to Q22
3	Concerns about the quality of the drainage elements pre, during & post hazards (presence of water on roads)	Y	Y	N	Y	Q10, 13, 14, 16	Q17 to Q22
4	Concerns about the capacity of the transportation network to support safe evacuation processes during hazards	Y	Y	Y	Y	Q10, 13, 14, 16	Q17 to Q22
5	Concerns about the fuel availability during and post natural hazards (evacuation and re-entry)	Y	Y	Y	Y	Q10, 13, 14, 16	Q17 to Q22
6	Concerns about receiving clear communications about hazards for preparation and evacuation prepardness (pre-hazards)	Y	Y	N	Y	Q10, 13, 14, 16, 27	Q17 to Q22
7	Concerns about the robustness of the network in terms of its redundancy and clearance during evacuation and re-entry	Y	Y	Y	Y	Q10, 13, 14, 16	Q17 to Q22
8	Concerns about the emergency management processes during and post hazards	Y	Y	Y	Y	Q10, 13, 14, 16	Q17 to Q22
9	Concerns about the rapidity of the recoverability of the system post-hazards (e.g., debris management, power restoration)	Y	Y	Y	Y	Q10, 13, 14, 16	Q17 to Q22
10	Concerns about the system's capacity of meeting the socio-economic needs after hazards (e.g., accessibility to healthcare, stores, jobs)	Y	Y	Y	Y	Q21 to Q31	Q23 to Q29
11	Concerns about the adaptability of the organization to future hazard events	N/A	N/A	N/A	Y	N/A	Q20 to Q29
12	The sustainability and long term resilience needs of the transportation system were not concluded from the survey, but rather, from the literature review when the hierarchial framework was developed in Task II of the project. The recommendations included in this section of the matrix are not directly related to the needs of vulnerable populations as obtained from the survey. These recommendations can be viewed as growth [long-term] efforts for the FDOT to consider to enhance the long-term resilience of the transportation system.						

5.2 Policy Recommendations

The policy recommendations are broad in nature and are based on synthesis of all the previous project tasks outcomes. The policy recommendations also include corresponding implementation strategies. The research team has identified three main policy recommendations. Each of the policy recommendations include multiple implementation strategies.

<u>Policy Recommendation 1</u>: Incorporate and integrate vulnerable populations resilience considerations across FDOT offices and functions.

Transportation systems resilience is a complex endeavor and can involve many components and processes of transportation systems. Based on the literature review, experts and vulnerable population surveys, and discussions with FDOT staff, the research team recommends effective implementation of resilience for vulnerable populations can be achieved by integrating these resilience considerations across all relevant FDOT offices and functions. These vulnerable population considerations should be part of planning, design, construction, emergency management, communication and outreach, and any other relevant entity within FDOT.

The research team has identified the following implementation strategies to achieve this policy recommendation.

1. Incorporate vulnerable population resilience considerations into FDOT asset management. These vulnerable populations considerations can be integrated with FDOT risk-based and performance-based asset management plans. In this project the research team has developed a methodology to identify hot spot areas for vulnerable populations in the context of transportation and mobility needs. FDOT can map hot spot areas for the whole state transportation system and integrate them with asset management to be used for targeted interventions for vulnerable populations such as customized maintenance cycles and intervention thresholds.

2. Establish or assign a central entity within FDOT to coordinate resilience for vulnerable populations within different offices at FDOT, as well as with other regional and local agencies. For example, it was determined from the surveys that local road conditions were one of the highly ranked concerns amongst vulnerable populations. Even though local roads are outside the jurisdiction of FDOT, it is imperative to coordinate with and guide local agencies to achieve a more effective transportation system resilience for vulnerable populations.

3. Continue to develop and support research projects to address knowledge gaps and identify opportunities for improvement of transportation system resilience for vulnerable populations. One example of a potential research project is developing implementation guidelines to integrate vulnerable population resilience into asset management. Another example is studying the feasibility and implementation issues for using new technologies to assist vulnerable populations and improve their resilience. These technologies may include autonomous vehicles, alternative energy, drones, etc.

<u>Policy Recommendation 2:</u> Identify and prioritize multimodal transportation system improvements that enhance the system's performance and reliability in vulnerable population hotspot areas.

Based on the literature review, experts and vulnerable population surveys, and discussions with FDOT staff, the research team recommends improving the transportation system modality and capacity at the hot spot vulnerable populations areas. Many of vulnerable population survey respondents indicated their inability to recover quickly after natural hazards was due to their inability to commute to work, and travel to government assistance locations, healthcare facilities, etc.

The research team has identified the following implementation strategies to achieve this policy recommendation.

1. Map and periodically update system-wide vulnerable population hot spot areas (using census track and vulnerability indexes as outlined in this project). This hotspot mapping can be utilized by FDOT, MPOs, and other local agencies to identify and map strategic multi-modal transportation corridors for vulnerable population evacuations and access to services (during and after hazards). Once these strategic corridors are identified, FDOT resources can be optimized to improve the efficiency and resilience in these vulnerable population hotspot areas.

2. Improve transit capacity and efficiency at vulnerable population hotspot areas. FDOT can coordinate with transit agencies to review and improve transit capacity and efficiency to ensure vulnerable populations can commute to work, and travel to government assistance locations, healthcare facilities, etc. after natural hazards.

Policy Recommendation 3: Promote community-based resilience approaches that improve transportation systems resilience for vulnerable populations.

Based on the literature review, experts and vulnerable population surveys, and discussions with FDOT staff, the research team recommends FDOT improve its engagement with local and regional agencies and community-based resilience initiatives to achieve the overarching goal of transportation system resilience for vulnerable populations. FDOT can be a source of guidance and support for local agencies and communities to achieve this goal.

The research team has identified the following implementation strategies to achieve this policy recommendation.

1. Coordinate and engage with MPO's and local and regional agencies, including metropolitan planning organizations (MPOs), to improve resilience for vulnerable populations, especially conditions of local roads which was identified as a major issue by both experts and vulnerable populations. FDOT can provide guidance and technical assistance to these agencies as well as coordination of efforts to achieve more effective transportation system resilience. Additionally, FDOT can identify and support local and community projects related to resilience of vulnerable populations.

2. Improve information dissemination and exchange with vulnerable populations through public involvement planning community events, social media, and other forums or means e.g., Trans Plex. Effective communication strategies would enable FDOT to better understand and respond to vulnerable populations needs and concerns.

Additionally, vulnerable population improved access to information can solve or improve some of their issues and concerns.

3. Promote and incentivize development or redevelopment in patterns that include a mix uses (housing, retail, office, etc.) and maximize opportunities to walk or take transit to destinations. One example is Transportation Oriented Development. FDOT can identify mechanisms to promote and incentivize such patterns which will improve the vulnerable population transportation resilience.

5.3 Planning Recommendations

FDOT Policy 000-525-053, Resiliency of State Transportation Infrastructure, indicates the Department will continue to: (1) identify risks; particularly related to sea level rise, flooding, and storms; (2) assess potential impacts; and (3) employ strategies to avoid, mitigate, or eliminate impacts. The policy recognizes that shocks and stresses vary across the state, and thus, the Department must collaborate with the appropriate agencies and organizations for information sharing and alignment of resiliency strategies. Elements of the policy indicate that resilience planning efforts are context specific (in terms of space and time), and thus, special considerations must be in place for different transportation system users.

Based on the literature review, experts and vulnerable population surveys, statistical analysis of the surveys, and discussions with FDOT staff, the research team developed targeted planning recommendations to address the issues and concerns identified. The research team has classified the planning recommendations into four categories based on the key issues from the survey responses (**Error! Reference source not found.**): (1) Physical conditions, (2) System functionality, (3) System recovery, and (4) Communications and outreach.

The planning recommendations are proposed as the next steps in strengthening the implementation of the FDOT's resiliency policies and plans. They will augment the efforts of the FDOT in enhancing the transportation infrastructure's resilience against two types of natural hazards (hurricanes and storm surges), for the needs of vulnerable populations. Even though these planning recommendations were developed to address specific concerns of vulnerable populations, they can still be of value to all users of transportation systems and align with the current resilience goals undertaken by FDOT. The planning recommendations are summarized in tabular format in the next four sub-sections. In each sub-section, the issues are organized according to the above categorization, and the respective recommendations are shown. Each of the recommendations' table is followed by a brief discussion on the implementation strategies and the expected outcomes where appropriate.

5.3.1 Physical Conditions

Table 40. Planning recommendations - Physical conditions of the transportation system

Issue	Priority		Actionable Recommendation(s)	Responsible Department/Agency
	VPs	Experts		
#1: Concerns about the condition of local roads during and post hazards (evacuation and re-entry)	High	High	• Engage with and provide guidance to local agencies to identify areas where local roads conditions are substandard. • Prioritize funding and local guidance for areas with high concentrations of vulnerable populations and prioritize the debris removal from local roads in these areas. • Identify and map transportation network corridors critical for vulnerable populations during hazards.	State FDOT, MPOs and Local Departments

Issue	Priority		Actionable Recommendation(s)	Responsible Department/Agency
	VPs	Experts		
#2: Concerns about the supporting elements of the system (power and communication elements) during & post hazards	High	High	• Develop and have protocols for rapid maintenance of supporting elements within critical areas of the network in vulnerable population areas. • Enhance the robustness of the transportation system by having in-place solar power alternatives in critical roadway sections, especially those serving the evacuation and re-entry process. • Use technologies (drones, sensors, fixed cameras) to assess and monitor drainage and road conditions during and after hazards.	State FDOT, MPOs and Local Departments Utility and communications providers

Issue	Priority		Actionable Recommendation(s)	Responsible Department/Agency
	VPs	Experts		
#3: Concerns about the quality of the drainage elements pre, during & post	High	High	• Identify areas where the condition of the drainage systems is sub-standard as	FDOT and Local Agencies

hazards (presence of water on roads)			it relates to hazards that result in evacuations.	
			• Develop and document plans to guide the funding process of enhancing the capacity of the drainage systems in critical areas based on the future risk-scenarios of these areas.	
			• Consider adopting an adaptive planning process to maximize the utility of the available resources and funds based on the needs of the areas of vulnerable populations (e.g., risk-adjusted decision trees).	

The above set of recommendations were developed to strengthen the physical conditions of the (sub-systems) transportation system. The survey results (Task III) show that there are three system components that are of high levels of concerns to the vulnerable populations and the experts during natural hazards. These system components are:

- Local roads within vulnerable populations areas, especially areas with high concentrations of rural and minority populations.
- The quality of supporting elements of the transportation system, namely, the power infrastructure and the communications infrastructure within the roadway network (e.g., traffic signals, hazard signs, etc.).
- The capacity of the drainage systems during natural hazards, and their capabilities of reducing the risks of flooding within the roadway section, especially along evacuation routes.

The recommendations shown in tables above can be implemented in three pre-hazard phases on the basis of information-driven decision making (Figure 29):

- The first phase, (Documentation of Information) is intended to identify the risk areas and allow the FDOT to document the information required to make informed decisions in the case of a natural hazard. This phase includes identifying the risk areas by engaging and coordinating with local agencies and emergency management offices (EMOs) to document the critical sections of the transportation systems during natural hazards (e.g., mapping process). These critical sections can be sub-optimal local roads connecting to main evacuation routes (e.g., highways), and/or local roads in areas where vulnerable populations are highly concentrated. The existence of such information and maps can allow the involved agencies to better monitor hazard events and allocate resources appropriately.
- The second phase is the actual decision-making process. In this phase, FDOT could implement the actionable recommendations that result in positive change to address the

concerns of vulnerable populations, such as making investment decisions to increase the robustness of the supporting power systems by exploring using alternative energy such as solar power for traffic lights. FDOT could engage with local agencies in discussions and determine the appropriate investments according to the information gathered in the first phase

- The third phase (Documenting the Strategy) is intended to document the plans required to address the special needs of vulnerable populations. This phase depends on the implementation of the first and the second phases, especially as they relate to the prioritization of funds and resource allocations. The value of having the strategies documented is allowing the involved agencies to have a clear vision and a guide to make timely decisions when required. Availability of such documents is important to coordinate efforts between the state and the local departments involved in serving the mobility related needs of vulnerable populations.

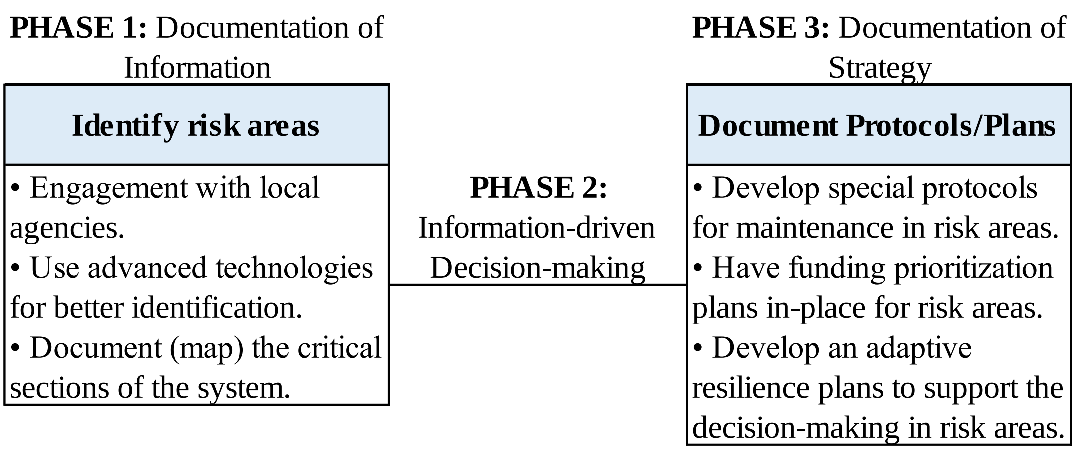


Figure 29. Pre-hazard recommendations plan

Figure 29 illustrates a timeline for the implementation of the planning recommendations shown in Table 36, Recommendations related to identifying the risk areas (or the vulnerable populations hotspots) should be implemented before documenting the plans for mitigating or eliminating the risks. This will allow FDOT to make better decisions when it comes to strengthening the resilience of the network in critical sections.

In addition to improving the physical conditions of the local roads and supporting infrastructure elements, and the drainage systems for transportation infrastructure, these recommendations are expected to improve FDOT's capacity in implementing its resilience plans by developing protocols and methodologies that can assist in guidance and support of local agencies, especially in issues related to investments made to enhance the strength of the technical infrastructure components of the transportation system.

5.3.2 System Functionality

Table 41. Planning recommendations - The functionality of the transportation system

Issue	Priority		Actionable Recommendation(s)	Responsible Department/Agency
	VPs	Experts		
#4: Concerns about the capacity of the transportation network to support safe evacuation processes during hazards	High	High	• Formulate guidelines for the evacuations to prioritize the vulnerable populations. Have phased-evacuation processes to avoid excessive traffic and road closures.	State (FDOT), (MPOs) and Local Agencies
			• Promote the use of transit for vulnerable and other populations for evacuation, and plan pickup spots for people without access to vehicles.	
#7: Concerns about the robustness of the network in terms of its redundancy and clearance during evacuation and re-entry			• Develop plans to enhance the communication process with respect to evacuation alerts, and document clear guidelines for the communications with groups that are at-risk, specifically due to the lack of clear guidance (e.g., on-native speakers)	
			• Prioritize and expedite facilities and road-related restoration services for return after hazards.	

Issue	Priority		Actionable Recommendation(s)	Responsible Department/Agency
	VPs	Experts		
#5: Concerns about the fuel availability during and post	High	High		

Issue	Priority		Actionable Recommendation(s)	Responsible Department/Agency
natural hazards (evacuation and re-entry)			• Develop maps of all gas stations overlayed with areas of special needs (e.g., identified rurality)	State (FDOT), (MPOs) and Local Agencies
			• Develop and document plans to adjust the future land use plans to expand gas stations as an approved use in fuel deserts.	
			• Have protocols in place to communicate with vulnerable populations in fuel deserts and offer guidance about where they can find fuel resources, especially when evacuation is required.	
			• Offer guidance to formally integrate communications about fuel availability, and monitoring fuel availability during disasters within the pre-emergency planning processes of EMOs.	
			• Encourage and promote the use of electric vehicles (EVs) for vulnerable populations (e.g., provide charging stations, disseminate information about EVs, etc.)	

Issue	Priority		Actionable Recommendation(s)	Responsible Department/Agency
	VPs	Experts		
	High	High		

#8: Concerns about the emergency management processes during and post hazards			• Create a forum for community members to channel their input (mobility related) in the long-range and short-term projects that address transportation system resilience/recovery.	State (FDOT): Collection of mobility related data. Local Emergency Management Agencies.
			• Offer guidance to the EMOs to formally integrate the obtained concerns of community members in emergency management processes and develop methods to communicate clear indicators to the populations about hazards, especially as they relate to their concerns.	
			• Integrate the strategic, programmatic, and tactical elements of the EMOs' local mitigation plans within the FDOT resiliency plans where appropriate; then develop and document a shared vision about the safety goals of the transportation system, especially for vulnerable populations.	

The above set of recommendations was developed to address the concerns of the vulnerable populations and the experts about the functionality of the transportation system (the network and the supporting elements), especially as it relates to the evacuation and re-entry processes during natural hazards.

The recommendations are expected to strengthen/improve the following:

- The disaster debris management processes of the evacuation routes (connecting roadway sections and highways in risk areas).
- The disaster debris management processes of the critical roadway (roadway sections connecting to essential services such as healthcare and grocery stores) and sections within areas where vulnerable populations are highly concentrated (especially the rural and minority groups).
- The availability of fuel during natural hazards.
- The communication efforts between the owners and operators of the transportation system (including FDOT and the local departments) and the transportation system's users to incorporate the input of the users into the resilience planning process.

The recommendations shown in Table 37 can be implemented by adopting a similar framework to the one shown in Figure 29. The agency is advised to collect and document the relevant data that assist in the decision-making process (such as the mapping of areas with fuel shortages, and information from vulnerable communities and other transportation system users), then share the information with other involved agencies (e.g., local agencies, and emergency management offices) to be integrated in their emergency plans. Documenting the decisions (plans and protocols) is crucial for the successful implementation of these recommendations.

5.3.3 System Recovery

Table 42. Planning Recommendations - The recoverability of the transportation system

Issue	Priority		Actionable Recommendation(s)	Responsible Department/Agency
	VPs	Experts		
#9: Concerns about the rapidity of the recoverability of the system post-hazards (e.g., debris management, drainage systems restoration, power restoration)	High	High	• Prioritize and expedite the debris clearance and road repair processes in vulnerable populations hotspot areas, especially in critical roadway sections that provide accessibility to basic services (e.g., healthcare and retail stores). • Prioritize the road clearance work before other road services, e.g., repair/maintenance processes. • Consider integrating the national flooding guidelines within the organization's emergency plans and promote these policies where appropriate to avoid flood damages.	State (FDOT), (MPOs) and Local Agencies

Issue	Priority		Actionable Recommendation(s)	Responsible Department/Agency
	VPs	Experts		
#10: Concerns about the system's capacity of meeting	High	High	• Develop plans to ensure that transportation system services are	Federal, State, and Local

the socioeconomic needs after hazards (e.g., accessibility to healthcare, stores, jobs)			available to vulnerable populations post-hazards.	
			• Develop plans to use public transit services to connect vulnerable populations to essential services (FEMA funds can be allocated to waive/reimburse the transit fees to low-income groups).	
			• Provide adequate transportation access to post-hazard services e.g., unemployment assistance, healthcare, etc.	

Issue	Priority		Actionable Recommendation(s)	Responsible Department/Agency
	VPs	Experts		
#11: Concerns about the adaptability of the organization to future hazard events	High	High	• Develop an overarching vision to adopt adaptive resilience practices within the FDOT.	State and Local
			• Document the vision and develop a plan that mandates the consideration of previous disaster events in the resilience planning processes of the FDOT and local agencies.	
			• Provide clear guidelines for applications of the adaptive resilience process among all the stakeholders. The plans should facilitate the communication processes between the agencies to allow for an effective and timely decision-making process.	
			• Have plans to review and enhance policies in the process of updating local and regional transportation plans and ensure that the policies are directed towards protecting the needs of vulnerable populations.	

The recommendations for system recovery are intended to support the system's performance to meet the vulnerable populations' needs post hazards. These recommendations address the system's performance from three fronts:

- Safety of the transportation network, specifically as related to addressing clearance of disaster debris from the network and standing water due to the incapacitation of the drainage systems.
- The connectivity of the transportation network. This includes the clearance of the critical roadway sections [connecting the vulnerable populations to healthcare and other essential services], and the availability of transit services post-hazards.
- The adaptability of FDOT and other agencies to hazards, and their capacity to improve their performance to enhance the long-term resilience of the transportation system.

The implementation framework shown in Figure 33 can be followed to implement the System Recovery strategies. Having a clear and shared vision among the involved agencies through well-documented plans is essential for the effective implementation of post-hazard strategies, especially since time is critical to the recovery of the impacted vulnerable populations.

It is worth mentioning that the concept of adaptive resilience planning is of great value to the FDOT to manage its existing resources during hazards. The adaptive planning concept is a process that starts by documenting a basic plan based on the most likely scenario and plans further for potential future events by documenting a series of actions with specific trigger points to guard the system (and its users) against enhanced vulnerabilities hindering the efficient performance of the system to meet its goals (Holling, 1996; Singh et al., 2020; Smit et al., 2000; UNISDR, 2012; Wall et al., 2015). The agency is encouraged to use its existing plans as the basic plans, then plan further to update the plans and include trigger points and additional protocols based on the results obtained in this research. The following considerations are of value when considering the adaptive planning process to meet the System Recovery concerns:

- Consideration of previous disaster events, including an assessment of the costs which could have been avoided if more effective plans were set (e.g., timely implementation of emergency management protocols such as the delivery of alerts and evacuation notices, quicker debris removal, etc.). The consideration of such information would allow the agency to update its protocols to avoid costs stemming from implementation issues within the system.
- Consideration of the role of inputs of the vulnerable communities (systems users). The recommendation made in section **Error! Reference source not found.** to enhance the emergency management processes (set #3) are of considerable value to the system recovery and the concept of adaptive resilience planning. Obtaining information from the system users through different communications avenues would provide valuable data to FDOT to determine the appropriate trigger points and develop appropriate actions to take to address these trigger points.
- Documenting plans and setting clear protocols to update the adaptive plans and sharing such protocols with local agencies are important. Having a shared vision would make the flow of information and data exchange more effective between agencies.

The adaptive planning concept is an emerging concept in the resilience literature to deal with future uncertainties. While this concept is of greater value when dealing with system recovery and the long-term resilience goals of the transportation system, the elements of the concept are applicable in other aspects as well. The same concept can also be used to enhance the implementation of the other sets of recommendations in this document (i.e., the Physical Conditions, the System Functionality, and the Communications and Outreach).

5.3.4 Communications and Outreach

Table 43. Planning recommendations to enhance the communications and outreach efforts

Issue	Priority		Actionable Recommendation(s)	Responsible Department/Agency
	VPs	Experts		
#6: Concerns about receiving clear communications about hazards for preparation and evacuation preparedness (pre-hazards)	High	High	• Coordinate with Florida's Department of Emergency Management, MPOs, and local EM to improve information dissemination about hazard events.	State (FDOT), (MPOs) and Local Agencies
			• Streamline hazard-related communications through regular media and social media.	

Many governmental institutions are shifting their attention towards the role of collaboration in achieving successful transportation management (FHWA 2018[1]). Transportation agencies across the nation are now pursuing collaboration as an input to advance their performance management practices. To improve on this front, there is a need for theoretical and operational guidance that informs future actions and best practices. The relationship between collaboration and performance was further emphasized by the inclusion of external collaboration as one of the 10 components of the transportation performance management framework (TPMF) (FHWA 2018[1]). The TPMF is a strategic data-driven approach that utilizes information to make informed investment and policy decisions to achieve the performance goals. Within this framework, external collaboration and coordination are defined as the effort to organize people (or groups) to work together effectively to accomplish a given task. This will allow partners to leverage from resources and capabilities to establish goals, objectives, evaluate performance, and develop planning documents and programs. The TPMF views collaboration as a necessary element for effective performance and outlines the potential interactions and feedback between collaboration and the other framework components. Despite the theoretical benefits emphasized by the framework, it offers limited guidance on the process of operationalizing the regional collaboration (Smith-Colin, Amekudzi-Kennedy, & Kingsley,2021).

[1] FHWA (Federal Highway Administration). 2018. "TPM toolbox." Accessed

The recommendations shown in **Error! Reference source not found.** are intended to strengthen the coordination and collaboration efforts between the FDOT and other agencies involved in mobility-related efforts. Research-based evidence shows that the availability of resources and access to tools for collaboration cause significant differences between high-performing and low-performing collaborations (Smith-Colin et al., 2021). A well-structured and documented plan to guide the collaboration efforts is a key factor in their effective implementation.

The set of recommendations outlined in the table can be of benefit to other efforts within the agencies, such as enhancing the planning process for improving system functionality. To make the efforts directly tied to the specific concerns of the vulnerable populations and experts (concerns about clear communications), the developed documents by the FDOT should clearly outline the objective(s) of the coordination and set specific performance measures to track the progress towards these specific objectives.

While developing the coordination documents and setting the objectives to address the communications concerns, the following questions (not limited) should be kept in mind to guide the process:

- What were the goals of previous communication efforts (e.g., alerts about hazards, mandating evacuation…) and how was the timeline for communication determined?
- Who were the target group(s)? And how were they determined?
- What were the methods involved in the communications and were they context-sensitive? (e.g., using social media may not be the best method of communications for some rural and elderly populations).

Thinking about such issues would help the agency use information from previous disaster events to set clear objectives that can be used to focus the efforts by multiple agencies and make it directed towards a common goal. This would also allow the agency to determine the appropriate tools for collaboration.

Additionally, FDOT is encouraged to improve communications with vulnerable populations especially around natural hazard events. Examples of outreach efforts include community engagement events such as Transportation Day, increased regular media and social media presence and updates, and frequent interviews and surveys.

5.4 Resilience Communications Guidelines

Resilience is a complex endeavor, and it involves internal and external entities including multiple offices within FDOT, other government agencies and partners, and the public. Having a structured resilience communications plan could benefit FDOT, regional and local agencies, the general population, and vulnerable populations.

The following are general resilience recommendations for communications and outreach regarding vulnerable populations.

1. Communication within FDOT and with Other Agencies:
    - Clearly define what constitutes vulnerable populations and resilience goals and desired outcomes for these populations.
    - Develop specific initiatives (messages) and align them with agency goals.
    - Be consistent with messages and deliver them multiple times through multiple avenues.
    - Customize the message to the audience and the audience's specific set of skills and responsibilities.
    - Continue to educate staff and partners using seminars, workshops, online training, etc.
    - Conduct frequent interactive engagements for brainstorming and feedback.
    - Measure the agency communication plan's effectiveness. Solicit evaluations, develop metrics, and collect data.
2. Communication with Vulnerable Populations:
    - Utilize multiple channels to reach out to vulnerable populations: regular media, social media, mail, community events, etc.
    - Simplify the message and provide context or explanation when needed.
    - Focus on framing the messages in a positive way, e.g., correct misconceptions, depoliticize the messages, etc.
    - Understand your target audience and tailor the message to the audience. Be sensitive to cultural, racial, educational background.
    - Focus on local contexts and impacts.
    - Use visuals to overcome language and education barriers.

Chapter 6: Conclusions

For this research project, the following specific tasks were performed:

1. *Literature Review:* A comprehensive literature review was conducted to achieve the following objectives: (1) to provide a general understanding of the concept of social vulnerability and the attributes that define socially vulnerable groups and to provide a discussion on the practical challenges of determining social vulnerabilities, (2) to discuss the concept of resilience in the context of transportation, especially for vulnerable populations, and highlight the difficulties associated with measuring the resilience of transportation systems, and (3) provide discussion on some of the viable approaches used to incorporate resilience in transportation systems planning pertaining to vulnerable populations.

2. *Experts and Vulnerable Populations Surveys:* The surveys' task objective was to understand the perceptions shared by transportation experts and vulnerable populations (older adults, ethnic minority, and rural populations) about the resilience of transportation systems. To this end, two surveys were designed and deployed using two different online surveying platforms. The results of the surveys provide insights about the specific concerns of both the experts and vulnerable populations about the transportation systems' performance before, during, and after natural hazards. The surveys requested basic data on the respondents' organizations, demographics, and socioeconomic status; and four content-specific sections aimed to investigate the following: (1) previous disasters Experiences, (2) mobility and resilience, (3) economic impacts, and (4) social impacts.

3. *Assessment of Transportation Systems Resilience for Vulnerable Populations:* This task focused on analyzing the results of the surveys administrated in Task II to, firstly, determine and prioritize the needs (concerns) of vulnerable populations and, secondly, evaluate the transportation systems' capacity in meeting these needs. The results of this task provide methodologies and tools to identify, analyze, and prioritize transportation systems' resilience needs of vulnerable populations as well as to determine the hotspot areas for vulnerable populations. For this task, the following broad outcomes were achieved: (1) statistical analysis of the two surveys, (2) geospatial analysis for vulnerable population case study areas, and (3) economic analysis for the case study areas.

4. *Policy and Planning Recommendations:* This task focused on developing policy and planning recommendations based on the surveys and analysis performed in Tasks II and III of the project and developing resilience communications guidelines. The outcomes of this task provide recommendations that can be integrated into the Florida Transportation Plan's (FTP) Vision and Policy elements as well as potential future research topics. The policy recommendations are broad in nature and are based on synthesis of all the project findings. The policy recommendations also include corresponding implementation strategies. The planning recommendations are based on the experts and vulnerable populations survey responses, as well as statistical analysis to determine priorities of issues and concerns. Additionally, a presentation and workshop with Florida

Department of Transportation (FDOT) staff was conducted to discuss and refine these planning and policy recommendations. The resilience communications guidelines are based on literature review and best-practice methods of various transportation agencies. The outcomes of this task were: (1) Development of policy recommendations and their potential implementation strategies. (2) Development of actionable planning recommendations including their priority importance to vulnerable populations. (3) Development of general vulnerable populations resilience communication guidelines. (4) Review of proposed recommendations with Florida Department of Transportation (FDOT) staff during a presentation/workshop conducted on April 20, 2022.

6.1 Key Findings

Resilience Planning

- Current resilience and emergency management planning processes identify the actions that agencies take to mitigate the impacts of natural hazards on transportation systems, but to lesser extent they include means to protect people, especially those belonging to vulnerable groups.
- More studies must be conducted to understand the relationships between the social vulnerability attributes and the geophysical factors that result in increased levels of vulnerabilities to natural hazards.

Vulnerable Populations Survey Perceptions

- The quality of infrastructure elements (e.g., the drainage system) is of high concern among the surveyed experts. This indicates that the transportation system has high levels of vulnerability during natural hazards.
- In both surveys, the functionality of the transportation system (i.e., provision of basic mobility) during natural hazards is an issue of high concern and should be prioritized.
- There are consistent levels of high concern about the safety of the transportation system during natural hazards (as reported by the three groups of vulnerable populations).

Experts Survey Perceptions

- The experts survey indicated that the disruptions of the transportation system due to natural hazards lead to negative social and economic impacts on vulnerable populations. This finding was further validated by the vulnerable populations survey, as the majority of the respondents reported suffering socioeconomic impacts due to transportation related issues.

Research Team's Analysis

- Ranking of importance (prioritization) of resilience issues was developed using statistical analysis of the surveys' results.
- Vulnerability hotspot maps were prepared to identify the locations of vulnerable populations along the I-4 corridor (the study area) using Census Tract, Social Vulnerability Index (SoVi), and Composite Index (CI) developed by the research team.
- The developed economic impact analysis supports the main hypothesis, as areas with high concentrations of vulnerable populations suffer higher impacts than other areas. These

impacts are both technical (cost damages to the roads) and social (suffered by the populations in terms of loss of employment, loss of income, loss of economic output, and loss of tax-revenues).

Research Team's Recommendations

- Policy recommendations are broad in nature and are based on synthesis of all the previous project tasks outcomes. The policy recommendations also include corresponding implementation strategies. The policy recommendations include:
    1. Incorporate and integrate vulnerable populations resilience considerations across FDOT offices.
    2. Identify and prioritize multimodal transportation system improvements that enhance system's performance and reliability in vulnerable population hot spot areas.
    3. Promote community-based resilience approaches that improve transportation systems resilience for vulnerable populations.
- The planning recommendations are based on the experts and vulnerable populations survey responses, as well as statistical analysis to determine priorities of issues and concerns. The planning recommendations are categorized as follows:
    1. Physical conditions
    2. System functionality
    3. System recovery
    4. Communications and outreach

6.2 Recommendations for Future Research

Based on synthesis of all the findings of this project, the research team recommends to FDOT to continue to develop and support research projects to address knowledge gaps and identify opportunities for improvement of transportation system resilience for vulnerable populations.

The research team recommends studies in these areas:

1. Developing implementation guidelines to integrate vulnerable population resilience into FDOT asset management. Integrating vulnerable population resilience guidelines will streamline the planning, design, and construction of transportation systems for vulnerable populations. For example, including specific interventions threshold for vulnerable populations hotspot areas will facilitate resilience outcomes improvement for these populations.
2. Studying the feasibility and implementation issues for using technologies to improve transportation planning for vulnerable populations resilience. These technologies may include remote sensing, autonomous vehicles for transit, alternative energy, drones for reconnaissance and emergency management, and other appropriate technologies.

3. Identify and map state-wide vulnerable population hot spot areas (using census track and vulnerability indexes as outlined in this project). This hotspot mapping can be utilized to identify and map strategic multi-modal transportation corridors for vulnerable populations

evacuations and access to services (during and after hazards). Once these strategic corridors are identified FDOT resources can be optimized to ensure the efficiency and resilience of its transportations system for these vulnerable populations hotspot areas.

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Appendices

Appendix A: Social Vulnerability and GIS Assessment

Appendix 1 is organized as follows: in the first section, the definition of place-based social vulnerability is established, and the overall research streams including case studies conducted in Florida are identified. Secondly, the weighting issue (one of the issues involved in determining the social vulnerability scores) is discussed. Thirdly, social vulnerability assessment using GIS from choropleth mapping to spatial associations using statistical techniques such as geographically weighted regression is discussed. Finally, discussion about local contexts related to the modifiable areal unit problem's effects on social vulnerability computation is presented.

Vulnerability to Natural Hazards

Wisner and Luce (1993) noted that vulnerability does not simply mean poverty. They suggest vulnerability is a deeper concept that can be deconstructed by one's personal and social characteristics such as gender, ethnicity, age, and disability, which are all factors relating to potential unequal access to resources.

Vulnerability research can be considered as proceeding along a series of themes working around three interrelated areas. The first is the study of potential exposure to hazards, treating vulnerability as a pre-existing condition. The second is to study the differentiation of vulnerability among people and communities. The third theme is to assess vulnerability from a 'hazards-of-place' perspective, considering potential exposure to hazards and differential loss (Rygel, O'sullivan, & Yarnal, 2006).

The concept of 'hazards-of-place' model (HOP model) of vulnerability was developed by Cutter (1996). This came from the idea that exposure to hazards and a vulnerable population necessarily occupy 'places.' The sentiment of the HOP model is based on the thought that people living in vulnerable places will be unequally vulnerable to hazards due to their social, economic, and political characteristics. In general, in the United States the model is constructed based on a certain spatial unit, such as counties, census tracts, or census block groups, and explores differentiation of vulnerability across areas.

As the most popular and widely used vulnerability index, the Social Vulnerability Index (SoVI) is a quantitative social vulnerability measure to natural hazards. It was developed in 2003 and applied to counties in the United States. The index has gained general acceptance as one of the representative measures for social vulnerability (Cutter, Emrich, Morath, & Dunning, 2013).

Table A1. Social vulnerability concepts and their effects (Source: Cutter et al. (2003))

Concept	Effect on social vulnerability (+ indicates increased vulnerability; - indicates decreased vulnerability)
Socioeconomic status	High status (+/-) Low income or status (+)
Gender	Women (+)
Race and ethnicity	Nonwhite (+) Non-Anglo (+)
Age	Elderly (+) Children (+)
Commercial and industrial development	High density (+) High value (+/-)
Employment loss	Loss (+)
Rural/urban	Rural (+) Urban (+)
Residential property	Mobile homes (+)
Infrastructure and lifelines	Extensive infrastructure (+)
Renters	Renters (+)
Occupation	Professional or managerial (-) Clerical or laborer (+) Service sector (+)
Family structure	High birth rates (+) Large families (+) Single-parent households (+)
Education	Little education (+) Highly educated (-)
Population growth	Rapid growth (+)
Medical services	Higher density of medical (-)
Social dependence	High dependence (+) Low dependence (-)

Special needs populations	Large special needs population (+)

This was the first research that used SoVI provided factors and their influences on social vulnerability (Table A1). Of these concepts, age, gender, race, and socioeconomic status are generally accepted (Cutter et al., 2003). In addition to socioeconomic status, these concepts include characteristics of the built environment (e.g., commercial and industrial development, and rural/urban classifications), medical services, and social dependence. This is a good starting point to understand what factors social vulnerability includes. Based on these concepts, Cutter et al. (2003) collected 42 initial variables and used 11 principal components as the final SoVI.

There is a common methodological procedure to assess social vulnerability. The tasks include a selection of variables, data collection and normalization, principal component analysis (PCA), construction of composite scores, and GIS mapping (Tate, 2013). In the first step, variables that can be relevant to vulnerability are selected. The second step is to collect data, then the data are normalized and standardized for the next step due to the different scales of each variable. The third step is to reduce data dimensionality. In this step, principal component analysis, which is one of the techniques that reduce data dimensionality, is employed to reduce multicollinearity among the variables selected. In the next step, using the results of the PCA, scores are composited with weighting. The last step is to explore areas that are vulnerable by mapping the composite scores.

Several vulnerability indexes that are derived from the SoVI have been introduced to date. The following indices originated from the SoVI and have a specific objective to certain domains. For instance, the Flood Vulnerability Index (FVI) is a measure that assesses vulnerability to flood hazards (Balica et al., 2009). Medical Vulnerability Index (MedVI) proposed by Morath (2010) is also a subset of SoVI, takes into account medical vulnerability. And the Coastal Community Social Vulnerability Index (CCSVI) considers the coastal community against coastal hazards (Bjarnadottir et al., 2011).

The United State Department of Transportation (USDOT) provided a guide for transportation agencies which are interested in assessing their vulnerability to hazards. They suggested that key climate variables to be considered are temperature, extreme precipitation events, sea-level and coastal storm surge, permafrost thaw, and snowmelt hydrology.

Yoon (2012) assessed the social vulnerability to natural hazards in counties along the Gulf of Mexico and Atlantic coastal areas, comparing two approaches: a deductive approach using standardization techniques and an intuitive approach using data-reduction techniques. The study showed that vulnerable coastal counties are more affected by disaster damages and the two approaches produced different outcomes although the difference was insignificant.

Hames et al. (2017), using Cutter's SoVI and Morath's MedVI, assessed the social and medical vulnerability of older adults living in the tri-county region in south Florida. They also used the PCA method for data reduction. Despite using GIS, their analysis was primarily limited to the visualization of the vulnerability index.

Case Studies in Florida

In the State of Florida, the research by Emrich et al. (2014) is significant, as it presents an overview of vulnerability to different kinds of hazards, such as flash flooding, sea-level rise, hurricane winds, storm surge, extreme heat, drought, and wildland fires. This analysis in Florida was conducted at the census tract level. It offered several maps and used BEVI (Built Environment Vulnerability Index) and MedVI (Medical Vulnerability Index) as well as SoVI. Table 1.3 shows the list of variables used to compute SoVI-FL2010 of the research. While it follows the classification of Cutter et al. (2003), the types of variables are different than Cutter et al. (2003)'s since Emrich et al. (2014)'s SoVI was derived at the census tract level.

Table A2. Variables used to compute SoVI-FL2010 (source: Emrich et al. (2014))

Type	Variable
Race & ethnicity	% African American
	% Native American
	% Asian or Pacific Islander
	% Hispanic
Socioeconomic Status	Per capita income
	% households earning more than $200,000
	% poverty
Gender	% females in labor force
	% female population
	% female headed household, no spouse present
Age	Age-dependent populations (% population under 5 years old and % population over 65)
	Median age
Rural/Urban	% urban population
	Population density
Family structure	Average number of people per household
	% families
Employment	% civilian labor force unemployed
Education	% population over 25 with no high school diploma
Population growth	% ESL (poorly or not at all)
Social dependency and Special needs populations	% collecting social security benefits
	Per capita residents in nursing homes
	% no automobile

As an ideal case study area in Florida, Hillsborough County (Chakraborty et al., 2005; Chen, Lu, Peng, & Ash, 2015) and Sarasota County (Frazier, Thompson, Dezzani, & Butsick, 2013; Tate, 2013; C. Wang & Yarnal, 2012) have been examined by several researchers.

Chakraborty et al. (2005) developed two quantitative indicators which are a geophysical risk index and social vulnerability index in Hillsborough County. The product of the two indicators represented the overall evacuation assistance need. This is obtained from GIS-based analysis via overlaying the physical components and social components. As a result of the analysis, they concluded that while the geophysical index is static, social vulnerability is not a static measure because evacuation assistance will vary over time due to people's behavior and the measure will be dynamic according to different types of hazards. In addition, they addressed that GIS has helped emergency management.

Using the SLOSH model (Sea, Lake, and Overland Surges from Hurricanes), (C. Wang & Yarnal, 2012) assessed social vulnerability to hurricane hazards in Sarasota, Florida for the elderly population. The research also used PCA to construct composite values from their data and then derived principal components of social vulnerability including ‘financially secure young-old,’ ‘triply disadvantaged old-old,’ ‘elderly in group quarters’, ‘financially challenged young-old,’ ‘financially affluent elderly’. Their analysis was based on census block group data and concluded that all elderly populations are not equally vulnerable because the elderly are mixed in needs, capabilities, and vulnerability to various hurricane hazards.

Frazier et al. (2013) quantified vulnerability and resilience to hurricanes, which are based on the place-based model, compared different kinds of weights for the indicators through participatory focus groups, and considered spatial and temporal contexts in their analysis in Sarasota County, Florida. They demonstrated that local scale estimates are more useful to community hazard mitigation than national scale metrics.

Tate (2013) also assessed social vulnerability in Sarasota County, Florida, and investigated uncertainties of the index construction, scale of analysis, measurement error, data transformation, normalization of data, and weighting. Using Monte Carlo-based uncertainty analysis, the author assessed and visualized uncertainty and addressed that the weighting is a key driver of uncertainty for the model in the Sarasota area.

Weighting issues when aggregating variables into a composite vulnerability index

To make composite scores derived from PCA output, while the equal weighting method has been widely used, it has been recognized that a certain variable or component may have a higher priority in the index and structuring those accordingly leads to a more consistent result. Examples of mathematical weighting in this literature are equal weighting, Pareto ranking, and Gini coefficients, and survey approaches including Delphi survey, focus group survey, and AHP (analytic hierarchy process). These weighting methods have been demonstrated in several studies (e.g., de Loyola Hummell et al. (2016); Emrich et al. (2014); Rygel et al. (2006); I Willis and Fitton (2016); Iain Willis, Gibin, Barros, and Webber (2014)).

de Loyola Hummell et al. (2016) used a Delphi survey method to make weights based on the opinions of researchers and practitioners. These participatory approaches have benefits such that weights can be constructed by local practitioners and planners with more targeted knowledge. It helps researchers construct weights that reflect the local context and leads to outcomes that may be more easily acceptable by local practitioners, but the weights should be carefully compared across study areas if transferability is a question.

In terms of mathematical approaches, Rygel et al. (2006) proposed a new classification method, called Pareto ranking. It has the benefits of not needing to develop arbitrary weights due to the characteristics of Pareto ranking that orders cases on multiple criteria within the context of genetic algorithms.

I Willis and Fitton (2016) compared the three social vulnerability indices of Cutter et al. (2003), Rygel et al. (2006), and Iain Willis et al. (2014). As a result of the comparison, while the three methods have consistency and could be interpreted as providing a general picture of social vulnerability when comparing them using mean scores, Rygel et al. (2006)'s index using Pareto ranking exhibited higher uncertainty at the census level result when compared to Cutter et al. (2003)'s SoVI and Iain Willis et al. (2014)'s Gini coefficient weighting.

GIS in Vulnerability Assessment

GIS (geographic information systems) has the potential to give researchers and practitioners many opportunities to assess social vulnerability, but the role of GIS in vulnerability assessment and analysis has been limited for a time. In other words, GIS has been used to visualize the distribution of social vulnerability or simply explore the most and least vulnerable areas based on the standard deviation classification method. More in-depth approaches that take advantage of GIS technologies are not always utilized.

Chropleth Maps

Figure A1 shows a representative visualization of social vulnerability. The values of social vulnerability are classified by standard deviation. Since the standard deviation classification method uses 1 or 1.5 standard deviation from mean value of social vulnerability, this helps to find areas having extreme values. As can be seen in Figure A.1, areas colored most darkly are classified as the most vulnerable areas because high values mean high social vulnerability.

Figure A1 represents another visualization and shows an association of social vulnerability with hazard risks. In Figure A2, Emrich et al. (2014) visualized their results using bivariate choropleth map. These kinds of maps provide insights into how the vulnerability index and natural hazards can be represented together. For instance, purple (blue + red) indicates an area with higher flood risk and vulnerability according to the legend on the map.

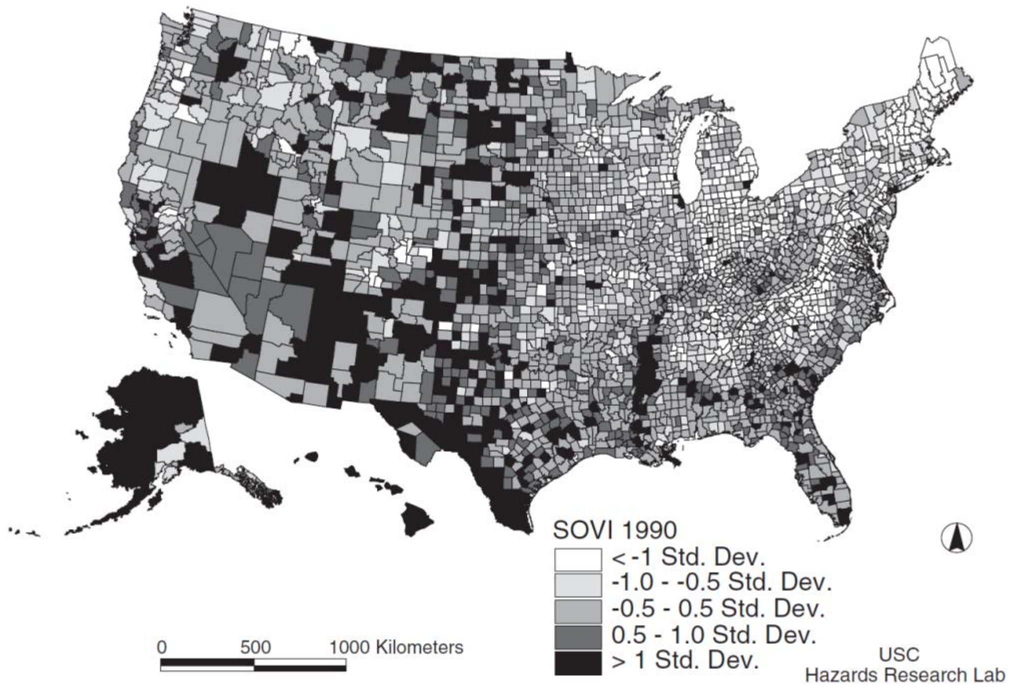

Figure A1. Example of SoVI mapping with the standard deviation

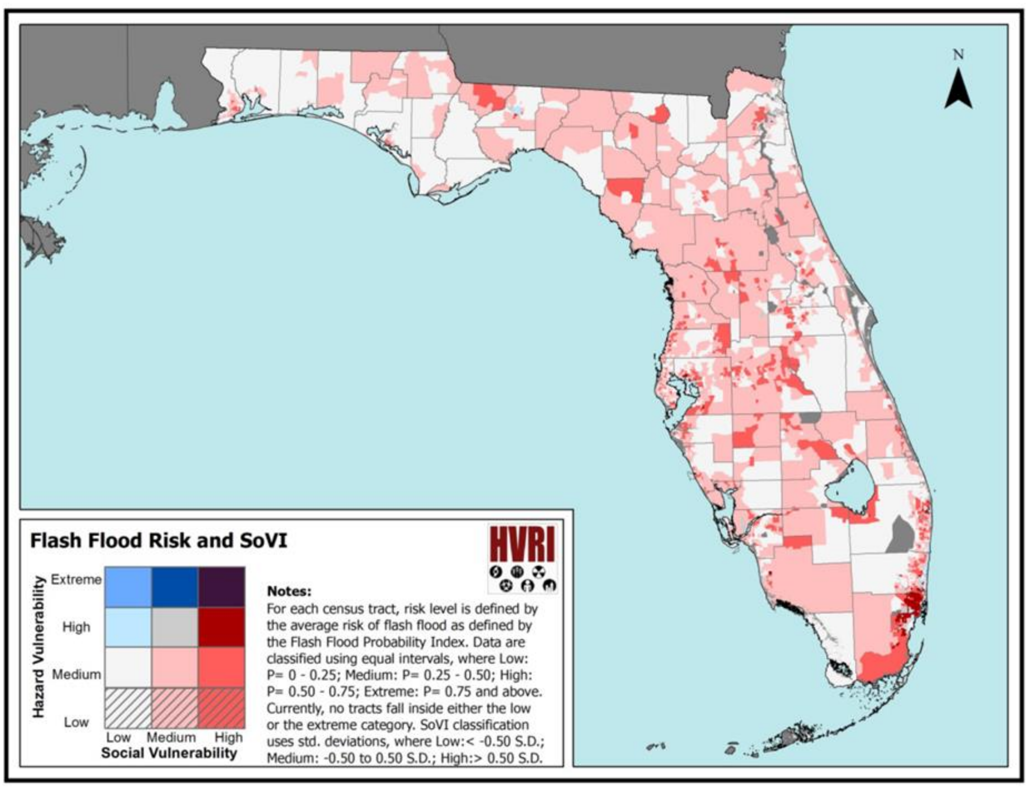

Figure A2. Example of bivariant representation of two variables

Spatial Associations

Even though these visualizations are useful to explore the spatial distribution of social vulnerability, recently there have been efforts to investigate spatial associations of social vulnerability, for instance, overlay, spatial clustering, and geographically weighted regression. As such efforts are seen in Figure A3, this is an example of a GIS-based multi-criteria analysis. The maps from A to I are ingredients for a composite vulnerability index. Using this analysis method, Moradi et al. (2017) assessed vulnerability to earthquakes in Tehran city, Iran. Incorporating the Choquet integral and game theory, the researchers asked five experts to determine locations' degree of seismic vulnerability and they produced a vulnerability map.

Using nine flood conditioning factors such as slope, elevation, soil type, rainfall intensity, flow accumulation, LULC, NDVI, and distance from rivers and roads, Mukherjee and Singh (2020) incorporated a GIS-based weighted multi-criteria analysis to detect flood-prone areas in Harris County, Texas. By overlaying the factors previously mentioned with weights, vulnerable areas to flooding were identified.

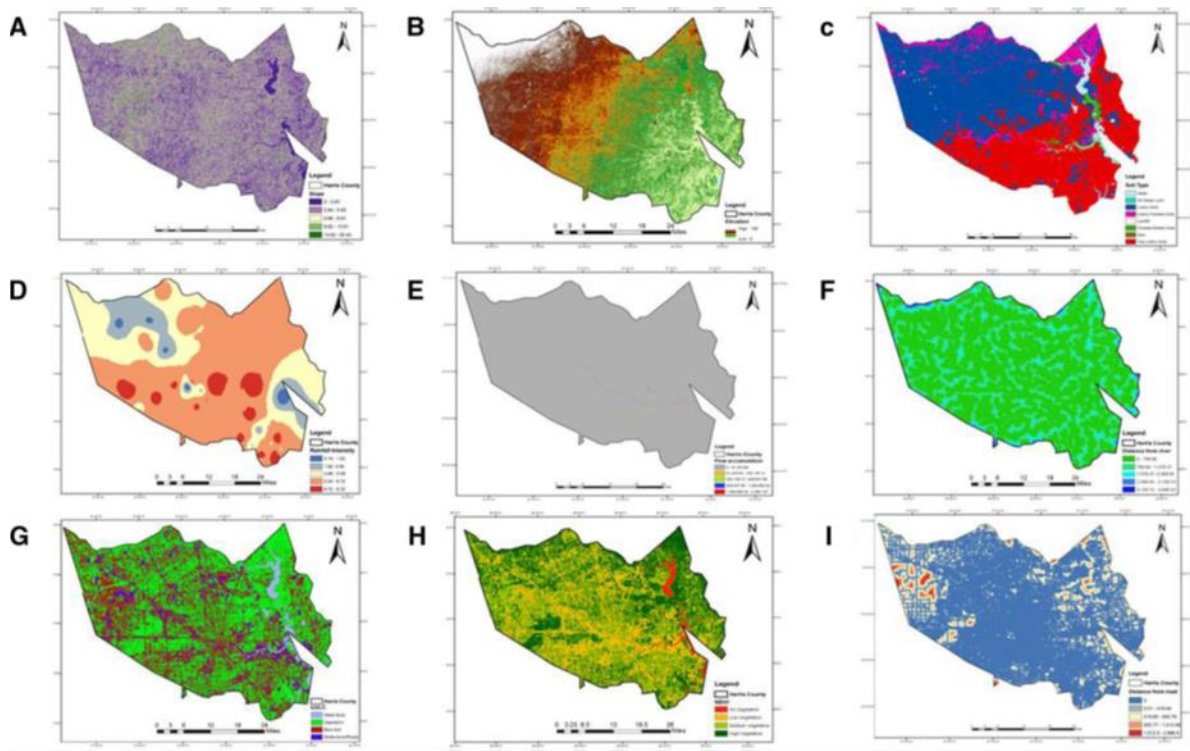

Figure A3. Thematic Maps for Overlay in GIS (source: (Mukherjee & Singh, 2020))

Another significant effort is to detect spatial clusters of vulnerable areas using LISA (local indicators of spatial association) (Armaș & Gavriș, 2013; Frazier et al., 2013; Frigerio & De Amicis, 2016).

LISA is a local version of the Moran's I that measures spatial autocorrelation (Anselin, 1995). By using LISA in social vulnerability assessment, researchers can investigate spatial patterns of the social vulnerability index. LISA provides four information tiers about spatial associations: high-high, low-low, high-low, and low-high associations. High-high and low-low associations mean spatial clusters of observations with high values and observations with low values in a study area. It can help to find the clusters of the most and least vulnerable areas. High-low and low-high associations indicate spatial outliers. High-low means an area with a high value is surrounded by areas with a low value, and in contrast, a low-high means an area with a low value is surrounded by areas with high value. Thus, LISA can detect the vulnerable area as a pocket within less vulnerable areas or less vulnerable areas as a pocket within more vulnerable areas.

Frazier et al. (2013) showed that indicators vary across space in their study which used the LISA statistic. Although it conducted the analysis for resilience, their spatial analysis could be applied to social vulnerability assessment as well. Assessing social vulnerability using spatial multi-criteria analysis (SEVI model), Armaș and Gavriș (2013) discussed that LISA may provide beneficial information for authorities and stakeholders in policy and decision making.

Frigerio and De Amicis (2016) studied the geographical distribution of the social vulnerability indicators and performed a spatial clustering analysis to explore the spatial patterns of vulnerability in Italy. The map shown in Figure A4 is an example of an analysis using LISA. The red color reveals a high level of social vulnerability and blue denotes a low level of social vulnerability. The map represents clusters of high social vulnerability on the north-western and southern part of Italy, which reveals there are segregations of social vulnerability (Frigerio and De Amicis, 2016).

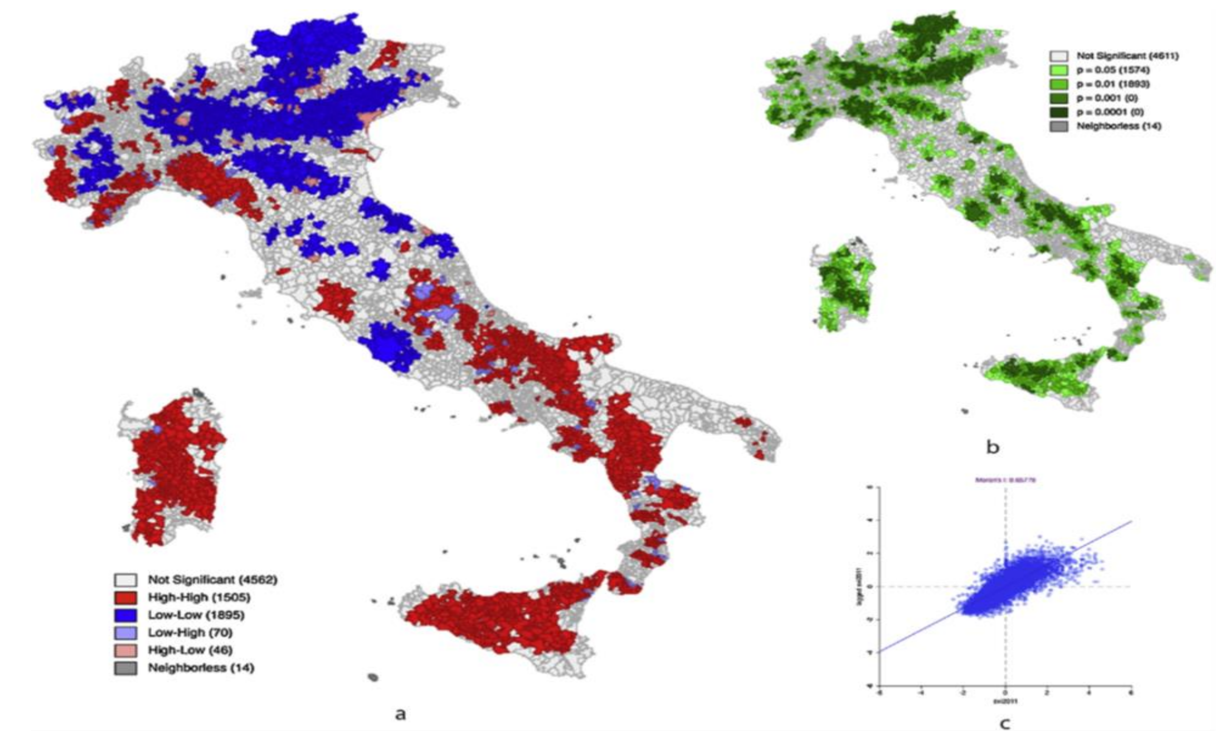

Figure A4. An example of LISA with social vulnerability (source: Frigerio and De Amicis (2016))

Importance of Local Context

It has been discussed that areal units, or the shapes and sizes of aggregate geographies, can impact quantitative results in geographical analysis. This is known as the modifiable areal unit problem (MAUP). When aggregating areal units, variances in the observations in the study area are reduced much like a smoothing effect. In contrast, the smaller the areal units, the greater the variances in values across the study area (Fotheringham and Wong, 1991). When considering the characteristics of spatial data, interpretation of results should be cautious with areal units. Thus, there have been studies taking the MAUP into account in social vulnerability analysis.

Original SoVI work was based on the County level of geography in the United States (Cutter et al., 2003). The value of SoVI is that it is a composite value derived from PCA. However, several researchers have discussed that the PCA technique may not be relevant for local context (Oulahen et al., 2015; Wood et al., 2010). In particular, at the smaller census block level analysis, scale-dependent deficiencies were discussed by Wood et al. (2010). It implies that the PCA-based SoVI metric may inappropriately focus on outliers within individual blocks instead of significant regional trends.

To avoid the problem, Wood et al. (2010) suggested that below county-level of geography, emergency managers should interpret SoVI results within the regional/local context, and also it was suggested to interpret the results with original data. Oulahen et al. (2015) also discussed the issue of social vulnerability assessment in small area analysis. They claimed that social vulnerability analysis should take into account local practitioners' participation in the analysis to conduct suitable analyses such as focus group surveys since the local knowledge is important to interpret local context, unlike the national-level analysis.

Summary

Overall, there is a general agreement in the literature to what vulnerability means and who can be considered vulnerable. There is also agreement on many of the social factors that define a vulnerable individual or a group (evident by the redundancy in the social vulnerability determinants found in the literature; summarized in Appendix A), although there is uncertainty on how to use these social factors to determine the most vulnerable groups. This, in part, is due to the lack of clear numeric expressions for these social factors. Moreover, the complex interrelationships between the social factors are yet to be fully understood and require further investigations. The recommendation is not to take any social vulnerability framework as a definitive statement but rather an aid-memory for planners to make informative decisions. Vulnerability is a context-specific concept, thereby; the metrics selected for determining the socially vulnerable groups should be identified in accordance with the hazards (geophysical risks) unique to the region. The relationships between the social factors and the hazard effects should be defined as well to inform the emergency planning process.

We summarize recommendations obtained from the covered literature, as a step forward to achieve the objectives of this project:

- Local governments should explicitly include the special needs of vulnerable groups in their documented plans and provide special guidelines (for emergency mitigation and emergency response) suitable to their needs.
- Agencies are encouraged to formulate their own frameworks for identifying the socially vulnerable groups. Vulnerability is a context-specific concept, and the attributes compounding the social vulnerabilities have varying effects on the level of vulnerability depending on factors such as the type of hazard and the available resources.
- Agencies should consider both the geophysical risks and socioeconomic factors that result in increased levels of exposure to their communities in their framework. The relationships between the geophysical risks and social vulnerability attributes should be investigated.
- Engaging professional and academic experts in the process is important to help overcome the complex nature of the interrelationships between the social vulnerability determinants.

Appendix B: The Experts Survey

Objective

The purpose of the experts' survey is to understand practitioners' experiences, perceptions, and concerns related to the transportation systems' response to vulnerable populations during a natural hazard event. The survey was comprised of six parts: organizational data, respondent data, previous disaster experience, mobility and resilience, economic impacts, and social impacts. The survey also included a section for sharing documentation on the agencies' approach to meeting transportation needs of vulnerable populations during a disaster event. The six sections of the survey are defined below:

(i) *Organizational Data:* identifies the organization where the practitioners work.

(ii) *Respondent Data:* this section seeks to understand the professional background of respondents. This section consists of seven questions requiring the respondents to identify their profession, their level of experience in working with vulnerable populations, and transportation systems resilience.

(iii) *Previous Disaster Experiences:* this section gathers information about respondents' specific experience with hazardous events. It consists of four questions that require the identification of specific events that the respondent has personally experienced and managed in a professional capacity.

(iv) *Mobility and Resilience:* this section seeks to understand the nature of mobility and resilience-related concerns within the professional community. The section consists of six questions that address the hazard-related vulnerability of infrastructure elements, the transportation needs of residents, and resilience planning and monitoring for vulnerable populations.

(v) *Economic Impacts:* this section evaluates the expert opinion on the level of economic-needs for vulnerable populations within their organization's jurisdiction. The section consists of three questions related to monitoring the economic needs, the level of concern of economic needs, and potential economic needs related to transportation access.

(vi) *Social Impacts:* this section evaluates the expert opinion on the level of social impacts of vulnerable populations within the respondent's jurisdiction. The section consists of three questions related to monitoring the social impacts, the level of concern for hazard-driven social impacts, and potential social impacts related to transportation systems.

Survey Questions

1. **Organizational Data:**

1.a. "Please provide the name of the organization you work for or represent."

2. **Respondent Data:**

2.a. "How would you best define your background and/or experience?" (check all that apply)
A. Executive/elected official
B. Public administrator
C. Planner
D. Emergency Manager
E. Engineer
F. Other (Short Answer Space)

2.b "What is your level of professional experience?"
A. Less than 5 years
B. 5 - 9 years
C. 10 - 14 years
D. 15 - 19 years
E. 20 - 24 years
F. 25 years or longer

2.c "To what extent to you deal with transportation infrastructure issues in your job?"
A. Not at all
B. Somewhat
C. Frequently
D. It is my primary focus

2.c "To what extent do you deal with transportation issues in your job?"
A. Not at all
B. Somewhat (a few times a year)
C. Frequently (approximately once a month)
D. It is my primary focus

2.d "To what extent do you work in or are engaged in planning for resilience and/or hazard mitigation in your job?"
A. Not at all
B. Somewhat (a few times a year)

C. Frequently (approximately once a month)
D. It is my primary focus

2.e "To what extent do you serve vulnerable populations on your job?"
A. Not at all
B. Somewhat (a few times a year)
C. Frequently (approximately once a month)
D. It is my primary focus

2.f. “Vulnerable populations can be comprised of many different groups. Which of the following groups do you serve in your work?" (check all that apply)

A. Older populations (older than 65 years old)
B. Racial or ethnic minorities
C. People who speak English as a second language
D. People without access to vehicles
E. People with disabilities and/or access or functional needs
F. Rural populations
G. Other (Short answer space)

3. <u>Previous Disaster Experiences:</u>

3.a. How long have you resided in Florida as a permanent or seasonal resident?

A. Less than 5 years
B. 5 - 9 years
C. 10 - 14 years
D. 15 - 19 years
E. 20 - 24 years
F. 25 years or longer
G. Prefer not to answer

3.b. “Have you ever worked on a current/active natural hazard event or issues related to past hazard event while in Florida?”
A. Yes
B. No

3.c. "What types of hazards have you experienced in Florida? (Check all that apply)"

A. Hurricane (includes Tropical Storm)
B. Severe Weather (includes severe thunderstorms)
B. Tornado
C. Flooding (includes flooding from a river, flooding from rainfall and tidal flooding, such as King Tides)

D. Wildfire
E. Sinkholes
F. Coastal Erosion
G. Other
H. None

3.d. "What types of hazards have you had to work with as part of your job duties? (Check all that apply)"
A. Hurricane (includes Tropical Storm)
B. Severe Weather (includes severe thunderstorms)
B. Tornado
C. Flooding (includes flooding from a river, flooding from rainfall and tidal flooding, such as King Tides)
D. Wildfire
E. Sinkholes
F. Coastal Erosion
G. Other
H. None

4. **<u>Mobility and Resilience:</u>**

4.a. "Please rank your level of concern regarding the hazard vulnerability of the following infrastructure elements within the geographic area your agency serves" (mark each on a scale of 1-5, with 1 meaning no concern and 5 very high concern)

A. Critical emergency response facilities like police and fire stations
B. Public shelters
C. Medical facilities like hospitals and clinics
D. The federal and/or state highway system
E. Local roads
F. Bridges
G. Power / communications infrastructure
H. Drainage
I. Ports/ airports
J. Rail
K. Other

4.b. "Please rank your level of concern regarding transportation issues relative to the needs of the residents within your agency's jurisdiction?" (mark each on a scale of 1-5, with 1 meaning no concern and 5 very high concern)

A. Evacuation
B. Re-entry
C. Fuel accessibility

D. Temporary road closures due to flooding or debris
E. Long-term road closures due to disaster-related damage
F. Disruption to public transportation routes or schedules
G. Lack of service at airports or ports
H. Long-term disruption to airports or ports

4.c "Does your organization have plans or measures in place to monitor and address the access needs of special or vulnerable populations outside of the context of a natural hazard?"
A. Yes
B. No

4.d ""Does your organization have plans or measures in place to monitor and address resilience needs of vulnerable populations?".
A. Yes
B. No

4.e "Does your resilience planning for vulnerable populations address the following issues? (check all that may apply)
A. Evacuation
B. Re-entry
C. Post-disaster access to medical services and amenities
D. Special subsidies for public transit
E. Other

4.f. "On a scale of 1-5, with 1 meaning no concern and 5 very high concern, how would you rank your level of concern regarding resilience needs of vulnerable populations within your agency's geographic and/or responsibilities jurisdiction?"

5. <u>Economic Impacts:</u>
5.a "Does your organization have plans or measures in place to monitor and address hazard-related economic needs of vulnerable populations?"

A. Yes
B. No

5.b. "On a scale of 1-5, with 1 meaning no concern and 5 very high concern, how would you rank your level of concern regarding hazard-related economic needs of vulnerable populations within your agency's geographic and/or responsibilities jurisdiction?"

5.c. "On a scale of 1-5, with 1 low and 5 high, to what extent would you say that the potential economic needs of vulnerable populations within your agency's geographic and/or responsibilities jurisdiction are or could be related to their access or transportation needs?"

6. <u>Social Impacts:</u>

6.a "Does your organization have plans or measures in place to monitor and address hazard-related social impacts (including physical and mental health, access to government services, social isolation) to vulnerable populations within your agency's geographic and/or responsibilities jurisdiction?"
A. Yes
B. No

6.a "On a scale of 1-5, with 1 meaning no concern and 5 very high concern, how would you rank your level of concern regarding hazard-related social impacts (including physical and mental health, access to government services, social isolation) to vulnerable populations within your agency's geographic and/or responsibilities jurisdiction?"

6.b "On a scale of 1-5, with 1 is low and 5 is high, to what extent would you say that the potential social impacts to vulnerable populations within your agency's jurisdiction are or could be related to by their access or transportation needs?"

Shared data link

"It will help the research team to review formal or informal organizations' transportation resilience plans for vulnerable populations. If you would like to share documentation of plans or measures in place within your organization to monitor and address the transportation resilience needs of vulnerable populations, please share it here."

Plan name: ____________

Link to upload/email document to the research team.

Appendix C: The Vulnerable Populations Survey

Objective

The purpose of the vulnerable population survey is to understand the experiences and concerns of Florida residents about transportation systems and related issues, focusing on those who are specifically vulnerable to natural hazards. Similar to the Experts survey, the vulnerable populations survey is composed of six parts: location data (corresponds to the organizational data in the experts' survey), demographic data (corresponds to the respondent data in the experts' survey), previous disaster experiences, mobility and resilience, economic impacts, and social impacts. The six sections of the survey are defined below:

(i) *Location:* identifies the location of residence of the respondent.

(ii) *Demographics Data:* this section asks about relevant personal background of respondents. The section contains six questions that require the respondent to identify their gender, age, race, ethnicity, level of education, and spoken languages.

(iii) *Previous Disaster Experiences:* this section gathers information about Florida residents' experiences with natural hazards. It contains four questions that require the identification of the specific hazard events experienced by the respondent, as well as the specific concerns the respondent had during the event(s).

(iv) *Mobility and Resilience:* this section evaluates the mobility performance and level of resilience of the transportation system during natural hazards, as viewed by vulnerable populations. The section consists of eight questions with the primary focus of assessing if the transportation system can meet evacuation needs during hazards by understanding the vulnerable populations concerns while evacuating and returning. The questions also aim to assess the level of safety of the system, as viewed by the vulnerable populations.

(v) *Economic Impacts:* This section evaluates the level of economic impacts (due to transportation related issues) suffered by vulnerable populations after natural hazards. The section consists of six questions that seek to understand what (if any) major economic impacts are related to the transportation system.

(vi) *Social Impacts:* This section evaluates the level of social impacts (due to transportation related issues) suffered by vulnerable populations after natural hazards. The section consists of five questions that seek to understand what (if any) major social impacts are related to the transportation system.

Survey Questions

1. **<u>Location:</u>**

1.a. "What is your Zip Code?"

1.b. "How would you characterize the type of area in which you live?"
A. Urban
B. Suburban
C. Rural
D. Prefer not to answer

2. **<u>Demographic Data:</u>** (Gender, Age, Ethnicity, Education, Marital Status)

2.a. "What is your gender identity?"
A. Male
B. Female
C. Nonbinary
D. Other_______ (Short Answer Space)
E. Prefer not to answer

2.b "What is your age group?"
A. Under 18
B. 18 - 29 years old
C. 30 - 44 years old
D. 45 - 59 years old
E. 60 - 74 years old
F. 75 years or older
G. Prefer not to answer

2.c "How do you identify your race or ethnicity?"
A. White
B. Black
C. Native American
D. Asian
E. Pacific Islander
F. Some other race
G. Two or more races
H. Prefer not to answer

2.c.1 "Are you of Hispanic, Latinx or Spanish origin?"
A. No – Not of Hispanic, Latinx or Spanish origin
B. Yes – Mexican, Mexican American, Chicano
C. Yes – Puerto Rican
D. Yes – Cuban
E. Yes – Another Hispanic, Latinx or Spanish origin

F. Prefer not to say

2.d "What is the highest degree or level of education you have completed?"
A. Some High School
B. High School
C. Bachelor's Degree
D. Master's Degree
E. Ph.D. or higher
F. Postgraduate or professional degree
G. Trade School
H. Prefer not to say

2.e "How many people in your household (including yourself?"

2.f "What languages to you speak fluently? (Check all that apply)"
A. English
B. Spanish
C. French Creole
D. Other
E. Prefer not to say

3. <u>Previous Disaster Experiences:</u>

3.a. How long have you resided in Florida as a permanent or seasonal resident?

A. Less than 5 years
B. 5 - 9 years
C. 10 - 14 years
D. 15 - 19 years
E. 20 - 24 years
F. 25 years or longer
G. Prefer not to answer

3.b. "Have you ever experienced a natural hazard event while living in Florida?"
A. Yes
B. No

If YES, please continue the survey.
If No, survey ends here.

3.c. "What types of natural hazard events have you experienced in Florida? (Check all that apply)"

A. Hurricane (includes Tropical Storm)
B. Severe Weather (includes severe thunderstorms)
B. Tornado
C. Flooding (includes flooding from a river, flooding from rainfall and tidal flooding, such as King Tides)
D. Wildfire
E. Sinkholes
F. Coastal Erosion
G. Other
H. Prefer not to say

3.d. “What concerned you the most during the hazard event(s) you experienced?” (Rank each on a scale of 1 -5, with 1 representing no concern and 5 representing extreme concern)

A. My personal safety and/or that of my family members
B. Potential damage to my home or apartment
C. My access to transportation (my car or other ways I would normally get around)
D. Damage to roads and/or bridges
E. Traffic congestion on roads
E. A place to go to (such a as a home of a friend or relative, a public shelter, or a hotel/motel)
F. Utilities (electricity, water)
G. Food and supplies (including medical supplies)
H. Disaster debris
I. Length of time away from home
J. Other

4. <u>Mobility and Resilience:</u>

4.a. “Have you ever evacuated as a result of a natural hazard event?”
A. Yes
B. No
C. Prefer not to say

If YES, please complete 4.a.1-5.
If no, proceed to 4.b.

4.a.1. “On a scale of 1-5, with 5 being very safe, how safe did you feel evacuating?’

4.a.2. “What things concerned you while you were evacuating?” (Rank each on a scale of 1 -5, with 1 representing no concern and 5 representing extreme concern)

A. Lack of official communications or directions
B. Quality of my vehicle
C. Quality of the roads

D. Excessive traffic congestion
E. Availability of fuel
F. Availability of food and amenities
G. Presence of standing water
H. Excessive disaster debris
I. Well-being of family and friends
J. Well-being of pets
k. Uncertainty about when you would be able to return home

4.a.3. “On a scale of 1-5, with 5 being very safe, how safe did you feel returning to your home?

4.a.4. “What things concerned you while you returning to your home or reentering your home area?” (Rank each on a scale of 1 -5, with 1 representing no concern and 5 representing extreme concern)

A. Lack of official communications or directions
B. Quality of my vehicle
C. Quality of the roads
D. Excessive traffic congestion
E. Availability of fuel
F. Availability of food and amenities
G. Presence of standing water
H. Excessive disaster debris
I. Well-being of family and friends
J. Well-being of pets

4.b. “When you have evacuated in the past, where did you go?” (Check all that apply)
A. Home of a friend or relative
B. Hotel / Motel (including an Airbnb)
C. Public Shelter
D. Other location
E. Prefer not to say

4.c. “If you were asked to evacuate in the future, what would be your primary modes of transportation during periods of natural hazard events” (check all that apply)
A. Personal vehicle
B. A private vehicle driven by a friend or relative
C. Taxi or Uber/Lyft
D. Public transit
E. Bicycle

F. Walking
G. Other
H. Prefer not to say

4.d. "Please rate your past evacuation experience." (Rank on a scale of 1 -5, with 1 representing very easy and 5 representing very difficult)

4.e. "Based on your past evacuation experience, how far did you travel to relocate?"
A. In county
B. Out of county, close to home
C. Out of county, far from home
D. Out of state

4.f. "Based on your past evacuation experience, how long were you away from home?"
A. 1 – 3 days
B. 4- 7 days
C. 7 – 14 days
D. Longer than 2 weeks

5. <u>Economic Impacts:</u>

5.a "Have you ever experienced any of the following situations because of a hazard event(s)? (check all that apply)

A. Physical injury to self or family
B. Housing damage
C. Damage to vehicle
D. Interruption or changes in the way you get to work or services (car, bus, rail)
E. Need to relocate to temporary housing
F. Isolation (stuck in house after a disaster has subsided due to unsafe conditions outside)
G. Loss of employment (permanent or temporary)

5.b "If you were ever unemployed due to a hazard event, please indicate the reasons." (check all that apply)

A. Closure of workplace
B. Disruption of transit services
C. Damage to personal vehicle
D. Relocation from home
E. Damaged or closed travel routes
F. Personal health issues

5.c "Did you need to change the route you took to get to work or to access any amenities after a natural hazard event because of damaged or closed roads?"

A. Yes
B. No
C. Prefer not to say

5.d "Did you ever need to postpone or cancel a visit to any of the following locations due to natural hazard-related damage to your car, a lack of a vehicle or disruption in public transit?" (check all that apply)

A. Routine doctor or dentist visit
B. A visit to a doctor or dentist / hospital for a planned procedure
C. A pharmacy
D. A grocery store
E. Non-essential shopping
F. A social engagement that you would pay for, such as a sports game, theater/movie, park/museum visit
G. Other social engagements that would not have cost money, such as a party or work/church/school function
H. Other

5.e "Did you ever need to postpone or cancel a visit to any of the following locations due to hazard related damaged or closed roads?" (check all that apply)

A. Routine doctor or dentist visit
B. A visit to a doctor or dentist / hospital for a planned procedure
C. A pharmacy
D. A grocery store
E. Non-essential shopping
F. A social engagement that you would pay for, such as a sports game, theater/movie, park/museum visit
G. Other social engagements that would not have cost money, such as a party or work/church/school function

5.f "Have you ever received government assistance as a result of a natural hazard event?"

A. Yes
B. No
C. Prefer not to say

6. **Social Impacts:**

6.a “What is your primary source of trusted information during a hazard event?”

A. Local Officials
B. Local TV News
C. Cable TV News
D. Radio
C. Online Sources (e.g., social media platforms such as Facebook or Twitter)
E. Information from family and friends
F. Other
G. Prefer not to say

6.b “Has your physical or mental health been impacted by your experience of any natural hazard event that impacted your transportation mobility (ability to drive and/or use public or private transportation)?”

A. Yes
B. No
C. Prefer not to say

If YES, please complete 6.b.1
If NO, proceed to 6.c

6.b.1 “Did any of the following affect your physical or mental health recovery”? (check all that apply)

A. Damage to my vehicle
B. Availability of fuel
B. Cost of fuel
C. Damage or closed roads
D. Disruption to public transportation routes or service

6.c “Did you have adequate access to the social services (e.g., counseling, public assistance) you needed during and after a natural hazard event?”

A. Yes, all I needed
B. Yes to most, but not to all needed
C. Yes, but only to a few I needed
D. No
E. Prefer not to say

If YES, please complete 6.c.1
If no, end survey

6.c.1 "Did any of the following affect your access to social services you needed after a natural hazard event?" (check all that apply)

A. Damage to my vehicle
B. Availability of fuel
B. Cost of fuel
C. Damage or closed roads
D. Disruption to public transportation routes or service

Table C1. Rural locations in Florida

Rural zip codes (Florida)
32008, 32009, 32011, 32024, 32025, 32026, 32034, 32038, 32040, 32044, 32046, 32052, 32053, 32054, 32055, 32058, 32059, 32060, 32061, 32062, 32063, 32064, 32066, 32071, 32072, 32083, 32087, 32091, 32094, 32096, 32097, 32102, 32110, 32112, 32131, 32136, 32136, 32136, 32136, 32137, 32139, 32140, 32147, 32148, 32157, 32164, 32174, 32177, 32180, 32181, 32187, 32189, 32193, 32320, 32321, 32322, 32323, 32324, 32327, 32328, 32330, 32331, 32332, 32333, 32334, 32336, 32340, 32343, 32344, 32346, 32347, 32348, 32350, 32351, 32352, 32355, 32356, 32358, 32359, 32361, 32420, 32421, 32423, 32424, 32425, 32425, 32425, 32425, 32425, 32425, 32425, 32425, 32425, 32426, 32427, 32428, 32430, 32431, 32431, 32431, 32431, 32432, 32433, 32435, 32437, 32439, 32440, 32442, 32443, 32445, 32446, 32447, 32448, 32449, 32455, 32456, 32459, 32460, 32461, 32462, 32463, 32464, 32465, 32531, 32550, 32564, 32567, 32619, 32621, 32622, 32625, 32626, 32626, 32626, 32626, 32628, 32639, 32640, 32648, 32666, 32668, 32680, 32683, 32692, 32693, 32693, 32693, 32693, 32693, 32693, 32693, 32693, 32693, 32696, 32697, 33001, 33036, 33037, 33040, 33042, 33043, 33050, 33051, 33070, 33430, 33438, 33440, 33471, 33476, 33493, 33538, 33825, 33834, 33843, 33852, 33857, 33865, 33867, 33870, 33872, 33873, 33875, 33876, 33890, 33921, 33924, 33930, 33935, 33944, 33945, 33956, 33960, 34266, 34268, 34269, 34449, 34498, 34739, 34773, 34972, 34974

Rural zip codes (I-4 corridor)
32102, 32180, 33538, 33825, 33834, 33843, 33852, 33857, 33865, 33867, 33870, 33872, 33873, 33875, 33876, 33890, 33960, 34266, 34268, 34269, 34739, 34773, 34972

The I-4 corridor counties
Brevard, Highlands, Orange, Volusia, Okeechobee, Osceola, Hernando, Lake, Hillsborough, Polk, Sumter, Hardee, DeSoto, Pasco, Manatee, Pinellas, Citrus, Marion, and Seminole

Appendix D: Statistical Correlation Analysis

Correlation analysis is a statistical method that measures the strength of the linear relationship between two variables and compute their degree of association. Positive correlation between two variables indicates that both variables move in the same direction, i.e., an increase in the first variable leads to an increase in the other variable and vice versa. In this research, a positive correlation between the two variables (two concerns) in the responses of the populations indicate that a high level of concern about a particular measure (e.g., personal safety) leads to increases in the level of concern of another (e.g., presence of standing water in the road).

The Spearman's rank-order correlation is used in the analysis, since the variables in the study are nonparametric. Spearman's correlation coefficients are used to measure the strength and direction of association between the study variables. In the analysis, a positive correlation coefficient (+) indicates a that the variables move in the same direction, the strength of the association is measured by the value of the coefficient as follows:

0.8 – 1.0 = very strong (high) correlation

0.6 – 0.79 = strong correlation

0.4 – 0.59 = moderate correlation

0.2 – 0.39 = weak correlation

0 – 0.19 = very weak correlation

The correlation coefficients were calculated for the vulnerable population surveys, focusing on the *Mobility* & *Resilience* section, to understand strength and direction of an association between the concerns of the populations. Correlation coefficients matrices were obtained for the following:

1- The variables of Q10, which inquired about the concerns of the populations during hazard event(s): *Q10. What concerned you the most during the hazard event(s) you experienced? (Rank each on a scale of 1-5, with 1 representing no concern and 5 representing extreme concern)*.
2- The variables of Q13, which inquired about the concerns of the populations while evacuating: *Q13. What things concerned you while you were evacuating? (Rank each on a scale of 1-5, with 1 representing no concern and 5 representing extreme concern)*
3- The variables of Q15, which inquired about the concerns of the populations while returning back after evacuating: *Q15. What things concerned you while returning to your home or reentering your home area? (Rank each on a scale of 1-5, with 1 representing no concern and 5 representing extreme concern)*
4- The correlations between Q13 & Q15, i.e., the correlations between the concerns while evacuating and while returning.

In all questions, the populations were asked to rank their concerns from 1 (least concern) to 5 (most concern) and were given a number of options. The tables below show the concerns and the key codes referring to them in the correlation coefficients tables.

Q10:

A1	My personal safety and/or that of my family members
A2	Potential damage to my home or apartment
A3	My access to transportation (my car or other ways I would normally get around)
A4	Damage to roads and/or bridges
A5	Traffic congestion on roads
A6	A place to go to (such as home of a friend or relative, a public shelter, or a hotel/motel)
A7	Utilities (electricity, water)
A8	Food and supplies (including medical supplies)
A9	Disaster debris
A10	Length of time away from home
A11	Other (any other specific concern not listed above)

Q13:

A1	Lack of official communications or directions
A2	Quality of my vehicle
A3	Quality of the roads
A4	Excessive traffic congestion
A5	Availability of fuel
A6	Availability of food and amenities
A7	Presence of standing water
A8	Excessive disaster debris
A9	Well-being of family and friends
A10	Well-being of pets
A11	Uncertainty about when you would be able to return home

Q15:

B1	Lack of official communications or directions
B2	Quality of my vehicle
B3	Quality of the roads
B4	Excessive traffic congestion
B5	Availability of fuel
B6	Availability of food and amenities
B7	Presence of standing water
B8	Excessive disaster debris
B9	Well-being of family and friends
B10	Well-being of pets

MATLAB is used to calculate the correlation coefficients between the study variables. The results are reported in tabular formats, showing the values of the coefficients between all the variables show in the previous tables. As can be seen, all the variables have positive correlations, with the majority of them having a very strong degree of association.

Minority Survey

[1] Urban areas:

Correlation coefficients of the previous disaster concerns - Q10											
	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11
A1	1	0.938983	0.92696	0.918389	0.925938	0.913193	0.965132	0.950967	0.925319	0.896179	0.891945
A2	0.938983	1	0.959587	0.94021	0.957355	0.930776	0.935016	0.960366	0.946255	0.919237	0.911591
A3	0.92696	0.959587	1	0.967214	0.961191	0.95309	0.925244	0.938855	0.969203	0.945153	0.952312
A4	0.918389	0.94021	0.967214	1	0.952275	0.9849	0.923823	0.933507	0.978242	0.925548	0.912592
A5	0.925938	0.957355	0.961191	0.952275	1	0.939788	0.925693	0.959817	0.960429	0.94732	0.924408
A6	0.913193	0.930776	0.95309	0.9849	0.939788	1	0.921679	0.924612	0.963591	0.925033	0.910966
A7	0.965132	0.935016	0.925244	0.923823	0.925693	0.921679	1	0.936102	0.914956	0.879417	0.87129
A8	0.950967	0.960366	0.938855	0.933507	0.959817	0.924612	0.936102	1	0.935007	0.904981	0.891538
A9	0.925319	0.946255	0.969203	0.978242	0.960429	0.963591	0.914956	0.935007	1	0.933236	0.916092
A10	0.896179	0.919237	0.945153	0.925548	0.94732	0.925033	0.879417	0.904981	0.933236	1	0.979172
A11	0.891945	0.911591	0.952312	0.912592	0.924408	0.910966	0.87129	0.891538	0.916092	0.979172	1

Correlation coefficients of concerns while evacuating - Q13											
	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11
A1	1	0.947915	0.924636	0.963336	0.920832	0.914039	0.955836	0.941289	0.876338	0.967646	0.942617
A2	0.947915	1	0.917415	0.941735	0.91409	0.916886	0.929603	0.94811	0.814286	0.943754	0.932967
A3	0.924636	0.917415	1	0.928536	0.986494	0.913841	0.942664	0.914921	0.891319	0.903959	0.917379
A4	0.963336	0.941735	0.928536	1	0.929846	0.941961	0.967078	0.937533	0.892007	0.951057	0.951042
A5	0.920832	0.91409	0.986494	0.929846	1	0.922142	0.944363	0.916339	0.895611	0.906557	0.923165
A6	0.914039	0.916886	0.913841	0.941961	0.922142	1	0.931461	0.932402	0.899969	0.933109	0.964303
A7	0.955836	0.929603	0.942664	0.967078	0.944363	0.931461	1	0.938506	0.922003	0.932491	0.957003
A8	0.941289	0.94811	0.914921	0.937533	0.916339	0.932402	0.938506	1	0.823168	0.972158	0.936636
A9	0.876338	0.814286	0.891319	0.892007	0.895611	0.899969	0.922003	0.823168	1	0.837187	0.929874
A10	0.967646	0.943754	0.903959	0.951057	0.906557	0.933109	0.932491	0.972158	0.837187	1	0.934082
A11	0.942617	0.932967	0.917379	0.951042	0.923165	0.964303	0.957003	0.936636	0.929874	0.934082	1

Correlation coefficients of concerns while returning - Q15										
	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
B1	1	0.959352	0.94577	0.974334	0.943818	0.921097	0.938539	0.969158	0.953285	0.932965
B2	0.959352	1	0.939536	0.924389	0.932436	0.911432	0.936026	0.949194	0.900564	0.926996
B3	0.94577	0.939536	1	0.929658	0.931065	0.965417	0.938879	0.936584	0.938216	0.915049
B4	0.974334	0.924389	0.929658	1	0.943716	0.923733	0.935539	0.967101	0.949717	0.941826
B5	0.943818	0.932436	0.931065	0.943716	1	0.939495	0.981016	0.960771	0.917253	0.961213
B6	0.921097	0.911432	0.965417	0.923733	0.939495	1	0.951399	0.932832	0.931363	0.94001
B7	0.938539	0.936026	0.938879	0.935539	0.981016	0.951399	1	0.949574	0.916884	0.944673
B8	0.969158	0.949194	0.936584	0.967101	0.960771	0.932832	0.949574	1	0.944587	0.969294
B9	0.953285	0.900564	0.938216	0.949717	0.917253	0.931363	0.916884	0.944587	1	0.907036
B10	0.932965	0.926996	0.915049	0.941826	0.961213	0.94001	0.944673	0.969294	0.907036	1

Correlation coefficients of concerns evacuating & returning										
	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
A1	0.992027	0.953063	0.945118	0.974562	0.949831	0.923019	0.943341	0.971504	0.957156	0.938083
A2	0.948165	0.947017	0.925847	0.958706	0.93314	0.907046	0.932098	0.947511	0.893624	0.919731
A3	0.929926	0.958933	0.949003	0.905683	0.929449	0.916487	0.946566	0.923864	0.893028	0.913033
A4	0.962426	0.945281	0.930366	0.957956	0.967947	0.931937	0.954364	0.988246	0.93514	0.979461
A5	0.92477	0.949263	0.940932	0.906446	0.932696	0.927349	0.950531	0.923742	0.89324	0.91897
A6	0.910945	0.904637	0.934206	0.922547	0.954302	0.964697	0.949209	0.931362	0.920184	0.954367
A7	0.953882	0.951243	0.936886	0.935452	0.976749	0.940695	0.977866	0.96232	0.92703	0.945701
A8	0.93173	0.930469	0.934472	0.949872	0.948434	0.93543	0.939525	0.94901	0.915301	0.944549
A9	0.885411	0.86439	0.907342	0.856475	0.898131	0.922535	0.918154	0.874945	0.899613	0.871752
A10	0.958452	0.923128	0.924437	0.975215	0.942727	0.930107	0.93262	0.962387	0.932852	0.959686

[2] Suburban areas:

Correlation coefficients of the previous disaster concerns - Q10											
	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11
A1	1	0.917335	0.906407	0.915068	0.922812	0.915287	0.977118	0.945752	0.916401	0.900727	0.892697
A2	0.917335	1	0.919557	0.945117	0.954989	0.931536	0.904652	0.944845	0.91787	0.93588	0.918448
A3	0.906407	0.919557	1	0.949685	0.949216	0.973366	0.90285	0.929206	0.983949	0.955917	0.931018
A4	0.915068	0.945117	0.949685	1	0.973547	0.971471	0.915242	0.936749	0.948078	0.95112	0.911428
A5	0.922812	0.954989	0.949216	0.973547	1	0.956998	0.925577	0.940709	0.950311	0.957468	0.896909
A6	0.915287	0.931536	0.973366	0.971471	0.956998	1	0.920254	0.923938	0.973556	0.94539	0.940969
A7	0.977118	0.904652	0.90285	0.915242	0.925577	0.920254	1	0.935467	0.912635	0.906499	0.90266
A8	0.945752	0.944845	0.929206	0.936749	0.940709	0.923938	0.935467	1	0.923055	0.945281	0.896208
A9	0.916401	0.91787	0.983949	0.948078	0.950311	0.973556	0.912635	0.923055	1	0.944439	0.929713
A10	0.900727	0.93588	0.955917	0.95112	0.957468	0.94539	0.906499	0.945281	0.944439	1	0.92557
A11	0.892697	0.918448	0.931018	0.911428	0.896909	0.940969	0.90266	0.896208	0.929713	0.92557	1

Correlation coefficients of concerns while evacuating - Q13											
	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11
A1	1	0.948909	0.958726	0.940325	0.890542	0.923138	0.928592	0.95353	0.928405	0.931635	0.925167
A2	0.948909	1	0.948878	0.925568	0.92147	0.921192	0.926339	0.938831	0.927669	0.954123	0.918566
A3	0.958726	0.948878	1	0.937623	0.916351	0.942192	0.949375	0.960922	0.908893	0.94801	0.913095
A4	0.940325	0.925568	0.937623	1	0.924127	0.95924	0.935181	0.977147	0.919036	0.940874	0.960159
A5	0.890542	0.92147	0.916351	0.924127	1	0.932948	0.940609	0.924149	0.948298	0.907521	0.89786
A6	0.923138	0.921192	0.942192	0.95924	0.932948	1	0.974431	0.963328	0.923328	0.925341	0.922438
A7	0.928592	0.926339	0.949375	0.935181	0.940609	0.974431	1	0.965345	0.934751	0.924028	0.900873
A8	0.95353	0.938831	0.960922	0.977147	0.924149	0.963328	0.965345	1	0.922682	0.953893	0.949693
A9	0.928405	0.927669	0.908893	0.919036	0.948298	0.923328	0.934751	0.922682	1	0.91821	0.928652
A10	0.931635	0.954123	0.94801	0.940874	0.907521	0.925341	0.924028	0.953893	0.91821	1	0.929784
A11	0.925167	0.918566	0.913095	0.960159	0.89786	0.922438	0.900873	0.949693	0.928652	0.929784	1

Correlation coefficients of concerns while returning - Q15										
	B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**
B1	1	0.946782	0.93102	0.975944	0.912971	0.896229	0.900847	0.915036	0.91895	0.972419
B2	0.946782	1	0.904899	0.944529	0.854536	0.828586	0.909326	0.882819	0.841044	0.964425
B3	0.93102	0.904899	1	0.918263	0.929854	0.926624	0.950238	0.989157	0.914379	0.928353
B4	0.975944	0.944529	0.918263	1	0.886328	0.870865	0.889562	0.901973	0.893872	0.977716
B5	0.912971	0.854536	0.929854	0.886328	1	0.980472	0.918231	0.917172	0.959435	0.887445
B6	0.896229	0.828586	0.926624	0.870865	0.980472	1	0.891652	0.936782	0.977482	0.867187
B7	0.900847	0.909326	0.950238	0.889562	0.918231	0.891652	1	0.93894	0.876942	0.903324
B8	0.915036	0.882819	0.989157	0.901973	0.917172	0.936782	0.93894	1	0.924402	0.91129
B9	0.91895	0.841044	0.914379	0.893872	0.959435	0.977482	0.876942	0.924402	1	0.884244
B10	0.972419	0.964425	0.928353	0.977716	0.887445	0.867187	0.903324	0.91129	0.884244	1

Correlation coefficients of concerns evacuating & returning										
	B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**
A1	0.959916	0.938468	0.930963	0.979729	0.883923	0.86661	0.898465	0.911747	0.892374	0.969427
A2	0.97977	0.946307	0.923607	0.95263	0.909898	0.893211	0.929427	0.90763	0.915856	0.962179
A3	0.955734	0.909723	0.956874	0.942354	0.938817	0.925309	0.906251	0.940267	0.928662	0.93981
A4	0.945826	0.928925	0.967948	0.942889	0.934174	0.930658	0.936324	0.957259	0.923203	0.933544
A5	0.924583	0.857576	0.913858	0.896252	0.966119	0.963185	0.90363	0.918566	0.97119	0.89782
A6	0.936672	0.909077	0.9426	0.925043	0.937796	0.941546	0.898925	0.93933	0.958251	0.913296
A7	0.937344	0.887176	0.920361	0.92718	0.943992	0.946667	0.878577	0.917552	0.961	0.913014
A8	0.957411	0.929066	0.943352	0.952093	0.937108	0.928099	0.912539	0.930753	0.937077	0.938417
A9	0.936307	0.903673	0.897459	0.937334	0.924961	0.91668	0.882539	0.893367	0.929803	0.94514
A10	0.961157	0.941453	0.950185	0.937531	0.916092	0.904117	0.921246	0.939113	0.905712	0.970663

[3] Rural areas:

Correlation coefficients of the previous disaster concerns - Q10											
	A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**	**A9**	**A10**	**A11**
A1	1	1	0.909684	0.86881	0.927063	0.920252	0.865015	0.997294	0.834058	0.881321	0.878308
A2	1	1	0.909684	0.86881	0.927063	0.920252	0.865015	0.997294	0.834058	0.881321	0.878308
A3	0.909684	0.909684	1	0.922722	0.966906	0.918338	0.915397	0.913113	0.934053	0.926876	0.955154
A4	0.86881	0.86881	0.922722	1	0.957358	0.909122	0.921881	0.866459	0.9	0.933799	0.96395
A5	0.927063	0.927063	0.966906	0.957358	1	0.954307	0.894324	0.927928	0.911924	0.974526	0.950317
A6	0.920252	0.920252	0.918338	0.909122	0.954307	1	0.870211	0.917762	0.925651	0.974856	0.936735
A7	0.865015	0.865015	0.915397	0.921881	0.894324	0.870211	1	0.862674	0.888957	0.877033	0.932919
A8	0.997294	0.997294	0.913113	0.866459	0.927928	0.917762	0.862674	1	0.8318	0.878936	0.875931
A9	0.834058	0.834058	0.934053	0.9	0.911924	0.925651	0.888957	0.8318	1	0.917417	0.929928
A10	0.881321	0.881321	0.926876	0.933799	0.974526	0.974856	0.877033	0.878936	0.917417	1	0.945122
A11	0.878308	0.878308	0.955154	0.96395	0.950317	0.936735	0.932919	0.875931	0.929928	0.945122	1

Correlation coefficients of concerns while evacuating - Q13											
	A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**	**A9**	**A10**	**A11**
A1	1	0.93645	0.932029	0.911341	0.769082	0.855186	0.936701	0.897758	0.775545	0.83808	0.905107
A2	0.93645	1	0.92809	0.895487	0.796421	0.815987	0.866415	0.824485	0.796421	0.796325	0.933471
A3	0.932029	0.92809	1	0.927428	0.82517	0.928477	0.959026	0.884448	0.829536	0.918102	0.971114
A4	0.911341	0.895487	0.927428	1	0.89043	0.91386	0.969576	0.937043	0.89043	0.900544	0.928835
A5	0.769082	0.796421	0.82517	0.89043	1	0.881682	0.848233	0.691095	0.992537	0.863112	0.869475
A6	0.855186	0.815987	0.928477	0.91386	0.881682	1	0.954427	0.816497	0.893438	0.97759	0.871602
A7	0.936701	0.866415	0.959026	0.969576	0.848233	0.954427	1	0.935144	0.852721	0.943763	0.91903
A8	0.897758	0.824485	0.884448	0.937043	0.691095	0.816497	0.935144	1	0.691095	0.825723	0.864159
A9	0.775545	0.796421	0.829536	0.89043	0.992537	0.893438	0.852721	0.691095	1	0.851224	0.860693
A10	0.83808	0.796325	0.918102	0.900544	0.863112	0.97759	0.943763	0.825723	0.851224	1	0.877253
A11	0.905107	0.933471	0.971114	0.928835	0.869475	0.871602	0.91903	0.864159	0.860693	0.877253	1

Correlation coefficients of concerns while returning - Q15										
	B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**
B1	1	0.931038	0.914533	0.925327	0.786214	0.8111	0.92478	0.942483	0.943456	0.910326
B2	0.931038	1	0.862633	0.93308	0.856052	0.854097	0.92465	0.96586	0.89172	0.853627
B3	0.914533	0.862633	1	0.94716	0.717805	0.742025	0.922305	0.928235	0.920263	0.948715
B4	0.925327	0.93308	0.94716	1	0.85769	0.877562	0.949677	0.958203	0.917252	0.913076
B5	0.786214	0.856052	0.717805	0.85769	1	0.977356	0.705024	0.771393	0.833333	0.808891
B6	0.8111	0.854097	0.742025	0.877562	0.977356	1	0.750898	0.799421	0.841612	0.824651
B7	0.92478	0.92465	0.922305	0.949677	0.705024	0.750898	1	0.967487	0.85567	0.845095
B8	0.942483	0.96586	0.928235	0.958203	0.771393	0.799421	0.967487	1	0.904392	0.872524
B9	0.943456	0.89172	0.920263	0.917252	0.833333	0.841612	0.85567	0.904392	1	0.954554
B10	0.910326	0.853627	0.948715	0.913076	0.808891	0.824651	0.845095	0.872524	0.954554	1

Correlation coefficients of concerns evacuating & returning										
	B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**
A1	0.987103	0.898171	0.934709	0.918795	0.740613	0.779854	0.933367	0.923092	0.916949	0.918779
A2	0.966726	0.947112	0.90134	0.941349	0.768498	0.781313	0.940862	0.975571	0.900998	0.849539
A3	0.929074	0.906311	0.959	0.980843	0.804084	0.833902	0.949677	0.946795	0.923208	0.946967
A4	0.937686	0.905961	0.914634	0.931374	0.883452	0.881435	0.850437	0.89886	0.993884	0.958983
A5	0.813234	0.862813	0.742025	0.871013	0.977356	0.992537	0.735438	0.812419	0.855186	0.824651
A6	0.867493	0.844329	0.82885	0.887211	0.866025	0.893438	0.814092	0.829298	0.8981	0.934027
A7	0.931935	0.868747	0.937122	0.929487	0.826558	0.857209	0.876605	0.885313	0.967379	0.98778
A8	0.889499	0.807093	0.937043	0.859178	0.707107	0.691095	0.818096	0.82759	0.942809	0.946713
A9	0.819638	0.862813	0.728533	0.873196	0.977356	0.995025	0.750898	0.80592	0.855186	0.813292
A10	0.842612	0.826796	0.851111	0.872197	0.846618	0.863112	0.77896	0.820032	0.882299	0.955439

Rural Survey

[1] Urban areas:

Correlation coefficients of the previous disaster concerns - Q10											
	A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**	**A9**	**A10**	**A11**
A1	1	0.923621	0.91199	0.960367	0.956422	0.930799	0.941591	0.966017	0.922175	0.944608	0.941297
A2	0.923621	1	0.945216	0.943037	0.937873	0.964624	0.951943	0.911861	0.948321	0.965808	0.920277
A3	0.91199	0.945216	1	0.939688	0.938518	0.952828	0.93298	0.898457	0.954956	0.948608	0.943517
A4	0.960367	0.943037	0.939688	1	0.976027	0.948629	0.955176	0.944782	0.924162	0.975386	0.926824
A5	0.956422	0.937873	0.938518	0.976027	1	0.946022	0.974283	0.933294	0.944167	0.9742	0.935775
A6	0.930799	0.964624	0.952828	0.948629	0.946022	1	0.934234	0.926649	0.956854	0.963	0.928656
A7	0.941591	0.951943	0.93298	0.955176	0.974283	0.934234	1	0.916272	0.952376	0.972406	0.933779
A8	0.966017	0.911861	0.898457	0.944782	0.933294	0.926649	0.916272	1	0.890811	0.93066	0.916465
A9	0.922175	0.948321	0.954956	0.924162	0.944167	0.956854	0.952376	0.890811	1	0.939212	0.943928
A10	0.944608	0.965808	0.948608	0.975386	0.9742	0.963	0.972406	0.93066	0.939212	1	0.925272
A11	0.941297	0.920277	0.943517	0.926824	0.935775	0.928656	0.933779	0.916465	0.943928	0.925272	1

Correlation coefficients of concerns while evacuating - Q13											
	A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**	**A9**	**A10**	**A11**
A1	1	0.894338	0.98947	0.945254	0.916231	0.925851	0.909032	0.947058	0.969364	0.914906	0.94571
A2	0.894338	1	0.903038	0.907227	0.874687	0.874948	0.870794	0.911933	0.887936	0.871597	0.912874
A3	0.98947	0.903038	1	0.938613	0.936656	0.935072	0.914602	0.949729	0.972993	0.917427	0.957698
A4	0.945254	0.907227	0.938613	1	0.869385	0.877684	0.873383	0.980514	0.917921	0.867884	0.933886
A5	0.916231	0.874687	0.936656	0.869385	1	0.99061	0.959491	0.896928	0.947481	0.964002	0.922517
A6	0.925851	0.874948	0.935072	0.877684	0.99061	1	0.966407	0.906304	0.955957	0.971304	0.913486
A7	0.909032	0.870794	0.914602	0.873383	0.959491	0.966407	1	0.875776	0.926958	0.99523	0.892735
A8	0.947058	0.911933	0.949729	0.980514	0.896928	0.906304	0.875776	1	0.938663	0.882663	0.950294
A9	0.969364	0.887936	0.972993	0.917921	0.947481	0.955957	0.926958	0.938663	1	0.932231	0.939288
A10	0.914906	0.871597	0.917427	0.867884	0.964002	0.971304	0.99523	0.882663	0.932231	1	0.89669
A11	0.94571	0.912874	0.957698	0.933886	0.922517	0.913486	0.892735	0.950294	0.939288	0.89669	1

Correlation coefficients of concerns while returning - Q15										
	B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**
B1	1	0.950047	0.950647	0.962453	0.942942	0.948436	0.955199	0.983801	0.941299	0.92632
B2	0.950047	1	0.937684	0.978309	0.991657	0.937321	0.930077	0.937663	0.909882	0.901901
B3	0.950647	0.937684	1	0.946476	0.929684	0.996334	0.992281	0.940588	0.971198	0.955949
B4	0.962453	0.978309	0.946476	1	0.979146	0.94955	0.940954	0.949603	0.918512	0.909227
B5	0.942942	0.991657	0.929684	0.979146	1	0.935244	0.924955	0.928581	0.90523	0.896238
B6	0.948436	0.937321	0.996334	0.94955	0.935244	1	0.992901	0.933244	0.967955	0.953511
B7	0.955199	0.930077	0.992281	0.940954	0.924955	0.992901	1	0.937316	0.971441	0.955664
B8	0.983801	0.937663	0.940588	0.949603	0.928581	0.933244	0.937316	1	0.924919	0.907324
B9	0.941299	0.909882	0.971198	0.918512	0.90523	0.967955	0.971441	0.924919	1	0.977358
B10	0.92632	0.901901	0.955949	0.909227	0.896238	0.953511	0.955664	0.907324	0.977358	1

Correlation coefficients of concerns evacuating & returning										
	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
A1	0.946484	0.912454	0.984613	0.922834	0.901884	0.977546	0.981602	0.955549	0.965378	0.94509
A2	0.921025	0.959696	0.916917	0.942017	0.951316	0.912589	0.907014	0.911823	0.893726	0.887426
A3	0.959235	0.923352	0.989613	0.934805	0.91568	0.984981	0.990552	0.944922	0.978132	0.959578
A4	0.976631	0.931061	0.935579	0.944341	0.921637	0.926132	0.929101	0.99084	0.91848	0.897289
A5	0.908471	0.884437	0.934682	0.89507	0.887293	0.935983	0.936259	0.880718	0.956961	0.974075
A6	0.90311	0.88277	0.935483	0.892748	0.882829	0.933016	0.932768	0.891356	0.952608	0.972853
A7	0.880746	0.871108	0.922806	0.878222	0.865013	0.9162	0.912709	0.875534	0.930146	0.948268
A8	0.98851	0.939035	0.94124	0.954469	0.937961	0.937731	0.942392	0.988916	0.932608	0.915446
A9	0.935798	0.903682	0.967136	0.916539	0.899494	0.964002	0.967746	0.927703	0.991832	0.971123
A10	0.885487	0.873781	0.923062	0.882152	0.86949	0.918572	0.915882	0.882277	0.932347	0.950948

[2] Suburban areas:

Correlation coefficients of the previous disaster concerns - Q10											
	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11
A1	1	0.930487	0.914065	0.835954	0.886423	0.889329	0.927372	0.922263	0.864692	0.891991	0.893779
A2	0.930487	1	0.921056	0.914527	0.925859	0.923504	0.937495	0.954892	0.91964	0.932768	0.873291
A3	0.914065	0.921056	1	0.939101	0.929513	0.950724	0.939175	0.957155	0.951346	0.949152	0.949189
A4	0.835954	0.914527	0.939101	1	0.939663	0.957621	0.915917	0.930242	0.970791	0.948148	0.886374
A5	0.886423	0.925859	0.929513	0.939663	1	0.966545	0.925903	0.917444	0.933902	0.93993	0.940528
A6	0.889329	0.923504	0.950724	0.957621	0.966545	1	0.945961	0.932423	0.958692	0.958198	0.934484
A7	0.927372	0.937495	0.939175	0.915917	0.925903	0.945961	1	0.924799	0.928624	0.938521	0.901155
A8	0.922263	0.954892	0.957155	0.930242	0.917444	0.932423	0.924799	1	0.936233	0.950963	0.914929
A9	0.864692	0.91964	0.951346	0.970791	0.933902	0.958692	0.928624	0.936233	1	0.958232	0.893336
A10	0.891991	0.932768	0.949152	0.948148	0.93993	0.958198	0.938521	0.950963	0.958232	1	0.908516
A11	0.893779	0.873291	0.949189	0.886374	0.940528	0.934484	0.901155	0.914929	0.893336	0.908516	1

Correlation coefficients of concerns while evacuating - Q13											
	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11
A1	1	0.90608	0.947663	0.94552	0.941986	0.929223	0.963741	0.943107	0.869083	0.872414	0.922575
A2	0.90608	1	0.912614	0.931949	0.949522	0.932721	0.922999	0.959623	0.873743	0.930321	0.90816
A3	0.947663	0.912614	1	0.912206	0.903845	0.931209	0.930299	0.93064	0.856068	0.872053	0.895392
A4	0.94552	0.931949	0.912206	1	0.974284	0.934339	0.929378	0.949979	0.924814	0.919657	0.938638
A5	0.941986	0.949522	0.903845	0.974284	1	0.928329	0.923439	0.952756	0.895525	0.91956	0.930014
A6	0.929223	0.932721	0.931209	0.934339	0.928329	1	0.964344	0.971934	0.921202	0.941684	0.917947
A7	0.963741	0.922999	0.930299	0.929378	0.923439	0.964344	1	0.961546	0.901037	0.9108	0.935582
A8	0.943107	0.959623	0.93064	0.949979	0.952756	0.971934	0.961546	1	0.908607	0.923389	0.944302
A9	0.869083	0.873743	0.856068	0.924814	0.895525	0.921202	0.901037	0.908607	1	0.940543	0.874098
A10	0.872414	0.930321	0.872053	0.919657	0.91956	0.941684	0.9108	0.923389	0.940543	1	0.864801
A11	0.922575	0.90816	0.895392	0.938638	0.930014	0.917947	0.935582	0.944302	0.874098	0.864801	1

Correlation coefficients of concerns while returning - Q15										
	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
B1	1	0.93416	0.952998	0.952806	0.962566	0.941129	0.961187	0.944074	0.906514	0.922724
B2	0.93416	1	0.881148	0.916439	0.934918	0.915276	0.914587	0.931975	0.867661	0.911053
B3	0.952998	0.881148	1	0.936807	0.941597	0.936574	0.945957	0.917671	0.839292	0.849832
B4	0.952806	0.916439	0.936807	1	0.953179	0.9363	0.956824	0.966777	0.900418	0.90836
B5	0.962566	0.934918	0.941597	0.953179	1	0.949789	0.946418	0.948577	0.923566	0.925907
B6	0.941129	0.915276	0.936574	0.9363	0.949789	1	0.960377	0.962859	0.906321	0.918836
B7	0.961187	0.914587	0.945957	0.956824	0.946418	0.960377	1	0.963527	0.917334	0.94735
B8	0.944074	0.931975	0.917671	0.966777	0.948577	0.962859	0.963527	1	0.947287	0.929729
B9	0.906514	0.867661	0.839292	0.900418	0.923566	0.906321	0.917334	0.947287	1	0.945713
B10	0.922724	0.911053	0.849832	0.90836	0.925907	0.918836	0.94735	0.929729	0.945713	1

Correlation coefficients of concerns evacuating & returning										
	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
A1	0.948654	0.894532	0.971165	0.949621	0.93637	0.947528	0.952699	0.936485	0.864946	0.891342
A2	0.938947	0.949608	0.881296	0.954052	0.929717	0.924599	0.947122	0.942989	0.891724	0.94944
A3	0.928681	0.87505	0.922224	0.949087	0.918993	0.92694	0.935654	0.944923	0.866683	0.883913
A4	0.979261	0.920162	0.947882	0.951582	0.970766	0.93565	0.946851	0.944514	0.928946	0.93563
A5	0.95121	0.914718	0.92527	0.959778	0.94904	0.920925	0.931356	0.937721	0.912018	0.933656
A6	0.947206	0.910535	0.909402	0.954105	0.930199	0.952765	0.967238	0.96988	0.936709	0.933864
A7	0.944089	0.896706	0.93171	0.93367	0.928875	0.955833	0.968753	0.940351	0.896748	0.934985
A8	0.951728	0.923385	0.930029	0.981054	0.940447	0.950418	0.978007	0.970366	0.920527	0.941926
A9	0.903601	0.863337	0.847963	0.884224	0.925389	0.922512	0.906621	0.933653	0.985698	0.931868
A10	0.906972	0.888134	0.826801	0.896951	0.909452	0.921152	0.928609	0.926803	0.95648	0.981649

[3] Rural areas:

Correlation coefficients of the previous disaster concerns - Q10											
	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11
A1	1	0.925217	0.919225	0.912349	0.787159	0.910958	0.971169	0.908194	0.902272	0.842294	0.891479
A2	0.925217	1	0.918862	0.936881	0.837298	0.907676	0.915697	0.965702	0.914352	0.865079	0.892347
A3	0.919225	0.918862	1	0.96658	0.907675	0.974393	0.928255	0.944897	0.954349	0.932813	0.90276
A4	0.912349	0.936881	0.96658	1	0.895662	0.946026	0.916695	0.952523	0.976901	0.903473	0.873024
A5	0.787159	0.837298	0.907675	0.895662	1	0.9205	0.772063	0.893284	0.871916	0.945004	0.841794
A6	0.910958	0.907676	0.974393	0.946026	0.9205	1	0.88626	0.932942	0.928555	0.928494	0.880249
A7	0.971169	0.915697	0.928255	0.916695	0.772063	0.88626	1	0.902878	0.91227	0.834077	0.889768
A8	0.908194	0.965702	0.944897	0.952523	0.893284	0.932942	0.902878	1	0.930126	0.907897	0.910165
A9	0.902272	0.914352	0.954349	0.976901	0.871916	0.928555	0.91227	0.930126	1	0.881936	0.889251
A10	0.842294	0.865079	0.932813	0.903473	0.945004	0.928494	0.834077	0.907897	0.881936	1	0.902978
A11	0.891479	0.892347	0.90276	0.873024	0.841794	0.880249	0.889768	0.910165	0.889251	0.902978	1

Correlation coefficients of concerns while evacuating - Q13											
	A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**	**A9**	**A10**	**A11**
A1	1	0.930904	0.929332	0.911356	0.875715	0.855638	0.919247	0.858834	0.863874	0.932261	0.928008
A2	0.930904	1	0.889482	0.895333	0.912659	0.870806	0.895563	0.892677	0.909765	0.914068	0.936636
A3	0.929332	0.889482	1	0.975338	0.895988	0.937562	0.97517	0.936764	0.898303	0.934355	0.96387
A4	0.911356	0.895333	0.975338	1	0.907412	0.965816	0.949732	0.956411	0.901202	0.926708	0.964662
A5	0.875715	0.912659	0.895988	0.907412	1	0.877165	0.904008	0.882475	0.951954	0.928801	0.924982
A6	0.855638	0.870806	0.937562	0.965816	0.877165	1	0.911925	0.968944	0.85214	0.880611	0.930816
A7	0.919247	0.895563	0.97517	0.949732	0.904008	0.911925	1	0.924776	0.898175	0.924392	0.937287
A8	0.858834	0.892677	0.936764	0.956411	0.882475	0.968944	0.924776	1	0.872676	0.88621	0.919123
A9	0.863874	0.909765	0.898303	0.901202	0.951954	0.85214	0.898175	0.872676	1	0.915947	0.951393
A10	0.932261	0.914068	0.934355	0.926708	0.928801	0.880611	0.924392	0.88621	0.915947	1	0.931688
A11	0.928008	0.936636	0.96387	0.964662	0.924982	0.930816	0.937287	0.919123	0.951393	0.931688	1

Correlation coefficients of concerns while returning - Q15										
	B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**
B1	1	0.933713	0.910219	0.9555	0.952525	0.924166	0.935829	0.86973	0.897573	0.956699
B2	0.933713	1	0.914872	0.923709	0.914759	0.92145	0.928426	0.909581	0.938526	0.941095
B3	0.910219	0.914872	1	0.904701	0.924852	0.940552	0.923346	0.917634	0.913459	0.932749
B4	0.9555	0.923709	0.904701	1	0.909966	0.92769	0.919432	0.871027	0.875177	0.935852
B5	0.952525	0.914759	0.924852	0.909966	1	0.95862	0.942344	0.907817	0.935122	0.970294
B6	0.924166	0.92145	0.940552	0.92769	0.95862	1	0.94679	0.92268	0.911269	0.963885
B7	0.935829	0.928426	0.923346	0.919432	0.942344	0.94679	1	0.918327	0.904769	0.930776
B8	0.86973	0.909581	0.917634	0.871027	0.907817	0.92268	0.918327	1	0.905173	0.898585
B9	0.897573	0.938526	0.913459	0.875177	0.935122	0.911269	0.904769	0.905173	1	0.93519
B10	0.956699	0.941095	0.932749	0.935852	0.970294	0.963885	0.930776	0.898585	0.93519	1

Correlation coefficients of concerns evacuating & returning										
	B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**
A1	0.958984	0.944794	0.896537	0.972982	0.924141	0.940036	0.926189	0.861869	0.884278	0.952708
A2	0.915668	0.975363	0.943977	0.912146	0.907939	0.924395	0.897802	0.895892	0.916239	0.936979
A3	0.9373	0.919907	0.922645	0.925764	0.945757	0.950483	0.989522	0.928075	0.912138	0.935964
A4	0.927297	0.929373	0.939194	0.91402	0.935709	0.946022	0.965585	0.952139	0.928	0.938069
A5	0.895177	0.912906	0.91725	0.869506	0.926441	0.917797	0.899702	0.910391	0.949856	0.92662
A6	0.87023	0.911979	0.893458	0.867112	0.901189	0.907175	0.928669	0.977663	0.911315	0.886705
A7	0.938948	0.918592	0.929058	0.907261	0.938254	0.931033	0.982502	0.90031	0.9091	0.92308
A8	0.88044	0.918488	0.925036	0.879159	0.899145	0.898608	0.931982	0.948502	0.928391	0.888587
A9	0.875141	0.878913	0.953447	0.848754	0.934372	0.932333	0.893896	0.883865	0.935963	0.928042
A10	0.965447	0.925098	0.914121	0.926323	0.981785	0.941487	0.928989	0.886241	0.93606	0.972177

Age Survey

[1] Urban areas:

Correlation coefficients of the previous disaster concerns - Q10											
	A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**	**A9**	**A10**	**A11**
A1	1	0.947293	0.859308	0.94009	0.890949	0.898617	0.947293	0.919144	0.900126	0.836167	0.880348
A2	0.947293	1	0.876205	0.923574	0.927225	0.915877	1	0.928344	0.905834	0.848236	0.897169
A3	0.859308	0.876205	1	0.915692	0.96608	0.938532	0.876205	0.95026	0.94758	0.940619	0.822397
A4	0.94009	0.923574	0.915692	1	0.930618	0.931361	0.923574	0.937833	0.948032	0.921332	0.915456
A5	0.890949	0.927225	0.96608	0.930618	1	0.920194	0.927225	0.95604	0.949672	0.920942	0.845373
A6	0.898617	0.915877	0.938532	0.931361	0.920194	1	0.915877	0.920383	0.92333	0.932692	0.91889
A7	0.947293	1	0.876205	0.923574	0.927225	0.915877	1	0.928344	0.905834	0.848236	0.897169
A8	0.919144	0.928344	0.95026	0.937833	0.95604	0.920383	0.928344	1	0.980494	0.900827	0.835315
A9	0.900126	0.905834	0.94758	0.948032	0.949672	0.92333	0.905834	0.980494	1	0.92858	0.851012
A10	0.836167	0.848236	0.940619	0.921332	0.920942	0.932692	0.848236	0.900827	0.92858	1	0.857067
A11	0.880348	0.897169	0.822397	0.915456	0.845373	0.91889	0.897169	0.835315	0.851012	0.857067	1

Correlation coefficients of concerns while evacuating - Q13											
	A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**	**A9**	**A10**	**A11**
A1	1	0.819892	0.930261	0.806226	0.766667	0.814092	0.852013	0.882442	0.876714	0.885438	0.814092
A2	0.819892	1	0.83205	0.83205	0.869582	0.70014	0.816497	0.793816	0.653464	0.659966	0.840168
A3	0.930261	0.83205	1	0.884615	0.826898	0.932083	0.962435	0.962435	0.893246	0.902134	0.893246
A4	0.806226	0.83205	0.884615	1	0.930261	0.912664	0.962435	0.943564	0.893246	0.882523	0.990338
A5	0.766667	0.869582	0.826898	0.930261	1	0.761906	0.862156	0.862156	0.814092	0.769488	0.887151
A6	0.814092	0.70014	0.932083	0.912664	0.761906	1	0.971825	0.933715	0.882353	0.891133	0.921569
A7	0.852013	0.816497	0.962435	0.962435	0.862156	0.971825	1	0.981481	0.905131	0.914138	0.971825
A8	0.882442	0.793816	0.962435	0.943564	0.862156	0.933715	0.981481	1	0.95277	0.96225	0.95277
A9	0.876714	0.653464	0.893246	0.893246	0.814092	0.882353	0.905131	0.95277	1	0.990148	0.882353
A10	0.885438	0.659966	0.902134	0.882523	0.769488	0.891133	0.914138	0.96225	0.990148	1	0.891133
A11	0.814092	0.840168	0.893246	0.990338	0.887151	0.921569	0.971825	0.95277	0.882353	0.891133	1

Correlation coefficients of concerns while returning - Q15										
	B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**
B1	1	0.82584	0.990148	0.882353	0.961716	0.873828	0.882353	0.961716	0.756238	0.834966
B2	0.82584	1	0.834058	0.805194	0.911372	0.94054	0.805194	0.911372	0.71665	0.692349
B3	0.990148	0.834058	1	0.891133	0.971286	0.882523	0.891133	0.971286	0.763763	0.843274
B4	0.882353	0.805194	0.891133	1	0.904013	0.932083	1	0.904013	0.907485	0.939336
B5	0.961716	0.911372	0.971286	0.904013	1	0.933376	0.904013	1	0.816015	0.870251
B6	0.873828	0.94054	0.882523	0.932083	0.933376	1	0.932083	0.933376	0.898717	0.868243
B7	0.882353	0.805194	0.891133	1	0.904013	0.932083	1	0.904013	0.907485	0.939336
B8	0.961716	0.911372	0.971286	0.904013	1	0.933376	0.904013	1	0.816015	0.870251
B9	0.756238	0.71665	0.763763	0.907485	0.816015	0.898717	0.907485	0.816015	1	0.966092
B10	0.834966	0.692349	0.843274	0.939336	0.870251	0.868243	0.939336	0.870251	0.966092	1

Correlation coefficients of concerns evacuating & returning										
	B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**
A1	0.78278	0.989071	0.790569	0.814092	0.890728	0.930261	0.814092	0.890728	0.724569	0.7
A2	0.81683	0.884652	0.824958	0.70014	0.80127	0.83205	0.70014	0.80127	0.540062	0.521749
A3	0.873828	0.94054	0.882523	0.932083	0.933376	1	0.932083	0.933376	0.898717	0.868243
A4	0.990338	0.838307	0.980581	0.912664	0.952424	0.884615	0.912664	0.952424	0.748931	0.826898
A5	0.939336	0.824226	0.895979	0.761906	0.870251	0.826898	0.761906	0.870251	0.644061	0.677778
A6	0.882353	0.805194	0.891133	1	0.904013	0.932083	1	0.904013	0.907485	0.939336
A7	0.95277	0.872797	0.96225	0.971825	0.962659	0.962435	0.971825	0.962659	0.881917	0.912871
A8	0.95277	0.902894	0.96225	0.933715	0.990697	0.962435	0.933715	0.990697	0.881917	0.912871
A9	0.901961	0.867132	0.891133	0.882353	0.961716	0.893246	0.882353	0.961716	0.831861	0.887151
A10	0.891133	0.875761	0.9	0.891133	0.971286	0.902134	0.891133	0.971286	0.840139	0.895979

[2] Suburban areas:

Correlation coefficients of the previous disaster concerns - Q10											
	A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**	**A9**	**A10**	**A11**
A1	1	0.967449	0.853782	0.817842	0.925553	0.88922	0.939794	0.896155	0.915801	0.894109	0.895613
A2	0.967449	1	0.87316	0.839307	0.920919	0.907929	0.963351	0.921078	0.914206	0.910206	0.896142
A3	0.853782	0.87316	1	0.957596	0.946612	0.959399	0.904029	0.931898	0.928029	0.968479	0.880855
A4	0.817842	0.839307	0.957596	1	0.933267	0.955303	0.871448	0.932642	0.931217	0.95318	0.836188
A5	0.925553	0.920919	0.946612	0.933267	1	0.950278	0.924619	0.956978	0.960707	0.946647	0.881916
A6	0.88922	0.907929	0.959399	0.955303	0.950278	1	0.929427	0.93715	0.943163	0.983763	0.915985
A7	0.939794	0.963351	0.904029	0.871448	0.924619	0.929427	1	0.914465	0.908153	0.935112	0.894106
A8	0.896155	0.921078	0.931898	0.932642	0.956978	0.93715	0.914465	1	0.976927	0.934202	0.855526
A9	0.915801	0.914206	0.928029	0.931217	0.960707	0.943163	0.908153	0.976927	1	0.938518	0.875961
A10	0.894109	0.910206	0.968479	0.95318	0.946647	0.983763	0.935112	0.934202	0.938518	1	0.917448
A11	0.895613	0.896142	0.880855	0.836188	0.881916	0.915985	0.894106	0.855526	0.875961	0.917448	1

Correlation coefficients of concerns while evacuating - Q13											
	A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**	**A9**	**A10**	**A11**
A1	1	0.874466	0.918994	0.84213	0.838135	0.847772	0.875675	0.884296	0.854543	0.865493	0.882385
A2	0.874466	1	0.938279	0.876366	0.853024	0.905043	0.914029	0.912818	0.856625	0.951718	0.907988
A3	0.918994	0.938279	1	0.886656	0.878866	0.91479	0.929385	0.933039	0.880731	0.919097	0.940327
A4	0.84213	0.876366	0.886656	1	0.922779	0.922828	0.956765	0.965605	0.879354	0.933725	0.864411
A5	0.838135	0.853024	0.878866	0.922779	1	0.931903	0.907639	0.896407	0.947217	0.928409	0.879549
A6	0.847772	0.905043	0.91479	0.922828	0.931903	1	0.947752	0.950893	0.879347	0.936533	0.907142
A7	0.875675	0.914029	0.929385	0.956765	0.907639	0.947752	1	0.986445	0.878219	0.947893	0.906392
A8	0.884296	0.912818	0.933039	0.965605	0.896407	0.950893	0.986445	1	0.866492	0.946071	0.891039
A9	0.854543	0.856625	0.880731	0.879354	0.947217	0.879347	0.878219	0.866492	1	0.913683	0.898873
A10	0.865493	0.951718	0.919097	0.933725	0.928409	0.936533	0.947893	0.946071	0.913683	1	0.898692
A11	0.882385	0.907988	0.940327	0.864411	0.879549	0.907142	0.906392	0.891039	0.898873	0.898692	1

Correlation coefficients of concerns while returning - Q15										
	B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**
B1	1	0.919384	0.980323	0.90089	0.884747	0.888831	0.902572	0.900532	0.921552	0.908796
B2	0.919384	1	0.903109	0.914706	0.883861	0.904424	0.874566	0.885386	0.939962	0.964325
B3	0.980323	0.903109	1	0.895137	0.886483	0.883076	0.894164	0.892239	0.91102	0.904138
B4	0.90089	0.914706	0.895137	1	0.929558	0.982298	0.931906	0.946887	0.970709	0.9425
B5	0.884747	0.883861	0.886483	0.929558	1	0.92956	0.921749	0.923678	0.919112	0.952017
B6	0.888831	0.904424	0.883076	0.982298	0.92956	1	0.944825	0.949011	0.969149	0.936597
B7	0.902572	0.874566	0.894164	0.931906	0.921749	0.944825	1	0.958989	0.910147	0.902049
B8	0.900532	0.885386	0.892239	0.946887	0.923678	0.949011	0.958989	1	0.919393	0.913541
B9	0.921552	0.939962	0.91102	0.970709	0.919112	0.969149	0.910147	0.919393	1	0.947923
B10	0.908796	0.964325	0.904138	0.9425	0.952017	0.936597	0.902049	0.913541	0.947923	1

Correlation coefficients of concerns evacuating & returning										
	B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**
A1	0.934522	0.858557	0.947592	0.86695	0.881727	0.857008	0.87752	0.891823	0.880633	0.87815
A2	0.933822	0.972906	0.916345	0.910116	0.902019	0.901411	0.875897	0.891309	0.926447	0.960404
A3	0.951953	0.952752	0.942002	0.941973	0.900141	0.939255	0.906164	0.923718	0.967872	0.936742
A4	0.861865	0.860607	0.859526	0.932247	0.977989	0.932355	0.916552	0.932711	0.910324	0.923571
A5	0.862116	0.850227	0.852856	0.941789	0.920462	0.920208	0.890165	0.914467	0.903335	0.897612
A6	0.885338	0.913614	0.875045	0.973401	0.932995	0.966977	0.947913	0.923467	0.947236	0.938993
A7	0.901121	0.909141	0.901374	0.966903	0.952455	0.963526	0.935378	0.93911	0.953514	0.957665
A8	0.895862	0.905442	0.89745	0.96181	0.963326	0.961765	0.933006	0.931402	0.95381	0.950405
A9	0.87806	0.858134	0.86777	0.891232	0.906056	0.869192	0.842538	0.86557	0.903265	0.893517
A10	0.897463	0.933797	0.88922	0.943632	0.953318	0.932327	0.896701	0.914724	0.933382	0.975182

[3] Rural areas:

Correlation coefficients of the previous disaster concerns - Q10											
	A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**	**A9**	**A10**	**A11**
A1	1	0.90134	0.859394	0.904674	0.93456	0.910335	0.909821	0.75459	0.932674	0.86037	0.849612
A2	0.90134	1	0.911752	0.899657	0.839758	0.896592	0.927778	0.666066	0.825918	0.768293	0.918693
A3	0.859394	0.911752	1	0.94829	0.803339	0.970261	0.839966	0.679807	0.81808	0.794703	0.979033
A4	0.904674	0.899657	0.94829	1	0.85508	0.954449	0.917742	0.859538	0.86887	0.911341	0.928407
A5	0.93456	0.839758	0.803339	0.85508	1	0.811263	0.849742	0.77098	0.985861	0.874241	0.782865
A6	0.910335	0.896592	0.970261	0.954449	0.811263	1	0.856326	0.732877	0.825501	0.824865	0.949918
A7	0.909821	0.927778	0.839966	0.917742	0.849742	0.856326	1	0.805823	0.848027	0.867533	0.839303
A8	0.75459	0.666066	0.679807	0.859538	0.77098	0.732877	0.805823	1	0.749117	0.89715	0.694365
A9	0.932674	0.825918	0.81808	0.86887	0.985861	0.825501	0.848027	0.749117	1	0.882598	0.768752
A10	0.86037	0.768293	0.794703	0.911341	0.874241	0.824865	0.867533	0.89715	0.882598	1	0.761383
A11	0.849612	0.918693	0.979033	0.928407	0.782865	0.949918	0.839303	0.694365	0.768752	0.761383	1

Correlation coefficients of concerns while evacuating - Q13											
	A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**	**A9**	**A10**	**A11**
A1	1	0.937958	0.906693	0.852574	0.819782	0.937958	0.983739	0.954864	0.725866	0.898027	0.852574
A2	0.937958	1	0.893939	0.889898	0.889898	1	0.953463	0.985184	0.80403	0.783349	0.889898
A3	0.906693	0.893939	1	0.905789	0.874007	0.893939	0.874007	0.925476	0.904534	0.870388	0.905789
A4	0.852574	0.889898	0.905789	1	0.766667	0.889898	0.866667	0.876714	0.948683	0.63901	1
A5	0.819782	0.889898	0.874007	0.766667	1	0.889898	0.766667	0.939336	0.737865	0.821584	0.766667
A6	0.937958	1	0.893939	0.889898	0.889898	1	0.953463	0.985184	0.80403	0.783349	0.889898
A7	0.983739	0.953463	0.874007	0.866667	0.766667	0.953463	1	0.939336	0.737865	0.821584	0.866667
A8	0.954864	0.985184	0.925476	0.876714	0.939336	0.985184	0.939336	1	0.792118	0.857493	0.876714
A9	0.725866	0.80403	0.904534	0.948683	0.737865	0.80403	0.737865	0.792118	1	0.57735	0.948683
A10	0.898027	0.783349	0.870388	0.63901	0.821584	0.783349	0.821584	0.857493	0.57735	1	0.63901
A11	0.852574	0.889898	0.905789	1	0.766667	0.889898	0.866667	0.876714	0.948683	0.63901	1

Correlation coefficients of concerns while returning - Q15										
	B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**
B1	1	0.953463	0.909091	0.905789	1	0.905789	0.953463	0.783349	0.909091	0.954545
B2	0.953463	1	0.826334	0.9	0.953463	0.95	1	0.730297	0.905789	0.905789
B3	0.909091	0.826334	1	0.874007	0.909091	0.889898	0.826334	0.783349	0.954545	0.969697
B4	0.905789	0.9	0.874007	1	0.905789	0.9	0.9	0.730297	0.953463	0.905789
B5	1	0.953463	0.909091	0.905789	1	0.905789	0.953463	0.783349	0.909091	0.954545
B6	0.905789	0.95	0.889898	0.9	0.905789	1	0.95	0.63901	0.953463	0.953463
B7	0.953463	1	0.826334	0.9	0.953463	0.95	1	0.730297	0.905789	0.905789
B8	0.783349	0.730297	0.783349	0.730297	0.783349	0.63901	0.730297	1	0.783349	0.696311
B9	0.909091	0.905789	0.954545	0.953463	0.909091	0.953463	0.905789	0.783349	1	0.954545
B10	0.954545	0.905789	0.969697	0.905789	0.954545	0.953463	0.905789	0.696311	0.954545	1

Correlation coefficients of concerns evacuating & returning										
	B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**
A1	0.937958	0.819782	0.906693	0.819782	0.937958	0.7542	0.819782	0.898027	0.844162	0.875428
A2	0.954545	0.874007	0.969697	0.826334	0.954545	0.889898	0.874007	0.783349	0.909091	0.969697
A3	0.954545	0.953463	0.893939	0.953463	0.954545	0.905789	0.953463	0.870388	0.954545	0.909091
A4	0.953463	0.9	0.889898	0.95	0.953463	0.9	0.9	0.63901	0.905789	0.953463
A5	0.810443	0.783333	0.953463	0.833333	0.810443	0.866667	0.783333	0.821584	0.953463	0.889898
A6	0.954545	0.874007	0.969697	0.826334	0.954545	0.889898	0.874007	0.783349	0.909091	0.969697
A7	0.953463	0.833333	0.889898	0.783333	0.953463	0.766667	0.833333	0.821584	0.810443	0.889898
A8	0.940403	0.861058	0.985184	0.861058	0.940403	0.876714	0.861058	0.857493	0.940403	0.95533
A9	0.904534	0.948683	0.80403	0.948683	0.904534	0.948683	0.948683	0.57735	0.904534	0.904534
A10	0.783349	0.730297	0.783349	0.730297	0.783349	0.63901	0.730297	1	0.783349	0.696311

The Experts Survey

The correlation coefficients were calculated for the *Mobility & Resilience* section variables. The matrices shown in this section report the correlation coefficients obtained for the following:

1- The variables of Q17, which asked about the concerns about the performance of infrastructure elements within the geographic area of the agency: *Q17: Please rank your level of concern regarding the hazard vulnerability of the following infrastructure elements within the geographic area your agency serves (mark each on a scale of 1-5, with 1 meaning no concern and 5 very high concern)*
2- The variables of Q18, which asked about the concerns regarding relevant transportation issues that impact the capacity of the system to meet the needs of the vulnerable populations: *Q18: Please rank your level of concern regarding transportation issues relative to the needs of the residents within your agency's jurisdiction (mark each on a scale of 1-5, with 1 meaning no concern and 5 very high concern)*

In both questions, the experts were asked to rank their concerns from 0 (no concern) to 5 (most concern). The tables below summarize the lists of concerns provided in the survey.

Q17:

A1	Critical emergency response facilities like police and fire stations
A2	Medical facilities like hospitals and clinics
A3	The federal and/or state highway system
A4	Local roads
A5	Public shelters
A6	Power / communications infrastructure
A7	Drainage
A8	Ports/ airports
A9	Rail
A10	Bridges
A11*	Other

*A11 was left out of the analysis as the degree of association with a non-specific variable (other) is not useful.

Q18:

B1	Evacuation
B2	Re-entry
B3	Fuel accessibility
B4	Temporary road closures due to flooding or debris
B5	Long-term road closures due to disasters damage
B6	Disruptions to public transportation routes or shedules
B7	Lack of service at airports or ports
B8	Long-term disruptions to airports or ports

Q17:

Concerns about the vulnerability of infrastructure elements										
	A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**	**A9**	**A10**
A1	1	0.671807	0.827014	0.765906	0.799093	0.726978	0.737273	0.467776	0.575363	0.82669
A2	0.671807	1	0.807273	0.856962	0.872802	0.855076	0.847917	0.734623	0.842804	0.802975
A3	0.827014	0.807273	1	0.910594	0.933979	0.927865	0.924782	0.587379	0.690895	0.956246
A4	0.765906	0.856962	0.910594	1	0.946472	0.939697	0.956032	0.629264	0.740616	0.906271
A5	0.799093	0.872802	0.933979	0.946472	1	0.933753	0.940384	0.626226	0.718319	0.941924
A6	0.726978	0.855076	0.927865	0.939697	0.933753	1	0.961596	0.650779	0.704041	0.861602
A7	0.737273	0.847917	0.924782	0.956032	0.940384	0.961596	1	0.630391	0.706409	0.889983
A8	0.467776	0.734623	0.587379	0.629264	0.626226	0.650779	0.630391	1	0.81531	0.557664
A9	0.575363	0.842804	0.690895	0.740616	0.718319	0.704041	0.706409	0.81531	1	0.696014
A10	0.82669	0.802975	0.956246	0.906271	0.941924	0.861602	0.889983	0.557664	0.696014	1

Q18:

Concerns about the transportation issues to the needs of the populations								
	B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**
B1	1	0.821387	0.796348	0.886713	0.85277	0.837334	0.606206	0.750688
B2	0.821387	1	0.92306	0.797946	0.952193	0.952348	0.705696	0.826231
B3	0.796348	0.92306	1	0.683963	0.896454	0.930635	0.741543	0.836322
B4	0.886713	0.797946	0.683963	1	0.781541	0.749889	0.518031	0.665261
B5	0.85277	0.952193	0.896454	0.781541	1	0.970854	0.700426	0.838169
B6	0.837334	0.952348	0.930635	0.749889	0.970854	1	0.706097	0.836583
B7	0.606206	0.705696	0.741543	0.518031	0.700426	0.706097	1	0.825512
B8	0.750688	0.826231	0.836322	0.665261	0.838169	0.836583	0.825512	1

Appendix E: Statistical Importance Scores of Responses

The Vulnerable Populations Survey

To prioritize the concerns of the populations, and determine which concerns are significant compared to the others, the statistical percentages and means were used as a method of providing an importance score to the responses based on the overall responses of the populations. The score used to rank the concerns is calculated by diving the sum of the products of the responses (taking into account the degree of concerns) over the maximum possible points in a specific response. For example, if we take Q10 from the minority survey as an example:

MATRIX, SINGLE SELECTION

Q10. What concerned you the most during the hazard event(s) you experienced? (Rank each on a scale of 1-5, with 1 representing no concern and 5 representing extreme concern)

#	Statements	1 - no concern	2	3 - moderate concern	4	5 - extreme concern
A1	My personal safety and/or that of my family members	10 *(6.41%)*	6 *(3.85%)*	40 *(25.64%)*	25 *(16.03%)*	75 *(48.08%)*

The importance counts for the '*Safety*' concern are calculated by multiplying the degree of concern by the number of respondents, for example, for concern level 1, the importance count is $1 \times 10 = 10$.

Level of concern	1	2	3	4	5
Importance count	10	12	120	100	375

The sum of products of respondents is then calculated by summing the importance counts = 617.

The value of the maximum possible points is calculated by multiplying the number of total respondents by the highest level of concern possible. In the example, we have 156 respondents, with the maximum level of concern being 5, giving a maximum possible points value of $156 \times 5 = 780$.

The statistical percentage of responses is then calculated by dividing the sum of importance counts by the maximum possible points:

$$\frac{617}{780} \times 100\% = 79.10\%$$

The importance scores (statistical percentages) are calculated for all variables in all surveys, to rank the concerns of different population groups (e.g., minority, rural, and older). The results are reported as follows:

1- The importance scores are calculated for different population groups, e.g., minority, rural, and older separately.
2- The importance scores are calculated for each group based on the level of development within the region. For example, the concerns of minority groups living in urban, suburban, and rural areas are reported separately.

The importance scores for the surveys are reported in the following tables.

Importance scores

[1] Minority Survey:

Overall:

Products & Means of Results																	
Minority Survey																	
Concern		Respondents Scoring					Importance count					Total respond.	Sum of products	Mean Value	Max. Points	%age
		1	2	3	4	5	1	2	3	4	5					
During hazard	Safety	10	6	40	25	75	10	12	120	100	375	156	617	3.955128	780	79.10%
	Accessibility to transportation	20	17	42	35	42	20	34	126	140	210	156	530	3.397436	780	67.95%
	Quality (functionality) of network	10	13	53	34	46	10	26	159	136	230	156	561	3.596154	780	71.92%
	Capacity of the network	15	13	45	30	53	15	26	135	120	265	156	561	3.596154	780	71.92%
During evacuation	Safety	28	20	28	9	5	28	40	84	36	25	90	213	2.366667	450	47.33%
	Clear communication/directions	11	9	32	17	21	11	18	96	68	105	90	298	3.311111	450	66.22%
	Quality (functionality) of network	6	7	27	24	26	6	14	81	96	130	90	327	3.633333	450	72.67%
	Capacity of the network	10	10	23	19	28	10	20	69	76	140	90	315	3.5	450	70.00%
	Fuel availability	7	3	24	20	36	7	6	72	80	180	90	345	3.833333	450	76.67%
	Quality of drainage systems	11	7	26	15	31	11	14	78	60	155	90	318	3.533333	450	70.67%
	Network clearance (debris)	6	7	37	12	28	6	14	111	48	140	90	319	3.544444	450	70.89%
During return	Safety	33	21	29	3	4	33	42	87	12	20	90	194	2.155556	450	43.11%
	Clear communication/directions	15	10	26	17	22	15	20	78	68	110	90	291	3.233333	450	64.67%
	Quality of network	10	5	23	22	30	10	10	69	88	150	90	327	3.633333	450	72.67%
	Capacity of the network	7	11	33	16	23	7	22	99	64	115	90	307	3.411111	450	68.22%
	Fuel availability	5	9	27	14	35	5	18	81	56	175	90	335	3.722222	450	74.44%
	Quality of drainage systems	8	10	26	23	23	8	20	78	92	115	90	313	3.477778	450	69.56%
	Network clearance (debris)	10	6	30	21	23	10	12	90	84	115	90	311	3.455556	450	69.11%

Urban areas only:

Urban																
Concern		Respondents Scoring					Importance count					Total respond.	Sum of products	Mean Value	Max. Points	%age
		1	2	3	4	5	1	2	3	4	5					
During hazard	Safety	4	2	12	10	26	4	4	36	40	130	54	214	3.962963	270	79.26%
	Accessibility to transportation	6	7	12	11	18	6	14	36	44	90	54	190	3.518519	270	70.37%
	Quality (functionality) of network	3	4	19	11	17	3	8	57	44	85	54	197	3.648148	270	72.96%
	Capacity of the network	4	4	15	11	20	4	8	45	44	100	54	201	3.722222	270	74.44%
During evacuation	Safety	2	3	10	11	15	2	6	30	44	75	41	157	3.829268	205	76.59%
	Clear communication/directions	8	4	12	8	9	8	8	36	32	45	41	129	3.146341	205	62.93%
	Quality (functionality) of network	2	3	10	14	12	2	6	30	56	60	41	154	3.756098	205	75.12%
	Capacity of the network	5	5	12	9	10	5	10	36	36	50	41	137	3.341463	205	66.83%
	Fuel availability	3	2	11	13	12	3	4	33	52	60	41	152	3.707317	205	74.15%
	Quality of drainage systems	7	4	9	10	11	7	8	27	40	55	41	137	3.341463	205	66.83%
	Network clearance (debris)	3	4	18	5	11	3	8	54	20	55	41	140	3.414634	205	68.29%
During return	Safety	1	1	13	9	17	1	2	39	36	85	41	163	3.97561	205	79.51%
	Clear communication/directions	9	4	11	8	9	9	8	33	32	45	41	127	3.097561	205	61.95%
	Quality of network	6	2	7	11	15	6	4	21	44	75	41	150	3.658537	205	73.17%
	Capacity of the network	4	5	15	9	8	4	10	45	36	40	41	135	3.292683	205	65.85%
	Fuel availability	2	6	13	9	11	2	12	39	36	55	41	144	3.512195	205	70.24%
	Quality of drainage systems	2	6	12	9	12	2	12	36	36	60	41	146	3.560976	205	71.22%
	Network clearance (debris)	6	4	13	8	10	6	8	39	32	50	41	135	3.292683	205	65.85%

Suburban areas only:

Suburban																
Concern		Respondents Scoring					Importance count					Total	Sum of	Mean	Max.	
		1	2	3	4	5	1	2	3	4	5	respond.	products	Value	Points	%age
During hazard	Safety	4	4	22	12	40	4	8	66	48	200	82	326	3.97561	410	79.51%
	Accessibility to transportation	11	9	24	19	19	11	18	72	76	95	82	272	3.317073	410	66.34%
	Quality (functionality) of network	6	7	27	19	23	6	14	81	76	115	82	292	3.560976	410	71.22%
	Capacity of the network	7	8	26	15	26	7	16	78	60	130	82	291	3.54878	410	70.98%
During evacuation	Safety	9	6	13	5	2	9	12	39	20	10	35	90	2.571429	175	51.43%
	Clear communication/directions	2	4	15	5	9	2	8	45	20	45	35	120	3.428571	175	68.57%
	Quality (functionality) of network	3	2	14	7	9	3	4	42	28	45	35	122	3.485714	175	69.71%
	Capacity of the network	2	4	10	8	11	2	8	30	32	55	35	127	3.628571	175	72.57%
	Fuel availability	3	0	11	6	15	3	0	33	24	75	35	135	3.857143	175	77.14%
	Quality of drainage systems	3	1	14	4	13	3	2	42	16	65	35	128	3.657143	175	73.14%
	Network clearance (debris)	3	3	12	6	11	3	6	36	24	55	35	124	3.542857	175	70.86%
During return	Safety	11	8	13	2	1	11	16	39	8	5	35	79	2.257143	175	45.14%
	Clear communication/directions	4	4	12	5	10	4	8	36	20	50	35	118	3.371429	175	67.43%
	Quality of network	3	2	11	10	9	3	4	33	40	45	35	125	3.571429	175	71.43%
	Capacity of the network	2	5	14	4	10	2	10	42	16	50	35	120	3.428571	175	68.57%
	Fuel availability	3	2	10	4	16	3	4	30	16	80	35	133	3.8	175	76.00%
	Quality of drainage systems	3	3	9	13	7	3	6	27	52	35	35	123	3.514286	175	70.29%
	Network clearance (debris)	3	0	13	10	9	3	0	39	40	45	35	127	3.628571	175	72.57%

Rural areas only:

Rural																
Concern		Respondents Scoring					Importance count					Total	Sum of	Mean	Max.	
		1	2	3	4	5	1	2	3	4	5	respond.	products	Value	Points	%age
During hazard	Safety	1	0	3	3	9	1	0	9	12	45	16	67	4.1875	80	83.75%
	Accessibility to transportation	3	0	4	4	5	3	0	12	16	25	16	56	3.5	80	70.00%
	Quality (functionality) of network	0	0	6	4	6	0	0	18	16	30	16	64	4	80	80.00%
	Capacity of the network	3	1	3	3	6	3	2	9	12	30	16	56	3.5	80	70.00%
During evacuation	Safety	4	2	4	1	1	4	4	12	4	5	12	29	2.416667	60	48.33%
	Clear communication/directions	1	1	4	3	3	1	2	12	12	15	12	42	3.5	60	70.00%
	Quality (functionality) of network	1	1	3	2	5	1	2	9	8	25	12	45	3.75	60	75.00%
	Capacity of the network	3	0	1	2	6	3	0	3	8	30	12	44	3.666667	60	73.33%
	Fuel availability	1	0	2	1	8	1	0	6	4	40	12	51	4.25	60	85.00%
	Quality of drainage systems	1	1	3	1	6	1	2	9	4	30	12	46	3.833333	60	76.67%
	Network clearance (debris)	0	0	6	0	6	0	0	18	0	30	12	48	4	60	80.00%
During return	Safety	5	4	3	0	0	5	8	9	0	0	12	22	1.833333	60	36.67%
	Clear communication/directions	2	1	3	3	3	2	2	9	12	15	12	40	3.333333	60	66.67%
	Quality of network	1	0	5	1	5	1	0	15	4	25	12	45	3.75	60	75.00%
	Capacity of the network	1	1	2	3	5	1	2	6	12	25	12	46	3.833333	60	76.67%
	Fuel availability	0	0	4	0	8	0	0	12	0	40	12	52	4.333333	60	86.67%
	Quality of drainage systems	2	0	5	1	4	2	0	15	4	20	12	41	3.416667	60	68.33%
	Network clearance (debris)	1	2	4	1	4	1	4	12	4	20	12	41	3.416667	60	68.33%

[2] Rural Survey:

Overall:

Rural Survey																		
Concern		Respondents Scoring					Importance count					Total	Sum of	Mean	Max.	
		1	2	3	4	5	1	2	3	4	5	respond.	products	Value	Points	%age
During hazard	Safety	9	10	39	32	75	9	20	117	128	375	165	649	3.933333	825	78.67%
	Accessibility to transportation	25	23	36	39	42	25	46	108	156	210	165	545	3.30303	825	66.06%
	Quality (functionality) of network	14	18	55	28	50	14	36	165	112	250	165	577	3.49697	825	69.94%
	Capacity of the network	17	23	57	28	40	17	46	171	112	200	165	546	3.309091	825	66.18%
During evacuation	Safety	44	23	36	2	4	44	46	108	8	20	109	226	2.073394	545	41.47%
	Clear communication/directions	16	10	30	25	28	16	20	90	100	140	109	366	3.357798	545	67.16%
	Quality (functionality) of network	13	13	30	23	30	13	26	90	92	150	109	371	3.40367	545	68.07%
	Capacity of the network	10	8	24	32	35	10	16	72	128	175	109	401	3.678899	545	73.58%
	Fuel availability	5	4	26	25	49	5	8	78	100	245	109	436	4	545	80.00%
	Quality of drainage systems	9	12	25	30	33	9	24	75	120	165	109	393	3.605505	545	72.11%
	Network clearance (debris)	7	12	29	32	29	7	24	87	128	145	109	391	3.587156	545	71.74%
During return	Safety	46	30	27	4	2	46	60	81	16	10	109	213	1.954128	545	39.08%
	Clear communication/directions	15	14	26	30	24	15	28	78	120	120	109	361	3.311927	545	66.24%
	Quality (functionality) of network	13	9	29	27	31	13	18	87	108	155	109	381	3.495413	545	69.91%
	Capacity of the network	14	13	33	21	28	14	26	99	84	140	109	363	3.330275	545	66.61%
	Fuel availability	9	10	25	28	37	9	20	75	112	185	109	401	3.678899	545	73.58%
	Quality of drainage systems	10	14	27	25	33	10	28	81	100	165	109	384	3.522936	545	70.46%
	Network clearance (debris)	8	12	24	31	34	8	24	72	124	170	109	398	3.651376	545	73.03%

Urban areas only:

Urban																
Concern		Respondents Scoring					Importance count					Total	Sum of	Mean	Max.	
		1	2	3	4	5	1	2	3	4	5	respond.	products	Value	Points	%age
During hazard	Safety	5	3	11	11	26	5	6	33	44	130	56	218	3.892857	280	77.86%
	Accessibility to transportation	6	5	12	16	17	6	10	36	64	85	56	201	3.589286	280	71.79%
	Quality (functionality) of network	3	7	13	9	24	3	14	39	36	120	56	212	3.785714	280	75.71%
	Capacity of the network	8	3	10	12	23	8	6	30	48	115	56	207	3.696429	280	73.93%
During evacuation	Safety	22	11	9	0	1	22	22	27	0	5	43	76	1.767442	215	35.35%
	Clear communication/directions	5	1	4	14	19	5	2	12	56	95	43	170	3.953488	215	79.07%
	Quality (functionality) of network	5	3	4	12	19	5	6	12	48	95	43	166	3.860465	215	77.21%
	Capacity of the network	3	2	4	17	17	3	4	12	68	85	43	172	4	215	80.00%
	Fuel availability	3	0	9	9	22	3	0	27	36	110	43	176	4.093023	215	81.86%
	Quality of drainage systems	4	1	4	11	23	4	2	12	44	115	43	177	4.116279	215	82.33%
	Network clearance (debris)	3	1	7	15	17	3	2	21	60	85	43	171	3.976744	215	79.53%
During return	Safety	23	11	7	1	1	23	22	21	4	5	43	75	1.744186	215	34.88%
	Clear communication/directions	2	4	6	14	17	2	8	18	56	85	43	169	3.930233	215	78.60%
	Quality of network	6	3	5	10	19	6	6	15	40	95	43	162	3.767442	215	75.35%
	Capacity of the network	5	0	9	13	16	5	0	27	52	80	43	164	3.813953	215	76.28%
	Fuel availability	3	1	10	14	15	3	2	30	56	75	43	166	3.860465	215	77.21%
	Quality of drainage systems	2	4	7	11	19	2	8	21	44	95	43	170	3.953488	215	79.07%
	Network clearance (debris)	4	2	4	16	17	4	4	12	64	85	43	169	3.930233	215	78.60%

Suburban areas only:

Suburban																	
Concern		Respondents Scoring					Importance count					Total	Sum of	Mean	Max.	
		1	2	3	4	5	1	2	3	4	5	respond.	products	Value	Points	%age
During hazard	Safety	3	2	11	7	23	3	4	33	28	115	46	183	3.978261	230	79.57%
	Accessibility to transportation	9	10	6	11	10	9	20	18	44	50	46	141	3.065217	230	61.30%
	Quality (functionality) of network	4	6	19	7	10	4	12	57	28	50	46	151	3.282609	230	65.65%
	Capacity of the network	5	10	15	9	7	5	20	45	36	35	46	141	3.065217	230	61.30%
During evacuation	Safety	10	7	9	0	2	10	14	27	0	10	28	61	2.178571	140	43.57%
	Clear communication/directions	3	5	10	4	6	3	10	30	16	30	28	89	3.178571	140	63.57%
	Quality (functionality) of network	4	5	11	5	3	4	10	33	20	15	28	82	2.928571	140	58.57%
	Capacity of the network	4	2	6	6	10	4	4	18	24	50	28	100	3.571429	140	71.43%
	Fuel availability	2	1	8	7	5	2	2	24	28	25	23	81	3.521739	115	70.43%
	Quality of drainage systems	3	5	8	7	5	3	10	24	28	25	28	90	3.214286	140	64.29%
	Network clearance (debris)	4	7	5	6	6	4	14	15	24	30	28	87	3.107143	140	62.14%
During return	Safety	10	11	6	1	0	10	22	18	4	0	28	54	1.928571	140	38.57%
	Clear communication/directions	6	6	6	6	4	6	12	18	24	20	28	80	2.857143	140	57.14%
	Quality of network	3	3	12	4	6	3	6	36	16	30	28	91	3.25	140	65.00%
	Capacity of the network	4	7	8	3	6	4	14	24	12	30	28	84	3	140	60.00%
	Fuel availability	2		7	6	9	2	0	21	24	45	24	92	3.833333	120	76.67%
	Quality of drainage systems	6	4	6	6	6	6	8	18	24	30	28	86	3.071429	140	61.43%
	Network clearance (debris)	4	6	4	7	7	4	12	12	28	35	28	91	3.25	140	65.00%

Rural areas only:

Rural																	
Concern		Respondents Scoring					Importance count					Total	Sum of	Mean	Max.	
		1	2	3	4	5	1	2	3	4	5	respond.	products	Value	Points	%age
During hazard	Safety	0	5	16	12	24	0	10	48	48	120	57	226	3.964912	285	79.30%
	Accessibility to transportation	8	6	17	12	14	8	12	51	48	70	57	189	3.315789	285	66.32%
	Quality (functionality) of network	5	3	22	12	15	5	6	66	48	75	57	200	3.508772	285	70.18%
	Capacity of the network	3	8	31	7	8	3	16	93	28	40	57	180	3.157895	285	63.16%
During evacuation	Safety	10	4	18	2	1	10	8	54	8	5	35	85	2.428571	175	48.57%
	Clear communication/directions	8	4	13	7	3	8	8	39	28	15	35	98	2.8	175	56.00%
	Quality (functionality) of network	4	4	13	6	8	4	8	39	24	40	35	115	3.285714	175	65.71%
	Capacity of the network	3	4	13	7	8	3	8	39	28	40	35	118	3.371429	175	67.43%
	Fuel availability	0	2	8	9	16	0	4	24	36	80	35	144	4.114286	175	82.29%
	Quality of drainage systems	2	6	13	10	4	2	12	39	40	20	35	113	3.228571	175	64.57%
	Network clearance (debris)	0	4	16	9	6	0	8	48	36	30	35	122	3.485714	175	69.71%
During return	Safety	11	8	13	2	1	11	16	39	8	5	35	79	2.257143	175	45.14%
	Clear communication/directions	7	4	12	9	3	7	8	36	36	15	35	102	2.914286	175	58.29%
	Quality of network	4	3	11	12	5	4	6	33	48	25	35	116	3.314286	175	66.29%
	Capacity of the network	5	6	14	5	5	5	12	42	20	25	35	104	2.971429	175	59.43%
	Fuel availability	3	5	8	7	12	3	10	24	28	60	35	125	3.571429	175	71.43%
	Quality of drainage systems	2	6	13	7	7	2	12	39	28	35	35	116	3.314286	175	66.29%
	Network clearance (debris)	0	3	16	8	8	0	6	48	32	40	35	126	3.6	175	72.00%

[3] Age Survey:

Overall:

Age Survey																
Concern		Respondents Scoring					Importance count					Total respond.	Sum of products	Mean Value	Max. Points	%age
		1	2	3	4	5	1	2	3	4	5					
During hazard	Safety	6	11	43	24	69	6	22	129	96	345	153	598	3.908497	765	78.17%
	Accessibility to transportation	33	14	58	24	24	33	28	174	96	120	153	451	2.947712	765	58.95%
	Quality (functionality) of network	13	27	64	23	26	13	54	192	92	130	153	481	3.143791	765	62.88%
	Capacity of the network	23	18	44	30	38	23	36	132	120	190	153	501	3.27451	765	65.49%
During evacuation	Safety	16	13	18	6	2	16	26	54	24	10	55	130	2.363636	275	47.27%
	Clear communication/directions	12	8	26	7	2	12	16	78	28	10	55	144	2.618182	275	52.36%
	Quality (functionality) of network	13	11	17	7	7	13	22	51	28	35	55	149	2.709091	275	54.18%
	Capacity of the network	3	6	10	15	21	3	12	30	60	105	55	210	3.818182	275	76.36%
	Fuel availability	3	4	13	10	25	3	8	39	40	125	55	215	3.909091	275	78.18%
	Quality of drainage systems	6	11	17	8	13	6	22	51	32	65	55	176	3.2	275	64.00%
	Network clearance (debris)	10	7	16	7	15	10	14	48	28	75	55	175	3.181818	275	63.64%
During return	Safety	14	20	15	4	2	14	40	45	16	10	55	125	2.272727	275	45.45%
	Clear communication/directions	8	13	22	3	9	8	26	66	12	45	55	157	2.854545	275	57.09%
	Quality (functionality) of network	8	11	23	9	4	8	22	69	36	20	55	155	2.818182	275	56.36%
	Capacity of the network	5	9	16	12	13	5	18	48	48	65	55	184	3.345455	275	66.91%
	Fuel availability	5	8	8	14	20	5	16	24	56	100	55	201	3.654545	275	73.09%
	Quality of drainage systems	6	7	21	13	8	6	14	63	52	40	55	175	3.181818	275	63.64%
	Network clearance (debris)	5	8	19	15	8	5	16	57	60	40	55	178	3.236364	275	64.73%

Urban areas only:

Urban																
Concern		Respondents Scoring					Importance count					Total respond.	Sum of products	Mean Value	Max. Points	%age
		1	2	3	4	5	1	2	3	4	5					
During hazard	Safety	3	2	9	1	9	3	4	27	4	45	24	83	3.458333	120	69.17%
	Accessibility to transportation	6	2	10	2	4	6	4	30	8	20	24	68	2.833333	120	56.67%
	Quality (functionality) of network	2	5	7	7	3	2	10	21	28	15	24	76	3.166667	120	63.33%
	Capacity of the network	4	4	9	4	3	4	8	27	16	15	24	70	2.916667	120	58.33%
During evacuation	Safety	4	1	0	1	1	4	2	0	4	5	7	15	2.142857	35	42.86%
	Clear communication/directions	4	0	2	1	0	4	0	6	4	0	7	14	2	35	40.00%
	Quality (functionality) of network	3	1	1	1	1	3	2	3	4	5	7	17	2.428571	35	48.57%
	Capacity of the network	1	1	3	1	1	1	2	9	4	5	7	21	3	35	60.00%
	Fuel availability	1	0	4	0	2	1	0	12	0	10	7	23	3.285714	35	65.71%
	Quality of drainage systems	2	1	2	1	1	2	2	6	4	5	7	19	2.714286	35	54.29%
	Network clearance (debris)	2	1	1	1	2	2	2	3	4	10	7	21	3	35	60.00%
During return	Safety	3	2	1	1	0	3	4	3	4	0	7	14	2	35	40.00%
	Clear communication/directions	1	1	3	0	2	1	2	9	0	10	7	22	3.142857	35	62.86%
	Quality of network	2	0	3	2	0	2	0	9	8	0	7	19	2.714286	35	54.29%
	Capacity of the network	2	1	3	0	1	2	2	9	0	5	7	18	2.571429	35	51.43%
	Fuel availability	2	2	0	1	2	2	4	0	4	10	7	20	2.857143	35	57.14%
	Quality of drainage systems	2	1	3	1	0	2	2	9	4	0	7	17	2.428571	35	48.57%
	Network clearance (debris)	2	0	2	1	2	2	0	6	4	10	7	22	3.142857	35	62.86%

Suburban areas only:

Suburban																
Concern		Respondents Scoring					Importance count					Total respond.	Sum of products	Mean Value	Max. Points	%age
		1	2	3	4	5	1	2	3	4	5					
During hazard	Safety	3	7	31	20	56	3	14	93	80	280	117	470	4.017094	585	80.34%
	Accessibility to transportation	21	12	44	21	19	21	24	132	84	95	117	356	3.042735	585	60.85%
	Quality (functionality) of network	8	19	53	15	22	8	38	159	60	110	117	375	3.205128	585	64.10%
	Capacity of the network	18	13	29	23	34	18	26	87	92	170	117	393	3.358974	585	67.18%
During evacuation	Safety	11	10	16	4	1	11	20	48	16	5	42	100	2.380952	210	47.62%
	Clear communication/directions	7	7	21	5	2	7	14	63	20	10	42	114	2.714286	210	54.29%
	Quality (functionality) of network	9	8	14	6	5	9	16	42	24	25	42	116	2.761905	210	55.24%
	Capacity of the network	2	3	6	14	17	2	6	18	56	85	42	167	3.97619	210	79.52%
	Fuel availability	2	3	6	10	21	2	6	18	40	105	42	171	4.071429	210	81.43%
	Quality of drainage systems	4	8	12	6	12	4	16	36	24	60	42	140	3.333333	210	66.67%
	Network clearance (debris)	7	5	13	5	12	7	10	39	20	60	42	136	3.238095	210	64.76%
During return	Safety	10	18	10	2	2	10	36	30	8	10	42	94	2.238095	210	44.76%
	Clear communication/directions	5	11	17	3	6	5	22	51	12	30	42	120	2.857143	210	57.14%
	Quality of network	5	10	18	5	4	5	20	54	20	20	42	119	2.833333	210	56.67%
	Capacity of the network	3	7	11	9	12	3	14	33	36	60	42	146	3.47619	210	69.52%
	Fuel availability	3	4	7	11	17	3	8	21	44	85	42	161	3.833333	210	76.67%
	Quality of drainage systems	4	3	16	11	8	4	6	48	44	40	42	142	3.380952	210	67.62%
	Network clearance (debris)	2	8	13	13	6	2	16	39	52	30	42	139	3.309524	210	66.19%

Rural areas only:

Rural																
Concern		Respondents Scoring					Importance count					Total respond.	Sum of products	Mean Value	Max. Points	%age
		1	2	3	4	5	1	2	3	4	5					
During hazard	Safety	0	2	3	3	4	0	4	9	12	20	12	45	3.75	60	75.00%
	Accessibility to transportation	6	0	4	1	1	6	0	12	4	5	12	27	2.25	60	45.00%
	Quality (functionality) of network	3	3	4	1	1	3	6	12	4	5	12	30	2.5	60	50.00%
	Capacity of the network	1	1	6	3	1	1	2	18	12	5	12	38	3.166667	60	63.33%
During evacuation	Safety	1	2	2	1	0	1	4	6	4	0	6	15	2.5	30	50.00%
	Clear communication/directions	1	1	3	1	0	1	2	9	4	0	6	16	2.666667	30	53.33%
	Quality (functionality) of network	1	2	2	0	1	1	4	6	0	5	6	16	2.666667	30	53.33%
	Capacity of the network	0	2	1	0	3	0	4	3	0	15	6	22	3.666667	30	73.33%
	Fuel availability	0	1	3	0	2	0	2	9	0	10	6	21	3.5	30	70.00%
	Quality of drainage systems	0	2	3	1	0	2	4	9	4	0	6	19	3.166667	30	63.33%
	Network clearance (debris)	1	1	2	1	1	1	2	6	4	5	6	18	3	30	60.00%
During return	Safety	1	0	4	1	0	1	0	12	4	0	6	17	2.833333	30	56.67%
	Clear communication/directions	2	1	2	0	1	2	2	6	0	5	6	15	2.5	30	50.00%
	Quality of network	1	1	2	2	0	1	2	6	8	0	6	17	2.833333	30	56.67%
	Capacity of the network	0	1	2	3	0	0	2	6	12	0	6	20	3.333333	30	66.67%
	Fuel availability	0	2	1	2	1	0	4	3	8	5	6	20	3.333333	30	66.67%
	Quality of drainage systems	0	3	2	1	0	0	6	6	4	0	6	16	2.666667	30	53.33%
	Network clearance (debris)	1	0	4	1	0	1	0	12	4	0	6	17	2.833333	30	56.67%

Ranking of concerns of the populations based on the level of development of the area

[1] Minority Survey:

Urban areas:

Minority: Urban		
Rank	**Concern**	**Timeline**
1	Safety	during return
2	Safety	during hazard
3	Safety	during evacuation
4	Quality (functionality) of network	during evacuation
5	Capacity of the network	during hazard
6	Fuel availability	during evacuation
7	Quality of network	during return
8	Quality (functionality) of network	during hazard
9	Quality of drainage systems	during return
10	Accessibility to transportation	during hazard
11	Fuel availability	during return
12	Network clearance (debris)	during evacuation
13	Capacity of the network	during evacuation
14	Quality of drainage systems	during evacuation
15	Capacity of the network	during return
16	Network clearance (debris)	during return
17	Clear communication/directions	during evacuation
18	Clear communication/directions	during return

Suburban areas:

Minority: Suburban		
Rank	**Concern**	**Timeline**
1	Safety	during hazard
2	Fuel availability	during evacuation
3	Fuel availability	during return
4	Quality of drainage systems	during evacuation
5	Capacity of the network	during evacuation
6	Network clearance (debris)	during return
7	Quality of network	during return
8	Quality (functionality) of network	during hazard
9	Capacity of the network	during hazard
10	Network clearance (debris)	during evacuation
11	Quality of drainage systems	during return
12	Quality (functionality) of network	during evacuation
13	Clear communication/directions	during evacuation
14	Capacity of the network	during return
15	Clear communication/directions	during return
16	Accessibility to transportation	during hazard
17	Safety	during evacuation
18	Safety	during return

Rural areas:

Minority: Rural		
Rank	**Concern**	**Timeline**
1	Fuel availability	during return
2	Fuel availability	during evacuation
3	Safety	during hazard
4	Quality (functionality) of network	during hazard
5	Network clearance (debris)	during evacuation
6	Quality of drainage systems	during evacuation
7	Capacity of the network	during return
8	Quality (functionality) of network	during evacuation
9	Quality of network	during return
10	Capacity of the network	during evacuation
11	Accessibility to transportation	during hazard
12	Capacity of the network	during hazard
13	Clear communication/directions	during evacuation
14	Quality of drainage systems	during return
15	Network clearance (debris)	during return
16	Clear communication/directions	during return
17	Safety	during evacuation
18	Safety	during return

[2] Rural Survey:

Urban areas:

Rural: Urban		
Rank	**Concern**	**Timeline**
1	Quality of drainage systems	during evacuation
2	Fuel availability	during evacuation
3	Capacity of the network	during evacuation
4	Network clearance (debris)	during evacuation
5	Clear communication/directions	during evacuation
6	Quality of drainage systems	during return
7	Clear communication/directions	during return
8	Network clearance (debris)	during return
9	Safety	during hazard
10	Quality (functionality) of network	during evacuation
11	Fuel availability	during return
12	Capacity of the network	during return
13	Quality (functionality) of network	during hazard
14	Quality of network	during return
15	Capacity of the network	during hazard
16	Accessibility to transportation	during hazard
17	Safety	during evacuation
18	Safety	during return

Suburban areas:

Rural: Suburban		
Rank	**Concern**	**Timeline**
1	Safety	during hazard
2	Fuel availability	during return
3	Capacity of the network	during evacuation
4	Fuel availability	during evacuation
5	Quality (functionality) of network	during hazard
6	Quality of network	during return
7	Network clearance (debris)	during return
8	Quality of drainage systems	during evacuation
9	Clear communication/directions	during evacuation
10	Network clearance (debris)	during evacuation
11	Quality of drainage systems	during return
12	Accessibility to transportation	during hazard
13	Capacity of the network	during hazard
14	Capacity of the network	during return
15	Quality (functionality) of network	during evacuation
16	Clear communication/directions	during return
17	Safety	during evacuation
18	Safety	during return

[3] Age Survey:

Urban areas:

Age: Urban		
Rank	**Concern**	**Timeline**
1	Safety	during hazard
2	Fuel availability	during evacuation
3	Quality (functionality) of network	during hazard
4	Clear communication/directions	during return
5	Network clearance (debris)	during return
6	Capacity of the network	during evacuation
7	Network clearance (debris)	during evacuation
8	Capacity of the network	during hazard
9	Fuel availability	during return
10	Accessibility to transportation	during hazard
11	Quality of drainage systems	during evacuation
12	Quality of network	during return
13	Capacity of the network	during return
14	Quality (functionality) of network	during evacuation
15	Quality of drainage systems	during return
16	Safety	during evacuation
17	Clear communication/directions	during evacuation
18	Safety	during return

Suburban areas:

Age: Suburban		
Rank	**Concern**	**Timeline**
1	Fuel availability	during evacuation
2	Safety	during hazard
3	Capacity of the network	during evacuation
4	Fuel availability	during return
5	Capacity of the network	during return
6	Quality of drainage systems	during return
7	Capacity of the network	during hazard
8	Quality of drainage systems	during evacuation
9	Network clearance (debris)	during return
10	Network clearance (debris)	during evacuation
11	Quality (functionality) of network	during hazard
12	Accessibility to transportation	during hazard
13	Clear communication/directions	during return
14	Quality of network	during return
15	Quality (functionality) of network	during evacuation
16	Clear communication/directions	during evacuation
17	Safety	during evacuation
18	Safety	during return

Rural areas:

Age: Rural		
Rank	**Concern**	**Timeline**
1	Safety	during hazard
2	Capacity of the network	during evacuation
3	Fuel availability	during evacuation
4	Capacity of the network	during return
5	Fuel availability	during return
6	Capacity of the network	during hazard
7	Quality of drainage systems	during evacuation
8	Network clearance (debris)	during evacuation
9	Safety	during return
10	Quality of network	during return
11	Network clearance (debris)	during return
12	Clear communication/directions	during evacuation
13	Quality (functionality) of network	during evacuation
14	Quality of drainage systems	during return
15	Quality (functionality) of network	during hazard
16	Safety	during evacuation
17	Clear communication/directions	during return
18	Accessibility to transportation	during hazard

Rural areas:

Rural: Rural		
Rank	**Concern**	**Timeline**
1	Fuel availability	during evacuation
2	Safety	during hazard
3	Network clearance (debris)	during return
4	Fuel availability	during return
5	Quality (functionality) of network	during hazard
6	Network clearance (debris)	during evacuation
7	Capacity of the network	during evacuation
8	Accessibility to transportation	during hazard
9	Quality of network	during return
10	Quality of drainage systems	during return
11	Quality (functionality) of network	during evacuation
12	Quality of drainage systems	during evacuation
13	Capacity of the network	during hazard
14	Capacity of the network	during return
15	Clear communication/directions	during return
16	Clear communication/directions	during evacuation
17	Safety	during evacuation
18	Safety	during return

The Experts Survey

To prioritize the concerns regarding the vulnerability of infrastructure elements (Q17), and the transportation issues that impact the performance for the needs of vulnerable populations (Q18), importance scores are calculated for the variables of the two questions.

Q17:

Concerns about the vulnerability of infrastructure elements																
Concern	Respondents Scoring						Importance count					Total	Sum of	Mean	Max.	
	0	1	2	3	4	5	1	2	3	4	5	respond.	products	Value	Points	%age
Critical emergency response facilities like police and fire stations	2	3	5	9	4	10	3	10	27	16	50	33	106	3.212121	165	64.24%
Medical facilities like hospitals and clinics	1	3	4	6	4	13	3	8	18	16	65	31	110	3.548387	155	70.97%
The federal and/or state highway system	1	1	4	8	9	9	1	8	24	36	45	32	114	3.5625	160	71.25%
Local roads	1	0	2	5	8	16	0	4	15	32	80	32	131	4.09375	160	81.88%
Public shelters	1	1	3	8	5	14	1	6	24	20	70	32	121	3.78125	160	75.63%
Power / communications infrastructure	1	1	2	3	7	18	1	4	9	28	90	32	132	4.125	160	82.50%
Drainage	1	1	0	4	9	17	1	0	12	36	85	32	134	4.1875	160	83.75%
Ports/ airports	2	5	5	9	3	5	5	10	27	12	25	29	79	2.724138	145	54.48%
Rail	1	8	8	6	3	4	8	16	18	12	20	30	74	2.466667	150	49.33%
Bridges	3	2	3	2	0	5	2	6	6	0	25	15	39	2.6	75	52.00%
Other	1	3	1	12	6	9	3	2	36	24	45	32	110	3.4375	160	68.75%

Q18:

Concerns about the transportation issues to the needs of the populations																
Concern	Respondents Scoring						Importance count					Total	Sum of	Mean	Max.	
	0	1	2	3	4	5	1	2	3	4	5	respond.	products	Value	Points	%age
Evacuation	0	1	5	3	8	16	1	10	9	32	80	33	132	4	165	80.00%
Re-entry	0	2	7	5	7	11	2	14	15	28	55	32	114	3.5625	160	71.25%
Fuel accessibility	0	2	1	8	4	17	2	2	24	16	85	32	129	4.03125	160	80.63%
Temporary road closures due to flooding or debris	0	3	0	5	14	11	3	0	15	56	55	33	129	3.909091	165	78.18%
Long-term road closures due to disasters damage	1	3	3	2	10	13	3	6	6	40	65	32	120	3.75	160	75.00%
Disruptions to public transportation routes or shedules	0	3	2	8	6	13	3	4	24	24	65	32	120	3.75	160	75.00%
Lack of service at airports or ports	1	7	6	2	10	4	7	12	6	40	20	30	85	2.833333	150	56.67%
Long-term disruptions to airports or ports	2	6	7	3	9	4	6	14	9	36	20	31	85	2.741935	155	54.84%