

## ABSTRACT

Several major disasters have occurred in the United States and impacted coastal and river valley communities. The economic and societal impact of such disasters have demonstrated a need for better emergency planning, response, recovery, and adaptation. Through the understanding of the behavior, characteristics of past events, much informed decisions can be made. This study will utilize data from Hurricane Irma (2017) to compare traffic characteristics during the evacuation with those observed during routine non-emergency operations. The 2017 evacuation of Hurricane Irma has been referred to as the largest evacuation in the history of the nation with approximately 6.5 million Floridians under mandatory or voluntary evacuation orders. The presented research will be focusing on the evacuation process of the coastal communities in the Florida Keys. This research seeks to better understand the evacuation process of Coastal and River Valley communities in the Florida Keys, FL and to assist in the planning, mitigation, response, recovery, and adaptation of these areas from disasters. It is also expected that the findings from this research can be applied to evacuations of any hazard type or location.



## INTRODUCTION

Mass evacuations, particularly those at a statewide level, represent the largest single-event traffic movements that can occur. These complex transportation events can last several days, span thousands of miles of roadway, and include hundreds of thousands of people and vehicles traveling with vital urgency. Often, they are also plagued by enormous travel delay and congestion and are nearly always criticized for their inefficiency and lack of management. Several major disasters have occurred in the United States and impacted communities in Florida. The economic and societal impact of such disasters have demonstrated a need for better emergency planning, response, recovery, and adaptation. Through the understanding of the behavior, characteristics of past events, much informed decisions can be made. This study will utilize data from Hurricane Irma (2017) to compare traffic characteristics during the evacuation with those observed during routine non-emergency operations. The 2017 evacuation of Hurricane Irma has been referred to as the largest evacuation in the history of the nation with approximately 6.5 million Floridians under mandatory or voluntary evacuation orders. The present research will be focusing on the evacuation process of the Florida Keys.

Often, the perceived success of an evacuation, or lack thereof, is based on media reports, anecdotal observation or, worse, rumors and social media discussion. In reality, a highly effective evacuation could be assumed a failure because of a few limited but highly visible areas of congestion. This has suggested the need for a better way to describe and assess large statewide evacuations in more systematic and objective ways. Unfortunately, this is not easy to accomplish because there are few, if any, data records or performance measures generated that accurately and effectively describe the conditions of these events. In fact, there is no standardized methodology to quantify the characteristics of an evacuation that is transferable and repeatable between state departments of transportation.

## BACKGROUND

The 2017 evacuation from Hurricane Irma has been referred to as the largest evacuation in the history of the United States. Approximately 6.5 million Floridians were placed under either mandatory or voluntary evacuation orders [1]. The overwhelming response to Hurricane Irma was fueled by several factors that were unique to the storm:

- 1) Hurricane Irma had already devastated a number of Caribbean islands, including the U.S. Virgin Islands and Puerto Rico, resulting in several known deaths at the time [2].
- 2) At one point, Hurricane Irma was the fifth strongest hurricane ever recorded in the Atlantic Ocean.
- 3) The storm's path and "cone-of-uncertainty" threatened nearly the entire state of Florida.
- 4) Fluctuations in the storm's path indicated possible devastating storm surge to nearly all of Florida's coastal areas, where the majority of residents live.



The National Hurricane Center's (NHC) storm path prediction for Hurricane Irma 67 hours before landfall suggested a Saffir-Simpson scale Category 4 hurricane making landfall in Southeast Florida and continuing up the eastern coast. However, 21 hours later the NHC's revised storm path predicted a landfall on the Florida Keys and a northern approach along the western coast [3]. It can be surmised that the storm's path generated evacuees from both the eastern and western portions of the state as well as coastal regions in the south from Key West, north to Jacksonville, FL.

Ultimately, Hurricane Irma made two landfalls within the state of Florida. The first was near Cudjoe Key in the lower Florida Keys, on September 10th 2017 at approximately 9:10 AM ET as a Category 4 hurricane with sustained winds of 130 mph (209 kph). The second landfall was at approximately 3:35 PM ET near Marco Island, just south of Naples, FL as a Category 3 hurricane with winds of 115 mph (161 kph) [4]. The storm left approximately 6.7 million homes (65 percent of the state), without power [5]. Hurricane Irma was attributed to taking the lives of 75 Floridians and costing an estimated \$49 billion [6]. The lower Florida Keys remained closed to non-residents for approximately three weeks following the storm [7].

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## METHODOLOGY

To provide a basis of measurement and comparison, this research seeks to develop a microscopic traffic simulation model of the Florida keys to evaluate evacuation strategies such as contra-flow, hard-shoulder use, demand metering, and unconventional intersection control strategies. More importantly, the research seeks to illustrate methods to measure and quantify evacuations in an unbiased, practical, and repeatable fashion that is both intuitive and beneficial to state officials. Traffic volume counts collected during Hurricane Irma will serve as a validation parameter for model development.

Based on these ideas, the objectives of the research seek to better understand the evacuation process of vulnerable communities in the Florida Keys, FL to assist in the planning, mitigation, response, recovery, and adaptation of these areas from disasters. It is also expected that the findings from this research can be applied to evacuations of any hazard type or location. Specially, this research seeks to:

- 1) Develop a state-of-the-art traffic simulation model of the Florida Keys using PTV VISSIM
- 2) Validate the model performance against empirical data collected during the Hurricane Irma evacuation event.
- 3) Incorporate into the model the current evacuation traffic management plan proposed by the Florida Department of Transportation (FDOT).
- 4) Develop alternative evacuation traffic management plans incorporating the most advanced research in the field.
- 5) Evaluate the impact of the advanced traffic management plan against the current management plan



These objectives are achieved through the simulation and modeling of roadway volumes collected from ground based sensors (predominately, magnetic-loop detectors) during hurricanes Irma (2017) evacuation. This two events provide a unique opportunity to study the evacuation phenomenon because it is among the largest in the history of the United States; it affected nearly all of the major metropolitan population centers of the state; and traffic volumes are recorded on a geographic scale and at levels of fidelity rarely achieved in prior evacuation studies.

This research seeks to provide a system for state departments of transportation and emergency management officials to analyze future auto-based evacuations. The method also facilitates parametric comparisons between evacuation events, an area needed to continue to evolve and improve evacuation practice. Standardize measures for hurricane evacuations are needed to facilitate systematic evaluations of performance. Future researchers could build upon methods presented here to develop a level-of-service (LOS) analysis for emergency evacuations. This would be similar to the way the Highway Capacity Manual uses the standardized collection and processing of freeway densities for its LOS evaluations. With additional research, the methods laid out in this paper could also lead to a more comprehensive understanding of evacuation traffic processes and behavioral responses to improve their planning and management. The scientific contribution of this work is that it demonstrates a straightforward and reproducible methodology to evaluate the auto-based evacuation response for an impacted area. The proposed methods demonstrated in this paper have a significant practical value for state transportation and/or emergency management agencies seeking to accurately assess evacuation traffic management plans. Finally, this research creates a set of aggregate evacuation parameters that can be used to calibrate and validate evacuation planning and simulation models for future research studies.

## DATA ANALYSIS

The traffic simulation model for this project was created in PT VISSIM. This program is the world's standard for traffic and transportation planning because it provides a realistic and detailed overview of the traffic flow and the impacts this would have on the community. In addition, what-if scenarios can provide a reliable predicative simulation that accounts for driver behavior and decision making in a transportation network. The traffic model that was created can be seen below.



This model includes the main road that connects all of the Florida Keys, US-1. In addition, route 905A, which is also known as Card Sound Rd, provides a second route back to the main peninsula. This model includes the main roads and every intersection off of these two roads. Vehicles can enter the network using these access points.

In addition to using PT VISSIM, this project utilized ArcGIS. ArcGIS offers unique capabilities and is flexible when applying location-based analytics to the project. It provides great insights using contextual tools to visualize and analyze the data using interactive maps.



ArcGIS was used to analyze population data that we then used for our simulation model in PT VISSIM to generate traffic to the main roads US-1 and route 905A. The data was collected from the U.S. Census Bureau, that provided population data from 2010. The maps generated in ArcGIS provide the model with the number of citizens evacuating from each voting precinct. The data imported into ArcGIS to spatially represent the population was provided by the U.S. Census Bureau.

To determine the accuracy of the model, travel information and traffic data from a real evacuation is needed. Travel times for September and October of 2017 were provided by the FDOT, District 6. Hurricane Irma hit Key West September 10<sup>th</sup>, 2017 and the evacuation process started days before and the return to the Florida Keys took place starting September 16<sup>th</sup> and 17<sup>th</sup>, 2017. The travel times and the Census data will allow for an accurate representation of the evacuation process and the reentering of the keys proceeding hurricane Irma. With the Census data providing volumes and the travel time data providing delays, our model will be able to provide an accurate model of the evacuation process.

## DATA ANALYSIS

Due to COVID-19, this project has not been fully completed because of the reliance on various programs. The Data Analysis section above explains the different data sources and the programs and processes used to generate the model and traffic simulation.