

## Evaluation and Analysis of Post-Disaster Re-Entry in Megaregions: A Pilot Study

### RESEARCH AGENDA

#### 1. BACKGROUND

Evacuation procedures are the primary focus of emergency managers (and researchers) when planning for disaster in at-risk areas. However, re-entry could be more difficult than evacuation when evacuees are scattered across multiple regions or states (Lin et al, 2013). Furthermore, properly timed and organized re-entry is essential for the safety of returning residents while also helping the recovery process begin as soon as possible (Texas Division of Emergency Management, 2013). A systematic reentry plan also helps to support the recovery process by allowing it to be managed and begins as soon as possible (Texas Division of Emergency Management, 2013). The limited amount of research into re-entry processes and management has lead to a limited knowledge of the practical and theoretical aspects of the re-entry process and its smaller components (Siebeneck et al, 2013).

#### 2. RESEARCH QUESTIONS

The research proposed in this project will explore key concept related to the processes and procedures associated with post-event re-entries. Starting in localized events, then growing toward megaregion-level events for a proof- of-concept study working toward the development of guidance and information to support planning and decisions making processes and procedures for re-entries following disasters in megaregions.

#### 3. RESEARCH METHODOLOGY

Direct engagement with practitioners and thorough literature review of available research focused on re-entry. In addition to academic based research, the project team will also explore after action reports that have been published on recent evacuation causing natural disasters to include but not limited to Hurricane Gustav (2008); Hurricane Ike (2008); Hurricane Irene (2011); Hurricane Isaac (2012); Hurricane Sandy (2012); and Hurricane Mathew (2016). While the primary focus of recent events will be around large evacuation events such as hurricanes, the project team will also look evacuations that resulted from wildfires, flooding and other natural disasters.

Upon the completion of the comprehensive literature review, the project team will focus on direct engagements with federal (FEMA), state and local governments directly involved with evacuations over the last ten years. The initial method will involve a small sample via phone interviews and face-to-face interviews with evacuation personnel at all levels of government to gain knowledge on the decision-making process involving re-entry and any barriers identified for re-entry. The survey will be followed by direct engagements with willing officials with the most relevant experience and knowledge as determined by the content provided on the survey.

#### 4. RESEARCH CONTRIBUTION

The general idea is to assess current practices and condense it for a general understanding of current guidelines and procedures for return-entry process and procedures. This may also allow disaster management agencies to demonstrate a broader benefit to the community resulting in increased level of support from many area transportation agencies (DOTs, counties, cities, MPOs, etc.) and the public.

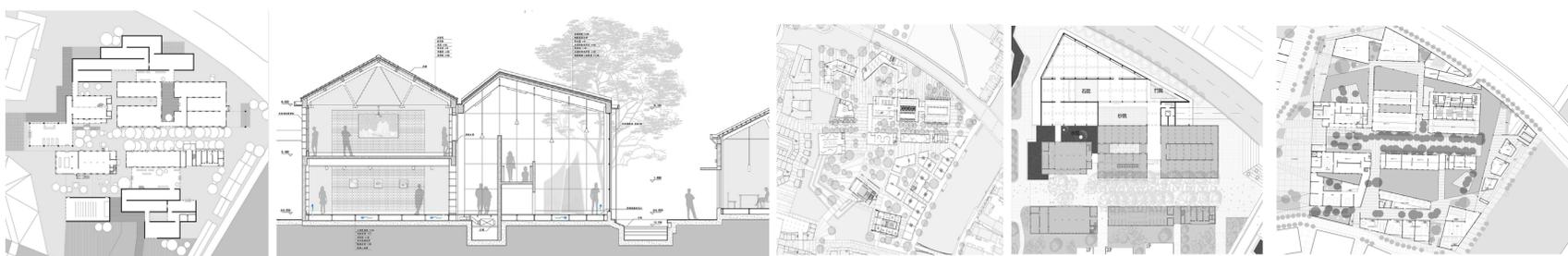
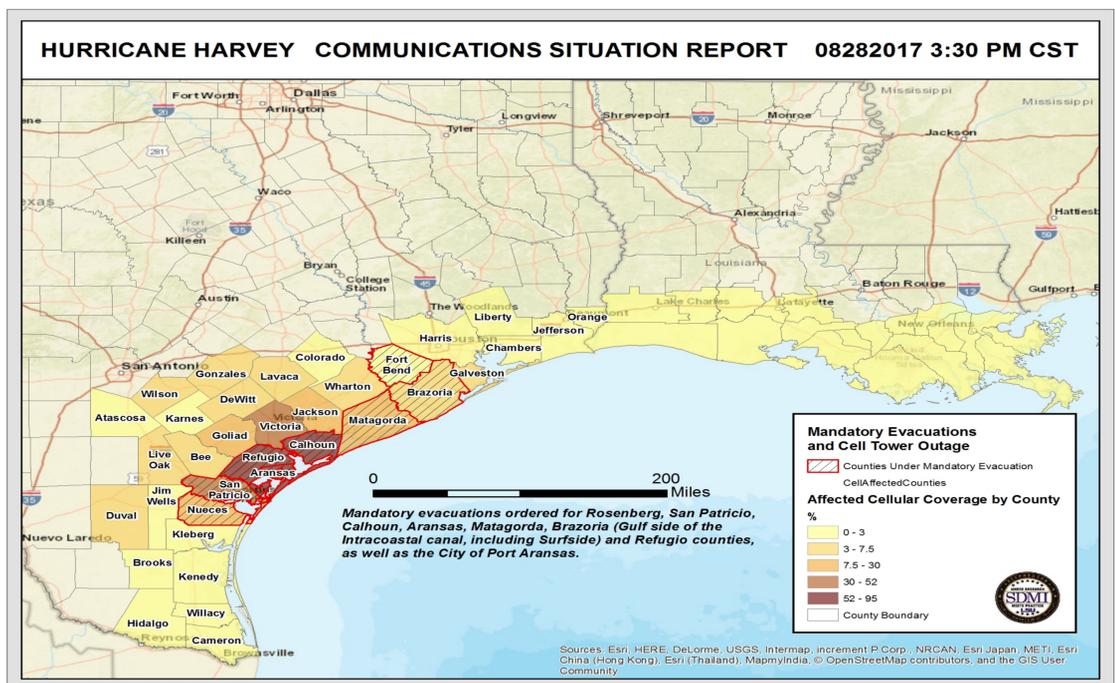
The research output will come not only from new development of new guidance but also from the standpoint of creating and disseminating knowledge that may exist in practice but has never been systematically quantify or assessed from a research perspective. These contributions are expected to be both useful insignificant to both research and practice because primarily little if any information currently exists. The findings of this study are also expected to serve as a basis for future development of guidance document that includes a classification system that can be used by agencies to determine the type of reentry plan that is appropriate for various hazard conditions.

### ACHIEVEMENTS

#### 1. Post-Disaster Re-Entry Practices

Many re-entry systems operate by utilizing a tiered system to systematically reintroduce qualified personnel as recovery progresses. The State and Federal Plans Unit of the Texas Division of emergency Management has taken into account Homeland Security Presidential Directive 5 (HSPD-5) and Presidential Policy 8 (PPD-8) to create a single comprehensive National Incident Management System that provides processes and procedures dealing with tiered re-entry following a disaster. This system covers a wide range of all-hazard environments. The objectives of this system are to ensure proper execution for re-entry so that further complications, such as premature re-entry, can be avoided and includes tiered information and procedures for local and regional level decision-makers so that these objectives can be executed safely and efficiently. Another important component of re-entry involves efficiently incorporating SWEAT-MSO (Sewer, Water, Electricity, Academics, Trash, Medical, Safety, Others) alongside properly organized and executed re-entry procedures. SWEAT-MSO, or Infrastructure Reconnaissance as it is otherwise known (United States Army Engineer School), operates similarly to many re-entry systems in that it is accomplished in stages and is defined by the Headquarters Department of the Army and United States Marine Corps as “the gathering of technical information on the status of the large-scale public systems, services, and facilities of a country or region that are necessary for economic activity”. Optimally, SWEAT-MSO will begin before preparations for re-entry are made and will operate based on survey and assessment through the use of methods such as geo-tagging areas of interest and collecting and reporting using similar procedures (United States Army Engineer School). However, it is also important to ensure that there is compliance with re-entry plans by all involved parties. Evacuees’ concerns and insight should be addressed to avoid any further complications of the situation. In most cases, premature re-entry is the biggest concern and can complicate the officials’ efforts to properly execute re-entry procedures and expose those entering the evacuation zones to safety hazards. In the past, there has been limited compliance to seemingly established re-entry protocols following hurricanes (Siebeneck et al., 2013). After Hurricane Ike, household compliance with official entry plans was at 38% (Siebeneck and Cova, 2008) and, relatively, “... people’s responses generally are based on environmental cues and hazard information obtained from authorities, mass media, and peers” (Kang et al, 2007). Of course, geographic, communication, and demographic factors also influence re-entry compliance, so it is critical to gain an understanding of the spatial and temporal perspectives evacuees experience to create effective re-entry plans (Siebeneck and Cova, 2012).

Following the establishment of this grant research, major tropical cyclones have made landfall in the continental United States and have forced major evacuations and re-entries to be conducted in Texas and Florida. Public sources have been queried to determine timelines and counties that issued mandatory evacuation orders. An assessment of all mandatory evacuations along with damage assessments from cellular radio towers was integrated to determine the counties that were most significantly impacted (see map below for an assessment of Hurricane Harvey on Texas). An interview guide to conduct a qualitative analysis on criteria utilized for the decision making process for re-entry has been completed and several initial interviews on understanding how State government utilizes SWEAT for current response and immediate recover operations has been completed. State and local emergency managers are being scheduled for interviews to take place in June through August to collect information on the feasibility of using SWEAT to integrate into the decision making process for Re-Entry.



## The Effect of Shadow Evacuation on Megaregion Disasters: A Pilot Study

### RESEARCH AGENDA

#### 1. BACKGROUND

Strategic emergency plans are essential to protect the health and safety of the public under disaster threats. The time to evacuate officially declared evacuation zones may be affected by the demand not only within these zones but also in lower-risk areas. This is because based on the perceived threat, some proportion of the population in proximity to the official evacuation zones are also likely to evacuate. The evacuation of areas not under mandatory evacuation are referred to as shadow evacuation.

#### 2. RESEARCH QUESTIONS

Shadow evacuees can cause unwanted congestion for the population under a mandatory evacuation. The modeling of shadow evacuation has been based on assumptions related to the simulation and evacuation process description, both of which are a function of behavioral response during emergencies. The first assumption is related to the expected percent of people in the shadow region that would evacuate. The second assumption is related to the departure of vehicles from their points of origin to begin an evacuation trip. Understanding the effect of shadow evacuation is important for the emergency planning process. This research assessed and quantified the effect of different shadow evacuation participation rates on the evacuation process of an area under mandatory evacuation.

#### 3. RESEARCH METHODOLOGY

Emergency planners have turned to traffic simulation to capture the dynamic nature of the evacuation process [1]. Traffic simulation tools have continued to evolve and allow to model thousands of individual vehicles, moving over hounded of thousands of miles of roadway network, while encompassing time durations that can span multiple days. Experiments were modeled with a megaregion traffic simulation model of the Gulf Coast region of the United States developed by Zhang et al. [2] shown in Figure 1. Key components of the base network model include geographic information system (GIS) data, an evacuation demand estimate model, and the TRANSIMS mesoscopic traffic simulation platform.

#### 4. RESEARCH CONTRIBUTION

The expected research products and contributions to practice from this project are anticipated to include a report of findings that will include the assessment of different shadow evacuation participations. This is expected to provide emergency planners and personnel a better understanding of the impact of shadow evacuation in large scale mass evacuations in the Gulf-Coast Megaregion. The knowledge and results gained can be adapted and transferred for the evaluation of other locations with different road networks, populations, transportation resources, and hazard threats. This contribution is expected to be significant to both research and practice as there is currently little information on this topic in practice and research.

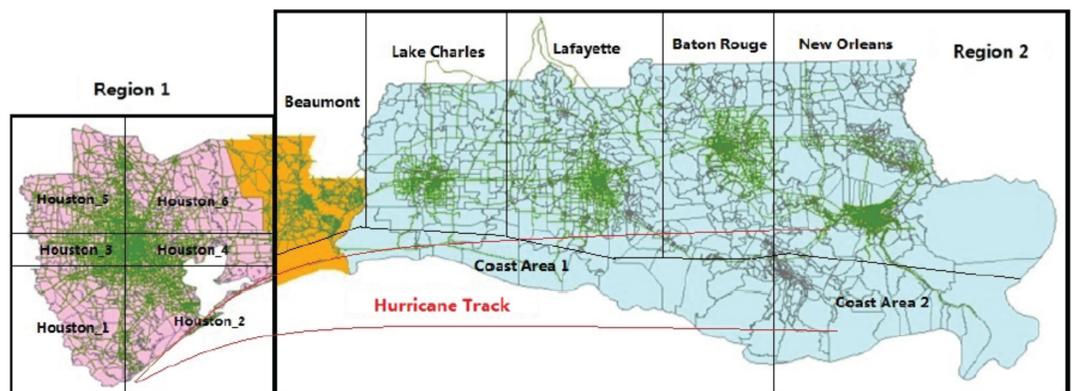


Figure 1: U.S. Gulf Coast megaregion road network and hurricane track.

### ACHIEVEMENTS

#### 1. Shadow Evacuation Scenarios

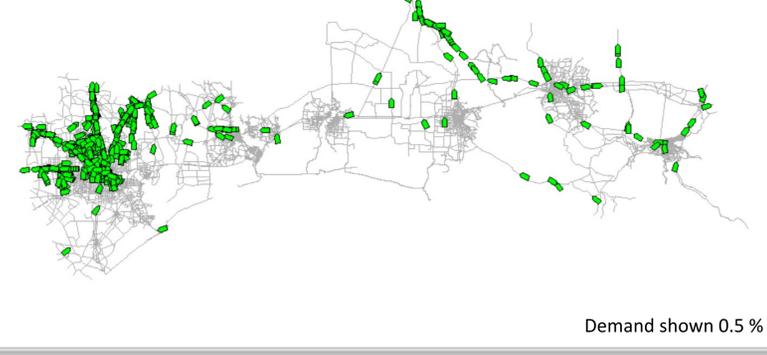
In this research, different shadow evacuation participation scenarios were modeled using the megaregion traffic simulation model of the Gulf Coast region of the United States developed by Zhang et al. (2) and shown in Figure 1. The event modeled was a Category 4 storm based on unknown hurricane with a forecast uncertainty that threatened the full Gulf Coast study area in 1867. Coast 1 and Coast 2 were modeled under mandatory evacuation and all other areas modeled as shadow evacuation.

Table 1: Evacuation and Shadow Evacuation Demand (Percentage)

Scenario	New Orleans	Baton Rouge	Lafayette	Lake Charles	Beaumont	Coast 1	Coast 2	Houston
1 (Base)	93.6	90.7	76.1	93.8	93.8	86.6	86.4	95.5
2	84.24	81.63	68.49	84.42	84.42	77.94	77.76	85.95
3	74.88	72.56	60.88	75.04	75.04	69.28	69.12	76.4
4	65.52	63.49	53.27	65.66	65.66	60.62	60.48	66.85
5	56.16	54.42	45.66	56.28	56.28	51.96	51.84	57.3
6	46.8	45.35	38.05	46.9	46.9	43.3	43.2	47.75

#### 2. Preliminary Results

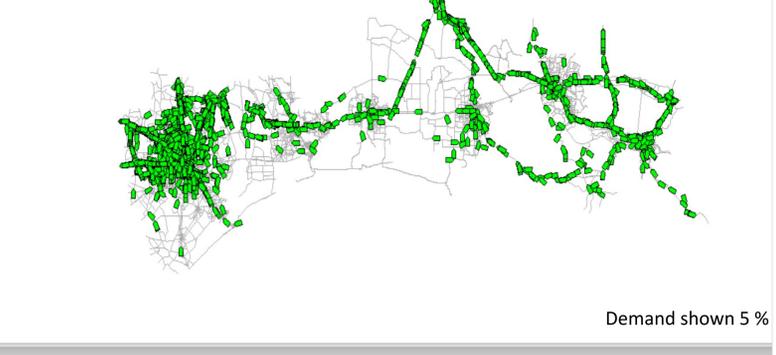
Scenario 5



Scenario 6



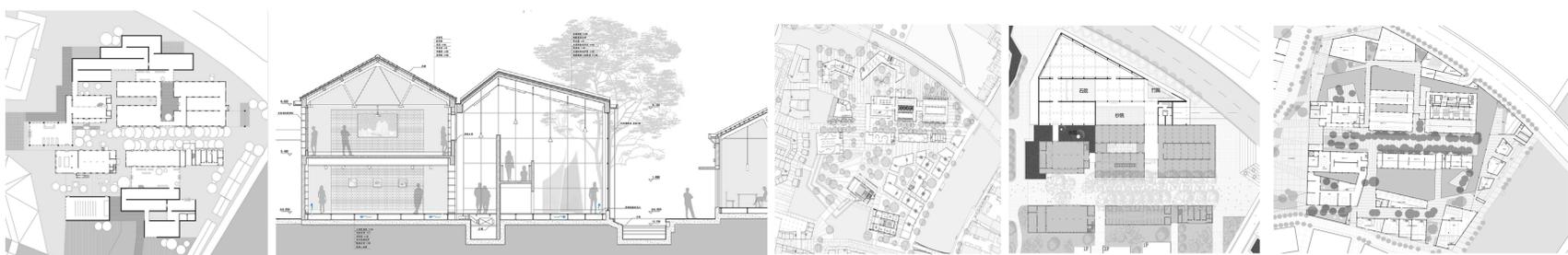
Scenario 5



Scenario 6



Figure 2: Shadow evacuation Scenarios 5 and 6 modeled using TRANSIMS



## Assessment of Post-disaster Re-Entry in Megaregions: A Pilot Study

### RESEARCH AGENDA

#### 1. BACKGROUND

Post-disaster reentry plans are essential to ensure the safety of returning evacuees and the effectiveness of recovery/restoration processes (Wolshon, 2009, Texas Division of Emergency Management, 2013). After an evacuation, potential hazardous conditions may pose a risk to evacuees returning to their homes, businesses, or properties. For example, downed electrical lines, gas line leaks, collapsed bridges, flooded roads, landslides, washed-out roads, etc. may create hazardous environments for returning evacuees (Wolshon, 2009). These conditions may also challenge the recovery/restoration processes as additional personnel, special machinery, etc. may be required.

#### 2. RESEARCH QUESTIONS

Post-disaster reentry, in some cases, may be challenged with a large number of evacuees that may be returning from distant communities across multiple regions or states (Lin et al., 2013). As such, the transportation system could be significantly congested due to high demands in transportation network that may not be fully functional. Although post-disaster reentry could be more challenging and complex than evacuations (Lin et al., 2013), it was evidenced in the literature that re-entry research is limited and there is, in most cases, a lack of formal planning (Wolshon, 2009).

#### 3. RESEARCH CONTENTS

This project seeks to assess various post-disaster reentry scenarios that could be used to support transportation agencies as they assist emergency management and law enforcement agencies in post-disaster reentry efforts. The scenarios to be assessed in this project could include various re-entry procedures, demand/response rates, network accessibility conditions, road blockages, etc. which could be used to support traffic management plans for reentry. Post-disaster re-entry in some cases may also be challenged by the large number of evacuees that returning from distant communities across multiple regions or states (Lin et al., 2013). Some efforts towards traffic management during post-disaster re-entries have been considered (e.g. inbound contraflow) (Wolshon, 2009). However, there is still a lack of planning in post-disaster re-entry efforts.

This research builds upon a currently ongoing research under the CM2 consortium related to post-disaster re-entry which focuses on lessons learned from recent natural disasters from an extensive literature review and direct engagements with federal (FEMA), state and local governments directly involved with evacuations over the last ten years. In addition, this research will implement re-entry curves from recent Hurricane Irma which had approximately 6.5 million Floridians under mandatory or voluntary evacuation orders (Marshall, 2017; Cook, 2017).

#### 4. RESEARCH METHODOLOGY

This research will employ traffic simulation modeling techniques to assess various conditions associated with post-disaster re-entries in megaregions. Re-entry scenarios will be modeled with a megaregion traffic simulation model of the Gulf Coast region of the United States developed by Zhang et al. (2). Key components of the base network model include geographic information system (GIS) data, an evacuation demand estimate model, and the TRANSIMS mesoscopic traffic simulation platform. The scope of the work is proposed to encompass traffic simulation modeling of various scenarios to, ultimately, assess the effect of post-disaster re-entry scenarios in megaregions; documentation of the results describing the findings of, conclusions drawn from, and (where appropriate) recommendations for the application of the results.

#### 5. RESEARCH CONTRIBUTION

The expected research products and contributions to practice from this project are anticipated to include a report of findings that will include the assessment of different scenarios (e.g. re-entry plans, demand/response rates, road blockages, accessibility constraints, etc.) which could ultimately be used to support the development of post-disaster re-entry plans at the local or state level within megaregions. This contribution is expected to be significant to both research and practice as there is currently little information on this topic in practice and research.

### ACHIEVEMENTS

#### 1. Post-Disaster Re-Entry Demand

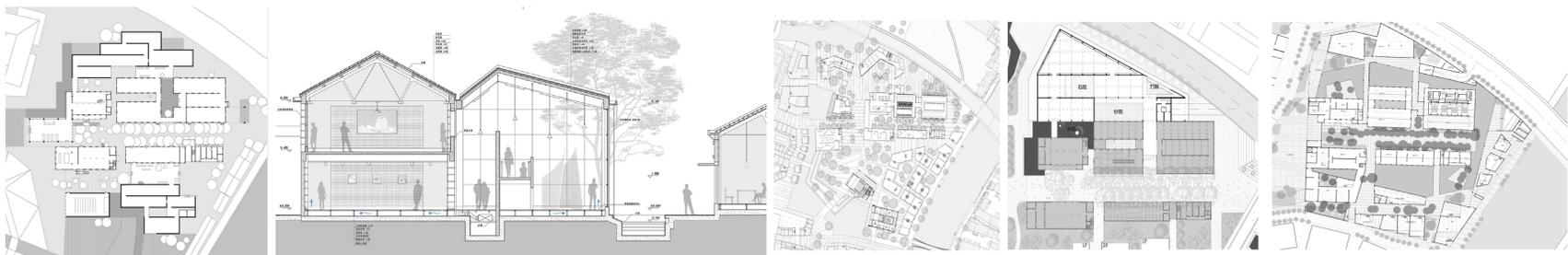
Re-entry scenarios will be modeled with a megaregion traffic simulation model of the Gulf Coast region of the United States developed by Zhang et al. (2). However, there is lack of post-disaster re-entry data available for the Gulf-Coast megaregion. Therefore, this study will implement re-entry curves derived from Hurricane Irma's re-entry process. Figure 1 shows re-entry data from Hurricane Irma that will be used to derive the re-entry curves to be used in the traffic simulation scenarios in this study.



Figure 1: Sample of Re-Entry Data from Hurricane Irma to derive re-entry curves

#### 2. Post-Disaster Re-Entry Scenarios

Review of relevant, prior research was conducted to identify re-entry scenarios to be assessed in this project. The scenarios selected are variation of re-entry curves to distribute the demand over time. Additional scenarios include road blockages on links carrying high traffic volume. Model performance metrics will encompass both qualitative and quantitative assessments of each scenario. The analyses will compare the traffic conditions generated by each re-entry scenario. Although the specific performance measures will be selected at the time of the analyses, it is assumed that system performance will likely be assessed based on traffic conditions such as link travel speeds as well as delay and travel times



## Effect of Disruptions on Megaregion Evacuations: A Pilot Study

### RESEARCH AGENDA

#### 1. BACKGROUND

Emergency planning is essential to protect the health and safety of the public under disaster threats. Traffic simulation has been widely used to support the development of these plans as it captures spatial-temporal conditions during an evacuation and provides insights about the overall clearance process. For example, traffic simulation may support the decision to shelter in-place or evacuate in the event of a nuclear power plant emergency (NUREG/CR 7002); identify resources needed in the event of an evacuation (Murray-Tuite & Wolshon, 2013), etc. Considerations of possible network disruptions are also of particular importance to assist decision makers (Wolshon, 2009). This is because, network disruptions could affect the overall evacuation clearance process.

#### 2. RESEARCH QUESTIONS

Few, if any, studies have assessed the effect of network disruptions on emergency evacuations at the megaregional scale. The research proposed here, therefore, seeks to fill this information gap by assessing the effect of various disruptive events on megaregion emergency evacuations. The network disruption events to be assessed in this project could include access restrictions to neighbor cities or states, traffic incidents (e.g. abandoned or disabled vehicles, crashes, etc.), work zones, flooded roads, adverse weather, traffic signal failure, etc.

#### 3. RESEARCH CONTENTS

The effect of network disruptions vary depending on the characteristics of the disruption (e.g. complete or partial lane closure, duration, physical extent, etc.). For example, completely blocking a road segment reduces the capacity of that segment to zero. However, the effect of the closure depends on the demand on that corridor and redundancy of the highway system as it relates to that road segment (Sullivan, 2010). It was suggested that high volume edges with limited number of alternative routes are important to consider when identifying critical roadway segments that may significantly impact the network if disruptions occur on those roads. Hence, critical road segments are not necessarily those that are not only located on the highest traffic volume routes, but also segments located on relatively high volume routes with limited number of alternate routes (Sullivan, 2010). Prior research has also investigated the effects of traffic incidents on the evacuation process (Collins et al., 2014; Yuan et al., 2016). However, few, if any, studies have been conducted in megaregions. The research proposed here, therefore, seeks to fill this information gap by assessing the effect of various disruptive events on megaregion emergency evacuations. The events to be assessed in this project could include traffic incidents (e.g. abandoned or disabled vehicles, crashes, etc.), work zones, flooded roads, adverse weather, traffic signal failure, etc. which could affect the network capacity and, ultimately, impact the overall clearance process.

#### 4. RESEARCH METHODOLOGY

Traffic simulation has been largely used to assess the effect of various conditions during evacuations with varying levels of demand, trip generation times and traffic routing on the overall clearance process. For example, assessment of transit routes and schedules (Abdelgawad & Abdulhai, 2010; Chen and Chou, 2009; Naghawi & Wolshon, 2009), staged evacuation (Zhao et al., 2014), contraflow (Wolshon et al., 2010), traffic control (Parr and Wolshon, 2015), and route choice (Pel et al., 2011; Pel et al., 2012) have been conducted in the literature using traffic simulation. Network disruption scenarios will be modeled with a megaregion traffic simulation model of the Gulf Coast region of the United States developed by Zhang et al. (2). Key components of the base network model include geographic information system (GIS) data, an evacuation demand estimate model, and the TRANSIMS mesoscopic traffic simulation platform.

#### 5. RESEARCH CONTRIBUTION

Deepen understanding of the effects of disruptions on megaregion emergency evacuations which state and local officials could use in emergency planning and decisions making activities related to the transportation network robustness and redundancy, incident management strategies, etc. This contribution is expected to be significant to both research and practice as there is currently little information on this topic in practice and research.

### ACHIEVEMENTS

#### 1. Network Disruption Scenarios

