Deployment and strategies for application of intelligent transportation system elements for contra flow hurricane evacuation and emergency response

Ingrid Leuchtenmueller Birenbaum

University of South Florida

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Deployment and Strategies for Application of Intelligent Transportation System Elements
for Contra Flow Hurricane Evacuation and Emergency Response

by

Ingrid Leuchtenmueller Birenbaum

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering
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Dedication

For limitless encouragement, my mother. For endless support, my husband. For boundless enthusiasm, my son.
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Deployment and Strategies for Application of Intelligent Transportation System Elements for Contra Flow Hurricane Evacuation and Emergency Response

Ingrid Leuchtenmueller Birenbaum

ABSTRACT

This thesis is focused upon the deployment and strategies for the application of Intelligent Transportation System (ITS) elements for contra flow hurricane evacuation and emergency response. A 99-mile segment of the Mainline of Florida’s Turnpike, State Road 91, comprises the research corridor. This segment stands as the potential one way evacuation route for major hurricane evacuations and other types of natural and man-made disasters for the Turnpike System. Plans have been developed and modified over time to address and improve various facets of contra flow evacuations; however, none of these plans have considered advanced transportation technologies as a means through which operational improvements may be implemented.

This thesis presents the ways in which contra flow corridors may be enhanced through the proactive application of technologies. ITS provides for the betterment of operations, communications, and procedures for emergency situations in real-time. Improvements in effectiveness and efficiency of the contra flow corridor are realized through the instrumentation of the evacuation route, and benefits are realized by all involved in the evacuation scenario: transportation agencies and their many partners, law enforcement and emergency managers, and the public. This thesis presents a proposal for
a migration plan to full roadway instrumentation and ITS deployment that allows for evolving capabilities and protocols. Specific strategies outline steps to be taken that are not entirely dependent upon technology; these strategies are therefore flexible and usable for an evolving contra flow operations plan and a growing ITS program.

ITS deployment and strategies for use of the evolving Intelligent Transportation System are of benefit to normal, everyday roadway operations as well. However, the application of these technologies and strategies provide specific, vital benefits during the course of emergency events that utilize contra flow operations, ensuring the promotion of motorist safety and mobility through the combination of people and technologies.
Chapter 1

Introduction

1.1 Background

Hurricane evacuation and emergency response to natural and man-made threats are of great concern to public entities. The Florida Department of Transportation (FDOT), the public agency responsible for the operation of all State Road facilities within Florida, is a major player in the coordination of such emergency activities.

1.2 Hurricane Evacuation

Coastal evacuees that decide to leave their counties of residence are encouraged to use major transportation corridors. The FDOT is expected to be prepared to address the issues that ensue once a hurricane strike is considered possible and coastal evacuation orders are prepared. Past storm events with large scale evacuations have shown that the roadway infrastructure cannot manage the influx of evacuees. The roadway infrastructure is inadequate; there are not enough travel lanes to prevent system failures resulting from too many motorists trying to use the same facility at one time. This does not even factor in the breakdowns, crashes, or other emergencies that could occur. Motorists expect certain levels of response during “normal” roadway operations. Their expectations are raised during response to evacuation orders, even when they are facing the evacuation with less planning than they would for normal travel.
1.3 Contra Flow Issues

The FDOT has developed contra flow plans to try to maximize the capacity of existing limited access corridors, essentially trying to increase roadway capacity by adding additional temporary roadway lanes. However, these plans are labor intensive because they require continual monitoring for safety. Law enforcement and other motorist safety service personnel alone cannot address changing field conditions.

Contra flow operations are initiated only for extreme circumstances when the need to accommodate the evacuation of thousands of residents in a compressed time frame forces public agencies to find new ways to increase the capacity of the roadway infrastructure. Several issues arise as a result of motorists driving the normally wrong way in an evacuation scenario. There are the safety issues initially related to the clearance of normal-direction vehicles and then those concerning the actual one way operation. Moreover, the roadway infrastructure can expect to be overwhelmed by the influx of thousands of evacuees, even despite the additional capacity created by the new contra flow lanes. There is also an important need to maintain a moving traffic stream. Under normal circumstances, incidents cause delays that need to be figured into a commute; however, dangerous or deadly circumstances could occur if drivers become stranded in an evacuation scenario because the traffic queue is not moving. Lastly, emergency responders and struggling evacuees need to leave the roadway before the onset of storm force winds to ensure their safety.

These issues all have merit when considered individually; however, in the context of a contra flow operation for an emergency evacuation; they together form a scenario that the transportation agencies must act on with the highest levels of urgency.
1.4 Intelligent Transportation System Enhancements

Intelligent Transportation System (ITS) elements are deployed to enhance safety and mobility on the transportation corridors during normal operations. Accordingly, ITS technologies can be used during contra flow operations to effectively and efficiently address emergency response issues in an adaptive manner. Several FDOT Districts and Florida’s Turnpike Enterprise have initiated ITS programs. Typical ITS devices found in the roadway or field are Closed Circuit Television (CCTV) Cameras, various types of Vehicle Detection Systems (VDS), Highway Advisory Radios (HAR), and Dynamic Message Signs (DMS). These devices are used for incident detection and information dissemination by Traffic Management Centers (TMCs) monitoring roadway conditions. TMCs work closely with emergency response personnel such as the Florida Highway Patrol (FHP) and the Road Ranger Service Patrols to share information regarding roadway emergencies, stranded motorists, and other incidents. The TMCs control the field devices through varied communications infrastructure such as fiber optic cable (FOC), telephone, and microwave transmission via voice, video, and data integration.

ITS technologies have been shown to be effective for “normal” roadway operations; they have a special, integral role to play in addressing a subset of transportation concerns during contra flow operations and emergency response in the hours leading up to hurricane landfall. ITS is vital in the processes of incident detection and confirmation, emergency plan response and coordination, and information dissemination. Intelligent Transportation Systems are a critical element of the FDOT’s mission to keep its facilities operating as effectively and efficiently as possible.
1.5 Turnpike Enterprise Strategic Initiatives

In 2002, the Florida legislature and governor created Florida’s Turnpike Enterprise. Doing so has allowed a segment of the FDOT to pursue innovation and best practices in order to improve cost effectiveness and timeliness in project delivery, to increase revenues and expand the capital program, and to improve quality of service. The legislation was intended to allow the Turnpike System to operate as a business to meet the State of Florida’s growing transportation needs. Figure 1 shows the roadways that are part of the Turnpike System.

Specific strategies were identified that allowed for improvement projects, expansion projects, and investments in innovative technologies. Strategies specific to the concept of contra flow operations for hurricane evacuation and emergency response are:

- Provide Innovative Customer Service
- Deploy a Fiber Optic Network System-Wide

1.6 Study Approach

ITS deployment and strategies are applicable at all times for the enhancement of traffic operations. ITS is a tool the traffic engineer can use to maximize operational effectiveness and efficiency by increasing capacity without additional roadway infrastructure. The focus of this thesis is the application of transportation technologies to meet special needs during contra flow hurricane evacuations and emergency response. The following steps define the scope and extent of this thesis:

- Overview of Emergency Events
- Identification of Need for Enhanced Operations
- Contra Flow Operations and Emergency Response
- Introduction of ITS for Improved Roadway Operations
- Deployment Strategies to Address System Gaps
- Summary, Recommendations, and Conclusions

This thesis is comprised of six chapters. Chapter 2 describes the literature review conducted to gather resource materials that form the foundation of the thesis statement. Chapter 3 illustrates the key elements involved in present-day contra flow hurricane evacuations and emergency response plans. Chapter 4 presents a case study using a true-to-life contra flow corridor slated to be utilized during hurricane evacuation and emergency response situations. Chapter 5 discusses the system gaps in the existing contra flow corridor that need to be addressed by using ITS in order to provide maximum operational roadway effectiveness and efficiency. Chapter 6 provides recommendations and conclusions.
Figure 1. Florida's Turnpike System
Chapter 2

Literature Review

This section provides an overview of information and research available with respect to the deployment and strategies for ITS elements for contra flow hurricane evacuation and emergency response. The objective is to create an understanding of how different ITS elements can be used to assist in incident detection, congestion mitigation, and information dissemination, thereby enhancing motorist safety and managing traffic issues more effectively and efficiently. A background is presented to provide an understanding of the issues surrounding contra flow hurricane evacuations. Evolving ITS technologies are then reviewed to gain a better understanding of how they may be applied to these types of emergency responses.

The scope and breadth of hurricanes must be clearly understood to comprehend the magnitude of the impact they create for coastal populations in terms of evacuation response. The National Hurricane Center (1) and the National Oceanic and Atmospheric Administration (2) provide vital background information that imparts a foundation for the premise that hurricanes can be catastrophic events for which public entities must plan and mitigate. Gladwin et al (3) provided historical and evacuation data for Hurricane Floyd.

The Transportation Research Board’s Highway Capacity Manual (4) provides techniques for estimating capacities and levels of service for different types of
transportation facilities. While the Manual does not establish legal standards for design or construction, the document was the first to quantify capacity concepts for roadways and other facilities. There is no specific scenario for contra flow operations; however, techniques can be blended to simulate increased capacities resulting from reverse-lane scenarios.

The National ITS Program Plan (5) discusses the need for prevention and detection of incidents and the effective and efficient handling of crises. Recognizing that natural and man-made threats cannot necessarily be prevented, their impacts can be minimized through a combination of technological inputs and human assessments. The expected result is that transportation systems can be better managed to allow for the continued movement of people and goods.

Badgett (6) discusses the need for an operational perspective to manage one way operations in addition to the required changes in thinking and practice to make a contra flow successful.

The Turnpike’s Annual Report (7) and Enterprise Model (8) documents provide background for the nature of the Turnpike System. In addition to providing a sense of customer focus, they present the foundation for a series of initiatives that enhance the process of ITS project design, installation, and delivery.

The Turnpike’s 2000 Contra Flow Plan (9) sets the stage for the initial concept of limited one way operations. This plan was developed prior to the implementation of a major ITS program and relies heavily on limited human resources. Previous plans (10) created contra flow scenarios for most of the Turnpike and were subsequently rejected as unfeasible.
Giblin et al (11) provided an overview in understanding the impacts of management, installation, and operations of traffic control systems, specifically to ITS applications. The Traffic Operations / Traffic Management Center Emergency Response Plan (12) blends issues surrounding hurricane evacuations and potential contra flow situations with ITS applications.

The Post Buckley Schuh & Jernigan (13) report analyzed different contra flow corridors within the State of Florida. A significant outcome was the realization that one way plans need to be continually reviewed to address changing roadway geometrics, law enforcement needs, resource availability, and changing evacuation behavioral trends.

Wolshon et al (14) provided a comprehensive report of hurricane evacuation plans and policies throughout states prone to such storm events. The report met its objectives to advance state-of-the-art knowledge of hurricanes and their impacts on the natural, built, and human environments; to stimulate interdisciplinary and collaborative research activities; to transfer this knowledge to others; and to assist others in reducing their vulnerability to these powerful and potentially devastating storms.

The Sun Sentinel article (15) provided information for the deadliest and costliest storms to hit the United States since storm records were kept. Of the 30 deadliest and costliest storms identified, Hurricane Floyd appears on both lists (twenty-first most deadly, sixth most costly). Given the scope of Floyd’s evacuation throughout several states, the number of deaths could have been significantly higher had landfall been farther south, for example, in Florida, and had people been stranded in their vehicles. The statistics show how critical it is to have evacuation plans in place, with states prepared to address crushing traffic volumes and congestion.
The varied documents listed above cover different aspects of issues related to effective contra flow operations and emergency response. ITS elements have been recognized for years as useful tools to improve traffic scenarios for recurring and non-recurring congestion. ITS benefits continue to be realized as urban populations grow, particularly along coastal corridors. However, contra flow operations during hurricane evacuations are new concepts that have not seen widespread application because of many institutional, safety, and operational barriers. Public sector agencies have had to consider new emergency response needs in an effort to address increased public security measures. Using ITS for enhanced traffic flow efficiency and effectiveness during contra flow operations or emergency response has not been fully documented in terms of conclusive operational analyses. This thesis’ objective is to provide a framework for these analyses and an implementation plan for this type of highly specialized ITS device deployment and operation.
Chapter 3

Elements of Present-Day Contra Flow Hurricane Evacuation and Emergency Response

3.1 Background

The objective of this thesis is to discuss deployment and strategies for the application of ITS elements for contra flow hurricane evacuations and emergency response. The goal of this chapter is to provide the background needed to understand the criticality of evacuation and emergency response issues and thereby develop a framework of the elements needed to lead to a successful ITS deployment. This issue is important to any coastal state that faces hurricane evacuations and other types of emergency response, so while the particulars in this thesis are specific to the State of Florida, the processes described can be generalized to be relevant to locations outside the study area. A brief overview is given of the associated elements related to this issue, followed by a case study along one of Florida’s Intra-State Highway System (FIHS) corridors in the next chapter.

3.2 Hurricanes – An Overview

Given the correct combination of sustained weather conditions that include warm ocean temperatures, moisture, light winds, and pre-existing weather disturbances, low pressure systems may develop in the tropics that are known as hurricanes in the western hemisphere (Atlantic Ocean) and tropical cyclones in the eastern hemisphere (Pacific
Ocean). A hurricane, or tropical cyclone, is associated with violent winds, torrential rains, and significant waves and flooding. While many storms never make landfall, an average of ten storms can be expected to develop per storm season, which is defined as the months June through November.

The National Hurricane Center, a division of the National Weather Service, maintains archives of past storm seasons with comprehensive information on storm events, their history, meteorological statistics, damage and casualties, and post-event storm tracking. The archives also include text advisories and graphic images used during a storm event. This information is continually evaluated, and models have been developed to aid in storm tracking and the development of coastal weather advisories.

3.2.1 Hurricane Categories

Hurricanes are classified by their wind speed as defined by the Saffir – Simpson Hurricane Scale, which is described in Table 1. It is important to note that storms can inflict greater damage than would be supposed by their classification through a combination of wind damage and flooding. Each storm carries with it its own particular set of hazards. Some storms with relatively high winds have moved quickly, inflicting minimal property damage with few or no casualties, and others with lower wind speeds have moved slowly while producing heavy associated rainfall and flooding with significant damage and even loss of life. Each storm event is unique even as it follows historical paths that can be modeled with varying degrees of success.

The storm category and its associated wind speeds are critical factors as they have an enormous influence on evacuation plans for coastal and low-lying areas. As the number of the storm category goes up from 1 to 5, the number of evacuees grows. Figure
2 shows an example of areas that were affected by evacuations during Hurricane Floyd, a storm that threatened most of Florida’s eastern coast in 1999. The X’s denote zip codes of persons that chose to evacuate.

Table 1. Saffir – Simpson Hurricane Scale

<table>
<thead>
<tr>
<th>Hurricane Classification</th>
<th>Wind Speed (mph)</th>
<th>Impact</th>
<th>Evacuation Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category 1</td>
<td>74-95</td>
<td>No major structural damage</td>
<td>Generally none</td>
</tr>
<tr>
<td>Category 2</td>
<td>96-110</td>
<td>Minor damage and flooding</td>
<td>Limited</td>
</tr>
<tr>
<td>Category 3</td>
<td>111-130</td>
<td>Greater damage and inland flooding</td>
<td>Growing</td>
</tr>
<tr>
<td>Category 4</td>
<td>131-155</td>
<td>Extensive structural damage, erosion, and flooding</td>
<td>Significant</td>
</tr>
<tr>
<td>Category 5</td>
<td>156+</td>
<td>Complete structural failures, major erosion and flooding</td>
<td>Extensive</td>
</tr>
</tbody>
</table>

Figure 2. 1999 Hurricane Floyd Evacuations by Zip Code

Data have been collected and evaluated in order to develop tools that describe the progress of a “typical” hurricane season. The typical progression starts with few named storms early in the season, June to July, with increasing numbers of Category 3 or greater
storms as the season progresses into late summer and early fall. By September, there is an expectation that four storm events would have occurred, with two of those hurricanes at Category 3 or higher. Evacuations associated with Category 3 or higher storms are significant events that public entities have a keen interest in managing effectively.

3.2.2 Hurricane Watch / Warning Process

Based upon the anticipated landfall, the National Weather Service will issue hurricane watches and warnings. A hurricane watch is issued for an area that is expected to experience hurricane force winds within 36 hours; a hurricane warning is issued for an area that is expected to experience hurricane force winds within 24 hours or less. While a watch generally allows time for emergency preparations, a warning is understood to be the time that these preparations are to have been completed and protective shelter secured.

3.3 Historical Overview

The southeastern coast of the United States has been subjected to many hurricanes. There have been more than 20 storms of the greater-than-or-equal-to Category 3 variety since record keeping was initiated in the beginning of the twentieth century. Each significant event seems to bring with it growing economic impacts; however, the swelling coastal populations are creating pre-storm event problems of their own. For example, despite storm projections, many people are reluctant to make emergency preparations or evacuate until the time of an actual hurricane warning. Consequently, a surge of people enters a roadway system that cannot efficiently or effectively service the overwhelming numbers of cars. If not resolved in time, the
resultant gridlock can lead to deadly consequences trapping people on roadways in their vehicles without ready access to safe shelter as they face the storm’s onslaught. This gridlock is exacerbated when the expansion of the roadway infrastructure does not keep pace with the growth of the coastal population.

3.3.1 Hurricane Floyd

The storm that seemed to bring the problem of major evacuation to the forefront for policy makers and public safety and transportation officials was 1999’s Hurricane Floyd. This Category 4 storm was initially expected to strike southern Florida, but changing conditions took the hurricane up the eastern coast of the United States, triggering warnings and evacuations through most of eastern Florida and all of coastal Georgia.

The storm finally made landfall in North Carolina near Cape Fear; however, impacts were felt up the eastern seaboard for another week. Floyd is remembered for its massive rainfall and flooding, causing in excess of $6 billion in damage and 70 deaths. Floyd is also memorable for the evolution it incurred in the State’s evacuation planning efforts. Figure 3 is a graphic from the National Weather Service archives showing an aerial view of the storm as of September 15, 1999. The graphic clearly shows both the size of the storm and its threat to essentially the entire eastern coast of Florida.

Because of Floyd’s uncertain track, nearly 800,000 Florida households evacuated as the storm approached. Table 2 shows a regional comparison of evacuees as determined in the 1999 Florida International University (FIU) / Florida Poll, a statewide random sample telephone survey done late that fall. The first column divides the eastern coast of Florida into regions from north to south. The second column of the table gives
the percentage of survey respondents that evacuated. The remaining four columns of the table give a comparative breakdown of the actions taken by the respondents that answered that they did indeed evacuate.

Figure 3. Hurricane Floyd, September 15, 1999²

Table 2. 1999 FIU / Florida Preliminary Poll Report No.1

<table>
<thead>
<tr>
<th>Florida Region</th>
<th>Respondents Evacuated</th>
<th>Stayed in Area</th>
<th>Went Inland</th>
<th>Went Elsewhere in Florida</th>
<th>Left Florida</th>
</tr>
</thead>
<tbody>
<tr>
<td>NE Coast</td>
<td>36.8%</td>
<td>3%</td>
<td>43%</td>
<td>14%</td>
<td>40%</td>
</tr>
<tr>
<td>Central East Coast</td>
<td>26.8%</td>
<td>10%</td>
<td>52%</td>
<td>33%</td>
<td>6%</td>
</tr>
<tr>
<td>SE Coast to Broward County</td>
<td>12.2%</td>
<td>50%</td>
<td>11%</td>
<td>29%</td>
<td>11%</td>
</tr>
<tr>
<td>Miami-Dade County</td>
<td>6.4%</td>
<td>73%</td>
<td>0%</td>
<td>18%</td>
<td>9%</td>
</tr>
</tbody>
</table>

3.4 Roadway Operations

Freeways are defined as divided highways with full access control and two or more travel lanes in each direction. Freeways provide uninterrupted flow; that is, there are no at-grade intersections, and there is no direct access from abutting properties.
Access is entirely limited to interchanges whose ramps may or may not be signalized. Medians, with or without barriers, provide separation between travel directions. Tolled roadways are similar to freeways except that tolls are collected at points along the facility; in practice, operations are considered the same as freeways except at the toll plazas. For purposes of discussion, the terms freeway and expressway will be used interchangeably in this paper to be inclusive of tolled roadways.

3.4.1 Roadway Performance

In the absence of incidents, freeway performance is mostly impacted by the performance of the ramps used for ingress into and egress out of the facility. Vehicles trying to enter or exit the freeway are limited by the capacity of the arterial or local street system. Ramps serve to move and store vehicles between the limited and non-limited access systems. Ramp performance is adversely affected when traffic demand exceeds ramp capacity, which in turn affects freeway performance.

Table 3 describes levels of service (LOS) for freeway operations as being representative of various combinations of speed, density, and flow rate. Essentially a qualitative way to describe how a facility is operating, the different letters do have quantitative measures and calculations behind them. State transportation agencies such as Florida’s Turnpike typically design for level of service D or E.
Table 3. Levels of Service for Freeway Segments

<table>
<thead>
<tr>
<th>LOS</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational Characteristics</td>
<td>Free-flow speeds prevail</td>
<td>Free-flow speeds maintained</td>
<td>Speeds at or near free-flow speed</td>
<td>Speeds decline</td>
<td>Operation at capacity</td>
</tr>
<tr>
<td>Incident Effect</td>
<td>Easily absorbed</td>
<td>Easily absorbed</td>
<td>Queues develop behind blockages</td>
<td>Queues develop quickly behind blockages</td>
<td>Disruption waves propagate through upstream traffic flow</td>
</tr>
<tr>
<td>Maneuverability in Traffic Stream</td>
<td>Unimpeded</td>
<td>Slightly restricted</td>
<td>Noticeably restricted</td>
<td>Noticeably limited</td>
<td>No usable gaps in traffic stream</td>
</tr>
</tbody>
</table>

Figure 4, excerpted from the Highway Capacity Manual, shows the relationship between speed and traffic flow. Speeds are generally insensitive to low or moderate flow rates, measured in passenger cars per hour per lane (pc/h/ln). However, as flow rates increase, free flow speeds begin to decrease. Free flow speed is the mean rate of speed that can be accommodated under prevailing conditions; it can be derived in part from measured average speeds. Free flow speed is otherwise defined as the mean speed of passenger cars that can be accommodated under low to moderate flow rates on a uniform freeway segment under prevailing roadway and traffic conditions; free flow speed can be impacted by number of lanes, lane width, lateral clearance to obstructions, and interchange spacing. Figure 4 also indicates that increased flow rates begin to reduce average passenger car speeds between 1300 and 1750 pc/h/ln. For consistency, a flow rate of 1500 pc/h/ln will be assumed for the lane capacity of roadway segments under discussion in this paper.
3.4.2 Intelligent Transportation System

ITS is the application of technology, communications, and field devices to surface transportation. When used effectively, ITS allows new ways to understand, operate, and use the existing transportation system. The ITS vision may defined as follows:

*The transformation of surface transportation into an effectively managed, well integrated, universally available, and affordable system that provides for the safe, secure, efficient, and economical movement of people and goods as well as enhancing customer satisfaction and addressing environmental concerns.*

This vision ensures that transportation systems are managed in a way that provides seamless, end-to-end travel regardless of location or jurisdiction. It also requires an innovative, secure, customer oriented, performance driven approach to the management of transportation infrastructure. ITS blends physical, electronic, and information infrastructures to maximize system effectiveness and efficiency.

ITS and the associated communications network it provides serve as the means to detect problems and manage the roadways during times of crisis such as hurricane evacuations and emergency response. A fundamental role of ITS is the provision of timely, accurate information to travelers during response to regional crises. ITS can help
save lives, money, and goods as it enhances the security and mobility of the traveling public.

3.4.3 Contra Flow Operations

Significant traffic backups during recent major hurricane events have public agencies looking toward new ways to increase roadway capacity in order to move unprecedented amounts of coastal evacuation traffic. Coastal populations have grown more rapidly than roadway capacity has been added, a situation common to most urban areas. Roadway infrastructure simply has not been able to keep pace with growth in urban and suburban areas. Moreover, the public has been demanding that roadway agencies come up with ways to allow evacuation traffic to move even more expeditiously.

Rather than widening or constructing new facilities, state transportation agencies have begun to consider creating contra flow operations on evacuation routes to increase capacity in the reversed direction. The terms *contra flow* and *one way* operation are used interchangeably in this thesis. One way operations are achieved by prohibiting the desired wrong-way direction of traffic from using the roadway and allowing evacuating vehicles to use these lanes. For example, southbound traffic could be prevented from using a north-south route so that northbound traffic could make use of all available lanes. Pre-event planning has shown theoretical capacity increases of up to 60% from normal conditions by making an interstate or other limited access four-lane roadway into a one way facility. Table 4 shows theoretical capacities of several lane configurations for a number of different limited access facilities.
Table 4. Roadway Capacities

<table>
<thead>
<tr>
<th>Facility Type</th>
<th>Lane Capacity (vphpl)</th>
<th>Total Capacity (vph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Interstate (2 Lanes)</td>
<td>1500</td>
<td>3000</td>
</tr>
<tr>
<td>3-Lane w/Contra flow</td>
<td>1300</td>
<td>3900</td>
</tr>
<tr>
<td>3-Lane w/Shoulder</td>
<td>1400</td>
<td>4200</td>
</tr>
<tr>
<td>One way Interstate Using 4 Lanes</td>
<td>1250</td>
<td>5000</td>
</tr>
</tbody>
</table>

vphpl = vehicles per hour per lane
vph = vehicles per hour

3.4.4 Contra Flow Enhancements and Improvements

Planning, however, is not sufficient to make contra flow operations successful. There are major issues concerning safety and communications that are of interest to public safety personnel and jurisdictional entities in addition to the traveling public. These groups are all interested in information pertaining to roadway conditions, reverse lane status, motorist services, entry and exit information, etc. There is a great need to fine-tune operations and test communications to ensure that one way operations can be conducted safely, efficiently, and effectively. Additionally, there are many roadway and roadside enhancements that need to be made in order to allow motorists driving on the “wrong” side of the roadway to have the same information as those on the “right” side.

Depending on the scope and breadth of a one way operation, significant staff and resources are needed for successful implementation. A great deal of “up-front” work needs to be done to mobilize the necessary people and resources in advance of an emergency situation in order to maximize the limited time for the actual contra flow deployment. Decisions regarding jurisdiction, information, and resource allocation need to be finalized before a contra flow operation is ever even envisioned. This is also the
time to address information enhancements, how to handle safety concerns, what additional infrastructure is needed, etc.

The ultimate goal of the planning and analysis is to estimate the time needed to get evacuees to a safe location off the roadway before the onset of storm-force winds; the effort calculates the clearance time needed to get all evacuation traffic off the major roadway facilities. This clearance time provides the framework within which all other activities must take place: set-up of the contra flow section including deployment of personnel and equipment, clearance of the newly-reversed side of the facility, the contra flow operation itself, and the closure of the operation once official personnel are made to vacate the area for their own personal safety.

3.4.5 ITS and Contra Flow

ITS features are used to provide incident detection and verification as well as information dissemination. This is accomplished through the use of field devices such as Highway Advisory Radios, Dynamic Message Signs, Closed Circuit Television Cameras, and Vehicle Detection Systems. These field devices are managed by TMCs that control the various devices through a variety of different communications media. The devices are used during “normal” roadway operations to detect, verify, and resolve incidents and congestion.

The TMCs also interface with other intra- and inter- agency partners; the role of a TMC is to receive and disseminate information and assist and coordinate with various incident efforts. ITS comprises a technological tool that can be used by others to enhance their operations and improve safety.
While contra flow operations have really only been tested in Florida within simulated environments, ITS elements are expected to be especially useful in helping contra flow operations run with greater effectiveness and efficiency. ITS can be used in the unique circumstances of a contra flow operation to harness the abilities of technology and provide a safer, quicker evacuation scenario for both the motorists fleeing the impending hurricane and the personnel charged with controlling the operation.

3.5 Emergency Response

ITS technologies play an important role in the safety, security, and efficiency of transportation systems. ITS is effectively used to detect, report, and respond to incidents ranging from traffic crashes to major natural disasters. A new part of the challenge to implement ITS strategies is to apply the technologies to man-made disasters, both deliberate and inadvertent. Transportation agencies have been forced to take a closer look at their infrastructure management plans as a result of the tragic events of September 11, 2001, for infrastructure protection, crisis management, and disaster planning and prevention, as well as the more traditional activities of incident detection and response. ITS is now an integral component of Homeland Security, not only in the obvious arena of transportation system security, but also in the support of other stakeholders’ planning and response efforts.

This chapter provides a broad overview of the elements expected to be associated with contra flow operations and emergency response. The next chapter will provide the background for a test corridor within the Turnpike System.
Chapter 4

Test Corridor for Contra Flow Hurricane Evacuation and Emergency Response

4.1 Overview of Florida’s Turnpike System

Florida’s Turnpike System consists of a 449-mile limited access tolled roadway network throughout the State of Florida. These roadways include the original Florida Turnpike extending from Florida City in Miami-Dade County to Wildwood in north-central Florida, the Sawgrass Expressway in Broward County, the Veterans Expressway and Suncoast Parkway in the Tampa area, the Polk Parkway near Lakeland, and the BeeLine Expressway, East-West Expressway, Southern Connector, and Seminole Expressway in the greater Orlando area. Additionally, the System includes a number of Turnpike-Operated (but not owned) toll facilities throughout the state. The different roadways traverse rural areas and connect major metropolitan centers in South, Central, and Southwest Florida.

Evolving and growing over time, the Turnpike System has provided Florida’s motorists with a safe and efficient means of travel since 1957. Throughout its lifetime, the Turnpike has striven to provide innovative customer initiatives and enhanced levels of service in order to provide value to each and every toll-paying customer. With annual revenues approaching $500 million, the System serves over one million toll paying patrons every day. Figure 5 provides a picture of the extent of the System and identifies the limits of the contra flow corridor.
Figure 5. Florida’s Turnpike System and Contra Flow Corridor
4.1.1 Florida’s Turnpike Enterprise

Florida’s Turnpike Enterprise is an innovative experiment in governance. The State of Florida’s largest revenue-producing asset has been authorized in law to run using private sector models from within the public sector, allowing for improved efficiency and effectiveness, while maintaining public sector motives. Its objectives are to improve cost effectiveness and timeliness in project delivery, to increase revenues and expand its capital program, and to improve its quality of service. In short, the Enterprise is intended to be run as a business in order to help meet Florida’s growing transportation needs.

With these objectives in mind, the Enterprise’s vision (statement providing a compelling image of the future) and mission (statement providing a method of operation) have been developed as follows:

**Vision:** Helping to keep Florida on the move through customer-oriented, environmentally sound, user-financed facilities

**Mission:** To help meet the State’s growing transportation needs, ensuring value to customers, protecting investors, and managing the Turnpike System in a business-like manner

To produce positive transportation impacts by the year 2008, a series of strategies have been developed. Two of these strategies relate directly to the subject of this thesis:

- Provide Innovative Customer Service
- Deploy a Fiber Optic Network System-Wide

Innovative customer service relates to opportunities to use a variety of operational changes to better serve customers. Increasing roadway capacity through the creation of a contra flow corridor for hurricane evacuations and then enhancing that corridor with state-of-the-art ITS equipment is one such means of providing innovative customer
service. The deployment of a system-wide fiber optic network provides the communication means for the TMCs and ITS field devices to allow efficient incident detection, traffic monitoring, information dissemination, and emergency response.

4.2 Overview of Test Corridor

“The Mainline” of Florida’s Turnpike, extending for 304 miles between Florida City in Miami-Dade County and Wildwood in Sumter County, contains the test corridor that is the subject of this paper. The 99-mile contra flow corridor segment of the Mainline starts just after the Fort Pierce / State Road 70 interchange at Milepost (MP) 153 and ends just after the Osceola Parkway interchange at MP 252. It allows only northbound traffic.

Traversing the most rural portion of the Mainline, this four-lane segment of roadway passes by three interchanges (YeeHaw Junction / State Road 60, Kissimmee – St. Cloud, and Osceola Parkway), two service plazas (Fort Drum and Canoe Creek), and one mainline toll plaza (Three Lakes). The contra flow section goes through some of the most sparsely populated, rural sections of St. Lucie, Indian River, Okeechobee, and Osceola Counties.

During normal operations, this segment of the Turnpike experiences lighter traffic volumes than the urban sections in the South Florida and Orlando areas. Normal traffic tends to traverse this portion to get from the former to the latter metropolitan area (or the reverse); commuter trips are less common here.

The roadway cross section has four lanes, two in each direction, with paved inside and outside shoulders. The inside and outside shoulders have ground-in rumble strips to catch the attention of an errant driver before his vehicle tires leave the paved surface.
There is a grassy median between the north- and south- bound lanes, there is a grassy, unobstructed roadside, and there are several narrow bridges and culverts. Despite having been built nearly 50 years ago, the right-of-way features generally meet currently accepted roadway and roadside design criteria for rural freeway sections.

4.3 Overview of Turnpike Contra Flow Plans

The Turnpike prepared reverse lane plans prior to Hurricane Floyd; however, these ambitious plans created a one way operation for nearly the entire Mainline Turnpike and were never formally adopted. A new plan was developed in 2000. The 2000 plan addressed many, but not all, of the shortfalls of the previous plan.

4.3.1 1994 and 1997 Contra Flow Plans

In 1994, the Turnpike and FHP prepared a contra flow plan that was later updated in 1997. This plan attempted to address issues related to implementing a reversible lane system on a limited access facility in the event of a large-scale evacuation from South Florida. One way use of the Turnpike was evaluated between MP 88 (Lantana Mainline Toll Plaza in Palm Beach County) and MP 305 (Wildwood Interchange in Sumter County), a distance of 217 miles. The report discussed the following issues:

Safety – This issue has two primary components: keeping drivers using the southbound lanes as “express lanes” going northbound in a safe manner and preventing drivers from entering the Turnpike at interchanges with the intention of going southbound.

Only after the southbound Turnpike has been completely cleared of all southbound traffic can evacuees be allowed to go northbound. A very real danger lies in
the possibility that, seeing a wide-open roadway ahead of them, drivers could attempt to
drive at speeds in excess of the speed limit. Pilot cars, presumably FHP with its law
enforcement powers, would be needed to pace traffic to ensure that motorists do not exceed a safe speed.

There are no signs or pavement markings to provide guidance in the new northbound lanes, as they will be facing the opposite direction. The reflective pavement markers on the ramps will be red, for they are designed to let drivers know they are going the (normally) wrong direction. Guardrails may or may not provide protection from fixed objects such as signs and bridge piers in the roadway’s clear recovery area, and guardrail end treatments will be absent, posing the potential for extremely serious accidents if they are hit.

The 1997 plan required 258 FHP troopers working 12-hour shifts to mobilize and deploy the one way plan. These troopers needed to be stationed at every single interchange to prevent vehicles from entering the Turnpike to go southbound. They were also needed at the service plazas to ensure motorists did not head back to the south. This figure did not include the troopers needed for functions other than traffic control. Additional interchanges have been added since 1997, so this number, in reality is even greater.

The troopers will be pulled off the roadway when the winds reach a certain point for their own safety. Motorists on the roadway will ultimately be left to fend for themselves on a facility that will lack proper guidance, as they will be traveling in the (normally) wrong direction.
Traffic congestion – This is an obvious effect from the evacuation of a large number of people from South Florida. While many coastal County regional plans call for east-to-west evacuations, after Hurricane Andrew hit South Florida in 1992, many residents expressed their future intentions to evacuate south-to-north. None of the limited access facilities leaving South Florida have the capacity to handle thousands of evacuees in the 48 to 72 hour time period before a hurricane strike.

Less than ideal conditions must be assumed as well: cars will become stranded due to mechanical failure, running out of gas, accidents, etc., exacerbating the congestion. Police enforcement over and above those noted previously will be needed for assistance, as will tow trucks, emergency response, etc. Response times will be severely impacted if rescue vehicles are limited to northbound movements only. Not only will they become stuck in traffic, but they will also be unable to return south to resume their patrols.

Severe congestion may be expected at the crossover points, due to both the heavy merge / diverge movements and potential confusion resulting from unfamiliar traffic maneuvers. Because mid-interchanges will be limited to northbound movements only, they will experience congestion as cars will only be allowed to enter from one direction. Additionally, northbound cars will not be allowed to exit until the terminus of the one way section.

Stranded motorist rescue – Whether or not a one way operation is implemented, motorists will become stranded because they will have accidents, run out of gas, have mechanical failures, or become physically incapacitated. They will need emergency and other services. The ability to reach these motorists will be severely hampered if these services are unable to move through the traffic. With both roadway directions going
northbound and without a means to travel back south, it is unclear how effectively these services can be sustained.

*Housing evacuees* – The 1997 plan proposed the Wildwood area as the terminus of the one way operation. However, there are inadequate facilities for food, fuel, and lodging in this remote area. Evacuees will likely travel north to reach shelter, taking them further from their points of origin. After the emergency event, the heavy southward flow of traffic could cause all the northbound evacuation problems to be repeated in the opposite direction.

*Temporary loss of the Turnpike as a transportation facility* – In order to implement the one way plan, it needs to go into effect 48 to 72 hours in advance of the emergency event. Once both travel directions are made northbound only, a major roadway corridor to South Florida will be eliminated. Pre- and post- event supplies, personnel, etc., will not be able to get through.

*Evacuee perception* – Making the limited access facilities one way out of South Florida may actually encourage evacuation by making it appear easier to leave the area. As indicated previously, most coastal County plans call for inland (east-to-west) movement rather than northward. People who may have felt encouraged to leave the area rather than find a safe place near home could become stranded on the roadway during a storm because the roadways simply lack the capacity to move thousands of evacuees in a short period of time.

4.3.2 Current Contra Flow Plan (2000)

A plan that provides for one way operations on the Turnpike along the bulk of its length presents numerous logistical problems. However, there may be scenarios that
could accommodate reversible lanes without overextending resources or hampering public safety. Reversible operations on the Turnpike may be considered feasible if the area in question is of short length and has limited ingress / egress points. As an alternative to reversing 217 miles of the Turnpike, the 2000 plan focuses on the stretch of roadway between MP 153 (Fort Pierce / State Road 70) and MP 252 (Osceola Parkway) as being a viable area for one way operations with the following main points:

*Few interchanges* – There are only a few interchanges. In addition to drastically reducing the manpower needed by law enforcement to provide safe operations, southbound recirculation by law enforcement, emergency medical services, wrecker services, etc., would be simplified because less than 100 miles of the Turnpike would be affected. However, this area does pose a problem with regard to proximity to hospitals and other services.

*Proximity* – These two interchanges at the new plan’s termini are in close proximity to other major routes: I-95 in the Fort Pierce area, Osceola Parkway, Bee Line Expressway, and I-4 in the Orlando area.

*Time* – The time to set up and later dismantle the one way operation would be much shorter. Not only would the southward flow of goods and services prior to the emergency event be preserved for the maximum time possible, evacuees would have a greater array of choices for end destinations until the “express lane” implementation limits their ability to exit the Turnpike.

*Safety* – The time to clear the roadway of southbound vehicles would be lessened, and the potential for wrong way maneuvers would be decreased because of the fewer
interchanges and shorter length. The shorter length should also decrease emergency response times.

Resources – Fewer resources (cones, signs, barricades, etc.) would be needed simply by virtue of the shorter length of roadway affected. For the same reason, fewer highway law enforcement personnel would be needed.

Miscellaneous – The area is rural in nature. The interchanges are widely spaced, allowing for minimal conflict points. There are two service plazas available for fuel and food. The end point of the operation is near an area with ample lodging for evacuees.

Upon the Governor’s completion of an Executive Order and at least 49 hours (Hurricane Watch) prior to the landfall of tropical storm force winds of a Category 4 or 5 hurricane that is expected to strike South Florida, Turnpike staff begins its contra flow plan implementation. This includes the preparation and staging of equipment, signs, barricades, and personnel for reversing the Turnpike’s southbound travel lanes between MP 153 (Fort Pierce / State Road 70) and MP 252 (Osceola Parkway). All traffic control devices are staged at pre-planned locations in preparation of the one way operation.

The Executive Order authorizes the Florida Highway Patrol to mobilize its resources and direct interagency efforts at least 24 hours (Hurricane Warning) prior to landfall of tropical storm force winds. The contra flow operation is effective during daylight hours only, and resources are dispatched by the Turnpike’s Emergency Operations Center (EOC) located in Pompano Beach. The Turnpike’s Contra Flow Operation is generally implemented as follows6:
Close southbound movements from MP 254 to Interstate 4 in Orlando, preventing all new southbound traffic from entering the Turnpike and providing time for the existing traffic to leave the future contra flow corridor.

FHP monitors the southbound lanes to keep the roadway status current.

Turnpike personnel place cones, signs, barricades, and other traffic control devices to restrict southbound entry at all interchanges and toll and service plazas within the contra flow corridor.

FHP runs an “All Clear” check of the roadway by driving the new contra flow section from south to north, making certain that no errant vehicles remain anywhere in the corridor.

Working behind FHP, Turnpike personnel place appropriate traffic control devices facing the newly created northbound lanes to provide appropriate guidance.

No northbound movements on the new contra flow corridor are permitted until two FHP vehicles are available at the Northern Crossover to pace traffic and prevent uncontrolled speeds.

Northern and Southern Crossovers are opened, and northbound traffic is allowed to enter contra flow corridor via the Southern Crossover. Upon reaching Osceola Parkway, all northbound traffic is diverted back to the correct side of the roadway via the Northern Crossover.

One way operations are monitored by FHP and the Turnpike’s Emergency Response Team, and the contra flow operation will be in effect until wind speeds reach 40 mph. At that time, all public safety personnel will be required to leave their stations and seek appropriate shelter.

Figures 6 to 11 show sample locations with detailed listings of needed resources. The figures provide examples of each type of locale an evacuating driver may expect to encounter throughout the contra flow corridor: the two crossovers at the start and terminus of the contra flow section, intermediate interchanges, service plazas, and mainline toll plazas. Tolls will have been waived as part of the Executive Order to facilitate the evacuation, and the sub plan for the toll plazas are to provide guidance through the unmanned toll collection lanes. Figure 12 is an example of the typical signing that motorists can expect to encounter.
During the contra flow operation, disabled vehicles will be moved to the grassy area beyond the paved shoulder so as not to impede evacuation operations. The TMC will be appropriately staffed for the duration of the emergency. In the likely event that the Pompano Beach TMC needs to be closed down to allow staff to return to safe locations, the Turkey Lake TMC in Orlando will take over all ITS operations and responsibilities. Direction for the emergency situation will come from the EOC.

Motorist advisory messages using the Highway Advisory Radio stations will be made, and the flashing beacons on the signs providing the broadcast frequency will be activated to inform customers of URGENT messages. The Dynamic Message Signs will be activated to provide information with respect to travel conditions and other pertinent information.

Figure 6. Fort Pierce Sub Plan Including Southern Crossover
Figure 7. YeeHaw Junction Sub Plan

Figure 8. Osceola Parkway Sub Plan
Figure 9. Service Plaza Sub Plan

Figure 10. Mainline Toll Plaza Sub Plan
Figure 11. Northern Crossover Sub Plan

Figure 12. Typical Signing for Approaches to Contra Flow Section
4.4 Existing ITS Program Overview

The Turnpike is making significant progress in its ability to provide real-time traffic information to the traveling public, enabling the customer to have a safe and convenient means of travel. Technology to increase capacity and enhance safety is at the heart of the Turnpike Enterprise’s customer-focused organization. Work is being done to address needs in the TMC, the field end devices, and the communications media to provide the necessary infrastructure to allow for an effective ITS.

4.4.1 Traffic Management Centers

Two Traffic Management Centers have been constructed for the monitoring of traffic conditions and the dissemination of traffic information to the traveling public. Open 24 hours a day, 7 days a week, one center is located in South Florida at the Pompano Beach Service Plaza in Broward County, and the other is located in the Orlando area at the Turkey Lake Service Plaza. Located over 200 miles apart, the two centers function as a single unit and communicate via a leased T1 telephone line (with a transfer rate of 1.544 Mbits/sec). This unitary function is facilitated through the use of a highly advanced central TMC software system (SunNavSM), thorough operational procedures and policies, and a commitment to communication, customer service, and excellence.

The TMCs are information clearinghouses for the Turnpike System. TMC Operators work closely with intra- and inter- Agency partners to detect, verify, and mitigate incidents safely and quickly. Figures 13 and 14 depict the console workstation area with video wall and back room with computers and equipment racks typical of the TMCs.
Figure 13. Console Workstation Area with Video Wall

Figure 14. Back Room with Computers and Equipment Racks
4.4.2 Field Devices

Field devices consist of any end-device that is used to detect, verify, or disseminate information through communications with the TMC.

4.4.2.1 Highway Advisory Radio

The Federal Communication Commission (FCC) has authorized government agencies to use low-power AM radio transmitters to provide noncommercial voice information to motorists. Known as Highway Advisory Radio (HAR), these stations broadcast traffic information relating to congestion, road conditions, hazards, work zones, and other types of advisories. Figure 15 shows an example of a HAR sign and transmitter typical of what is used along the Turnpike. The flashing beacons on the sign are activated to advise motorists of urgent messages.

Figure 15. HAR Information Sign and Transmitter

The Turnpike has installed a system of nine HAR along the Mainline, with each radio transmitting on the same frequency. With a three to five mile transmission range, the radios have been strategically placed near service plazas to provide incident and
traveler information. They normally broadcast travel advisories, incident information, and general information with respect to the Turnpike System; however, special HAR scripts have been developed to provide information specific to contra flow operations.

4.4.2.2 Dynamic Message Signs

After information is received and verified by the TMCs, Dynamic Message Signs (DMS) are used in conjunction with the HAR to communicate information to the traveling public. DMS are electronically illuminated signs that display messages to motorists about real-time upstream traffic conditions. They are designed to meet several requirements that give them an advantage over static (non-changeable) signs: conspicuity or prominent visibility in the roadway environment, legibility to allow motorists to read their messages quickly and easily, comprehensibility or the ease in which their messages are understood, and credibility in which the drivers may be confident of their messages.

The Turnpike has installed 22 shuttered fiber optic DMS along the Mainline in the general vicinity of the Service Plazas and major traveler decision points. Figure 16 is a graphic of the DMS locations along the roadway. The numbers refer to specific DMS location descriptions. Figure 17 shows an example of a typical Turnpike DMS.

DMS control is accomplished through a device driver in the SunNavSM software system. Current communications are through dedicated, bridged telephone circuits with an ultimate, long-term communications transition to fiber optic cable.
Figure 16. DMS Locations Along the Turnpike

Figure 17. Typical Turnpike DMS
4.4.2.3 Closed Circuit Television Cameras

Closed Circuit Television (CCTV) cameras with the ability to pan, tilt, and zoom (PTZ) are critical for DMS message and incident verification. They are also useful in dispatching the appropriate incident or emergency responders as they can be used to identify the type and severity of incidents. Cameras can be placed up to one mile apart without appreciable degradation in video image quality, assuming that the roadway geometry itself does not present visual obstructions.

Image quality depends largely upon the communications medium in use, ranging from leased telephone lines to fiber optic cable. Telephone circuits have varying rates of transmission depending upon the frame size / resolution and the modem speed, with six to seven frames per second (fps) being somewhat typical on the Turnpike’s current system. Fiber optic cable allows media-quality image transmission with transmission rates in excess of 30 fps. The Turnpike has installed eight CCTV cameras in South Florida and six in the Orlando area; plans for additional cameras will ultimately provide complete system coverage. They are controlled via a partial fiber optic backbone, capturing the roadway images and returning them back to the TMC. At the TMC, switching equipment is used to place the camera images on video monitors or a video wall. Figure 18 shows an example of typical CCTV equipment, and Figure 19 is an example of the ITS architecture used for the South Florida fiber optic cable installation.
4.4.2.4 Vehicle Detection Systems

Different types of Vehicle Detection Systems (VDS) are in use for traffic detection, with inductive loop detectors being the prevalent type in the United States. Other types of detectors that are considered more reliable (magnetic, microloop, ultrasonic, microwave radar, infrared, and video image detection) are becoming more popular.
Inductive loops consist of a wire loop and an electronic component to measure loop inductance. While relatively inexpensive, they have disadvantages in that they must be installed in the pavement, and they are prone to failure.

Magnetic detectors consist of a wire coil in a protective housing that is installed under the pavement. There is an electronic amplifier located in a controller cabinet. Their application is limited in that they detect vehicle passage but not vehicle presence. Magnetometer detectors are similar to magnetic detectors; they are installed in the pavement. However, they are not recommended for occupancy or speed determination; their primary use is recommended for traffic volume determination. Microloops are also similar to magnetic detectors, but they too cannot detect the presence of a vehicle.

Ultrasonic detectors measure vehicle presence, occupancy, and speed by using a high frequency tone that is reflected by approaching vehicles. They are non-intrusive (not installed in the pavement), but they are not able to differentiate well between vehicles that are not clearly in a lane or cars that travel closely side-by-side. They are also affected by high wind speeds.

Microwave radar detectors beam microwave energy onto an area of the roadway and detect a vehicle’s effect on this energy. They can measure speed over multiple lanes as well as volume, occupancy, and gap information; however, they may pick up false data.

Infrared detectors transmit light beams that then detect the portion reflected back to the detector by approaching vehicles. They provide presence, speed, count, and occupancy data; however, adverse weather conditions cause degradation of the data.
Video image processing is becoming more popular for non-intrusive detection technologies. Images generated by video cameras are used in conjunction with a processor that determines vehicle presence or passage and software that uses algorithms to perform operations for surveillance. A primary drawback is the need for communications media to send the data back to the processing site.

The Turnpike’s detection program is still in its infancy, due primarily to the lack of fiber optic communications infrastructure to transmit the data. A pilot detection program is being tested in the Orlando area using an existing fiber optic link. Future detection projects are on hold until the communications infrastructure is in place.

There are many ITS field devices in addition to those discussed above. The focus in this thesis is for those devices needed to accomplish the goals of an effective contra flow plan for the Turnpike

4.4.3 Communications Infrastructure

Reliability, availability, and redundancy requirements are important factors in the design of a communications system. Available technology choices need to be optimized with costs in order to meet system communication needs for the short- and long-term.

A communications network will transmit data, voice, and video, with the first two having relatively low bandwidth requirements and video being bandwidth-intensive. The need for video and its associated quality, measured in frames per second, will drive the design of a communications system.

The Turnpike’s current ITS communications infrastructure is a combination of leased telephone circuits and fiber optic cable. A partial fiber optic backbone has been
installed in the South Florida and Orlando areas. Sixty-eight miles of fiber optic cable have been installed in a section of the Mainline in Miami-Dade, Broward, and Palm Beach Counties, providing important links to existing DMS, HAR, CCTV cameras, and the Pompano Beach TMC. Fiber optic cable, from the Orlando TMC running six miles north, is being utilized for voice communications as well as image transmission from the CCTV cameras located within that corridor. Upcoming projects provide for additional miles of fiber optic cable. The communications system is not expected to be completely migrated to fiber optic cable for at least five years.

4.5 Other Data Partners

The Turnpike has a number of internal and external partners that work together to provide services and information to its customers. They also work directly with the TMC to provide live traffic condition updates.

4.5.1 Road Rangers

Road Ranger vehicles comprise the Turnpike’s service patrol. An internal agency partner, they provide roadside assistance in the form of minor repairs, tire changes, fuel and water replacement to Turnpike customers free of charge. Service patrols are becoming widely recognized as an important tool to remove disabled vehicles and debris from the roadway, facilitating the re-opening of closed travel lanes.

The Road Ranger vehicles have been equipped with Automated Vehicle Location (AVL) devices that communicate with the TMC and provide information about vehicle speed and location, affecting more efficient and effective incident response. The Road Rangers are operated in the urban portions of the Turnpike during peak hours; there are
no service patrols in the rural areas. Figure 20 shows an example of a Turnpike Road Ranger vehicle.

Figure 20. Road Ranger Vehicle

4.5.2 Advanced Traveler Information Service (ATIS) Providers

The Turnpike is participating in several efforts to share traffic information with public and private partners. The South Florida SunGuideSM effort shares information between Miami-Dade, Broward, and Palm Beach Counties, the Mid-Florida ITS Consortium (CITRIS) effort is in effect in the greater Orlando area, and the Turnpike has recently partnered with other entities in the Tampa Bay region to accomplish effective information sharing. Through the use of new and emergent technologies, the Turnpike can provide real-time information to the traveling public, with the jurisdictional boundaries made virtually invisible to the motorist.

4.5.2.1 National Traveler Information 511

The national traveler information service number, 511, has recently been implemented in Florida in two areas and will be implemented in another in the near future. The driver dials 511 from his landline or cellular telephone, keys in or speaks his
route information, and receives real-time travel updates. Figure 21 shows the 511 logo for traveler and transit information.

Figure 21. 511 Logo

4.5.3 Toll Operations Office

Toll Operations manages all toll transactions at all toll collection locations for the State of Florida. An internal agency partner, Toll Operations has instituted Electronic Toll Collection (ETC) through the SunPass™ toll collection system program. Vehicles that are equipped with SunPass™ toll transponders can drive through special toll collection lanes known as “dedicated lanes” that allow them to pay their toll without stopping. Future plans are showing a move to “open road” or all-electronic tolling. In addition to the enhanced customer service experienced by the motorist, efficiencies are realized in both toll collection and roadway operations.

An opportunity exists to use transponder-equipped vehicles as probes, providing a dynamic means of vehicle detection. Portable Roadside Readers (PRR) are being tested to determine what penetration level of transponders is needed to develop valid measurement parameters. The transponders-as-probes issue has some institutional and legal barriers to overcome with respect to privacy concerns, but there exists a valid detection technology. Figure 22 shows the SunPass™ logo, Florida’s method of ETC.
4.5.4 Planning

The Planning Office collects data from permanent traffic count stations located throughout the Turnpike System. As the principal source for highway data collection and analysis, the Planning Office is the clearinghouse for traffic trends and travel characteristics. This office is an important source of data for long-range planning and programming purposes.

4.6 Intra-Agency Partners

Florida’s Turnpike Enterprise is organized into departments that follow specific core processes: Planning and Production, Highway Operations, Business Development, Communications and Marketing, and Toll Operations. This list does not encompass all departments, but it does include those critical to the successful implementation of the Turnpike’s mission, vision, goals, and objectives. The focus in this thesis is on those partner offices that are critical to the successful operation of an Intelligent Transportation System.

4.6.1 Maintenance

The Maintenance Office, part of Highway Operations, protects the Turnpike’s significant infrastructure investment through preventive and periodic maintenance.
procedures and activities. Maintenance is also responsible for incident response, both in terms of traffic control and scene clearance and clean-up.

Maintenance field personnel communicate closely with the TMC keeping the TMC Operators apprised of traffic and scene conditions, to enable them to effectively update field devices with current information. The relationship between the two has grown such that there is a high level of trust and understanding of each other’s needs for current information and condition status. Maintenance personnel serve as the TMCs’ “eyes and ears” in the absence of ITS field devices.

4.6.2 Public Information Office

The Public Information Office (PIO) is a component of the Communications and Marketing Department. In addition to being the Turnpike’s mouthpiece for public inquires and media relations, PIO takes calls with respect to incidents and coordinates responses with the TMC. PIO manages a toll-free number that customers may use to comment on issues that run the gamut from system levels of service and safety to comfort, convenience, and value.

While formerly PIO was the first recipient of incident information, the Turnpike’s ITS program has evolved to the point that the TMC is the Turnpike’s preferred initial internal responder. After receiving incident information from the TMC, PIO uses its resources to contact entities such as the media and other public agencies to inform them of critical traffic events.
4.6.3 Service Plazas

The service plazas are components of the Business Development and Concession Management Department, an office unique to the Turnpike within the FDOT. Located approximately 40 miles apart along the Mainline Turnpike, the service plazas and their associated restaurant, fuel, repair, and restroom services are important stopping points for travelers that need to take a break.

During emergency events, the service plazas will be critical staging locations for evacuees that need to stop along their trip. The service plazas also provide information on parking lot usage, giving the TMC some indication of traffic loading and distribution along the System. Lastly, the Road Rangers and wrecker vehicles are dispatched through the service plazas, providing a critical incident management link to the TMC.

4.7 Inter-Agency Partners

The Turnpike works with many external partners in its efforts to provide customers premium value in return for the tolls that they pay. Some of the external partners critical to incident management and emergency response are mentioned here.

4.7.1 Florida Highway Patrol

The Turnpike funds a Florida Highway Patrol (FHP) Troop that is solely dedicated to activities on the Turnpike System. Troop K Troopers patrol the Turnpike providing law enforcement, motorist assistance, and other essential services. Because their activities are limited to Turnpike roadways, these troopers have an enhanced customer service focus for Turnpike patrons.
FHP works closely with the TMC in terms of incident information and response plans. While FHP is the true first responder in terms of emergency activities, the TMC monitors FHP’s web site and other information sources for the most up-to-date traffic and incident information. TMC staff are stationed in FHP’s Communications Dispatch Center for first-hand knowledge of events as they occur; these operators communicate immediately with TMC staff to initiate the correct response plans. As instrumentation of ITS devices occurs, FHP is transitioning to a purely law enforcement and traffic control function during incidents and emergencies, and the TMC is evolving into the defined incident information manager.

4.7.2 Other Emergency Responders

While FHP is the direct contact with fire-rescue services, hazardous clean-up crews, etc., these other emergency responders are important players in terms of incident response and emergency management. The TMC indirectly gains information about roadway closures and response times from these responders, allowing for updates to the various field devices in use.

4.7.3 Other Florida Department of Transportation Districts

FDOT Districts can be broken into two types for the purpose of this thesis: sending and receiving, that is, locations from which people leave and those to which they evacuate. Because each District has a major limited access facility such as an interstate highway that acts as an evacuation corridor during a major storm event, coordination and communication are critical to ensure smooth traffic flows and consistent and correct traveler information. Districts will likely act in parallel in the event of a major
evacuation, and they need to keep each other apprised of different activities to make sure that there are no inherent conflicts. Communications between inter-district TMCs are critical to this process.

4.7.4 Local Partners

Local governments are critical to the success of any evacuation; the individual counties begin the evacuation process for their own locales. They will then communicate with the Districts so that travelers can evacuate as smoothly as possible given the circumstances. Some local partners may even have their own TMCs to share information.

4.8 Overview of Current ITS Deployment and Practices in the Test Corridor

The previous sections of this chapter have detailed the existing ITS deployment for Florida’s Turnpike Enterprise in terms of TMCs, field end devices, and communications. The previous sections have also generally described how the TMC communicates with other intra- and inter- agency partners. This section will briefly highlight Turnpike ITS deployment and practices specifically within the contra flow corridor.

4.8.1 Storm Criteria

The Turnpike’s contra flow plan will only be initiated upon receipt of an executive order from Florida’s governor. The governor is the only person within the State authorized to make this type of decision. He will make his decision about whether or not to provide for reverse-laning of a limited access evacuation corridor based upon
the anticipated magnitude and path of a storm, the amount of anticipated evacuation traffic, etc.

4.8.2 Traffic Operations Office Emergency Response Plan

For use during emergency events, Florida’s Turnpike Enterprise has developed operational plans to address issues of jurisdiction, chain of command, continuity of operations, etc. Traffic Operations’ plan is a subset of the Enterprise’s plan; pre-storm activity portions are excerpted below:

**PURPOSE**

The purpose of this Plan is to outline the requirements and responsibilities relative to the procedures for emergency preparedness, response, and recovery within the Turnpike Traffic Operations and Traffic Management Center (TMC) and the inter-relationship to the Enterprise Emergency Operations Center (EEOC).

Preparations for response and recovery shall begin April 15 of each year. Efforts are to be coordinated between the Turnpike Traffic Operations Engineer, the TMC Manager, Senior Systems Engineer, and ITS Contract Manager or delegates.

**DEFINITIONS**

**ENTERPRISE EMERGENCY OPERATIONS CENTER**

The primary responsibility of the EEOC team is to coordinate the established Emergency Response Plan and to provide guidance to ensure the completion of the individual unit functions. The Emergency Communications Center (ECC) as part of the EEOC will be manned on a 24-hour basis, from the issuance of an alert notice, throughout the emergency, until the emergency conditions have been stabilized.

Under the direction of the EEOC Leader, all Turnpike emergency preparedness and response activities will be coordinated through the EEOC. Daily coordination meetings will be held at the EEOC. The Turnpike Traffic Operations Engineer and the TMC Manager or designee, and necessary support personnel shall be in attendance at these meetings.

**ALERT**

Defined in the Turnpike Emergency Response Plan as when an approaching storm is within 48 to 72 hours of possible landfall.
**HURRICANE WATCH**

Issued by the National Hurricane Center when a hurricane may threaten the coastal and inland areas. A watch is issued when a storm is within 24 to 48 hours of landfall.

**HURRICANE WARNING**

Issued by the National Hurricane Center when a storm is within 24 hours of landfall. Advisories containing hurricane warnings may also include, gale warnings for storm’s fringes, estimated storm effect, and recommended emergency procedures.

**IMPACTED AREA OR POTENTIALLY IMPACTED AREA**

The TMC facility that is located in the path of the storm or other emergency situation that may cause the loss of operability.

**PRIMARY RESPONSIBILITIES**

**TRAFFIC OPERATIONS MANAGEMENT**

Provide direction and support.

Designate staff to coordinate communications between the EEOC and the TMC facilities.

Review staffing levels for the duration of the emergency and institute emergency staffing as needed. Contact all key personnel to confirm the “alert” status. Review leave time of key personnel on an individual basis, and cancel as necessary. Release non-critical employees, working or residing in the impacted area, to go home to protect their property and seek shelter, if necessary. Set up rotation for critical employees. Advise all employees of their responsibility for reporting to work during recovery.

Monitor local conditions, directives, and warnings and transfer ITS device control to non-impacted facility as warranted.

TMC Manager will coordinate with other TMCs on emergency procedures, protocols, and interoperability issues.

**TRAFFIC ENGINEERING STAFF**

Coordinate with and provide support to Traffic Operations Management, ITS Maintenance, Construction, Roadway Maintenance, and other Turnpike Departments as needed.

Top off fuel, refresh water supply, and check condition of batteries in all vehicles within the Traffic Operations unit and comply with vehicle equipment requirements. Assign vehicles, identified as necessary for specific emergency assignments, to key personnel with post-disaster responsibilities.

Coordinate with Construction to review all existing roadway projects for lane reductions and other traffic flow obstructions.
Coordinate with and provide support to ITS Maintenance and Roadway Maintenance Emergency Response Damage Assessment Team during recovery efforts.

**ITS MAINTENANCE/NETWORKING STAFF**

Verify that all TMC and field equipment are in working order through system and field-testing.

Review and update personnel assignments and contractors and verify areas of responsibility for emergency damage assessment.

Notify maintenance contractor(s) to be on alert status.

Coordinate with TMC Manager on emergency procedures, protocols, and inoperability issues. Review and update TMC control transfer plan along with resulting operational changes if any.

Immediately after an “all clear” is announced, or prior to that time if so determined by the EEOC Management Team, personnel assigned to damage assessment shall go directly to the affected zone to perform preliminary damage assessment. Personnel outside of the impacted area will be assigned to field review, moving toward the damage area. The ITS Contract Manager will coordinate personnel movement.

Review/coordinate with the Toll Operations Office and Florida Highway Patrol regarding maintenance of traffic plans for continued suspension or resumption of toll collection at mainline barriers and ramp plazas.

**ATIS OPERATORS**

Update all information in this plan, including emergency phone lists and key personnel responsible for carrying out the assignments herein by May 15 of each year.

Review and update ITS device location charts along with coordinating message libraries.

Review and update information for maintenance personnel and areas of responsibility for emergency damage assessment of ITS devices and contractors for necessary emergency work.

Assist the TMC Operators as needed.

**TMC OPERATORS**

Review the Emergency Response plan each year by June 1.

The TMC will be the central contact point for Traffic Operations staff during an emergency. Operators will log ramp, travel lane, and toll lane closures, toll plaza, service plaza, roadway damage, and any other pertinent facility closures and/or damage as incidents in the SunNav™ system.

Traffic monitoring will be ongoing throughout the duration of the emergency.
Motorist advisory broadcasts will begin at the direction of the EEOC utilizing the nine Highway Advisory Radio transmitters with advisory beacons located as shown in Table 5:

Table 5. HAR Locations

<table>
<thead>
<tr>
<th>HAR Transmitter Locations</th>
<th>Milepost</th>
</tr>
</thead>
<tbody>
<tr>
<td>SW 8th Street</td>
<td>25</td>
</tr>
<tr>
<td>Miramar</td>
<td>46</td>
</tr>
<tr>
<td>Deerfield Beach</td>
<td>71</td>
</tr>
<tr>
<td>Lake Worth</td>
<td>94</td>
</tr>
<tr>
<td>Stuart</td>
<td>133</td>
</tr>
<tr>
<td>Fort Pierce</td>
<td>152</td>
</tr>
<tr>
<td>Canoe Creek</td>
<td>229</td>
</tr>
<tr>
<td>I-4 / Orlando</td>
<td>259</td>
</tr>
<tr>
<td>Wildwood</td>
<td>304</td>
</tr>
</tbody>
</table>

All Highway Advisory Radio messages will be approved by the EEOC through the TMC Manager prior to release.

Motorist advisory messages will be posted on the 22 permanent Dynamic Message Signs as shown in Table 6:

All Dynamic Message Sign messages will be approved by the EEOC through the TMC Manager prior to release. Sign-specific messages will be saved in the message library and retained indefinitely for use and coordination.

Once activated, verify field conditions (utilizing available Turnpike personnel and Florida Highway Patrol Troopers) such as sign visibility; message broadcast clarity, and accuracy concerning Highway Advisory Radio and Dynamic Message Sign messages.

TMC Dispatch Center Operator will remain on duty to provide a continuous communication link to the FHP Dispatch Center.
Table 6. DMS Locations

<table>
<thead>
<tr>
<th>Northbound Milepost</th>
<th>Southbound Milepost</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.3</td>
<td>20.95</td>
</tr>
<tr>
<td>34</td>
<td>34</td>
</tr>
<tr>
<td>56.3</td>
<td>51.4</td>
</tr>
<tr>
<td>73.6</td>
<td>73.6</td>
</tr>
<tr>
<td>85</td>
<td>101.3</td>
</tr>
<tr>
<td>114.7</td>
<td>119.3</td>
</tr>
<tr>
<td>133.2</td>
<td>155</td>
</tr>
<tr>
<td>184.1</td>
<td>195.75</td>
</tr>
<tr>
<td>227.6</td>
<td>246</td>
</tr>
<tr>
<td>256.9</td>
<td>270</td>
</tr>
<tr>
<td>271.1</td>
<td>307</td>
</tr>
</tbody>
</table>

**ALL STAFF**

*All scheduled leave will be cancelled until further notice upon notification of a Hurricane Alert. Key staff will be rotated in order to allow the securing of personal property.*

*Every employee should be wearing their Turnpike identification during alert status and will need to have a current copy of this emergency response plan in their possession.*

*As soon as the National Hurricane Center has lifted the hurricane warning advisory for the affected areas, or sooner if conditions warrant, all Traffic Operations staff are expected to report to their respective work locations according to their assigned schedule.*

4.8.3 ITS Devices in the Test Corridor

As detailed in previous sections of this chapter, the Turnpike has installed a number of field devices along the Mainline Turnpike; two TMCs have been brought on line as well. As detailed in Figure 23, there are two northbound DMS and two HAR transmitters in the contra flow section between Fort Pierce and the Osceola Parkway.
Figure 23. DMS and HAR Locations
Different measures have been taken to ensure that power and communications will be available in this remote portion of the Mainline Turnpike for these critical contra flow operations. For example, the DMS have been outfitted to allow power delivery from gas-powered generators, and the DMS will also accommodate remote communications through cellular modems. These measures allow remote power and communications should the “normal” means become unusable.

Because only limited information can be placed on the DMS for safety and readability, detailed scripts for one way operations have been developed for broadcast on the HARs in the contra flow corridor. A sample script is given below:

Due to the emergency storm evacuation of Hurricane [name], Florida's Turnpike will suspend tolls and operate as a one way northbound evacuation route as of [time and date].

All southbound traffic movement from the I-4 interchange (milepost 259) to the St. Lucie Interchange (milepost 142) is suspended until further notice due to the large-scale evacuation of South Florida from the impending hurricane’s landfall. The Turnpike mainline south of the St. Lucie Interchange will continue to be open for south- and north- bound motorists.

Evacuating northbound motorists can expect to be shifted to southbound lanes at the Fort Pierce interchange (Milepost 152). Traffic in all lanes will be able to enter the service plazas in the northbound-only section only for refueling and using restrooms. Traffic in all lanes will be able to exit the Turnpike at all interchanges within the route, but re-entry will not be possible.

Motorists are urged to drive with caution and to adhere to all posted traffic signs. Motorists who experience vehicle troubles are asked to move their vehicles onto the shoulder area as far as possible from the travel way. Emergency motorist aid call boxes are available at one-mile intervals, and the Florida Highway Patrol can be reached by dialing *FHP from a cellular telephone. Motorists will also see Florida Highway Patrol and Florida Nation Guard personnel staged periodically along the route.

In order to help alleviate congestion, motorists continue to tune to Turnpike information radios, located at 1640 on their AM dial, for updated information and instructions.
The discussions in this chapter create the foundation of current ITS and contra flow operations in the described test corridor. As will be discussed in the next chapter, system gaps will be identified in various process and information flows. Once these gaps are identified, they can then be addressed to maximize the ITS effectiveness and efficiency for contra flow operations and emergency response. An expected result from such improved processes and information flows is that “normal” traffic operations will improve as well.
Chapter 5

Identification of System Gaps for Maximum Roadway Operational Effectiveness and Efficiency in Contra Flow Corridor

5.1 Analysis of Contra Flow Operations for Hurricane Evacuation and Emergency Response

This section provides an overview of previously performed studies of contra flow operations.

5.1.1 Introduction

Florida’s largest hurricane evacuation occurred in September 1999 as a result of Hurricane Floyd. While the evacuees were able to leave their homes without harm from the storm that ultimately missed the Florida peninsula, they spent untold hours on Florida’s congested roadways. As a result, questions regarding reverse-laning of roadways were raised. A traffic management team was appointed in 1999 to identify routes that might be utilized in a contra flow condition, and Florida’s Mainline Turnpike was named as one such corridor within the state. Florida’s Turnpike Enterprise proceeded to develop a contra flow plan that resulted in the detailed plan presented in Chapter 4, with a 99-mile one way corridor being named as that rural portion of the Mainline Turnpike between Fort Pierce / State Road 70 and Osceola Parkway. While the contra flow plan has not been implemented to date, it has undergone continual evaluation
and refinement to address design and operational issues relative to roadway geometry, law enforcement issues, resource availability, and evolving evacuation behavior trends.

As a result of the events of September 11, 2001, public agencies have also realized that evacuation plans needed to be prepared for other types of emergency response, both natural and human-caused. These new scenarios could also necessitate major urban area evacuations and the implementation of contra flow plans outside the original arena of hurricane evacuations.

5.1.2 Contra Flow Analysis

Based upon statewide evacuation traffic modeling, behavioral analyses, and traffic studies, South Florida evacuation traffic volumes of 171,000 vehicles were determined to try to use the northbound Mainline Turnpike for a Category 4 or 5 hurricane. The origins of the traffic are determined as shown in Table 7:

Table 7. Evacuation Traffic Origins Entering Mainline Turnpike One Way Corridor

<table>
<thead>
<tr>
<th>County / Feeder Route</th>
<th>Entering Evacuation Traffic Volume (vehicles)</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monroe</td>
<td>10,000</td>
<td>6</td>
</tr>
<tr>
<td>Miami-Dade</td>
<td>72,000</td>
<td>42</td>
</tr>
<tr>
<td>Broward</td>
<td>28,000</td>
<td>16</td>
</tr>
<tr>
<td>Palm Beach</td>
<td>22,000</td>
<td>13</td>
</tr>
<tr>
<td>Martin</td>
<td>11,000</td>
<td>7</td>
</tr>
<tr>
<td>St. Lucie / SR 70</td>
<td>7000</td>
<td>4</td>
</tr>
<tr>
<td>Indian River / SR 60</td>
<td>6000</td>
<td>3</td>
</tr>
<tr>
<td>I-95 via SR 70</td>
<td>15,000</td>
<td>9</td>
</tr>
<tr>
<td>Total</td>
<td>171,000 vehicles</td>
<td>100%</td>
</tr>
</tbody>
</table>

During the course of a normal day, this total number of vehicles can be accommodated on the existing roadway. However, the magnitude of traffic volumes approaching 171,000 vehicles that will occupy three discrete sections of the Mainline
Turnpike in a rapid-loading scenario; i.e., the four-lane “normal” section prior to the contra flow corridor south of MP 153, the four-lane section of the one way corridor with its associated transitions at both ends, and the four-lane “normal” section that resumes at MP 252, make it difficult to thoroughly quantify or qualify the overall queuing, levels-of-service, or operational conditions along the Mainline Turnpike.

5.1.2.1 Anticipated Bottlenecks

As shown previously in Table 7, 64% of vehicles will come from Monroe, Miami-Dade, and Broward Counties. Adding Palm Beach and Martin County traffic, 84% of total entering volumes have to traverse the “normal” Mainline Turnpike before it ever approaches the contra flow section. This area of the Mainline Turnpike is three lanes per direction up to MP 81, and two lanes per direction through the contra flow section into the Central Florida area. There are plans to widen portions of the four-lane section to six lanes. In a rapid-loading evacuation scenario, widening will serve to smooth operations and get the vehicles to the one way corridor more quickly. Table 8 gives some examples of approach times for the entire volume of 171,000 vehicles and a lane capacity of 1500 vehicles per hour per lane (vphpl) with different roadway cross sections preceding the contra flow section. The approach time is roughly calculated as total number of vehicles divided by the total lane capacity in hours (h).
Table 8. Contra Flow Corridor Approach Times

<table>
<thead>
<tr>
<th>Northbound Lanes</th>
<th>Number of Vehicles Added</th>
<th>Total Lane Capacity (vph)</th>
<th>Approach Time (h)</th>
<th>Cumulative Approach Time (h)</th>
<th>End MP</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>110,000*</td>
<td>4500</td>
<td>24.4</td>
<td>24.4</td>
<td>81</td>
</tr>
<tr>
<td>2</td>
<td>33,000**</td>
<td>3000</td>
<td>11</td>
<td>35.4</td>
<td>140</td>
</tr>
<tr>
<td>2</td>
<td>28,000***</td>
<td>3000</td>
<td>9.3</td>
<td>44.7</td>
<td>154</td>
</tr>
<tr>
<td>Totals</td>
<td>171,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Monroe, Miami-Dade, and Broward County Traffic  
** Palm Beach and Martin County Traffic  
*** Remaining Entering Traffic

Because of high traffic volumes, reduced operating speeds, and the unusual nature of lane changes that accompany the northbound roadway transitions through the “normal” roadway and approaching the transition to a one way roadway, the traffic backups and delays along the route and at MP 153 will be significant.

5.1.2.2 Vehicle Throughput

Using derived data, Table 9 provides information regarding clearance times and commute times with the underlying assumption that vehicles would have sufficient time to reach the contra flow section. Clearance times required to process worst-case travel demand were calculated with and without the one way operation, and with the one way operation in place, reverse laning was considered for no more than 12 to 24 hours.
<table>
<thead>
<tr>
<th>Category 4-5 Storm</th>
<th>SFL Evac (h)</th>
<th>All Counties (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clearance Time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rapid Loading</td>
<td>43.5 / 26.5</td>
<td>66.25 / 40</td>
</tr>
<tr>
<td>Medium Loading</td>
<td>43.5 / 28.5</td>
<td>66 / 42.5</td>
</tr>
<tr>
<td>Long Loading</td>
<td>44.5 / 29</td>
<td>67 / 43.5</td>
</tr>
<tr>
<td>Commute Time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rapid Loading</td>
<td>37 / 19</td>
<td>59 / 35</td>
</tr>
<tr>
<td>Medium Loading</td>
<td>34 / 17</td>
<td>56 / 33</td>
</tr>
<tr>
<td>Long Loading</td>
<td>32 / 16</td>
<td>54 / 31</td>
</tr>
</tbody>
</table>

The contra flow operation is therefore assumed to save 15 to 17 hours for a South Florida evacuation and 23.5 to 26.25 hours for an all-county evacuation of corridor clearance time, and 16 to 18 hours for a South Florida evacuation and 23 to 24 hours for an all-county evacuation of corridor commute time by processing an additional 2000 vehicles per hour over a normal operation. It is important to note that even using loading times of four to five hours and a total clearance time upwards of 40 hours, the human behavioral element is not accounted for. There is no presumption of incidents, breakdowns, crashes, etc., nor is there any evaluation of vehicles other than passenger cars. Human behavioral elements can and will negatively impact clearance and commute times.

5.2 Traffic Management Strategies for Contra Flow Operations

Traffic management strategies will allow motorists to approach and traverse the contra flow corridor more effectively and efficiently. They focus on two main issues: spreading the traffic volumes entering Mainline Turnpike over the entire southern system as much as possible, and encouraging motorists to exit the Mainline Turnpike prior to
reaching the Osceola Parkway at the contra flow corridor’s end. By adopting fundamental traffic management techniques, additional relief may be obtained.

5.2.1 Phased Geographic Evacuation

By spreading the overall traffic entering the Turnpike over multiple entry points, especially the evacuating traffic from Monroe, Miami-Dade, and Broward Counties, the worst case traffic volumes of 171,000 vehicles and their times to load onto the roadway System will be more effectively and efficiently managed.

The main way to accomplish a phased geographic evacuation is to encourage motorists, through various information outlets, to access the Turnpike at earlier or later times than the anticipated peak flow timeframes.

This information will be transmitted to the motorists through a variety of methods, particularly the Public Information Office and the media. However, ITS components in advance of and throughout the contra flow corridor will play a crucial role in transmitting real-time traffic information to people that have already started the evacuation process.

The TMC will play an integral role in receiving roadway status conditions, coordinating with intra- and inter- agency partners, and transmitting this information back to the motorist through the appropriate field devices. Given the large geographic impact of wide-scale evacuations, TMC communication and coordination with other entities is crucial. This is an opportunity for the Turnpike TMCs to work with other statewide TMCs in order to improve traffic conditions along the evacuation corridors.

After receiving real-time roadway status information, the TMC can work with its partners on how to address congested locations, dispatch needed resources, and divert or
delay motorists at particular interchanges as needed with the intention of keeping the roadway leading to the contra flow section clear. An example would be notification of an incident in advance of the contra flow section. The simplified process for the TMC would be as follows:

\begin{itemize}
\item \textit{Receive incident notification}
\item \textit{Coordinate with intra- and inter- agency partners to dispatch necessary resources}
\item \textit{Transmit information to motorists via DMS and HAR about delays, possible diversion routes, etc.}
\item \textit{Monitor roadway status through field communications, CCTV cameras, etc.}
\item \textit{Provide update information via DMS and HAR}
\item \textit{Remove update information from DMS and HAR when incident is cleared}
\end{itemize}

A second example would be notification of an incident within the actual contra flow section. The simplified process for the TMC would be similar to the one shown above for vehicles approaching the contra flow section, but the objective here would be to route evacuating vehicles off of the one way corridor onto alternative evacuation routes, prevent evacuees from being stranded on the roadway, and providing alternative sheltering options:

\begin{itemize}
\item \textit{Receive incident notification}
\item \textit{Coordinate with intra- and inter- agency partners to dispatch necessary resources}
\item \textit{Transmit information to motorists via DMS and HAR about diversions off of the contra flow corridor onto alternative routes, etc.}
\item \textit{Monitor roadway status through field communications, CCTV cameras, etc.}
\item \textit{Provide update information via DMS and HAR}
\item \textit{Remove update information from DMS and HAR when incident is cleared}
\end{itemize}
5.2.2 Phased Toll Suspensions

All Turnpike System facilities are tollways; that is, drivers pay a user fee to traverse the different corridors. During emergencies such as hurricane evacuations, tolls are suspended by the Governor’s Executive Order to minimize the impedance experienced as a result of toll collection. Rather than suspending all tolls along the 300+ mile Mainline Turnpike, a strategy that could assist in traffic management is the gradual suspension of tolls, starting in the south and going north, in order to control the volume of vehicles entering the Mainline Turnpike. Despite its availability as an evacuation corridor with and without the contra flow section, the presence of required toll collection will keep some drivers off of the Mainline Turnpike. Once the tolls are suspended, drivers that would not otherwise use the Mainline Turnpike would use this corridor to facilitate their evacuation. A south-to-north toll suspension implemented in response to traffic volumes and roadway conditions in concert with the Executive Order is analogous to ramp metering. Ramp metering controls entering traffic, keeping it from suddenly flooding the roadway, potentially causing major traffic congestion and an eventual breakdown of freeway operations.

ITS elements such as detection and information dissemination devices are critical to the success of a gradual toll suspension. Upon some pre-determined congestion threshold at on-ramp and mainline toll plazas, tolls could be suspended to increase traffic throughput. This information would be transmitted back to the TMC, and the TMC would use DMS and HAR to advise drivers of the changing roadway conditions. A simplified possible scenario for the TMC is as follows:
Monitor traffic conditions at toll plazas and obtain notification regarding congestion either through the use of CCTV or voice/data communications with toll plaza personnel

Transmit information to motorists via DMS and HAR about graduated toll suspensions

Monitor roadway status through field communications, CCTV cameras, etc.
Provide update information via DMS and HAR

5.2.3 Intra- and Inter-Agency Coordination

Intra- and inter-agency coordination is critical in the process of identifying the availability of evacuation shelters through the contra flow section and beyond. When available, motorists can be exited from the contra flow section in locations such as Yeehaw Junction/State Road 60 in the near-center of the one-way operation until such time as the shelters reach capacity. This will remove evacuating vehicles from the traffic stream and lessen the demand to some extent. Perhaps more importantly, it will facilitate return to the evacuated area after the storm has passed by allowing evacuees to return from points closer to home.

Motorists can be advised through the use of DMS and HAR that they can exit the Mainline Turnpike at intermediate locations within the contra flow corridor to seek shelter. As shelters reach capacity, this information should be broadcast as well until all remaining drivers access shelters and hotels in the Orlando region beyond the contra flow corridor’s northern terminus. A simplified possible scenario for the TMC is as follows:

Monitor traffic conditions along contra flow corridor and obtain shelter availability information from intra- and inter-agency partners
Transmit information to motorists via DMS and HAR about shelter availability, advising them of the need to advance northward as shelters reach capacity
Monitor roadway and shelter status through field communications, CCTV cameras, etc.
Provide update information via DMS and HAR

5.2.4 Traffic Condition Monitoring

Traffic must be monitored in service plazas; strategic but difficult decisions to close plaza entrances might need to be made due to potential queue spillovers from the plazas into downstream traffic. Motorists need to be advised of service plaza condition status since the plazas will be used for food purchase, refueling, bathroom breaks, etc. Minor repairs may also be available for a limited time to allow vehicles with small mechanical problems to be quickly repaired so that they can continue on their journey. Real-time information about service plaza conditions and service availability can be transmitted to the evacuees via DMS and HAR.

Traffic must also be monitored along the approaches and through the contra flow section for incidents, dispatch of emergency services, and congestion. TMC coordination with field personnel and monitoring of all available devices is critical to keep the contra flow operation functioning. Any type of incident, even without lane blockage, will cause some delay that will create a shock-wave effect on downstream traffic. Delays during a hurricane evacuation that leave drivers stranded at the onset of storm force winds could be deadly. Immediate action is needed to clear vehicles from the travel lanes and get traffic moving again as quickly as possible. Information must also be transmitted back throughout the corridor to advise of traffic conditions on the roadway ahead so that drivers can make reasonable, informed decisions about their progress. A simplified possible scenario for the TMC for incidents is as follows:
Monitor traffic conditions along contra flow corridor and obtain incident / traffic congestion information from intra- and inter-agency partners and available traffic monitoring devices

Transmit information to motorists via DMS and HAR about upstream conditions with information relative to delay and lane closures

Monitor roadway and shelter status through field communications, CCTV cameras, and traffic monitoring devices

Provide continual update information via DMS and HAR

The primary objective is to keep traffic moving smoothly to facilitate the evacuation and contra flow processes. Along the approaches to and within the contra flow corridor, congestion will naturally occur due to the heavy traffic volumes. However, incidents will cause severe delays and potentially deadly consequences if they are not cleared quickly. The TMC and associated ITS devices, as well as communications with field personnel, will play a critical role in smoothing the operations and keeping traffic flowing.

5.3 Safety Needs

There are two primary issue relative to safety for the contra flow corridor: keeping drivers using the southbound lanes as “express lanes” going northbound in a safe manner and preventing drivers from entering the Turnpike at interchanges with the intention of going southbound once the contra flow has been implemented.

Upon implementation of the contra flow plan, evacuees will only be allowed to go northbound once the southbound Turnpike has been completely cleared of all southbound traffic. To facilitate a safe, orderly northbound contra flow evacuation, pilot cars driven by law enforcement officers are needed to pace traffic. These pilot cars can be equipped with Automatic Vehicle Location (AVL) equipment that sends information about speeds
and vehicle location back to the TMC. The TMC can then coordinate with other partners by relaying position and speed information to chart the evacuation’s progress and plan for any upstream contingencies.

Equipping every responder vehicle (i.e. law enforcement, fire rescue, wreckers and tow trucks, transportation agency personnel) playing a role in the contra flow evacuation with AVL equipment will allow further monitoring of traffic flow rates. This strategy will also allow the TMC to communicate with the vehicle closest to an incident to facilitate the appropriate response and rescue disabled motorists to prevent them from being stranded on the roadway at the onset of storm force winds. Motorists may face being stranded as a result of accidents, running out of gas, mechanical failures, or becoming physically incapacitated. The stranded motorists will need emergency and other services. The ability to reach these motorists will be facilitated by AVL equipment and TMC monitoring.

Law enforcement personnel will be staged at interchanges and service plazas to prevent errant entry vehicles from heading southbound once the one way operation is implemented. To supplement FHP’s “All Clear” check of the roadway, prior to the start of the contra flow, ITS field devices can monitor northbound vehicle departures and provide verification that the corridor is ready for one way use.

During the actual operation, monitoring devices will be used to support law enforcement and transportation agency efforts to make the contra flow operation as safe and smooth as possible. When wind speeds reach 40 MPH, the law enforcement personnel will be pulled off the roadway to seek safe shelter for themselves. With motorists on the roadway potentially left to fend for themselves on a facility that is taking
them in the normally wrong direction, ITS field devices can provide monitoring and guidance. CCTV cameras will be used to track vehicle progress, and DMS and HAR can be used to provide up-to-date information as determined by the TMC.

5.4 Enterprise Initiatives

Florida’s Turnpike Enterprise has defined a new culture, with new vision, mission, and values reflecting the commitment to operate like a business in the public interest. This new management plan has committed to new strategies that address improvement projects, expansion projects, and investments in innovative technologies. The strategic plan is a bold new approach that requires the combined talents of the entire Enterprise Team. Two strategies are specific to the concept of contra flow operations for hurricane evacuation and emergency response.

5.4.1 Provide Innovative Customer Service

To continue providing outstanding service for all customers on the road, at the service plazas, and at state-of-the-art toll collection facilities, the Turnpike will evaluate new services and technologies to ensure customer value and promote expanded use of System facilities. Motorists expect a safe, efficient, and reliable travel experience, and the Turnpike will work to ensure that they are receiving premium service.

5.4.2 Deploy a Fiber Optic Network System-Wide

The full deployment of a system-wide fiber optic network would permit the integrated transmission of video, voice, and data across the Turnpike System. It would allow for efficient incident detection, traffic monitoring, quicker emergency response, and information dissemination, resulting in enhanced traffic operations and safety.
A number of specific long-term benefits are associated with this project. Video cameras would be used to monitor traffic flow. Existing ITS field devices would be transitioned to fiber communications. FHP dispatch would directly monitor the roadway to facilitate incident verification and response. Future data communications for other uses would be facilitated.

The backbone of this project is the installation of four conduits and one 96-fiber optic cable along the entire Turnpike System. The conduit infrastructure is large enough to house additional fiber optic cables to accommodate any future expansion. Other projects would be constructed concurrently to provide communications links to field devices, toll plazas, etc.

5.4.3 Relationships of ITS Deployment and Strategies to Enterprise Initiatives for Contra Flow and Emergency Response

Contra flow operations for hurricane evacuation and emergency response on a limited access facility qualify as an innovative way to enhance driver throughput on the existing roadway by nearly half and therefore provide an innovative way to provide improved customer service. The deployment of a system wide fiber optic network supports contra flow operations by allowing more ITS devices to be available for use, enhancing the TMC ability to detect, verify, and monitor traffic conditions and incidents and then disseminate the appropriate real-time information to the driver.

By making more technological tools available, human resources such as law enforcement, emergency responders, and repair / response personnel are freed from the detection, verification, and monitoring aspects of the hurricane evacuation. By its very nature, a contra flow operation requires more personnel when these technological tools
are not employed just to make sure that the newly created one way facility is flowing smoothly with no one trying to use it in its “normal” direction. The use of detection devices such as VDS and CCTV cameras in combination with the TMC and field information dissemination devices such as DMS and HAR can replace the human resources that would normally have served these functions. In turn, these human resources can go back to their missions of law enforcement, provision of emergency response, and assistance to disabled motorists. The ITS technologies bring a new tool to the toolbox for traffic flow monitoring and incident management that improve the efficiency and effectiveness of each facet of the operation. A contra flow operation for hurricane evacuation or emergency response is a critical time in which the drivers may be distracted by the pending disaster, the unusual roadway cross section presented to them by the reversed roadway elements, and the massive traffic volumes surrounding them. Human resources on the roadway can provide personal assistance to these motorists so they feel secure in the support they are being provided by the Intelligent Transportation System that is in place.

5.5 Improvements in Test Corridor Needed

The present-day status of ITS device and communications infrastructure deployment has not yet reached the level for which the scenario mentioned above can occur with a high level of reliability. The contra flow corridor between Fort Pierce / State Road 70 and Osceola Parkway does not yet contain the necessary fiber optic infrastructure to provide communications and support the detection and verification field equipment to allow a full reliance on technology during one way operations. The information dissemination devices are also limited in this corridor with two northbound
DMS and two HAR. The current-day deployment level of ITS infrastructure in the contra flow corridor limits the TMC ability to make full use of its Intelligent Transportation System. As deployment increases and expands to cover every mile of the Turnpike System, TMC operations will grow and evolve to support the model presented earlier.

5.5.1 Specific ITS Improvements

Despite the fact that widening provides the maximum increase in levels of service, transportation agencies have quickly realized that there are insufficient funds to simply widen roadway corridors and vehicular throughput. As such, there is a need to find alternative ways to handle traffic. Table 10 repeats the information provided in Chapter 3 of this thesis for comparative purposes:

Table 10. Roadway Capacities

<table>
<thead>
<tr>
<th>Facility Type</th>
<th>Lane Capacity (vphpl)</th>
<th>Total Capacity (vph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Interstate (2 Lanes)</td>
<td>1500</td>
<td>3000</td>
</tr>
<tr>
<td>3-Lane w/Contra flow</td>
<td>1300</td>
<td>3900</td>
</tr>
<tr>
<td>3-Lane w/Shoulder</td>
<td>1400</td>
<td>4200</td>
</tr>
<tr>
<td>One way Interstate Using 4 Lanes</td>
<td>1250</td>
<td>5000</td>
</tr>
</tbody>
</table>

With 1500 vehicles per hour per lane (vphpl), total roadway capacities improve from 3000 to 5000 in the contra flow scenario. This is less than the 6000 vph expected on a 4-lane interstate. An even greater reduction of vehicular throughput on a one way section must be expected because of traffic congestion, incidents, and the driver’s conditioned reluctance to drive on the “wrong” side of the roadway.
A gap analysis provides the basis for several specific ITS improvements needed approaching and within the contra flow corridor relative to the traffic management strategies detailed earlier in this chapter.

5.5.1.1 Phased Geographic Evacuation Enhancements

In order to assist in the implementation of an effective phased geographic evacuation, the TMC must have access to real-time roadway information. They can then review roadway status conditions, coordinate with intra- and inter-agency partners, and transmit this information back to the motorist through the appropriate field devices.

Full coverage of CCTV cameras and VDS for detection and monitoring is needed to review traffic conditions on a real-time basis. CCTV cameras need to be deployed to give full video coverage at a rough spacing of one camera per mile, and VDS need to be deployed on a spacing that is reliant upon the type of detection technology selected. In order to support the large bandwidth requirements created by such intensive video coverage, the only feasible communications alternative is fiber optic cable. Other communications media simply do not provide enough bandwidth for reasonable and usable video images, particularly given that over 200 cameras will be in use.

Fortunately, plans are in place to install the needed fiber optic cable. Phased over several years, a south-to-north progression of fiber optic cable installation is planned and programmed. As the fiber optic cable goes into place, the associated CCTV cameras and VDS equipment needs to be installed as well.

CCTV cameras and VDS only provide information with respect to monitoring and verification back to the TMC. The tools required to inform motorists need to be in place
as well. In order to manage the strategy to phase geographic evacuations, substantially more DMS and HAR are needed.

Ideally, one DMS and one HAR would be placed in advance of every interchange starting at the southernmost section of the Mainline Turnpike and heading north to the terminus of the roadway in Sumter County to maximize the information made available to motorists. However, this approach is not financially feasible for implementation. Given how closely some interchanges are spaced within South Florida, this approach would provide unnecessary overlap in the range of the devices, particularly the HAR that have a broadcast range of three to five miles.

As an alternative, supplemental northbound DMS and HAR can be placed in advance of major decision points and interchanges in the urbanized area south of the contra flow corridor. Within the contra flow section, this would mean placing supplemental northbound DMS at the YeeHaw Junction / State Road 60, Kissimmee – St. Cloud, and Osceola Parkway interchanges, the Fort Drum and Canoe Creek Service Plazas, and the Three Lakes Toll Plaza. There are already two HAR transmitters in the corridor at the service plazas, so additional HAR installation would be optional.

5.5.1.2 Phased Toll Suspension Enhancements

Real-time information is necessary for a successful phased toll suspension. For the most effective control of traffic volumes entering the Mainline Turnpike, all the partners in the emergency evacuation need to be aware of roadway conditions as they change and evolve. In order for the gradual toll suspension to be successful, field devices such as VDS and CCTV cameras for detection and monitoring and information dissemination devices such as DMS and HAR are needed.
As before, a significant barrier to the complete instrumentation of the corridor is the lack of fiber optic communications infrastructure. Following the approach taken for phased geographic suspensions and assuming that instrumentation is provided as described, the additional location for DMS and HAR would be at mainline toll plazas. The mainline toll plazas at Miami-Dade, Broward, and Palm Beach Counties in advance of the contra flow corridor are candidates for additional DMS and HAR. These devices were provided for the Three Lakes mainline toll plaza within the contra flow corridor in the previous section.

5.5.1.3 Intra- and Inter- Agency Coordination Enhancements

Intra- and inter-agency coordination is necessary to identify the availability of evacuation shelters through the contra flow section and beyond. Motorists will be advised of changing conditions via DMS and HAR; however, the partner agencies need to establish communication protocols to make their respective roles flow smoothly. The TMC can provide an important link for information sharing and exchange. As the non-emergency partners are responding to minor incidents and ensuring that all appropriate traffic control devices are functioning as planned, the emergency responders can deal with their particular areas of responsibility. Rather than requiring each partner to figure out with whom he should be communicating, the TMC can provide a single interface and point of contact for the different entities to communicate with one another. Some of the tools at the disposal of the TMC can be as simple as landline and cellular telephone and radios, or they can be as complex as traffic management software that provides command and control of all available ITS elements. ITS tools can effectively be used to bring the
different partners together and allow them to establish protocols and processes that enable them to individually continue to meet their primary objectives.

5.5.1.4 Traffic Condition Monitoring Enhancements

Traffic monitoring is an outcome of an integrated ITS. Instrumentation has been covered in previous sections; however, within the contra flow section, special attention must be paid to ensure that the CCTV cameras installed cover both sides of the roadway. Assuming that some technology of VDS was placed for both “normal” directions of traffic, the algorithms used to determine vehicles speeds, volumes, and occupancy could be altered to allow for the contra flow direction so that visual verification does not have to be the only method for monitoring.

Traffic must be continuously and thoroughly monitored along the approaches and through the contra flow section for incidents, dispatch of emergency services, and congestion. TMC coordination with field personnel and monitoring of all available devices is critical to keep the contra flow operation functioning effectively and efficiently. All incidents must be quickly resolved; time will be of the essence, as only a limited window of hours prior to storm landfall will exist. The shock waves produced by incidents that leave latent delays for miles and hours after an incident is cleared are unacceptable and must be immediately mitigated. The TMC plays a crucial role in receiving and disseminating this information and working with its partners to resolve incidents quickly.

These supplemental devices would allow the TMC to provide information to drivers to ultimately improve traffic conditions within the evacuation corridor. The
combination of the supplemental field devices and enhanced communications infrastructure will allow the TMC to address congested locations, dispatch needed resources, and divert or delay motorists at particular interchanges as needed with the objective of keeping the roadway leading to the contra flow section flowing as smoothly as possible.

5.6 Contra Flow Management and Operations

There are essentially two ways to define the time to close down contra flow: reduction of traffic volumes and the onset of storm force winds. However, given that 171,000 vehicles are expected to evacuate, Florida is most likely to only use the latter criterion. Evacuees need to be prevented from being stranded on the roadway after law enforcement personnel are removed from their stations, and agencies may have to send evacuees to “Shelters of Last Resort” for the most extreme of circumstances. Such buildings might not have facilities such as food, water, bathrooms, or supervision, and they are not even guaranteed to be safe. However, they provide a better option than staying on the roadway during a storm. ITS field devices such as DMS can identify the time for these shelters to be used, and the HAR can provide the directions to their locations to prevent the stranding of evacuees. Finally, ITS monitoring devices such as CCTV cameras and VDS can monitor roadway conditions to help ensure that all motorists have left the roadway to avoid pre-landfall hazardous conditions such as storm force winds and possible storm surge flooding.
5.7 Inter- and Intra-Agency Coordination

Because agencies will be able to share the most accurate, real-time information as collected and disseminated by the TMC, they will be better able to define and coordinate their individual roles in the contra flow. Jurisdictional and chain-of-command issues can be clarified and simplified because everyone can share in the same process and information flows. Communication can be improved because everyone will have access to the same data. ITS will not solve all inter- and intra-agency coordination issues, but it can serve to level the playing field and give all the partners equal access to accurate information. ITS will also allow the partners to identify and address weaknesses in existing contra flow plans, playing a crucial role in continuous improvement. ITS provides unique and innovative means to enhance contra flow operations.
Chapter 6

Recommendations and Conclusions

6.1 Summary

Coastal regions are increasingly vulnerable to hurricanes because of growing populations and development in coastal zones, rising ocean levels, coastal erosion, and changing climactic trends. The potential for loss of life and property in coastal regions only continues to rise. While more stringent building codes have been enacted to reduce the damage from winds and flooding, not all coastal residents can remain protected in their homes. States have therefore initiated studies and major evacuation plans that involve innovative elements such as contra flow evacuations to make the process as safe, effective, and efficient as possible. These contra flow plans, originally created for major (Category 4 or 5) hurricane evacuations, have been extended for other types of emergency responses given the terrorist attacks of September 11, 2001.

Based on records kept since 1900, there have been many hurricanes whose costs in lives and dollars have been devastating. Of the deadliest / costliest storms shown in Tables 11 and 12, Hurricane Floyd appears on both lists. Given the scope of Floyd’s evacuation, the numbers of deaths could have been significantly higher had Florida been hit and evacuees stranded in their cars. It is critical to have evacuation plans in place and states need to be prepared to address crushing evacuation traffic volumes.
Table 11. Deadliest Storms to Hit the United States

<table>
<thead>
<tr>
<th>Storm Name</th>
<th>Year</th>
<th>Category</th>
<th>Location of Strike</th>
<th>Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mitch</td>
<td>1998</td>
<td>5</td>
<td>Honduras, Nicaragua, Florida</td>
<td>10,000</td>
</tr>
<tr>
<td>Unnamed</td>
<td>1900</td>
<td>4</td>
<td>Texas</td>
<td>8000</td>
</tr>
<tr>
<td>Unnamed</td>
<td>1928</td>
<td>4</td>
<td>Florida</td>
<td>1836</td>
</tr>
<tr>
<td>Georges</td>
<td>1998</td>
<td>4</td>
<td>Dominican Republic, Haiti, Mississippi, Florida</td>
<td>602</td>
</tr>
<tr>
<td>Unnamed</td>
<td>1919</td>
<td>4</td>
<td>Florida</td>
<td>600</td>
</tr>
<tr>
<td>Unnamed</td>
<td>1938</td>
<td>3</td>
<td>New England</td>
<td>600</td>
</tr>
<tr>
<td>Unnamed</td>
<td>1935</td>
<td>5</td>
<td>Florida</td>
<td>408</td>
</tr>
<tr>
<td>Audrey</td>
<td>1957</td>
<td>4</td>
<td>Louisiana, Texas</td>
<td>390</td>
</tr>
<tr>
<td>Unnamed</td>
<td>1944</td>
<td>3</td>
<td>NE United States</td>
<td>390</td>
</tr>
<tr>
<td>Unnamed</td>
<td>1909</td>
<td>4</td>
<td>Louisiana</td>
<td>350</td>
</tr>
<tr>
<td>Floyd</td>
<td>1999</td>
<td>4</td>
<td>North Carolina</td>
<td>70</td>
</tr>
</tbody>
</table>

Table 12. Costliest Storms to Hit the United States

<table>
<thead>
<tr>
<th>Storm Name</th>
<th>Year</th>
<th>Category</th>
<th>Location of Strike</th>
<th>Cost ($B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andrew</td>
<td>1992</td>
<td>4</td>
<td>Florida, Louisiana</td>
<td>30.4</td>
</tr>
<tr>
<td>Hugo</td>
<td>1989</td>
<td>4</td>
<td>South Carolina</td>
<td>8.5</td>
</tr>
<tr>
<td>Agnes</td>
<td>1972</td>
<td>1</td>
<td>Florida, NE United States</td>
<td>7.5</td>
</tr>
<tr>
<td>Betsy</td>
<td>1965</td>
<td>3</td>
<td>Florida, Louisiana</td>
<td>7.4</td>
</tr>
<tr>
<td>Camille</td>
<td>1969</td>
<td>5</td>
<td>Mississippi, Louisiana, Virginia</td>
<td>6.09</td>
</tr>
<tr>
<td>Floyd</td>
<td>1999</td>
<td>4</td>
<td>North Carolina</td>
<td>6</td>
</tr>
<tr>
<td>Mitch</td>
<td>1998</td>
<td>5</td>
<td>Central America, Florida</td>
<td>5.5</td>
</tr>
<tr>
<td>Diane</td>
<td>1955</td>
<td>1</td>
<td>NE United States</td>
<td>4.8</td>
</tr>
<tr>
<td>Frederic</td>
<td>1979</td>
<td>3</td>
<td>Alabama, Mississippi</td>
<td>4.3</td>
</tr>
<tr>
<td>Unnamed</td>
<td>1938</td>
<td>3</td>
<td>New England</td>
<td>4.1</td>
</tr>
</tbody>
</table>

As transportation agencies became players in evacuation scenarios, rather than the nearly exclusive previous group of emergency management officials, they began to realize the need for increased evacuation route capacity, better systems for reliable exchange of up-to-date information about traffic conditions, and better planning and coordination across administrative, institutional, and geographic boundaries. All these areas are improved with the implementation of ITS. The challenge is to identify the
strategies that enhance ITS deployment and allow them to meet the specialized needs of hurricane evacuation and emergency response.

ITS allows access to timely and accurate traffic information, an element critical to the evacuation process. Information about traffic flow rates and speeds, incidents, weather conditions, etc., is needed to safely guide evacuees. In addition to detection and monitoring capabilities for the transportation agencies and their partners, ITS allows real-time information to be transmitted back to the motorist, closing the information loop and allowing all parties involved to play their roles in the evacuation process with accurate knowledge. Given the unique circumstances surrounding a contra flow operation, accurate knowledge is critical to the operation’s success which can only measured in terms of safety, effectiveness, and efficiency: were the motorists safely evacuated to their sheltering area before the onset of storm force winds and flooding?

6.2 Recommendations

Intelligent Transportation Systems allow the acquisition and processing of traffic flow information to control and reroute traffic and the making of decisions surrounding emergency events such as the termination of an evacuation. ITS also provides tools that can be used to inform the media and the public of current conditions through the use of hardware, software, communications, controls, and electronics in an integrated manner.

ITS combines smart transportation systems with operational efficiency and effectiveness. There is the creation of public value and interagency collaborative ability. The public wants safe and efficient transportation systems, and ITS helps to attain this safety goal. ITS also helps to achieve high-quality operating systems, joint problem solving, and management of strategically sequenced processes. ITS is a set of tools that
involves electronic systems designed to automate data collection, data analysis, device control, and information sharing in order to improve transportation operations.

As transportation agencies plan for and implement Intelligent Transportation Systems, they need to be proactive, diligent, and clever as they build “smart” corridors, traffic management centers, and incident management programs in order to realize the benefits that ITS can bring. Transportation agencies have traditionally had the mission of building highways. Operation of transportation systems to achieve the greatest benefits is an evolved version of the mission, and ITS tools are integral components of this mission. Florida’s Turnpike Enterprise is putting the tools in place to realize and provide for this operations mission through funding and programming ITS projects in its Work Program.

While important next steps are to identify ITS instrumentation gaps, prioritize projects, and seek additional funding for implementation, this process will be expensive and time consuming. Because full instrumentation may not occur for years, operational concepts that look forward to an ultimate migration to ITS dependency are important to the success of an evolving, ITS-enhanced contra flow plan.

For example, the current ending of the contra flow operation is less than optimal, with four lanes of contra flow traffic reducing back to two normal northbound lanes at Osceola Parkway / MP 252 in Central Florida. Potential bottlenecks can be addressed by extending the contra flow corridor north to one of the major limited access corridors in Central Florida. Extensions can be implemented in order to alleviate traffic tie-ups at the existing northern crossover. The contra flow plan also needs to be consistent with local sheltering plans as they change. Driver information regarding public shelter, hotel, and motel availability must be provided as drivers make travel decisions at the north end of
the contra flow corridor. The TMC can get input from the field, and ITS field devices such as DMS and HAR are ideal for transmitting this information back to the public.

Another example is the implementation of a mobile Traffic Management Vehicle (TMV) concept. A mobile TMV, utilizing a box truck body, would be equipped with a mast-mounted wireless camera and a rear-mounted DMS, as well as other incident management equipment. The unit would be deployed on the Turnpike System in areas where there are no permanent ITS devices or to pre-determined areas of routine congestion, special-event traffic, and holiday traffic. The vehicles would provide the TMC the ability to post messages on the portable DMS units and offer pertinent operations and incident video monitoring data that would otherwise be unavailable. Dispatching the mobile units to previously identified high volume locations would also facilitate more accurate and timely use of the existing DMS and HAR. TMV deployment in the contra flow corridor for hurricane evacuation and emergency response is an excellent innovative step in the migration to full ITS instrumentation.

TMVs and other similar interim measures would augment the effective use and support ITS operations by providing real-time traffic information to Turnpike customers and to the permanent TMC for database entry and logging. In the contra flow operation, the TMV would provide staff the capability to monitor routine roadway system information within the corridor, visually verify and manage traffic incidents, and control field devices within an operational environment.

Because the new focus is managing the existing transportation system rather than building new infrastructure, agencies have begun to change their traditional thinking in terms of becoming more responsive to incidents that are evaluated through the
establishment of benchmarks and performance measures. ITS is an important tool in the effort to develop cooperative processes between transportation agencies, emergency management and law enforcement staff, weather services, and other partners. Interagency communications issues such as jurisdiction and legal authority, chain of command, data and resource sharing, compatible communications, role and responsibility clarification need to be addressed. Processes and protocols using ITS can be developed to make the management of contra flow operations as smooth as possible.

6.3 Conclusions

There are programmatic themes of applying technology to the problems and priorities of transportation: development of integrated transportation information networks, crash and incident detection, notification and response, and advanced transportation management. These themes comprise the traditional pursuit of Intelligent Transportation Systems. There are also enabling themes that allow for the application of technology to transportation: creation of a systems management and operations culture, public sector roles, relationships, and funding, and human factors. The latter theme category is the one within which the truly complex issues may be found; technical issues can be solved rather easily, but the social, institutional, and political factors are more difficult to resolve.

ITS offers opportunities to enhance transportation system operations, improve quality of life, and increase user satisfaction. Some goals relative to these enhancements are as follows:
Safety – Reduction in transportation-related fatalities

Security – Develop a well-protected transportation system against attacks; develop effective responses to natural and manmade threats and disasters to enable continued movement of people and goods

Efficiency and Economy – Save transportation dollars by enhancing throughput and capacity through better information, system management and congestion containment

Mobility and Access – Make information universally available to support seamless end-to-end travel choices

Energy and Environmental Preservation – Save billions of gallons of gasoline every year and reduce emissions proportionately through reductions in traffic congestion and incidents

This thesis described a number of issues relative to the implementation and operation of a contra flow corridor, and it then discussed how ITS strategies could integrate different technologies to address the concerns. The Turnpike’s 99-mile contra flow corridor was used to demonstrate that the concepts presented in earlier thesis chapters could be expanded to other emergency response settings through enhanced roadway instrumentation. These issues focused primarily on safety and roadway operations during the set-up, use, and break-down of the one way operation.

The safety issues relative to initial normal-direction roadway clearance and then maintenance of a moving, albeit slowly, traffic stream can be addressed by the migration to a fully instrumented roadway corridor. As the ability to detect and monitor the contra flow corridor and its approaches grows through growing use of CCTV cameras and various detection technologies, motorists will realize safety benefits as their driving needs are more quickly handled. The motorists themselves will be empowered to make better driving decisions as they receive real-time traffic condition updates from the DMS and HAR. At the same time, special operational issues created by the influx of thousands of
vehicles within a short time onto a roadway with limited capacity can be monitored and responded to as well. By working closely with intra- and inter-agency partners, the Traffic Management Centers can use the ITS field devices to better respond to changing conditions as they work to improve communications and adjust protocols to improve the contra flow operations.

Real-time traffic management is at the heart of a customer-focused organization. By actively pursing technology solutions to traffic management problems and applying those solutions to address administrative, institutional, and political issues, Florida’s Turnpike Enterprise can provide the enhanced convenience and service demanded by a traveling public that expects premium service in exchange for the toll that is paid.

Evacuation orders are an urgent and sensitive event, and contra flow is politically charged. ITS can provide real-time accurate traffic conditions for the best decision making possible, striving to eliminate some of the political posturing that occurs during any emergency event and allowing the decision making process to be objective rather than subjective. Even if the political machine takes off, ITS can allow the business of traffic management to remain independent and neutral in the face of outside pressures.

While the contra flow scenario has not been tested in “real life,” the modeling and continuous improvement of the contra flow plan allows transportation agencies and their partners to remain optimistic that this intense, critical operation can be successful. There is a new perspective and focus on traffic management operations, based not only upon weather-triggered events. Interagency communications, resource sharing, and partnering are vital to achieve shorter duration times for contra flow implementation and maximize the hours available for the actual contra flow operation. Success will depend upon and be
measured by contributions from people throughout the Turnpike organization as well as the Turnpike’s inter-agency partners. Intelligent Transportation System deployment and operational strategies will provide for safe, effective, and efficient contra flow operations for hurricane evacuation and emergency response, and they will also promote motorist safety and mobility through the combined use of people and technologies.
References


Bibliography


Appendix
### Appendix A: Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATIS</td>
<td>Advanced Traveler Information System</td>
</tr>
<tr>
<td>AVL</td>
<td>Automatic Vehicle Location</td>
</tr>
<tr>
<td>CCTV</td>
<td>Closed Circuit Television</td>
</tr>
<tr>
<td>CITRIS</td>
<td>Mid-Florida ITS Consortium</td>
</tr>
<tr>
<td>DMS</td>
<td>Dynamic Message Sign</td>
</tr>
<tr>
<td>ECC</td>
<td>Emergency Communications Center</td>
</tr>
<tr>
<td>EEOC</td>
<td>Enterprise Emergency Operations Center</td>
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<tr>
<td>EOC</td>
<td>Emergency Operations Center</td>
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<tr>
<td>ETC</td>
<td>Electronic Toll Collection</td>
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<tr>
<td>FCC</td>
<td>Federal Communication Commission</td>
</tr>
<tr>
<td>FDOT</td>
<td>Florida Department of Transportation</td>
</tr>
<tr>
<td>FHP</td>
<td>Florida Highway Patrol</td>
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<tr>
<td>FIHS</td>
<td>Florida Intra-State Highway System</td>
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<td>FIU</td>
<td>Florida International University</td>
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<tr>
<td>FOC</td>
<td>Fiber Optic Cable</td>
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<tr>
<td>HAR</td>
<td>Highway Advisory Radio</td>
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<tr>
<td>ITS</td>
<td>Intelligent Transportation System</td>
</tr>
<tr>
<td>LOS</td>
<td>Level of Service</td>
</tr>
<tr>
<td>MP</td>
<td>Milepost</td>
</tr>
<tr>
<td>PIO</td>
<td>Public Information Office</td>
</tr>
<tr>
<td>PRR</td>
<td>Portable Roadside Reader</td>
</tr>
<tr>
<td>PTZ</td>
<td>Pan, Tilt, Zoom</td>
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Appendix A: (Continued)

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tr>
<td>TMC</td>
<td>Traffic Management Center</td>
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<tr>
<td>TMV</td>
<td>Traffic Management Vehicle</td>
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<tr>
<td>VDS</td>
<td>Vehicle Detection System</td>
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