Best Practices in the Use of Hybrid Static-Dynamic Signs

Final Report

Contract No. BDK80 977-15

December 2012

Prepared by:

Lehman Center for Transportation Research
Florida International University

In collaboration with:

Research Center
Florida Department of Transportation

Final Report

Contract No. BDK80 977-15

Best Practices in the Use of Hybrid Static-Dynamic Signs

Prepared by:

Albert Gan, Ph.D., Professor
Dibakar Saha, M.S., Graduate Research Assistant
Kirolos Haleem, Ph.D., Research Associate
Priyanka Alluri, Ph.D., Research Associate
Dennis McCarthy, Ph.D., Assistant Professor

Lehman Center for Transportation Research
Florida International University
10555 West Flagler Street, EC 3680
Miami, FL 33174
Phone: (305) 348-3116
Fax: (305) 348-2802
E-mail: gana@fiu.edu

in cooperation with

Research Center
State of Florida Department of Transportation
605 Suwannee Street, M.S. 30
Tallahassee, FL 32399-0450

December 2012

DISCLAIMER

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the State of Florida Department of Transportation.

METRIC CONVERSION CHART

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
NOTE: volumes greater than 1000 L shall be shown in m^3				

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Best Practices in the Use of Hybrid Static-Dynamic Signs		5. Report Date December 2012 6. Performing Organization Code
7. Author(s) Albert Gan, Dibakar Saha, Kirolos Haleem, Priyanka Alluri, Dennis McCarthy		8. Performing Organization Report No.
9. Performing Organization Name and Address Lehman Center for Transportation Research Florida International University 10555 West Flagler Street, EC 3680, Miami, FL 33174		10. Work Unit No. (TRAIS) 11. Contract or Grant No. BDK80 977-15
12. Sponsoring Agency Name and Address Research Center State of Florida Department of Transportation 605 Suwannee Street, M.S. 30, Tallahassee, Florida 32399-0450		13. Type of Report and Period Covered Draft Final Report March 2011 - December 2012 14. Sponsoring Agency Code 99700-3596-119

15. Supplementary Notes
Mr. Jacques Defrant, P.E., of the Florida Department of Transportation (FDOT) District 4 succeeded Mr. Felix Delgado, P.E., formerly also of FDOT District 4, as the Project Manager for this project.

16. Abstract

Static signs are traditionally used to convey messages to the road users. The need to quickly communicate up-to-date messages to the road users has given rise to the increasing use of dynamic message signs (DMS). An alternative to DMS is hybrid signs, which display both static and dynamic messages on a single sign. A hybrid sign consists of a conventional retroreflective static sign that is embedded with one or more relatively small, dynamic, usually light emitting diode (LED) message panels. Potential advantages of hybrid signs over DMS include better legibility, shorter reading time, smaller size, and lower installation, operation, and maintenance costs.

This report first provides a comprehensive state-of-the-practice review of existing hybrid sign applications in both the U.S. and around the world. The review focused on several application areas, including speed control, parking guidance, travel time and travel distance information, dynamic rerouting information, and graphical route information. Further, it also identifies the companies that manufacture and market hybrid signs in the U.S. It was found that only a small number of sign manufactures have hybrid sign products for applications other than variable speed limit signs.

This report then describes an effort to identify potential hybrid sign applications on both freeways and arterials and evaluate them through a focus group study. A total of ten hybrid sign applications were selected and evaluated in terms of their usefulness, understandability, and preference for different sign designs. In total, ten focus groups involving 150 participants of different age, gender, and ethnic groups were conducted. For each application, the participants' responses were analyzed by age group, gender, and education level, and when applicable, by frequency of using toll roads and public transit service. The participants found parking availability information, arrival time information at bus/train stops, comparative travel times for express lane facilities, drawbridge opening, and travel times on distance signs to be particularly useful. However, bus/train arrival time information and drawbridge opening applications, along with other similar countdown applications, were found to have the following two main limitations: their deployment might create confusion when the dynamic information is not present and the signs could potentially encourage speeding.

17. Key Words	18. Distribution Statement
Hybrid static-dynamic signs, state-of-the-practice review, focus groups, hybrid sign applications.	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	247	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

ACKNOWLEDGEMENTS

This research was funded by the Research Center of the Florida Department of Transportation (FDOT) under the direction of Mr. Darryll Dockstader. The authors are grateful to their project managers, Mr. Jacques Defrant, P.E., of FDOT District 4, and Mr. Felix Delgado, P.E., formerly also of the FDOT District 4, for their guidance and support throughout the project.

The authors would like to thank the following graduate students from Florida International University (FIU) for their assistance in identifying potential hybrid sign applications:

- Mr. Erik Echezabal
- Mr. Marco Lux
- Mr. Joseph Mercel

The authors are also thankful to the following student assistants from FIU who assisted in conducting the focus group meetings and compiling the study results:

- Ms. Fiona Maldonado
- Ms. Katrina Meneses
- Ms. Stephanie Miranda
- Ms. Elizabeth Perez
- Ms. Anita Pourji

The contribution from the 150 focus group study participants is gratefully acknowledged. Last but certainly not the least, the authors would like to thank Ms. Vicki Morrison of the FDOT Research Center for her editing of this report.

EXECUTIVE SUMMARY

The main purpose of this project is to study the potential use of hybrid static-dynamic signs (or hybrid signs). A hybrid sign consists of a conventional retro-reflective static sign that is embedded with one or more relatively small, dynamic, usually light emitting diode (LED) message panels. These signs have several advantages over traditional dynamic message signs (DMS), making them more appealing for potential deployment. Some of the advantages of hybrid signs include better legibility, smaller size, and lower costs in installation and maintenance. Because of their smaller size, they may be suitable not only on freeways, but also on arterial streets. Accordingly, one major objective of this project is to identify and evaluate potential applications of hybrid signs on both freeways and arterial streets. A focus group study was conducted to assess the usefulness of potential hybrid sign applications, and the understanding of, and preference for, specific hybrid sign designs by the road users.

As part of this project, an extensive state-of-the-practice review on the use and design of existing hybrid signs was conducted. Given that the use of hybrid signs is only emerging in the U.S., the review covered hybrid sign applications in both the U.S. and around the world, including Europe, Australia, and Asia. The application areas included speed control, parking guidance, travel time and travel distance information, dynamic rerouting information, and graphical route information. In addition to the literature search, a review of the companies that manufacture and market hybrid signs in the U.S. was conducted. It was found that only a small number of sign manufactures have hybrid sign products for applications other than variable speed limit or speed feedback signs.

A major effort of the project was to identify potential hybrid sign applications on both freeways and arterials and evaluate them through focus groups. In total, 10 focus group meetings involving 150 participants of different age, gender, and ethnic groups were conducted. A total of 10 hybrid sign applications were selected and evaluated in terms of their usefulness, understandability, and preference for different sign designs. The 10 applications were grouped into the following four categories:

1. Countdown applications:
   - Drawbridge opening
   - School zone traffic diversion
   - Traffic diversion to avoid train crossing
   - Arrival time information at bus/train stops
   - Train arrival time information on freeways

2. Travel time information applications:
   - Travel times on distance signs
   - Comparative travel times for express lane facilities

3. Speed control applications:
   - Automated speed control
   - Advisory progression speed

4. Other application:
    - Parking availability information

The drawbridge opening application is intended to improve safety of pedestrians and bicyclists on drawbridges; school zone traffic diversion and traffic diversion to avoid train crossing are intended to improve mobility and safety on arterial streets; arrival time information at bus/train stops is to serve transit riders; and train arrival information is to serve freeway drivers who would like to take a train. Travel time applications provide travel time information to major destinations/exits on freeways. Speed control applications are geared toward monitoring speeding and improving safety and mobility on arterial streets. Finally, parking availability information signs provide real-time information on parking availability in garages and on specific floors of each garage.

The focus group study results showed that a higher percentage of older participants (age 65+) rated the applications as very useful, followed by middle age participants (age 25-64) and younger participants (age 18-24), respectively. Similar to older participants, participants with high school education were found to be more receptive to the applications in general. Furthermore, females were slightly more supportive of the applications compared to males.

Overall, the participants found parking availability information, arrival time information at bus/train stops, comparative travel times for express lane facilities, drawbridge opening, and travel times on distance signs to be particularly useful. A relatively high percentage of participants rated the application to display the advisory progression speed on arterials as not useful. Participants identified two major concerns with this application: drivers might not be able to differentiate between the advisory speed sign and the posted speed limit sign, and the hybrid sign might be frustrating at times when only a few drivers understand the sign.

The five countdown applications are designed such that the dynamic countdown timer is embedded in the static sign to countdown to a particular event, for example, to a bridge opening, bus/train arrival time, etc. These countdown applications have two main limitations that are difficult to overcome. First, these signs can be confusing when the dynamic information is not present. The focus group study results showed that participants had different and inconsistent interpretations when dynamic panels in the hybrid signs are blank or show dashes. Second, as noted by several participants, these hybrid signs with countdown times might encourage speeding to beat the countdown time. In summary, even though a majority of participants rated the countdown applications as very useful, their deployment might create confusion when the dynamic information is not present and could potentially encourage speeding.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS/ABBREVIATIONS

AC	Alternating Current
ADOT	Arizona Department of Transportation
ARRB	Australian Road Research Board
ATMS	Advanced Traffic Management System
CALTRANS	California Department of Transportation
CATS	Center for Advanced Transportation Technology
CEDR	Conference of European Directors of Roads
CDOT	Colorado Department of Transportation
CMS	Changeable Message Signs
dIRA (in German)	Dynamic Information Boards for Displaying Travel Times
DDMS	Dedicated Dynamic Message Signs
DMS	Dynamic Message Signs
DOT	Department of Transportation
DSDS	Dynamic Speed Display Signs
ERP	Electronic Road Pricing
FDOT	Florida Department of Transportation
FHWA	Federal Highway Administration
FIU	Florida International University
GDOT	Georgia Department of Transportation
GRIP	Graphical Route Information Panels
HOT	High Occupancy Toll
HOV	High Occupancy Vehicles
HSORTA	Hessian State Office for Road and Traffic Affairs
ICF	Informed Consent Form
IDOT	Illinois Department of Transportation
INDOT	Indiana Department of Transportation
INFORM	Information for Motorists
ITS	Intelligent Transportation Systems
LED	Light Emitting Diode
LOS	Level of Service
MPH	Miles per Hour
MUTCD	Manual on Uniform Traffic Control Devices
NSP	Northern State Parkway
NYSDOT	New York State Department of Transportation
ODOT	Ohio Department of Transportation
PGS	Parking Guidance System
SANDAG	San Diego Association of Governments
SMDS	Speed Monitoring Display Signs
SOV	Single Occupant Vehicles
SR	State Road
TIS	Traffic Information System
TTI	Texas Transportation Institute
TxDOT	Texas Department of Transportation
UAE	United Arab Emirates

UDOT	Utah Department of Transportation
UK	United Kingdom
US	United States
USA	United States of America
VDOT	Virginia Department of Transportation
VMS	Variable Message Signs
VSL	Variable Speed Limit
WMATA	Washington Metropolitan Area Transportation Authority
WSDOT	Washington State Department of Transportation

CHAPTER 1
INTRODUCTION

1.1 Background

The Florida Department of Transportation (FDOT) has deployed overhead dynamic message signs (DMS) on freeways throughout the state. These DMS are used to communicate important, up-to-date messages to drivers in real time. Priorities for displaying messages on these DMS are usually given to those related to traffic incidents, construction notices and warnings, route diversion, amber/silver alerts, and special events. When such messages are not on display, the practice has been to display travel times and distances to specific freeway locations, usually an interchange.

While travel times are considered a low priority for display on overhead DMS, they are nonetheless useful information for drivers. Currently, travel times are not displayed when a message with a higher priority, such as for an AMBER alert or a warning about a future road closure, is in effect. While the SunGuide Software, an advanced traffic management system (ATMS) that allows FDOT to monitor traffic conditions, does not currently provide accurate travel times under incident conditions, there have been efforts to develop algorithms that will predict incident durations, thus making travel times available during these conditions. However, overhead DMS will not be available to display such travel times as they will be used to display messages of higher priorities. This will create a situation in which travel times are not available when they are most needed, but are available only when traffic is free flowing and travel times are more predictable. Furthermore, it is also believed that reading messages on these traditional DMS may take longer time than reading from static signs, thus creating safety concerns.

An alternative to displaying travel times on traditional DMS is to have them displayed on "hybrid static-dynamic" signs. Also referred to as hybrid message signs (CATS, 2011), hybrid DMS (PB Americas et al., 2007) and dedicated DMS (Daktronics, 2011), hybrid signs, as they will be referred to hereafter, are conventional retroreflective static signs that are embedded with relatively small, dynamic, usually light emitting diode (LED) message panels (Chrysler and Nelson, 2009). The main advantages of hybrid signs over traditional DMS include better legibility, smaller size, and lower costs of installation and maintenance (PB Americas et al., 2007; Jenkins, 2011).

The most frequent implementation of hybrid signs in the United States (U.S.) has been for variable speed limit applications. These signs are usually deployed at work zones where speed limits are set temporarily and may need to vary with the changing work zone conditions. Other applications in which hybrid signs have increasingly been used in the U.S. include mainly travel time and tolling information on managed lanes. Internationally, hybrid signs have been deployed for many years for various applications. Because these signs are smaller and cost less to install and maintain, they may also be suitable for use on major local streets.

1.2 Project Objectives

The main purpose of this project is to study the potential use of hybrid static-dynamic signs on both freeways and arterial streets. The specific objectives include the following:

1. Review existing practices in the use of hybrid signs and the companies that manufacture and market them.
2. Identify potential applications of hybrid signs on both freeways and arterial streets.
3. Identify potential locations in FDOT District 4 where hybrid sign applications may be deployed.
4. Conduct focus group study to assess the usefulness of potential hybrid sign applications, and the understanding of, and preference for, specific hybrid sign designs by the road users.

1.3 Report Organization

The rest of the report is organized as follows. Chapter 2 covers a comprehensive review on existing applications of hybrid signs in both the U.S. and around the world. The companies in the U.S. that currently manufacture hybrid signs are identified and a summary on their products is provided. Chapter 3 describes the process of recruiting participants for the focus group study and the demographic characteristics of the study participants. Chapter 4 describes 10 select hybrid sign applications and summarizes the study results from the focus group study. Potential locations in FDOT District 4 for hybrid sign deployments for select applications, where applicable, are also identified. Finally, Chapter 5 gives a summary of the findings of this project effort and provides recommendations.

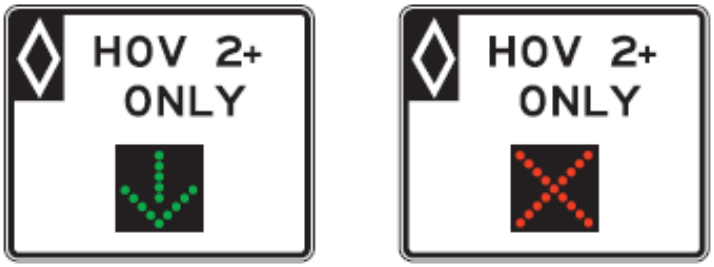
CHAPTER 2
EXISTING PRACTICES

This chapter provides a comprehensive state-of-the-practice review on existing hybrid sign applications. Given that the use of hybrid signs is only emerging in the U.S., this chapter covers hybrid sign applications in both the U.S. and around the world. This chapter starts by summarizing the instances of hybrid signs documented in the latest version of the Manual on Uniform Traffic Control Devices (MUTCD). It then proceeds to review existing hybrid sign applications for speed control, parking guidance, travel time and travel distance information, dynamic rerouting information, and graphical route information. A review on the companies in the U.S. that manufacture and market hybrid signs is also included in this chapter.

2.1 Hybrid Signs in MUTCD 2009

The current version of the Manual on Uniform Traffic Control Devices (MUTCD) does not include separate guidelines for hybrid signs. It includes hybrid signs as a special type of DMS that is used mainly in preferential and managed lane operations. The specific applications include those for lane-use control, variable toll charge display, and travel time display, as follows (FHWA, 2009):

- *Lane-Use Control*: This application involves the use of changeable message panels, either with legends (e.g., Figure 2-1) or text messages (e.g., Figure 2-2), are incorporated into regulatory lane-use control signs to indicate the status of reversible operation.



(a) Lane Open **(b) Lane Closed**

Figure 2-1: Hybrid Signs as Preferential Lane Regulatory Signs (Source: Figure 2G-1 from MUTCD)

(a) Lane Open **(b) Lane Closed**

Figure 2-2: Hybrid Signs as Preferential Lane Guide Signs (Source: Figure 2G-6 from MUTCD)

- *Variable Toll Charge Display*: This application involves the use of changeable message panels that are incorporated into regulatory signs for priced managed lanes to provide variable toll pricing information (e.g., Figure 2-3).

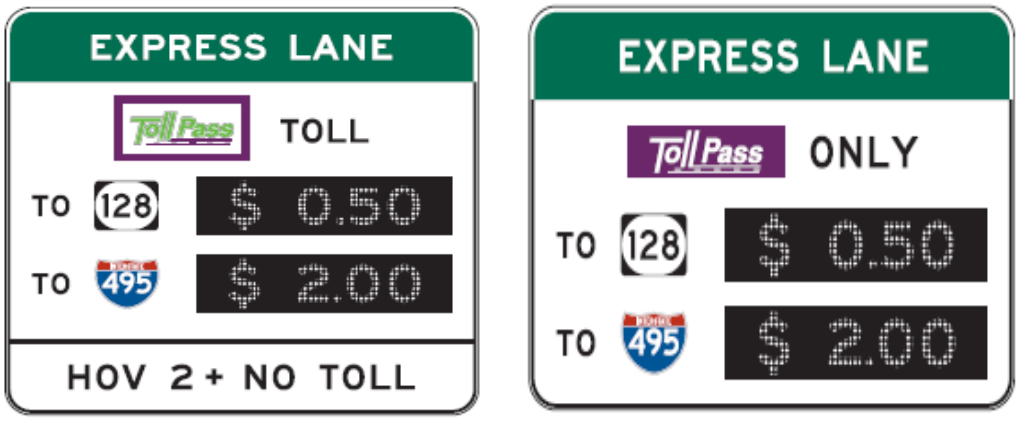


Figure 2-3: Hybrid Signs Providing Dynamic Toll Information (Source: Figure 2G-17 from MUTCD)

- *Travel Time Display*: This application involves the use of changeable message panels that are incorporated into guide signs for priced managed lanes to provide comparative travel times (e.g., Figure 2-4) for managed lanes versus general-purpose lanes.

Figure 2-4: Hybrid Sign Displaying Comparative Travel Time Information (Source: Figure 2G-20 from MUTCD)

2.2 Variable Speed Limit and Dynamic Speed Display

As aforementioned, the most common application of hybrid signs in the U.S. has been for the display of variable speed limit (VSL) to dynamically adapt speed limits to changing roadway conditions, such as in cases of congestion, school zones, incidents, or special events. Depending on whether it is for regular (e.g., in school zones) or temporary (e.g., in work zones) type of control, these signs can be installed permanently or attached to portable trailers (commonly known as speed trailers). Additionally, in many situations, the signs are equipped with radar

speed detectors to display the speeds of individual vehicles. Different names, including dynamic speed display signs (DSDS) (Rose and Ullman, 2003), speed monitoring display signs (SMDS) or speed feedback signs (Pesti and McCoy, 2001), have been used to refer to a variation of these signs.

Figure 2-5 shows two examples of portable hybrid signs. Specifically, Figure 2-5(a) display only the VSL and Figure 2-5(b) displays both the VSL and the vehicle speed. Brewer et al. (2005) studied the effectiveness of three devices including static speed limit sign, speed trailer and full-matrix Changeable Message Signs (CMS) to improve work zone speed limit compliance. Pesti and McCoy (2001) investigated the long-term (five weeks) effects of SMDS in work zones on rural highways in Nebraska. Both studies concluded that speed trailers were effective in reducing vehicle speeds and increasing the vehicle speed uniformity.

(a) VSL Display at a Work Zone in Michigan
(Source: FHWA, 2007a)

(b) VSL and Driver's Speed Display on Route 250 in Virginia
(Source: VDOT, 2011)

Figure 2-5: Portable Hybrid Signs Displaying Variable Speed Limit and Driver's Speed

Figure 2-6(a) shows a typical installation of permanent hybrid signs for speed harmonization on a major roadway in The Netherlands (Kuhn, 2010). Figure 2-6(b) shows an example of DSDS applied in school zone. Rose and Ullman (2003) investigated the effect of permanent hybrid VSL signs installed in different roadway environments, such as school zones, sharp horizontal curves, and high-speed signalized intersection approaches in Texas. The evaluation was sought before, immediately after (zero to three weeks), and several (two to four) months after installing DSDS. A consistent reduction in average speed from 4 to 9 mph was observed over the test period of four months at school zones, and at the approach to a signalized intersection on high-speed roadway where enforcement tends to be higher.

(a) VSL (Speed Harmonization) Sign on Express Roads – The Netherlands (Source: Kuhn, 2010)

(b) VSL Sign in School Zone – USA (Source: Information Display Company, 2011)

Figure 2-6: Permanent Varable Speed Limit Hybrid Signs

2.3 Parking Guidance System (PGS)

Another practice of hybrid signs is as a component in the parking guidance system (PGS) to provide real-time parking availability information. The dynamic panel either shows the exact number of available parking spaces or gives the status on parking availability, while the static part guides motorists in finding the parking facility, showing its name and direction. Text messages such as “EMPTY” or “FULL”, or “CLOSED” or just “SPACES”, are displayed to inform motorists about the status of a given parking facility, while numeric digits specify the exact number of available parking spaces (Rodier et al., 2008).

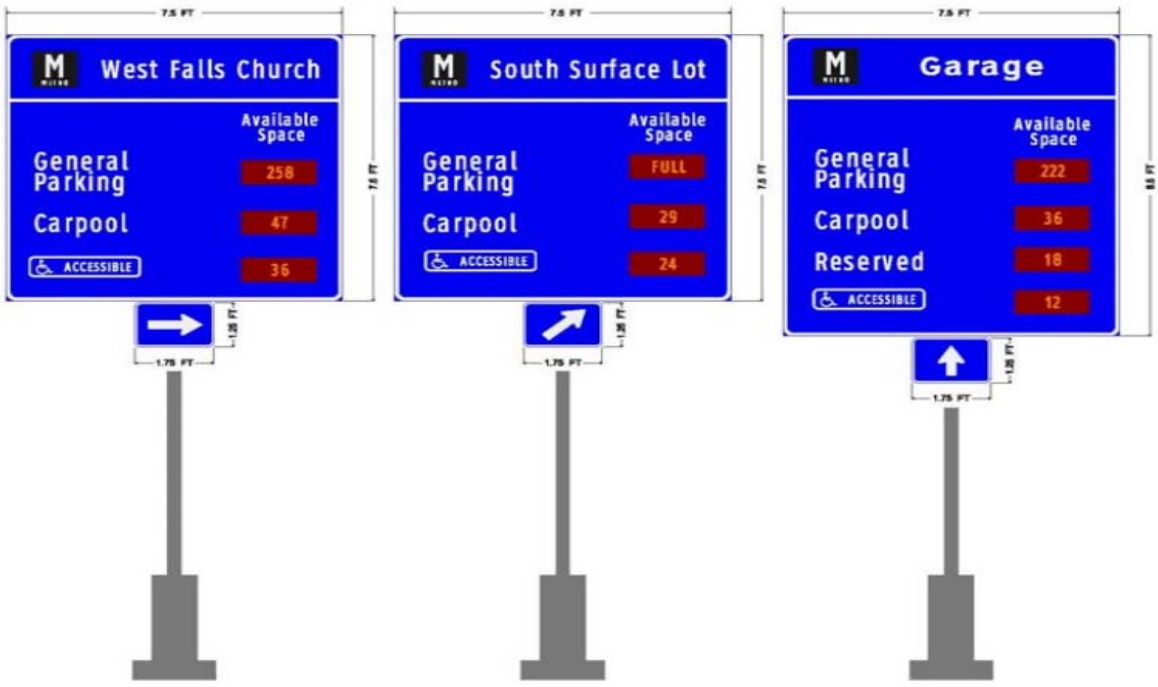
Hybrid signs for parking guide signs are usually installed before approaching parking facilities at city centers, transit stations, airports, shopping malls, hospitals and recreational places. Depending on the purpose and placement, these hybrid signs are used to provide space availability information on nearby multiple parking garages or level-wise at a particular parking garage. Hybrid signs for parking guidance have been deployed in many cities throughout Europe, the United Kingdom, and some countries in Asia (Waterson et al., 2001; New York City Department of City Planning, 2004; Rodier et al., 2008).

In the U.S., areas where hybrid signs have been implemented as part of the PGS include (PB Ferradyne and Leigh Fisher Associates, 2002; New York City Department of City Planning, 2004; FHWA, 2007b; Rephlo et al., 2008a; Rodier et al., 2008):

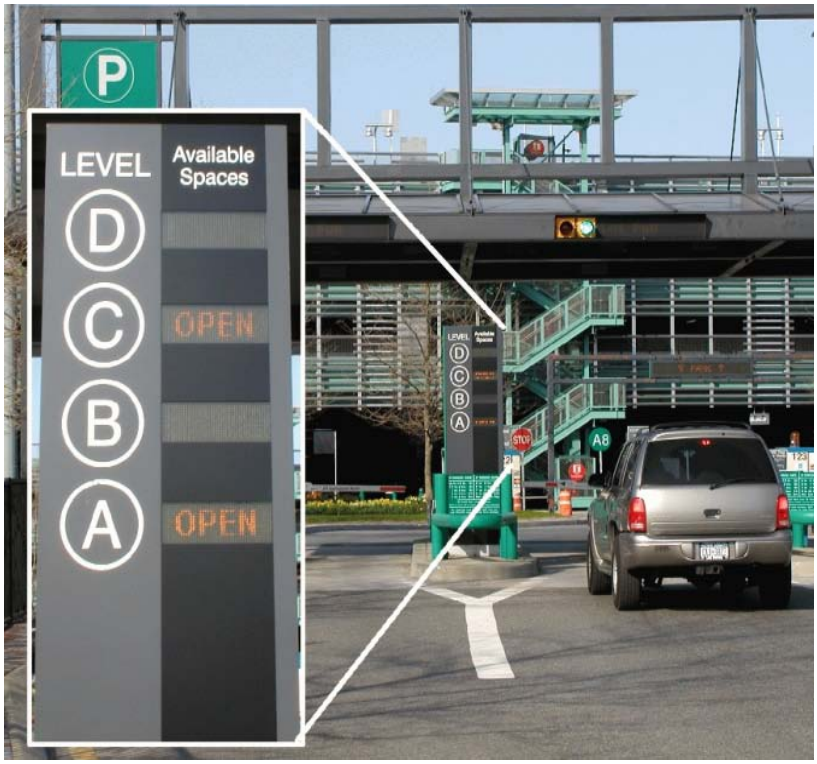
- Portland International Airport, Portland, Oregon
- Chicago Metra Park and Ride, near Chicago, Illinois
- City of St. Paul, Minnesota
- JFK International Airport, New York
- LaGuardia International Airport, New York
- City of Charlotte, North Carolina
- Los Angeles Downtown, California
- San Diego Downtown, California
- Seattle Center, Seattle, Washington

Figure 2-7(a) shows a hybrid sign that gives downtown parking information at San Jose, California. The sign also has an additional electronic panel to show the message in detail. Figure 2-7(b) shows the concept of signs developed for Washington Metropolitan Area Transit Authority’s (WMATA’s) Metrorail stations. The sign shows the number of available spaces for different types of riders. One of the striking features of these signs is the inclusion of handicapped parking space availability information. The signs were to be placed near arterials to inform drivers of the parking availability far ahead of the facility (Wilbur Smith Associates, 2009). Figure 2-7(c) demonstrates a hybrid parking information/guidance sign placed at the entrance of a multi-storied parking facility. The sign gives the available number of parking spaces at each level.

(a) Downtown Area, San Jose, California
(Source: Layman, 2012)



(b) WMATA Metrorail Station
(Source: Wilbur Smith Associates, 2009)



(c) JFK International Airport, New York
(Source: New York City Department of City Planning, 2004)

Figure 2-7: Examples of Hybrid Signs Used in Parking Guidance System

2.4 Dedicated Travel Time Display

One promising application of hybrid signs is the display of real-time estimates of travel times to major destinations. A number of countries outside the U.S. have been using hybrid signs to convey real-time traveler information. Within the U.S., the deployment of hybrid signs for travel time display has been limited mainly to those in managed lane operations. This section presents a detailed review of the use of hybrid signs for travel time display from around the world.

Cologne, Germany

In Cologne, Germany, a hybrid travel time sign was deployed on a key arterial in the city center before the approach to a park-and-ride lot and tram station. Figure 2-8 shows the placement and installment of the sign. The sign provides real-time comparative travel times to Neumarkt (translated from: *Fahrzeit zum Neumarkt*) by car and by public transportation from a tram station. It also provides arrival time of the next tram in the station. All of this time-related information helps motorists make more informed decisions on their transportation alternatives (Berman et al., 2006).

Figure 2-8: Hybrid Travel Time Sign in Cologne, Germany (Source: Berman et al., 2006)

Hessen, Germany

As part of mobility improvement in the "Congestion Free Hessen 2015" program, the Hessian Road and Traffic Authority implemented two hybrid travel time signs, referred to as the Dynamic Information Boards for Displaying Travel Times (or dIRA), in Hessen, Germany in 2006. These signs were deployed as an alternative to destination-distance signs. Figure 2-9 shows one of the two signs placed on the A5 freeway before the Freidburg junction in the approach to the Rhine-Main region. Travel times on these signs were updated every minute. A scientific perception study was conducted by the Hessian State Office for Road and Traffic Affairs (HSORTA) in 2006 to assess the benefit and acceptance of the signs. The majority of those interviewed showed a positive attitude toward the sign (Hessian Road and Traffic Authority, 2009).

Figure 2-9: Hybrid Travel Time Sign in Hessen, Germany (Source: Hessian Road and Traffic Authority, 2009)

Scotland, UK

Hybrid travel time signs have also been implemented in Scotland (CEDR, 2009). Figure 2-10 shows one hybrid travel time sign roadside along the M8 motorway in Scotland.

Figure 2-10: Hybrid Travel Time Sign in Scotland, U.K.
(Source: CEDR, 2009)

Copenhagen, Denmark

Figure 2-11 shows an example of a hybrid travel time signs in Denmark. The sign, which displays the *estimated driving time to downtown* (translated from: *Køretid til indre by*), was placed overhead along the Primary Route 16 motorway in the Copenhagen metropolitan area.

Figure 2-11: Hybrid Travel Time Signs in Copenhagen, Denmark
(Source: Chriszwolle, 2011)

Taiwan (Republic of China) and Japan

In Asia, hybrid travel time signs can be seen on the freeways in Taiwan (e.g., Figure 2-12) and Japan (Figure 2-13).

Figure 2-12: Hybrid Travel Time Signs in Taiwan, Republic of China (Source: Taiwan Area National Freeway Bureau, 2012)

Figure 2-13: Hybrid Travel Time Sign on Elevated Roads in Japan (Source: Skyscrapercity, 2012)

Washington, USA

In a feasibility study conducted by the Washington Department of Transportation (WSDOT), hybrid signs were proposed for travel time display in the Puget Sound Region as an active traffic management strategy (PB Americas, Inc. et al., 2007). Figures 2-14(a) and 2-14(b) show examples of sign designs used in the study for the display of comparative travel times for normal and congested conditions, respectively. The study concluded that hybrid signs were more effective than DMS in terms of capital, operations, and maintenance costs, and recommended that the signs be placed at three crucial locations along I-405, I-90, and I-5 in Washington.

(a) Normal Condition

(b) Congested Condition

Figure 2-14: Examples of Hybrid Signs for Display of Comparative Travel Times (Source: PB Americas Inc. et al., 2007)

Under the Moving Washington program intended for improving travel time by 10% and reducing collisions by 25% by 2020, the WSDOT installed its first three travel time signs on I-5 in December, 2009. Among the three hybrid signs, two were placed on Northbound I-5 at the South 216th Street overpass near SeaTac and just South of the I-405 interchange in Tukwila. The third sign was installed on Southbound I-5 near SR 96 in Mill Creek (WSDOT, 2012a).

In April 2011, the WSDOT unveiled three hybrid travel time signs as part of the Lake Washington Travel Time Signs Project (WSDOT, 2012c). These signs provide comparative travel times to Seattle using different routes. The signs were installed at the following locations:

- Westbound SR 520 in Bellevue (one mile East of I-405) providing travel times via SR 520 and I-90 (see Figure 2-15);
- Westbound SR 522 at the SR 202 overpass in Woodinville (one mile East of I-405 Northbound exit) providing travel times via SR 522 and SR 520; and
- Southbound I-405 at the NE 72nd Place overpass in Kirkland (1.3 miles North of SR 520) providing travel times via SR 520 and I-90.

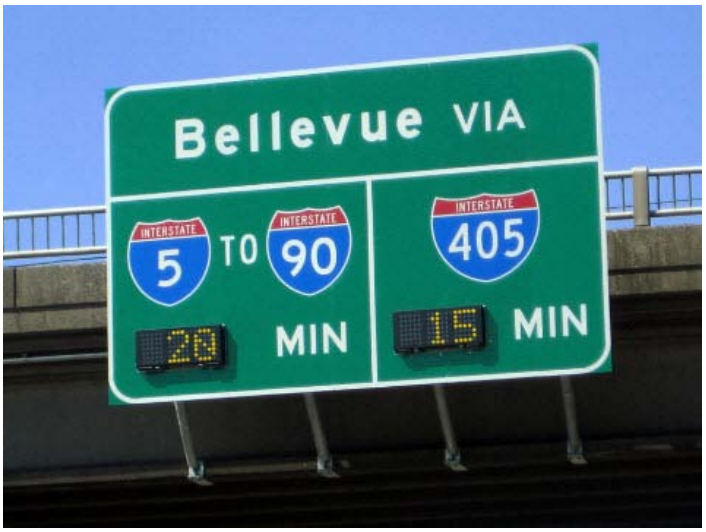


Figure 2-15: Hybrid Travel Time Sign on SR 520 in Bellevue, Washington (Source: Skyline Products Inc., 2012)

In June 2011, the WSDOT added three more hybrid signs on I-90 near North Bend, Cle Elum, and Ellensburg to provide travel time information to Snoqualmie Pass. Figure 2-16 shows the travel time sign near Cle Elum. Unlike the other signs from the WSDOT, the time unit, "MIN", in this sign is included in the dynamic panel (WSDOT, 2012b).

Figure 2-16: Hybrid Travel Time Sign on I-90 in Washington (Source: Skyline Products Inc., 2012)

New York, USA

The New York State Department of Transportation (NYSDOT) installed its first two hybrid travel time signs along the Staten Island Expressway in 2007. One of the two signs was placed at Hylan Boulevard to provide travel times to westbound traffic to Bradley Avenue, the Goethals Bridge, and the Outerbridge Crossing (see Figure 2-17). The other was placed at South Avenue

to provide travel times to Bradley Avenue, Clove Road, and the Verrazano Narrows Bridge for Eastbound traffic (Breen, 2007a).

As part of the INFORM (INFORMation for Motorists) project, the NYSDOT installed 12 more travel time signs along the Northern State Parkway (NSP) in Nassau and Suffolk counties on Long Island also in 2007. Some of these signs provided estimated travel times to multiple destinations while some facilitated motorists by providing comparative travel times for alternate routes to particular destinations. In the application, travel times are estimated and updated every minute based on information collected from various sensors including E-ZPass readers. Vehicles with E-ZPass transponders are detected by the readers that record the speed and passing time information between detectors. In addition, the TRANSMIT system calculates and renders the average travel time (Peters, 2007b).

A New York Times report (Ain, 2007) on the travel time signs along NSP revealed some ambivalence toward these signs. It was reported that some motorists did not pay attention to the signs while others lost interest in the information after they found that the travel times displayed did not match the actual numbers. One related comment stated that the sign would attract the attention of more commuters if placed on the median rather than on the roadside.

Figure 2-17: Hybrid Travel Time Sign in New York
(Source: Skyline Products Inc., 2012)

Indiana, USA

The Indiana Department of Transportation (INDOT) installed its first hybrid travel time sign along I-80/94 in Lake County in 2009. As can be seen in Figure 2-18, the sign aprovides both distance and travel time information. Travel time is estimated and updated based on average vehicle speed and traffic volume information collected from cameras and detectors. As part of its plan to deploy 40 more travel time signs statewide, the INDOT indicated that it would install 13 by 2012 (INDOT, 2011 and 2012).

Figure 2-18: Hybrid Travel Time Sign on I-80/94 in Lake County, Indiana (Source: Thomas, 2011)

Colorado, USA

The Colorado Department of Transportation (CDOT) placed five hybrid travel time signs along I-25 between Colorado Spring and Denver in August of 2010. Travel time information is updated based on sensor data collected from speed input devices including ramp meters, side-fire speed sensors, and toll transponders. The signs were installed at the following location (Thaxton, 2010):

- Southbound I-25
  - Just South of Castle Rock
  - Just North of Monument Hill
  - Just South of Monument

- Northbound I-25
  - Briar Gate Interchange area
  - Tomah Road Interchange area

Figure 2-19 shows the hybrid travel time sign installed on Northbound I-25 near Tomah Road.

Figure 2-19: Hybrid Travel Time Sign on I-25 near Tomah Road in Colorado (Source: Skyline Products Inc., 2012)

Utah, USA

The Utah Department of Transportation (UDOT) installed a number of hybrid travel time signs in 2010 along State Street in Utah County as part of the I-15 CORE project (Pugmire, 2010) to provide comparative travel times. Figure 2-20(a) shows two signs that successively display the comparative travel times of two alternate routes to a destination. In this application, information gathered from sensors at traffic signals was used to update travel times every six minutes. Figure 2-20(b) shows another design in Utah for the display of comparative travel times associated with two alternate routes. Unlike the sign in Figure 2-20(a), this sign include "MIN" in the dynamic panels.

(a) Successive Display of Comparative Travel Time (Source: Wimmer, 2010)

(b) Simultaneous Display of Comparative Travel Time (Source: Daktronics Inc., 2012)

Figure 2-20: Hybrid Travel Time Sign in I-15 CORE Area, Utah

Figure 2-21 shows yet another hybrid travel time sign which is installed on Westbound University Parkway and provides travel time to SR 92 in Lehi. On this particular sign, the unit "MINUTES" is also cleverly used to indicate "travel time", saving both space and cost.

Figure 2-21: Hybrid Travel Time Sign on University Parkway in Orem City, Utah (Source: CountyLemonade, 2012)

Ohio, USA

The Ohio Department of Transportation (ODOT) installed three hybrid travel time signs, referred to as destination dynamic message signs. Two of these signs were installed on I-75 between Dayton and Cincinnati and the other one on I-70 westbound. The exact locations of these signs are given as follows:

- I-75 southbound at Montgomery/Warren County Line.
- I-75 northbound at Kyle Station Road.
- I-70 westbound at CR 42/Watkins Road.

Figure 2-22(a) shows the sign installed at Montgomery/Warren County Line. These signs are in operation 24/7 to provide travel time information. Figure 2-22(b) shows that, when the road is closed, the signs would display the text "CLD" in the dynamic panel in place of numerical digits for travel time (ODOT, 2012).

(a) During Normal Operation **(b) During Road Closure**

Figure 2-22: Hybrid Travel Time Sign at Montgomery/Warren County Lane, Ohio (Source: ODOT, 2012)

Texas, USA

In a focus group research conducted by the Texas Department of Transportation (TxDOT), the hybrid sign shown in Figure 2-23 for travel time display was presented to 69 participants to assess their understanding of the sign. The participants found the sign to be useful and appreciated the comparative travel time information. They also recommended that the sign be installed at least a half-mile in advance of a ramp (Chrysler et al., 2007).

Figure 2-23: Hybrid Travel Time Sign for TxDOT Focus Group Research (Source: Chrysler et al., 2007)

Arizona, USA

The Arizona Department of Transportation (ADOT) considered hybrid signs as an option for travel time display, but did not recommend their use for two reasons (Kimley Horn and Associates Inc., 2011). The first stems from the estimation of a large capital cost for these signs as new communication systems need to be set up to calculate the travel times. The second reason has to do with the limitation of hybrid signs over traditional DMS in expanding or changing messages in the future.

2.5 Managed Lane Facilities

Hybrid signs are increasingly being used for managed lanes including high occupancy vehicle (HOV) and high occupancy toll (HOT) lanes (also known as express lanes), as can be seen from most examples used in MUTCD. This increasing use can largely be attributed to a recent increase in HOT lane projects from around the country. The application of hybrid signs in various express lane facilities in the U.S. is summarized in this section. One special application in an electronic road pricing system in Singapore is also included.

SR 167 HOT Lanes in Seattle, Washington

The hybrid signs used on SR 167 HOT lane facility display toll rate or different messages indicating lane-entry eligibility for different types of vehicles. Figure 2-24 shows an example of this sign. The static part of the sign uses pictograms of buses and carpools with 2+ to indicate

that these vehicles can use the facility for free provided the lanes are in normal operation. The dynamic panel can display four types of message depending on congestion level and time of day (WSDOT, 2011):

- "$ 3.25" indicates toll rates that registered vehicles with *GoodToGo* transponder have to pay to use the facility.
- "HOV ONLY" indicates that only HOVs are allowed *t*o use the facility during that time.
- "OPEN" indicates that all types of vehicles can use the facility for free. The facility is kept free during night-time between 7:00 PM and 5:00 AM.
- "CLOSED" indicates that the facility is closed to all traffic.

Figure 2-24: Hybrid Sign on SR 167 HOT Lane Facility in Seattle, Washington (Source: WSDOT, 2011)

I-15 Express Lanes in Salt Lake City, Utah

An example of hybrid sign used on the I-15 Express Lane facility in Salt Lake City, Utah is shown in Figure 2-25. The sign at the bottom, which shows "HOV 2+ NO TOLL", indicates that HOVs including carpools with two or more passengers, buses, motorcycles, emergency vehicles, and commercial decal vehicles, can use the toll lanes without charge. The dynamic panel displays the following four types of message (UDOT, 2012):

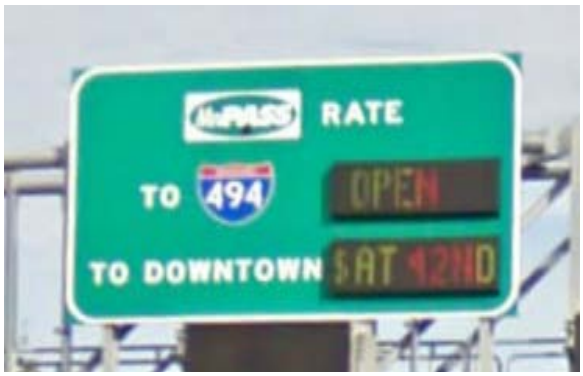
- Toll rate, for example "$ 0.25";
- "HOV ONLY" indicates that HOVs are allowed to use the facility;
- "FREE" indicates that all types of vehicles can use the facility for free with or without an Express Pass;
- "CLOSED" indicates that all drivers must exit the Express Lanes at the next exit.

Figure 2-25: Hybrid Sign on I-15 Express Lane Facility in Salt Lake City, Utah (Source: Skyline Products Inc., 2012)

I-35 W and I-394 Express Lanes in Minneapolis, Minnesota

Figures 2-26(a) and 2-26(b) show two examples of hybrid signs used on the I-35W and I-394 Express Lane facilities, respectively. The information displayed on the dynamic panels in these signs include (MnDOT, 2012):

- "OPEN" indicating the facility is open to all traffic at no charge.
- Toll rate followed by "$" symbol indicating single occupant vehicles (SOVs) can use the lane by paying the toll displayed. The pricing is adjusted based on traffic flow, length of the trip, and entry and exit points of the trip.
- "$ AT 42ND" or "$ AT 76TH" indicating that toll may be charged from that particular street.



(a) Displaying "OPEN" and "$ AT 42ND"

(b) Displaying "OPEN" and toll rate

Figure 2-26: Hybrid Sign on I-394 Express Lane Facility in Minneapolis, Minnesota (Source: Google, 2012)

I-680 and I-580 Express Lanes in Oakland, California

The hybrid signs used on I-680 and I-580 Express Lane facilities show either the toll rates for SOVs during designated hours (see Figure 2-27(a)) or "OPEN TO ALL" to indicate permission for all vehicles to use the lane free of charge (see Figure 2-27(b)) or "HOV only" to indicate exclusive use by HOVs only (Alameda County, 2012).

(a) Toll Rate Display **(b) Accessibility Information Display**

Figure 2-27: Hybrid Sign on I-680 Express Lane Facility in Oakland, California (Source: Google, 2012)

SR 237 Express Lanes in Silicon Valley, California

Figure 2-28 shows an example of hybrid sign used on SR 237 Express Lanes facility in Silicon Valley, California. The signs are similar in design to the ones used on I-680 and I-580 Express Lanes (Santa Clara Valley Transportation Authority, 2012).

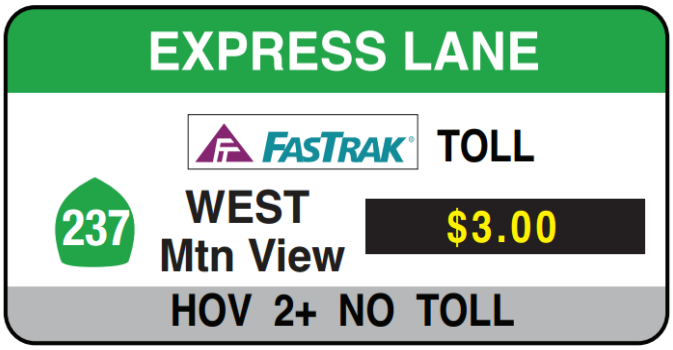


Figure 2-28: Hybrid Sign on SR 237 Express Lane Facility in Oakland, California (Source: Santa Clara Valley Transportation Authority, 2012)

I-85 Express Lanes in Atlanta, Georgia

The hybrid signs used on the I-85 Express Lane facility are placed at three points: two in northbound direction and one in southbound direction. Figure 2-29 shows one of these signs. In this sign, the information "PeachPass ONLY" indicates that all vehicles, regardless of carpools

or non-carpools, must have a registered PeachPass transponder to use the facility. However, information regarding toll-free vehicles is not displayed on the sign (State Road and Tollway Authority, 2012).

Figure 2-29: Hybrid Sign on I-85 Express Lane Facility in Atlanta, Georgia (Source: Getz, 2012)

I-95 Express Lanes in Florida

Figure 2-30 shows a hybrid sign used on the I-95 Express Lanes in Miami-Dade County. The sign shows the vehicle eligibility information at the top, including "REGISTERED CARPOOLS FREE" and "SUNPASS ONLY". The dynamic panels show either the toll rates or "CLOSED" in case of road closure. An extra LED panel is reserved for future use (FDOT, 2012).

Figure 2-30: Hybrid Sign on 95 Express Toll Lane Facility in Florida (Source: FDOT District 6, 2012)

I-15 Express Lanes in San Diego, California

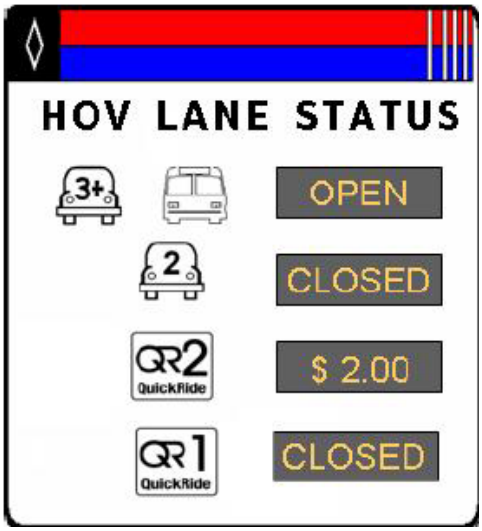
The managed lane signs used on the I-15 Express Lanes facility gives more information compared to those in other managed lane facilities. As shown in Figure 2-31, the signs display minimum toll and travel time in addition to exact toll to particular destinations (San Diego Association of Governments, 2012).

Figure 2-31: Hybrid Sign on I-15 Express Lanes in San Diego, California (Source: Google, 2012)

I-10 Katy Freeway in Houston, Texas

The hybrid signs used on this facility show different information depending on their placement. The hybrid signs used in the facility display both the destinations and their corresponding tolls in the dynamic panel. Figure 2-32(a) shows one of the signs in Katy Tollway for TxTag/EZ Tag registered vehicles. Toll rates vary based on time of day, vehicle occupancy, and axle count. Although the Katy Freeway is free for carpools with at least 3 occupants, "QuickRide" value pricing project allow vehicles with 2 occupants to use the facility during peak hours provided they have the required registration. Figure 2-32(b) shows an example of this sign. It is noted that SOVs, even with QuickRide transponder and vehicles having 2 occupants without QuickRide transponder, are not allowed to use the facility ("CLOSED" in the dynamic panel) where registered vehicles carrying two occupants can use the facility with a $2 toll (Texas Transportation Institute, 2012).

(a) TxTAG/ EZ Tag Toll Sign
(Source: FHWA, 2010)



(b) QuickRide Sign
(Source: Stockton and Burris, 2007)

Figure 2-32: Hybrid Signs on I-10 Katy Freeway in Houston, Texas

Electronic Road Pricing (ERP) in Singapore

In Singapore, hybrid signs are used to display pricing information for different types of vehicles as part of the so-called electronic road pricing (ERP) system. Figure 2-33 shows an example of this sign.

Figure 2-33: Hybrid Sign Used in ERP System in Singapore (Source: http://keropokman.blogspot.com/2007_05_01_archive.html)

New York State Thruway Plaza

The hybrid sign shown in Figure 2-34 is installed by the New York State Thruway Authority before the approach of a toll plaza to provide information about changes in the toll lane configuration. The numbers shown in the sign indicate lanes that are operating under the electronic toll collection system, whereas other lanes that are not shown in the dynamic panel either accept cash or are for mixed-use. The sign was installed with the intention of reducing drivers' confusion and improving safety at toll collection facilities (Rephlo et al., 2008b).

Figure 2-34: Hybrid Sign at New York State Thruway Plaza in New York (Source: Rephlo et al., 2008b)

Focus Group Study in Texas

In a focus group study conducted by Texas Transportation Institute (TTI), the participants were shown the sign in Figure 2-35. The sign includes travel times to two different destinations in addition to toll rate per mile. Participants unanimously found this sign very confusing and commented that they did not like to do calculations while driving (Chrysler et al., 2007).

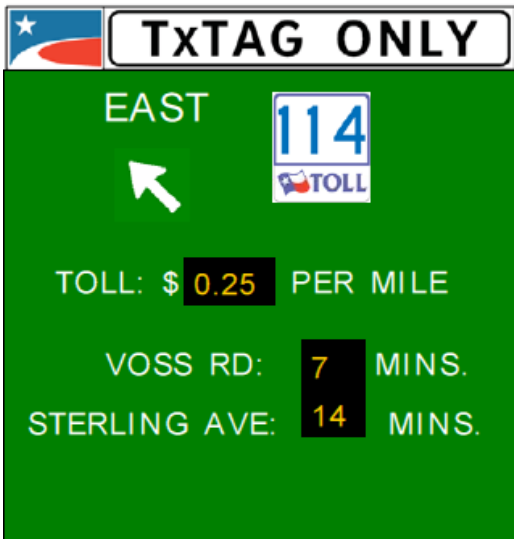


Figure 2-35: Focus Group Test Sign Showing Both Travel Time and Pricing (Source: Chrysler et al., 2007)

2.6 Dynamic Rerouting Information

In Germany and the Netherlands, dynamic rerouting information is provided through the use of rotational prism guide signs and dynamic message signs. However, in the aforementioned ATMS feasibility study (PB Americas Inc. et al., 2007) for the Puget Sound Region, potential hybrid signs were designed to provide dynamic rerouting information to motorists. Figure 2-36 shows examples of dynamic rerouting using hybrid signs during normal conditions (Figure 2-36(a)) as well as during congested conditions (Figure 2-36(b)), for which motorists would be redirected to take I-405 to reach Everett when I-5 is congested. It was suggested that a ring or radial network would be best suited for such dynamic rerouting. However, the network of the Puget Sound Region has two major freeways going N-S and E-W and, therefore, was found to be inappropriate for such a design.

(a) Normal Condition

(b) Congested Condition

Figure 2-36: Hybrid Signs for Dynamic Rerouting
(Source: PB Americas Inc. et al., 2007)

2.7 Graphical Route Information Panels

Another application of hybrid signs is for the so-called Graphical Route Information Panels (GRIPs). The signs are named so because current traffic status is provided graphically using a color-coded level-of-service (LOS) map of the road network. Travel time is also provided in many cases as supplemental information.

There are two types of GRIPs (Atkins, 2003; Gan, 2010) in use based on map diagram: network-based or route selection GRIPs, and link-based or road section GRIPs. The difference between these two types underlies on the representation of the road network. Network-based GRIP shows a schematic map of road network including alternate routes (see Figure 2-37), whereas link-based GRIP shows only the destinations directly ahead along the roadway in a vertical strand, rather than showing the network with alternate routes (see Figure 2-38).

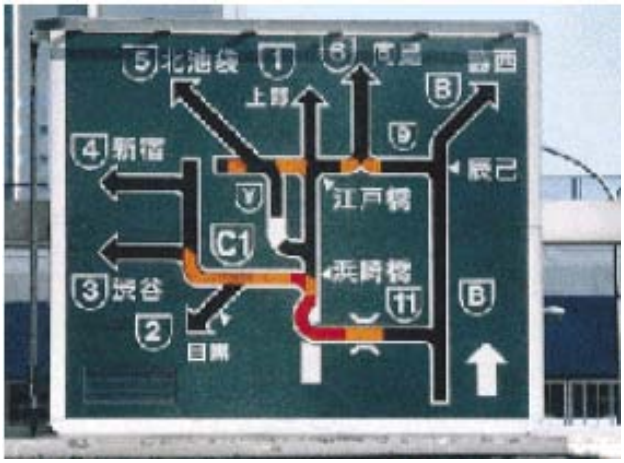


Figure 2-37: Network-based or Route Selection GRIP
(Source: CEDR, 2009)

Figure 2-38: Link-based or Road Section
(Source: Atkins, 2003)

Wei and Perugu (2009) mentioned GRIP as a low-cost alternative to traditional DMS. A study by Alkim et al. (2000) pointed out some advantages of graphical use in GRIP over the typical alphanumeric practice in DMS with regard to dissemination of information such as:

- More information can be provided to motorists while time taken to understand the traffic situation and make a route choice remains the same;
- Complex messages can be comprehended easily, for example, when there is congestion on several locations or when the network itself is complex;

- Information pertaining to different destinations can be given simultaneously while information on only one route at a time is provided on DMS.

GRIP experienced a slow progress for first two decades after its first deployment in 1980. In the last decade, however, the practices of utilizing GRIPs have been gradually increasing. This section covers the uses and guidelines of GRIPs and focuses on survey results regarding driver preferences to these signs.

Japan

Japan has been a pioneer in the development of GRIPs and has deployed these signs both on expressways and streets since 1980 (Alkim et al., 2000; Matsushima and Sakai, 2000; CEDR, 2009). Figure 2-39 shows an example of GRIP signs installed on a Japanese expressway. Vehicle detectors placed 300 m apart are used to collect vehicle speed and occupancy and determine the level of congestion. The standard practice in Japan to represent traffic condition on GRIP is red for congested traffic (speed 20 km/hr or less), orange for crowding traffic (speed 20-40 km/hr), flashing red "X" for accident, and red "X" for traffic lane closure. Matsushima and Sakai (2000) conducted a questionnaire survey to evaluate the conspicuousness, understanding, legibility, and feasibility of GRIPs. A majority of 95% among 4,973 drivers found GRIPs eye-catching. Approximately 69% found the signs legible, and 81% understood the implication of color-coded display. More importantly, around 85% respondents mentioned GRIPs useful while 70 percent of them found GRIPs easily understandable with regard to identifying the place of congestion.

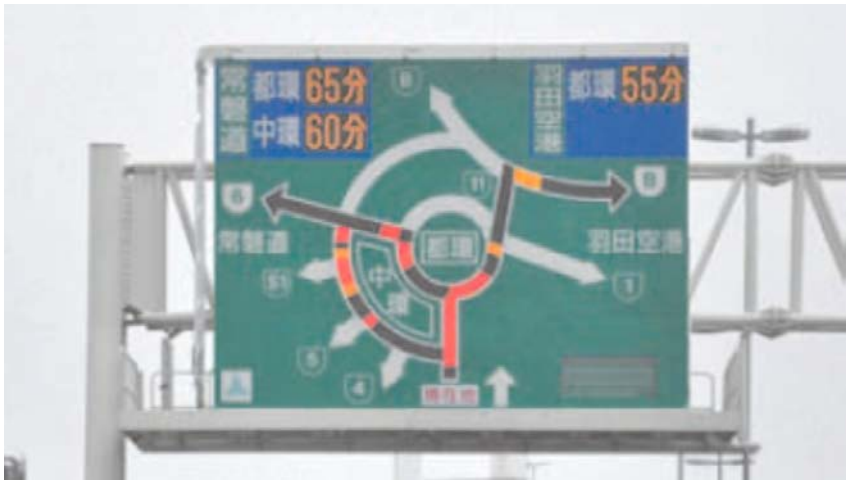
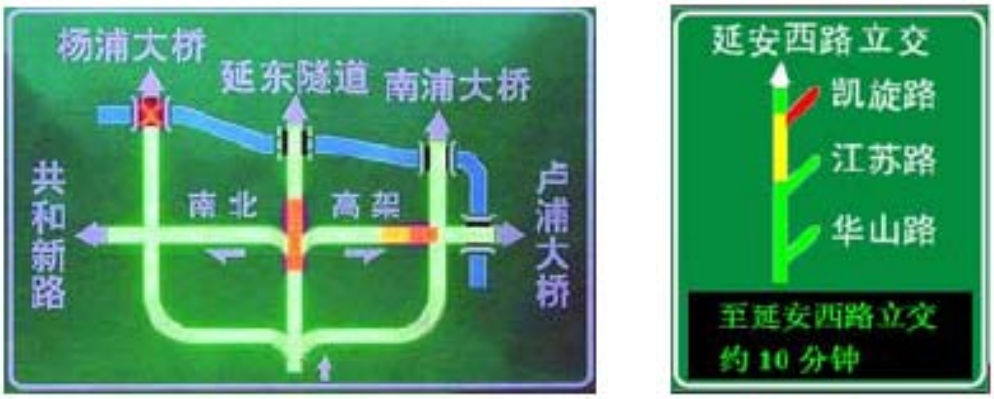


Figure 2-39: GRIP in Japan
(Source: Metropolitan Expressway Co., Ltd., 2012)

China

In China, both types of GRIP, as shown in Figure 2-40, were introduced on urban freeways in Shanghai as an intelligent transportation system (ITS) pilot project in 2003 (Gan et al., 2009). Since then, GRIPs have gained much attention in China and have also been applied in some other cities including Beijing, Ningbo, Hangzhou, Suzhou and Kunming (Gan, 2010).



(a) Network-level Sign **(b) Link-based Sign**

Figure 2-40: GRIP in China
(Source: Gan et al., 2009)

South Korea

GRIPs have also been deployed in South Korea (CEDR, 2009). Figure 2-41 shows an example of its use.

Figure 2-41: GRIP in South Korea
(Source: CEDR, 2009)

Australia

Australia first deployed link-based GRIP, referred to as Trip Information System (TIS), in 1995. By 2007, 13 such signs were installed on Melbourne's freeways (Ramsay and Luk, 1997; Nixon, 2007). These signs display travel time in addition to level of current traffic situation. Figure 2-42 shows one of the signs installed on Geelong Road Freeway in Melbourne. Traffic condition is represented using three-color scheme based on the ratio between current travel time and nominal travel time determined from posted speed limit. Green is used for light traffic corresponding to

the ratio less than or equal to 2, yellow for moderate traffic corresponding to the ratio between 2 and 3, and red for heavy traffic corresponding to the ratio greater than 3. The before-after evaluation survey conducted by Australian Road Research Board (ARRB) revealed that GRIPs were regarded as useful and comprehensible by 70 percent drivers those surveyed (Hearn et al., 1996).

Figure 2-42: GRIP in Victoria, Australia
(Source: Compusign Pty Ltd., 2012)

The Netherlands

The Ministry of Transport in The Netherlands carried a Computer Assisted Personal Interview in 1996 on 370 motorists to assess the acceptability of GRIP. Approximately 40 percent respondents considered the graphical format in GRIP as more effective in comparison with textural information in DMS. At the same time, 80 percent respondents comprehended GRIP as feasible and underscored for its detailed investigation (Schouten et al., 1998). A prototype GRIP, as shown in Figure 2-43, was placed at the AVV Delft test center in 2001 to study drivers' reactions toward the sign. The persons surveyed understood the intention of the sign along with the network and the direction shown in the sign (Atkins, 2003).

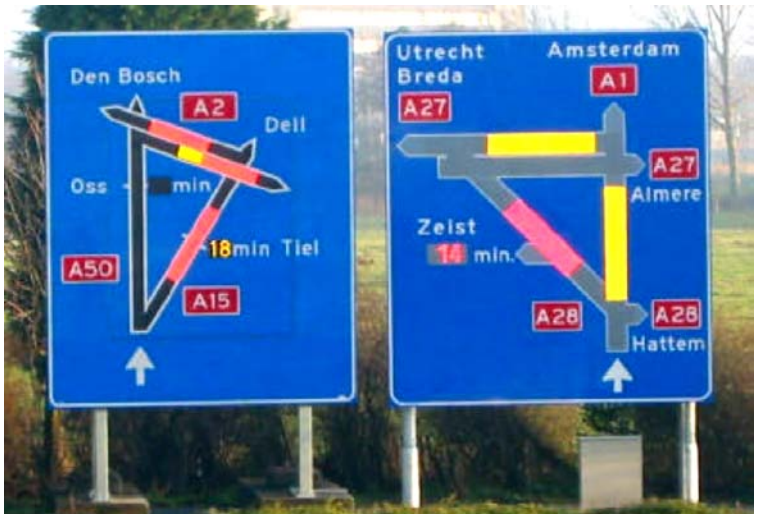
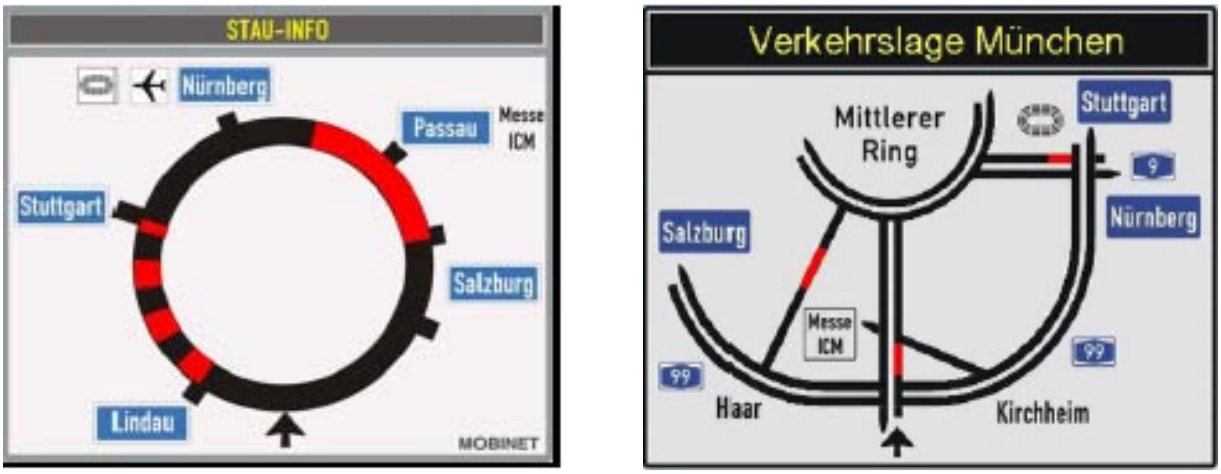


Figure 2-43: GRIP in the Netherlands
(Source: Atkins, 2003)

Germany

In order to reduce traffic congestion in the Munich area, the German Ministry of Education and Research deployed network-based GRIPs in 2003 (Richards et al., 2004). The prototypes were designed based on findings from the driving simulator study by Schönfeld et al. (2000), which concluded that a two-color format, i.e., red for congestion and black for no congestion, was preferred. Figure 2-44 shows two mock-ups of GRIPs implemented in the Munich area.

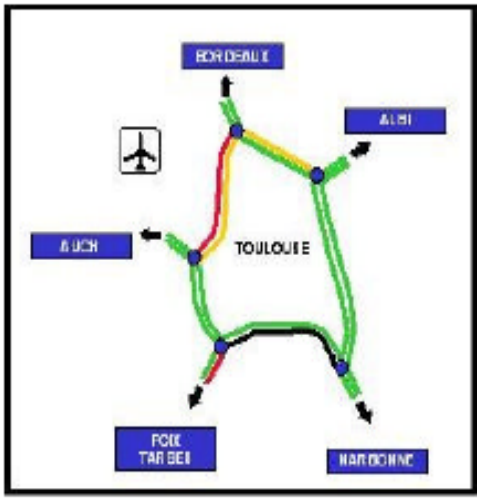


(a) Ring Network **(b) Other Network Type**

Figure 2-44: GRIP in Germany
(Source: Atkins, 2003)

France

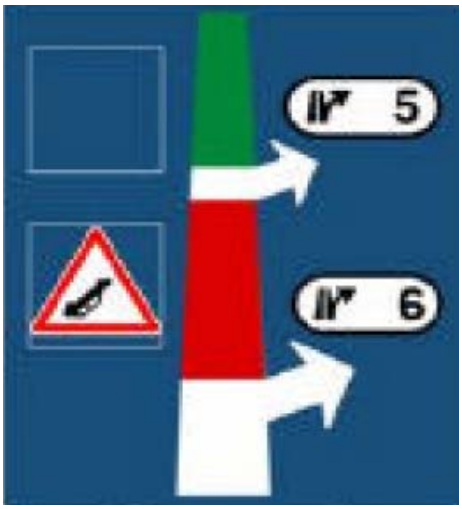
The French Roads Authority developed and tested both types of GRIPs with a four-color scheme, i.e., black for blocked, red for saturated, yellow for dense, and green for free-flow condition. Figure 2-45(a) shows the prototype and Figure 2-45(b) shows the off-road trial of network-based GRIP. The signs were designed to display traffic conditions in both directions. In the link-based prototypes, as can be seen from Figure 2-46, color-coded traffic status on the links is supplemented with either warning pictogram or travel time information when traffic condition on a particular link is not free-flow (Atkins, 2003).



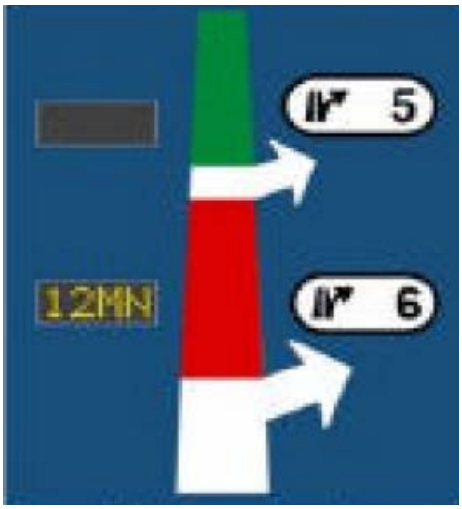
(a) Prototype

(b) Off-road Trial

Figure 2-45: Network-based GRIP in France
(Source: Atkins, 2003)



(a) Pictogram



(b) Travel Time

Figure 2-46: Link-based GRIP in France
(Source: Atkins, 2003)

The United Kingdom

In the U.K., the Transportation Research Group (TRG) at the University of Southampton, in association with Atkins Transport Systems, carried out laboratory research in driving simulator environment to determine the most appropriate sign among a wide range of designs for GRIP. Figure 2-47 shows two such alternative designs of GRIPs in which the color coding is based on comparative travel time rather than congestion levels. Green is used to indicate the shortest route, red to indicate the longest, and yellow to indicate the route between the longest and shortest time periods. The design of these signs was not found to be effective because these signs were determined to be the primary factor for crashes that occurred during a trial period (Atkins, 2003).

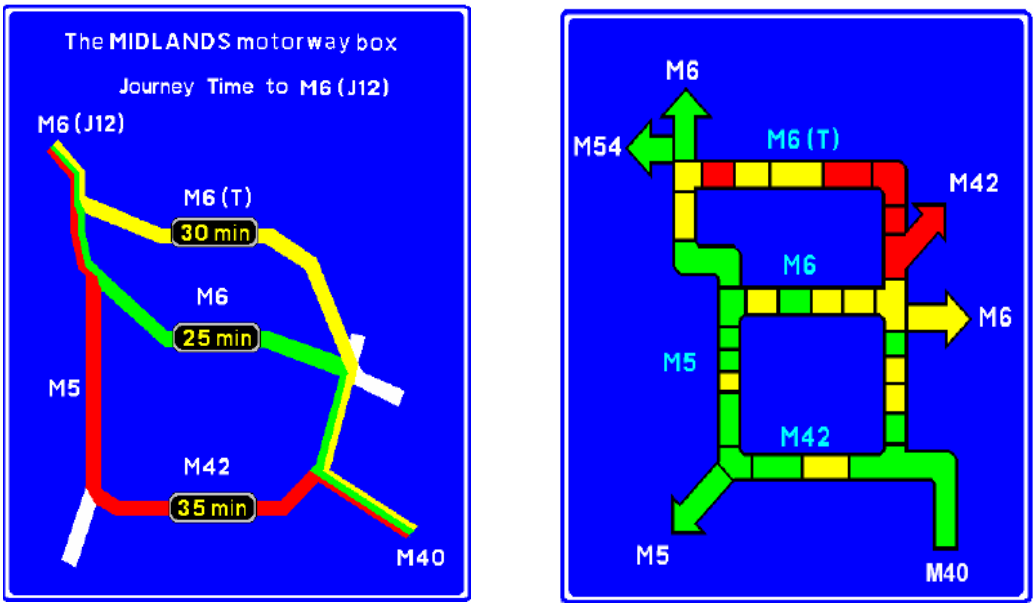


Figure 2-47: GRIP in the U.K.
(Source: Atkins, 2003)

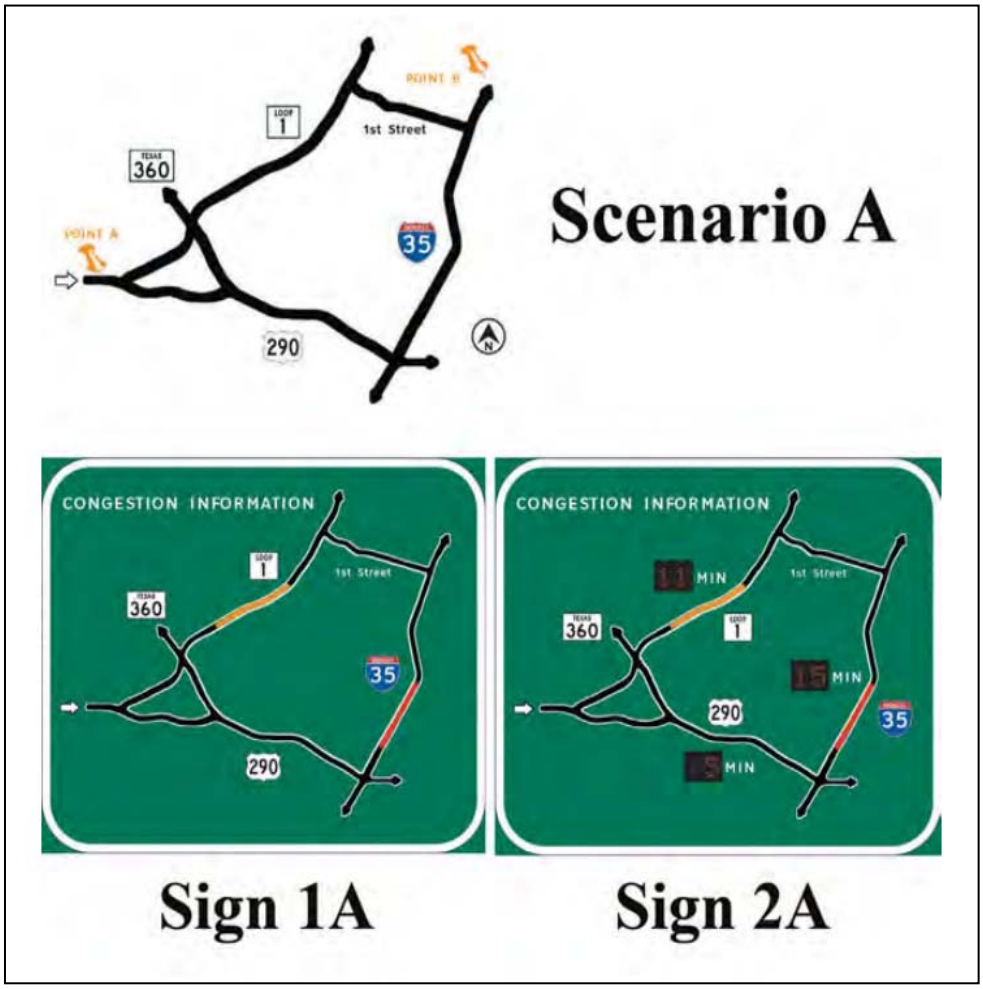
Guidelines for the Design of GRIP in Europe

With the objective of harmonizing the GRIP signs to reduce the confusion that results from the use of different color schemes in different countries within Europe, several recommendations were made at a workshop in Heathrow in March of 2003. The main recommendations are given below (Atkins, 2003):

- Red line or block should be used to indicate heavy congestion.
- Yellow line or block should be used to indicate light congestion.
- Green or blank may be used to indicate free flow conditions; supplemental travel time information should be provided in cases blank is used.
- Travel time to a particular location or exit should be given as total travel time from the current location.
- The orientation of signs should be in the direction of travel.
- Travel times should be displayed to the nearest minute.

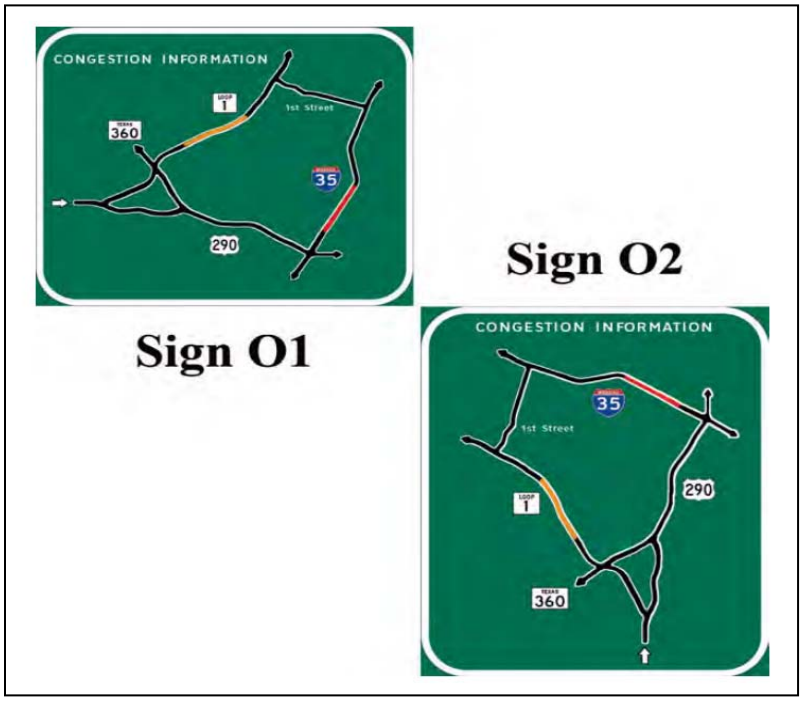
The United States

Although GRIPs have not been deployed in the U.S., Aitken et al. (2012) conducted an Internet-based multiple-choice survey in Texas in 2008 for three different scenarios with alternatives in each scenario. Scenario A, as can be seen in Figure 2-48(a), compares two network-based GRIPs with the only exception of additional travel time information in one sign. Scenario B compares link-based GRIP with traditional VMS (see Figure 2-48(b)) and scenario C deals with sign orientation (see Figure 2-48(c)). Approximately 95% of the 61 respondents from different demographics interpreted the meaning of red correctly. A majority of 52% drivers were likely to divert when confronted with link-based GRIPs compared to a lower 29% diversion in case of VMS presentation. A majority of the respondents were found to prefer the north-oriented sign (O1) over the driver-direction oriented sign (O2). In addition, 90% of the respondents considered GRIPs with travel time information as more easily comprehensible in assessing congestion level, while GRIP without travel time was deemed slightly better than VMS by 72% of the respondents.



(a) Scenario A: Network-based Grips with versus without travel time

(b) Scenario B: Link-based GRIP versus DMS



(c) Scenario C: Sign Orientation

Figure 2-48: GRIP for Testing in the United States (Source: Aiken et al., 2012)

2.8 Manufacturers of Hybrid Signs

This section summarizes information on the companies that currently manufacture and market hybrid signs in the U.S. An email was sent to the company representatives requesting for information about the type of hybrid signs they manufacture, their clients, specific projects and applications for which the signs were used, their product pricing relating to unit cost, installation, product warranty, technical support, and maintenance costs if available. Information provided by the companies that responded and/or can be obtained from the company websites are summarized below.

Adaptive Micro Systems, Inc.

Adaptive Micro Systems, Inc., manufactures hybrid VSL signs. LED pixels are available in white and amber. Both fixed format and driver speed feedback modes of signs are marketed.

ADDCO, LLC an IMAGO Company

ADDCO, LLC manufactures portable speed trailers with high intensity LED module. The K-Band radar can measure speed up to 150 mph from a distance of 1500 ft. Flashing over-speeding display, better legibility, automatic adjustment of LED brightness for ambient conditions are some of the other key features of this VSL sign.

Daktronics, Inc.

Daktronics, Inc., manufactures hybrid signs for various applications including display of VSL, toll rate (HOT lane), and travel time. The product for VSL display is specified by Vanguard VS-5220 and the product for displaying travel time, toll rate and lane status, referred to as Dedicated Dynamic Message Signs (DDMS), is specified by Vanguard VM-1020.

Some of the key features of Vanguard VS-5220 are:

- Black digits on white background,
- High intensity LED panel of 12400 cd/m^2,
- Automatic or manual brightness control,
- LED panel size of approximately 1’9” height by 2’8” width,
- Typical power supply requirement of 145 watts to maximum of 197 watts,
- Easy maintenance.

These hybrid VSL signs by Daktronics were deployed in New York and Orlando, Florida.

Some of the key features of Vanguard VM-1020 are:

- Easy and quick installation as LED panels are easily bolted to static panels.
- Relatively easy maintenance due to placement of controller and power supplies to roadside DDMS cabinet reducing the call for bucket trucks and lane closure.
- High intensity LED panel (as much as 9200 cd/m^2).

- High legibility with minimum glare.
- Amber LED pixels or combination of red, amber, green LED pixels to indicate high, moderate or low travel time or toll rate.
- Possible inclusion of up to six LED panels with one DDMS cabinet in a DDMS set.
- Available in different size ranges varying from 1’5” to 1’10” in height and 2’6” to 11’2” in width.
- Price range of Amber LED panel with control exposure between $15,000 and $20,000.

The travel time signs of VM-1020 series were deployed by the UDOT and Illinois Department of Transportation (IDOT). The signs of the same series for display of toll rate or lane status have been installed by Virginia and Georgia DOTs (VDOT and GDOT, respectively), and WSDOT.

Information Display Company

The company manufactures hybrid signs for display of VSL, dynamic speed based on technology, and progression speed limit for signals. Some of the key features of VSL and DSDS include:

- Two sizes of LED panels – 15” and 18” in height.
- White LED for VSL and Red or Amber LED for DSDS.
- Provision of flashing LED digits in case of violating speed limit.
- Provision of “Slow Down” message in case of over speeding.
- AC-powered or solar-powered display.
- Standard warranty of 3 years and 10 years for LED panels.

McCain, Inc.

McCain, Inc. manufactures hybrid signs for VSL display and parking guidance. Some of the key features of these signs are:

- Amber LED pixel.
- 7 pixel rows by 5 pixel columns per alphanumeric character.
- 256 sign brightness level.
- Easy maintenance due to internally housed controller.

Parking guidance signs from this company have been used in the campus premises of the University of San Diego, California.

Radarsign, LLC

Radarsign, LLC exclusively manufactures speed feedback signs. Some of the key features of these signs are:

- LED display panels in two sizes - 12” or 17” in height.
- Flashing over-speeding display.

- Flexible scheduling with calendar based complete year programming.
- AC, battery, or solar power supply.
- Solar panels of 40 watts or 65 watts.
- Extended 3 years warranty.

Skyline Products, Inc.

Skyline Products, Inc. manufactures hybrid signs for VSL, toll rate (HOT lane) and travel time display. Its toll rate signs have been deployed by UDOT on I-15 in Utah and by Caltrans on I-680 in California. In addition, its travel time signs have been implemented in New York, Colorado and Washington. Some of the key features of these signs are:

- No maintenance required for a longer period of time due to sealed LED modules.
- 1-7 years of warranty, covering all sign parts including the shipping cost and technical support during the warranty period.

SWARCO Traffic Americas, Inc.

SWARCO has manufactured hybrid signs using the LED technology for driver speed feedback display and parking guidance information display. Speed feedback signs have the provision of flashing when drivers cross the allowable maximum speed. The LED panels can display numbers for available parking spaces or display word messages “Free”, “Full” or “Closed”.

Transportation Control Systems

The company sells radar speed display signs manufactured by Canada-based Unipart Dorman. Some of the key features of this sign are:

- MUTCD compliant.
- Amber LED display.
- Night-time auto dimming of LED pixels.
- Flashing beacon incorporated into LED panels.
- Provision of “slow Down” message in case of over speeding.
- Easy installation (plug and play).
- AC- or solar-powered.

2.9 Summary

Hybrid signs have been implemented for a variety of applications in different countries. In the U.S., hybrid signs are being increasingly used in applications including display of variable speed limit, parking availability information, travel time, and toll amount or lane status on managed lanes. The reasons behind the growing practice of hybrid signs over DMS include better legibility, smaller size, and lower costs in installation and maintenance. Given that the use of hybrid signs is only emerging in the U.S., this chapter covered the review of hybrid sign applications in both the U.S. and around the world, including Europe, Australia, and Asia. The

application areas included speed control, parking guidance, travel time and travel distance information, dynamic rerouting information, and graphical route information.

In terms of the design of the hybrid signs, the color and size of the LED displays, placement of hybrid signs, such as overhead, roadside or on median, distance from important points downstream, and sequencing of signs (such as which type comes first and which comes next), is found to be the major decision criterion affecting whether signs attract motorists' attention. The content (how important the information is), extent (precise or not too much information), and reliability of information are important factors in making hybrid signs useful to motorists.

A special type of hybrid sign application is called the GRIPs. GRIPs can act as a viable alternative to dynamic rerouting and it can also serve the purpose of dedicated travel time display. When the network map presented by GRIP is less complicated, motorists find it easier to comprehend the displayed traffic situation. Given road users' familiarity with reading maps, GRIP is found to work better in aiding them to understand network information quickly compared to that provided through DMS.

Only a small number of sign manufacturers are identified to have hybrid sign products for applications other than variable speed limit or speed feedback signs. Among them, Daktronics Inc. and Skyline Products Inc. supplied hybrid signs to different Departments of Transportation (DOTs) in several projects.

The applications of hybrid signs in the studies reviewed focus primarily on active traffic management programs to reduce congestion. Research on safety aspects or before-after evaluation of using hybrid signs (except in some cases for VSL) in the U.S. has not received the attention it deserves. Furthermore, MUTCD has no separate guidelines on the design and placement for hybrid signs. Research and surveys are needed to identify useful applications and develop effective designs for the associated signs.

CHAPTER 3
FOCUS GROUP STUDY DESIGN AND PREPARATION

This chapter first introduces the 10 hybrid sign applications identified by the research group. Next, it presents in detail the process undertaken to evaluate these applications. A total of 150 participants were recruited to participate in the focus group study. The study was directed toward evaluating the usefulness of each application and obtaining feedback on understanding the applications.

3.1 Potential Hybrid Sign Applications

The research team identified several potential hybrid sign applications and finalized on 10 applications. The following are a few of the many applications that were initially reviewed but excluded from further analysis:

- address inadequate stopping sight distance issue on crest vertical curves,
- display variable speed limit at school zone locations during school zone time periods and during regular hours,
- display if the I-595 reversible lanes are open/closed to traffic,
- display advisory speed on reverse horizontal curves and off-ramps depending on weather and traffic conditions, and
- display countdown timer for pedestrians and bicyclists to cross at signalized intersections (based on the pedestrian signals).

The 10 applications that were identified for detailed analysis were grouped into the following four categories:

1. Countdown applications:
   - Drawbridge opening
   - School zone traffic diversion
   - Traffic diversion to avoid train crossing
   - Arrival time information at bus/train stops
   - Train arrival time information on freeways

2. Travel time information applications:
   - Travel times on distance signs
   - Comparative travel times for express lane facilities

3. Speed control applications:
   - Automated speed control
   - Advisory progression speed

4. Other application:
   - Parking availability information

Of the 10 applications, five are based on the concept of countdown timing. The drawbridge opening application is intended to improve safety of pedestrians and bicyclists on drawbridges; school zone traffic diversion and traffic diversion to avoid train crossing are intended to improve mobility and safety on arterial streets; arrival time information at bus/train stops is to serve transit riders; and train arrival information is to serve freeway drivers who would like to take a train. Travel time applications provide travel time information to major destinations/exits on freeways. Speed control applications are geared toward monitoring speeding and improving safety and mobility on arterial streets. Finally, parking availability information signs provide real-time information on parking availability in garages and on specific floors of each garage.

A total of 10 focus groups involving 150 participants were conducted to evaluate these 10 applications. The following sections discuss the participant recruitment process and the study procedure in detail.

3.2 Participant Recruitment

The research team recruited a total of 150 participants from different age, gender, and ethnic groups. Older participants (age 65+) were recruited from a database available with the College of Nursing and Health Sciences at Florida International University (FIU). Other participants were recruited through advertisements. Flyers in both English and Spanish languages were posted at places of public gatherings, gas stations, grocery stores, pharmacies, and departmental stores. The study was also advertised in the local newspaper, *The Miami Herald*. Interested subjects with a valid U.S. driver's license were required to call in for additional information. Subjects were then asked for their consent to participate in this study. After their verbal consent was provided, subjects were scheduled for the study per their convenience.

3.3 Study Procedure

A total of 10 focus group meetings were held between August 30, 2012 and September 16, 2012. The meetings were scheduled either on weekends or after regular office hours (after 5 p.m.) on weekdays. The focus groups met in the conference room in the FIU Engineering Center.

As participants of the focus groups gathered, their driver's licenses were checked to confirm their eligibility to participate in the study. To be eligible, participants need to have a valid U.S. driver's license and be 18 years or older. All the eligible participants were given the Informed Consent Form (ICF) to be signed and returned. The participants were given two sets of questionnaires: one for providing their demographic information and the other for answering the questions and writing down comments during the presentation. The questionnaires are provided in Appendix A. The demographic questions include the following:

- city of residence,
- gender,
- age,
- ethnicity,
- level of education,
- years of driving in the U.S.,

- frequency of driving on toll roads, and
- frequency of using public transit.

Table 3-1 gives the summary of demographic information of the participants. Table 3-2 gives the distribution of age, education level, frequency of driving on toll roads, and frequency of using public transit by gender.

Table 3-1: Demographic Information of Participants

Category	Frequency	Percentage
Gender		
Female	88	58.7
Male	62	41.3
Total	150	100.0
Age		
18 – 24 years	25	16.7
25 – 64 years	92	61.3
65+ years	31	20.7
Total[1]	148	98.7
Born in the U.S.		
Yes	75	50.0
No	74	49.3
Total[2]	149	99.3
Race and ethnicity		
Hispanic/Latino	80	53.3
White	37	24.7
Black	19	12.7
Others[3]	12	8.0
Total[1]	148	98.7
Level of education		
Up to high school	15	10.0
Some college	30	20.0
College degree	60	40.0
Advanced college degree	43	28.7
Total[1]	148	98.7
Frequency of driving on toll roads		
Never	8	5.3
Seldom	20	13.3
Sometimes	55	36.7
Often	65	43.3
Total[1]	148	98.7
Frequency of using public transit		
Never	64	42.7
Seldom	47	31.3
Sometimes	27	18.0
Often	10	6.7
Total[1]	148	98.7

[1] Two participants did not complete the demographics information.
[2] One participant did not answer the question.
[3] Others include Asian, South Asian, Middle Eastern, and mixed race people.

Table 3-2: Descriptive Statistics of Participants

	Male	Female
By Age Group		
Age 18-24	6	19
Age 25-64	37	55
Age 65+	17	14
Total	**60**	**88**
By Education Level		
Up to High School	6	9
Some college	10	20
College degree	24	36
Advanced college degree	20	23
Total	**60**	**88**
By Frequency of Driving on Toll Roads		
Never	1	7
Seldom	12	8
Sometimes	19	36
Often	28	37
Total	**60**	**88**
By Frequency of Using Public Transit		
Never	21	43
Seldom	21	26
Sometimes	13	14
Often	5	5
Total	**60**	**88**

Each focus group meeting was coordinated by one of the members of the research team and three other members served as note-takers and translators. For participants who do not understand English, the entire discussion was translated into Spanish by translators who sat one-on-one with the participants who needed translation. To document all the verbal discussion/responses from the participants, one member took notes. The notes included the participants' verbal comments and are incorporated in the analysis in Chapter 4.

The session coordinator first gave a brief introduction about the background of the research and the study objectives. The hybrid sign applications identified by the research group were then introduced to the participants using PowerPoint slides. The slides primarily included an introduction to hybrid signs, the proposed hybrid signs and their alternatives, typical layouts, and digitally edited photographs (see Appendix B for details). Participants were asked to evaluate the usefulness of each application and give comments/suggestions. For each application, a set of questions were asked to capture the participants' understanding of the signs. Then, a discussion was initiated on the sign's applicability, legibility, understandability, and preference.

Each focus group met for about 60-90 minutes. At the end of the focus group meeting, each participant received a $30 gift card as compensation to express appreciation for their time and contribution to the study.

CHAPTER 4
EVALUATION OF HYBRID SIGN APPLICATIONS

As mentioned in Chapter 3, a total of 10 applications were finalized and evaluated using ten focus group meetings. Five of the 10 applications are based on the concept of countdown timing. The drawbridge opening application is intended to improve safety of pedestrians and bicyclists on drawbridges, school zone traffic diversion and traffic diversion to avoid train crossing are intended to improve mobility and safety on arterial streets, arrival time information at bus/train stops is to serve transit riders, and train arrival information is to serve freeway drivers who would like to take a train. Travel time applications provide travel time information to major exits on freeways. Speed control applications are geared toward monitoring speeding and improving safety and mobility on arterial streets. Finally, parking availability information signs provide real-time information on parking availability in garages and on specific floors of each garage. The following sections discuss each of the 10 applications in detail. Results from the focus group study are presented in detail. Participants' comments and suggestions are also included.

4.1 Drawbridge Opening

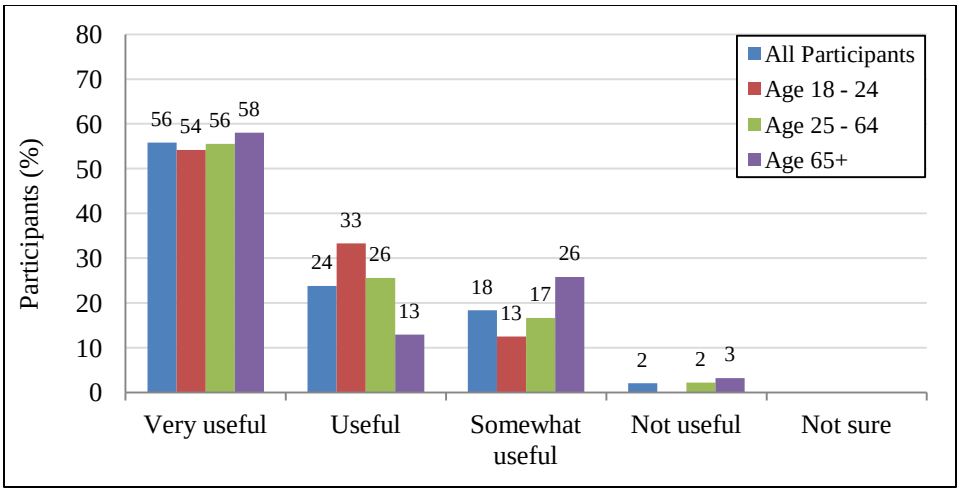
In South Florida, drawbridges that open for ships to cross are common. The existing static signs before approaching a drawbridge just convey a warning message that drawbridge is ahead. Even though vehicles are stopped by both signal and crossing gate just before drawbridge opening, this may not be helpful for pedestrians who could have already started crossing the bridge. There is currently no dedicated sign for pedestrians to inform them about the exact time the bridge will open.

A possible solution to this safety concern is to display a countdown timer to bridge opening primarily intended for pedestrians and bicyclists. A hybrid sign is designed such that the dynamic countdown timer is embedded in the static sign to convey the message "BRIDGE OPENS IN XX MIN". The countdown will start five minutes prior to the bridge opening, and the dynamic panel will display "00" when the bridge is open and till it is closed. Figure 4-1 shows the design and placement of the proposed hybrid sign. Appendix C lists the existing drawbridge locations in FDOT District 4 where this application could potentially be deployed.

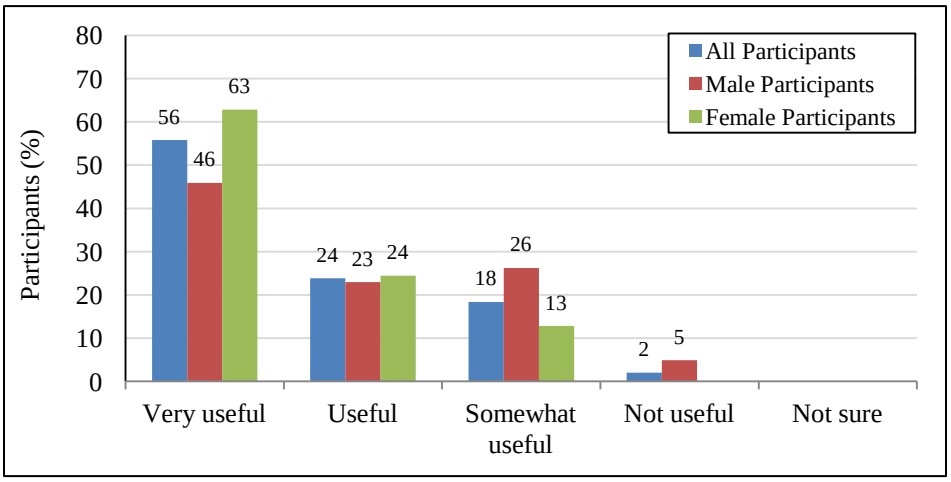
Figure 4-1: Proposed Hybrid Sign for Drawbridge Opening

Usefulness of Application

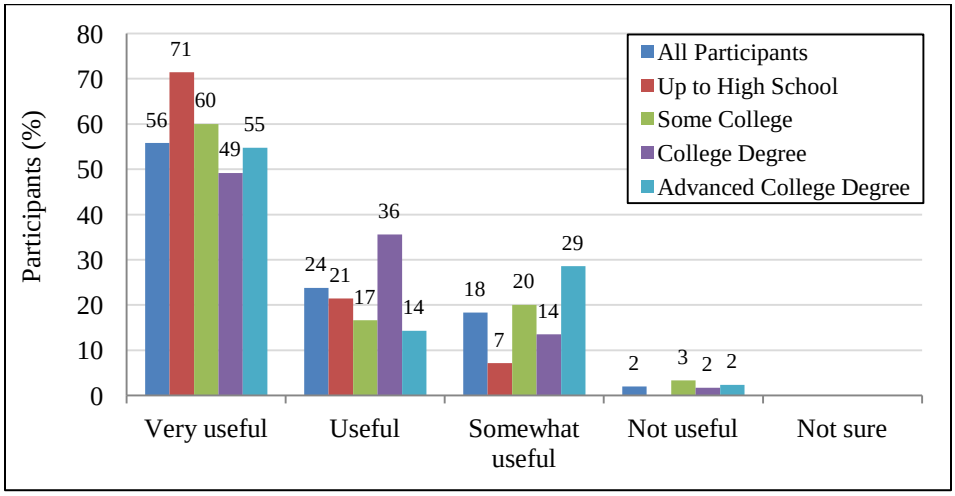
Figure 4-2 gives the usefulness rating of this application by age group, gender, and education level. A majority of participants rated the application as either very useful (56%) or useful (24%). The statistics are very similar for different age groups. Further, a greater percentage of females (63%) rated the application as very useful compared to 43% of males. On the other hand, a greater percentage of males considered the application to be either somewhat useful (26%) or not useful (5%), while a relatively low 13% of females considered the application as somewhat useful and no female considered it to be not useful. A majority of participants with lower education level (i.e., with high school or some college education) supported the application. Among the participants with advanced college degree, 31% considered the application as either somewhat useful or not useful.



(a) By Age Group



(b) By Gender



(c) By Education Level

Figure 4-2: Usefulness Rating of Drawbridge Application

Participants' Comments

Participants were asked to provide comments/suggestions about the application. The following are the selected responses from the participants.

- Replace the word "OPENS" in the sign with "RAISES" since some pedestrians might get confused by the word "OPENS" and think that the bridge is open to traffic.
- Add an image of a pedestrian on the sign for clarification.
- Use audio for mentioning the remaining time before the drawbridge is about to open.
- Add a cautionary warning and flashing light to the sign.
- In addition to the sign, add a pedestrian barrier for improved safety.
- The color of the numbers in the dynamic panel should be adjusted, preferably yellow or red.
- Some pedestrians use their cell phones; thus, are distracted and will pay little attention to the sign.
- Some pedestrians might think that they would be able to cross the bridge (e.g., when the countdown is about 1 minute), and then get stuck midway.
- The sign should be designed to allow time for slower/older people to cross the bridge.
- Place the sign in a conspicuous location.

Interpretation of Different Signs

Participants were asked to interpret the three signs shown in Figure 4-3. The three signs have the same static message, but the dynamic panels display different messages. In Figure 4-3(a), the dynamic panel shows "00", while in Figure 4-3(b) it is blank, and in Figure 4-3(c) the dynamic panel displays two dashes.

(a) **(b)** **(c)**

Figure 4-3: Drawbridge Application with Different Displays

Figure 4-3(a) will be displayed when the bridge is either about to open or already open, and pedestrians and bicyclists are not allowed to cross the bridge. Table 4-1 shows the frequency and percentage of different interpretations of this sign. From the table, it is found that a majority of participants correctly interpreted the sign as the bridge will open (60.6%) or the bridge is open (18.1%). On the other hand, only 12.9% of participants misunderstood the sign and incorrectly interpreted it as the bridge will not open (7.7%) or the bridge is closed (5.2%). Moreover, 5.8%

of the participants did not understand the sign and 2.6% thought that the sign is either broken or is turned off.

Table 4-1: Interpretation of the "00" Sign for Drawbridges

Interpretation	Frequency (Percentage)
Bridge will open	94 (60.6%)
Bridge is open	28 (18.1%)
Bridge won't open soon	12 (7.7%)
Do not understand/confusing	9 (5.8%)
Bridge is closed	8 (5.2%)
Sign is broken/off	4 (2.6%)
Total	**155 (100.0%)**[1]

[1] The total count is more than the number of participants (i.e., 150) since some participants provided more than one interpretation.

When the drawbridge is closed and pedestrians and bicyclists are allowed to cross the bridge, the dynamic panel in the hybrid sign could either be blank or show dashes, as shown in Figures 4-3(b) and 4-3(c). Table 4-2 gives the frequency and percentage of different interpretations of these signs. When the dynamic panel is blank, a majority of participants correctly interpreted the sign as the bridge will not open soon (34.4%) or the bridge is already closed (13.6%). Over one-third of the participants (33.8%) thought that the sign is off. In addition, a small percentage misunderstood the sign and incorrectly interpreted it as either the bridge will open (5.8%) or is already open (5.8%). Moreover, a small percentage (6.5%) did not understand the sign.

When the dynamic panel shows dashes, a majority of participants (26.5%) did not understand the sign and a similar percentage (25.9%) thought that the sign is either off or broken. Fewer participants correctly interpreted the sign as the bridge will not open soon (12.9%) or the bridge is closed (8.8%). From these responses, it could be inferred that the message "the bridge is closed or the bridge will not open soon" is correctly interpreted by a majority of participants when the dynamic panel is blank.

Table 4-2: Interpretation of the Blank and Dash Signs for Drawbridges

Interpretation	Frequency (Percentage)
When the Dynamic Panel is Blank	
Bridge won't open soon	53 (34.4%)
Sign is broken/off	52 (33.8%)
Bridge is closed	21 (13.6%)
Do not understand/confusing	10 (6.5%)
Bridge will open	9 (5.8%)
Bridge is open	9 (5.8%)
Total	**154 (100.0%)**[1]
When the Dynamic Panel Shows Dashes	
Do not understand/confusing	39 (26.5%)
Sign is broken/off	38 (25.9%)
Bridge will open	27 (18.4%)
Bridge won't open soon	19 (12.9%)
Bridge is closed	13 (8.8%)
Bridge is open	11 (7.5%)
Total	**147 (100.0%)**[2]

[1] The total count is more than the number of participants (i.e., 150) since some participants provided more than one interpretation.

[2] The total count of responses is less than 150 as some participants did not answer the question.

4.2 School Zone Traffic Diversion

Lower speed limit during school zone time period forces drivers to slow down, often forming long queues. Consequently, drivers often become impatient and careless imposing additional risk on pedestrians crossing the streets. A hybrid sign with countdown timer is therefore proposed to improve mobility and safety of road users in school zone areas during school zone time periods. Figure 4-4 shows the proposed sign that displays “SCHOOL ZONE STARTS IN XX MIN”, where XX indicates the countdown time to the start of the school zone. The purpose of this sign is to inform the drivers that the school zone period will start in a few minutes. This gives drivers an option to detour from the school zone area and thereby reduce traffic congestion at the school zones. To better serve the purpose, the sign has to be deployed three or four blocks upstream of the school zone area at all major roadways approaching the school zone. Additionally, this hybrid sign will be effective when placed at locations where there are alternative routes. Figure 4-5 shows the placement of the proposed hybrid sign on East Oakland Park Blvd, Broward County, FL.

Figure 4-4: Proposed Hybrid Sign for School Zone Traffic Diversion

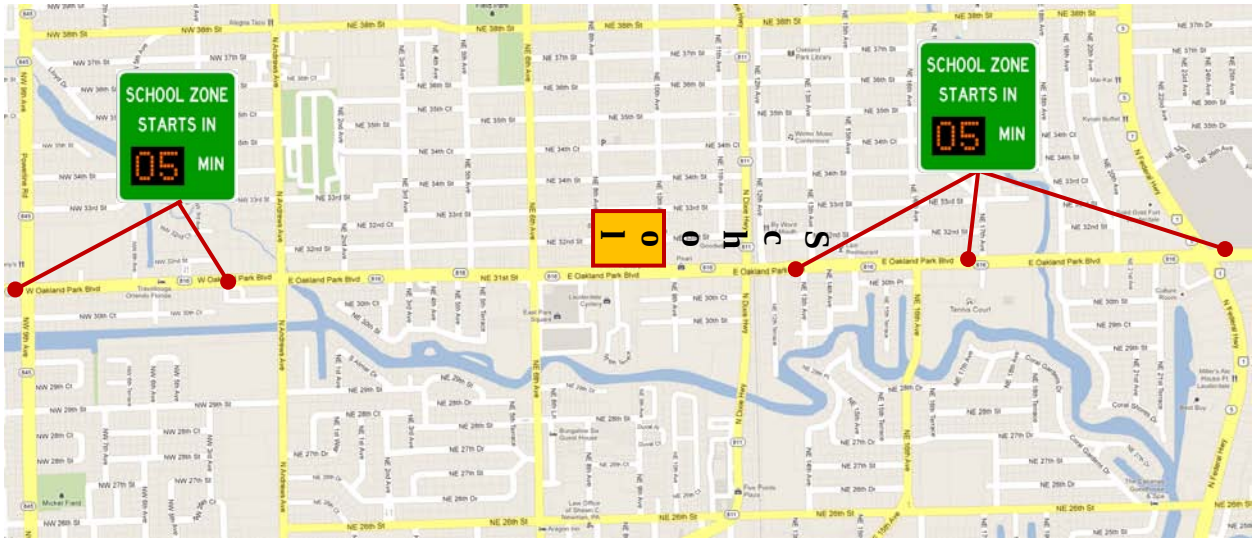
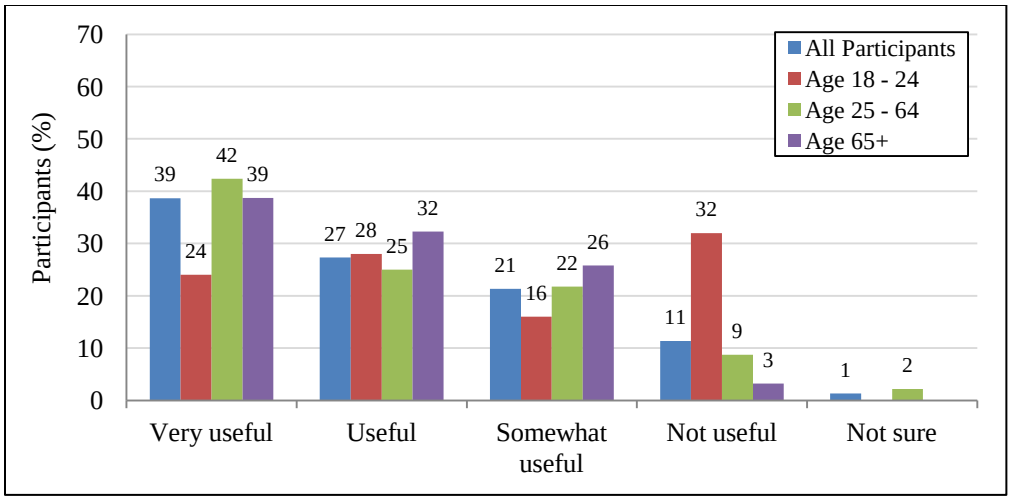


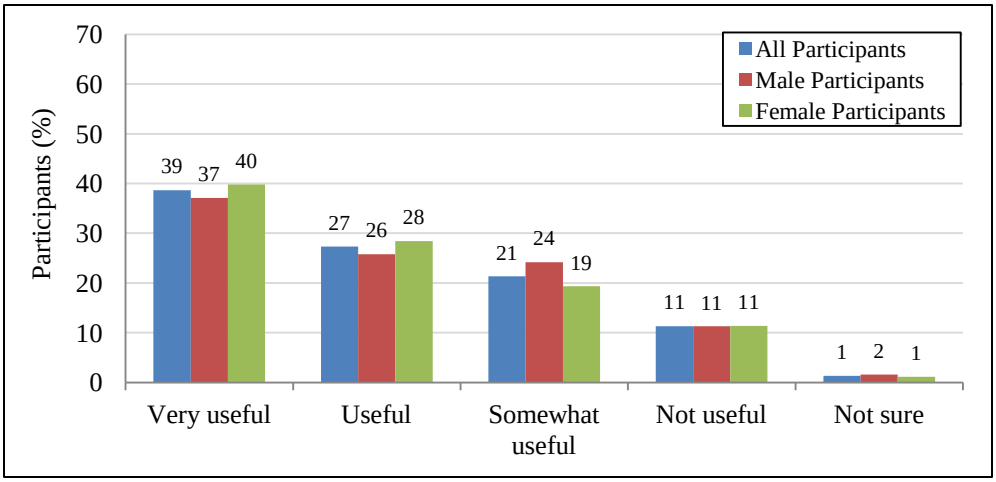
Figure 4-5: Potential Hybrid Sign Locations near a School Zone on East Oakland Park Blvd, Broward County, FL

Usefulness of Application

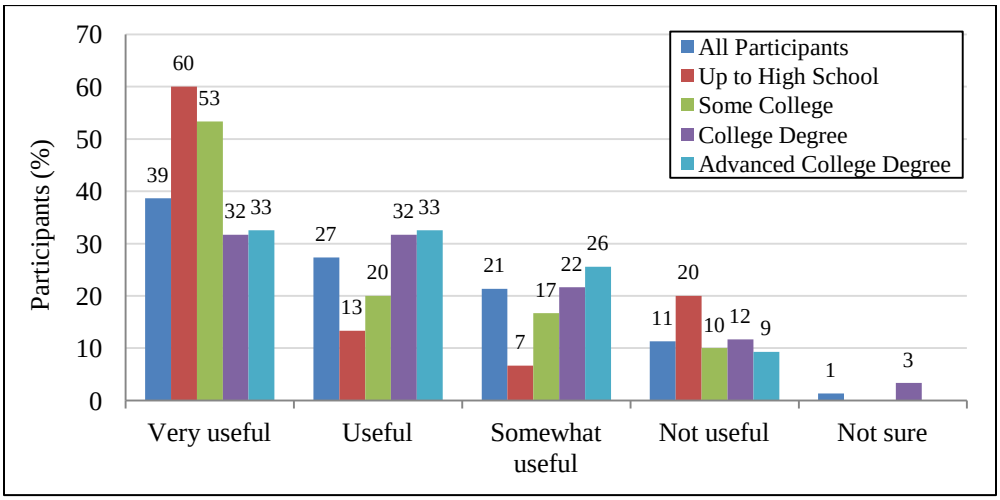
Figure 4-6 gives the usefulness rating of this application by age group, gender, and education level. A majority of participants rated this application as either very useful (39%) or useful (27%). It is also observed that the highest percentage of the middle age (age 25-64) and older participants (age 65+) rated the application as very useful at 42% and 39%, respectively. Interestingly, 32% of younger participants (age 18-24) rated the application as not useful. The figure also shows that 40% of female participants rated the application as very useful compared to 37% of male participants. Furthermore, a majority of participants with either high school or some college education rated the application as very useful. However, 20% of participants with high school education were unsure about the usefulness of this application.



(a) By Age Group



(b) By Gender



(c) By Education Level

Figure 4-6: Usefulness Rating of School Zone Traffic Diversion Application

Participants' Comments

Participants provided the following comments/suggestions about this application:

- The sign might cause drivers to speed up to beat the countdown time and increase the potential for crashes.
- Detouring route might get congested as a result of many vehicles diverting to it.
- Some detouring routes might be in residential neighborhoods with stop signs and the diverted traffic could increase crash risk and deteriorate safety in these neighborhoods.
- Add the word "AHEAD" to the sign to display "SCHOOL ZONE AHEAD STARTS IN XX MIN".
- The countdown timer should be started well ahead of 5 minutes.
- The countdown time should be flashing to better attract drivers' attention.
- Place the sign a few intersections before the school zone location.
- The sign is not required. Commuters are well aware of the school zone time period and can avoid the school zone at those times.
- The sign might be useful when alternative routes are available.
- Some areas may have multiple school zones, making detour to other roads impossible.
- All the drivers may not be familiar with detouring routes and get confused. The sign should use directional arrows to indicate available detouring options.

Preference for Different Alternatives

Three alternatives, as shown in Figure 4-7, were provided to the participants. The first alternative (Alternative A) displays the word "minutes" as "MIN", Alternative B displays "MINS", and the third alternative (Alternative C) spells out the entire word "MINUTES".

(A) **(B)** **(C)**

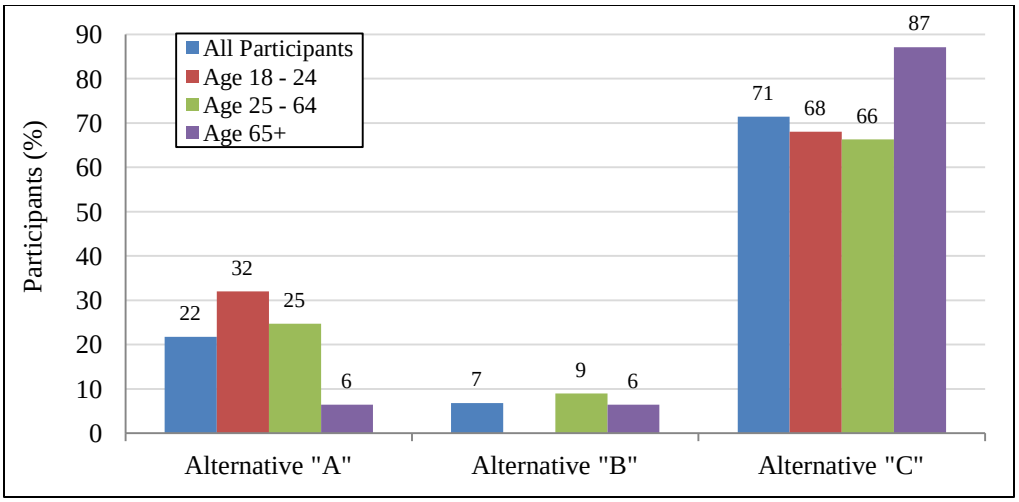
Figure 4-7: Alternatives for School Zone Traffic Diversion Application

Figure 4-8 shows participants preferences by age group, gender, and education level. Alternative C, with the word "MINUTES", was preferred by 71% of the participants. Following Alternative C, 22% preferred Alternative A (with "MIN"), and the remaining participants (7%) chose Alternative B (with "MINS"). The following are the reasons for preferring Alternative C:

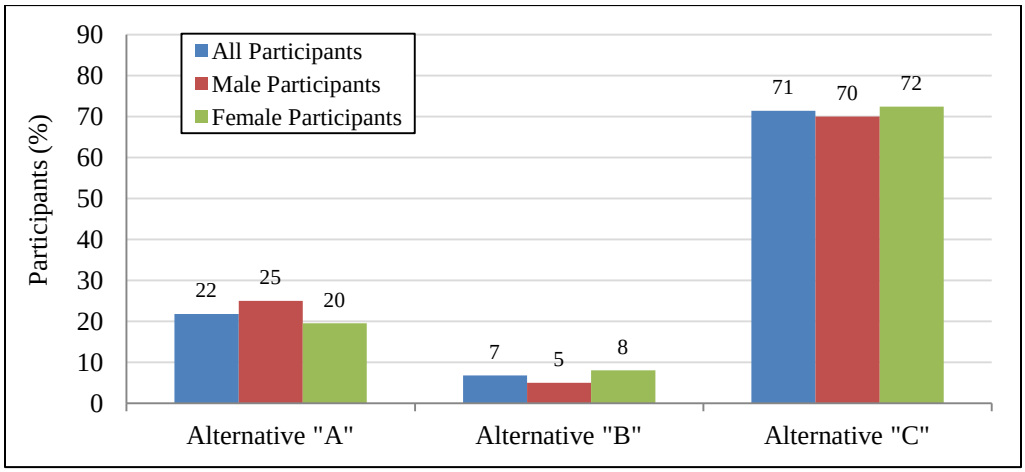
- It is clearer as it is spelled out.
- The entire word "MINUTES" should be useful for international visitors who are not familiar with abbreviations.

- "MIN" could be misunderstood as "Minimum" rather than "Minutes".
- "MINUTES" is easier to see from a long distance compared to "MIN" and "MINS".

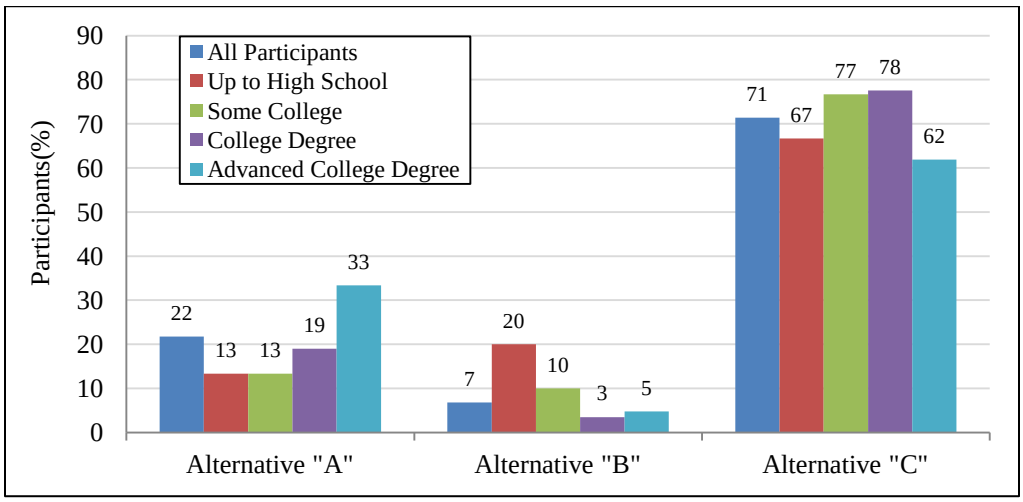
A high 87% of older participants preferred Alternative C. Younger participants were split between Alternative C (68%) and Alternative A (32%). A slightly higher percentage of females (72%) preferred Alternative C compared to males (70%), and this trend is reversed for Alternative A; 25% of males preferred Alternative A compared to 20% of females. At least 62% of participants from all education levels preferred Alternative C. Among the other two alternatives, 33% of participants with advanced college degree preferred Alternative A, while 20% of participants with high school education preferred Alternative B.



(a) By Age Group



(b) By Gender



(c) By Education Level

Figure 4-8: Preference of Alternatives for School Zone Traffic Diversion Application

4.3 Traffic Diversion to Avoid Train Crossing

Train crossings at major arterials often create traffic backups that could extend to multiple street blocks. Drivers are usually unaware of the exact time a train crossing will occur and are often trapped for a prolonged period of time. A hybrid sign with a countdown timer to train crossing placed on major arterials approaching the railroad crossing could help drivers detour. This application could reduce delays and improve mobility at locations with train crossings.

A hybrid sign, as shown in Figure 4-9, is designed to display "TRAIN CROSSES IN XX MIN", where XX indicates the countdown time to the train crossing. Figure 4-10 shows an example of the placement locations of this sign on the streets leading up to the railroad crossing on Hollywood Blvd, Broward County, FL. Note that this hybrid sign will only be effective when placed at locations where there are alternative routes to detour.

Figure 4-9: Proposed Hybrid Sign for Diversion to Avoid Train Crossing

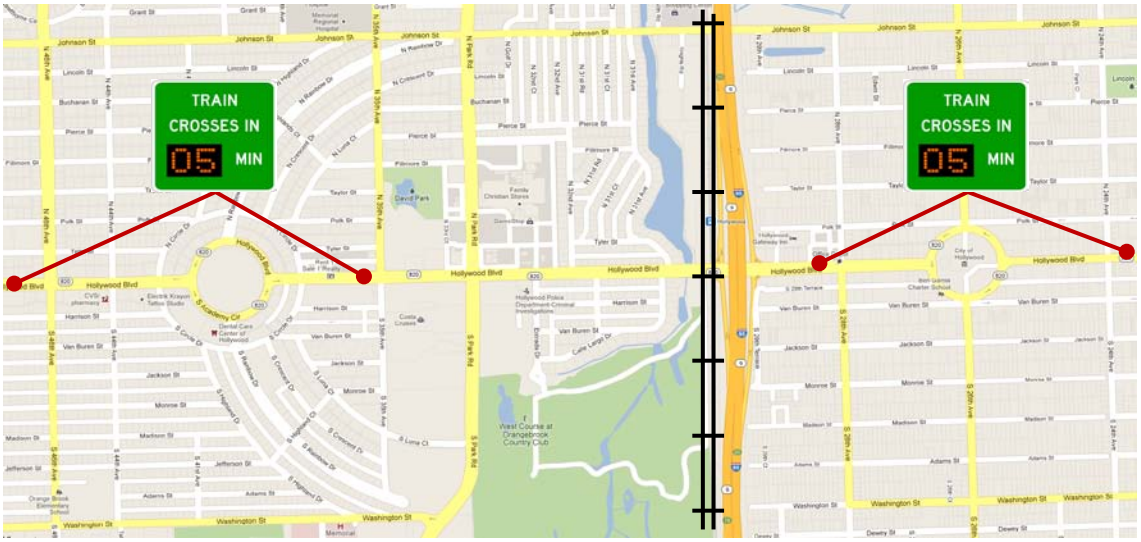


Figure 4-10: Demonstration of Placement of Hybrid Sign for Traffic Diversion to Avoid Train Crossing on Hollywood Blvd, Broward County, FL

Usefulness of Application

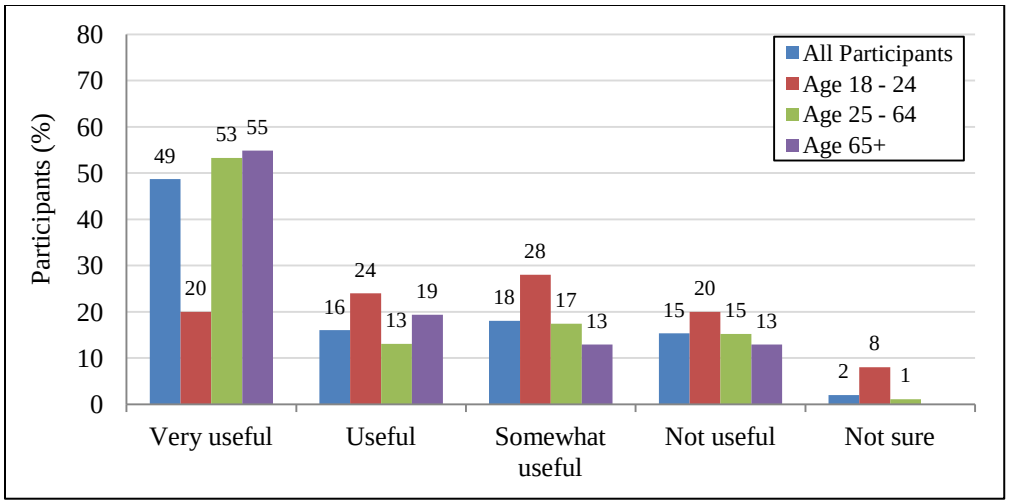
As this application is similar in concept to the school zone traffic diversion hybrid sign, participants were only asked to rate the usefulness of this application. Figure 4-11 gives the usefulness rating of this application by age group, gender, and education level. A majority of participants (49%) rated the application as very useful. Only 20% of younger participants (age 18-24) rated this application as very useful; the percentages of younger participants were also similar for useful (24%), somewhat useful (28%), and not useful (20%) ratings. Moreover, a majority of participants in middle and older-age groups (ages 25-64 and 65+, respectively) considered this application to be very useful.

Similar to the trend observed with ratings of the first two applications, a greater percentage of females rated this application as very useful (50%) compared to males (47%). Again, similar to the first two applications, a majority of participants with either high school or some college education supported this application (i.e., rated this application as either very useful or useful). Among the participants with advanced college degree, 49% considered the application as very useful and 23% as not useful.

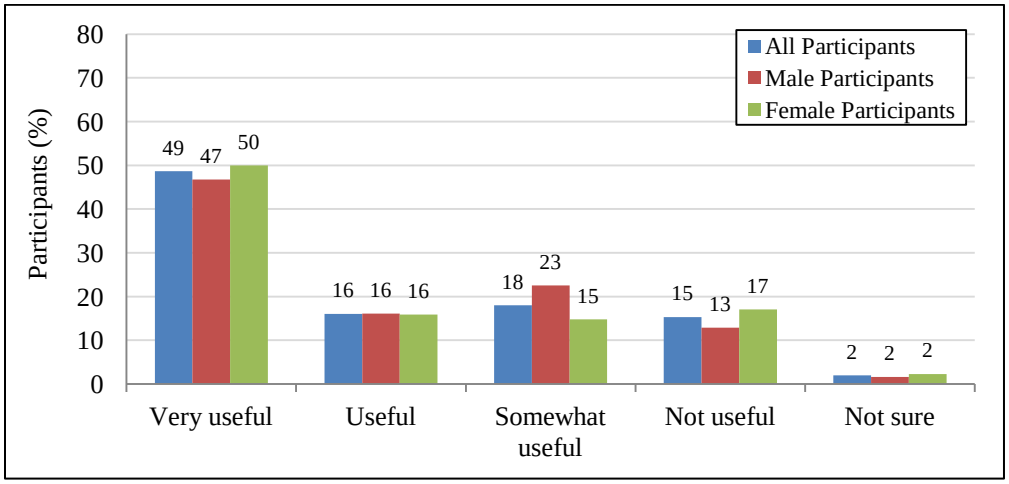
Participants' Comments

Useful comments/suggestions about this application are as follows:

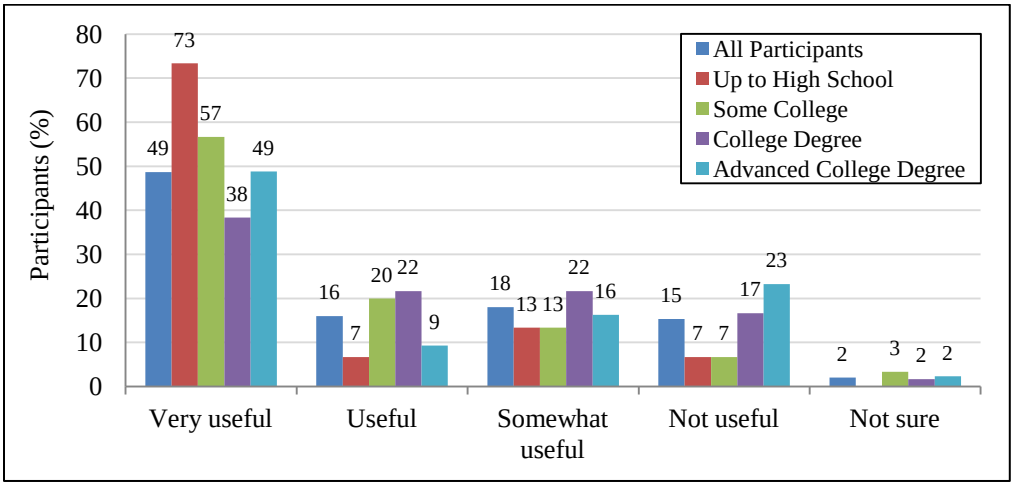
- Spell out "MINUTES".
- Add the word "AHEAD" to the sign to display "TRAIN CROSSES AHEAD IN XX MIN".
- Add flashing lights and audio components to this sign.
- The application might be useful only for longer trains.
- The sign might be useful when alternative routes are available and the signs are conspicuously placed and are relatively far from railroad crossing.
- The sign would be useful as long as real-time information is accurate and reliable.
- Place the sign only in areas where trains cross frequently.
- The sign might cause drivers to speed up to beat the countdown time and increase the potential for crashes.
- Drivers may not be familiar with detouring routes and get confused.
- Detouring routes might be congested because of excess diversion.



(a) By Age Group



(b) By Gender

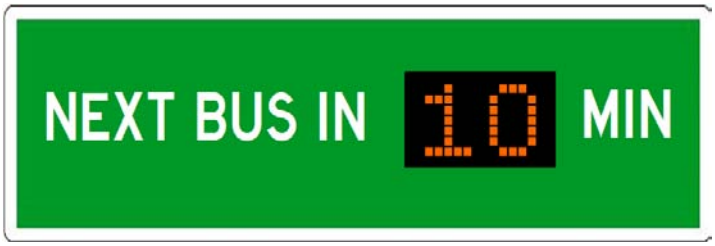


(c) By Education Level

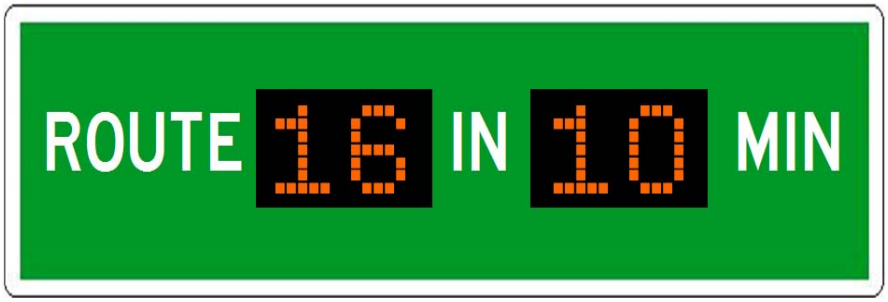
Figure 4-11: Usefulness Rating of Hybrid Sign Application for Train Crossings

4.4 Arrival Time Information at Bus/Train Stops

A majority of bus stops in Florida currently do not provide information on bus arrival time to the bus transit riders. On many occasions, lack of this arrival time information forces transit users to wait for longer-than-expected periods. This increases their anxiety, and reduces the convenience of using the public transit system; and hence, discourages public from using the service. A hybrid sign is therefore designed to display arrival time information at bus/train stops. As shown in Figure 4-12, the signs can be installed in bus stops serving either single (Figure 4-12(a)) or multiple destinations (Figure 4-12(b)).



(a) For Stops Serving Single Route



(b) For Stops Serving Multiple Routes

Figure 4-12: Hybrid Sign to Display Arrival Time Information at Bus/Train Stops

Usefulness of Application

Figure 4-13 gives the usefulness rating of this application by age group, gender, education level, and frequency of public transit use. Overall, a majority of participants rated this application as very useful; further, over 75% of middle and older-age participants (age 25-64 and 65+, respectively) rated the application as very useful. On the contrary, only 56% of younger drivers (age 18-24) considered this application as very useful. A possible explanation is that younger drivers might have access to real-time information through their smart phones and might not rely on the countdown time shown in the proposed hybrid sign.

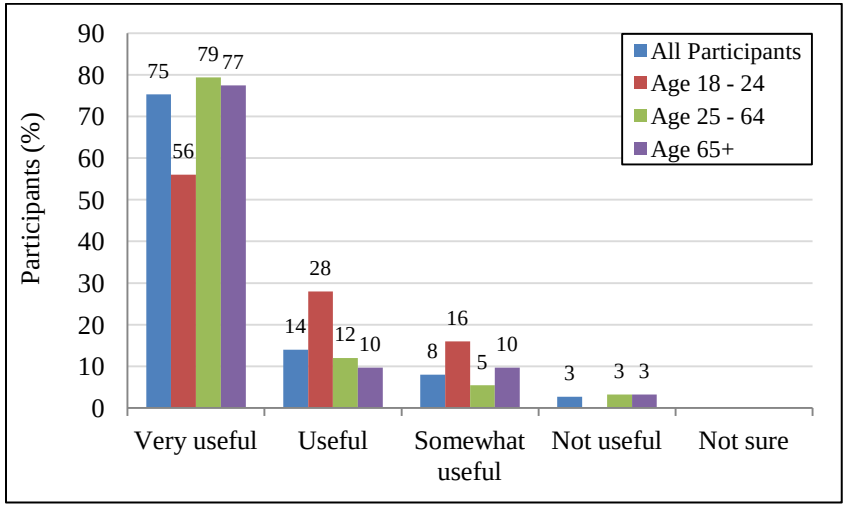
A greater percentage of females rated this application as very useful (77%) compared to males (73%). Additionally, a greater percentage of males rated this application as somewhat useful (11%) and not useful (5%), while the percentages of female participants were 6% for somewhat useful and 1% for not useful. A majority of participants within each education level rated this

application as very useful. Furthermore, participants with high school education rated the application as either very useful (87%) or useful (13%). Irrespective of their frequency of public transit use, a majority of participants in each of the four categories (i.e., participants who never, seldom, sometimes, or often use public transit) rated this application as very useful. Surprisingly, 10% of participants who often use public transit rated this application as not useful.

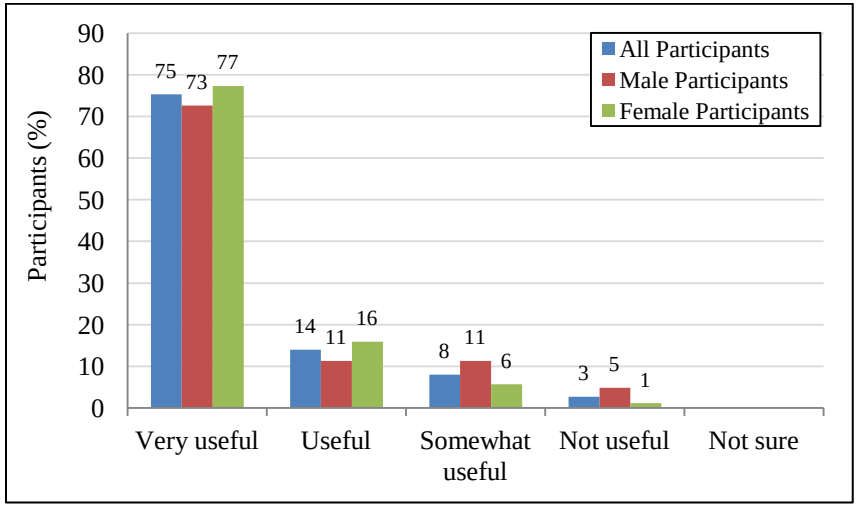
Participants' Comments

Useful comments/suggestions about this application are as follows:

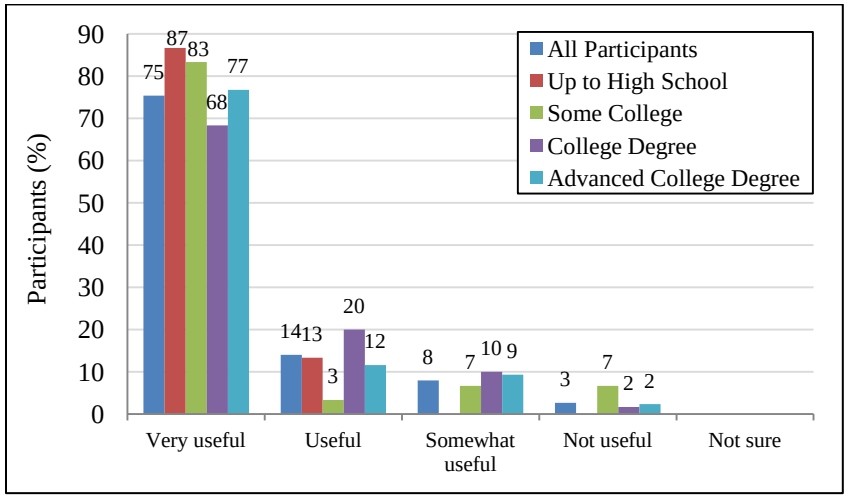
- The sign is useful as it lets people know when the bus will arrive and thus, people can have some coffee if time permits.
- The sign should be more useful for older people as younger people make use of the new technology, such as smart phones.
- Updates about the bus/train arrivals should also be incorporated in recent smart phone applications.
- Sign maintenance should be provided in case vandals destroy these signs.
- For stops serving multiple routes, the sign should display the information for all the routes altogether at the same time.
- The sign can attract more people to use public transit if information is being provided accurately.
- Do not use the word "Route".
- It may help to have hours also, or some indication that there are no more trains for the night.



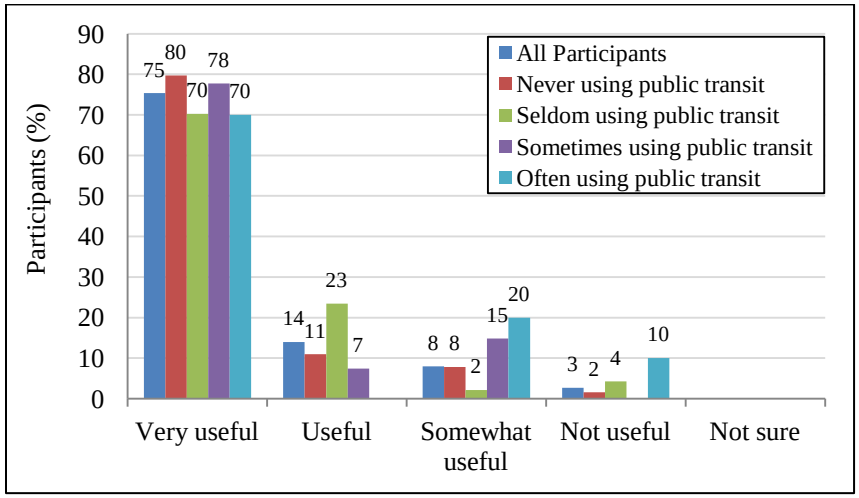
(a) By Age Group



(b) By Gender



(c) By Education Level



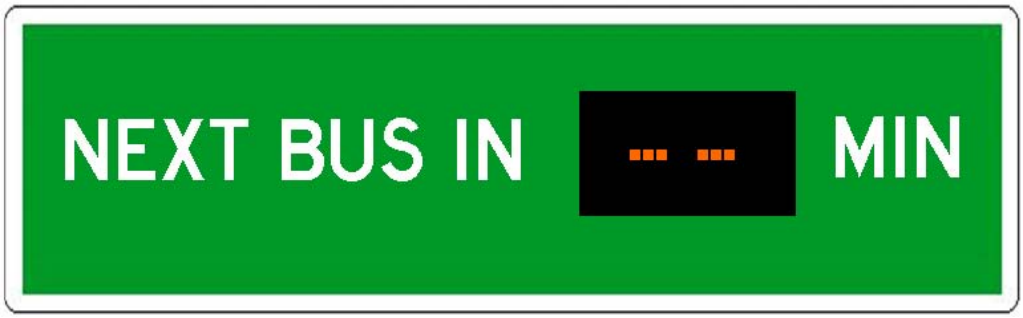
(d) By Frequency of Public Transit use

Figure 4-13: Usefulness of Hybrid Sign Application on Transit Arrival Time Information

Interpretation of Different Signs

When the bus is not scheduled to arrive anytime soon, the dynamic panel in the hybrid sign could either be kept blank or show dashes, as shown in Figures 4-14(a) and 4-14(b). Table 4-3 gives the frequency and percentage of participants' interpretations of these signs.

(a) Dynamic Panel is Blank



(b) Dynamic Panel Shows Dashes

Figure 4-14: Different Hybrid Signs at Bus Stops

When the dynamic panel is blank, a majority of participants (41.1%) interpreted the sign as being broken, 31.0% correctly indicated that the bus is not coming soon, 12.5% said the bus is not in service, 10.7% indicated that the information is not available, while a small percentage (4.8%) indicated that the sign is confusing.

When the dynamic panel shows dashes, only 21.4% correctly indicated that the bus is not coming soon. On the other hand, 28.3% thought that the information is unavailable, 26.9% interpreted the sign as being broken; 17.2% of participants found the sign to be confusing. The results indicate that it is better to show a blank dynamic panel when the bus is not coming soon. However, a high 41.1% of participants thought that this sign, with blank dynamic panel, is broken.

Table 4-3: Interpretation of the Blank and Dashes Signs at Bus Stops

Interpretation	Frequency (Percentage)
When the Dynamic Panel is Blank	
Sign is broken	69 (41.1%)
Bus is not coming soon	52 (31.0%)
Bus is not in service	21 (12.5%)
Information is not available	18 (10.7%)
Confusing	8 (4.8%)
Total	**168 (100.0%)**[1]
When the Dynamic Panel Shows Dashes	
Information is not available	41 (28.3%)
Sign is broken	39 (26.9%)
Bus is not coming soon	31 (21.4%)
Confusing	25 (17.2%)
Bus is not in service	9 (6.2%)
Total	**145 (100.0%)**[2]

[1] The total count is more than the number of participants (i.e., 150) since some participants provided more than one interpretation.
[2] The total count of responses is less than 150 as some participants did not answer the question.

4.5 Train Arrival Time Information on Freeways

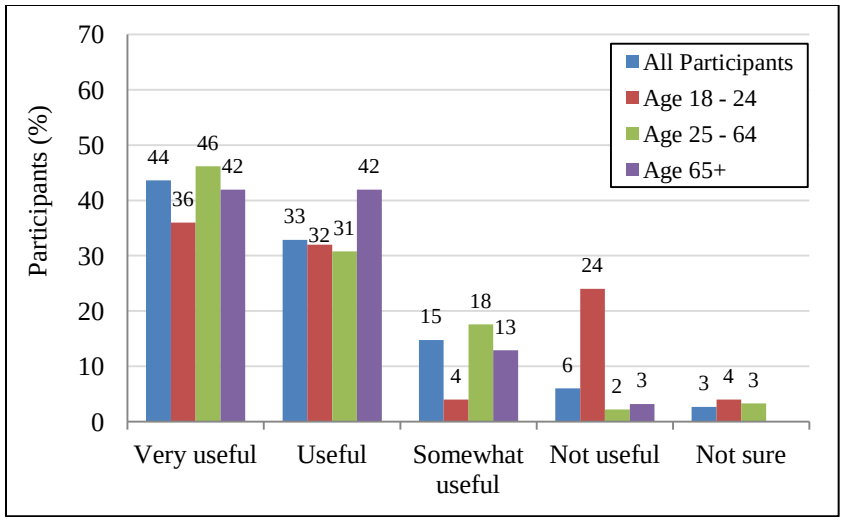
Freeways in Florida currently have static signs to inform drivers about the existing train park-and-ride facilities. However, these existing signs do not provide arrival time information of trains. Adding this information to the existing signs might help motorists make a better decision whether to directly go to the park-and-ride facility or to run some errands, such as filling up gas if time permits. Hybrid sign can be used to provide arrival time information of the next train in countdown setting, as shown in Figure 4-15 for the Tri-Rail service.

Figure 4-15: Proposed Hybrid Sign for Providing Tri-Rail Arrival Time Information on Freeways

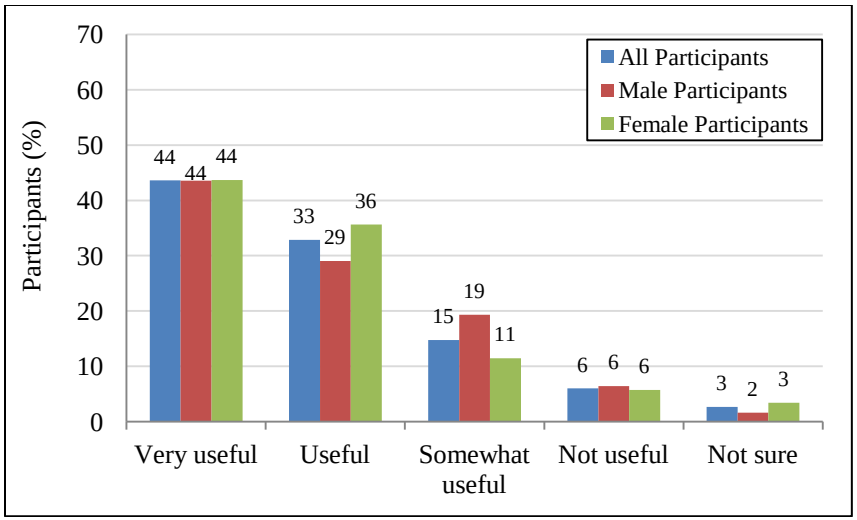
Usefulness of Application

Figure 4-16 gives the usefulness rating of this application by age group, gender, education level, and frequency of public transit use. A majority of participants (44%) rated the application as very useful. A relatively greater percentage of middle and older-age groups (ages 25-64 and 6%+, respectively) rated the application as very useful. Just over one-third (36%) of younger participants (age 18-24) rated the application as very useful, while 24% of younger participants considered this application as not useful. Among the older participants (age 65+), a high 84% rated the application as either very useful or useful. Equal proportion (44%) of males and females rated the application as very useful. However, the percentage differed for the "Useful" and "Somewhat useful" ratings; 29% of males rated the application as useful compared to 36% of females, and 19% of males rated as somewhat useful compared to 11% of females.

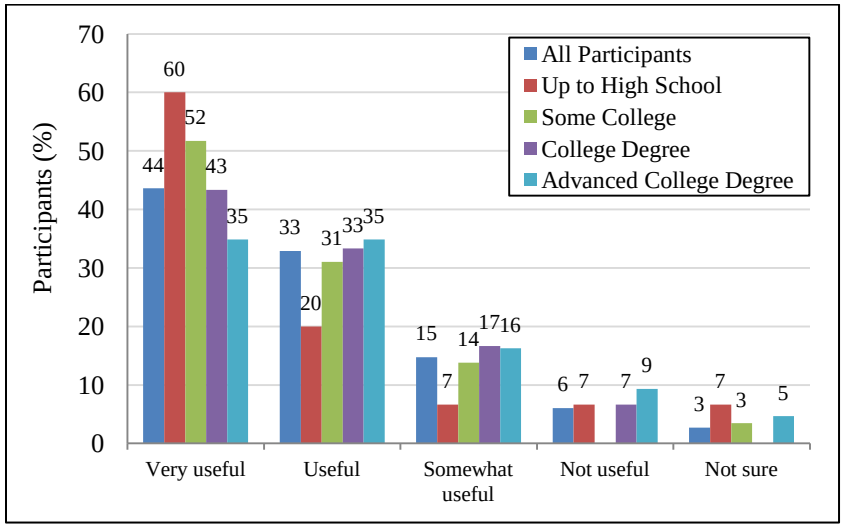
A majority of participants with high school education (60%) rated this application as very useful. Among the participants who often use public transit, a majority rated the application as either very useful (40%) or useful (30%), while the remaining 30% rated it as somewhat useful. None of the participants who often take public transit considered this application as not useful. Furthermore, a majority of participants who rated the application as not useful use public transit only sometimes.



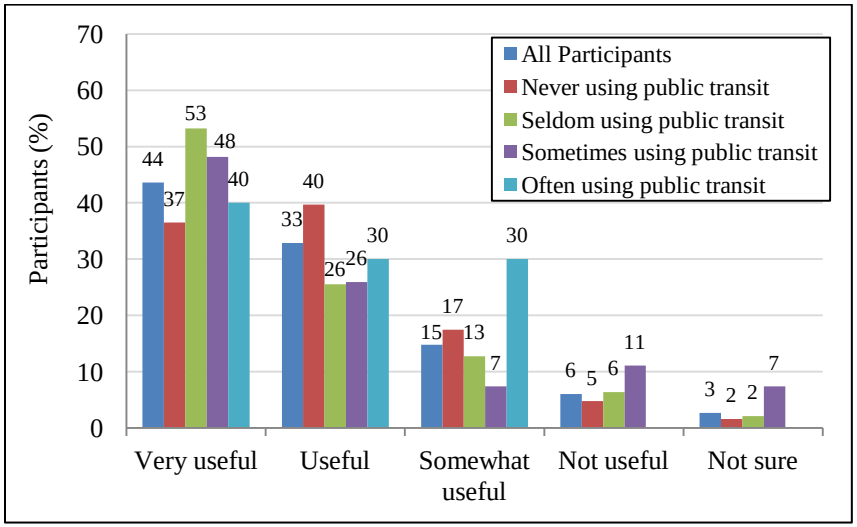
(a) By Age Group



(b) By Gender



(c) By Education Level



(d) By Frequency of Public Transit Use

Figure 4-16: Usefulness of Hybrid Sign Application for Providing Train Arrival Time Information

Participants' Comments

The following are the comments/suggestions about the application.

- The sign might not be useful to most drivers who are not transit users.
- Drivers might rush to catch the train and this could increase the potential for crashes.
- The signs need to be functioning properly and should not confuse drivers.
- The sign should add information about southbound train arrival as well.
- There is too much information on the sign to digest.
- The sign does not provide information about parking, but only train arrival time.
- The static portion "Tri-Rail Park-and-Ride NEXT EXIT" takes a lot of room, whereas the actual important message (i.e., "NEXT NORTH BOUND TRAIN 12 MIN") in the lower portion is too small. Overall, the sign should be bigger in size so that it can be seen from a distance.

Interpretation of Blank Dynamic Panel

The proposed hybrid sign will display the blank dynamic panel (shown in Figure 4-17) when the arrival time information of Tri-Rail is unavailable. Table 4-4 gives the frequency and percentage of different interpretations of this sign. A majority of participants (40.5%) said that the sign is broken, 36.6% indicated that the train is not coming soon, and only 11.8% correctly indicated that the information is unavailable. Further, several participants thought that the Tri-Rail train is broken down (5.9%) or train is already at the station (5.2%). Unlike for other applications, none of the participants indicated that the sign is confusing.

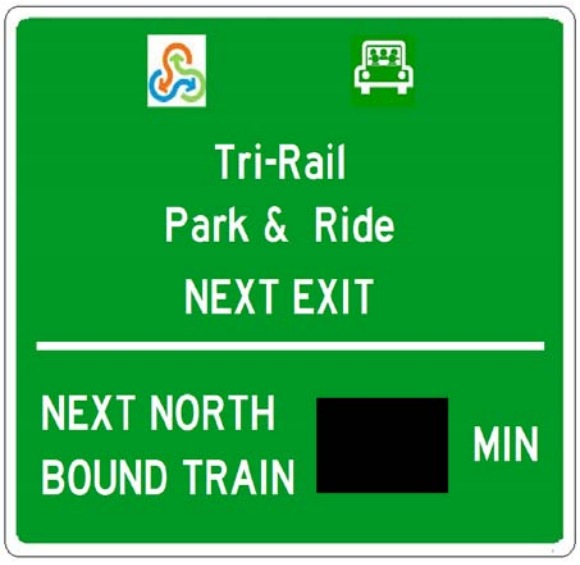


Figure 4-17: Hybrid Sign for Tri-Rail Arrival Time with a Blank Dynamic Panel

Table 4-4: Interpretation of the Blank Sign for the Tri-Rail Arrival Time

Interpretation	Frequency (Percentage)
Sign is broken	62 (40.5%)
Train is not coming soon	56 (36.6%)
Information is not available	18 (11.8%)
Train is broken	9 (5.9%)
Train is at station	8 (5.2%)
Total	**153 (100.0%)**[1]

[1] The total count is more than the number of participants (i.e., 150) since some participants provided more than one interpretation.

4.6 Travel Times on Distance Signs

Travel times are currently displayed on overhead DMS when no other important information, such as information on work zones, lane closures, etc., has to be displayed. While the SunGuide software does not currently provide accurate travel times under incident conditions, there have been efforts to develop algorithms that will predict incident durations; thus, making travel times available during these conditions. However, such travel times will not and cannot be displayed during incidents as the existing DMS would be used to display other related messages. This will create a situation in which travel times are not available when they are most needed, and are available only when traffic is free flowing and travel times are very much predictable.

A potential solution to this concern is to utilize the existing "interchange sequential" distance signs to show appropriate travel times to destinations by incorporating LED panels. With the relative distance and real-time travel time information to different exits/destinations, drivers can determine if any roadway segment is congested and decide whether to take an alternative route. Moreover, travel time information on these hybrid signs will be available throughout the entire day. Since travel time estimation requires traffic volume and speed data from loop detectors and cameras, these hybrid signs could only be deployed where the necessary infrastructures are available. Figure 4-18 shows the placement and design of the proposed hybrid sign. Appendix D lists the existing interchange sequential sign locations along I-95 and I-595 in FDOT District 4 that have the necessary infrastructures to estimate travel times to the destinations being displayed on these signs. For the purpose of travel time estimations, the appendix also identifies the number of available detectors between a sign location and each destination displayed on the sign.

Usefulness of Application

Figure 4-19 shows the usefulness rating of this application by age group, gender, and education level. This application was rated as very useful by 54% of participants. Compared to participants in middle and older age groups (ages 25-64 and 65+, respectively), only 44% of younger participants (age 18-24) considered this application as very useful. A significant percentage of younger participants (4%) were not sure about the usefulness of this application. Among the participants from older age groups, 84% considered the application as either very useful or useful. Over 70% of participants from each age group found this application as either very useful or useful.

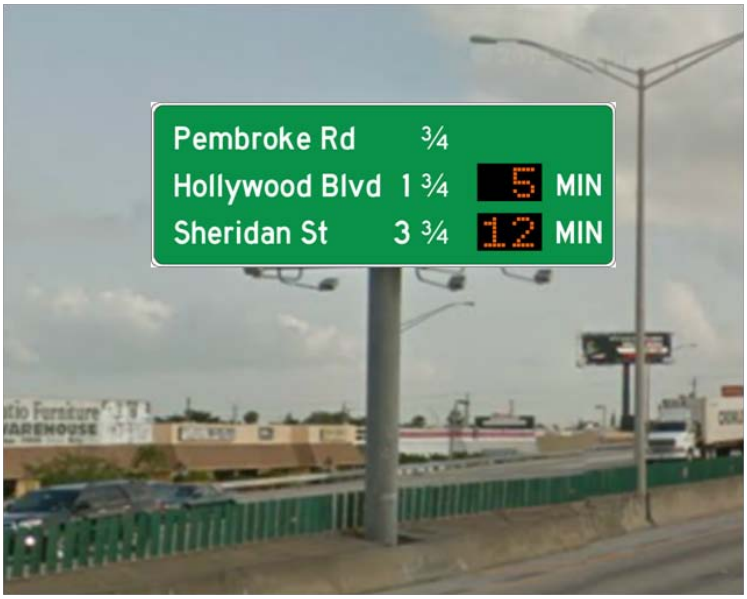


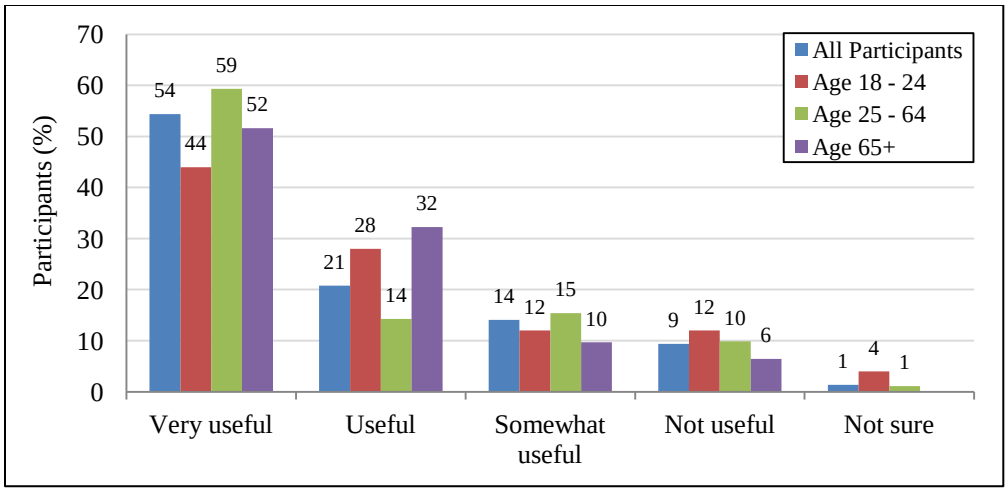
Figure 4-18: Proposed Hybrid Sign for Displaying Travel Time

A relatively high 62% of female participants thought that the application is very useful compared to 44% of male participants. A majority of participants with some college education (66%) rated this application as very useful while only 47% of participants with college degree rated it as very useful. This application was considered as not useful by 9% of all participants.

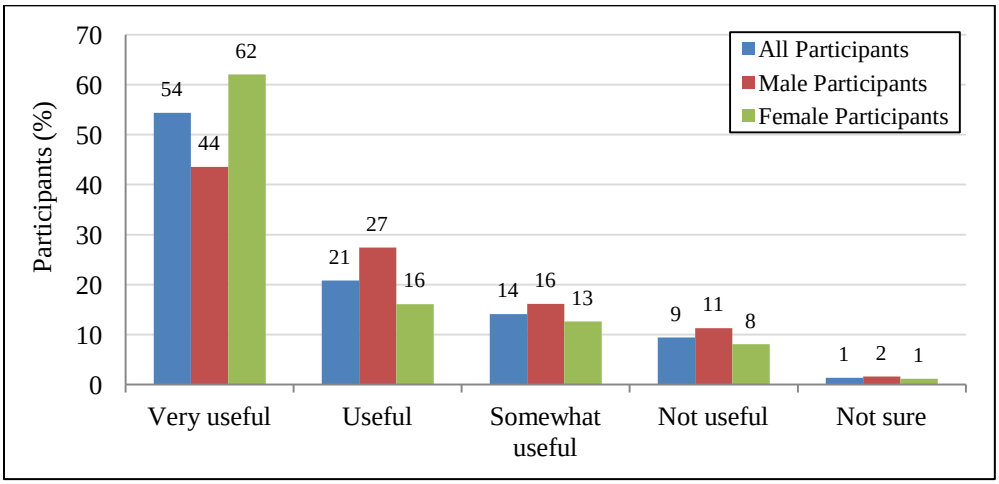
Participants' Comments

Participants provided the following comments/suggestions about this application:

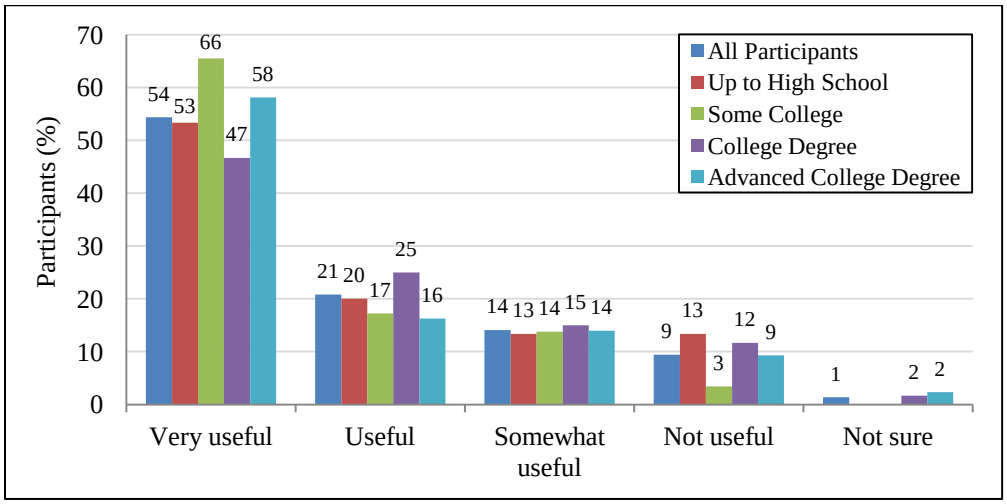
- The sign would be useful as drivers can have an idea on estimated travel times and could decide if they want to take a different route.
- The sign would only be useful when there is an incident ahead. During other times, commuters usually have a good idea on the time it takes to reach their destinations during peak and off-peak periods.
- The sign could include a dynamic panel at the bottom and display additional information on the type of incident.
- The panels should display travel times in different colors during congested time periods.
- The sign should replace the existing similar ones.
- Travel time information should be accurate.
- The sign has too much information and people will get distracted while reading the sign.
- Travel time information might be better if provided for longer distances.



(a) By Age Group



(b) By Gender



(c) By Education Level

Figure 4-19: Usefulness Rating of Travel Time Application

Interpretation of Different Signs

The proposed hybrid sign will not display travel time information when there is no information or when there is a mechanical failure. In such cases, the dynamic panel could either show dashes or be blank, as shown in Figure 4-20. Table 4-5 gives the frequency and percentage of different interpretations of this sign. When the dynamic panel is blank, about three-fourths of the participants (73.6%) assumed that the sign is broken. On the other hand, when the dynamic panel shows dashes, 41.1% thought that the sign is broken. When the dynamic panel is blank, 22.5% correctly thought that the information is unavailable, while the percentage was 38.8% when the dynamic panel shows dashes. Participants' interpretation that the time is being updated, could also be acceptable. Therefore, while only 26.4% made acceptable interpretations when the dynamic panel is blank, the percentage was relatively high at 59.0% when the panel shows dashes.

(a) Dynamic Panel is Blank

(b) Dynamic Panel Shows Dashes

Figure 4-20: Different Hybrid Signs for Travel Times on Distance Signs

Table 4-5: Interpretation of the Blank and Dashes Signs for Travel Time Display

Interpretation	Frequency (Percentage)
When the Dynamic Panel is Blank	
Sign is broken	95 (73.6%)
Information is not available	29 (22.5%)
Time is being updated	5 (3.9%)
Total	**129 (100.0%)**[1]
When the Dynamic Panel Shows Dashes	
Sign is broken	53 (41.1%)
Information is not available	50 (38.8%)
Time is being updated	26 (20.2%)
Total	**129 (100.0%)**[1]

[1] The total count of responses is less than 150 as some participants did not answer the question.

4.7 Comparative Travel Times for Express Lane Facilities

The existing signs on express lanes provide toll amount for traveling through the express lanes. However, in addition to the toll amount, drivers may need additional information such as travel times along express lanes and adjacent general-purpose lanes to better assess the need to/benefit of paying extra to use express lanes. A hybrid sign is therefore proposed to provide comparative travel times along express lanes and general-purpose lanes in addition to the toll amount on express lanes. Figure 4-21 shows the design of the proposed sign.

Figure 4-21: Proposed Hybrid Sign for Providing Comparative Travel Times for Express Lane Facilities

Usefulness of Application

Figure 4-22 shows the usefulness rating of this application by age group, gender, education level, and frequency of using toll roads. The percentages of participants in younger and middle age

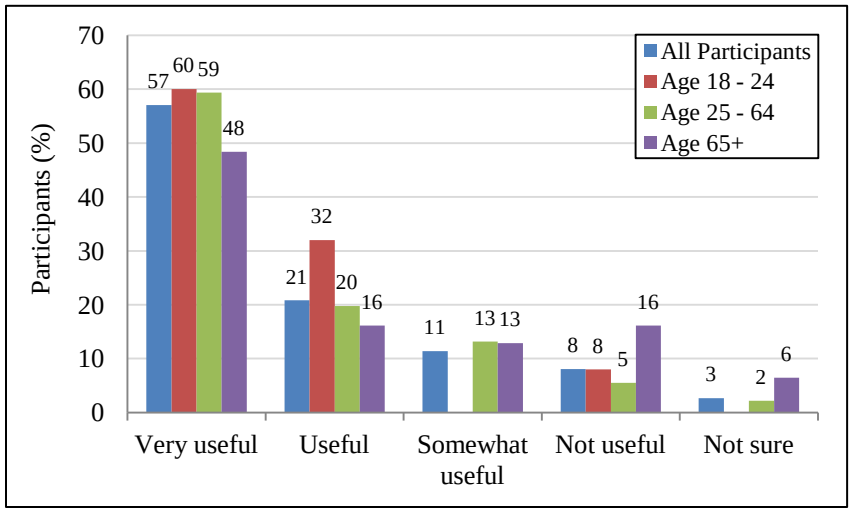
groups (ages 18-24 and 25-64, respectively) who rated the application as very useful were very similar (60% and 59%, respectively). Among the younger participants, 32% rated this application as useful while the remaining (8%) considered it as not useful. A relatively low percentage of older participants (48%) rated this application as very useful while 16% rated as not useful. The statistics show that this application is more appealing to younger participants. A greater percentage of females (64%) rated this application as very useful compared to 47% of males. Additionally, 11% of male participants considered this application as not useful compared to 6% of females.

Among the participants with different education levels, a relatively high 67% of participants with high school education rated this application as very useful. The rest of the participants in this group (i.e., with high school education) rated either useful (13%) or somewhat useful (20%). Participants with college degree least favored this application; only 50% rated very useful and a high 12% considered this application as not useful. Seven percent of participants with some college education were not sure about this application. A majority of participants who often use toll roads (65%) rated this application as very useful compared to 35% of participants who seldom use toll roads. One-fifth of the participants who seldom drive on toll roads considered this application as not useful. Similarly, 13% of participants who never use toll roads considered it as not useful.

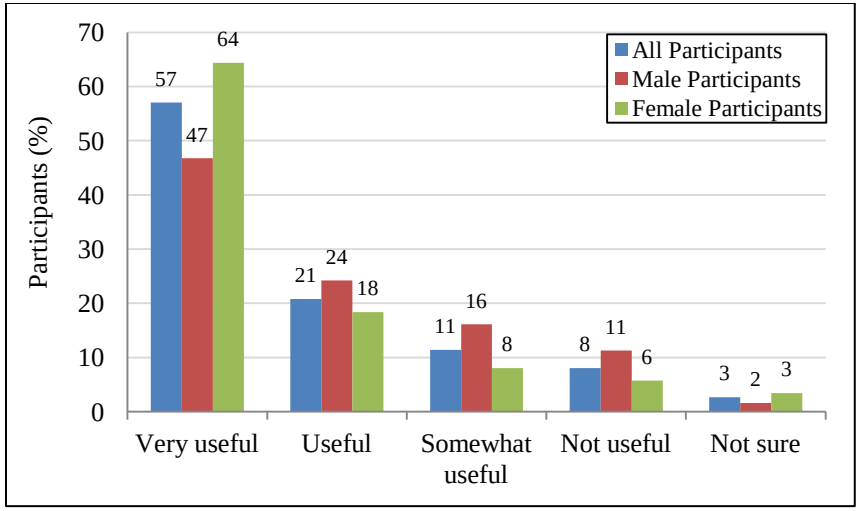
Participants' Comments

Participants provided the following comments/suggestions about this application:

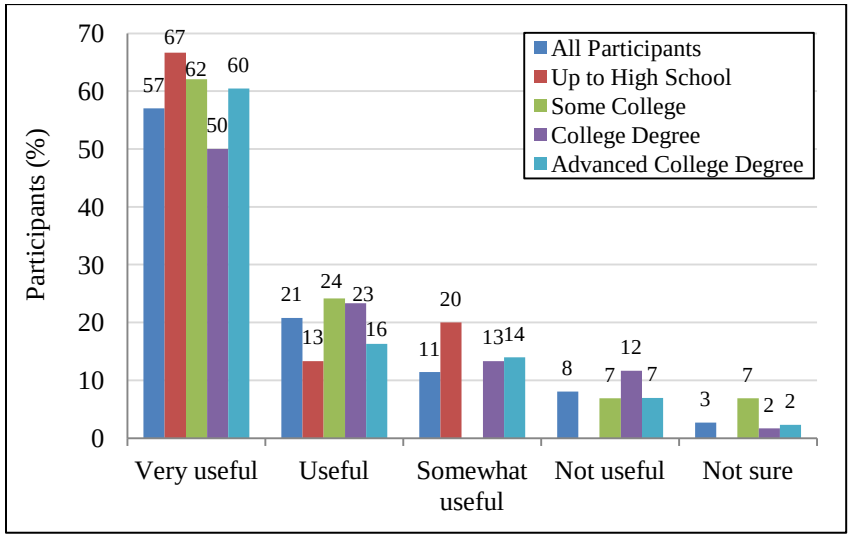
- The font should be bigger. The numbers have to be pretty clear.
- The sign should be placed at sufficient distance before entering the facility.
- The sign should be bigger so that drivers on the rightmost lane can see it clearly.
- The sign may be placed twice. So, if someone misses the first sign or couldn't comprehend the entire information, he/she can take another look.
- The information on the sign would help drivers better than the incident information on DMS.
- The sign would be helpful if it replaces the current toll sign. Otherwise, it would be distracting because there are already too many signs on highways.
- It might be better to just include the time saving in minutes.
- It may slow the traffic while reading the sign and may result in accidents.
- The sign should use Exit Number rather than destination name.
- Even though it is very useful, it is hard to perceive all the information while driving at a high speed.
- The travel time information should be accurate. Otherwise, drivers will not follow the sign.



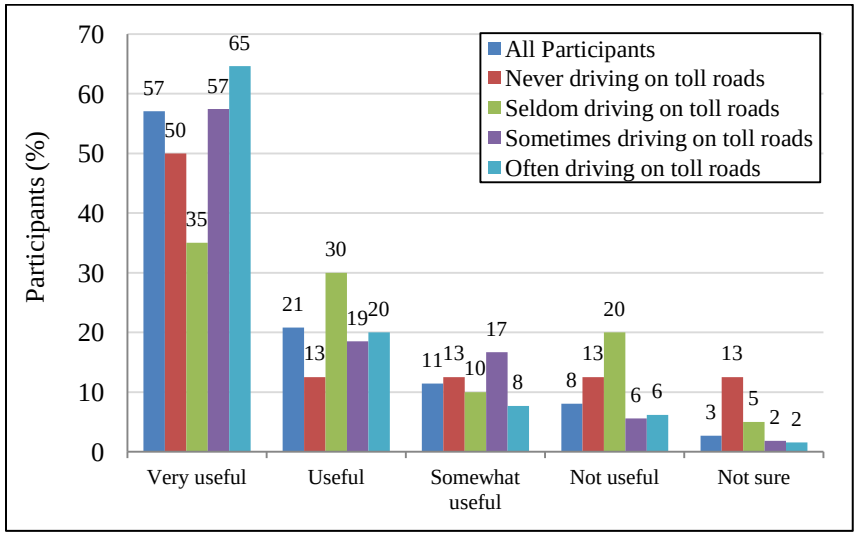
(a) By Age Group



(b) By Gender



(c) By Education Level



(d) By Frequency of Driving on Toll Road

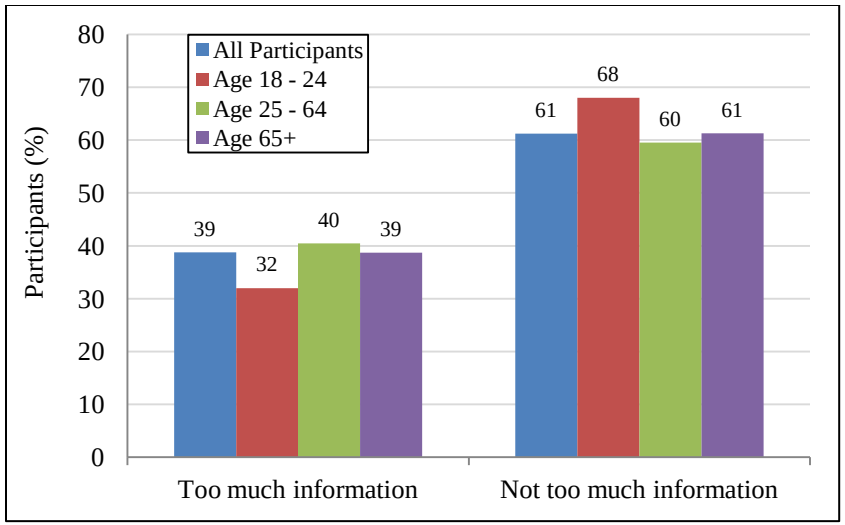
Figure 4-22: Usefulness Rating of Comparative Travel Times on Express Lane Facilities

Preference on Amount of Information on Sign

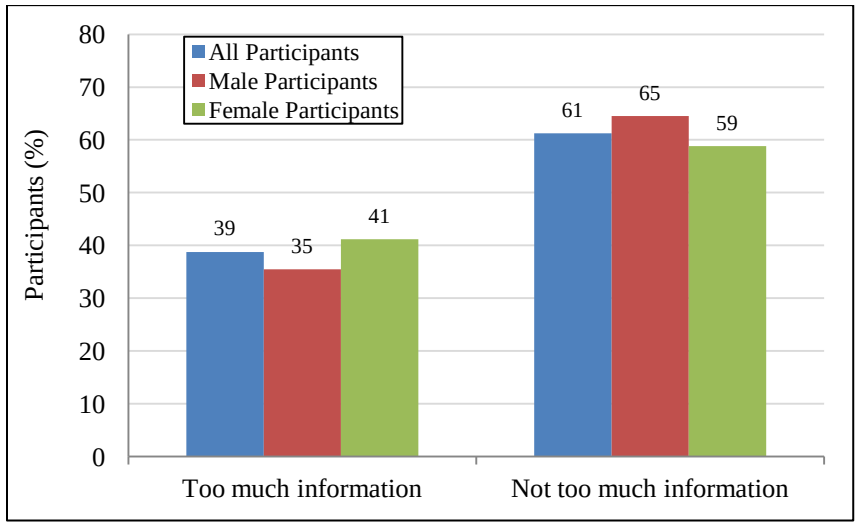
The proposed hybrid sign has information of toll amount on express lanes and travel times on both express lanes and general-purpose lanes. It may seem to some drivers that the entire information in one sign is a lot to read, comprehend, and respond in a short period of time. Therefore, participants' opinion about the amount of information included on the sign was gathered.

Figure 4-23 shows the participants' opinion on the amount of information displayed on the proposed sign by age group, gender, education level, and frequency of using toll roads. A majority of participants thought that there is not too much information on this sign. Especially, 68% of younger participants (age 18-24) thought that the sign is not overloaded with information. When analyzed by gender, 65% of males and 59% of females believed that the sign is not crowded with too much information.

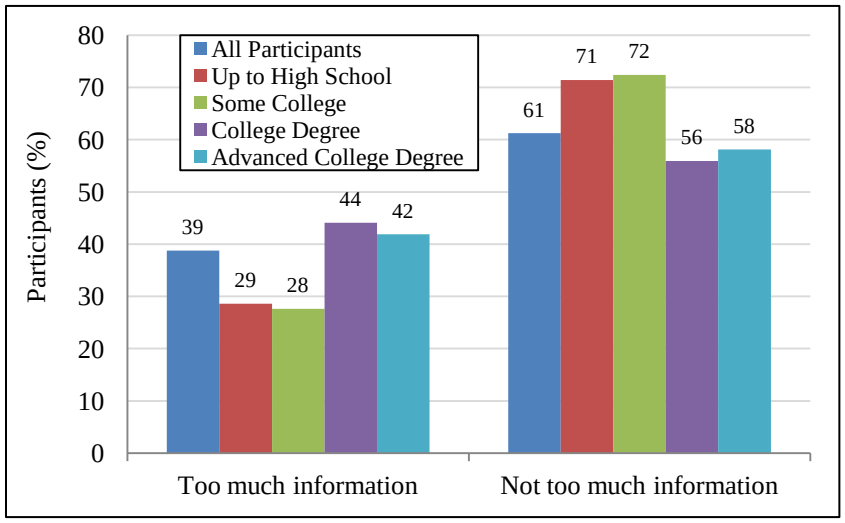
Interestingly, a majority of participants with either high school or some college education found the sign to be less complex. Also, at least 60% of participants from each of the groups, driving often, sometimes, and never on toll roads, thought that the sign did not have too much information. However, 60% of participants who seldom drive on toll roads thought that the sign contains too much information.



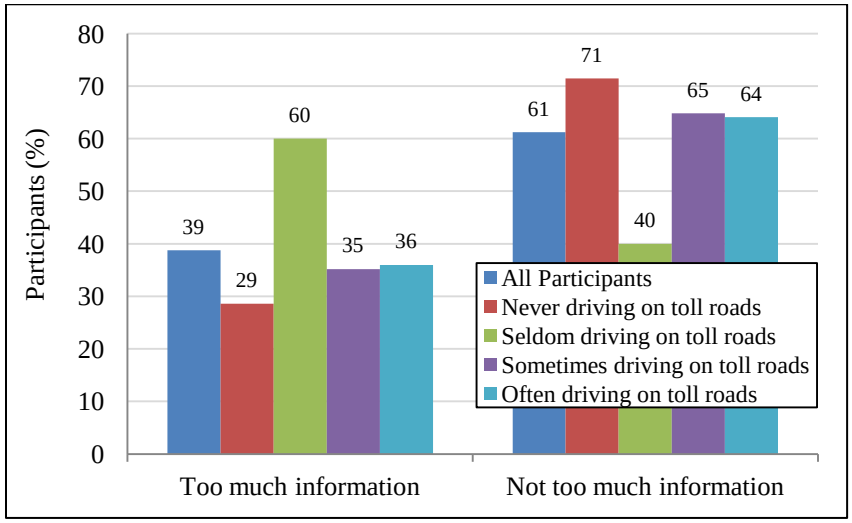
(a) By Age Group



(b) By Gender



(c) By Education Level



(d) By Frequency of Driving on Toll Road

Figure 4-23: Perception on the Amount of Information in the Hybrid Sign for Comparative Travel Times

Interpretation of Blank Dynamic Panel

The dynamic panel in the proposed hybrid sign will be blank (as shown in Figure 4-24) when the express lane facility is open to all types of traffic. However, it still may create confusion to drivers who might hesitate to use the facility if they do not correctly interpret the sign. Participants are therefore asked to interpret the sign when the dynamic panel is blank. Table 4-6 gives the frequency and percentage of participants' interpretations of this sign. The table shows that a majority of participants (72.3%) thought that the sign is out of order and approximately one-fourth (23.5%) thought that the information is not available. This indicates that the blank dynamic panels might cause confusion among drivers.

Figure 4-24: Blank Dynamic Panels in the Comparative Travel Time Sign

Table 4-6: Interpretation of the Blank Sign for Comparative Travel Times

Interpretation	Frequency (Percentage)
Sign is broken	86 (72.3%)
Information is not available	28 (23.5%)
Time is being updated	5 (4.2%)
Total	**119 (100.0%)[1]**

[1] The total count of responses is less than 150 as some participants did not answer the question.

Preference of Number of Signs to be Displayed

If displaying information on travel times on express lanes and general-purpose lanes and toll amount on one sign is considered to have too much information, the information could be split into two signs, i.e., toll rate in one sign and comparative travel times in another sign. Figure 4-25 shows an example of deploying two signs.

Figure 4-26 gives the participants' preference to either one or two signs by age group, gender, education level, and frequency of driving on toll roads. A majority of participants (59%) preferred one sign, while 31% preferred two signs, and 9% had no preference. This is consistent with the results shown in Figure 4-23 as 61% of participants thought that there is not too much information on this sign.

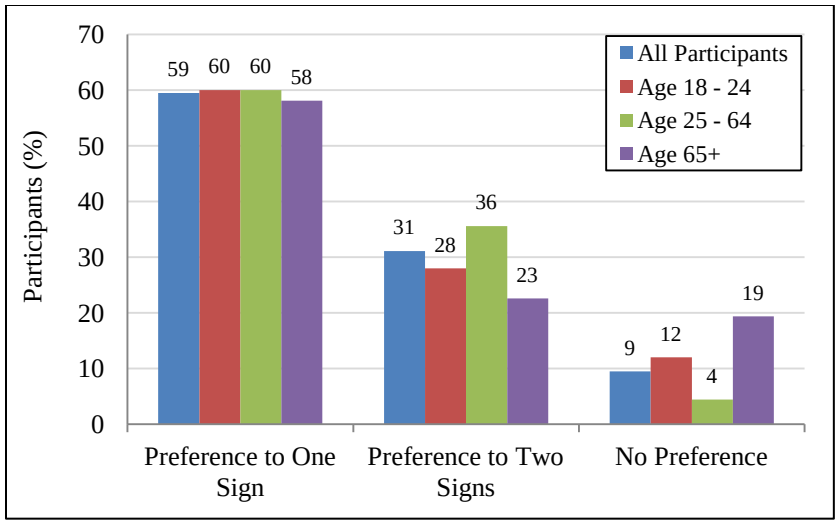
Figure 4-25: Comparative Travel Time and Toll Amount on Two Separate Signs

From Figure 4-26, it is observed that, about 60% of all participants preferred one sign. On the other hand, two signs were preferred by 36% of middle age participants (age 25-64), followed by 28% of younger participants (age 18-24), and 23% of older participants (age 65+). Compared to other age groups, a greater percentage of older participants (19%) had no preference.

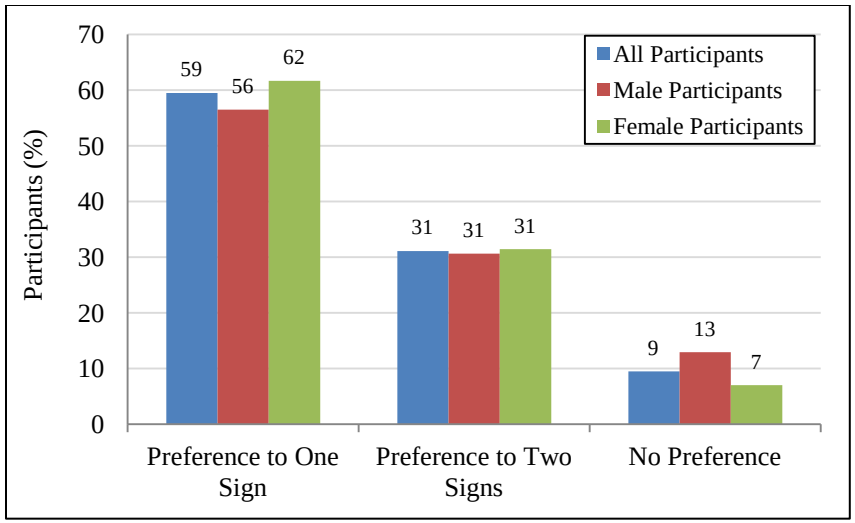
A slightly greater percentage of females (62%) preferred one sign compared to males (56%). On the other hand, 7% of females had no preference compared to 13% of male participants. It is observed that participants who have at least attended some college preferred to have all information on one sign. Only 43% of participants with high school education preferred to have all information on one sign. The statistics show that participants who are more familiar with toll roads preferred one sign. Also, as expected, a greater percentage of participants who never drive on toll roads (25%) had no preference.

In addition to their preference, participants provided their rationale behind their choice. Participants' comments and reasons for preferring all information on one sign are given below:

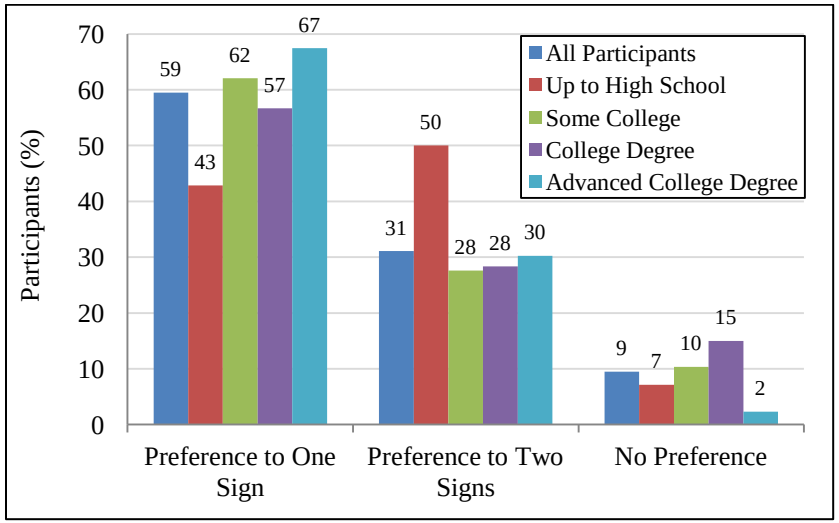
- It is easier to read and understand when the information is in one sign.
- It is simpler and less confusing to focus on one sign and make a decision; otherwise, in case of two signs, drivers have to remember the information left behind and then calculate the benefit.
- Single sign costs less than two signs.
- It is less distracting to have one sign because there are already too many signs on the highways.
- In the toll road sign, the words "NO TOLL" for free lanes can be removed.



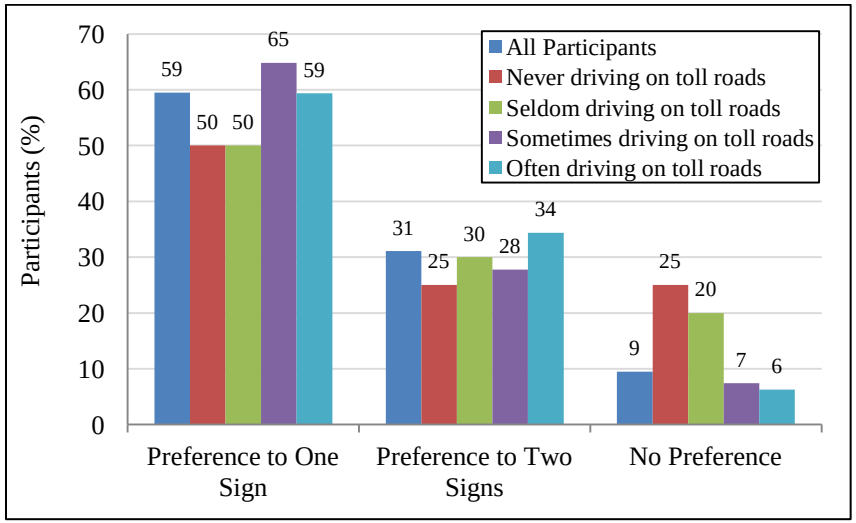
(a) By Age Group



(b) By Gender



(c) By Education Level



(d) By Frequency of Driving on Toll Road

Figure 4-26: Preference to Number of Signs

The following are the participants' reasons for preferring two signs:

- One can keep eye on the road because of less information to read at once.
- It is hard to read all the information from one sign while driving at higher speed on highways. Drivers do not have to reduce their speed to read the information when the information is displayed in two signs.
- Two signs should be placed on their respective lanes with travel time and toll amount information rather than separated by a quarter of a mile.
- Visitors (non-commuters) are more likely to miss one sign and cannot recall the information.

The following are the comments by participants who had no preference:

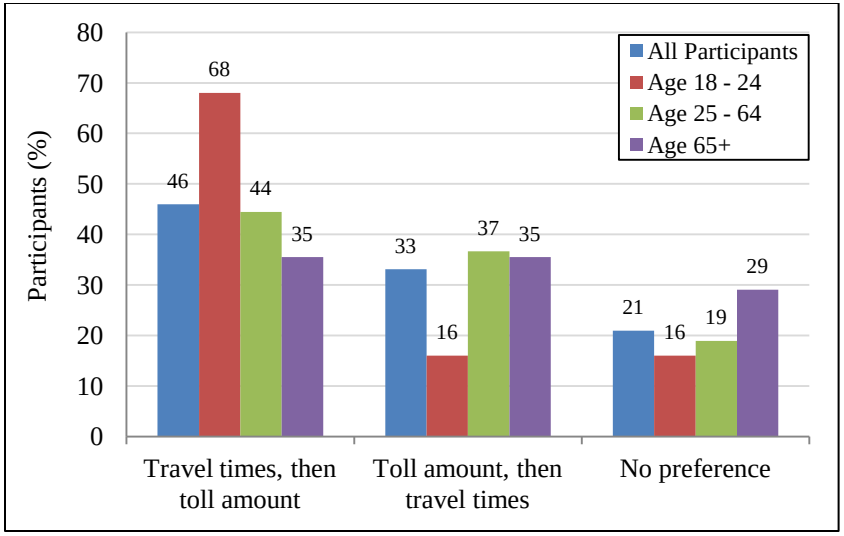
- Both the signs have too much information.
- The signs are not useful.

Order of Displaying Information on Two Separate Signs

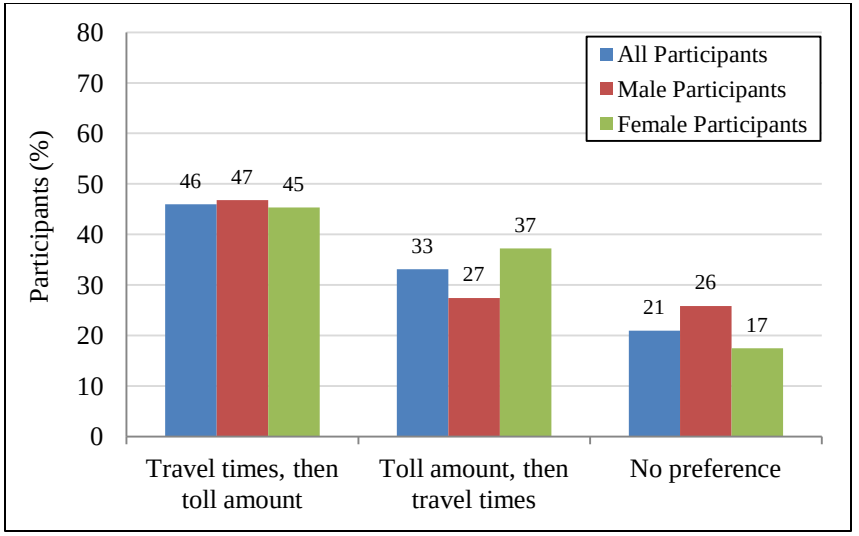
It is observed that a majority of the participants preferred one sign. However, irrespective of the participants' preference, their preferred order of display when two signs are to be deployed is collected. The sign's display order means whether the participants would like to see the sign with travel time information first or with toll amount first. Participants were also requested to provide the rationale behind their preference.

Figure 4-27 shows the participants' preference by age group, gender, education level, and frequency of using toll roads. A majority of participants (46%) would like to see comparative travel time information first, whereas 33% preferred to see toll amount first; and 21% of participants had no preference. It is also observed that 68% of younger participants (age 18-24) preferred to have travel time information first, which is followed by 44% of middle age participants (age 25-64). Older participants were equally divided between the two options; with 35% preferred to see travel times first and another 35% preferred toll amount first. The rest of the older participants (29%) had no preference.

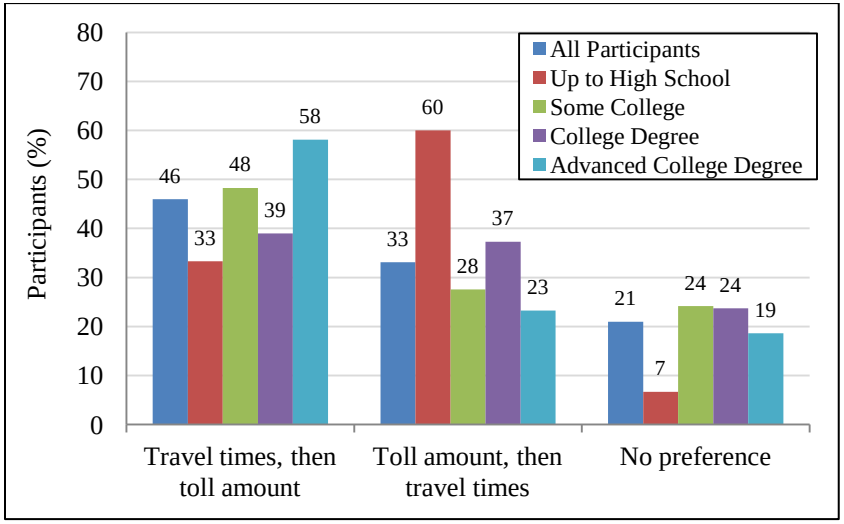
A majority of both males (47%) and females (45%) preferred to see travel time information first. The rest of the male participants were almost equally divided between preference to toll amount first (27%) and no preference (26%). A greater percentage of females (37%) preferred to see toll information first compared to males (27%). A majority of participants with advanced college degree preferred to see travel times first. Of all the participants with high school education, 33% preferred to see travel times first while 60% opted to know toll amount first; only 7% had no preference. A majority of participants who sometimes or often take toll roads preferred to know travel time information first. On the other hand, a majority of participants who never or seldom drive on toll roads preferred toll information first.



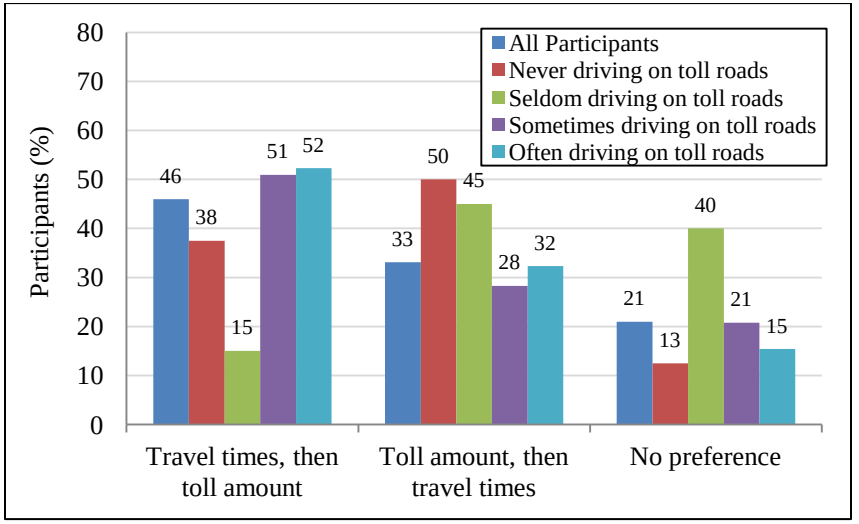
(a) By Age Group



(b) By Gender



(c) By Education Level



(d) By Frequency of Driving on Toll Road

Figure 4-27: Preference to Order of Displaying Information on Two Separate Signs

4.8 Automated Speed Control

An increasing number of “speed trailer” signs that display individual vehicle’s speed are being deployed for automated speed enforcement. Figure 4-28 shows an example of the existing sign. However, the effectiveness of these signs in getting the drivers to follow the speed limit may likely diminish as drivers are getting used to seeing these signs. To address this issue, an alternative sign that displays speeding fines in case of over-speeding is proposed. Figure 4-29 shows the alternative sign that displays would-be fines in the dynamic panel under the static-sign “YOUR TICKET”.

Figure 4-28: Existing Speed Trailer for Automated Speed Control

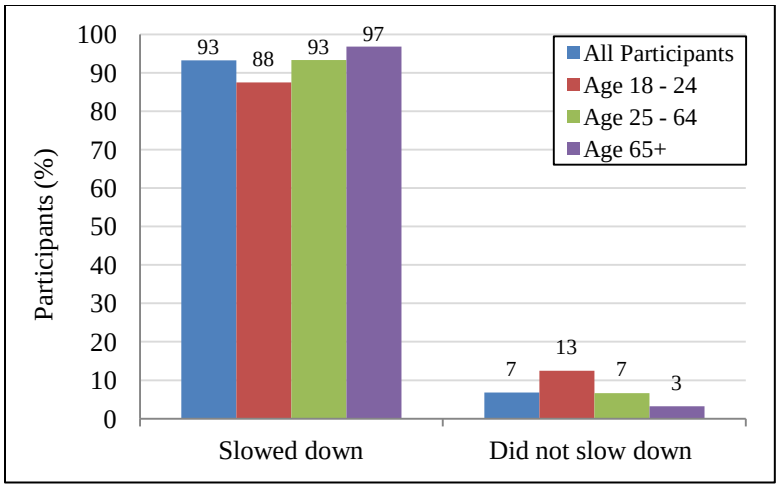
Figure 4-29: Proposed Information Display on Speed Trailer for Automated Speed Control

Opinion on Existing Speed Trailer

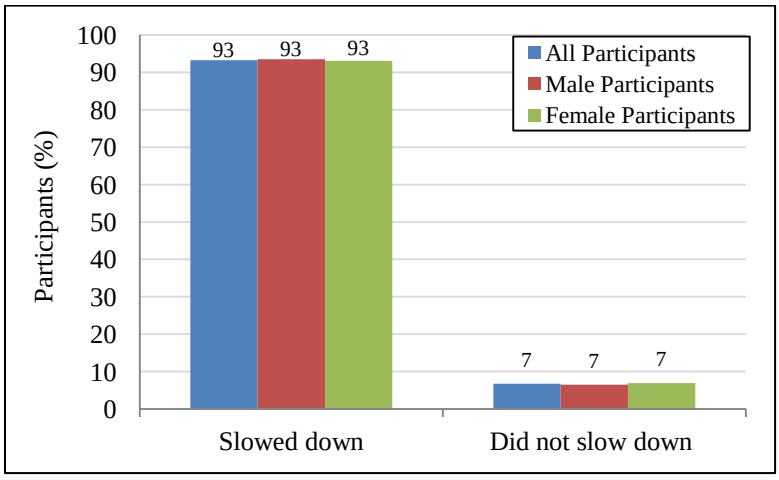
In order to determine if the existing speed trailer is successful in forcing drivers who were speeding to slow down, participants were asked about their experience in following the speed limit shown on speed trailer signs. Figure 4-30 shows the participants' responses by age group, gender, and education level. A majority of participants (93%) mentioned that they slowed down when they saw their speed on the trailer when speeding. A very high percentage of older participants (97%) said that they slowed down if speeding while 88% of younger participants (age 18-24) said the same. Equal percentage (93%) of males and females mentioned that they slowed down when they saw their speed on the trailer. All the participants with high school education said that they slowed down if they were speeding.

Likeliness to Follow the Proposed Sign

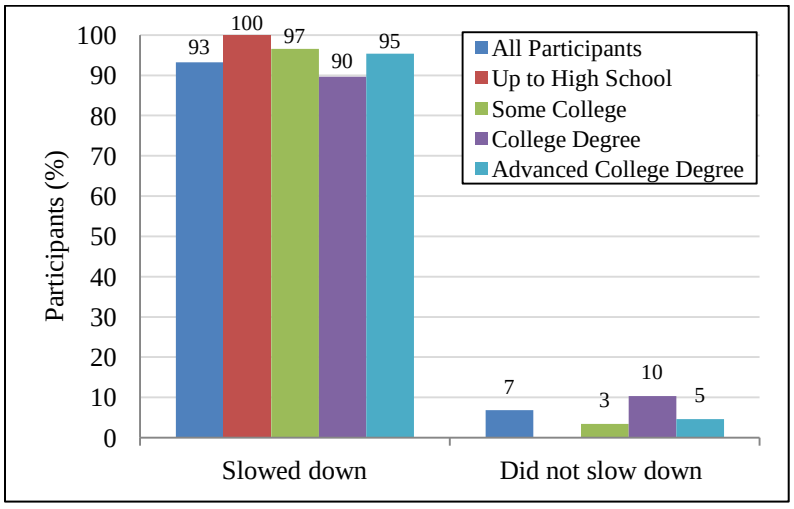
Figure 4-31 shows the participants' likeliness to slow down (or slow down more) if the sign would display ticket price rather than their speed by age group, gender, and education level. A majority of the participants (68%) indicated that they would be more likely to slow down if the sign shows the fines. It is also observed that a relatively high percentage of younger participants (76%) would be more likely to slow down when the fines are displayed. Also, 71% of females mentioned that they would be more likely to slow down compared to 65% of males. Compared to the participants with lower education levels, fewer percentages of participants with college degree and advanced college degree said that they would be more likely to slow down when the fines are displayed.



(a) By Age Group

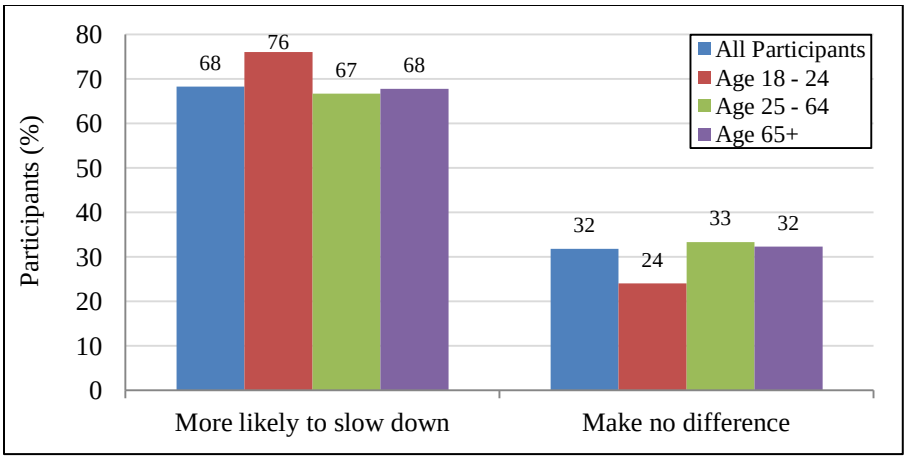


(b) By Gender

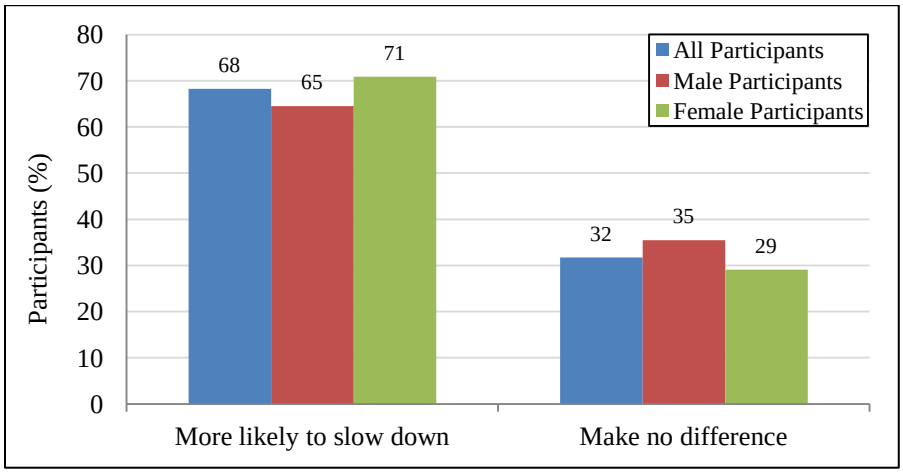


(c) By Education Level

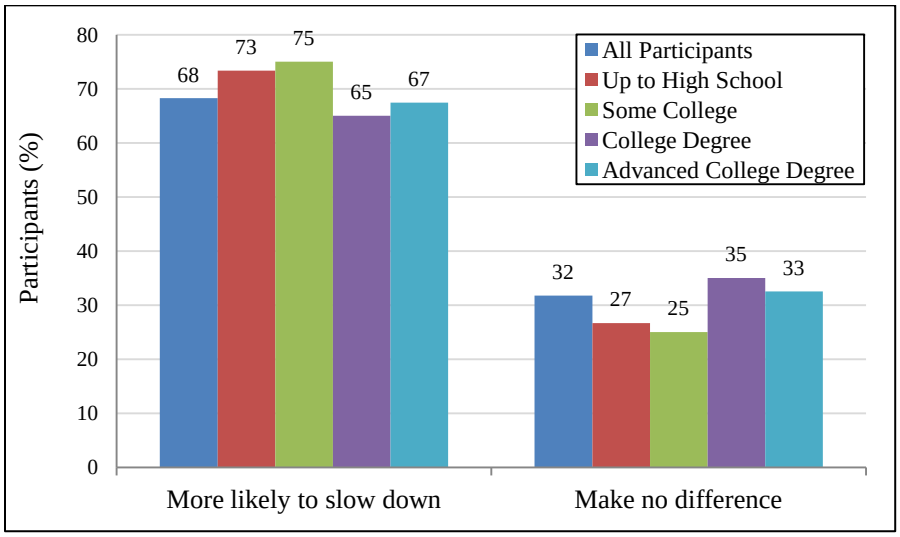
Figure 4-30: Feedback of the "Your Speed" Message from Past Experience



(a) By Age Group



(b) By Gender



(c) By Education Level

Figure 4-31: Likeliness to Follow the Proposed Speed Control Sign

4.9 Advisory Progression Speed

On coordinated streets, the signals for closely-spaced intersections are synchronized based on a certain travel speed. It means if drivers maintain a particular speed (for which the signals are set) they are less likely to stop at red lights at those coordinated intersections. The speed to be maintained, known as the advisory progression speed, is not necessarily the same as the posted speed limit, and is not known to the drivers. The advisory speed may change depending on traffic conditions, time of day, and other seasonal factors. Therefore, drivers tend to drive at different speeds, resulting in higher speed differentials, which are known to increase the potential for traffic crashes. Moreover, drivers have to stop more frequently at the signals. Thus, in order to improve safety and reduce speed-differentials, a hybrid sign, as shown in Figure 4-32, is proposed. The proposed sign will display the changeable speed set for the signals.

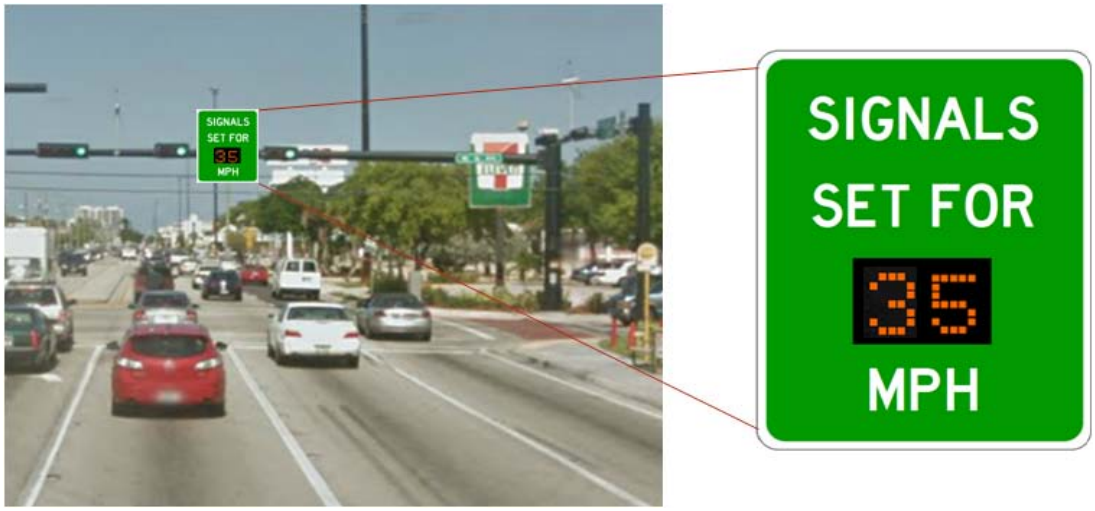
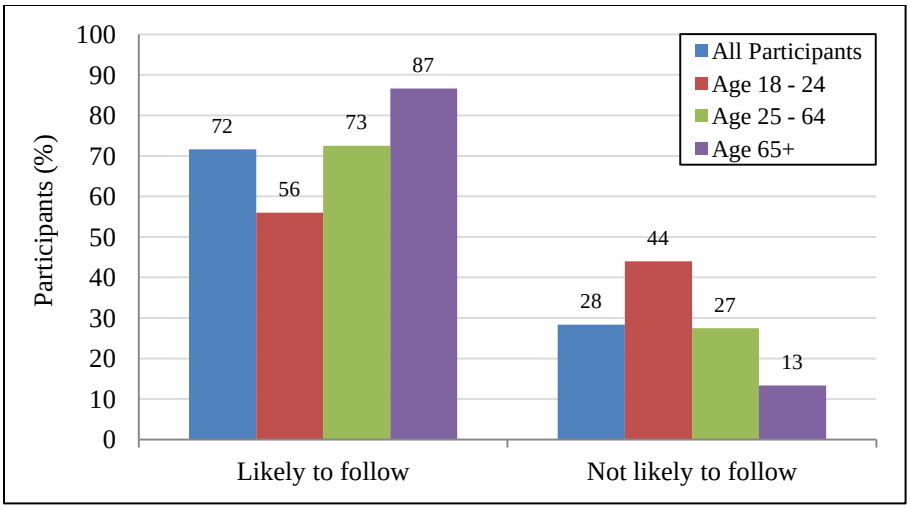


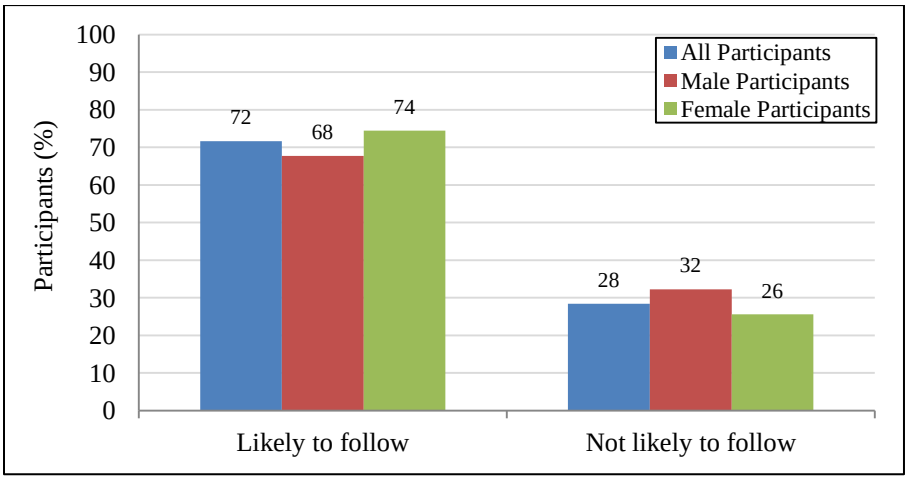
Figure 4-32: Proposed Hybrid Sign for Advisory Progression Speed

Likeliness to Follow the Proposed Advisory Speed Sign

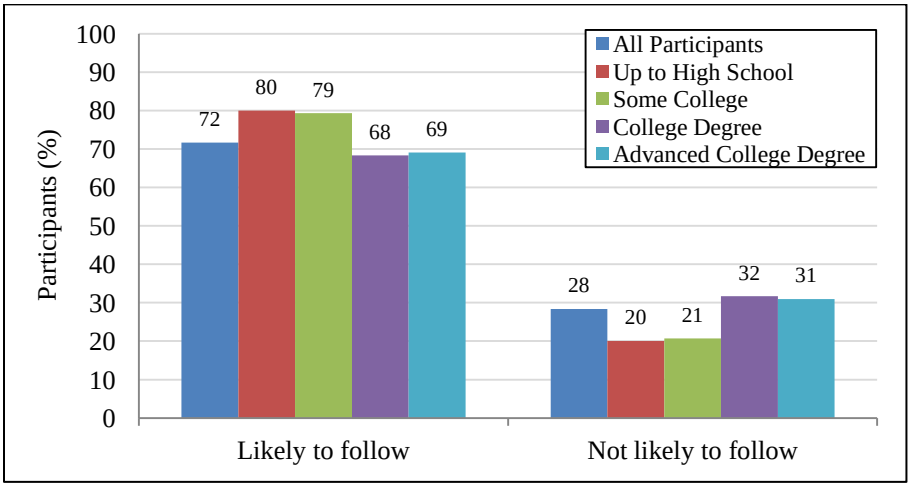
Figure 4-33 shows the participants' likeliness to follow the posted advisory speed by age group, gender, and education level. A majority of participants (72%) mentioned that they would follow the advisory speed. A high 87% of older participants (age 65+) mentioned that they would follow the sign, while the percentage was only 56% among younger participants (age 18-24). Female participants were more willing to follow the advisory speed than male participants, as indicated by 74% of females versus 68% of males. It is also clear from the figure that the likelihood to follow the advisory speed declined with higher education. A high 80% of participants with high school education mentioned that they would follow the sign while only 69% of participants with advanced college degree said they would follow the advisory speed limit. Note that these statistics are very similar between participants with high school education and some college education, and between participants with college degree and advanced college degree.



(a) By Age Group



(b) By Gender



(c) By Education Level

Figure 4-33: Likeliness to Follow the Proposed Advisory Speed Sign

Usefulness of Application

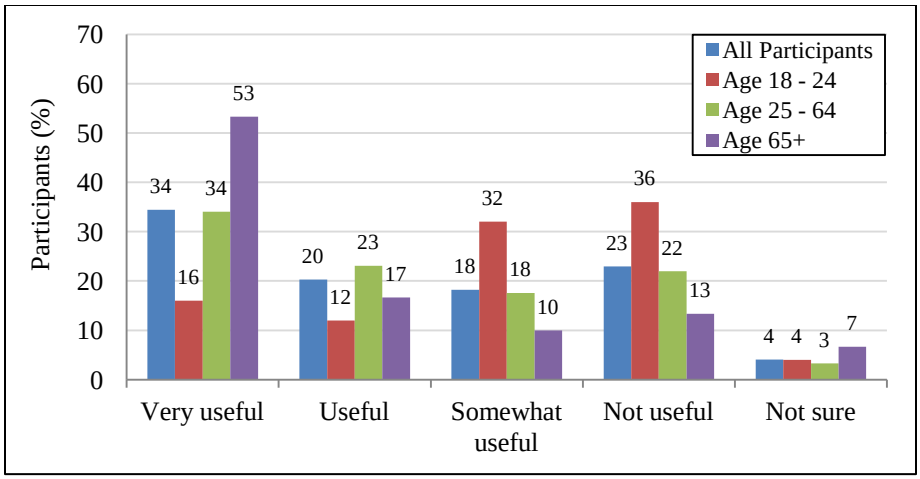
Figure 4-34 gives the usefulness rating of this application by age group, gender, and education level. Only 34% of all participants rated this application as very useful; only 16% of younger participants (age 18-24) rated as very useful, while a high 53% of older participants (age 65+) considered it as very useful. Similarly, a high 36% of younger participants considered this application as not useful, as opposed to only 13% of older participants.

A slightly greater percentage of females rated it as very useful compared to males (36% of females versus 33% of males). On the contrary, more females considered this application as not useful compared to males (24% of females versus 21% of males). Among the participants with different education levels, a relatively high 67% of participants with high school education rated this application as very useful. The participants that did not consider this application as useful were equally represented by all education levels.

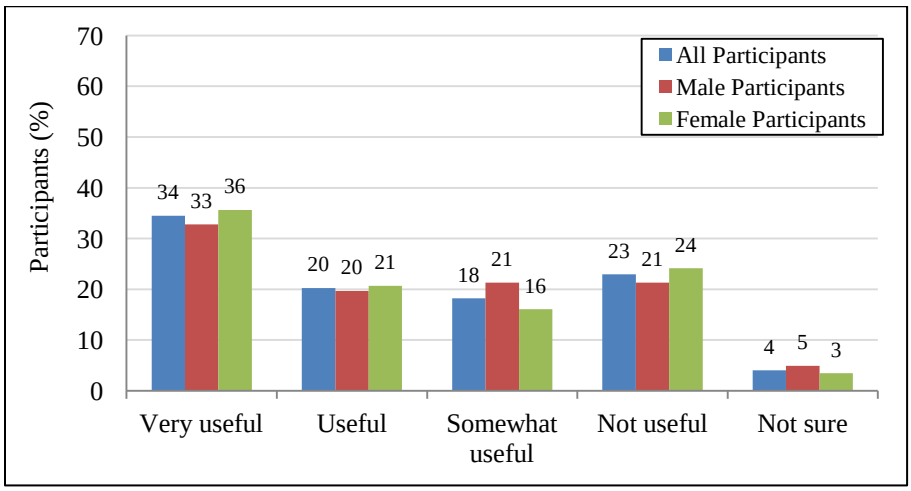
Participants' Comments

The following are the participants' comments/suggestions about this application:

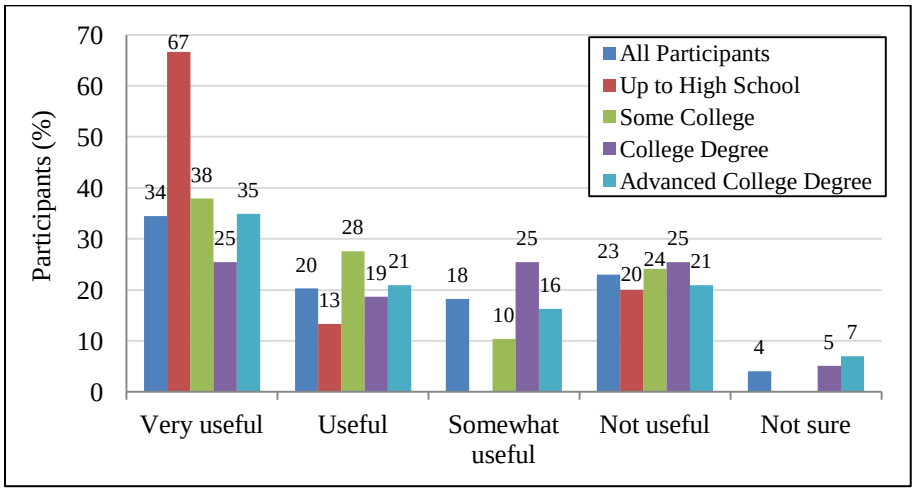
- The application might be helpful if several signs are put at the signals.
- The sign may create confusion among drivers because drivers may not differentiate between the advisory speed and the posted speed limit.
- The sign would not be helpful unless everyone can comprehend the meaning of the sign. It would be more frustrating at times to one who knows the meaning of the sign and is following the speed accordingly, but the drivers around him/her are not following the speed.



(a) By Age Group



(b) By Gender



(c) By Education Level

Figure 4-34: Usefulness Rating of Advisory Progression Speed Application

Interpretation of the Blank Dynamic Panel

When the signals are not in coordination, the dynamic panel of the proposed hybrid sign will be kept blank, as shown in Figure 4-35. Table 4-7 gives the frequency and percentage of different interpretations of this sign.

Figure 4-35: Blank Dynamic Panel in the Advisory Progression Speed Sign

A majority of participants (64%) interpreted that the sign is broken. The remaining 36% of participants thought that the information is unavailable, information is being updated, or to follow speed limit. Even though the correct interpretation is that the information is not available, the other two interpretations are also acceptable. Therefore, it could be stated that 36.0% of all participants made acceptable interpretations.

Table 4-7: Interpretation of the Blank Sign for Advisory Progression Speed

Interpretation	**Frequency (Percentage)**
Sign is broken	89 (64.0%)
Information is not available/no speed is set	37 (26.6%)
Follow speed limit	8 (5.8%)
Information is being updated	5 (3.6%)
Total	**139 (100.0%)**[1]

[1] The total count of responses is less than 150 as some participants did not answer the question.

4.10 Parking Availability Information

Lack of information on the availability of parking spaces increases the amount of circulating traffic both in and near the parking garages/lots. It wastes drivers' time, increases vehicle emissions, and increases the likelihood of crashes. If information on empty parking spaces is available, drivers do not have to randomly search for empty spots. Hybrid signs, as shown in Figure 4-36, are proposed to provide this information. Figure 4-36(a) displays information on available parking spaces in different garages, and can be placed on streets approaching major parking facilities. Similarly, Figure 4-36(b) provides the same information at each floor/level in a garage, and can be placed at the entrance of the garage.

(a) **Hybrid Sign for Parking Availability Information Specific to Garages**

(b) Hybrid Sign for Parking Availability Information Specific to Levels

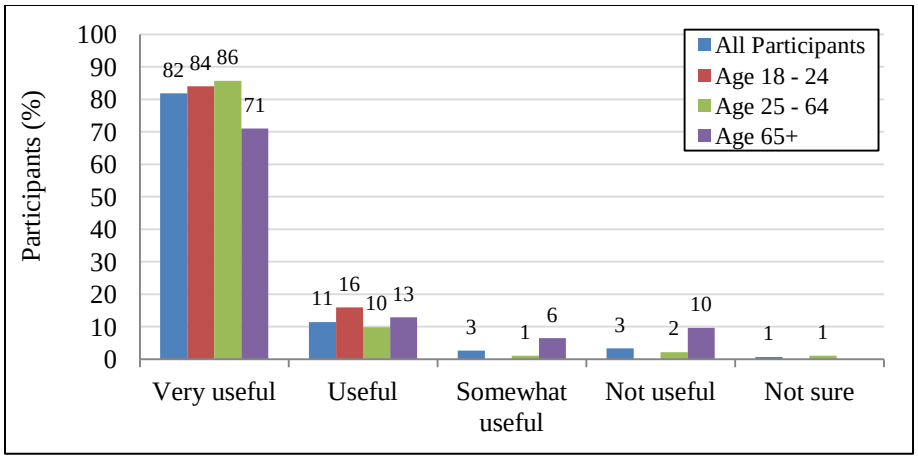
Figure 4-36: Proposed Hybrid Sign to Display Parking Availability Information

Usefulness of Application

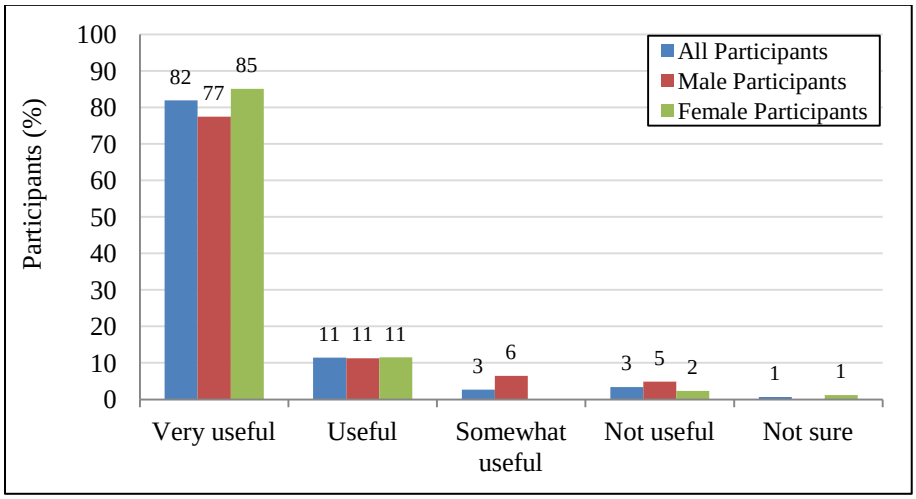
Figure 4-37 shows the usefulness rating of this application by age group, gender, and education level for garages. A majority of participants (82%) rated this application as very useful. Compared to younger (age 18-24) and middle age (age 25-64) groups, only 71% of older participants (age 65+) considered this application as very useful. Also, a significant percentage of older participants (10%) rated this application as not useful. More than 70% of participants from each age group found this application as either very useful or useful. Younger participants (age 18-24) were very supportive of this application since they rated the application as either very useful (84%) or useful (16%).

Similar to the trend observed with ratings of other applications, a greater percentage of females rated this application as very useful (85%) compared to males (77%). Additionally, a greater percentage of males rated this application as somewhat useful (6%) and not useful (5%), while the percentages of female participants were 0% for "Somewhat useful" and 2% for "Not useful". Over 70% of participants within each education level rated this application as very useful. Participants with high school education rated this application as either very useful (93%) or useful (7%). A majority of participants with college degree were also split between very useful (75%) and useful (18%).

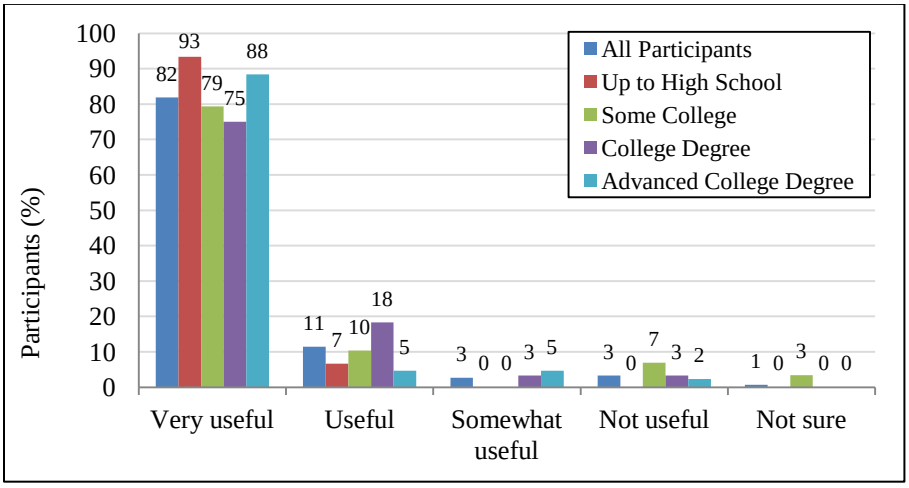
Figure 4-38 shows the usefulness rating of this application by age group, gender, and education level for specific floors in a garage. A majority of participants (70%) rated this application as very useful. Over 68% of participants within each age group rated this application as very useful. However, these percentages are lower compared to the participants' "Very useful" rating for this application for garages. Unlike the trend observed with this application for garages, a greater percentage of males rated this application as very useful (73%) compared to females (68%). There is no significant difference among the participants with all education levels.



(a) By Age Group

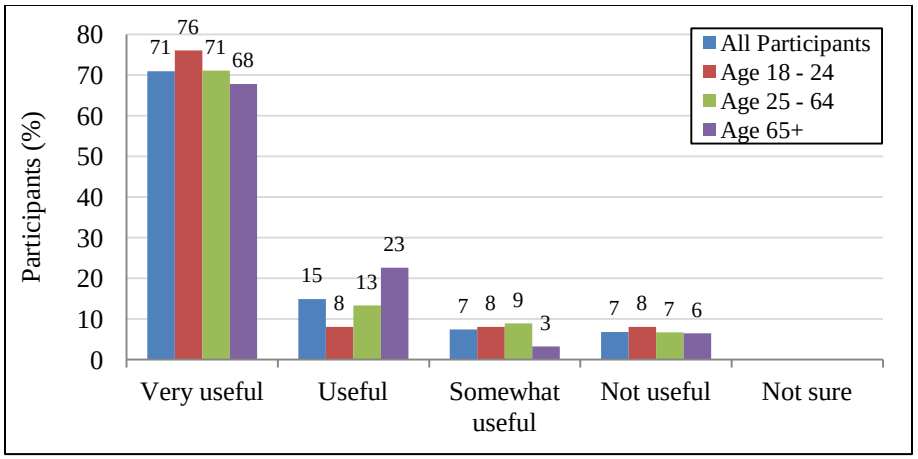


(b) By Gender

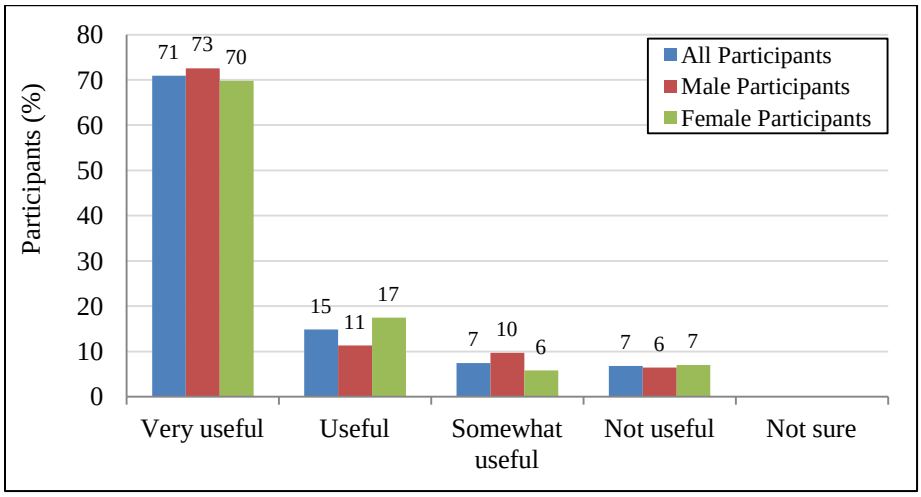


(c) By Education Level

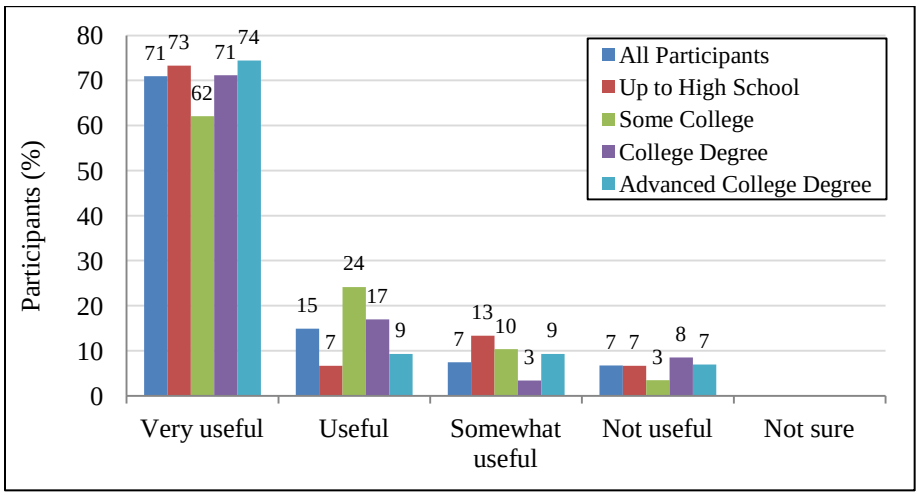
Figure 4-37: Usefulness Rating of Parking Availability Information Specific to Garages



(a) By Age Group



(b) By Gender



(c) By Education Level

Figure 4-38: Usefulness Rating of Parking Availability Information Specific to Levels

Participants' Comments

Participants provided the following comments/suggestions about this application:

- The sign with parking availability information for specific floors is less useful than the sign with parking information for garages.
- The sign that is specific to garages would be very effective if placed in college campuses or near stadiums or tourist attractions.
- The sign that is specific to floors might work well at airports, sea ports, and hospitals.
- The signs should have additional provision for displaying available parking spaces for handicapped drivers.
- The reliability of the displayed information is important.

4.11 Summary

This chapter discussed 10 hybrid sign applications for improving safety and mobility of road users. A total of 10 focus group meetings involving 150 participants were conducted to evaluate the potential applications in terms of their usefulness, understandability, and preference. For each of the 10 applications, participants' responses were analyzed using descriptive statistics. Participants' comments/suggestions were also documented. The 10 applications were grouped into the following four categories:

1. Countdown applications:
   - Drawbridge opening
   - School zone traffic diversion
   - Traffic diversion to avoid train crossing
   - Arrival time information at bus/train stops
   - Train arrival time information on freeways

2. Travel time information applications:
   - Travel times on distance signs
   - Comparative travel times for express lane facilities

3. Speed control applications:
   - Automated speed control
   - Advisory progression speed

4. Other application:
   - Parking availability information

Participants were asked to rate the usefulness of all the applications except the automated speed control application. Figure 4-39 provides the usefulness rating of the remaining nine applications. Note that the usefulness of parking application is presented twice: one for specific garages and the other for specific levels/floors. Table 4-8 gives the percentages of participants that rated either "Very useful" or "Useful" to all the applications.

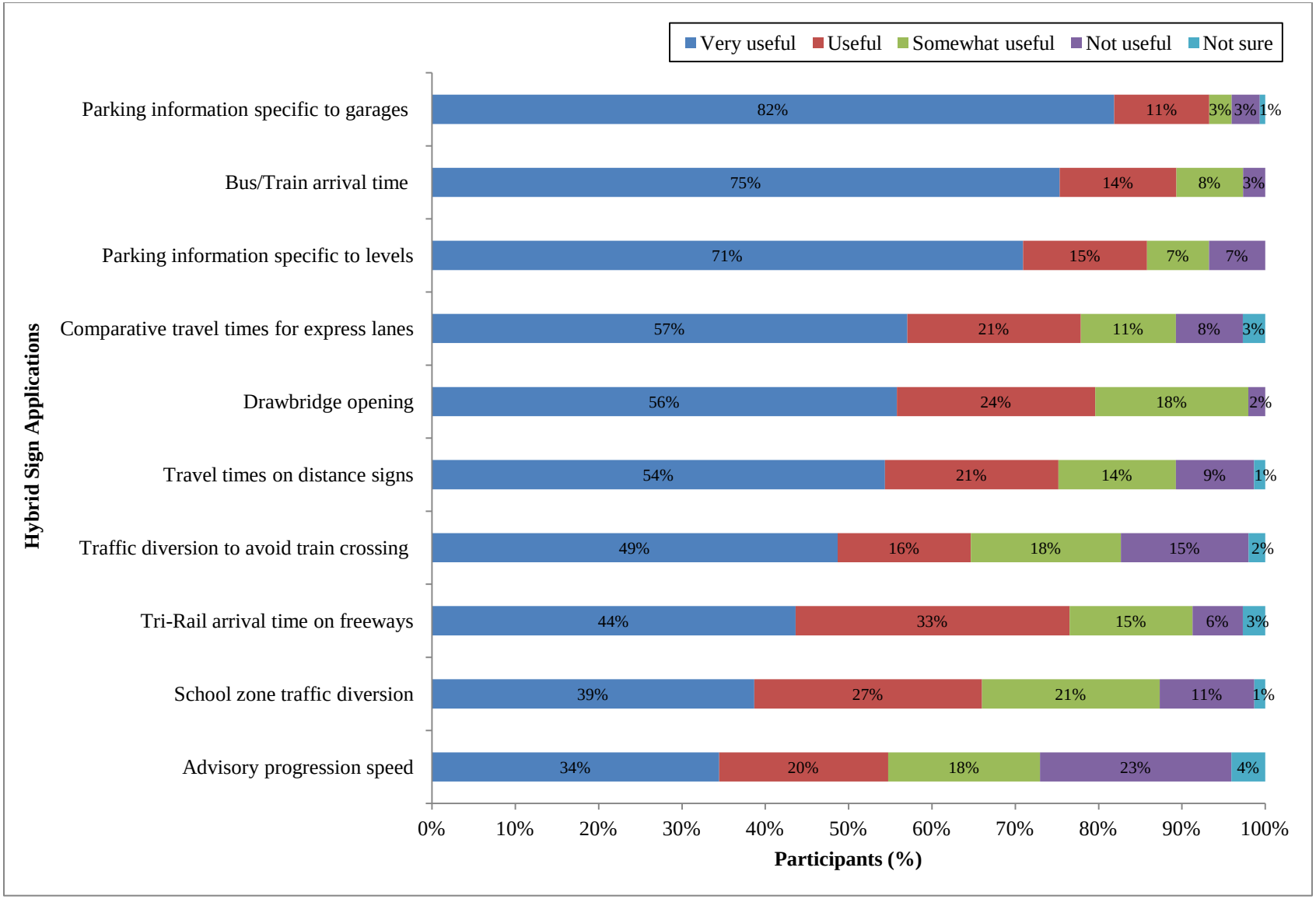


Figure 4-39: Usefulness Ratings of All Hybrid Sign Applications

Table 4-8: Percentages of Participants Who Rated "Very useful" or "Useful" for Each Application

Hybrid Sign Application	Percentage of participants that rated		(a)+ (b) (%)
	Very useful (a)	Useful (b)	
Parking information specific to garages	81.9	11.4	93.3
Bus/Train arrival time	75.3	14.0	89.3
Parking information specific to levels	70.9	14.9	85.8
Comparative travel times for express lanes	57.0	20.8	77.9
Drawbridge opening	55.8	23.8	79.6
Travel times on distance signs	54.4	20.8	75.2
Traffic diversion to avoid train crossing	48.7	16.0	64.7
Train arrival time on freeways	43.6	32.9	76.5
School zone traffic diversion	38.7	27.3	66.0
Advisory progression speed	34.5	20.3	54.7

The focus group study results showed that a higher percentage of older participants (age 65+) rated the applications as very useful, followed by middle age participants (age 25-64) and younger participants (age 18-24), respectively. Similar to older participants, participants with high school education were found to be more receptive to the applications in general. Furthermore, females were slightly more supportive of the applications compared to males. The following are some of the important findings from the study:

- The word "RAISES" is preferred to the word "OPENS" in the drawbridge opening sign design. This is because some pedestrians might get confused by the word "OPENS" and might think that the bridge is open for crossing.
- It is preferred to spell out the word "MINUTES" in the school zone traffic diversion sign.
- The countdown timer for the school zone diversion sign can start more than 5 minutes before the start of the school zone so that the drivers are given more time to divert.
- For travel time applications (e.g., bus/train arrival times, travel time on distance signs, and train arrival time on freeways), it is important to provide frequent sign maintenance in case of any malfunction.
- Blank signs or signs including dashes for travel time applications should be avoided to the extent possible as most participants misunderstood these signs. The intent of these signs is to indicate that the information is not available, while a majority of participants interpreted them as being broken.
- For the comparative travel times application, a majority of participants preferred to display both travel time and toll amount in one sign. If two consecutive signs were to be installed for this application, a majority of participants preferred travel time to be displayed first followed by toll amount.
- For the automated speed control sign, participants were more likely to slow down when the sign displays their would-be fine instead of their speed. Relating drivers' tendency to speed to their would-be fines (i.e., monetary amount) was considered to be more effective.

Overall, the participants found parking availability information, arrival time information at bus/train stops, comparative travel times for express lane facilities, drawbridge opening, and travel times on distance signs to be particularly useful. A relatively high percentage of participants rated the application to display the advisory progression speed on arterials as not useful. Participants identified two major concerns with this application: drivers might not be able to differentiate between the advisory speed sign and the posted speed limit sign, and the hybrid sign might be frustrating at times when only a few drivers understand the sign.

The five countdown applications are designed such that the dynamic countdown timer is embedded in the static sign to countdown to a particular event, for example, to a bridge opening, bus/train arrival time, etc. These countdown applications have two main limitations that are difficult to overcome. First, these signs can be confusing when the dynamic information is not present. The focus group study results showed that participants had different and inconsistent interpretations when dynamic panels in the hybrid signs are blank or show dashes. Second, as noted by several participants, these hybrid signs with countdown times might encourage speeding to beat the countdown time. In summary, even though a majority of participants rated the countdown applications as very useful, their deployment might create confusion when the dynamic information is not present and could potentially encourage speeding.

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

The main purpose of this project is to study the potential use of hybrid static-dynamic signs (or hybrid signs). A hybrid sign consists of a conventional retro-reflective static sign that is embedded with one or more relatively small, dynamic, usually LED message panels. These signs have several advantages over traditional DMS, making them more appealing for potential deployment. Some of the advantages of hybrid signs include better legibility, smaller size, and lower costs in installation and maintenance. Because of their smaller size, they may be suitable not only on freeways, but also on arterial streets. Accordingly, one major objective of this project is to identify and evaluate potential applications of hybrid signs on both freeways and arterial streets. A focus group study was conducted to assess the usefulness of potential hybrid sign applications, and the understanding of, and preference for, specific hybrid sign designs by the road users.

As part of this project, an extensive state-of-the-practice review on the use and design of existing hybrid signs was conducted. Given that the use of hybrid signs is only emerging in the U.S., the review covered hybrid sign applications in both the U.S. and around the world, including Europe, Australia, and Asia. The application areas included speed control, parking guidance, travel time and travel distance information, dynamic rerouting information, and graphical route information. In addition to the literature search, a review of the companies that manufacture and market hybrid signs in the U.S. was conducted. It was found that only a small number of sign manufactures have hybrid sign products for applications other than variable speed limit or speed feedback signs.

A major effort of the project was to identify potential hybrid sign applications on both freeways and arterials and evaluate them through focus groups. In total, 10 focus group meetings involving 150 participants of different age, gender, and ethnic groups were conducted. A total of 10 hybrid sign applications were selected and evaluated in terms of their usefulness, understandability, and preference for different sign designs. The 10 applications were grouped into the following four categories:

1. Countdown applications:
   - Drawbridge opening
   - School zone traffic diversion
   - Traffic diversion to avoid train crossing
   - Arrival time information at bus/train stops
   - Train arrival time information on freeways

2. Travel time information applications:
   - Travel times on distance signs
   - Comparative travel times for express lane facilities

3. Speed control applications:
   - Automated speed control
   - Advisory progression speed

4. Other application:
    - Parking availability information

The drawbridge opening application is intended to improve safety of pedestrians and bicyclists on drawbridges; school zone traffic diversion and traffic diversion to avoid train crossing are intended to improve mobility and safety on arterial streets; arrival time information at bus/train stops is to serve transit riders; and train arrival information is to serve freeway drivers who would like to take a train. Travel time applications provide travel time information to major destinations/exits on freeways. Speed control applications are geared toward monitoring speeding and improving safety and mobility on arterial streets. Finally, parking availability information signs provide real-time information on parking availability in garages and on specific floors of each garage.

The focus group study results showed that a higher percentage of older participants (age 65+) rated the applications as very useful, followed by middle age participants (age 25-64) and younger participants (age 18-24), respectively. Similar to older participants, participants with high school education were found to be more receptive to the applications in general. Furthermore, females were slightly more supportive of the applications compared to males.

Overall, the participants found parking availability information, arrival time information at bus/train stops, comparative travel times for express lane facilities, drawbridge opening, and travel times on distance signs to be particularly useful. A relatively high percentage of participants rated the application to display the advisory progression speed on arterials as not useful. Participants identified two major concerns with this application: drivers might not be able to differentiate between the advisory speed sign and the posted speed limit sign, and the hybrid sign might be frustrating at times when only a few drivers understand the sign.

The five countdown applications are designed such that the dynamic countdown timer is embedded in the static sign to countdown to a particular event, for example, to a bridge opening, bus/train arrival time, etc. These countdown applications have two main limitations that are difficult to overcome. First, these signs can be confusing when the dynamic information is not present. The focus group study results showed that participants had different and inconsistent interpretations when dynamic panels in the hybrid signs are blank or show dashes. Second, as noted by several participants, these hybrid signs with countdown times might encourage speeding to beat the countdown time. In summary, even though a majority of participants rated the countdown applications as very useful, their deployment might create confusion when the dynamic information is not present and could potentially encourage speeding.

REFERENCES

Ain, S., "On Commuting; Travel Time Signs Receive Mixed Reviews", *The New York Times*, November 18, 2007, http://query.nytimes.com/gst/fullpage.html?res=9B07E6D9123CF93BA25752C1A9619C8B63, Accessed on July 12, 2011.

Aitken, R. J., A. J. Conway, and C. M. Walton, "Implementing Graphic Route Information Panels (GRIPs) in the United States", Journal of the Institute of Transportation Engineers, 2012, pp. 42-47.

Alameda County, "Alameda County Express Lanes", http://www.680expresslane.org/Home.asp, Accessed on August 15, 2012.

Alkim, T. P., P. H. J. van der Mede, and W. H. Janssen, "Graphical Route Information on Variable Message Signs", Road Transport Information and Control Conference, Institute of Electrical and Electronics Engineering, Publication No. 472, London, U.K., 2000, pp. 32-36.

Atkins, "Graphical Congestion Delay Panels", Final Report, Highways Agency, June 2003.

Berman, W., D. Differt, K. Aufschneider, P. Decorla-Souza, A. Flemer, L. Hoane, R. Hull, E. Schreffler, and G. Zammit, "Managing Travel Demand: Applying European Perspectives to U.S. Practice", Report No. FHWA-PL-06-015, Federal Highway Administration, 2006.

Breen, C., "NYSDOT Announces Travel Time Signs in Staten Island: Pilot Project First in a Statewide Rollout", Press Release, New York State Department of Transportation (NYSDOT), July 10, 2007a, https://www.nysdot.gov/news/press-releases/2007/2007-07-10, Accessed on July 12, 2012.

Brewer, M. A., G. Pesti, and W. H. Schneider IV, "Identification and Testing of Measures to Improve Work Zone Speed Limit Compliance", Report No. FHWA/TX-06/0-4407-1, Texas Department of Transportation, 2005.

Center for Advanced Transportation Technology (CATS), "Vehicle Probe Project Guide for Posting Travel Times on Changeable Message Signs", Draft Report, I-95 Corridor Coalition, 2011.

Chriszwolle, http://www.flickr.com/photos/chriszwolle/5733435451/, Accessed on June 20, 2011.

Chrysler, S. T., A. A. Williams, and K. Fitzpatrick, "Preliminary Guidelines for Signing on Toll Facilities", Report No. FHWA/TX-07/0-5446-1, Texas Department of Transportation, Federal Highway Administration, 2007.

Chrysler, S. T. and A. Nelson, “Considerations and Guidance for Traffic Control Devices for HOT Lane Networks”, Part of the Houston lane Network Value Pricing Project 126XXIA005, Texas Department of Transportation, Federal Highway Administration, 2009.

Compusign Pty Ltd., “Intelligent Signs: Trip Information Signs (TIS)”, http://www.compusign.com.au/, Accessed on September 20, 2012.

Conference of European Directors of Roads (CEDR), “VMS Harmonization in Europe”, CEDR’s Secretariat General, 2009, http://www.cedr.fr/home/fileadmin/user_upload/Publications/2009/e_Variable_Message_Signs.pdf, Accessed on August 1, 2012.

CountyLemonade, http://www.flickr.com/photos/countylemonade/5480733055/, Accessed on June 25, 2012.

Daktronics Inc., Photo Gallery, http://www.daktronics.com/ProductsServices/PhotoGallery/Pages/photodetail.aspx?pn=WP-14999_1723120.jpg, Accessed on September 20, 2012.

Daktronics Inc., “Travel Time & Toll Rate DMS: VM-1020”, http://www.daktronics.com/Web%20Documents/Transportation-Documents/Vanguard-Products/VM-1020/Vanguard-VM-1020-DDMS-Overview.pdf, Accessed on June 20, 2011.

Florida Department of Transportation (FDOT) District 6, "How Do Toll Rates Work on the 95 Express?”, News Flash, March 12, 2010, http://www.sunguide.org/sunguide/index.php/home/news_flash/how_do_toll_rates_work_on_the_95_express/, Accessed July 20, 2012.

FDOT, “95 Express”, 2012, http://95express.com/home/tolling.shtm, Accessed on August 15, 2012.

Federal Highway Administration (FHWA), “Manual on Uniform Traffic Control Devices (MUTCD)”, U.S. Department of Transportation, Washington, D.C., December 2009.

FHWA, “Advanced Parking Management Systems: A Cross-Cutting Study”, Publication No. FHWA-JPO-07-011, U.S. Department of Transportation, 2007b.

FHWA, “Getting Started with Congestion Pricing: A Web-based Workshop for Local Partners”, 2010, http://ops.fhwa.dot.gov/publications/fhwahop11035/wkshoppresentations/part1/index.htm, Accessed on July 22, 2012.

FHWA, “Intelligent Transportation Systems for Work Zones: Deployment Benefits and Lessons Learned”, 2007a, http://ntl.bts.gov/lib/jpodocs/brochure/14320.htm, Accessed on June 12, 2011.

Gan, H., "Graphical Route Information Panel for the Urban Freeway Network in Shanghai, China", IET Intelligent Transport Systems, Vol. 4, No. 3, Institution of Engineering and Technology, 2010, pp. 212-220.

Gan, H. C., Q. Wang, and B. Fan, "Graphical Route Information Panel and Macroscopic Simulation based Investigation of its Control Benefits", IEEE International Conference on Control and Automation, New Zealand, 2009, pp. 1454-1459.

Getz, J., "100,000th Peach Pass Issued for Controversial HOT Lanes", The Atlanta Journal-Constitution News, http://www.ajc.com/photo/news/local/100000th-peach-pass-issued-for-controversial-hot-l/pcDdx/, Accessed on September 20, 2012.

Google, *Google Map*, 2012, https://maps.google.com/maps.

Hearn, B. M., E. Ramsay, J. E. Catchpole, and J. Luk, "Evaluation of the VicRoads Drive Time System", Proceedings of the Combined 18th ARRB Transport Research Conference and Transit New Zealand Land Transport Symposium, Christchurch, New Zealand, 1996, pp. 423-436.

Hessian Road and Traffic Authority, "Congestion Free Hessen 2015: A Success Story", Hessian State Office for Road and Traffic Affairs, 2009, http://invest-in-hessen.de/mm/Congestion_Free_Hessen_2015.pdf, Accessed on July 12, 2011.

Indiana Department of Transportation (INDOT), "INDOT Annual Report: Fiscal Year 2010", http://www.in.gov/indot/files/2010Annual_Report_Final.pdf, Accessed on July 12, 2011.

INDOT, "Connecting Indiana: Fiscal Year 2011 Annual Report", http://www.in.gov/indot/files/2011AnnualReport_122111.pdf , Accessed on August 15, 2012.

Information Display Company, "Radar Speed Signs, Speed Displays, Trailers and Accessories", http://www.informationdisplay.com/httpdocs/radar-speed-sign-products.php, Accessed on December 5, 2011.

Jenkins, S. E., "Comparison of LED-only VMS with Hybrid VMS in regard to their Viewing Angle", White Paper, http://solutions.3m.com/3MContentRetrievalAPI/BlobServlet?locale=en_US&lmd=1172092180000&assetId=1171989595648&assetType=MMM_Image&blobAttribute=ImageFile, Accessed on July 20, 2011.

Kimley Horn and Associates Inc., "ADOT DMS Travel Time Pilot Project Evaluation: Final Report", Arizona Department of Transportation, 2011, http://www.azdot.gov/highways/ttg/PDF/ADOT-DMS_TravelTimeEvaluation-FinalReport.pdf, Accessed on July 25, 2011.

Kuhn, B., "Efficient Use of Highway Capacity Summary", Report No. FHWA-HOP-10-023, U.S. Department of Transportation, Federal Highway Administration, 2010.

Layman, R., http://www.flickr.com/photos/rllayman/5909718759/, Accessed on June 20, 2012.

Matsushima, H. and M. Sakai, "Graphic Information Provision System on Metropolitan Expressway System", 77th World Congress on Intelligent Transport Systems, 2000.

Metropolitan Expressway Co., Ltd., "Corporate Profile: 2012", http://www.shutoko.co.jp/english/about/corporate, Accessed on September 20, 2012.

Minnesota Department of Transportation (MnDOT), "MnPass Express Lanes", http://www.mnpass.org/index.html, Accessed on August 15, 2012.

New York City Department of City Planning, "Preliminary Recommendations for Downtown Flushing Parking Guidance System", Transportation Division, 2004, http://www.nyc.gov/html/dcp/pdf/transportation/td_pt1_pgs_dwn_flushing.pdf, Accessed on September 20, 2012.

Nixon, S., "Over Your Time Limit? Here Is One for the Road", *The Sidney Morning Herald*, October 17, 2007.

Ohio Department of Transportation (ODOT), "Destination Dynamic Message Signs (DDMS)", http://www.dot.state.oh.us/Divisions/Operations/Traffic/FAQs/Pages/DDMS.aspx, Accessed on July 28, 2012.

PB Americas Inc., Carter & Burgess, Earth Tech Inc., and Telvent Farradyne Inc., "Active Traffic Management Feasibility Study", Washington State Department of Transportation, 2007, http://psrc.org/assets/524/ATMfeasiblitystudy.pdf, Accessed on August 1, 2012.

PB Ferradyne and Leigh Fisher Associates, "Portland International Airport: Intelligent Transportation Systems (ITS) Master Plan", Oregon Department of Transportation, 2002.

Pesti, G., and P.T. McCoy. "Long-Term Effectiveness of Speed Monitoring Displays in Work Zones on Rural Interstate Highways" Transportation Research Record 1754, Transportation Research Board, National Research Council, Washington D.C., September 2001.

Peters, E., "NYSDOT Announces Travel Time Signs on Long Island", Press Release, NYSDOT, October 9, 2007b, https://www.dot.ny.gov/portal/page/portal/news/press-releases/2007/2007-10-091, Accessed on July 12, 2012.

Pugmire, G., "New Signs Help Drivers Find Best Route from Provo to Lehi", The Daily Herald, November 4, 2010, http://www.heraldextra.com/news/local/article_b33d94c7-a33c-5661-9484-34d4d5acf4a2.html, Accessed on July 13, 2011.

Ramsay, E. D. and J. Y. K. Luk, "Route Choice under Two Australian Travel Information Systems", ARRB Transport Research, ARR 312, Australia, December 1997.

Rephlo, J., R. Haas, L. Feast, and D. Newton, "Evaluation of Transit Applications of Advanced Parking Management Systems – Final Evaluation Report", Report No. FHWA-JPO-08-052 /

FTA-TRI-11-2008.1, Research and Innovative Technology Administration and Federal Transit Administration, 2008a.

Rephlo, J., M. Carter, H. Howard, B. Katz, M. Robinson, L. Bedsole, and K. Philmus (DMJM Harris), "Strategies for Improving Safety at Toll Collection Facilities", Report No. FHWA-IF-08-005, Federal Highway Administration, 2008b.

Richards, A., M. McDonald, G. Fisher, and M. Brackstone, "Investigation of Driver Comprehension of Traffic Information on Graphical Congestion Display Panels using a Driving Simulator", European Journal of Transport and Infrastructure Research, Vol. 4, No 4, 2004, pp. 417-435.

Rodier, C. J., S. A. Shaheen, and C. Kemmerer, "Smart Parking Management Field Test: A Bay Area Rapid Transit (BART) District Parking Demonstration; Final Report", Report No. UCB-ITS- PRR-2008-5, California Panthers for Advanced Transit and Highways, 2008.

Rose E. R. and G. L. Ullman, "Evaluation of Dynamic Speed Display Signs (DSDS)", Texas Department of Transportation, 2003.

San Diego Association of Governments (SANDAG), "I-15 Express Lanes", http://fastrak.511sd.com/san-diego-toll-roads/i-15-express-lanes, Accessed on May 15, 2012.

Santa Clara Valley Transportation Authority, "Silicon Valley Express Lanes", http://www.vta.org/expresslanes/SR_237_project.html, Accessed on August 15, 2012.

Schönfeld, G., A. Reischl, and M. Tsavachidis, "Dynamic Driver Information Goes Graphical – A New Quality in Urban Traffic Information", Proceedings of the 7th World Congress on Intelligent Transport Systems, Turin, 2000.

Schouten, W. J. J. P., M. J. van Lieshout, and W. F. M. Spit, "VMS in the Polder: The Emergence of a Standardized Modular Information System to Control, Support and Promote Initiatives for VMS in Holland in a Flexible way", Road Transport Information and Control Conference, Publication No. 454, 1998, pp. 222-226.

Skyline Products Inc., Photo Gallery, http://icws233w4.myicontrol.com/icwstours/index.cfm?tourdirectory=382ffcfb-3774-4dfd-abc24933ae1b7cfa, Accesses on June 20, 2012.

Skyscrapercity, http://www.skyscrapercity.com/showthread.php?t=497099&page=12, Accessed on July 20, 2012.

State Road and Tollway Authority, "I-85 Express Lanes are Open", 2012, http://www.peachpass.com/peach-pass-toll-facilities/about-i-85-express-lanes, Accessed on August 15, 2012.

Stockton, W. R., and M. Burris, "Houston Value Pricing Project: Final Report", Texas Department of Transportation, 2007.

Taiwan Area National Freeway Bureau, "Travel Time Information Advocacy", *Translated by Google Translate*, http://www.freeway.gov.tw/Print.aspx?cnid=1566&p=1376, Accessed on July 20, 2012.

Texas Transportation Institute (TTI), "Houston Value Pricing: QuickRide", http://houstonvaluepricing.tamu.edu/quickride/, Accessed on September 25, 2012.

Thaxton, Z, "Trip-Timer Road Signs Set for Late-August Launch", August 5, 2010, http://www.koaa.com/news/trip-timer-road-signs-set-for-late-august-launch/, Accessed on July 23, 2012.

Thomas, http://www.flickr.com/photos/27013823@N03/4643527482/in/photostream, Accessed on June 25, 2011.

Utah Department of Transportation (UDOT), "Express Lanes", http://www.udot.utah.gov/expresslanes/, Accessed on August 15, 2012.

Virginia Department of Transportation (VDOT), http://www.flickr.com/photos/vadot/4307343896/, Accessed on June 25, 2011.

Washington State Department of Transportation (WSDOT), "SR 167 HOT Lanes User Guide", http://www.wsdot.wa.gov/Tolling/SR167HotLanes/userguide.htm, Accessed on July 15, 2011.

Waterson, B.J., N. B. Hounsell, and K. Chatterjee, "Quantifying the Potential Savings in Travel Time Resulting from Parking Guidance Systems - A Simulation Case Study", Journal of the Operational Research Society, Vol. 52, 2001, pp. 1067-1077.

Wei, H., and H. C. Perugu, "Oversaturation Inherence and Traffic Diversion Effect at Urban Intersections through Simulation", Journal of Transportation and Safety Research, Vol. 9, Issue 4, 2009, pp. 72-82.

Wilber Smith Associates, "Feasibility Study of Real Time parking Information at Metrorail Parking Facilities (Virginia Stations): Final Report", Washington Metropolitan Area Transit Authority, 2009.

Wimmer, N., "UDOT hopes Trailblazers will help ease Utah County commute", October 9, 2010, News at KSL.com, http://www.ksl.com/index.php?nid=838&sid=13016848, Accessed on June 20, 2011.

WSDOT, "I-5 - Travel Time Signs - Alaskan Way Viaduct Replacement - Complete December 2009", 2012a, http://www.wsdot.wa.gov/Projects/I5/AWVTravelTimeSigns/, Accessed on July 22, 2012.

WSDOT, "I-90 signs answer the question: 'Just how much longer until we get there?", 2012b,

http://www.wsdot.wa.gov/News/2011/06/6_23_I90traveltimesigns.htm., Accessed on July 23, 2012.

WSDOT, “Lake Washington Travel Time Signs Project - Complete April 2011”, 2012c, http://www.wsdot.wa.gov/projects/lkwamgt/traveltime/, Accessed on July 23, 2012.

APPENDIX A:

FOCUS GROUP PARTICIPANT INFORMATION AND STUDY QUESTIONNAIRE

Participant #: _____

Participant Information

Research Staff: Eligibility Confirmed (valid U.S. driver's license and 18+ years old)?

[ ] Yes, person is eligible
[ ] No, person is not eligible

---

1. **City of Residence:** _____
2. **Gender:** [ ] Male [ ] Female
3. **Age:** _____ years
4. **Were you born in the U.S.?** [ ] Yes [ ] No
5. **What is your race and ethnicity?**

   [ ] *Mixed Race/Biracial/Multiracial***(If you checked this selection, please check all that apply, below)**
   [ ] *Hispanic or Latino*: A person of Cuban, Mexican, Puerto Rican, South or Central American, or other Spanish culture or origin.
   [ ] *White (not of Hispanic origin)*:A person having origins in any of the original peoples of Europe.
   [ ] *Black, African American, or Caribbean Islander*: A person having origins in any of the black racial groups of Africa.
   [ ] *Middle Eastern*: A person having origins in any of the original peoples of North Africa or the Middle East. This areas is also called Southwestern Asia and includes Afghanistan, Bahrain, Cyprus, Egypt, Turkey, Iran, Iraq, Israel, Lebanon, Saudi Arabia, and Yemen.
   [ ] *American Indian or Alaska Native*: A person having origins in any of the original peoples of North, Central, or South America, and who maintains tribal affiliation or community attachment.
   [ ] *Asian*: A person having origins in any of the original peoples of the Far East, Southeast Asia, Cambodia, China, Japan, Korea, Malaysia, the Philippine Islands, Thailand, and Vietnam.
   [ ] *South Asian*: A person having origins in any of the original peoples of the Indian subcontinent and its surrounding regions. This area includes India, Pakistan, Bangladesh, Nepal, Bhutan, Sri Lanka, and Maldives.
   [ ] *Native Hawaiian or Other Pacific Islander*: A person having origins in any of the original peoples of Hawaii, Guam, Samoa, or other Pacific Islands.

6. **What is your highest level of education?**
   [ ] Less than high school
   [ ] High school diploma/GED
   [ ] Some college
   [ ] College degree
   [ ] Advanced college degree

7. **How many years have you been driving in the U.S.? _____** years

8. **How many miles do you drive per year? _____**miles (approximately)

9. **How often do you drive on toll roads?**
   [ ] Never
   [ ] Seldom
   [ ] Sometimes
   [ ] Often

10. **How often do you use public transit?**
   [ ] Never
   [ ] Seldom
   [ ] Sometimes
   [ ] Often

Application#1: Drawbridge Opening

1. **How do you rate the usefulness of this application?**

   [ ] Very useful

   [ ] Useful

   [ ] Somewhat useful

   [ ] Not useful

   [ ] Not sure

   Comment:

   _____

   _____

   _____

   _____

2. **Please describe what this sign means to you (when the dynamic panel shows "00").**

   _____

   _____

   _____

   _____

3. **Please describe what this sign means to you (when the dynamic panel is blank).**

   _____

   _____

   _____

4. **Please describe what this sign means to you (when the dynamic panel shows dashes).**

   _____

   _____

   _____

Application #2: School Zone Traffic Diversion

5. How do you rate the usefulness of this application?

[ ] Very useful

[ ] Useful

[ ] Somewhat useful

[ ] Not useful

[ ] Not sure

Comment:

_____

_____

_____

6. Which alternative do you prefer?

[ ] Alternative A

[ ] Alternative B

[ ] Alternative C

7. What is the reason for your preference?

_____

_____

_____

_____

_____

Application #3: Diversion to Avoid Train Crossing

8. How do you rate the usefulness of this application?

[ ] Very useful

[ ] Useful

[ ] Somewhat useful

[ ] Not useful

[ ] Not sure

Comment:

_____

_____

_____

Application #4: Arrival Time at Bus/Train Stops

9. How do you rate the usefulness of this application?

[ ] Very useful

[ ] Useful

[ ] Somewhat useful

[ ] Not useful

[ ] Not sure

Comment:

_____

_____

_____

10. Please describe what this sign means to you (when the dynamic panel is blank).

_____

_____

_____

_____

_____

11. Please describe what this sign means to you (when the dynamic panel shows dashes).

_____

_____

_____

_____

_____

Application #5: Tri-Rail Train Arrival Time

12. Please describe what this sign means to you.

_____

_____

_____

_____

_____

13. How do you rate the usefulness of this application?

[ ] Very useful

[ ] Useful

[ ] Somewhat useful

[ ] Not useful

[ ] Not sure

Comment:

_____

_____

_____

14. Please describe what this sign means to you (when the dynamic panel is blank).

_____

_____

_____

_____

_____

Application #6: Travel Times on Distance Signs

15. How do you rate the usefulness of this application?

[ ] Very useful

[ ] Useful

[ ] Somewhat useful

[ ] Not useful

[ ] Not sure

Comment:

_____

_____

_____

16. Please describe what this sign means to you (when the dynamic panel is blank).

_____

_____

_____

_____

_____

17. Please describe what this sign means to you (when the dynamic panel shows dashes).

_____

_____

_____

_____

_____

Application #7: Comparative Travel Times for Express Lane facilities

18. How do you rate the usefulness of this application?

[ ] Very useful
[ ] Useful
[ ] Somewhat useful
[ ] Not useful
[ ] Not sure

Comment:

_____

_____

_____

19. Do you feel that there is too much information on this sign?

[ ] Yes, there is too much information on this sign

[ ] No, there is not too much information on this sign

20. Please describe what this sign means to you (when the dynamic panels are blank).

_____

_____

_____

21. How do you like it if the information is to be displayed on two separate signs instead of all on one sign?

[ ] I prefer one sign

[ ] I prefer two separate signs

[ ] I have no preference

Comment:

_____

_____

_____

22. If two separate signs are to be used, in which order should they be displayed?

[ ] travel times, then toll amount

[ ] toll amount, then travel times

[ ] I have no preference

Reasons for your preference:

_____

_____

_____

Application #8: Automated Speed Control

23. Based on your past experience, did you slow down when you saw your speed on the trailer (if you were speeding)?

[ ] Yes

[ ] No

24. Please describe what this sign means to you.

_____

_____

_____

_____

_____

25. Are you more likely to slow down (or slow down more) if the sign is made to display your ticket price rather than your speed?

[ ] Yes, I am more likely to slow down (or slow down more).

[ ] It will make no difference.

Application #9: Advisory Progression Speed

26. Are you likely to follow the posted advisory speed?

[ ] Yes

[ ] No

27. How do you rate the usefulness of this application?

[ ] Very useful

[ ] Useful

[ ] Somewhat useful

[ ] Not useful

[ ] Not sure

Comment:

_____

_____

_____

28. Please describe what this sign means to you (when the dynamic panel is blank).

_____

_____

_____

_____

_____

Application #10: Parking Availability Information

29. How do you rate the usefulness of this application?

[ ] Very useful

[ ] Useful

[ ] Somewhat useful

[ ] Not useful

[ ] Not sure

Comment:

_____

_____

_____

30. How do you rate the usefulness of indicating the space availability of specific floors?

[ ] Very useful

[ ] Useful

[ ] Somewhat useful

[ ] Not useful

[ ] Not sure

Comment:

_____

_____

_____

APPENDIX B:

POWERPOINT PRESENTATION SLIDES FOR THE FOCUS GROUP STUDY

Welcome!

Focus Group Study on the Use of Hybrid Traffic Signs

Conducted by:

Lehman Center for Transportation Research
Florida International University

Sponsored by:

Florida Department of Transportation

Agenda

- Introduction
- Participant information
- Project background and overview
- Discussion on applications of hybrid signs

2

Types of Traffic Sign

Static Signs

Dynamic Signs

Hybrid Signs

3

Hybrid Sign Benefits over Dynamic Signs

- Hybrid signs contain static text that is easier to read.
- Hybrid signs are smaller and of lighter weight, making them cheaper to manufacture, install, and maintain.
- Hybrid signs require less support structure and consume less power.

4

Study Objective

- Florida Department of Transportation is interested in the potential applications of hybrid signs to improve safety and mobility of road users.
- We identified 10 new or existing applications of hybrid signs.
- We need your help to tell us if you believe these applications will be useful, if you have specific preferences, and how we might be able to improve them further.

5

Potential "Countdown" Applications

Application #1: Drawbridge Opening

Application #2: School Zone Traffic Diversion

Application #3: Traffic Diversion to Avoid Train Crossing

Application #4: Arrival Time Information at Bus/Train Stops

Application #5: Tri-Rail Train Arrival Time Information on Freeways or Streets

6

Application #1: Drawbridge Opening

Problem: Vehicles are stopped by both signal and crossing gate before drawbridge opening. However, there is currently nothing to prevent pedestrians from entering a drawbridge. There had been cases involving pedestrians who fell to their death.

7

Application #1: Drawbridge Opening

Potential Solution: Use the following countdown hybrid sign to alert pedestrians several minutes before bridge opening.

Q1. How do you rate the usefulness of this application?

8

Application #1: Drawbridge Opening

Q2. Please describe what this sign means to you (when the dynamic panel shows "00").

9

Application #1: Drawbridge Opening

Q3. Please describe what this sign means to you (when the dynamic panel is blank).

10

Application #1: Drawbridge Opening

Q4. Please describe what this sign means to you (when the dynamic panel shows dashes).

11

Application #2: School Zone Traffic Diversion

Problem: Through traffic during active school zone periods exposes students to additional risk.

12

Application #2: School Zone Traffic Diversion

Potential Solution: Use the following hybrid sign to inform the drivers that the school zone will be activated in a few minutes, so that some drivers could choose to use an alternate route.

Q5. How do you rate the usefulness of this application?

13

Application #2: School Zone Diversion Sign Alternatives

(a)

(b)

(c)

Q6. Which alternative do you prefer?

Q7. What is the reason for your preference?

14

Application #3: Diversion to Avoid Train Crossing

Problem: Train crossings at major roadways often create traffic backups that could extend to multiple street blocks.

15

Application #3: Diversion to Avoid Train Crossing

Potential Solution: Use the following sign to inform drivers of an approaching train crossing so that some may choose to use an alternate route.

Q8. How do you rate the usefulness of this application?

16

Application #4: Arrival Time at Bus/Train Stops

Problem: Lack of arrival time information forces passengers to wait at the stop or station (e.g., cannot go get a cup of coffee) and increases their anxiety. It reduces the comfort of using public transit and, thus, discourage them from using transit service.


17

Application #4: Arrival Time at Bus/Train Stops

Potential Solution: Use the following signs at bus stops to inform passengers of the arrival times.

For Stops Serving Single Route

For Stops Serving Multiple Routes

Q9. How do you rate the usefulness of this application?

18

Application #4: Arrival Time at Bus/Train Stops

Q10. Please describe what this sign means to you (when the dynamic panel is blank).

19

Application #4: Arrival Time at Bus/Train Stops

Q11. Please describe what this sign means to you (when the dynamic panel shows dashes).

20

Application #5: Tri-Rail Train Arrival Time

Problem: When a driver misses a Tri-Rail train, he or she will have to wait for a long time due to the relatively long headway of the Tri-Rail service.

21

Application #5: Tri-Rail Train Arrival Time

Potential Solution: Use the following sign to inform drivers of the arrival time of the next train so that they can better decide either to park and ride the train or run some errands such as putting gas if time permits.

Q12. Please describe what this sign means to you.

Q13. How do you rate the usefulness of this application?

22

Application #5: Tri-Rail Train Arrival Time

Q14. Please describe what this sign means to you (when the dynamic panel is blank).

23

Travel Time Information Applications

Application #6: Travel Times on Distance Signs

Application #7: Comparative Travel Times for Express Lane Facilities

24

Application #6: Travel Times on Distance Signs

Problem: Travel times are currently displayed on overhead dynamic massage signs. However, the sign is used to display more urgent information when needed. Thus, travel times information is not available when they are most needed.

Current practice: display travel times on overhead dynamic message signs

Overhead sign not available for travel time display when most needed

25

Application #6: Travel Times on Distance Signs

Potential Solution: Add travel times to "interchange sequential" distance signs so that travel time information will be always available.

Q15. How do you rate the usefulness of this application?

26

Application #6: Travel Times on Distance Signs

Q16. Please describe what this sign means to you (when the dynamic panel is blank).

27

Application #6: Travel Times on Distance Signs

Q17. Please describe what this sign means to you (when the dynamic panel shows dashes).

28

Application #7: Comparative Travel Times for Express Lane Facilities

Problem: Current practice for express lane facilities is to provide distances and toll amount. Information on the general-purpose lanes is not provided, making it difficult for drivers to make decision on whether to use the express lanes to their advantage.

29

Application #7: Comparative Travel Times for Express Lane Facilities

Potential Solution: Use the following hybrid sign to display comparative travel and toll information to help drivers make decision.

Q18. How do you rate the usefulness of this application?

Q19. Do you feel that there is too much information on this sign?

30

Application #7: Comparative Travel Times for Express Lane Facilities

Q20. Please describe what this sign means to you (when the dynamic panels are blank).

31

Application #7: Comparative Travel Times for Express Lane Facilities

(a) Displayed on one sign

(b) Displayed on two separate signs

Q21. How do you like it if the information is to be displayed on two separate signs instead of all on one sign?

32

Application #7: Comparative Travel Times for Express Lane Facilities

(a) Travel times, then toll amount

(b) Toll amount, then travel times

Q22. If two separate signs are to be used, in which order should they be displayed? And why is that?

33

Speed Control Applications

Application #8: Automated Speed Control

Application #9: Advisory Progression Speed

34

Application #8: Automated Speed Control

Problem: An increasing number of "speed trailer" signs are being deployed for automated speed enforcement. However, as drivers are accustomed to seeing these signs, their effectiveness in reducing speeds is likely diminishing.

Temporary

Permanent

35

Application #8: Automated Speed Control

Q23. Based on your past experience, did you slow down when you saw your speed on the trailer (if you were speeding)?

36

Application #8: Automated Speed Control

Q24. Please describe what this sign means to you.

37

Application #8: Automated Speed Control

Displaying Speed

Displaying Ticket Price

Q25. Are you more likely to slow down (or slow down more) if the sign is made to display your would-be ticket price rather than your speed?

38

Application #9: Advisory Progression Speed

Problem: On coordinated streets, the signals for adjacent intersections are synchronized based on a certain travel speed. This speed may change for different times of a day, depending on traffic conditions. The design speed is not necessarily the same as the speed limit and is not known to the drivers. As a result, drivers tend to drive at different speeds, resulting in higher speed differentials, which are known to increase potential for traffic accidents.

39

Application #9: Advisory Progression Speed

Potential Solution: Use the following hybrid sign to inform the driver of the best current speed to drive at.

Q26. Are you likely to follow the posted advisory speed?

Q27. How do you rate the usefulness of this application?

40

Application #9: Advisory Progression Speed

Q28. Please describe what this sign means to you (when the dynamic panel is blank).

41

Other Applications

Application #10: Parking Availability Information

42

Application #10: Parking Availability Information

Problem: Lack of information on the availability of parking spaces increases the amount of circulating traffic in parking garages. It wastes the driver's time, increases vehicle emissions, and increases accident probability.

43

Application #10: Parking Availability Information

Potential Solution: Use the following hybrid sign to indicate the space availability of different garages.

Q29. How do you rate the usefulness of this application?

44

Application #10: Parking Availability Information

Q30. How do you rate the usefulness of indicating the space availability of specific floors?

45

Thank you for your participation!

Please turn in your completed handouts.

APPENDIX C:

POTENTIAL DEPLOYMENT LOCATIONS IN FDOT DISTRICT 4 FOR DRAWBRIDGE OPENING APPLICATION

1. East Hallandale Beach Boulevard (SR 824) Bridge, mile 1074.0 at Hallandale
2. Hollywood Beach Boulevard (SR 820), mile 1072.2 at Hollywood
3. Sheridan St Bridge, mile 1070.5, at Fort Lauderdale
4. East Dania Beach Boulevard Bridge, mile 1069.4 at Dania Beach
5. SE 17th Street (Brooks Memorial) Bridge, mile 1065.9 at Fort Lauderdale
6. East Las Olas Bridge, mile 1064, at Fort Lauderdale
7. East Sunrise Boulevard (SR 838) Bridge, mile 1062.6, at Fort Lauderdale
8. East Oakland Park Boulevard (SR 816), mile 1060.5 at Fort Lauderdale
9. East Commercial Boulevard (SR 870) Bridge, mile 1059.0 at Lauderdale-by-the-Sea
10. East Atlantic Boulevard (SR 814) Bridge, mile 1056.0, at Pompano
11. NE 14th Street Bridge, mile 1055.0, at Pompano
12. East Hillsboro Boulevard (SR 810) Bridge, mile 1050.0, at Deerfield Beach
13. East Boca Club, Camino Real Bridge, mile 1048.2, at Boca Raton
14. Boca Inlet Bridge, mile 1048.0, at Boca Raton
15. East Palmetto Park (SR 798) Bridge, mile 1047.5, at Boca Raton
16. NE 40th Street, Spanish River Bridge, mile 1044.9, at Boca Raton
17. East Linton Boulevard Bridge, mile 1041.1, at Delray Bridge
18. East Atlantic Avenue (SR 806) Bridge, mile 1039.6, at Delray Bridge
19. NE 8th Street, George Bush Boulevard, mile 1038.7, at Delray Bridge
20. East Woolbright Road 15th Avenue, mile 1035.8, at Boynton Beach
21. East Ocean Avenue Bridge, mile 1035.0, at Boynton Bridge
22. East (Ocean Avenue Bridge, mile 1031.0, at Lantana
23. Lake Worth Bridge (SR 802), mile 1028.8, at Lake Worth
24. Southern Boulevard (SR 700/80) Bridge, mile 1024.7 at Palm Beach
25. Royal Park (SR 704) Bridge, mile 1022.6, at Palm Beach
26. Flagler Memorial (SR A1A) Bridge, mile 1020.8, at Palm Beach
27. Parker (US-1) Bridge, mile 1013.7, at Riviera Beach
28. PGA Boulevard Bridge, mile 1012.6, at North Palm Beach
29. Donald Ross Road, mile 1009.3, at North Palm Beach
30. East Indiantown Road (SR 706) Bridge, mile 1006.2, at Jupiter
31. West City Avenue (U.S. 1) Bridge, mile 1004.8, at Jupiter Island
32. County Highway 707/South Beach Road (SR 707, Jupiter Island Bridge, mile 1004.1, at Jupiter Island
33. County Rd 707/ SE Bridge Road (Martin County) (SR 708, Hobe Sound Bridge, mile 995.9, at Hobe Sound
34. Ernest Lyons, SR A1A, mile 984.9, at Stuart (Martin County)
35. SR A1A Bridge (North Beach Causeway Drive), mile 964.8, at Fort Pierce

APPENDIX D:

POTENTIAL DEPLOYMENT LOCATIONS IN FDOT DISTRICT 4 FOR DISPLAYING TRAVEL TIMES ON INTERCHANGE SEQUENTIAL SIGNS

Table D-1: Potential Deployment Locations on I-95 Northbound for Travel Time Signs

Sl. #	Sign Location	County	Exits Between
1	South of West Hallandale Beach Boulevard	Broward	18 and 19
2	North of Pembroke Road	Broward	19 and 20
3	South of Hollywood Boulevard	Broward	20 and 21
4	North of Sheridan Street	Broward	21 and 22
5	North of Stirling Road	Broward	22 and 23
6	South of Griffin Road	Broward	23 and 24
7	South of State Road 84	Broward	25 and 26
8	South of Sunrise Boulevard	Broward	29A and 29B
9	North of Oakland Park Boulevard	Broward	31A and 32
10	North of Commercial Boulevard	Broward	32 and 33A
11	North of Cypress Creek Road	Broward	33B and 36
12	South of Atlantic Boulevard	Broward	36 and 38
13	South of Copans Road	Broward	38 and 39
14	South of Sample Road	Broward	39 and 41
15	South of Hillsboro Boulevard	Broward	41 and 42A
16	North of Hillsboro Boulevard	Broward	42B and 44
17	South of Glades Road	Palm Beach	44 and 45
18	Glades Road	Palm Beach	45 and 48A
19	South of NW 51st Street	Palm Beach	48A and 48B
20	North of NW 51st Street	Palm Beach	50 and 51
21	South of Atlantic Avenue	Palm Beach	51 and 52
22	North of Atlantic Avenue	Palm Beach	52 and 56
23	South of Boynton Beach Boulevard	Palm Beach	56 and 57
24	North of Boynton Beach Boulevard	Palm Beach	57 and 59
25	North of Boynton Beach Boulevard	Palm Beach	59 and 60
26	North of Boynton Beach Boulevard	Palm Beach	60 and 61
27	North of Boynton Beach Boulevard	Palm Beach	61 and 63
28	North of Boynton Beach Boulevard	Palm Beach	63 and 64
29	South of Forest Hill Boulevard	Palm Beach	64 and 66
30	South of Southern Boulevard	Palm Beach	66 and 68
31	North of Southern Boulevard	Palm Beach	69 and 70
32	South of Okeechobee Boulevard	Palm Beach	70 and 71
33	North of Okeechobee Boulevard	Palm Beach	71 and 74
34	North of Blue Heron Boulevard	Palm Beach	76 and 77
35	North of Blue Heron Boulevard	Palm Beach	77 and 79A
36	North of Martin Highway	Martin	87B and 96
37	North of Becker Road	Martin	96 and 101
38	North of Gatlin Boulevard	St. Lucie	110 and 114
39	South of Crosstown Parkway	St. Lucie	114 and 118

Table D-2: Potential Deployment Locations on I-95 Southbound for Travel Time Signs

Sl. #	Sign Location	County	Exits Between
1	North of State Road 60	Indian River	156 and 147
2	South of Indrio Road	St. Lucie	138 and 131B
3	North of Midway Road	St. Lucie	129 and 126
4	South of Midway Road	St. Lucie	126 and 121
5	South of Martin Highway	Martin	110 and 102
6	South of Martin Highway	Martin	110 and 112
7	South of Kanner Highway	Martin	96 and 87B
8	North of Blue Heron Boulevard	Palm Beach	79A and 77
9	North of Blue Heron Boulevard	Palm Beach	77 and 76
10	South of Blue Heron Boulevard	Palm Beach	76 and 74
11	North of Okeechobee Boulevard	Palm Beach	74 and 71
12	South of Okeechobee Boulevard	Palm Beach	71 and 70
13	North of Southern Boulevard	Palm Beach	69B and 69A
14	North of Forest Hill Boulevard	Palm Beach	69A and 68
15	South of Forest Hill Boulevard	Palm Beach	68 and 66
16	South of Forest Hill Boulevard	Palm Beach	66 and 64
17	South of Forest Hill Boulevard	Palm Beach	64 and 63
18	South of Forest Hill Boulevard	Palm Beach	63 and 61
19	South of Forest Hill Boulevard	Palm Beach	61 and 60
20	North of Boynton Beach Boulevard	Palm Beach	60 and 59
21	South of Boynton Beach Boulevard	Palm Beach	59 and 57
22	South of Atlantic Avenue	Palm Beach	56 and 52
23	South of Atlantic Avenue	Palm Beach	52 and 51
24	South of Atlantic Avenue	Palm Beach	51 and 50
25	South of 51st Street	Palm Beach	50 and 48
26	Glades Road	Palm Beach	48 and 45
27	North of Hillsboro Boulevard	Palm Beach	45 and 44
28	North of Hillsboro Boulevard	Broward	44 and 42
29	South of SW 10th Street Exit	Broward	42 and 41
30	South of Sample Road	Broward	41 and 39
31	South of Copans Road	Broward	39 and 38B
32	South of Atlantic Boulevard	Broward	38A and 36B
33	North of Cypress Creek Road	Broward	36A and 33
34	North of Commercial Boulevard	Broward	33 and 32
35	North of Oakland Park Boulevard	Broward	32 and 31
36	North of Sunrise Boulevard	Broward	31 and 29
37	North of SR 84 Exit	Broward	29 and 27
38	North of Griffin Road	Broward	26 and 25
39	North of Stirling Road	Broward	23 and 22
40	North of Sheridan Street	Broward	22 and 21

Table D-3: Potential Deployment Locations on I-595 Westbound for Travel Time Signs

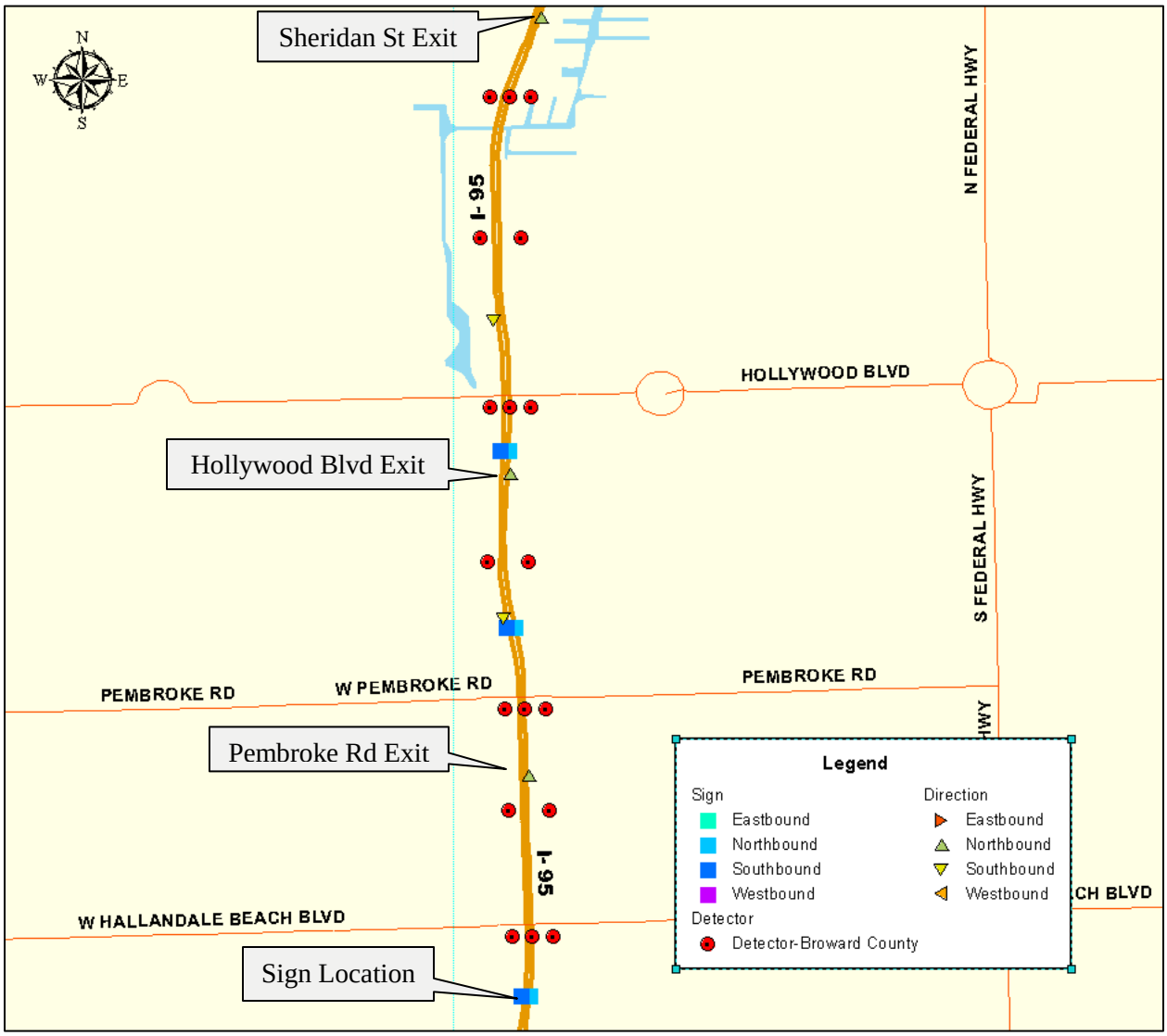
Sl. #	Sign Location	County	Exits Between
1	East of Miami Exit	Broward	10B and 7
2	East of University Drive	Broward	7 and 5
3	East of SW 136th Avenue	Broward	2 and 18

Table D-4: Potential Deployment Locations on I-595 Eastbound for Travel Time Signs

Sl. #	Sign Location	County	Exits Between
1	West of Turnpike	Broward	7 and 8A
2	West of West Palm Beach Exit	Broward	9 and 10 A

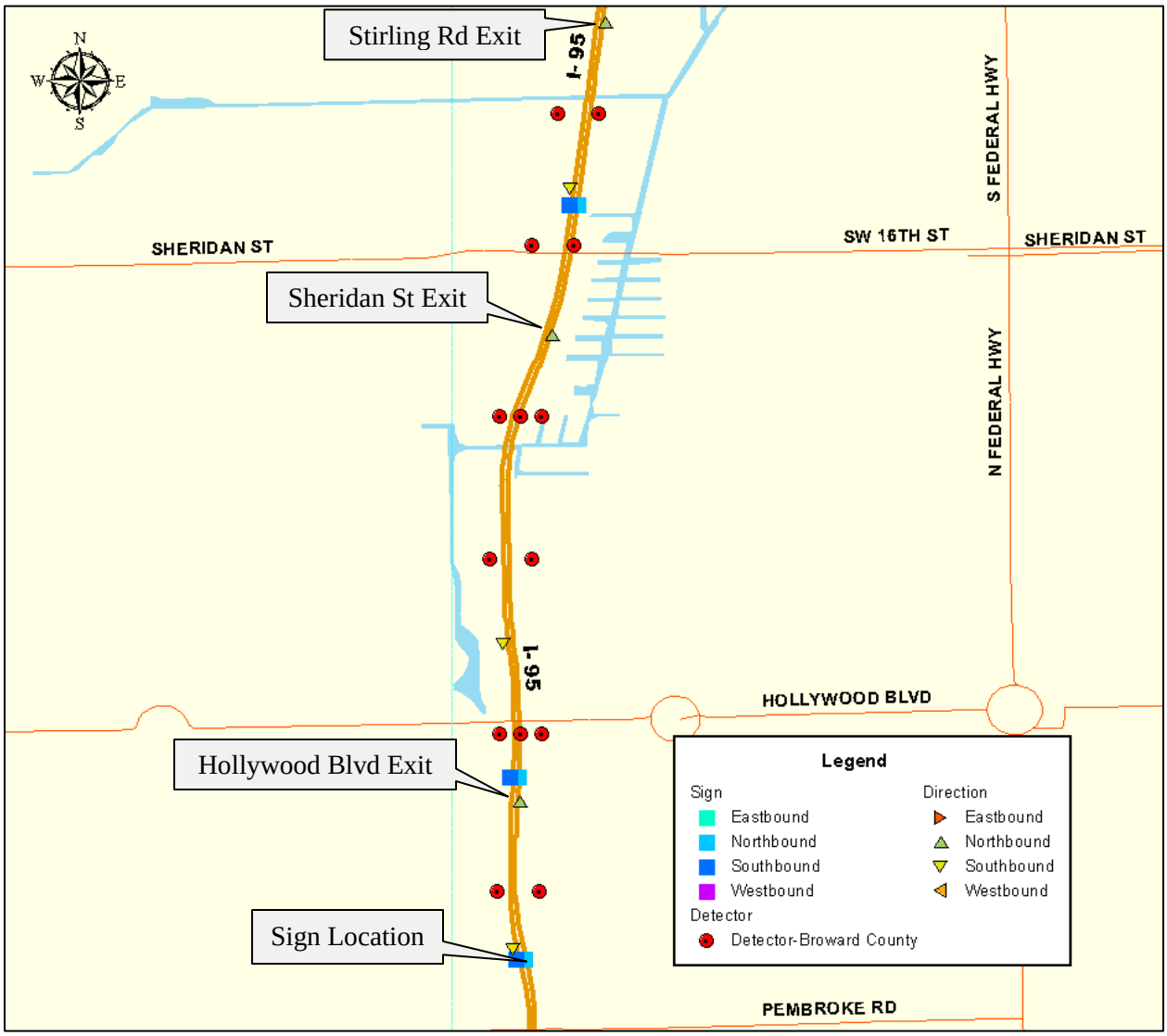
Sign Location: I-95 Northbound South of Hallandale Beach Boulevard (Broward County)

Pembroke Road: 0.75 mile; 2 detectors (in between sign location and that destination)
Hollywood Boulevard: 1.75 miles; 4 detectors
Sheridan Street: 3.75 miles; 7 detectors



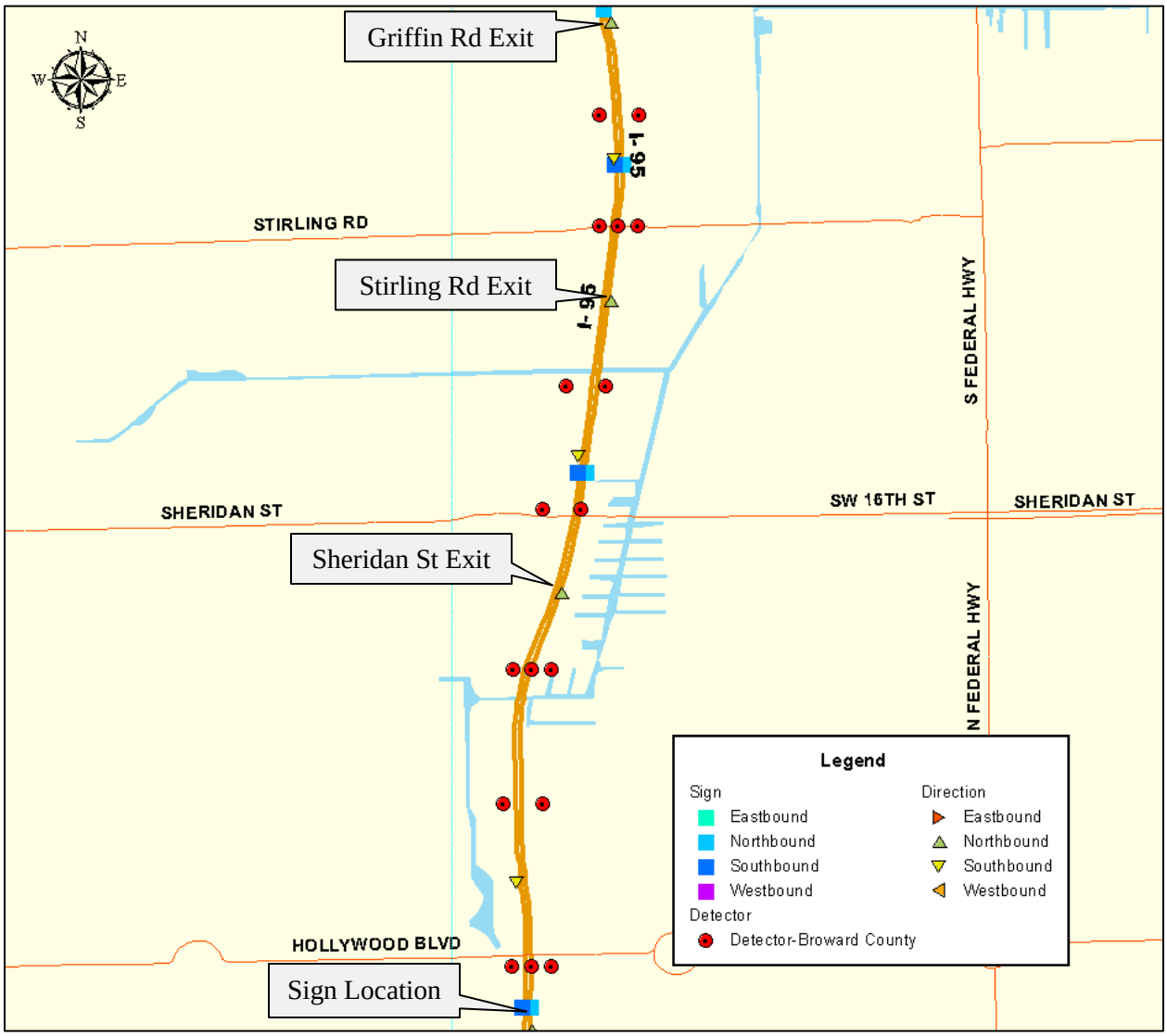
Sign Location: I-95 Northbound North of Pembroke Road (Broward County)

Hollywood Boulevard: 0.5 mile; 1 detector
Sheridan Street: 2 miles; 4 detectors
Stirling Road: 3 miles; 6 detectors



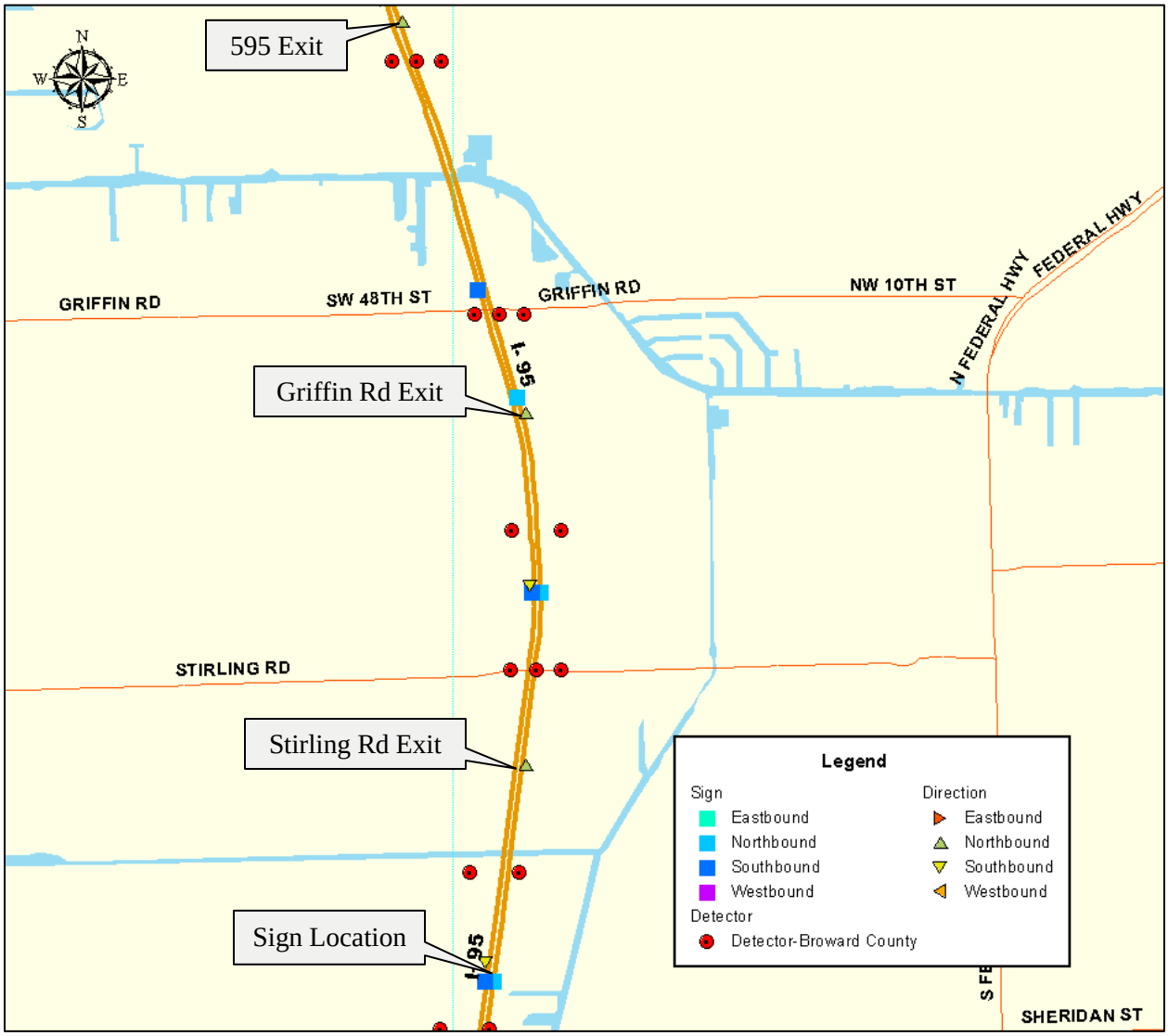
Sign Location: I-95 Northbound South of Hollywood Boulevard (Broward County)

Sheridan Street: 1.5 mile; 3 detectors
Stirling Road: 2.5 miles; 5 detectors
Griffin Road: 3.5 miles; 7 detectors



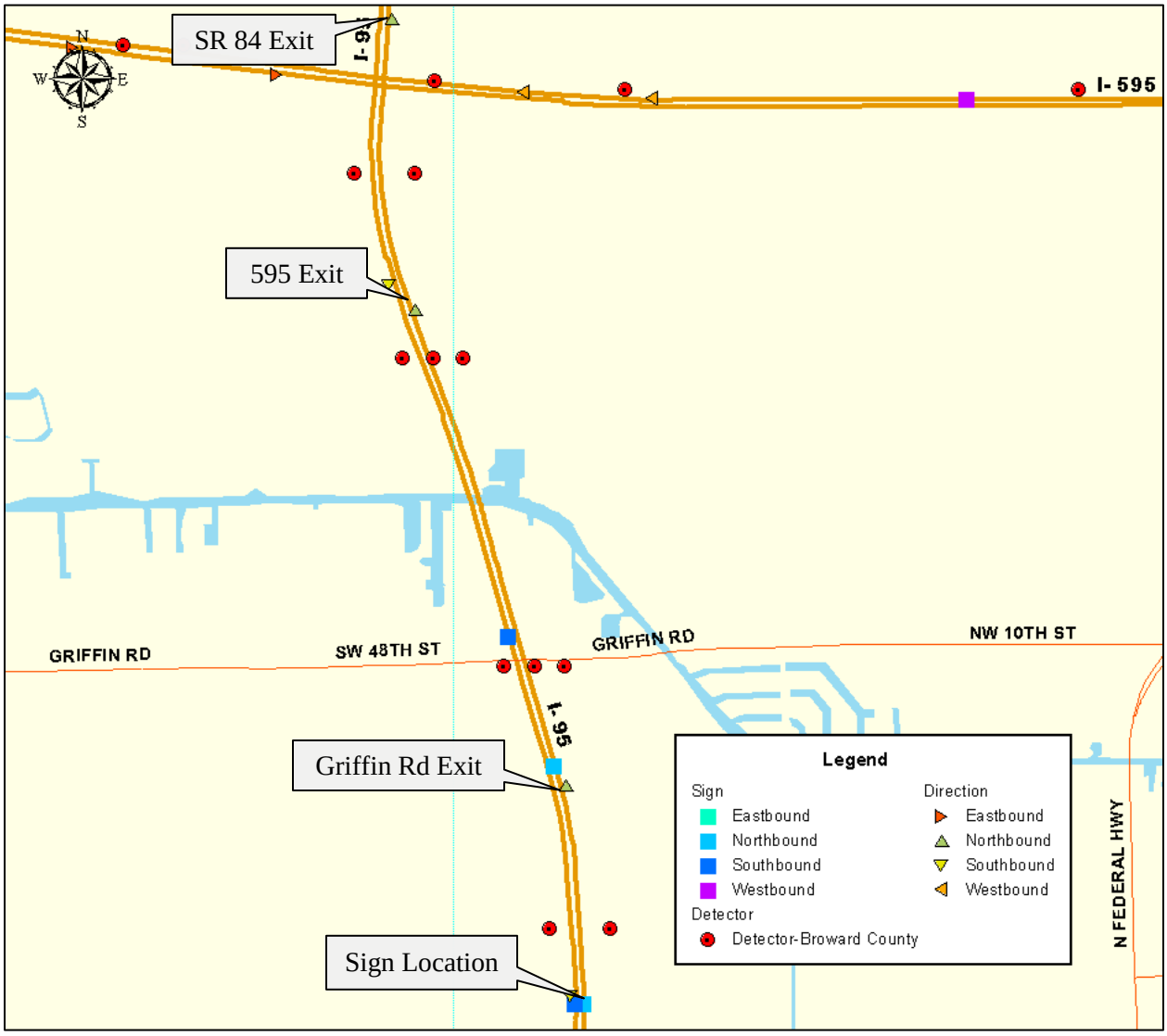
Sign Location: I-95 Northbound North of Sheridan Street (Broward County)

Stirling Road: 0.5 mile; 1 detector
Griffin Road: 1.5 miles; 3 detectors
I-595: 2.5 miles; 5 detectors



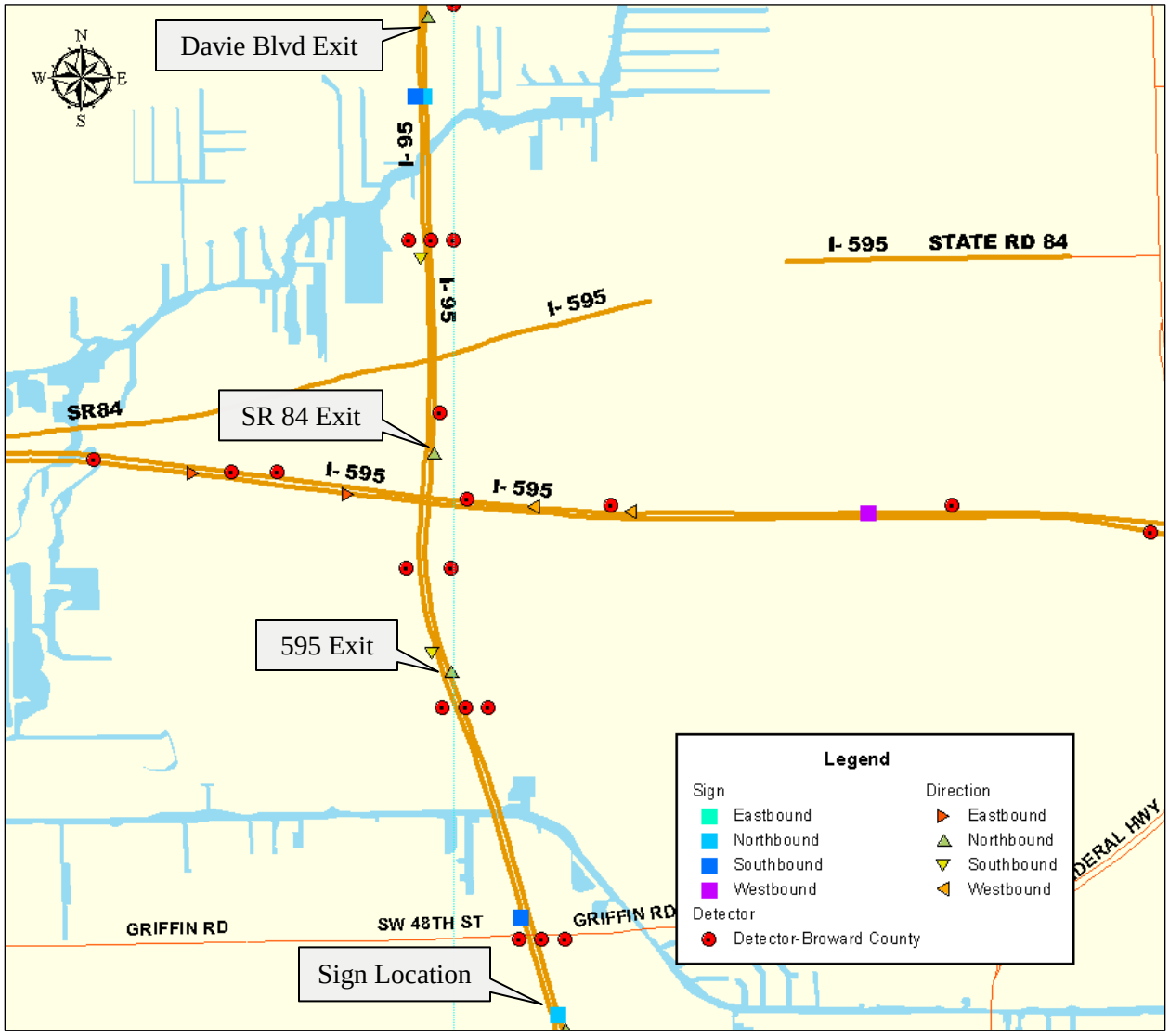
Sign Location: I-95 Northbound North of Stirling Road (Broward County)

Griffin Road: 0.5 mile; 1 detector
I-595: 1.5 miles; 3 detectors
SR 84: 2 miles; 4 detectors



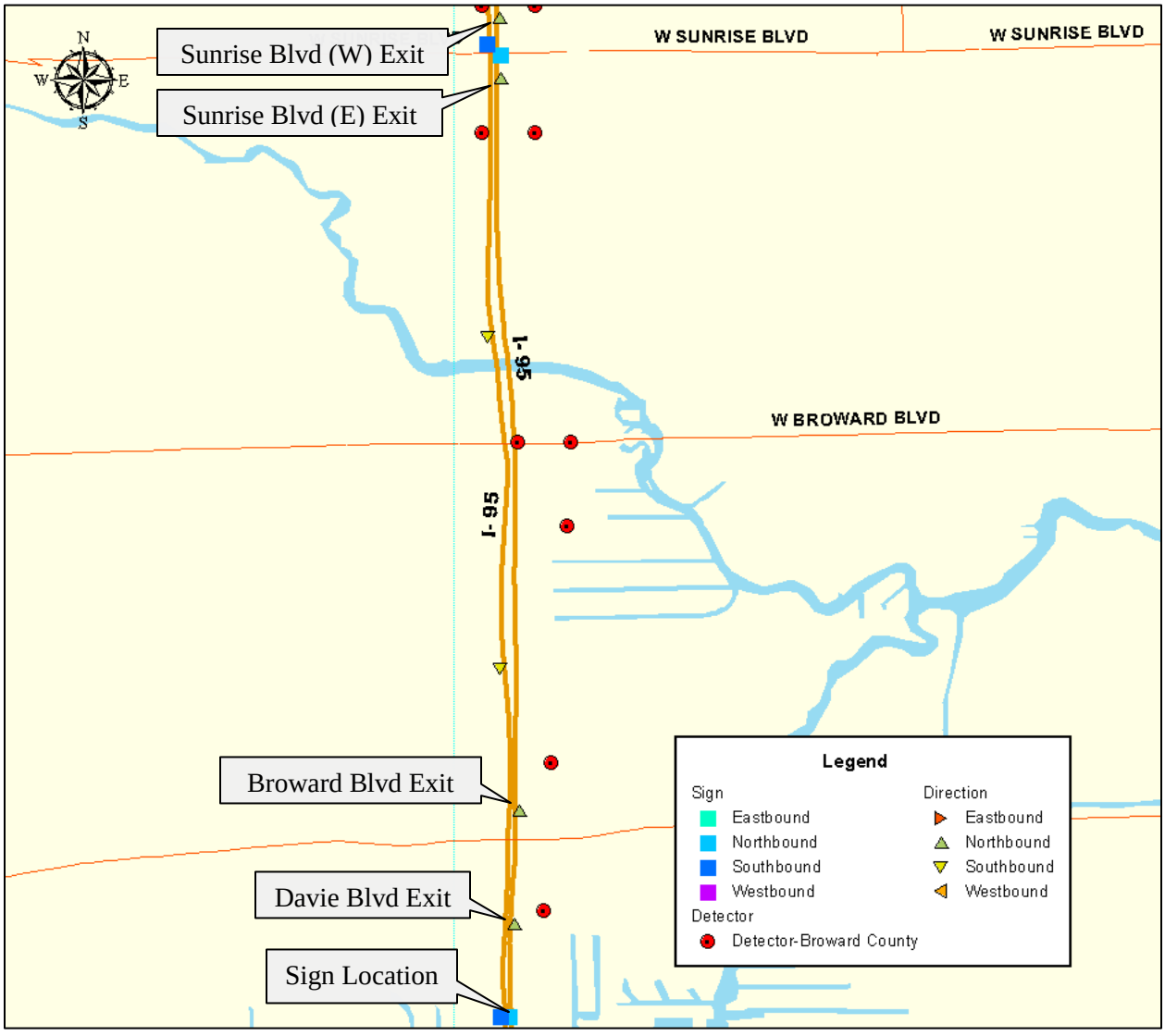
Sign Location: I-95 Northbound South of Griffin Road (Broward County)

I-595: 1 mile; 2 detectors
SR 84: 1.5 miles; 3 detectors
Davie Boulevard: 3 miles; 5 detectors



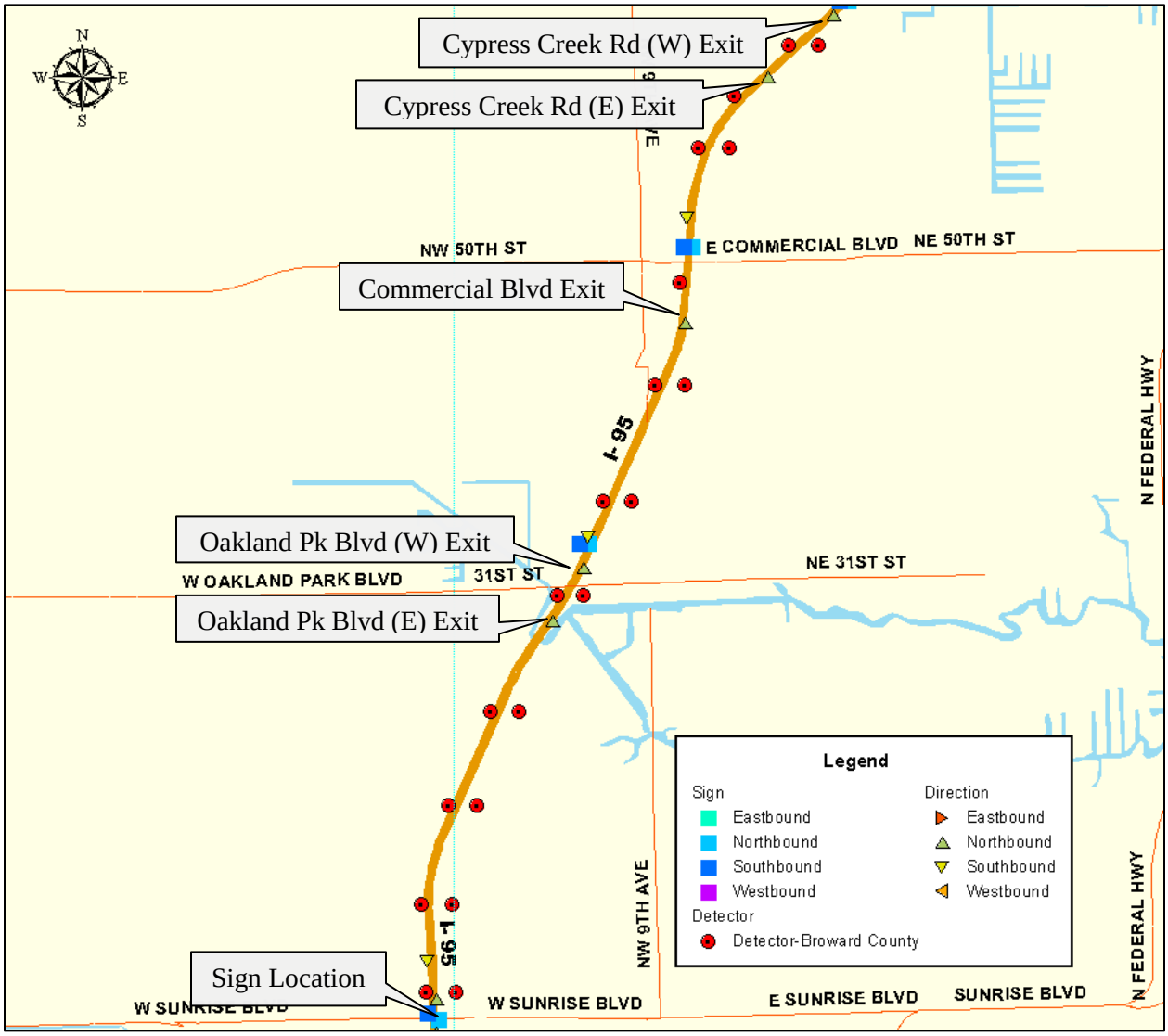
Sign Location: I-95 Northbound South of State Road 84 (Broward County)

Davie Boulevard: 0.25 mile; No detector
Broward Boulevard: 0.5 mile; 1 detector
Sunrise Boulevard: 2 miles; 5 detectors



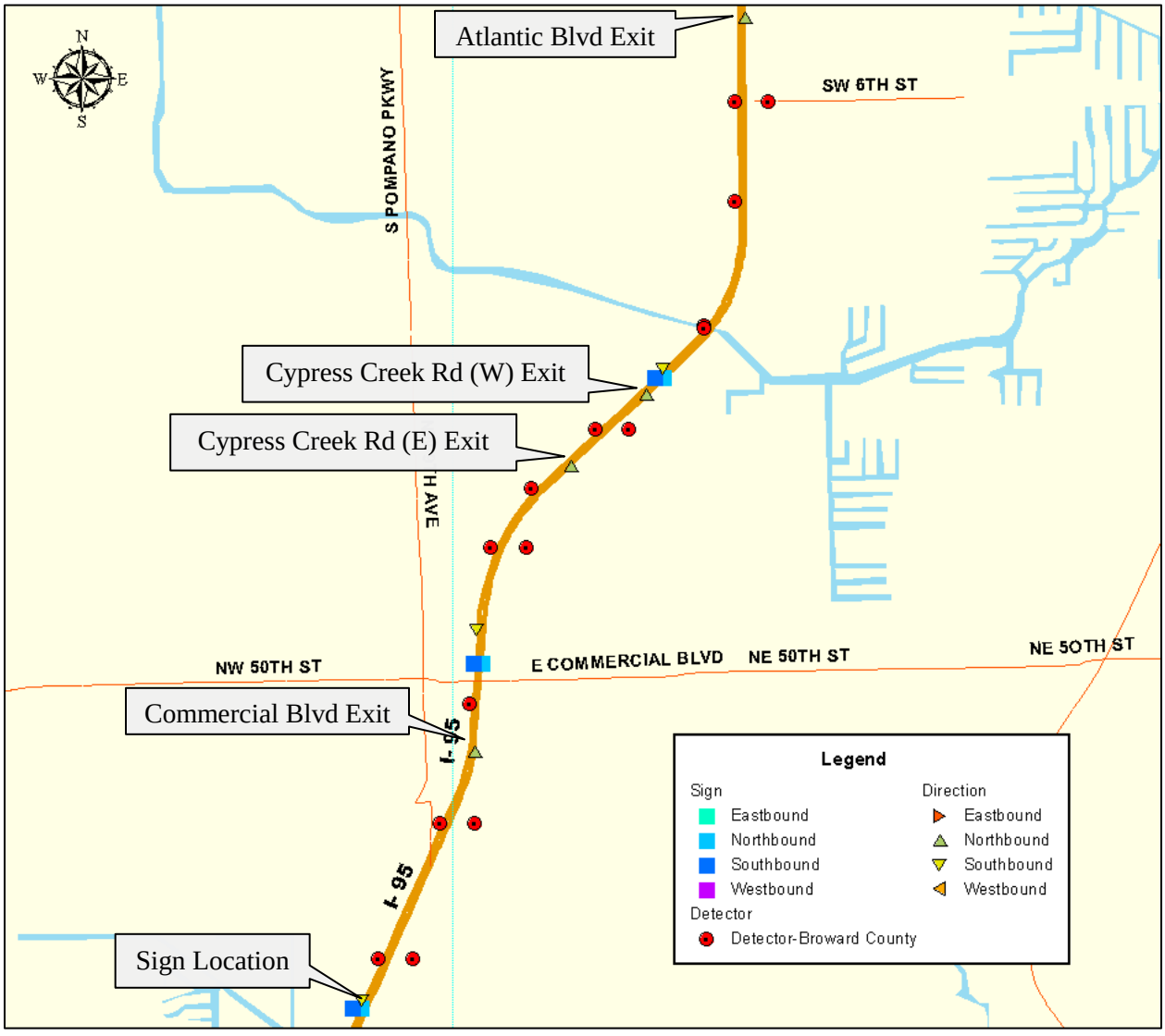
Sign Location: I-95 Northbound South of Sunrise Boulevard (Broward County)

Oakland Park Boulevard: 2 miles; 5 detectors
Commercial Boulevard: 3.75 miles; 7 detectors
Cypress Creek Road: 4.75 miles; 11 detectors



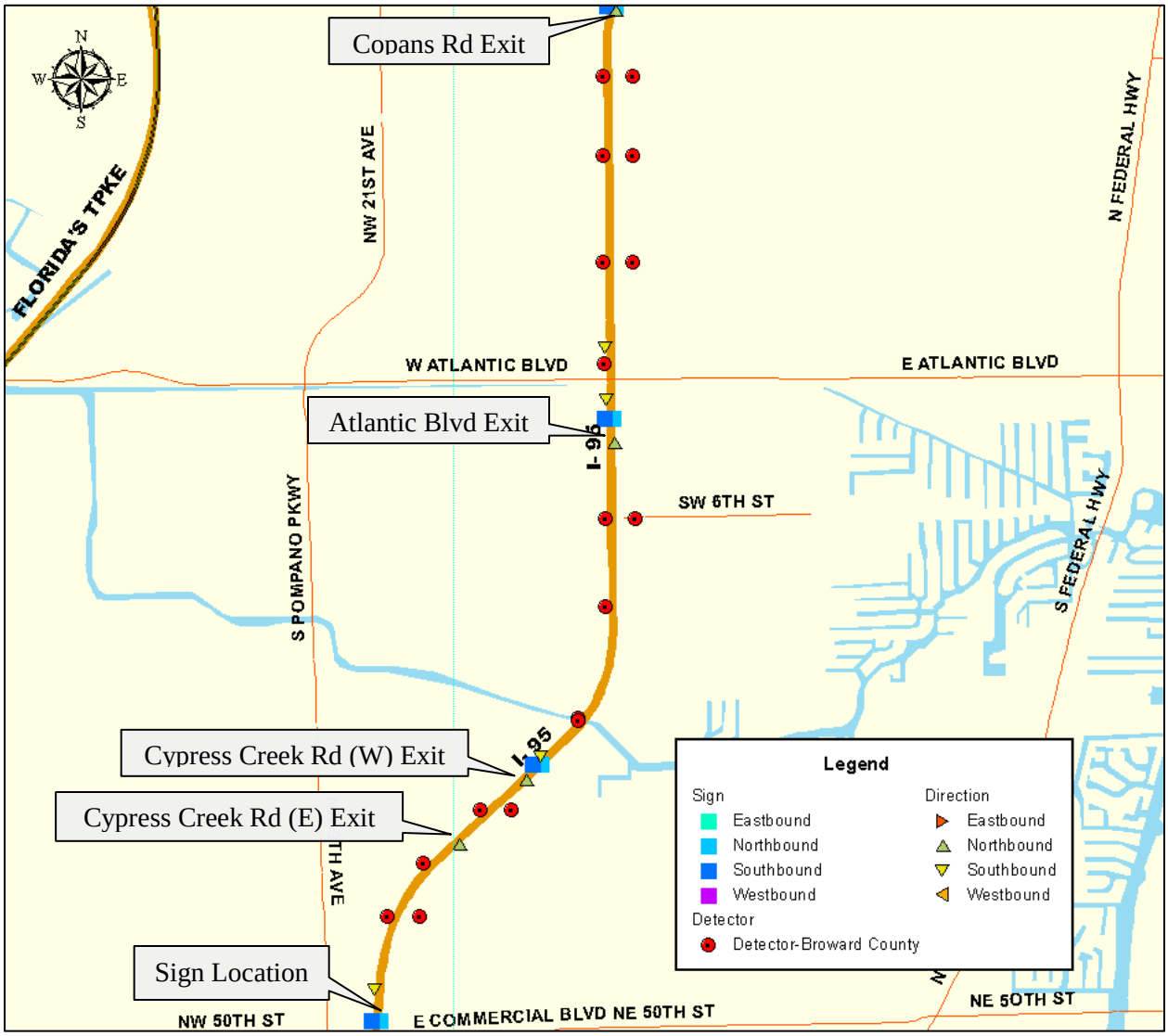
Sign Location: I-95 Northbound North of Oakland Park Boulevard (Broward County)

Commercial Boulevard: 1.25 miles; 2 detectors
Cypress Creek Road: 2.5 miles; 6 detectors
Atlantic Boulevard: 4.5 miles; 9 detectors



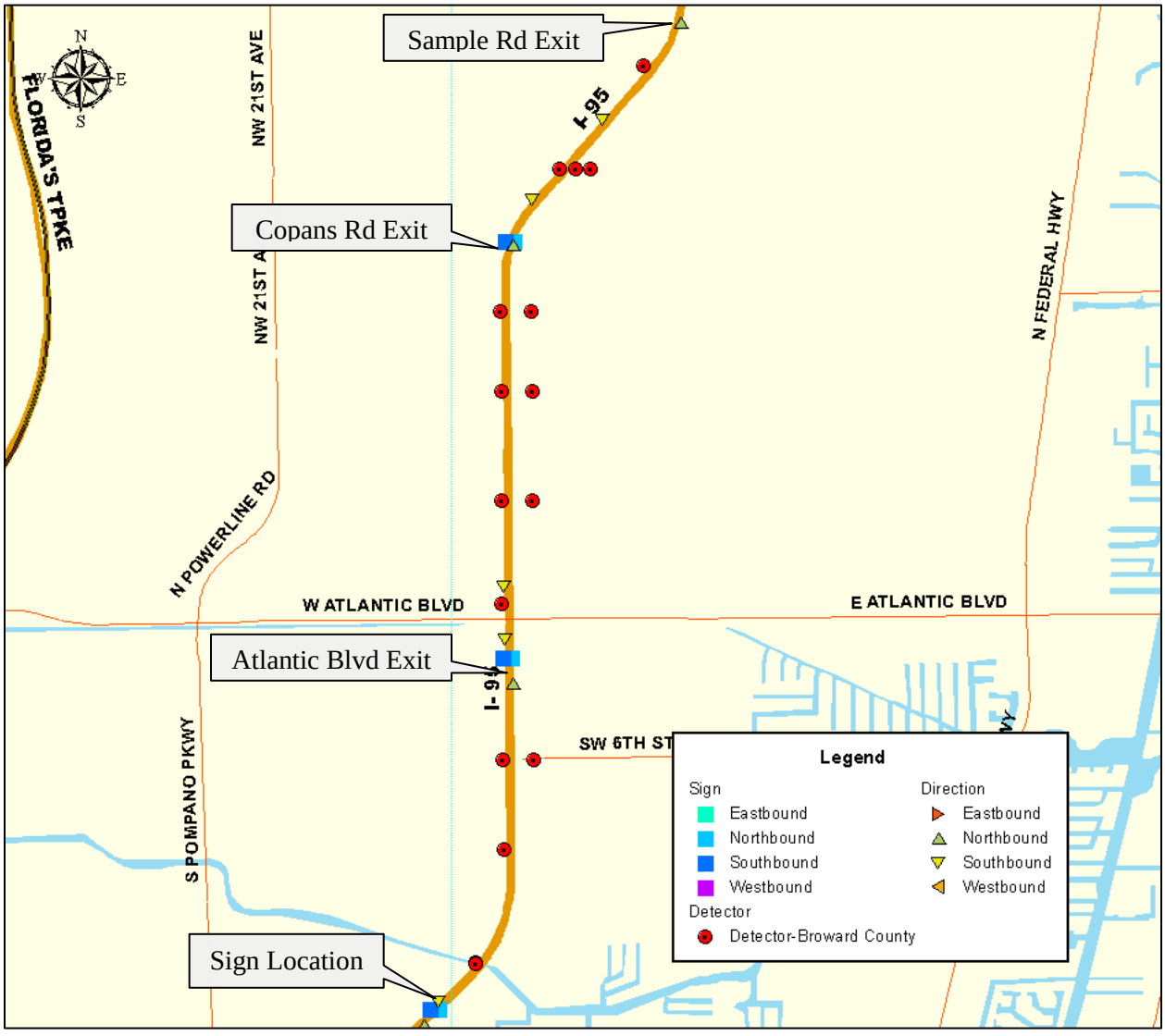
Sign Location: I-95 Northbound North of Commercial Boulevard (Broward County)

Cypress Creek Road: 0.75 miles; 3 detectors
Atlantic Boulevard: 3 miles; 6 detectors
Copans Road: 5 miles; 10 detectors



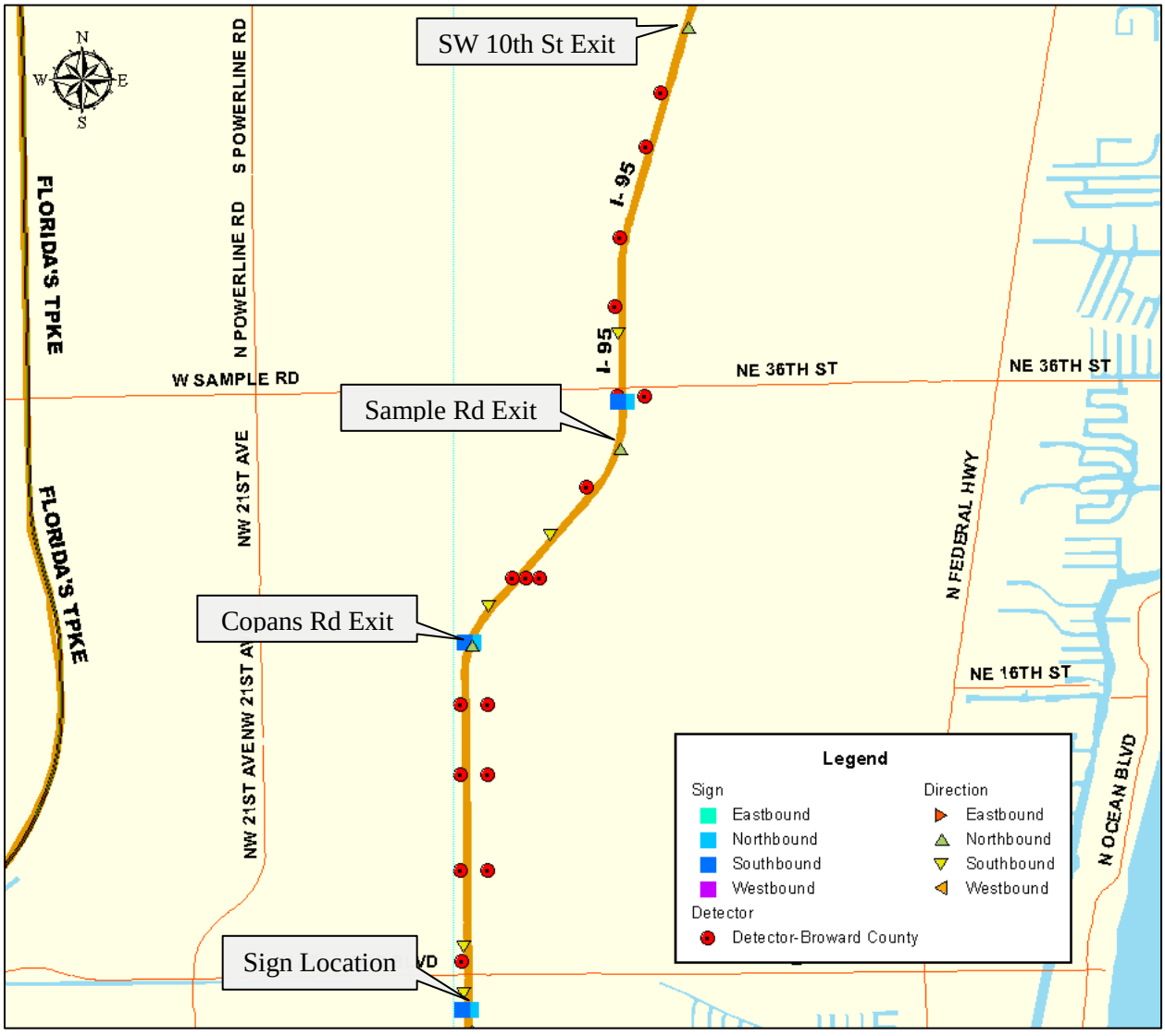
Sign Location: I-95 Northbound North of Cypress Creek Road (Broward County)

Cypress Creek Road: 1.5 miles; 3 detectors
Copans Road: 3.75 miles; 7 detectors
Sample Road: 4.75 miles; 9 detectors



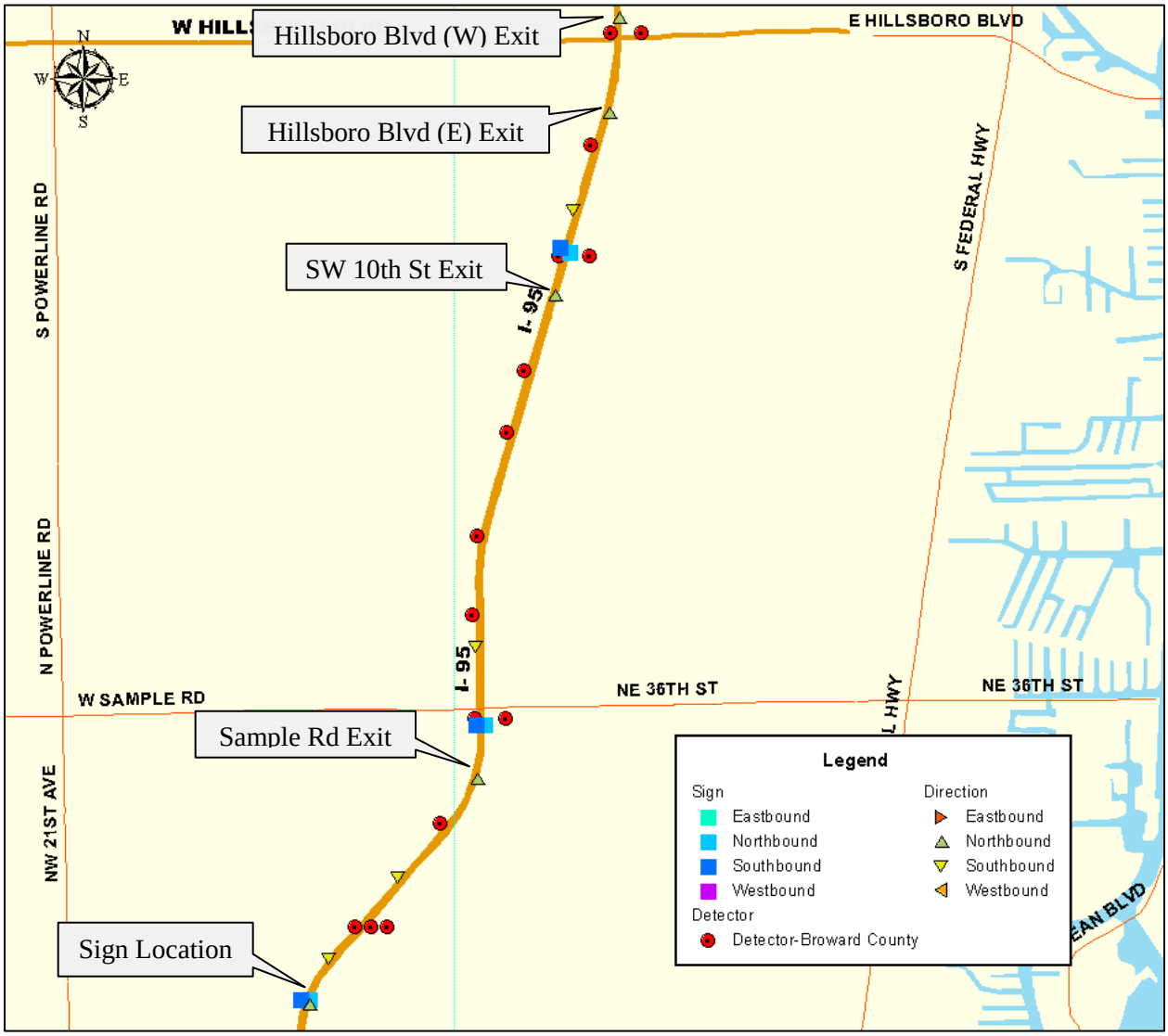
Sign Location: I-95 Northbound South of Atlantic Boulevard (Broward County)

Copans Road: 1.75 miles; 4 detectors
Sample Road: 3 miles; 6 detectors
SW 10th Street: 5 miles; 11 detectors



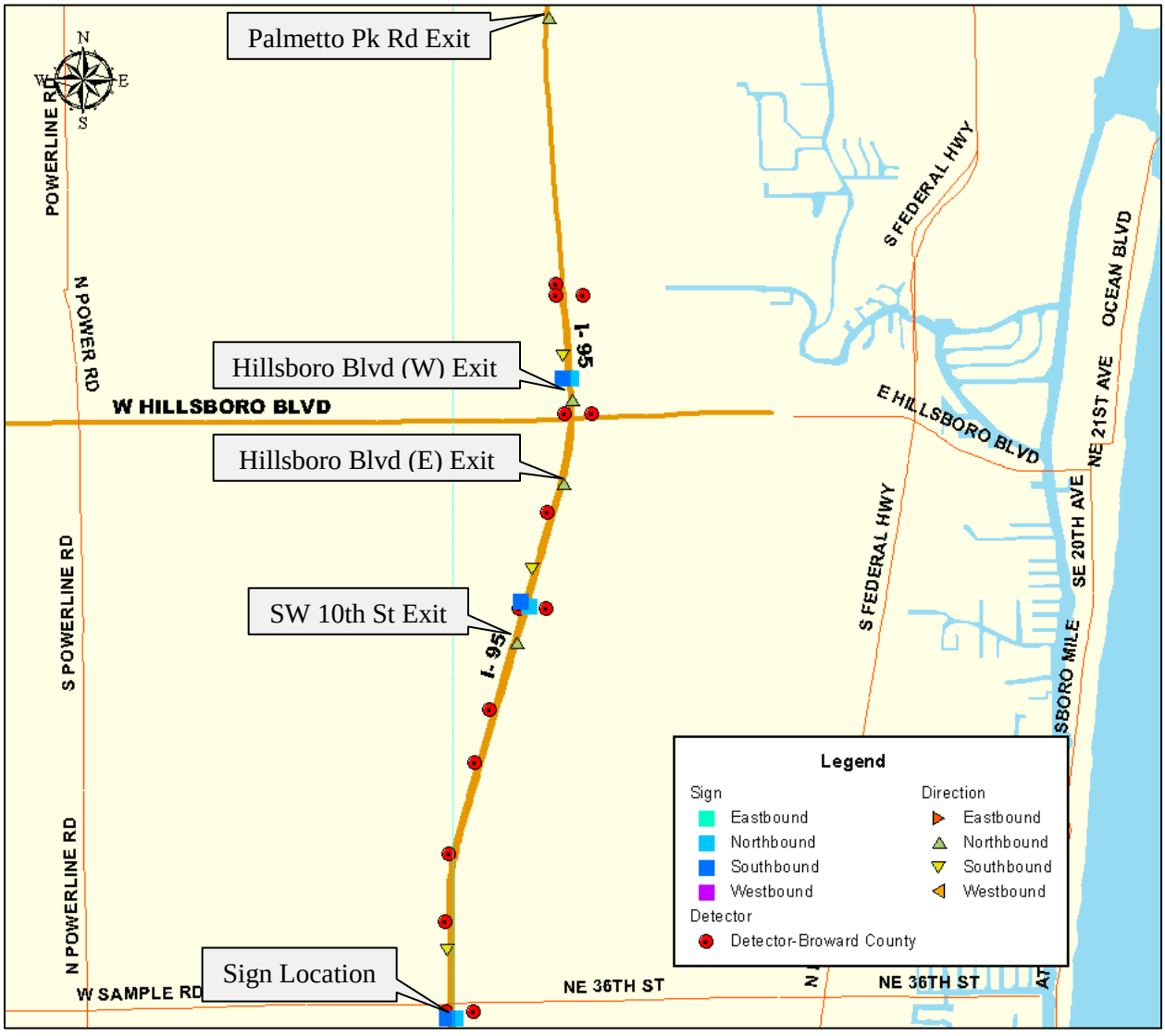
Sign Location: I-95 Northbound South of Copans Road (Broward County)

Sample Road: 1 mile; 2 detectors
SW 10th Street: 3 miles; 7 detectors
Hillsboro Boulevard: 4 miles; 10 detectors



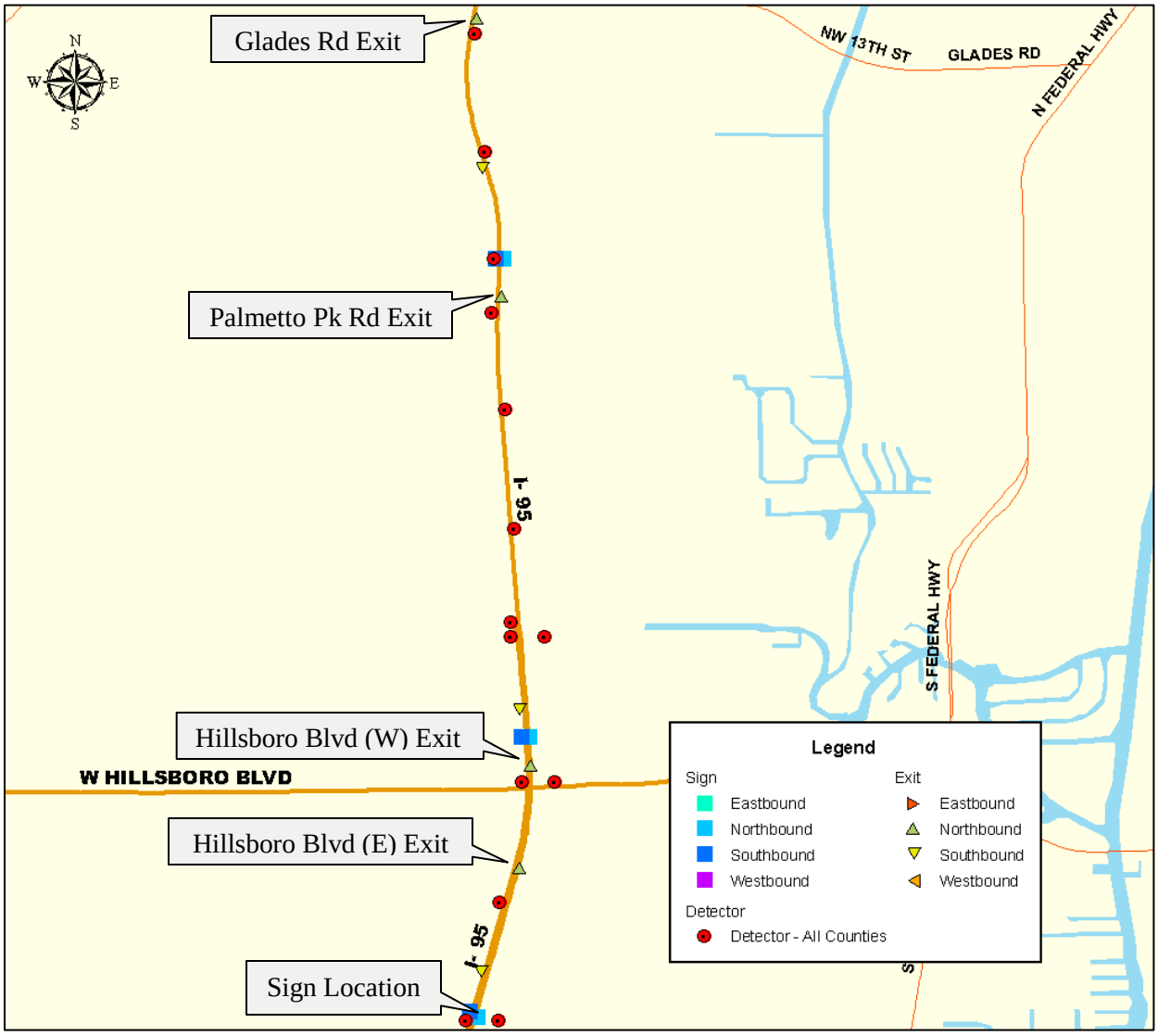
Sign Location: I-95 Northbound South of Sample Road (Broward County)

SW 10th Street: 1.75 miles; 5 detectors
Hillsboro Boulevard: 2.75 miles; 8 detectors
Palmetto Park Road: 5 miles; 9 detectors



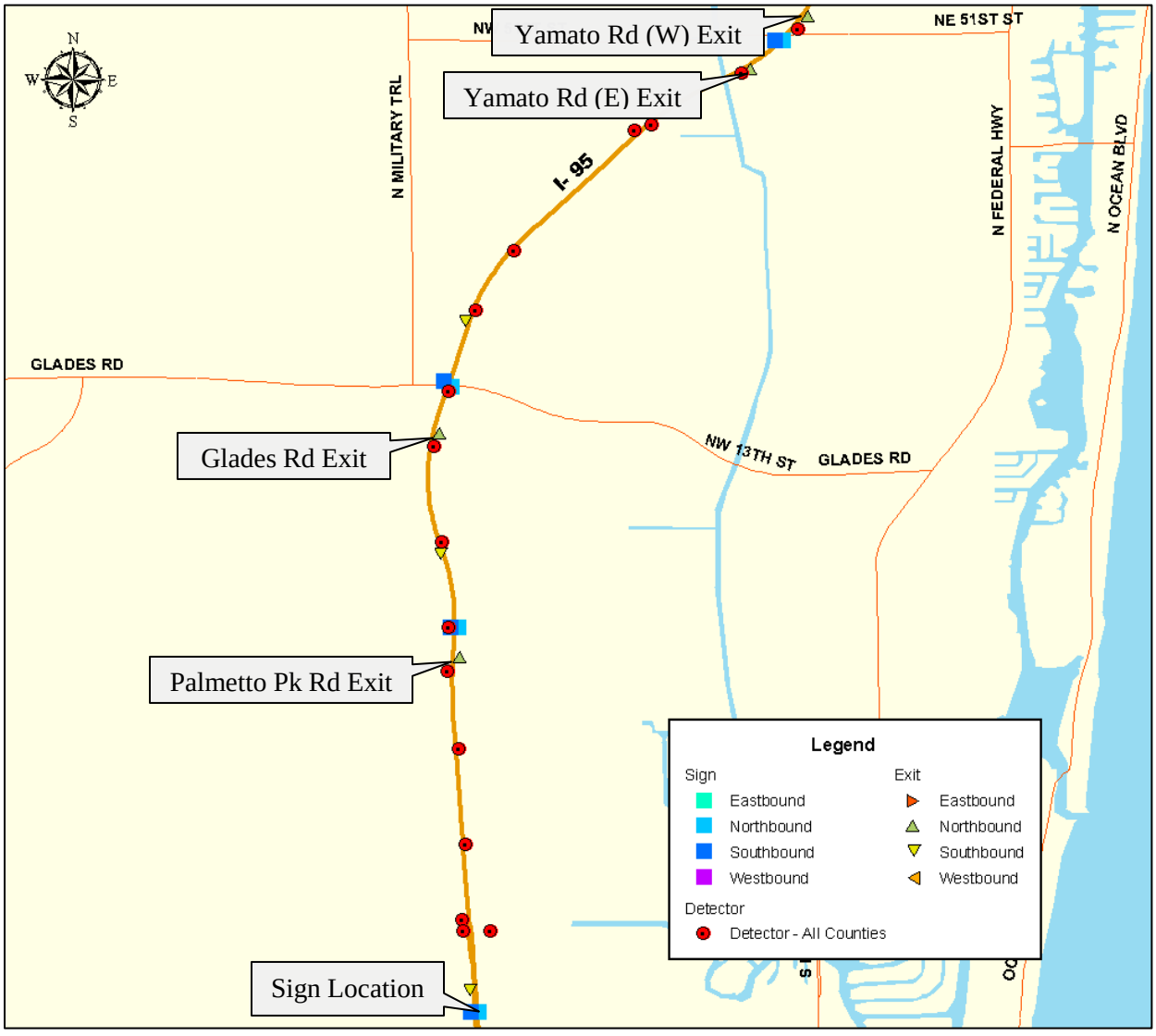
Sign Location: I-95 Northbound South of Hillsboro Boulevard (Broward County)

Hillsboro Boulevard: 1 mile; 2 detectors
Palmetto Park Road: 3 miles; 6 detectors
Glades Road: 5 miles; 9 detectors



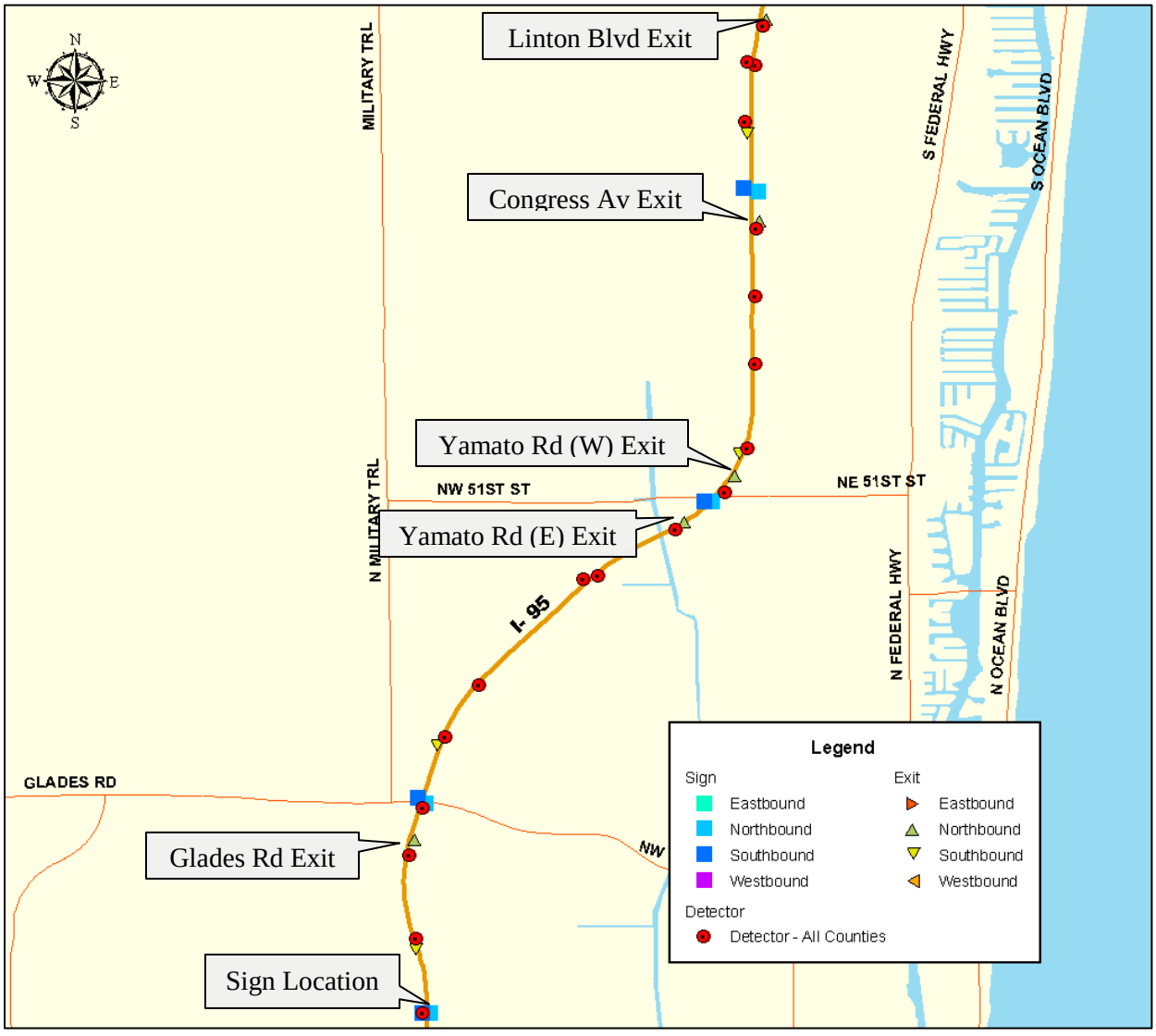
Sign Location: I-95 Northbound North of Hillsboro Boulevard (Palm Beach County)

Palmetto Park Road: 1.75 miles; 4 detectors
Glades Road: 2.75 miles; 7 detectors
Yamato Road: 4.75 miles; 13 detectors



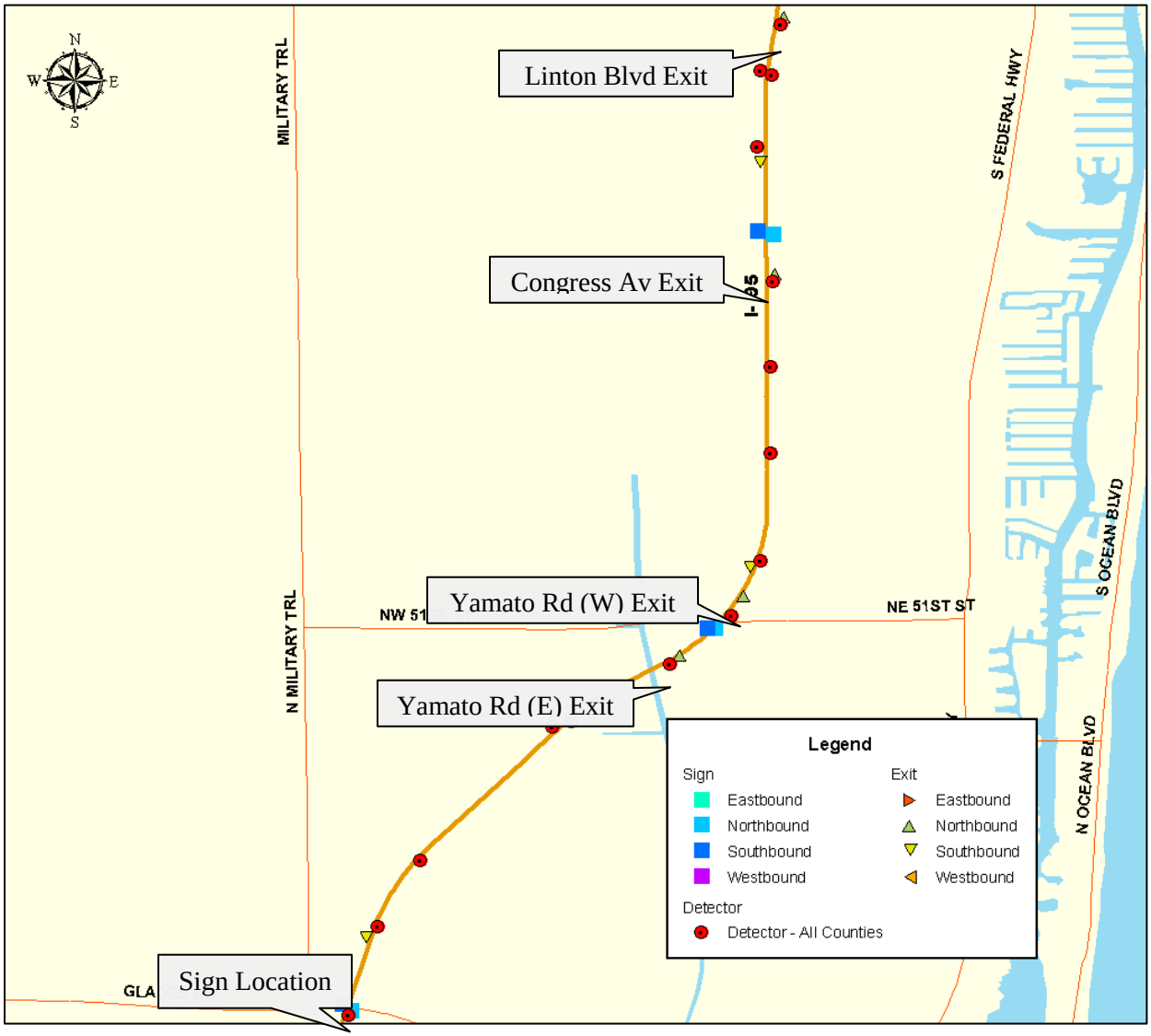
Sign Location: I-95 Northbound South of Glades Road (Palm Beach County)

Glades Road: 1 mile; 2 detectors
Yamato Road: 3.5 miles; 8 detectors
Linton Boulevard: 6.5 miles; 15 detectors



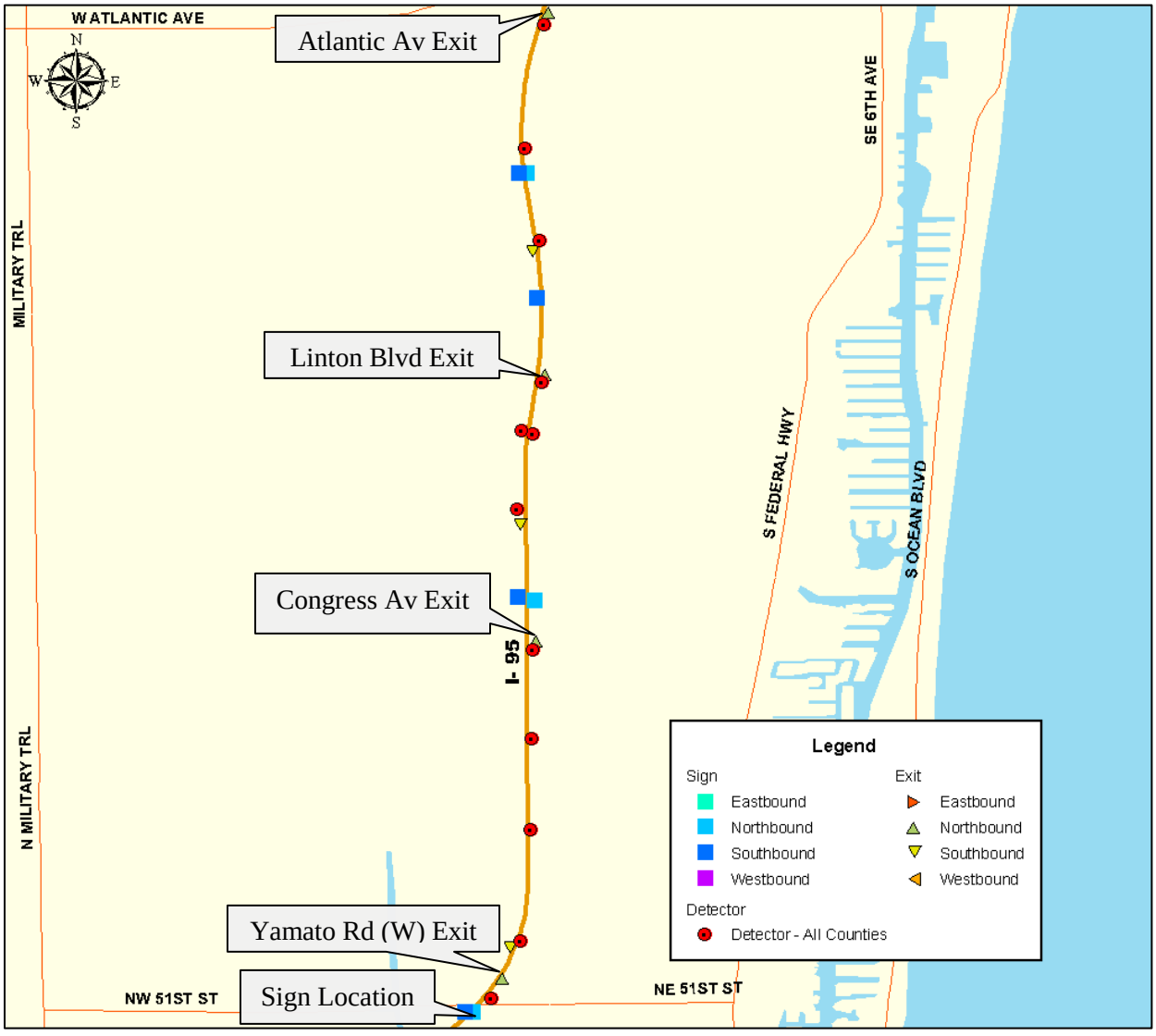
Sign Location: I-95 Northbound on Glades Road (Palm Beach County)

Yamato Road: 2.25 miles; 5 detectors
Congress Boulevard: 4 miles; 9 detectors
Linton Boulevard: 5.25 miles; 12 detectors



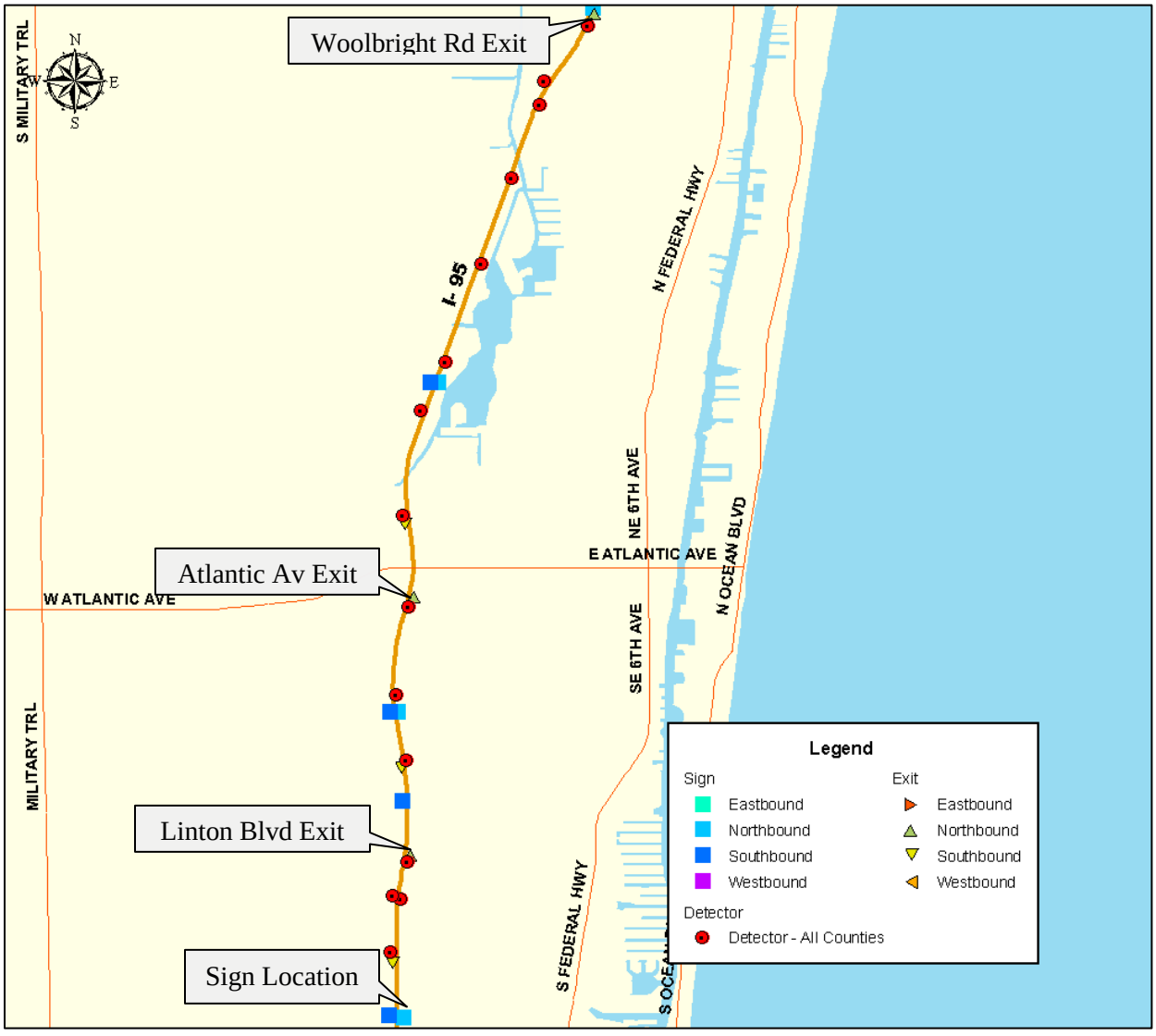
Sign Location: I-95 Northbound South of NW 51st Street (Palm Beach County)

Congress Boulevard: 1.5 miles; 5 detectors
Linton Boulevard: 2.5 miles; 8 detectors
Atlantic Avenue: 4.5 miles; 11 detectors



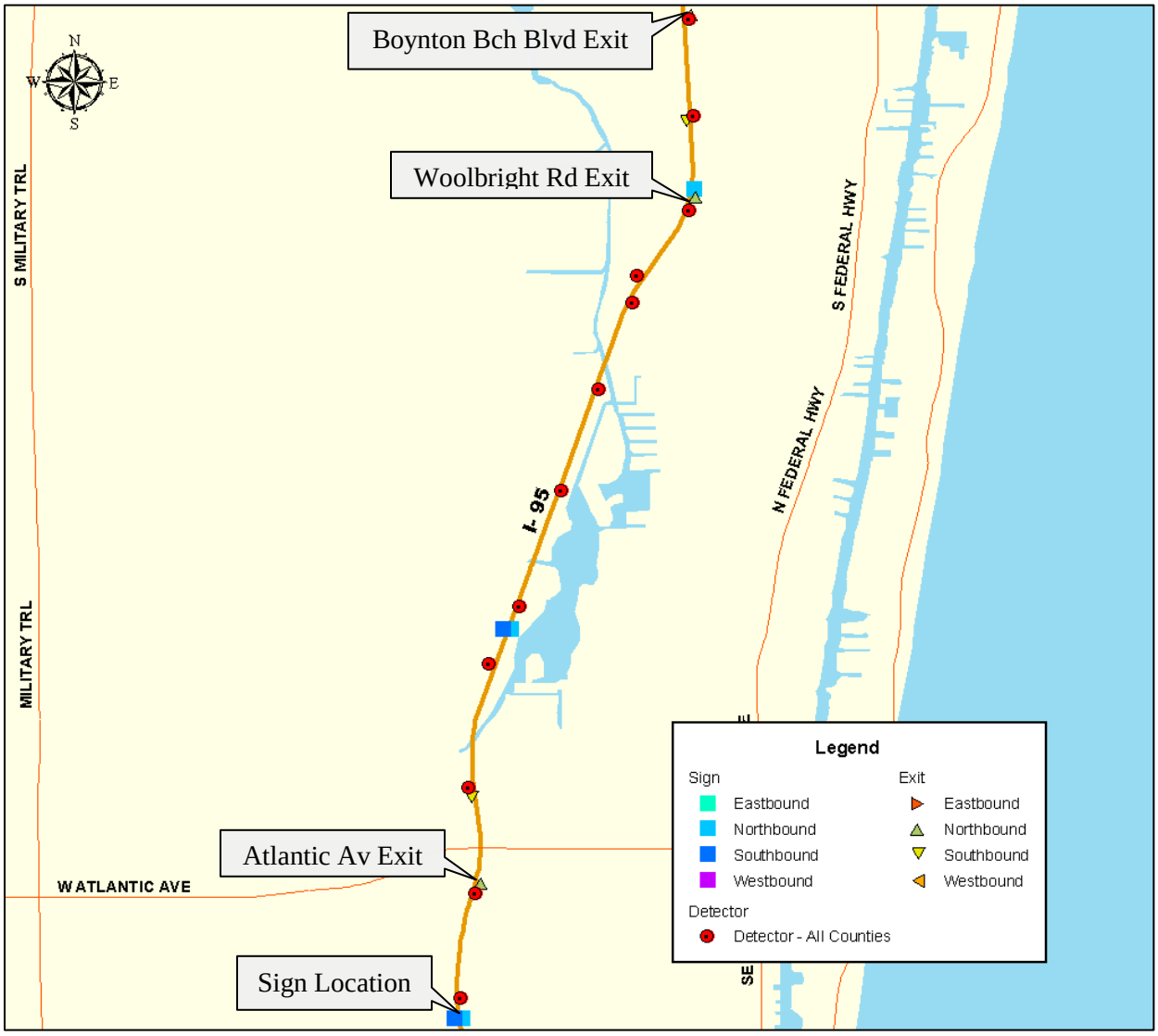
Sign Location: I-95 Northbound North of NW 51st Street (Palm Beach County)

Linton Boulevard: 1 mile; 3 detectors
Atlantic Avenue: 2.75 miles; 6 detectors
Woolbright Road: 6.75 miles; 13 detectors



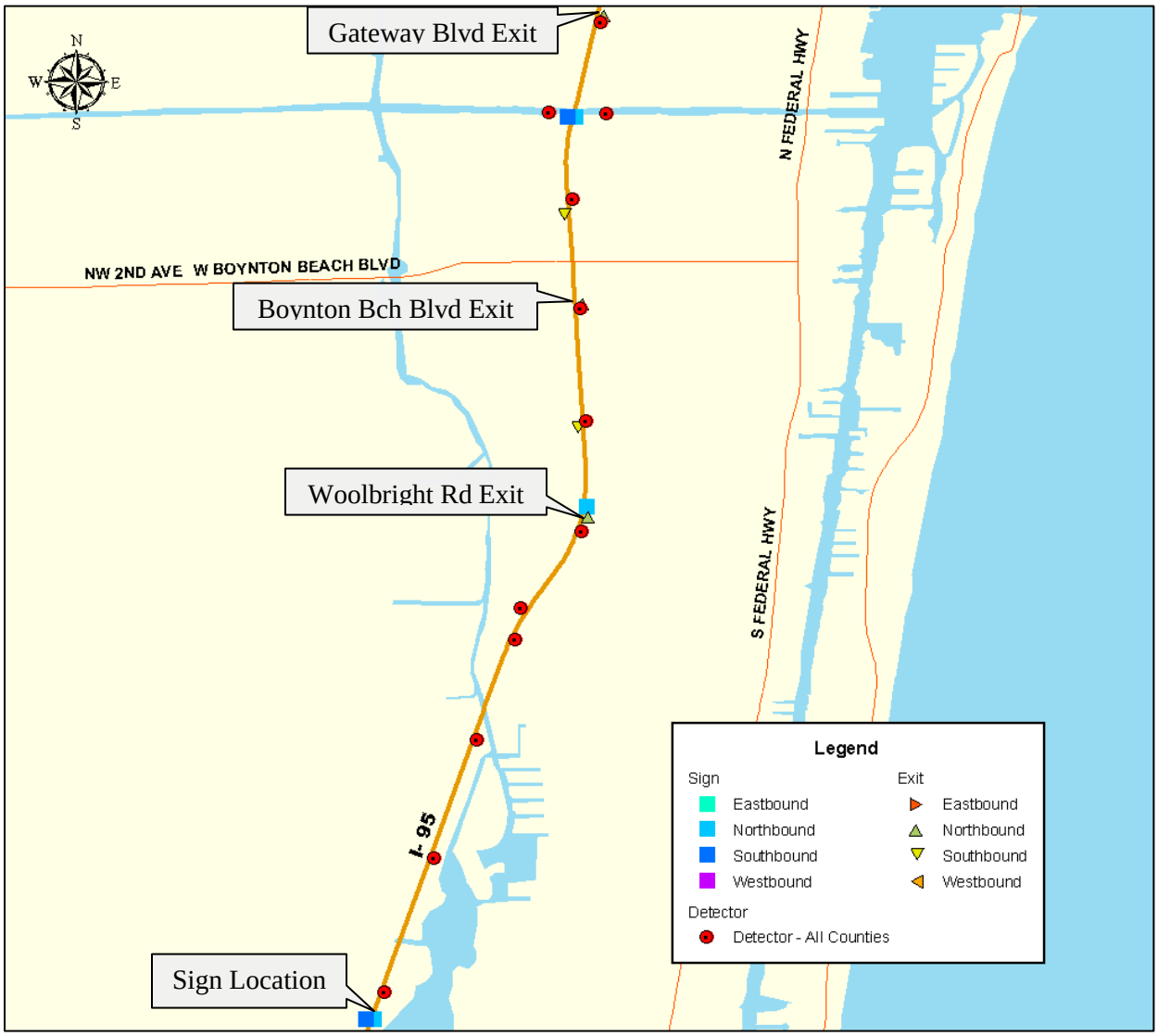
Sign Location: I-95 Northbound South of Atlantic Avenue (Palm Beach County)

Atlantic Avenue: 0.75 miles; 2 detectors
Woolbright Road: 4.75 miles; 9 detectors
Boynton Beach Boulevard: 5.5 miles; 11 detectors



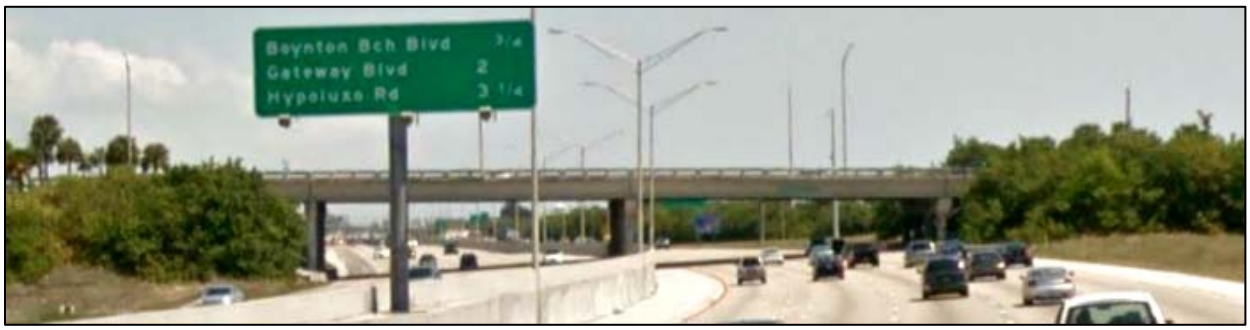
Sign Location: I-95 Northbound North of Atlantic Avenue (Palm Beach County)

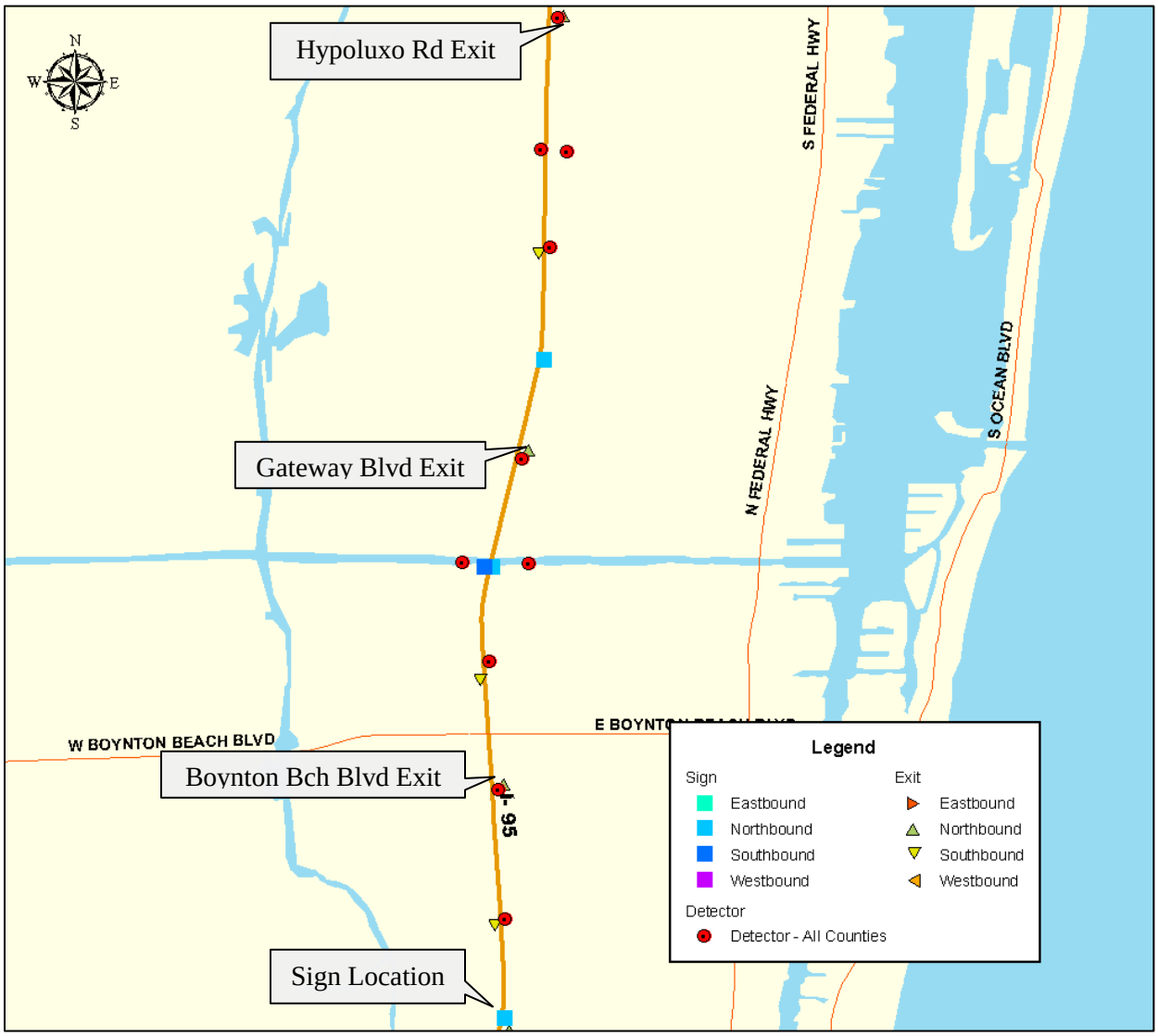
Woolbright Road: 2.25 miles; 5 detectors
Boynton Beach Boulevard: 3.25 miles; 7 detectors
Gateway Boulevard: 4.5 miles; 10 detectors



Sign Location: I-95 Northbound South of Boynton Beach Boulevard (Palm Beach County)

Boynton Beach Boulevard: 0.75 miles; 7 detectors
Gateway Boulevard: 2 miles; 5 detectors
Hypoluxo Road: 3.25 miles; 8 detectors





Sign Location: I-95 Northbound North of Boynton Beach Boulevard (Palm Beach County)

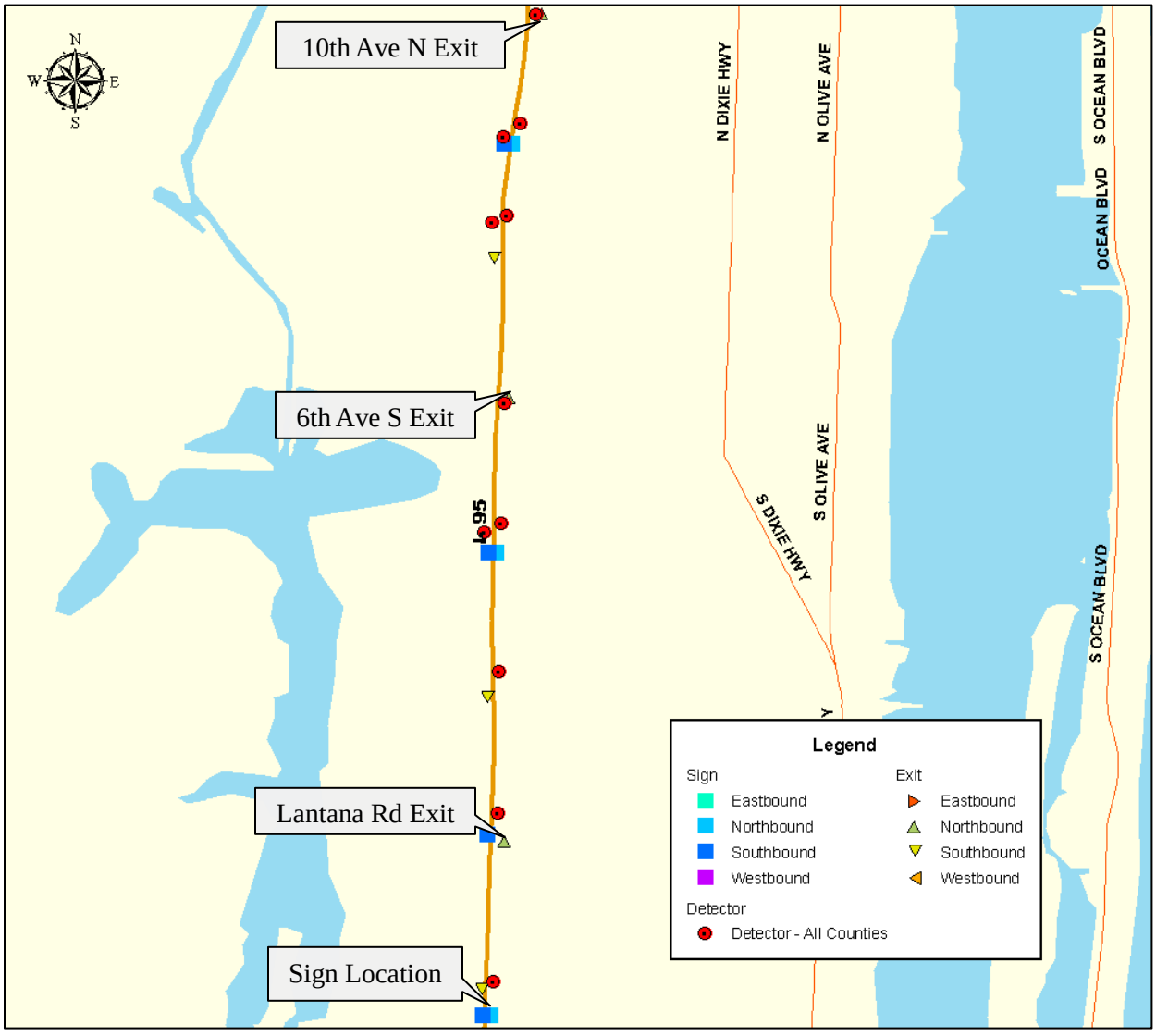
Gateway Boulevard: 0.25 miles; 2 detectors
Hypoluxo Road: 2 miles; 4 detectors
Lantana Road: 3 miles; 6 detectors

Sign Location: I-95 Northbound North of Boynton Beach Boulevard (Palm Beach County)

Hypoluxo Road: 1.25 miles; 2 detectors
Lantana Road: 2.25 miles; 4 detectors
6th Avenue South: 3.75 miles; 8 detectors

Sign Location: I-95 Northbound North of Boynton Beach Boulevard (Palm Beach County)

Lantana Road: 0.5 mile; 1 detector
6th Avenue South: 2 miles; 5 detectors
10th Avenue North: 3.5 miles; 7 detectors

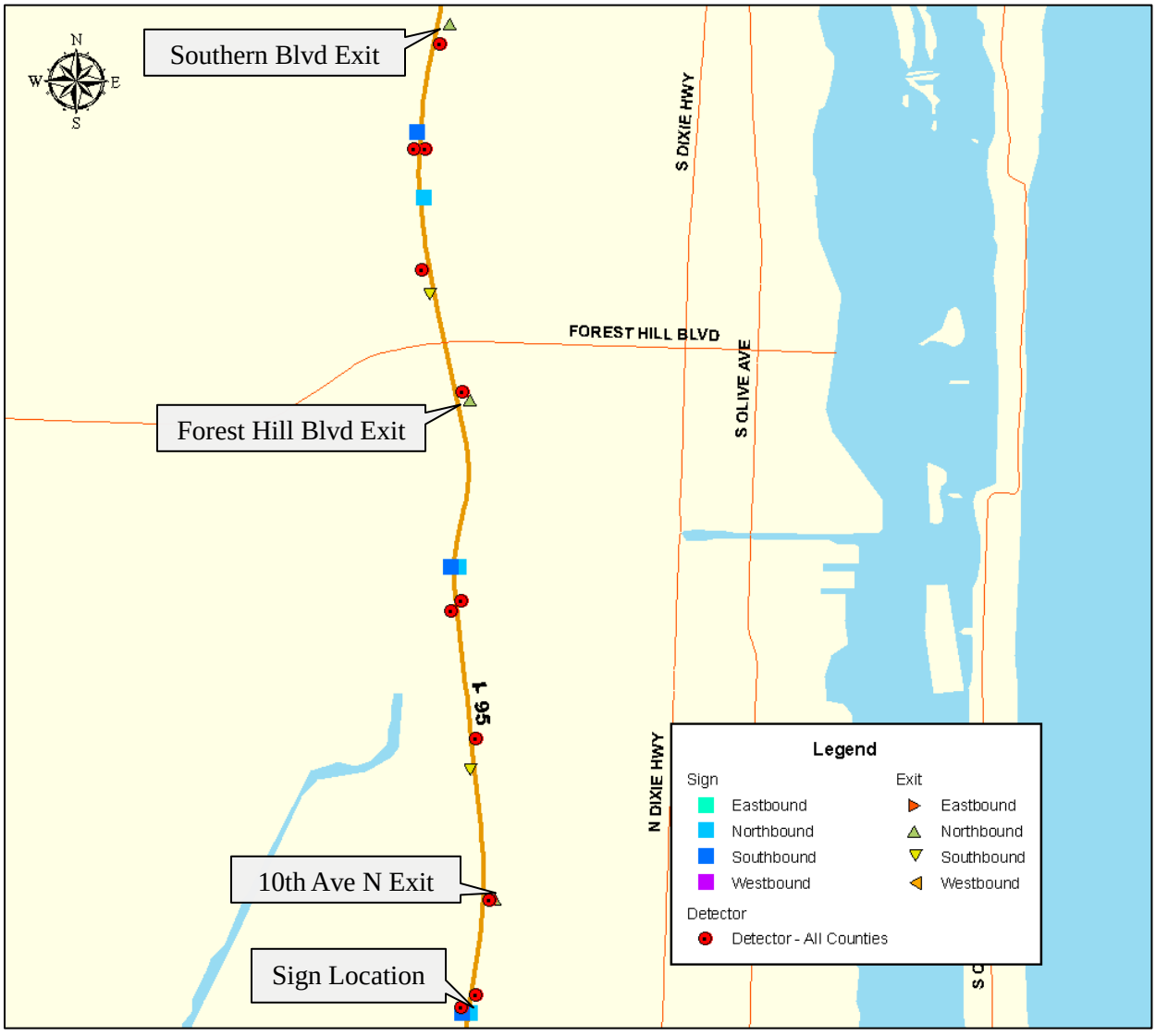


Sign Location: I-95 Northbound North of Boynton Beach Boulevard (Palm Beach County)

6th Avenue South: 0.5 mile; 2 detectors
10th Avenue North: 1.75 miles; 4 detectors
Forest Hill Boulevard: 3.75 miles; 7 detectors

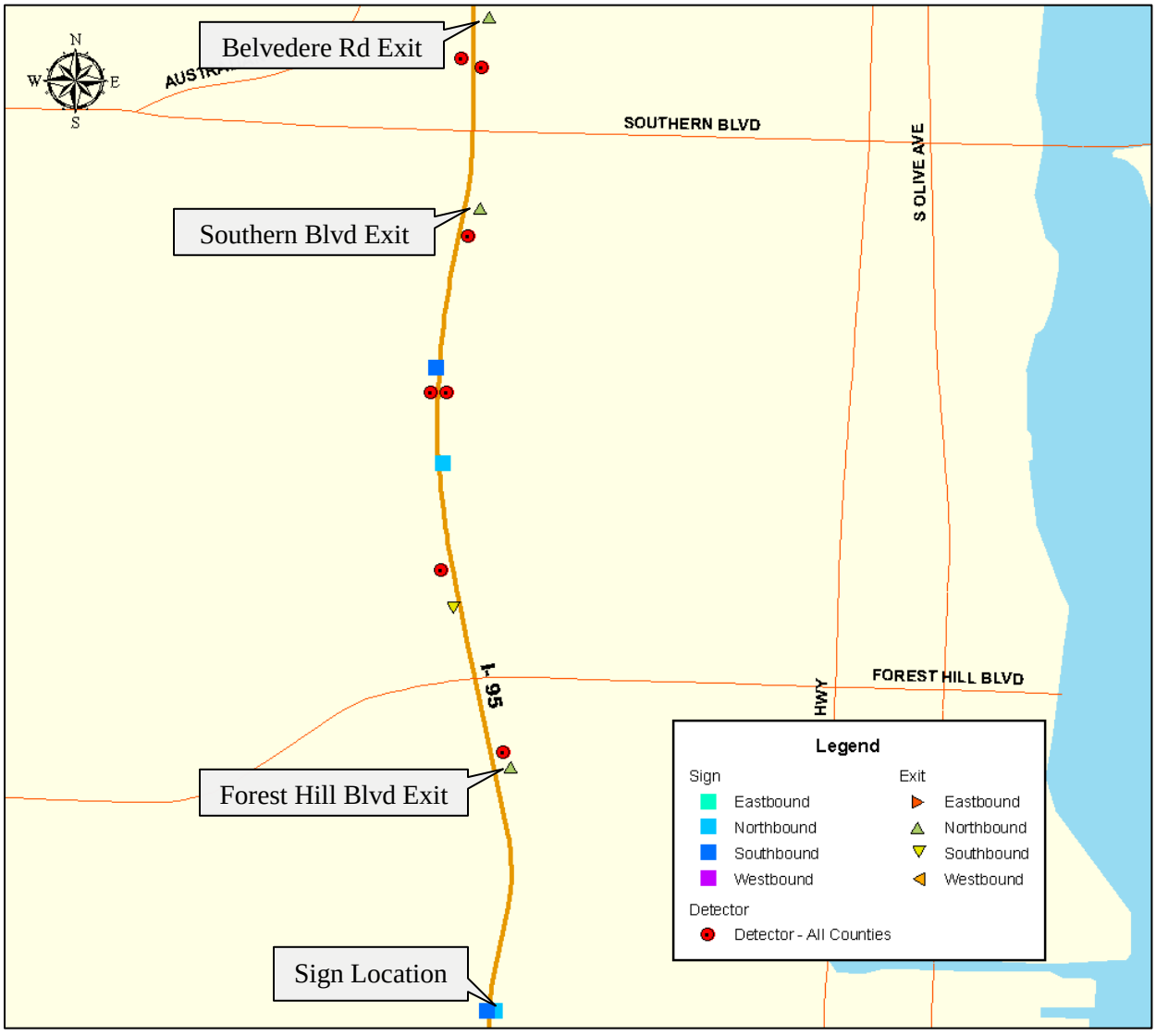
Sign Location: I-95 Northbound North of Boynton Beach Boulevard (Palm Beach County)

10th Avenue North: 0.25 mile; 1 detector
Forest Hill Boulevard: 2.25 miles; 4 detectors
Southern Boulevard: 3.75 miles; 8 detectors



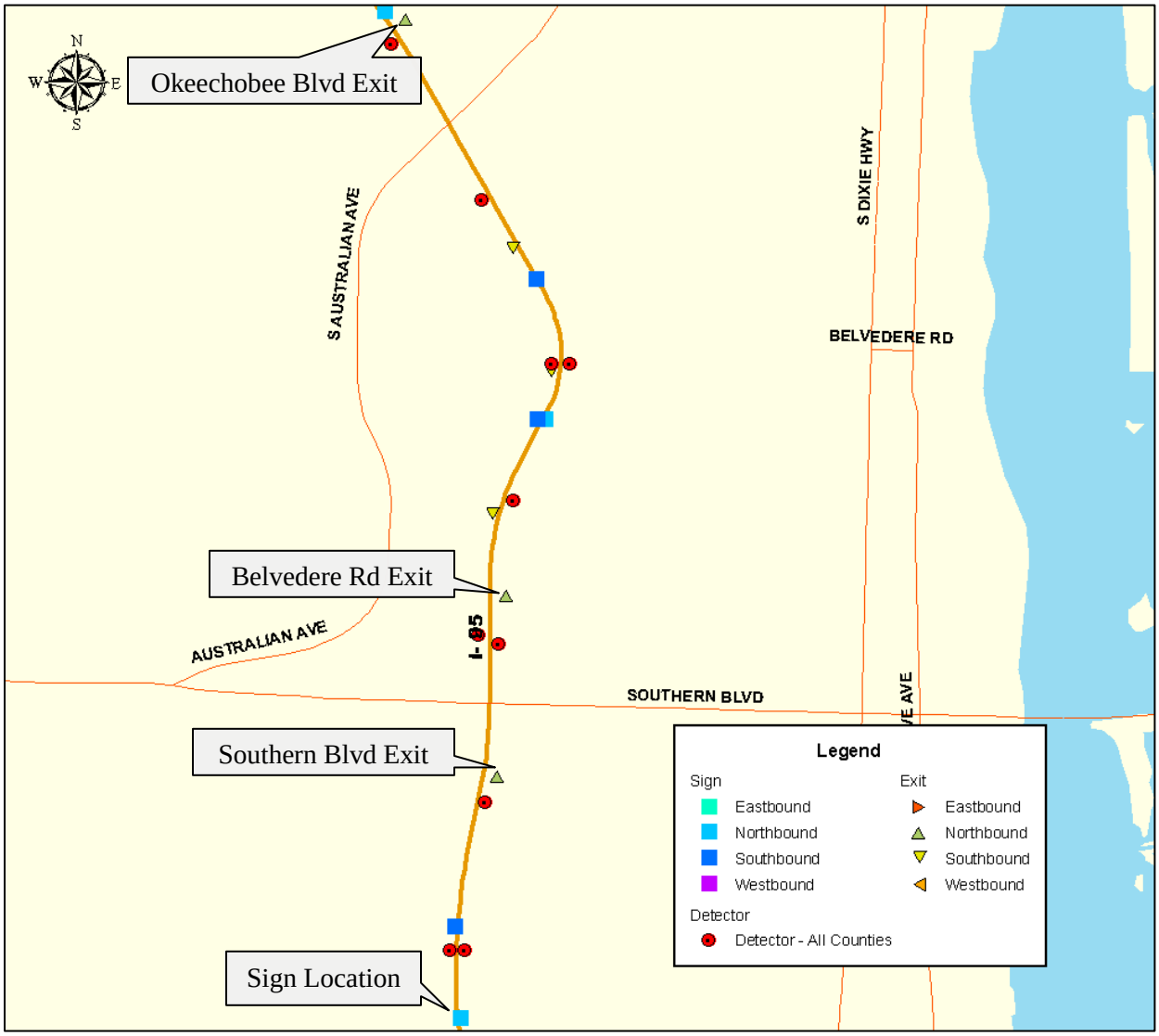
Sign Location: I-95 Northbound South of Forest Hill Boulevard (Palm Beach County)

Forest Hill Boulevard: 0.5 mile; no detector
Southern Boulevard: 2 miles; 4 detectors
Belvedere Road: 2.5 miles; 5 detectors



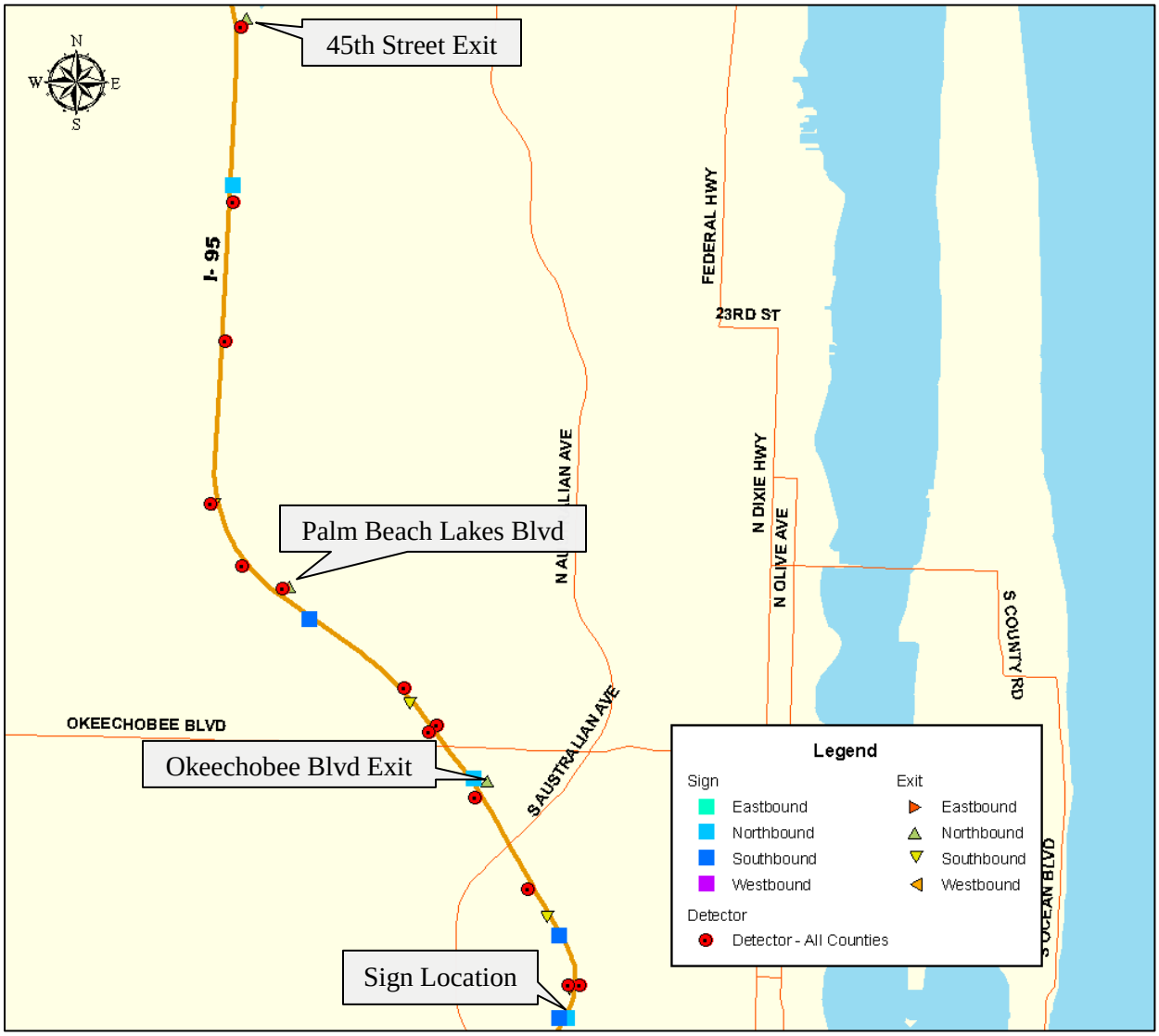
Sign Location: I-95 Northbound South of Southern Boulevard (Palm Beach County)

Southern Boulevard: 0.5 mile; 2 detectors
Belvedere Road: 1 mile; 3 detectors
Okeechobee Boulevard: 2.75 miles; 7 detectors



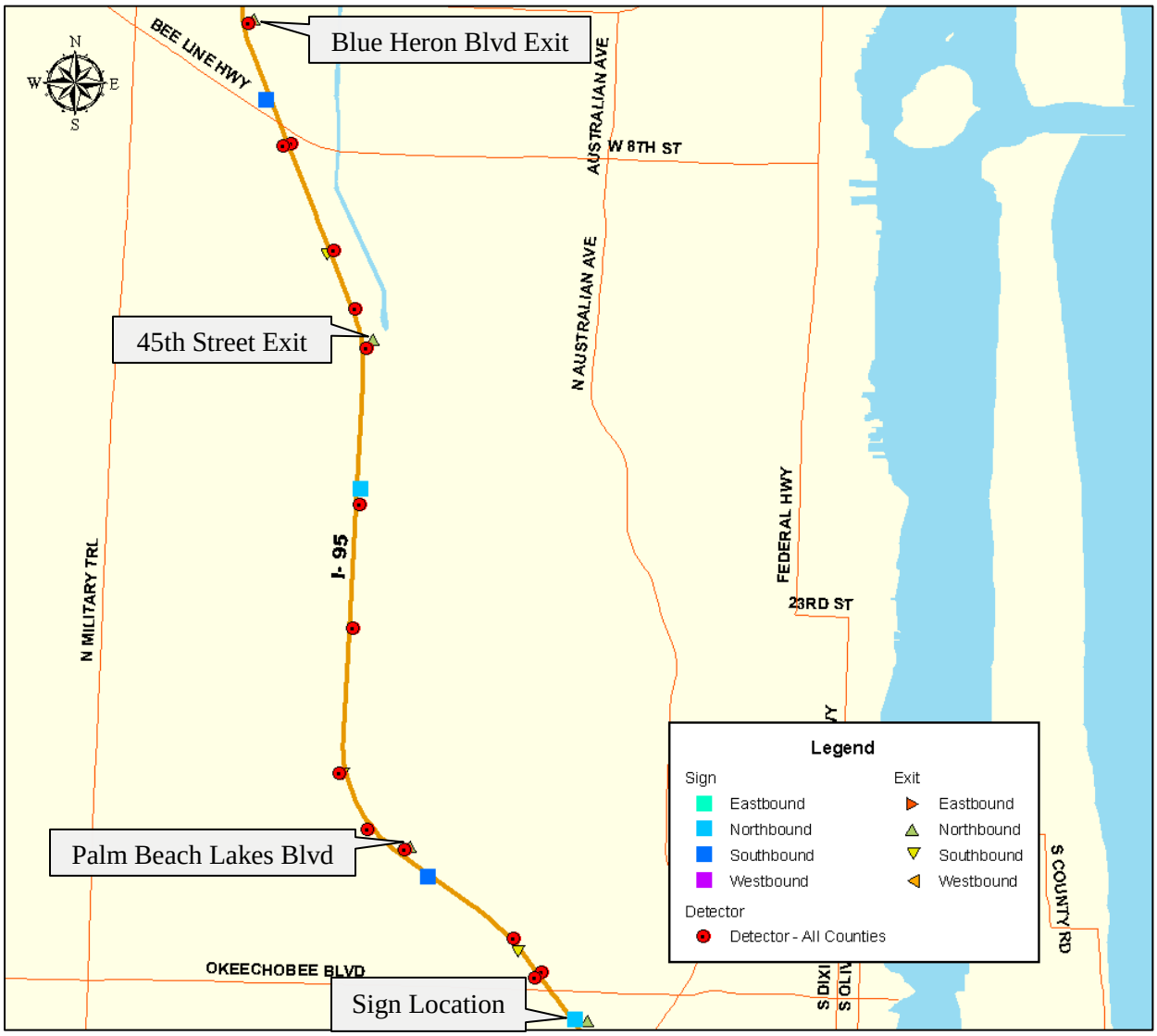
Sign Location: I-95 Northbound North of Southern Boulevard (Palm Beach County)

Okeechobee Boulevard: 1 mile; 3 detectors
Palm Beach Lakes Boulevard: 2.5 miles; 5 detectors
45th Street: 5 miles; 11 detectors



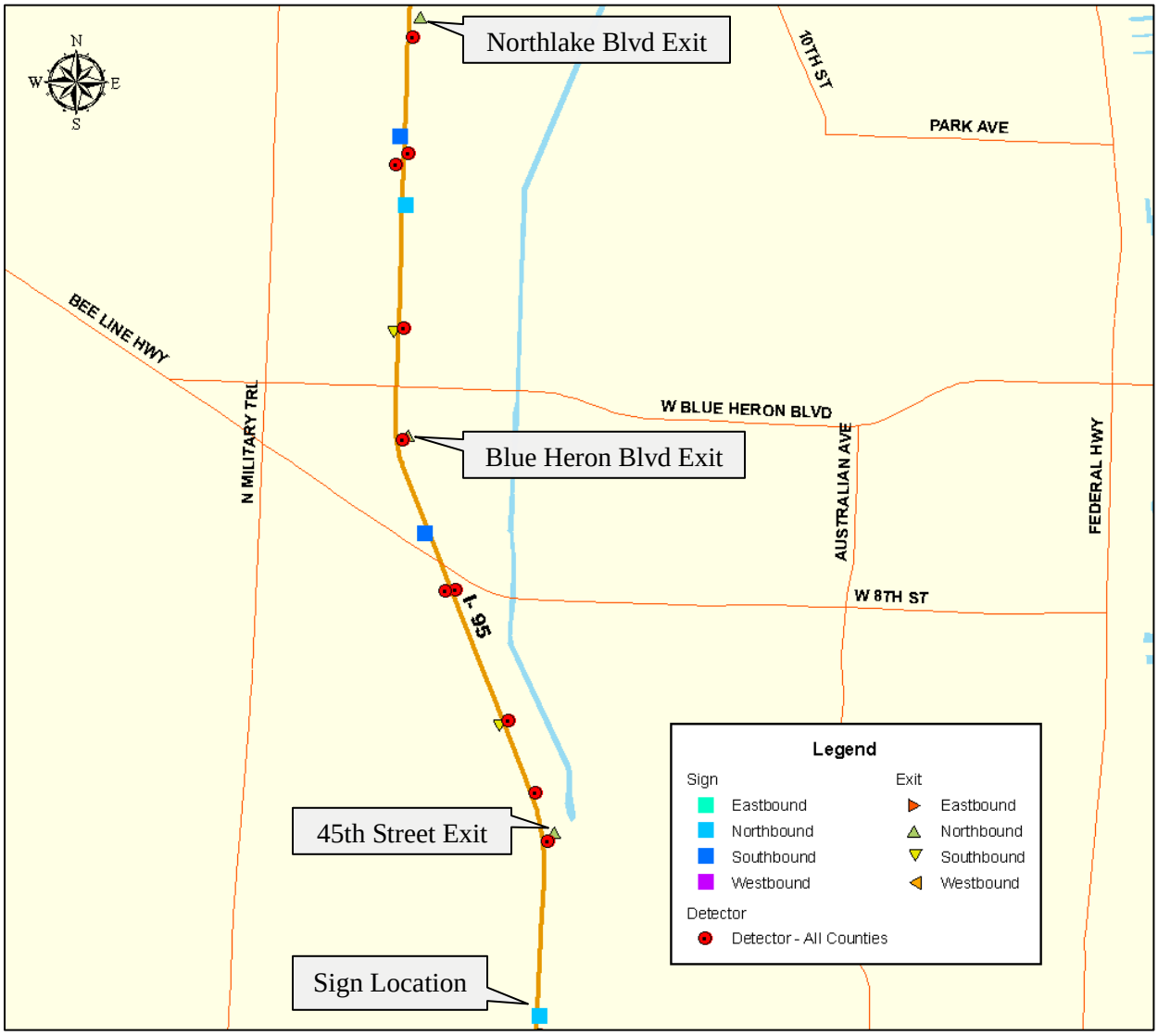
Sign Location: I-95 Northbound South of Okeechobee Boulevard (Palm Beach County)

Palm Beach Lakes Boulevard: 1.25 miles; 2 detectors
45th Street: 4 miles; 8 detectors
Blue Heron Boulevard: 6 miles; 12 detectors



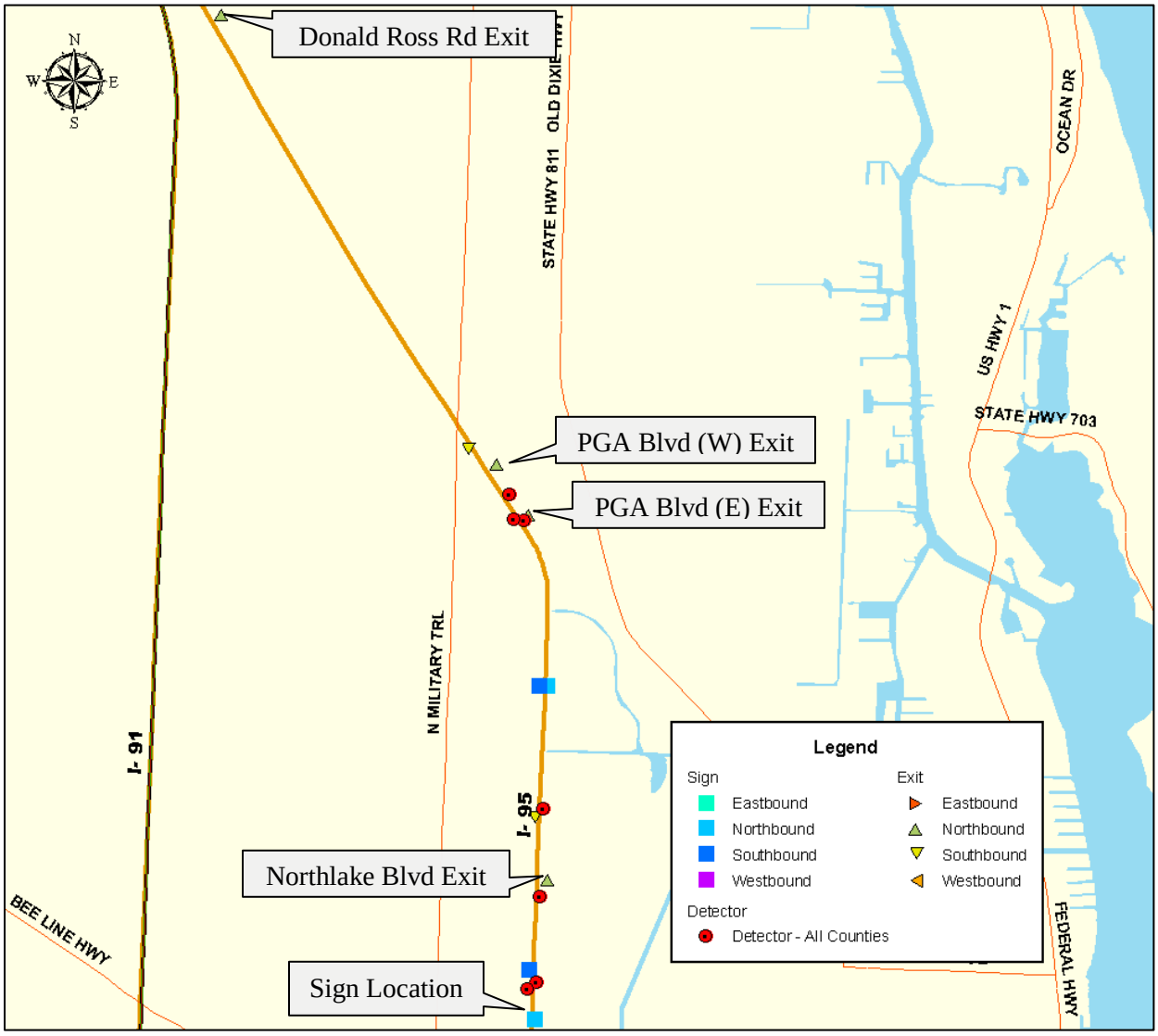
Sign Location: I-95 Northbound North of Okeechobee Boulevard (Palm Beach County)

45th Street: 0.75 mile; 1 detector
Blue Heron Boulevard: 2.5 miles; 4 detectors
Northlake Boulevard: 4.5 miles; 8 detectors



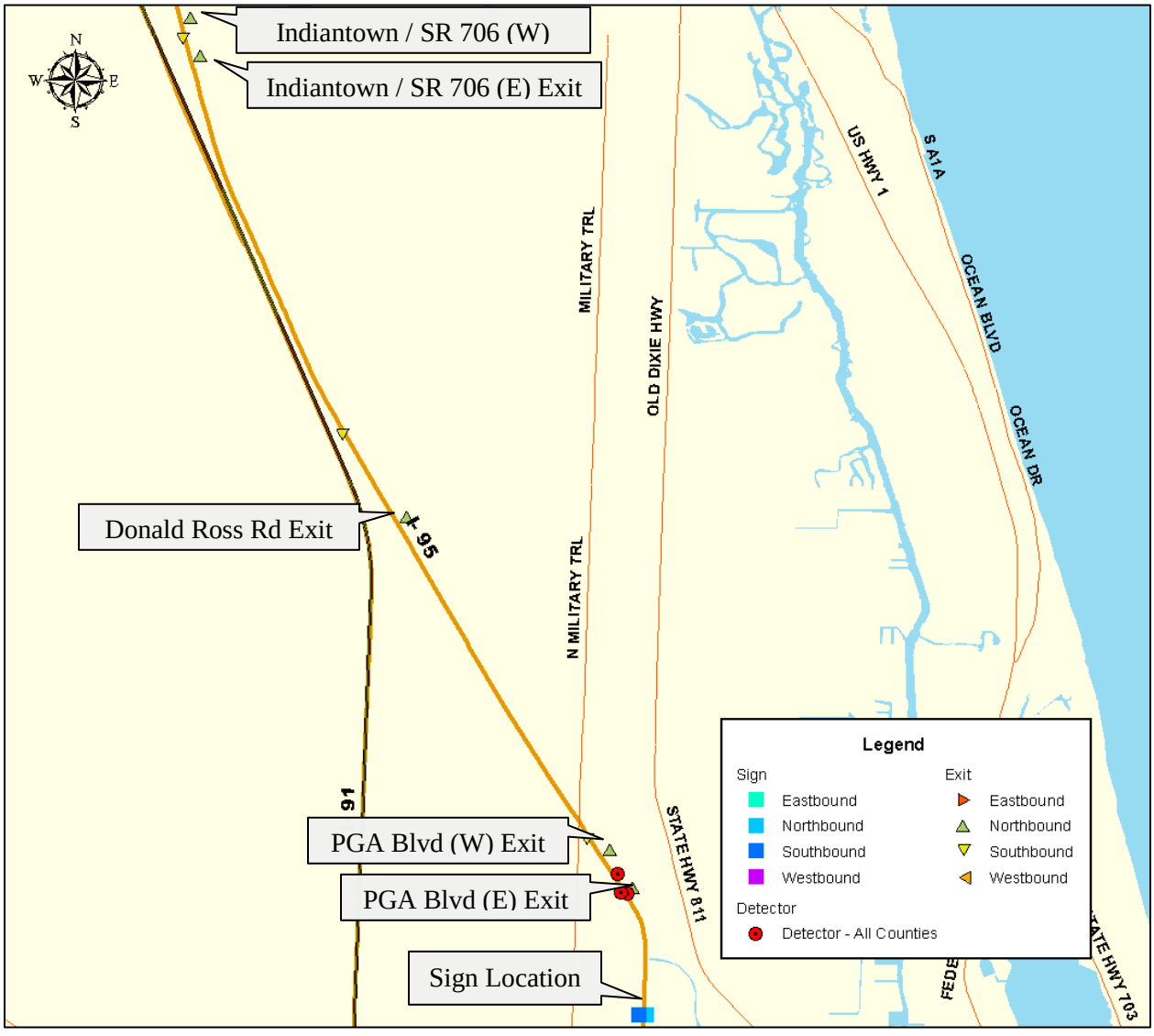
Sign Location: I-95 Northbound North of Blue Heron Boulevard (Palm Beach County)

Northlake Boulevard: 0.75 mile; 2 detectors
PGA Boulevard: 3 miles; 5 detectors
Donald Ross Road: 6.5 miles; 5 detectors



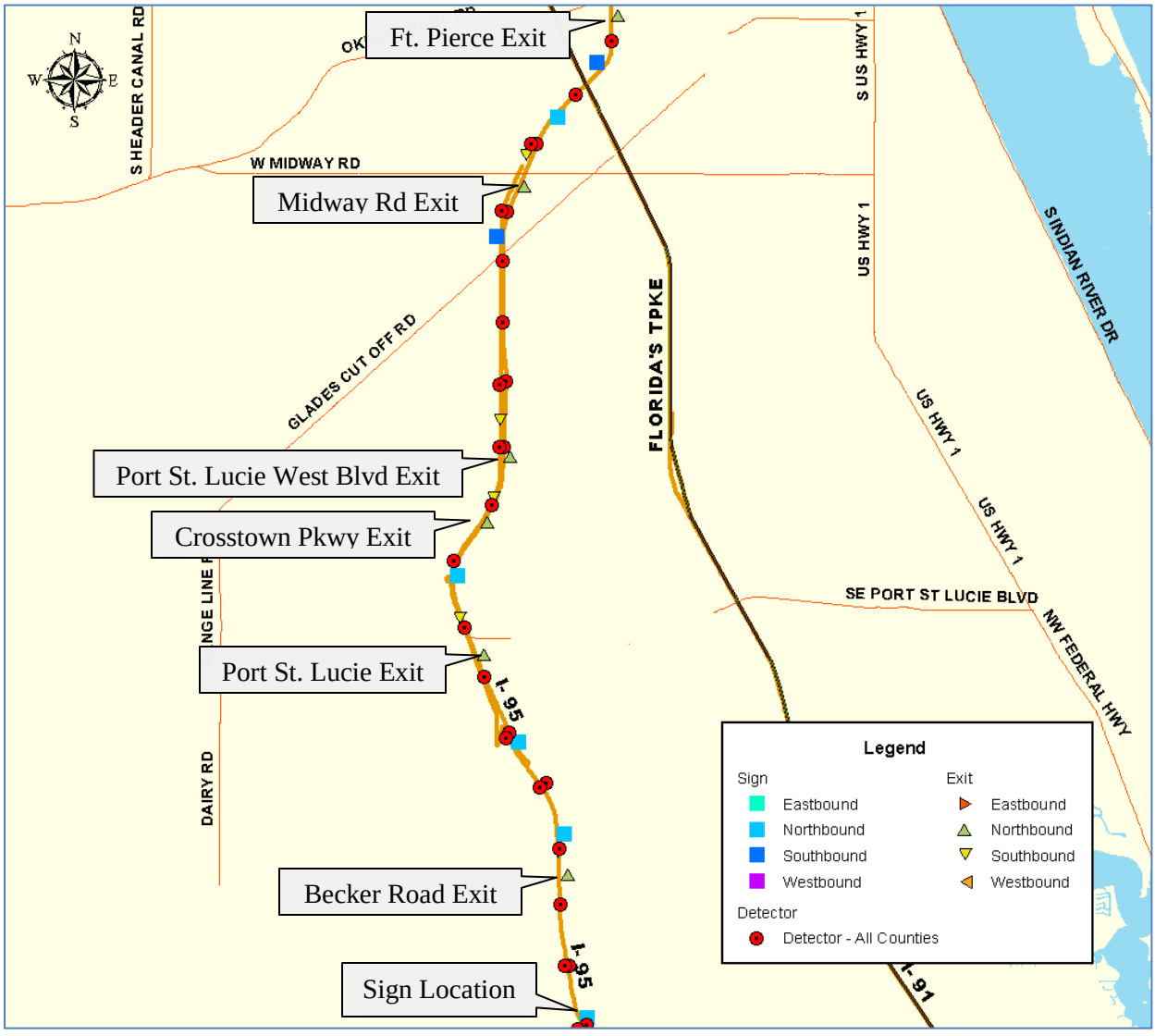
Sign Location: I-95 Northbound North of Blue Heron Boulevard (Palm Beach County)

PGA Boulevard: 1 mile; 2 detectors
Donald Ross Road: 4.25 miles; 5 detectors
Indiantown Road: 8.25 miles; 5 detectors



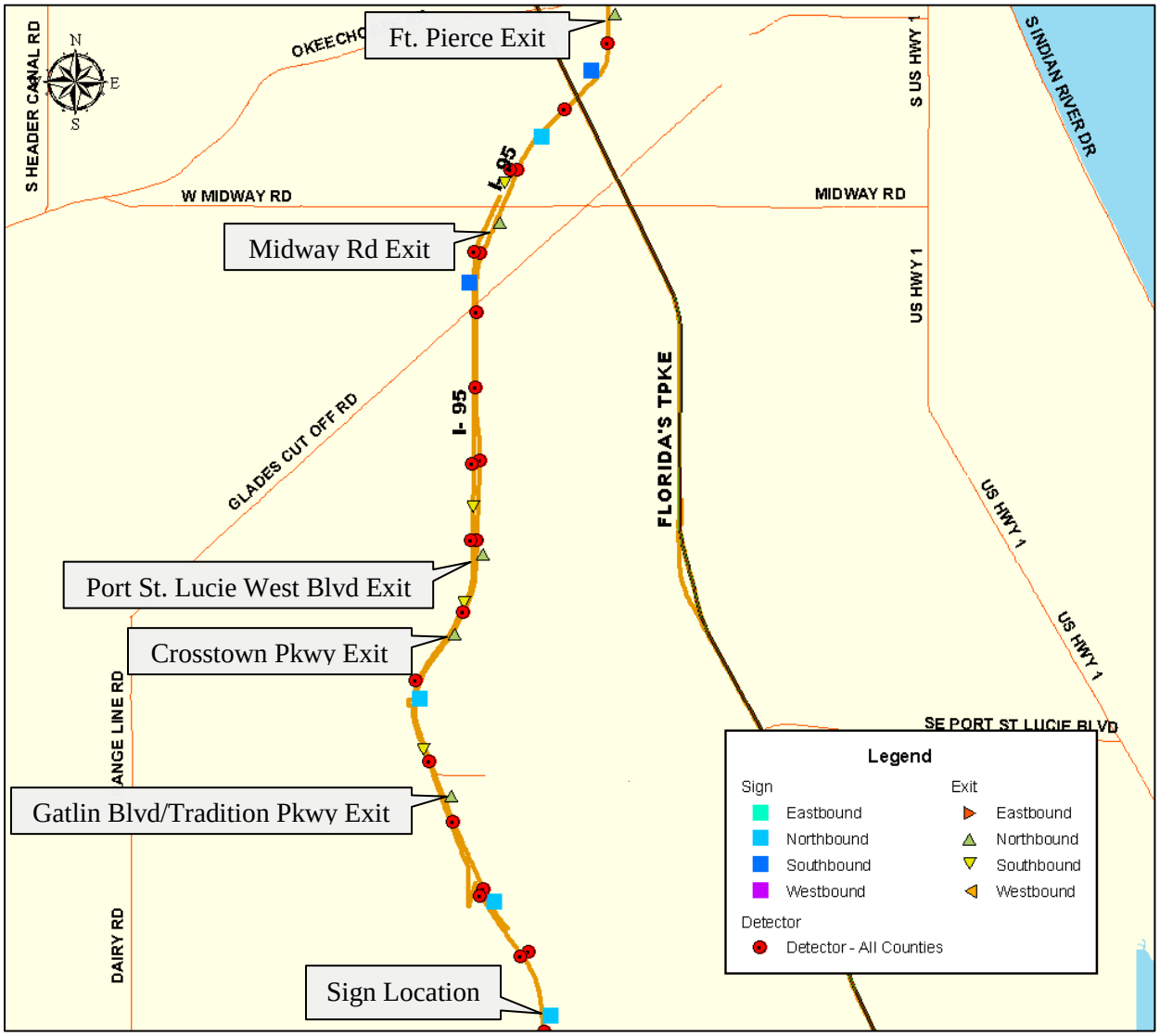
Sign Location: I-95 Northbound North of Martin Highway (Martin County)

Port St. Lucie: 6 miles; 6 detectors
Ft. Pierce: 24 miles; 17 detectors
Daytona Beach: 151 miles; *ouside of District 4*



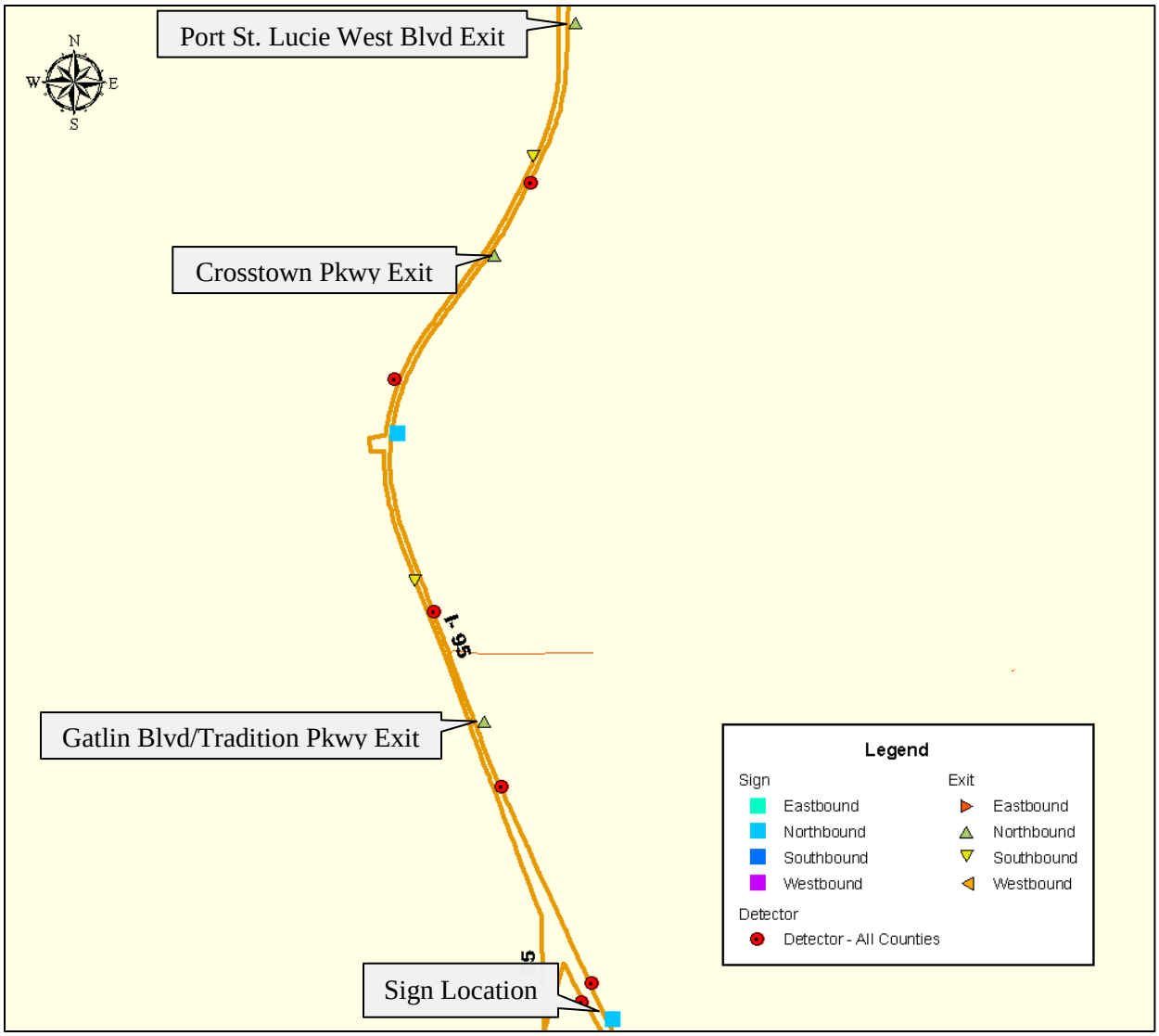
Sign Location: I-95 Northbound North of Becker Road (St. Lucie County)

Gatlin Boulevard/Tradition Parkway: 3 miles; 3 detectors
Ft. Pierce: 21 miles; 14 detectors
Daytona Beach: 148 miles; *ouside of District 4*



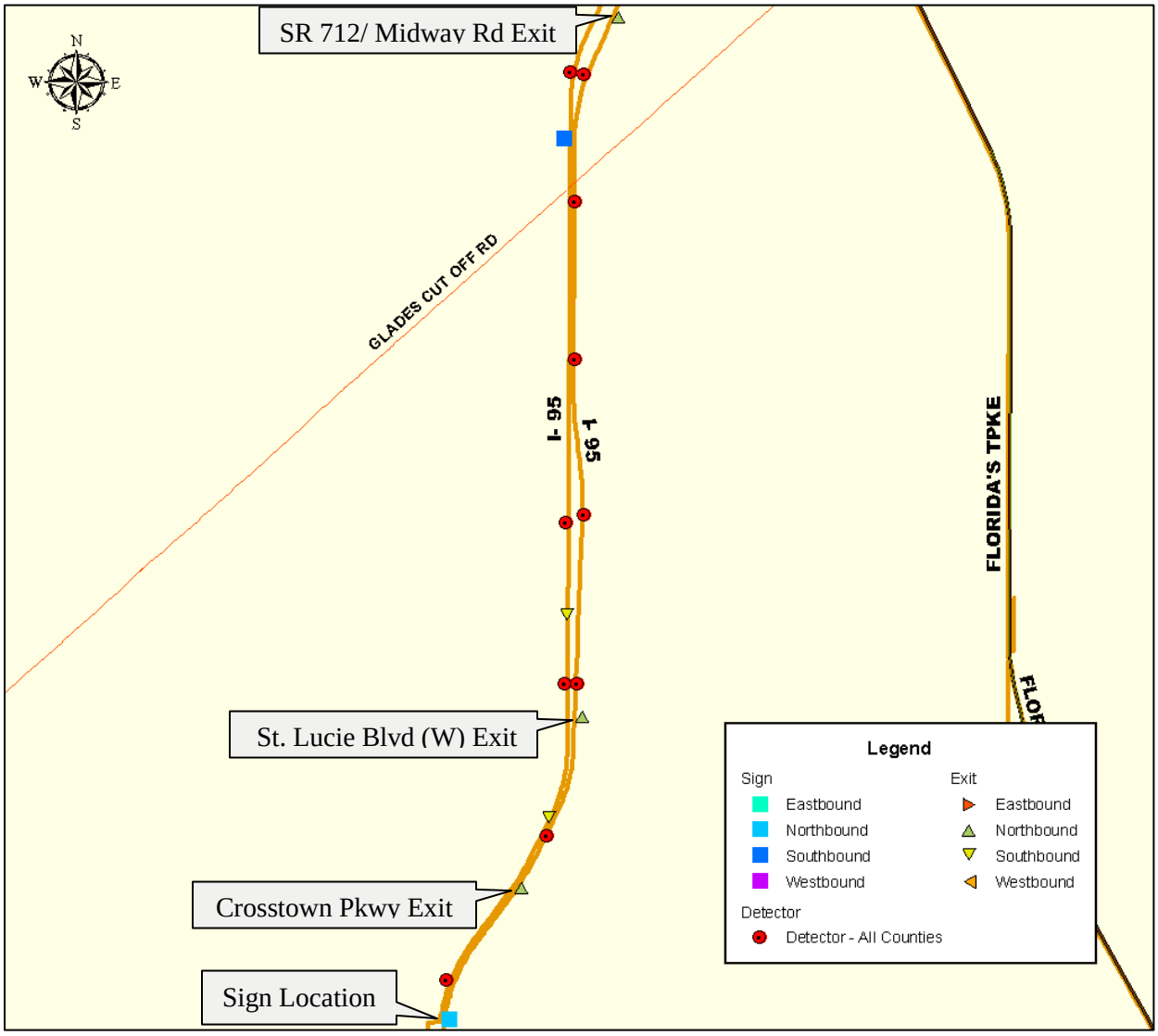
Sign Location: I-95 Northbound North of Gatlin Boulevard (St. Lucie County)

Port St. Lucie: Next 3 exits (less than 3 miles); 5 detectors



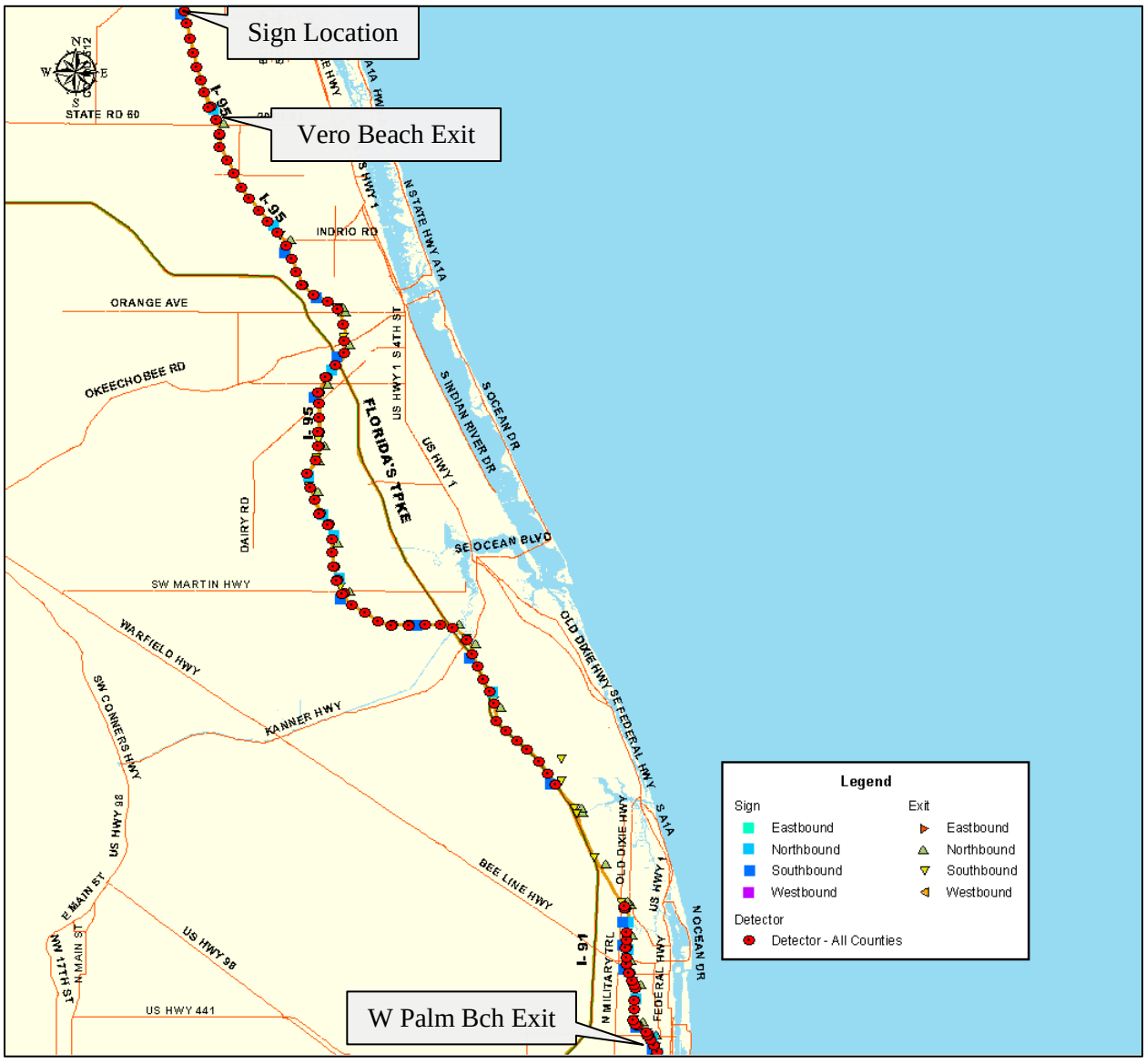
Sign Location: I-95 Northbound North of Martin Highway (St. Lucie County)

SR 712: 7 miles; 7 detectors
Daytona Beach: 143 miles; *ouside of District 4*.



Sign Location: I-95 Southbound North of State Road 60 (Indian River County)

Vero Beach: 14 miles; 7 detectors
West Palm Beach: 80 miles; 90 detectors

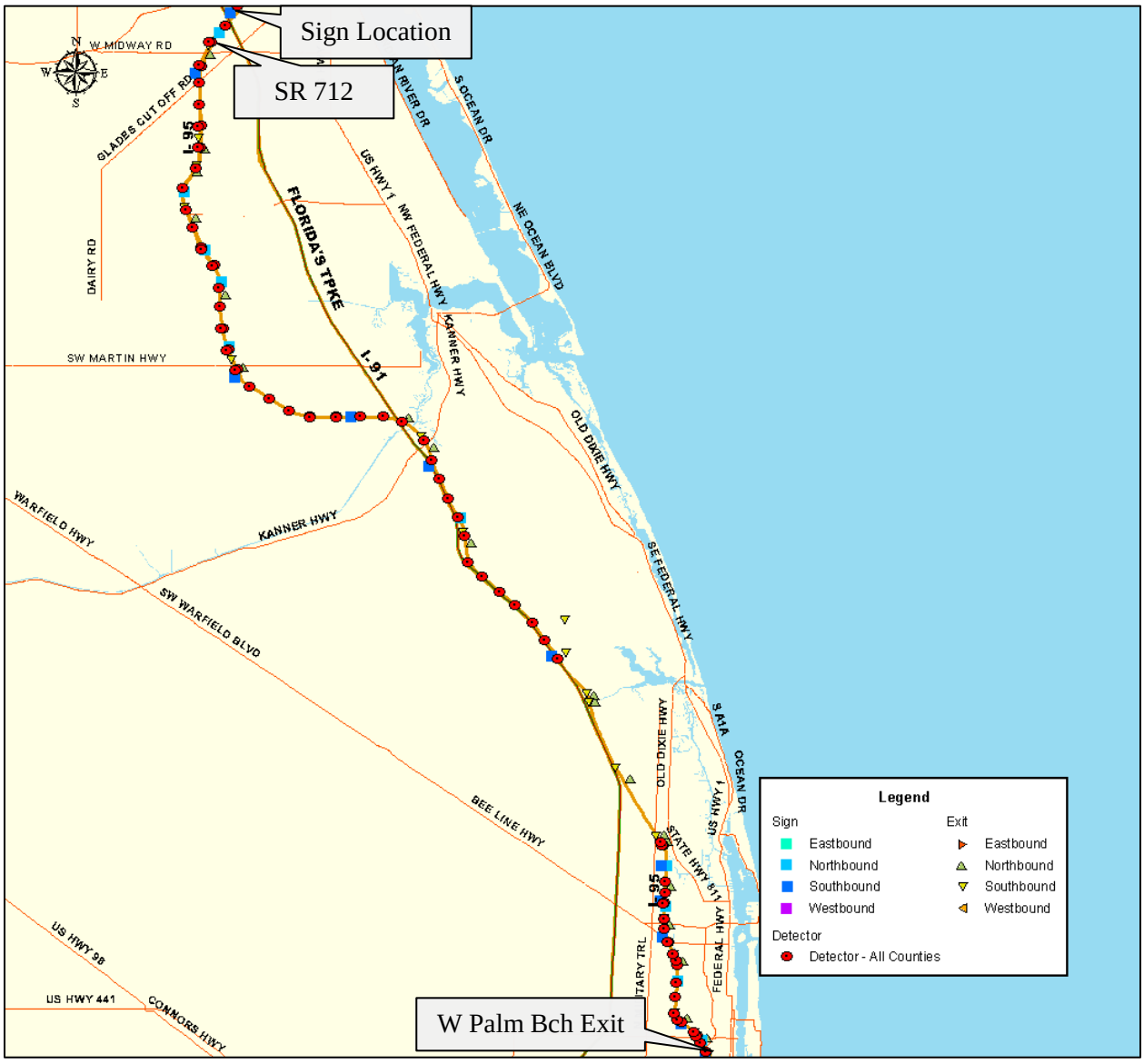


Sign Location: I-95 Southbound South of Indrio Road (St. Lucie County)

Ft. Pierce: 7 miles; 7 detectors
West Palm Beach: 61 miles; 67 detectors

Sign Location: I-95 Southbound North of Midway Road (St. Lucie County)

SR 712: 2 miles; 2 detectors
West Palm Beach: 57 miles; 63 detectors

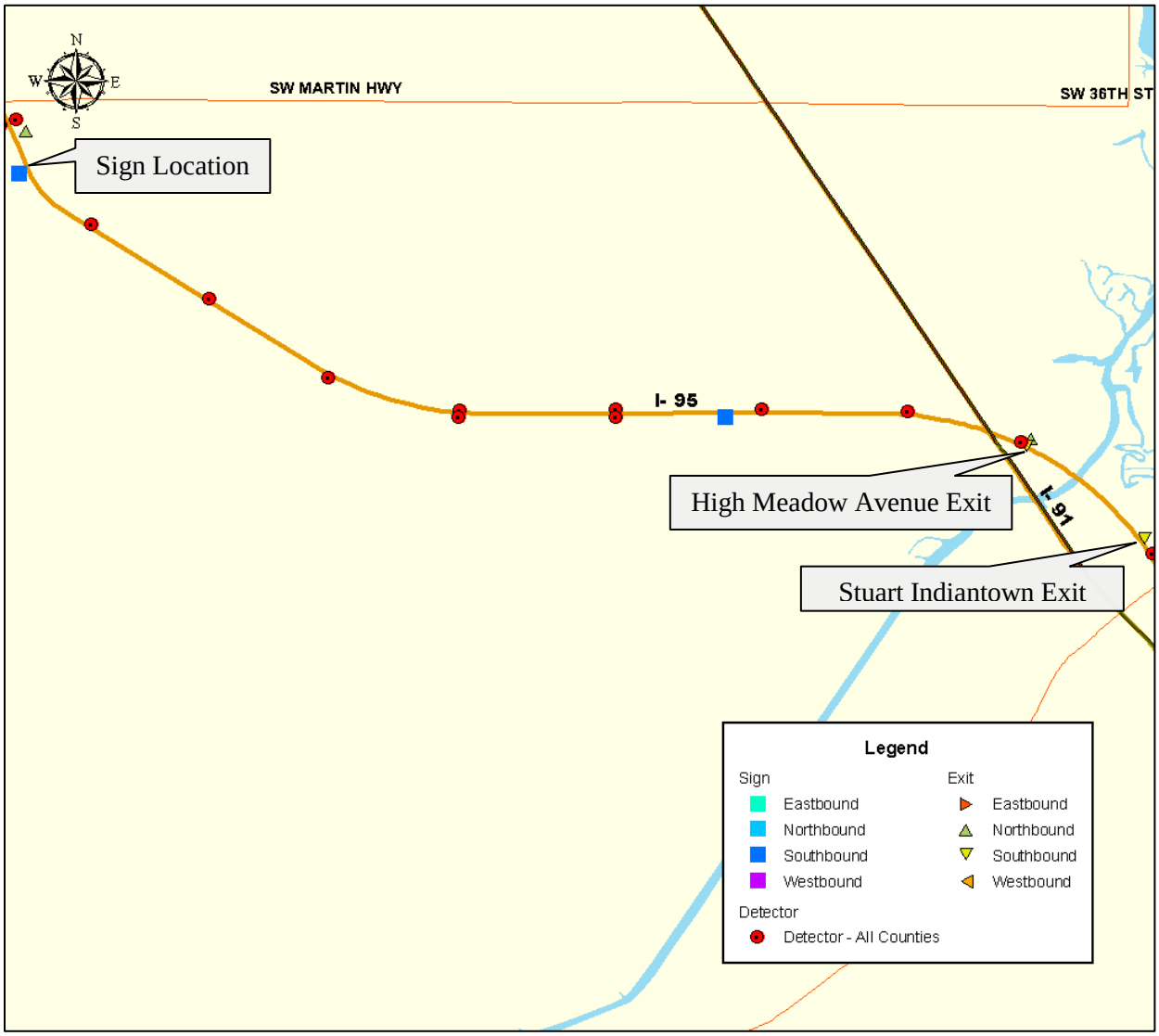


Sign Location: I-95 Southbound South of Midway Road (St. Lucie County)

Gatlin Boulevard/ Tradition Parkway: 7 miles; 14 detectors
West Palm Beach: 54 miles; 55 detectors;

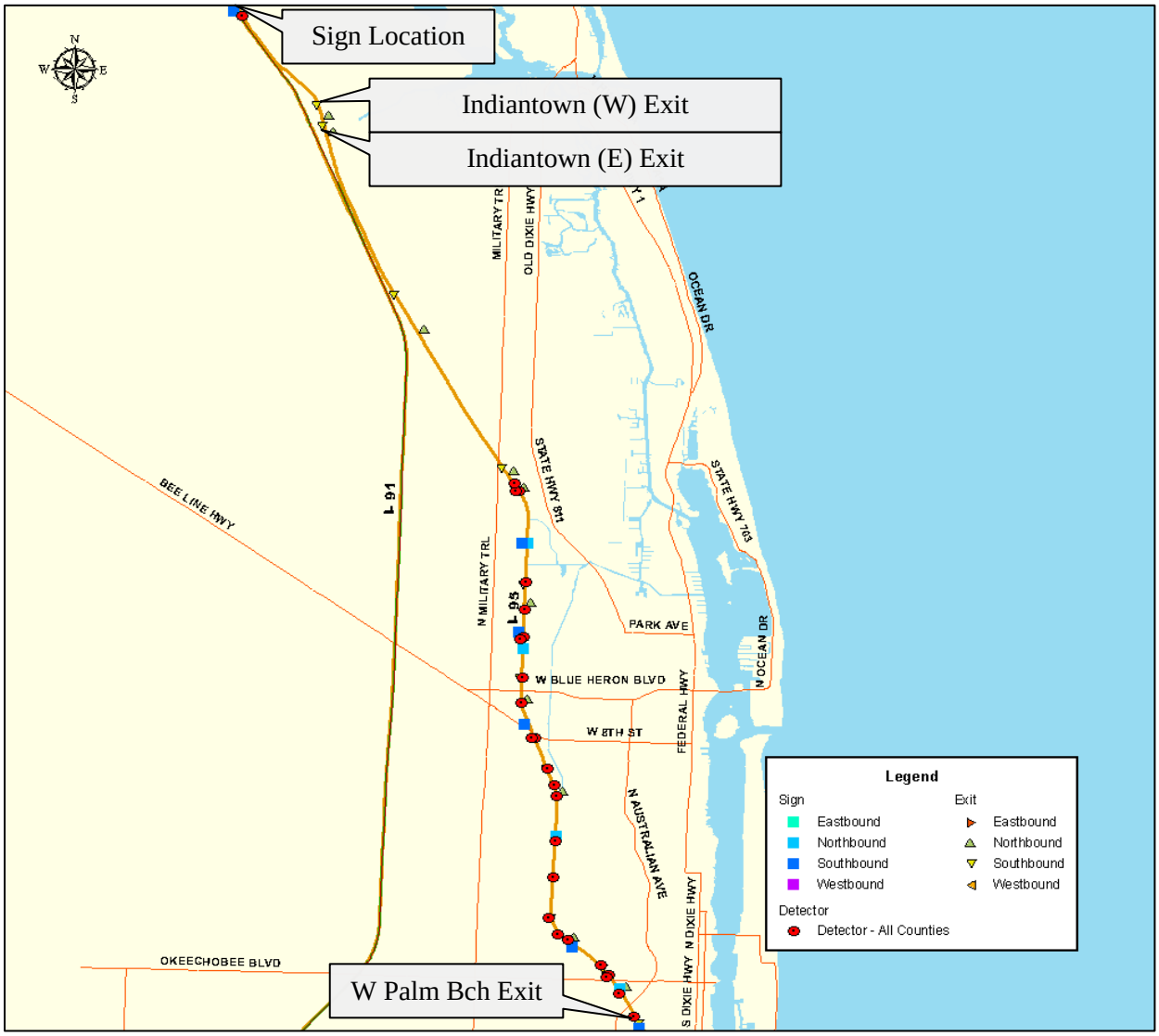
Sign Location: I-95 Southbound South of Martin Highway (Martin County)

High Meadow Avenue: 2 miles; 6 detectors
Stuart Indiantown: 3 miles; 7 detectors



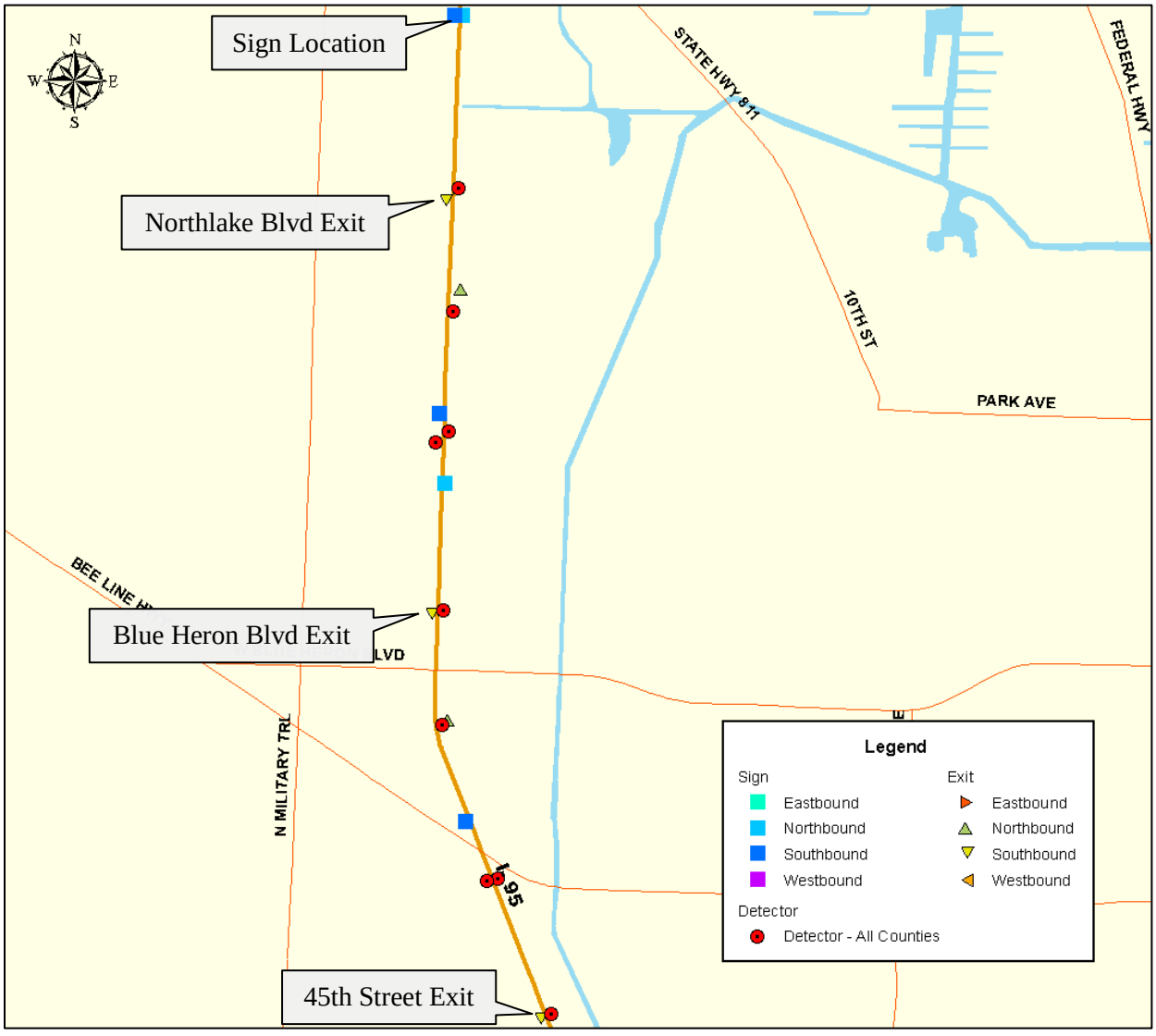
Sign Location: I-95 Southbound South of Kanner Highway (Martin County)

Indiantown Road: 2 miles; 1 detector
West Palm Beach: 15 miles; 20 detectors



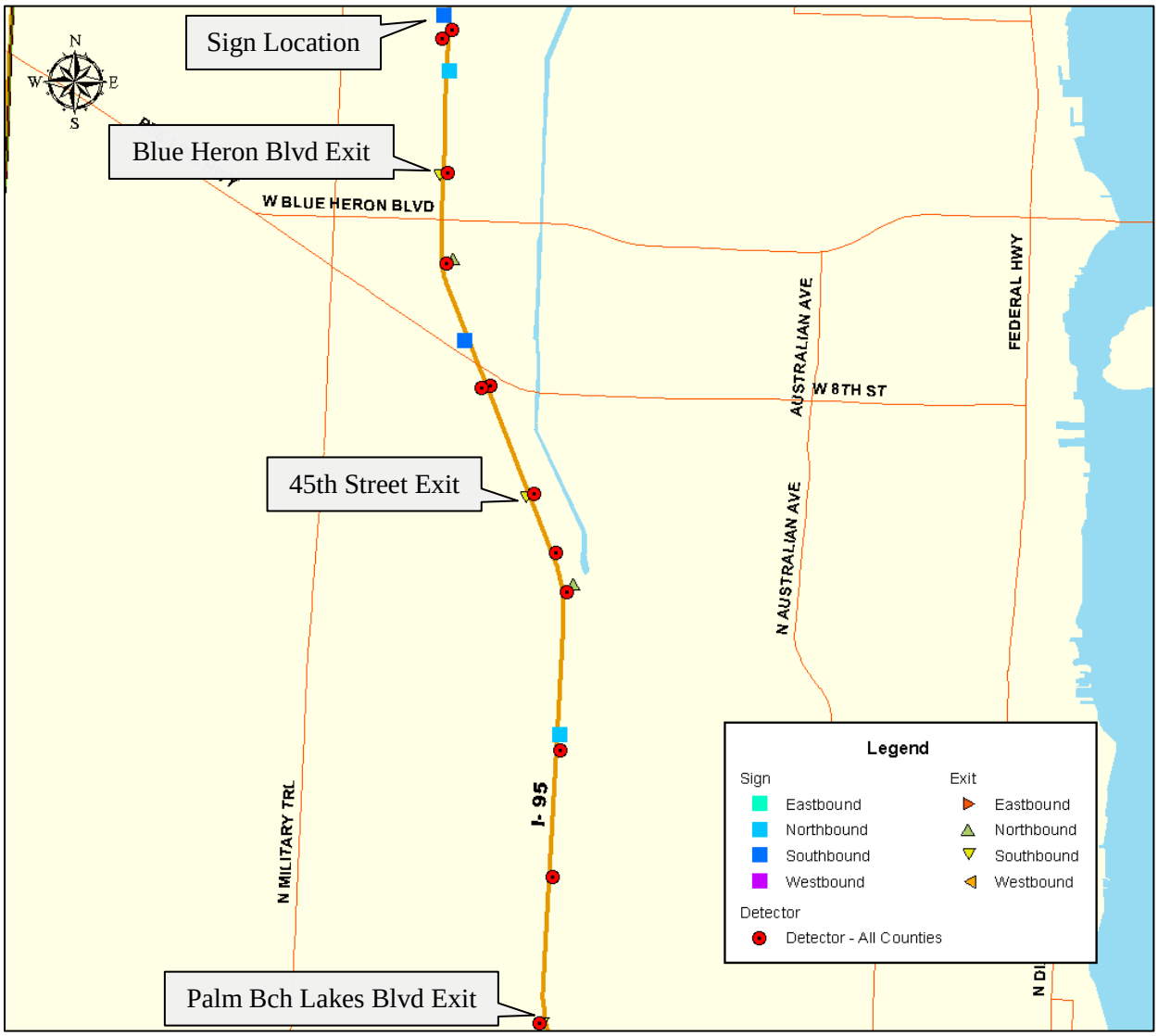
Sign Location: I-95 Southbound North of Blue Heron Boulevard (Palm Beach County)

Northlake Boulevard: 0.75 mile; 1 detector
Blue Heron Boulevard: 2 miles; 3 detectors
45th Street: 3.75 miles; 6 detectors



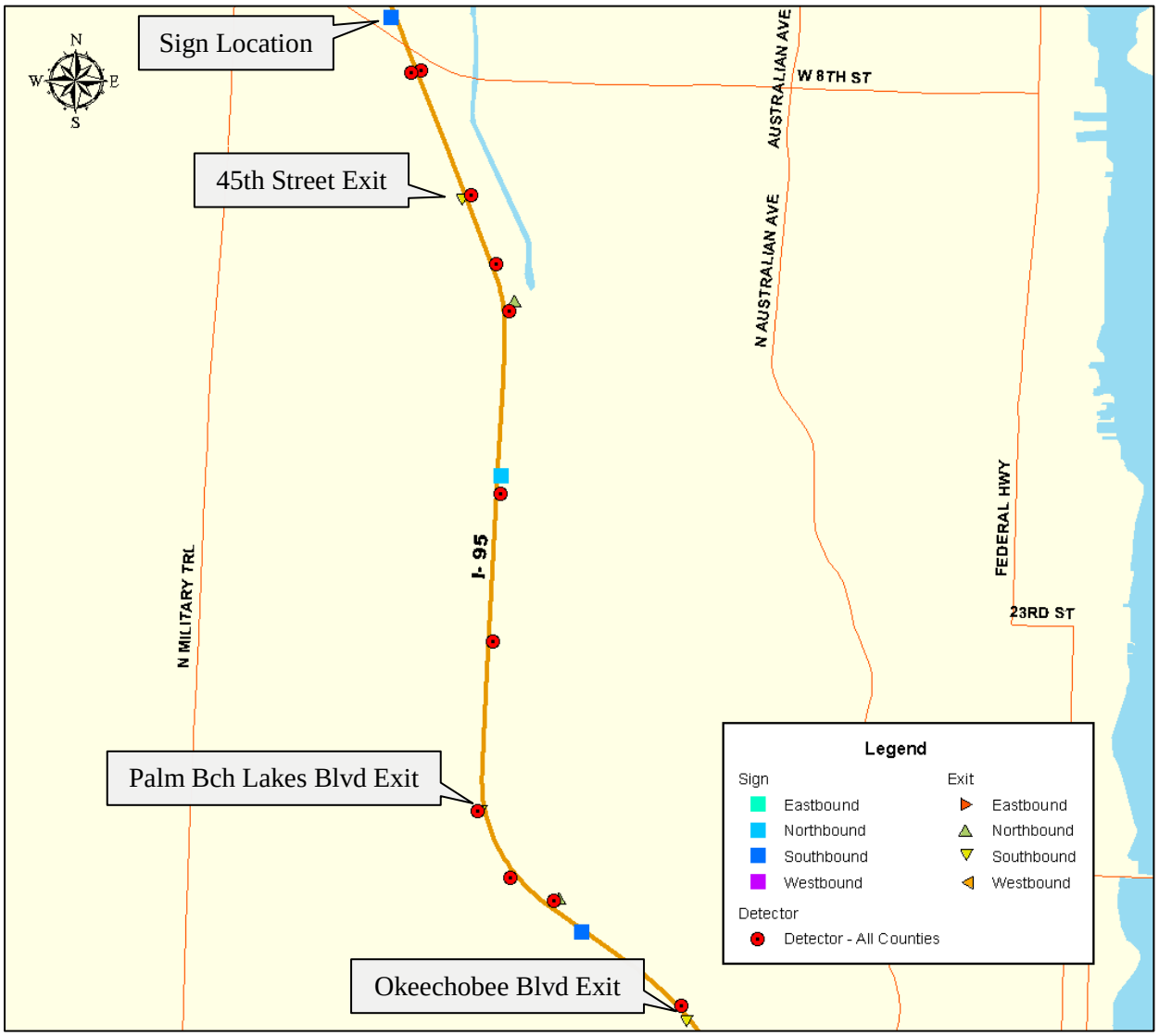
Sign Location: I-95 Southbound North of Blue Heron Boulevard (Palm Beach County)

Blue Heron Boulevard: 0.75 mile; 1 detector
45th Street: 2.5 miles; 4 detectors
Palm Beach Lakes Boulevard: 5.25 miles; 10 detectors



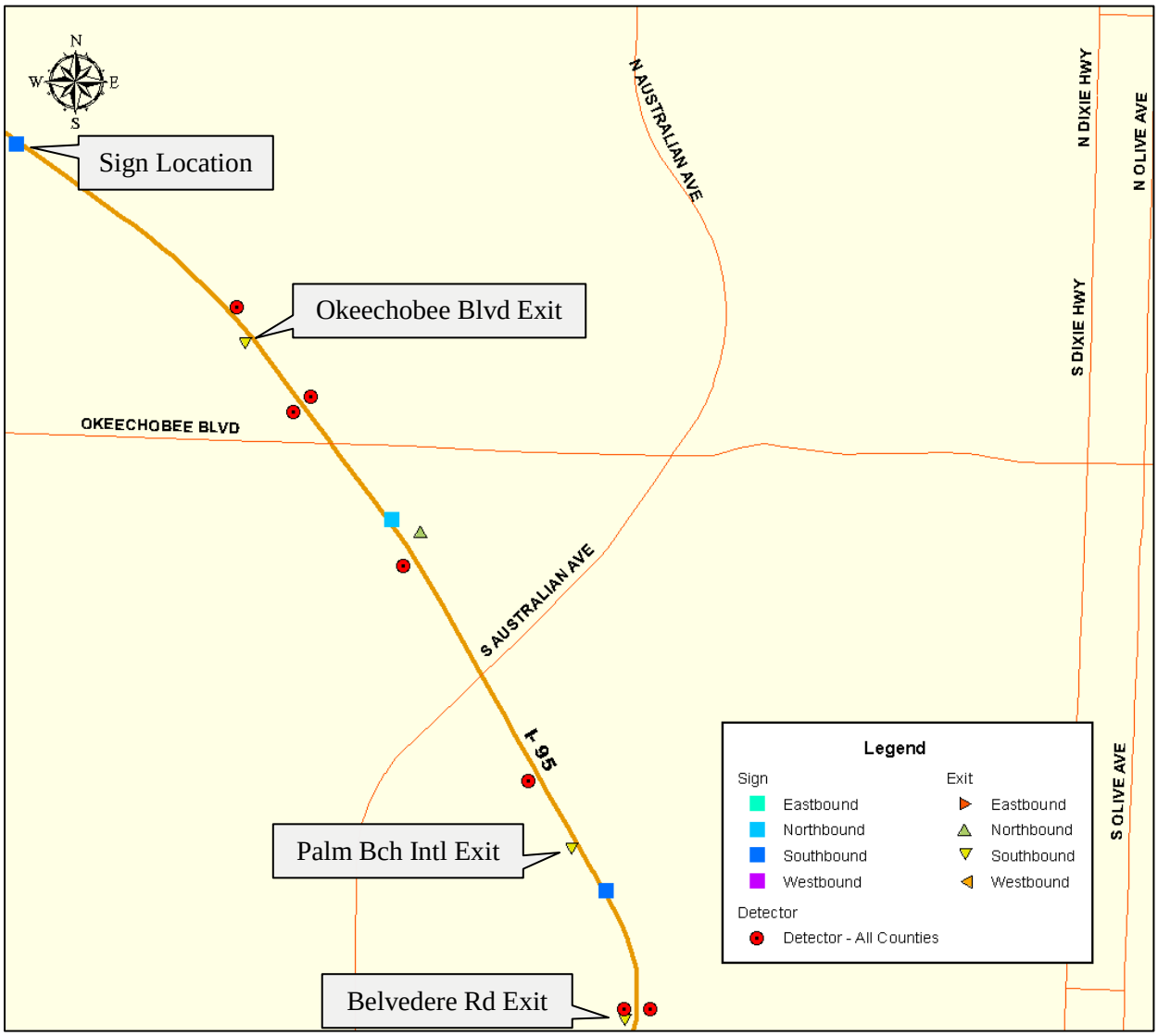
Sign Location: I-95 Southbound South of Blue Heron Boulevard (Palm Beach County)

45th Street: 0.75 mile; 1 detector
Palm Beach Lakes Boulevard: 3 miles; 6 detectors
Okeechobee Boulevard: 4.25 miles; 9 detectors



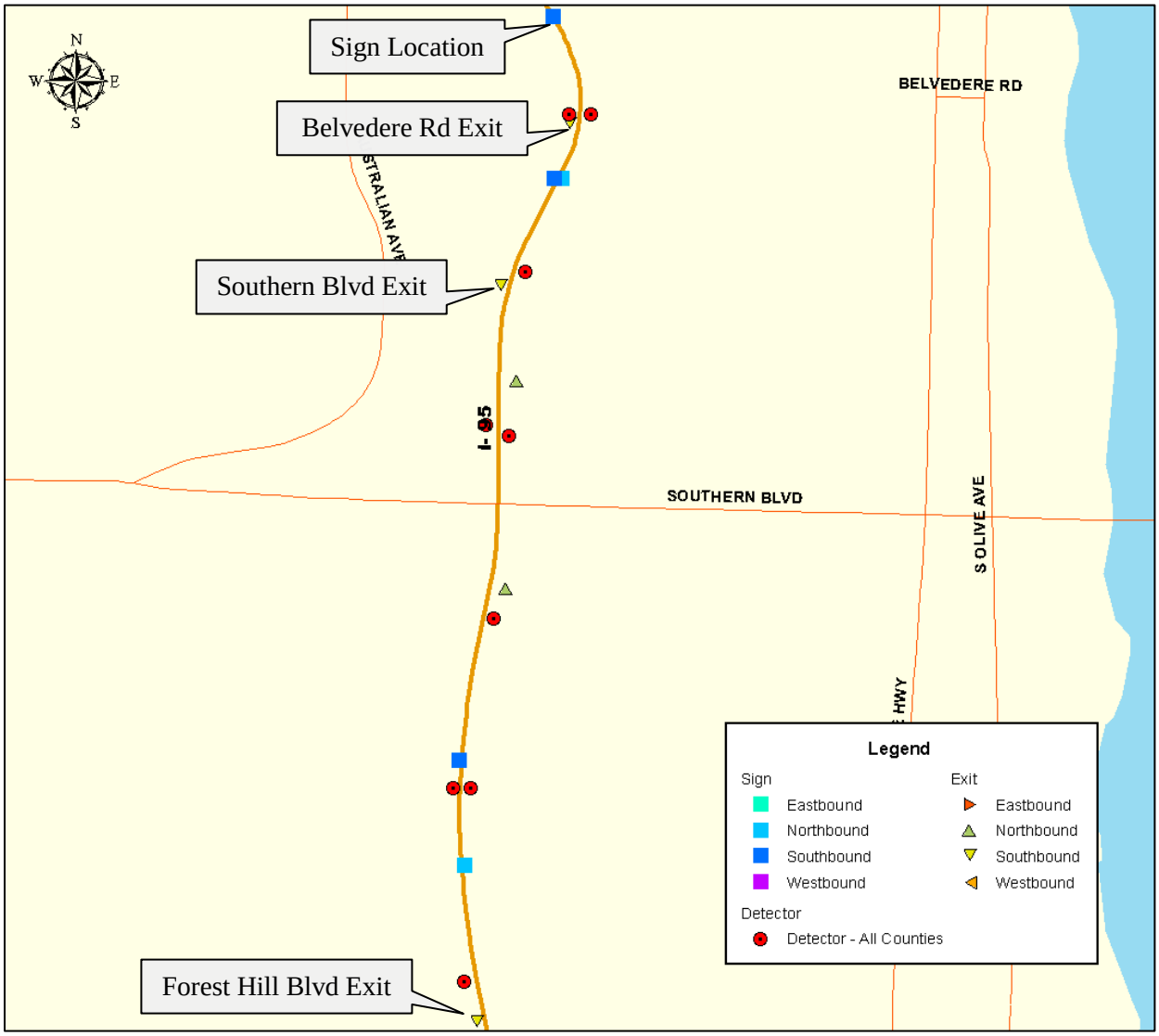
Sign Location: I-95 Southbound North of Okeechobee Boulevard (Palm Beach County)

Okeechobee Boulevard: 0.5 mile; 1 detector
Palm Beach International Airport: 1.5 miles; 4 detectors
Belvedere Road: 2 miles; 5 detectors



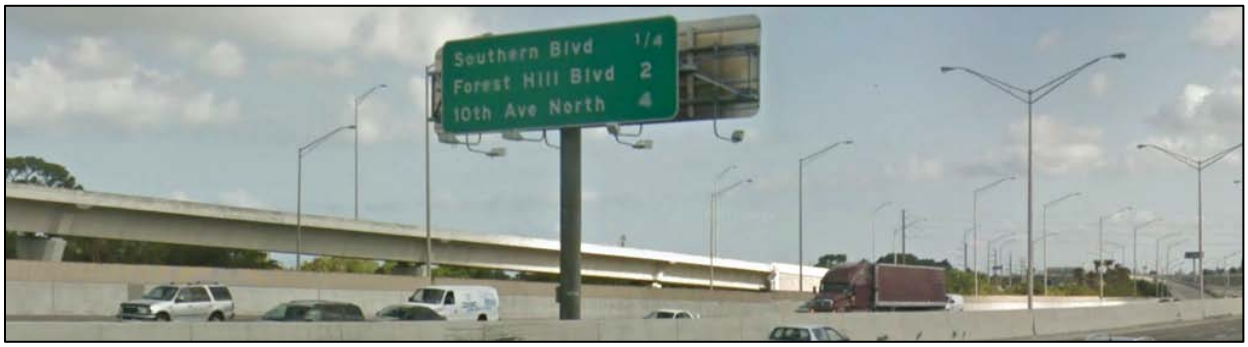
Sign Location: I-95 Southbound South of Okeechobee Boulevard (Palm Beach County)

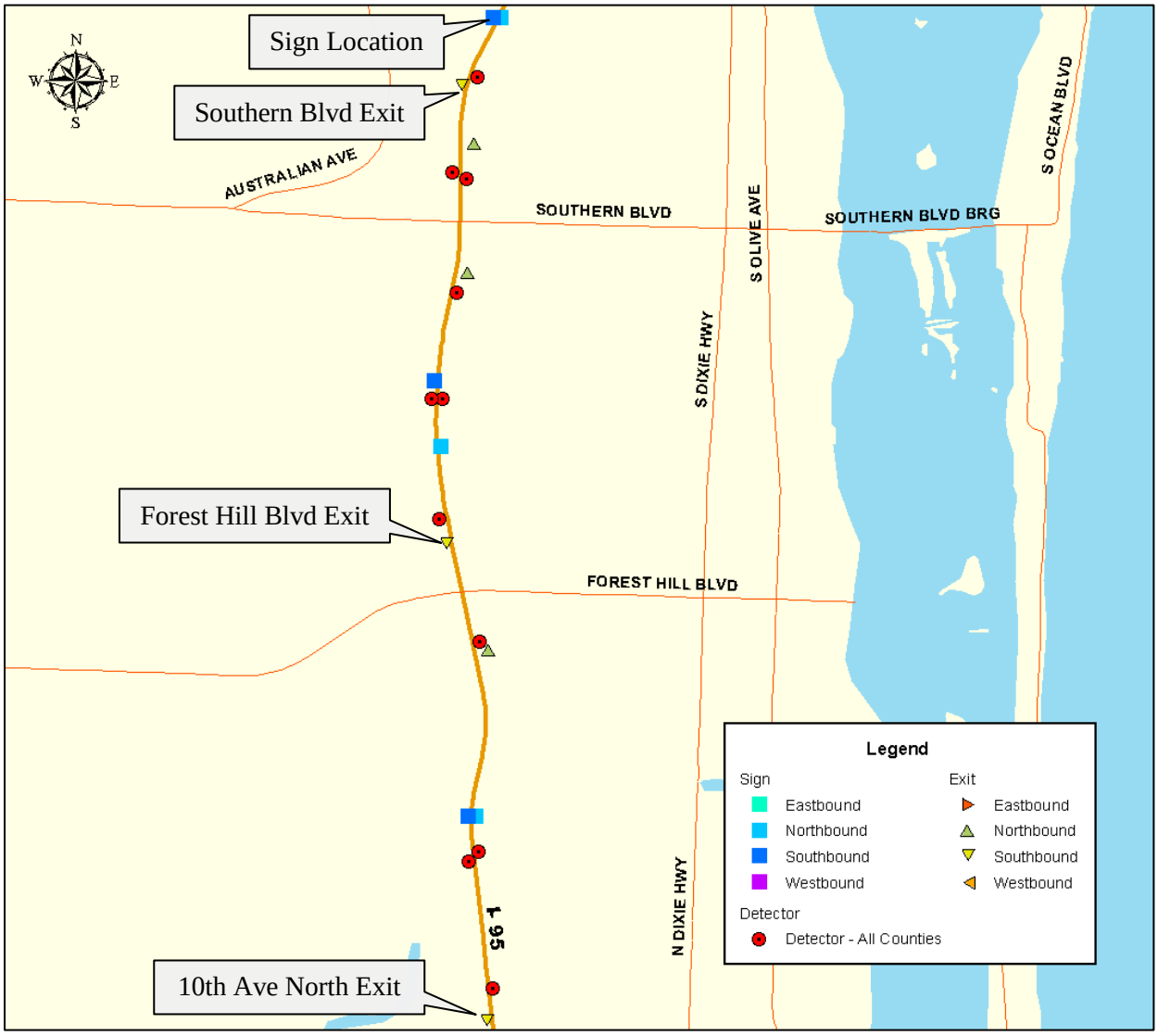
Belvedere Road: 0.25 mile; 1 detector
Southern Boulevard: 0.75 mile; 2 detectors
Forest Hill Boulevard: 2.25 miles; 6 detectors



Sign Location: I-95 Southbound North of Southern Boulevard (Palm Beach County)

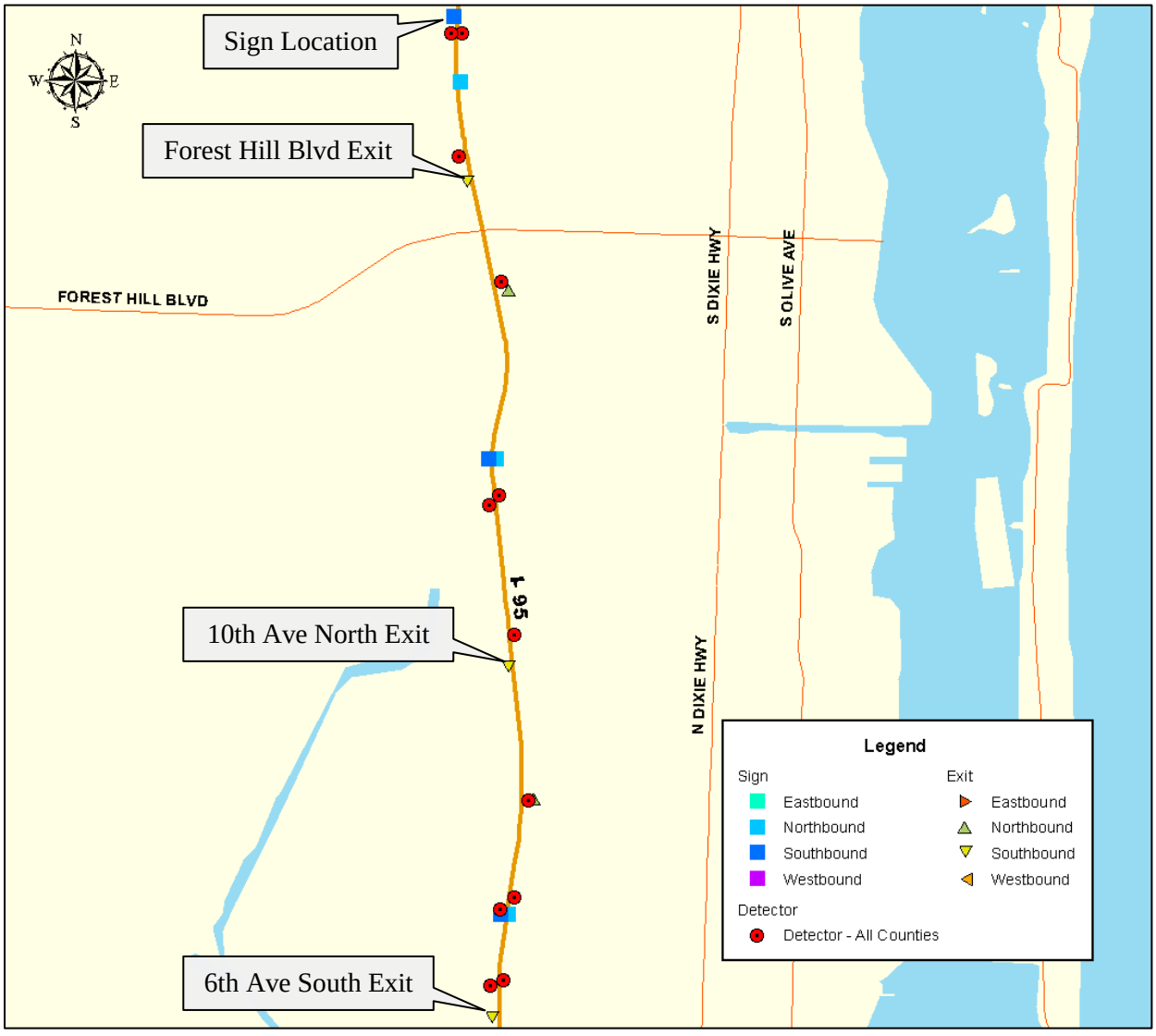
Southern Boulevard: 0.25 mile; 1 detector
Forest Hill Boulevard: 2 miles; 5 detectors
10th Avenue North: 4 miles; 8 detectors





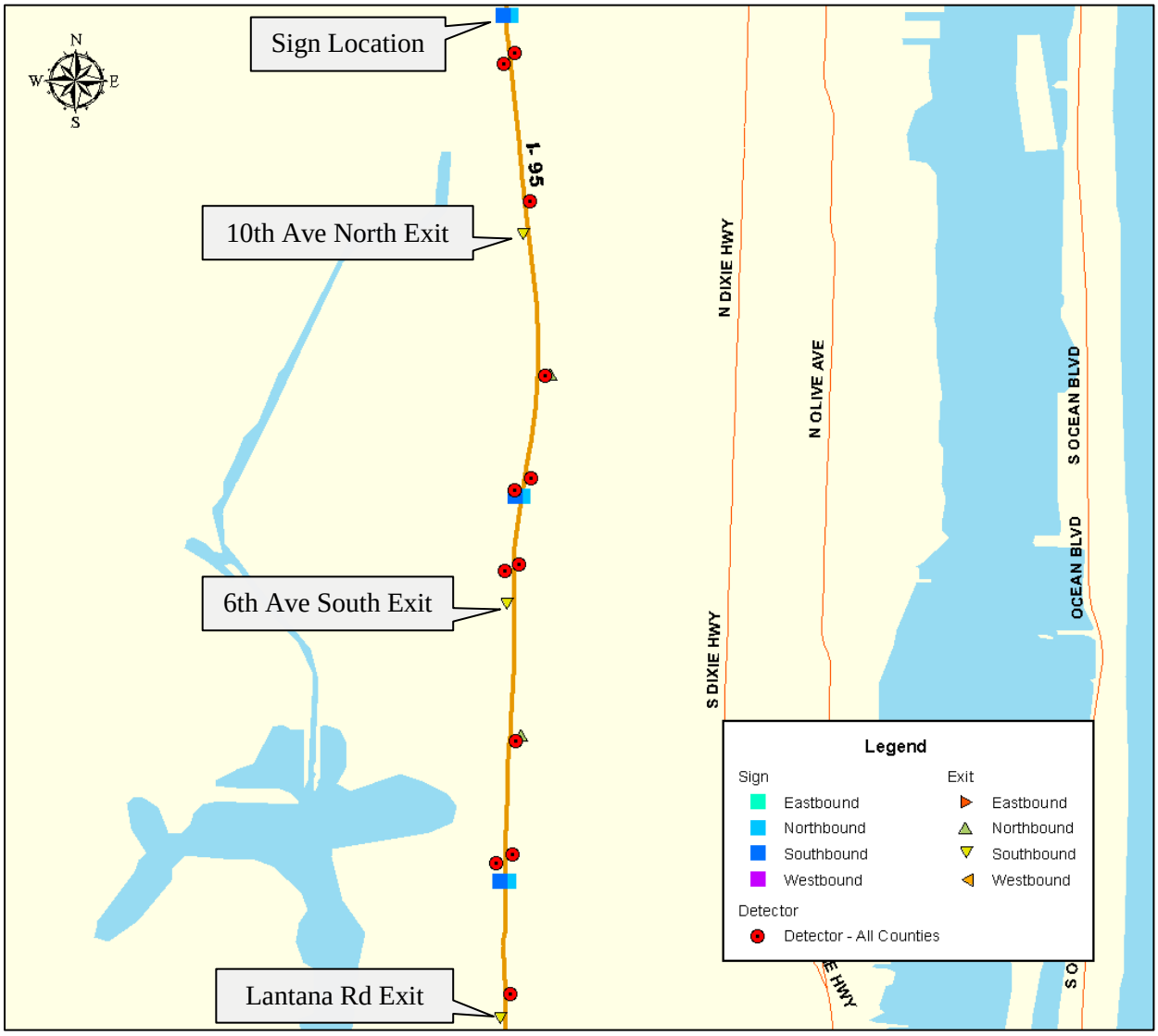
Sign Location: I-95 Southbound North of Forest Hill Boulevard (Palm Beach County)

Forest Hill Boulevard: 0.5 mile; 2 detectors
10th Avenue North: 2.5 miles; 5 detectors
6th Avenue South: 3.5 miles; 8 detectors



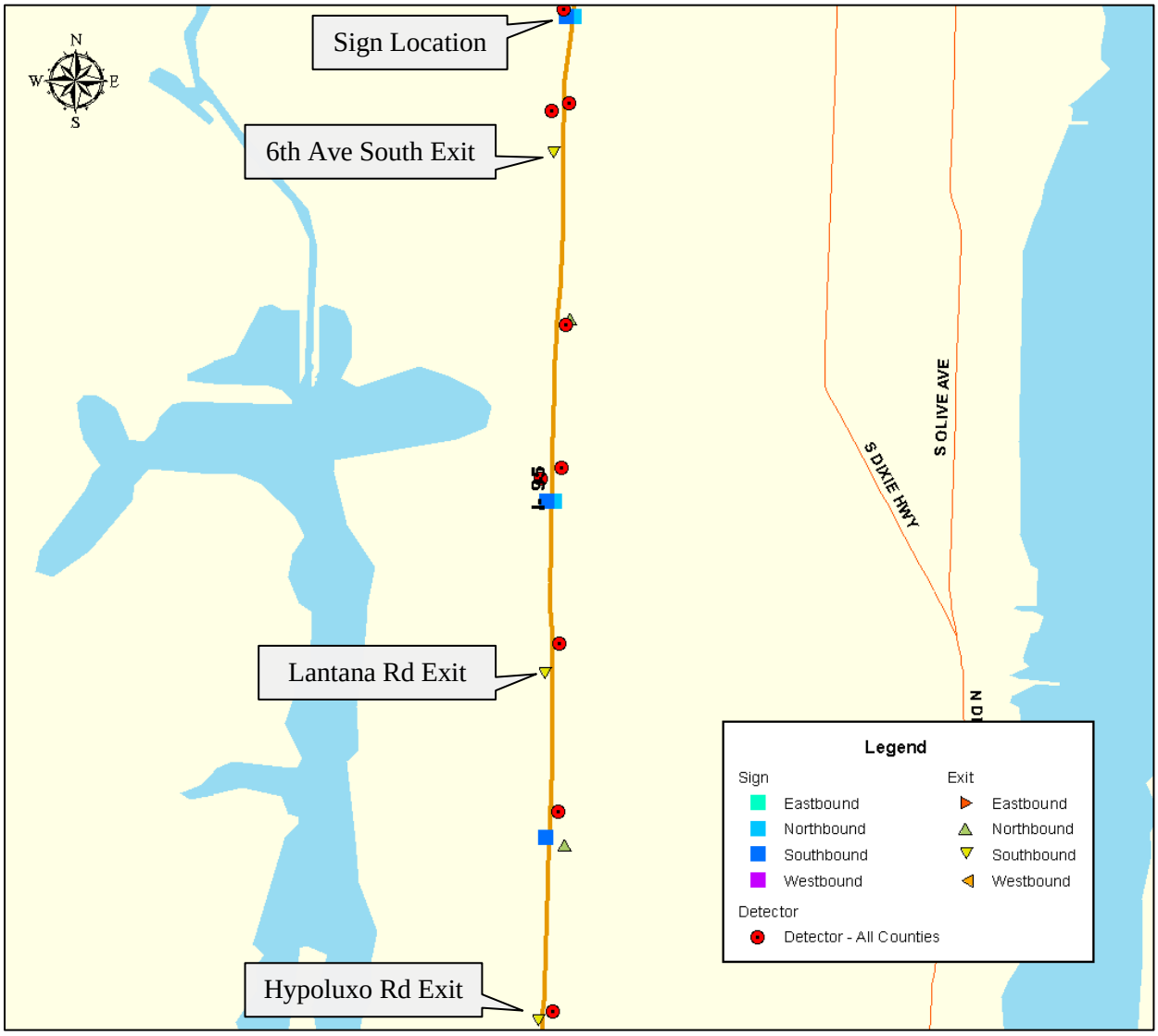
Sign Location: I-95 Southbound South of Forest Hill Boulevard (Palm Beach County)

10th Avenue North: 0.5 mile; 2 detectors
6th Avenue South: 1.75 miles; 5 detectors
Lantana Road: 3.25 miles; 8 detectors



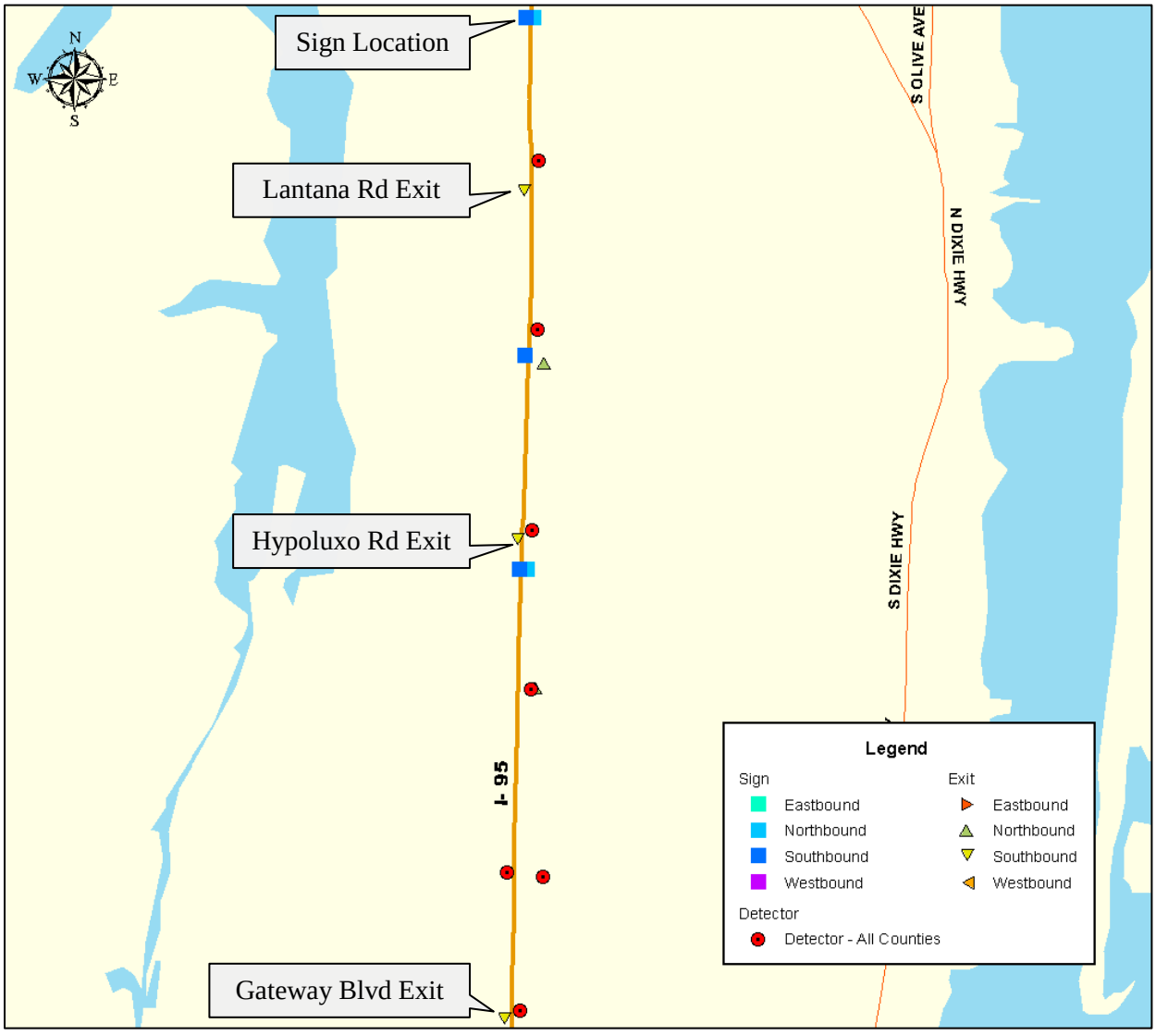
Sign Location: I-95 Southbound South of Forest Hill Boulevard (Palm Beach County)

6th Avenue South: 0.5 mile; 1 detector
Lantana Road: 1.75 miles; 4 detectors
Hypoluxo Road: 2.75 miles; 6 detectors



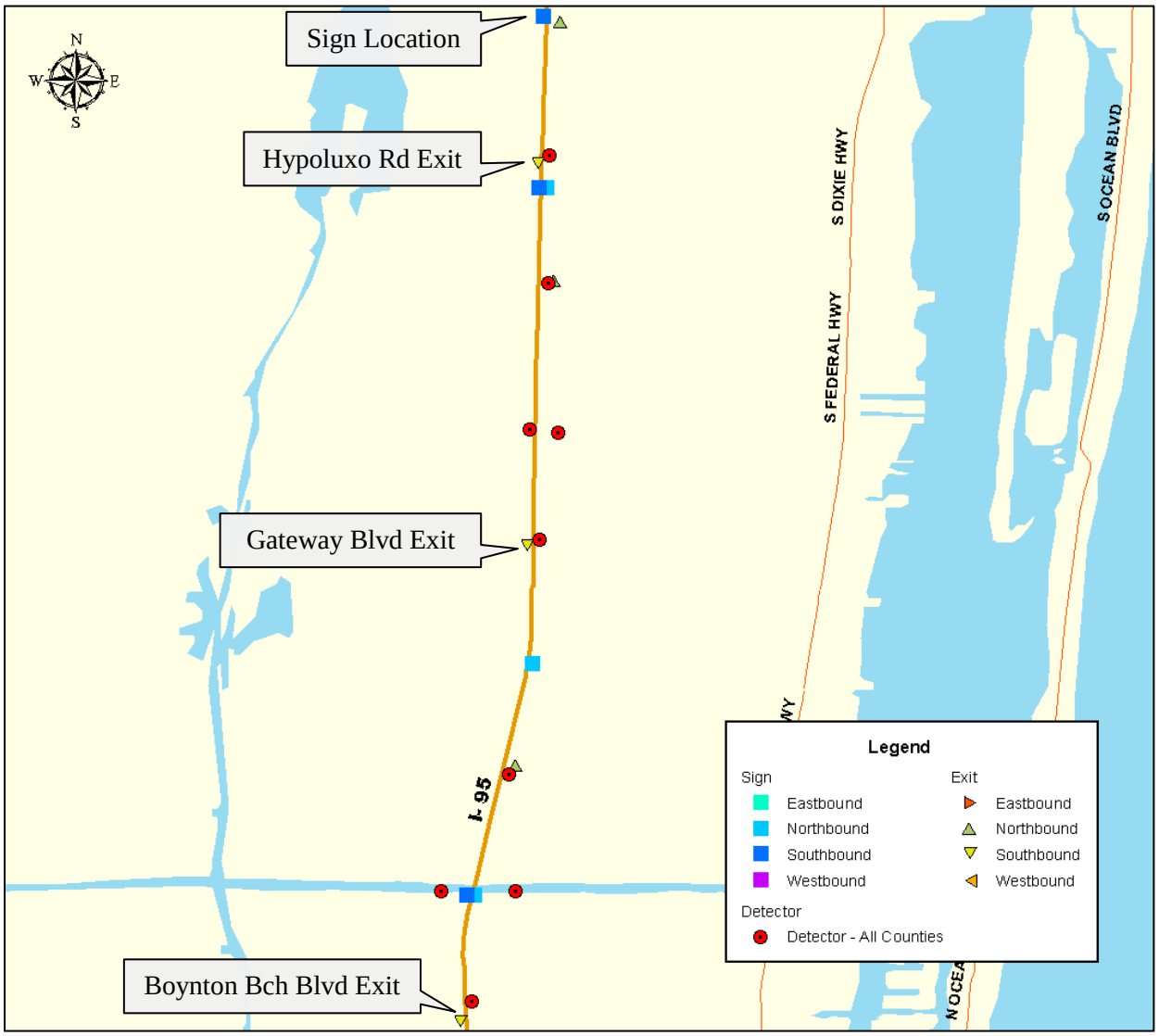
Sign Location: I-95 Southbound South of Forest Hill Boulevard (Palm Beach County)

Lantana Road: 0.5 mile; 1 detector
Hypoluxo Road: 1.5 miles; 3 detectors
Gateway Boulevard: 2.75 miles; 6 detectors



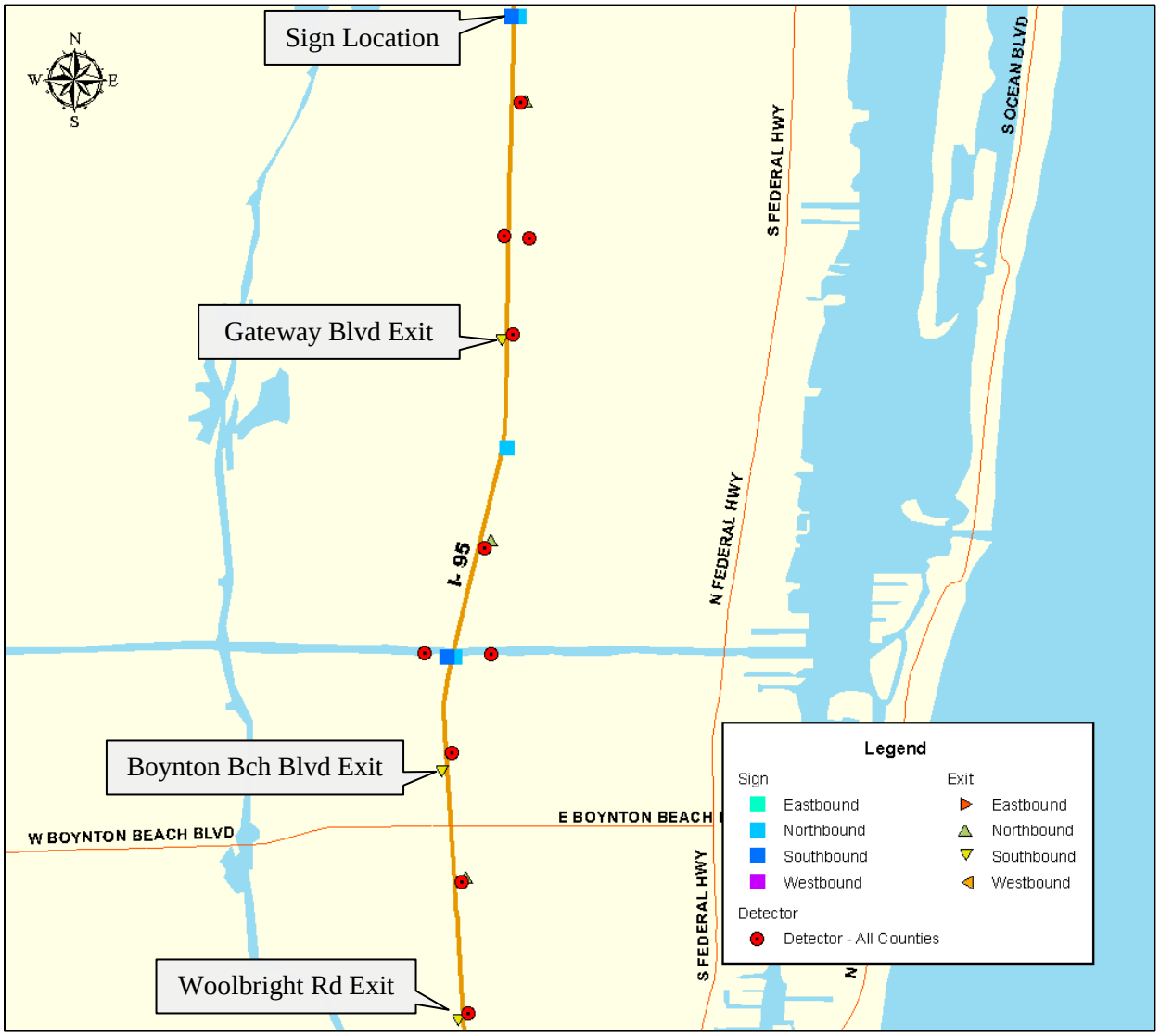
Sign Location: I-95 Southbound South of Forest Hill Boulevard (Palm Beach County)

Hypoluxo Road: 0.5 mile; 1 detector
Gateway Boulevard: 1.75 miles; 4 detectors
Boynton Beach Boulevard: 3.5 miles; 7 detectors



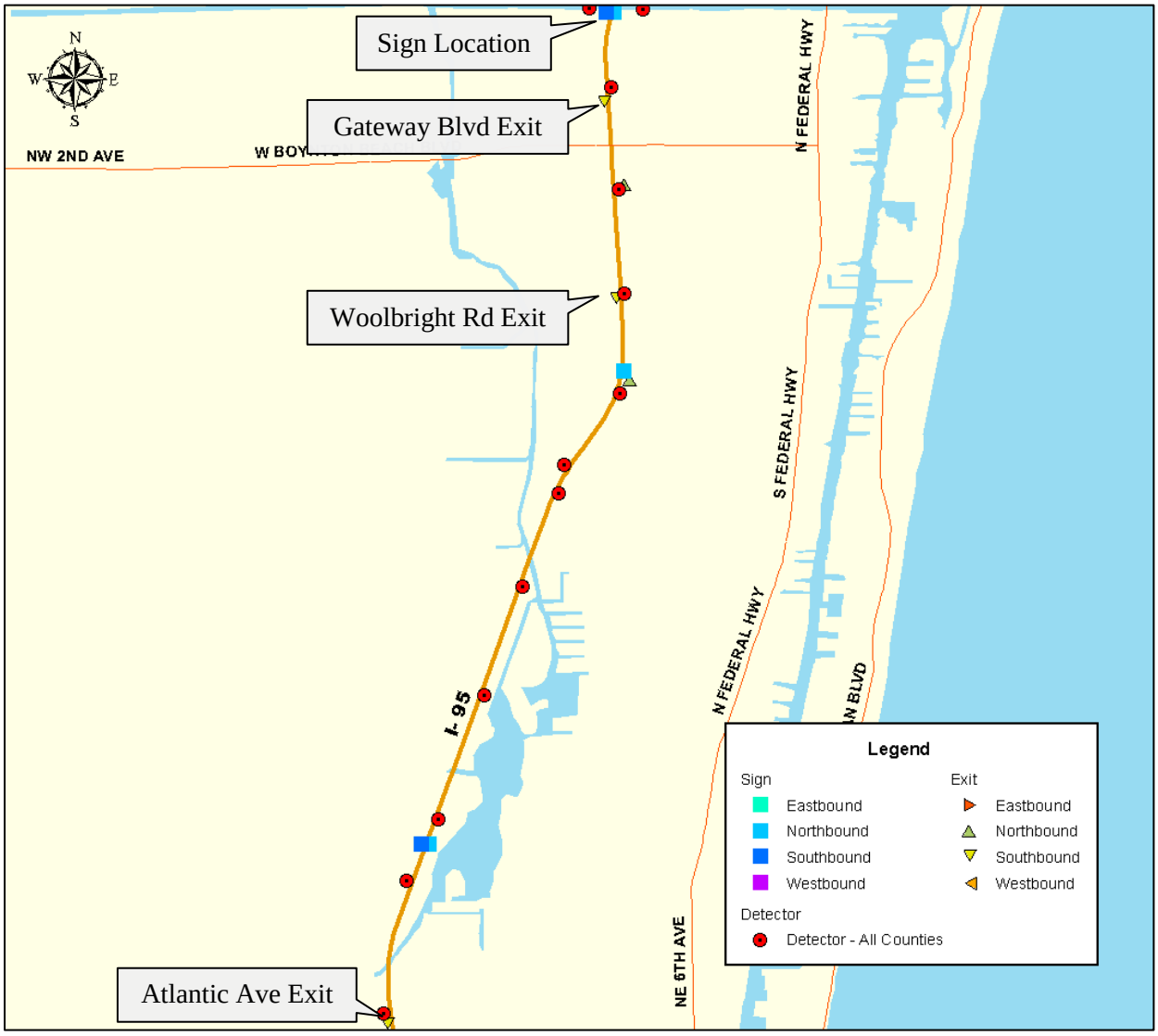
Sign Location: I-95 Southbound South of Forest Hill Boulevard (Palm Beach County)

Gateway Boulevard: 1 mile; 2 detectors
Boynton Beach Boulevard: 2.75 miles; 6 detectors
Woolbright Road: 3.75 miles; 8 detectors



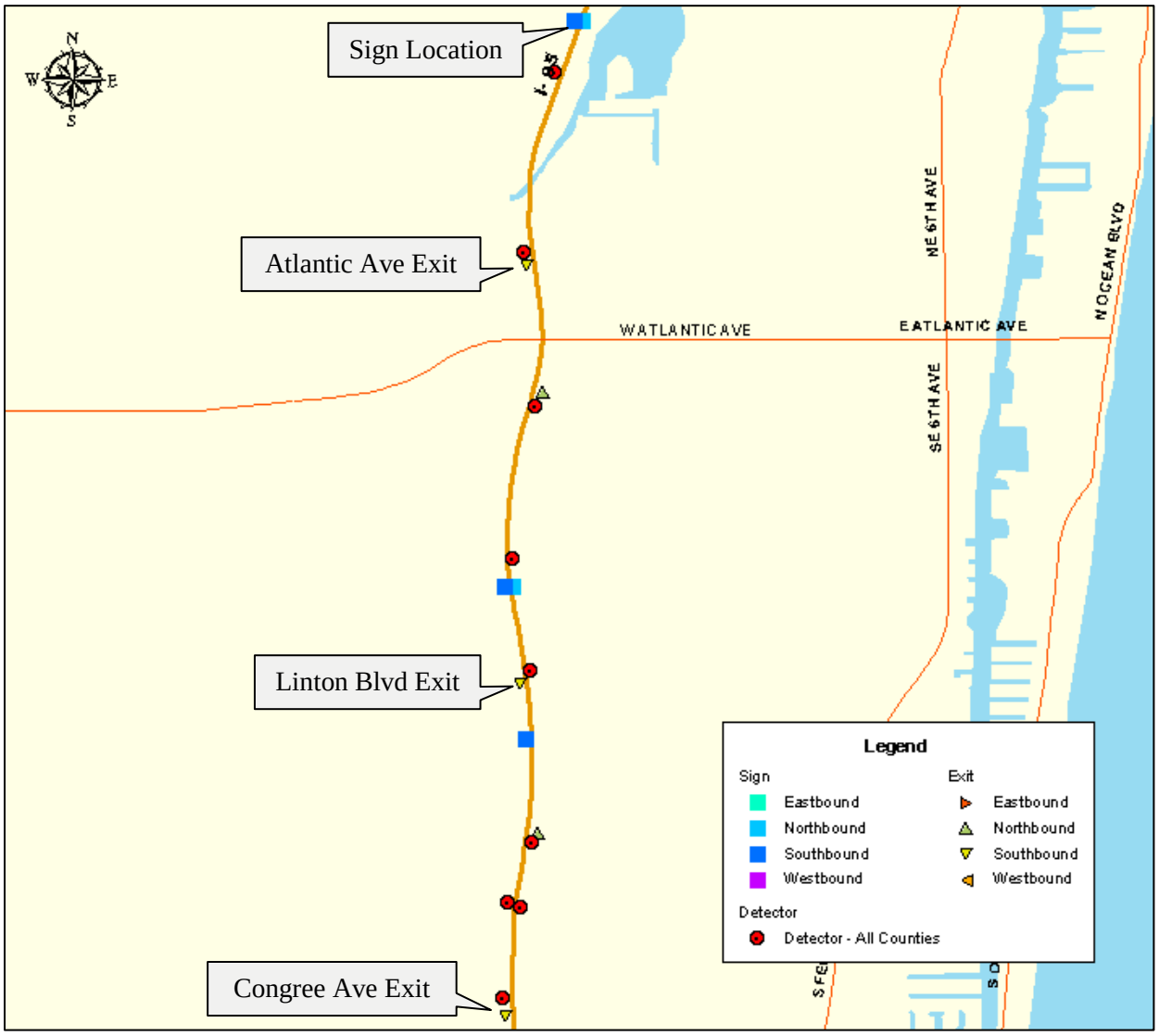
Sign Location: I-95 Southbound North of Boynton Beach Boulevard (Palm Beach County)

Boynton Beach Boulevard: 0.25 mile; 1 detector
Woolbright Road: 1.25 miles; 3 detectors
Atlantic Avenue: 4.75 miles; 10 detectors



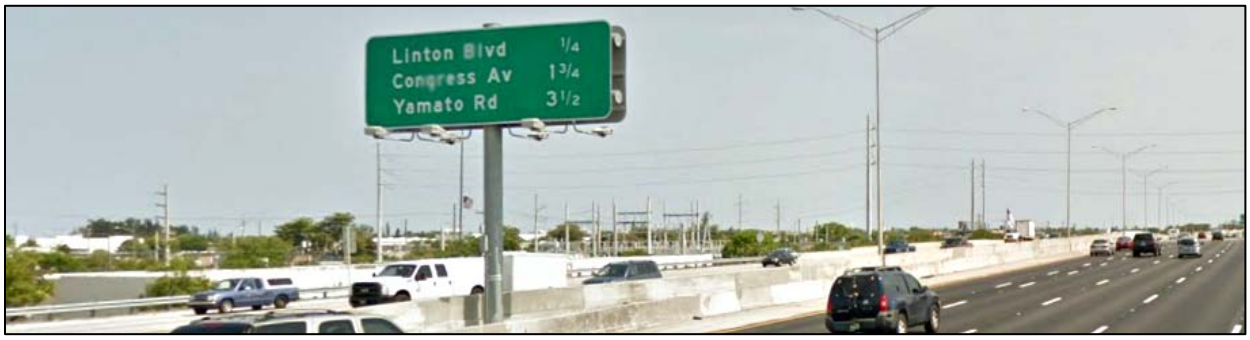
Sign Location: I-95 Southbound South of Boynton Beach Boulevard (Palm Beach County)

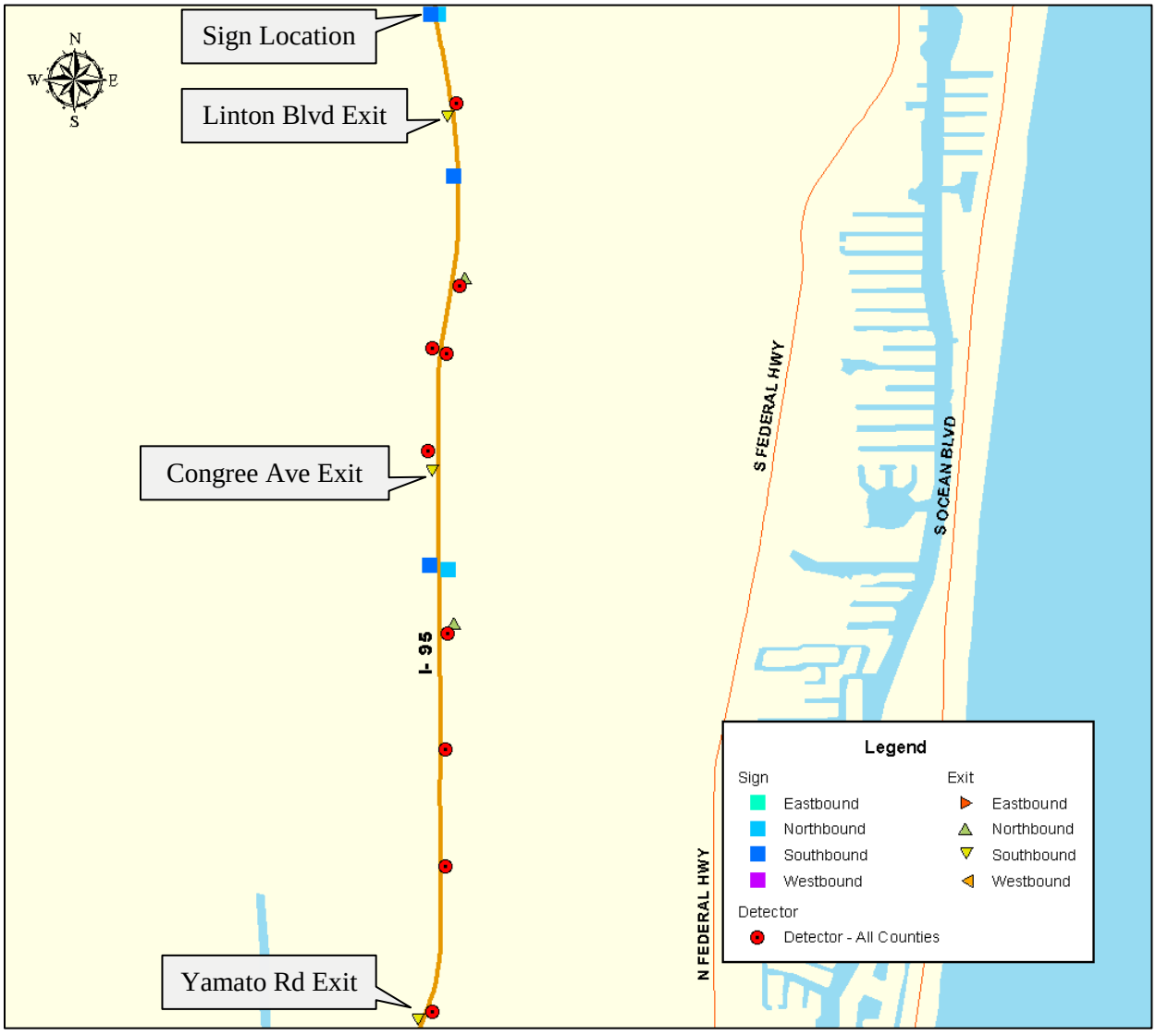
Atlantic Avenue: 0.75 mile; 2 detectors
Linton Boulevard: 2.25 miles; 5 detectors
Congress Avenue: 3.5 miles; 8 detectors



Sign Location: I-95 Southbound South of Atlantic Avenue (Palm Beach County)

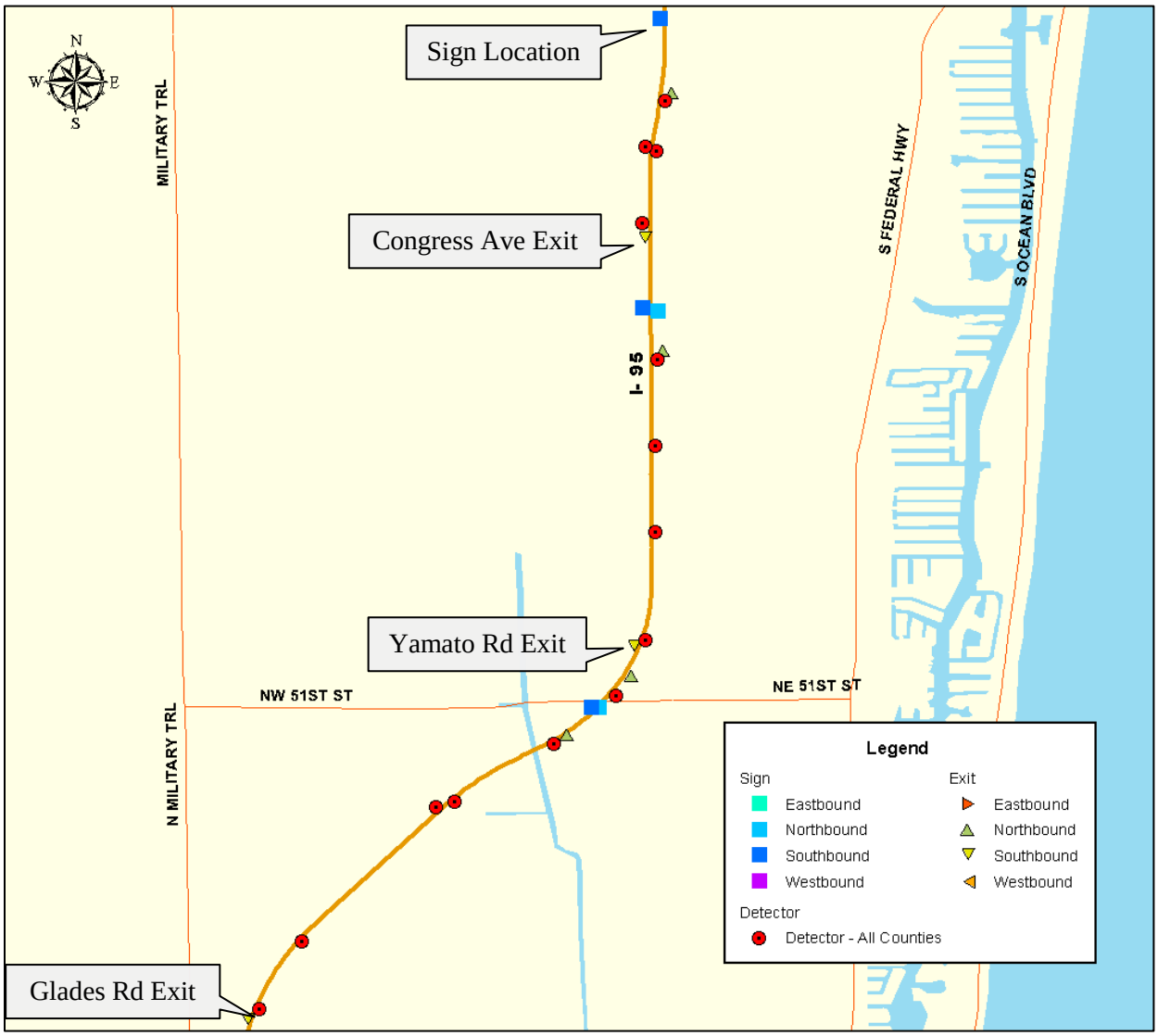
Linton Boulevard: 0.25 mile; 2 detectors
Congress Avenue: 1.75 miles; 4 detectors
Yamato Road: 3.5 miles; 8 detectors





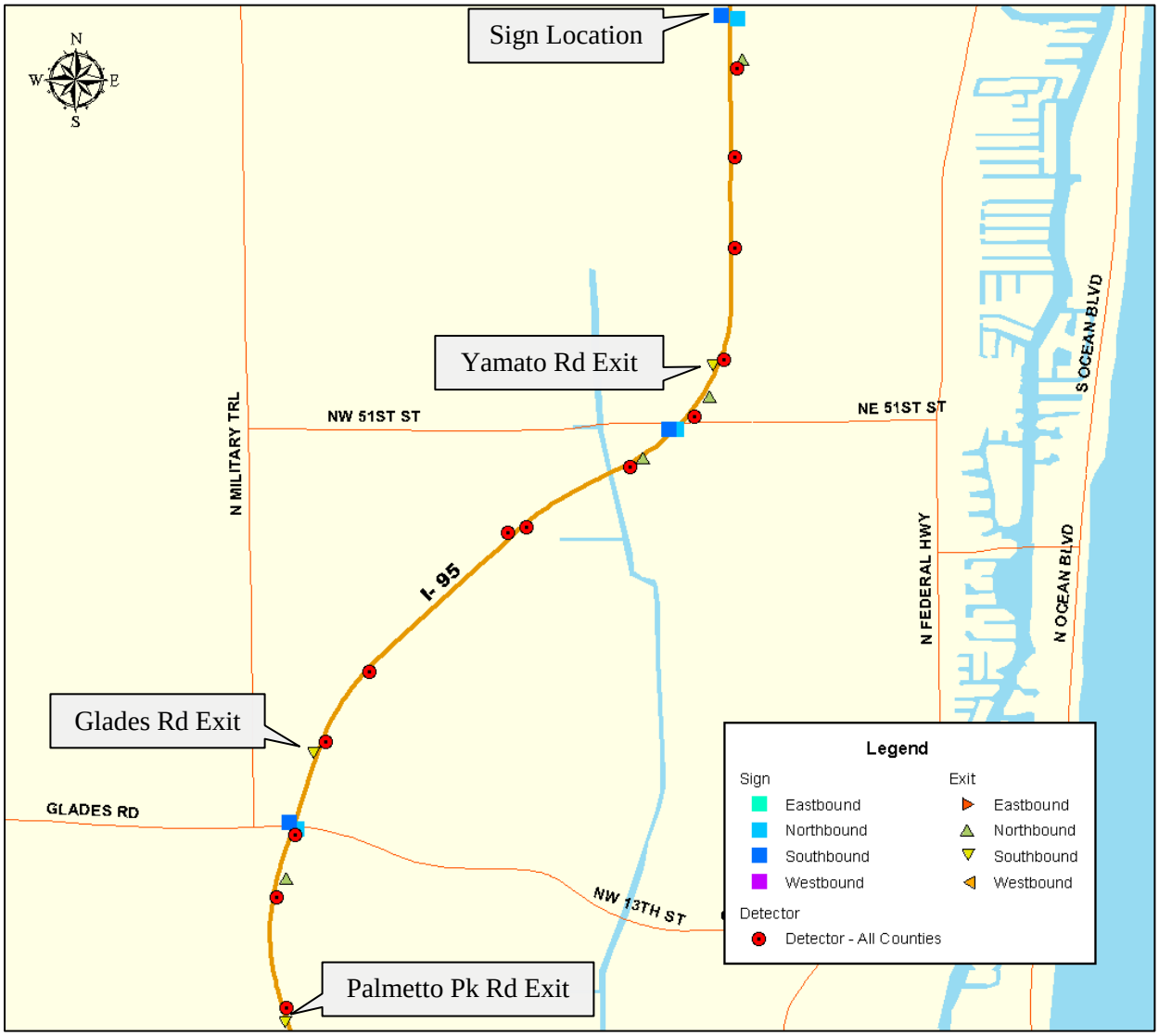
Sign Location: I-95 Southbound South of Atlantic Avenue (Palm Beach County)

Congress Avenue: 1 mile; 3 detectors
Yamato Road: 3 miles; 7 detectors
Glades Road: 5 miles; 12 detectors



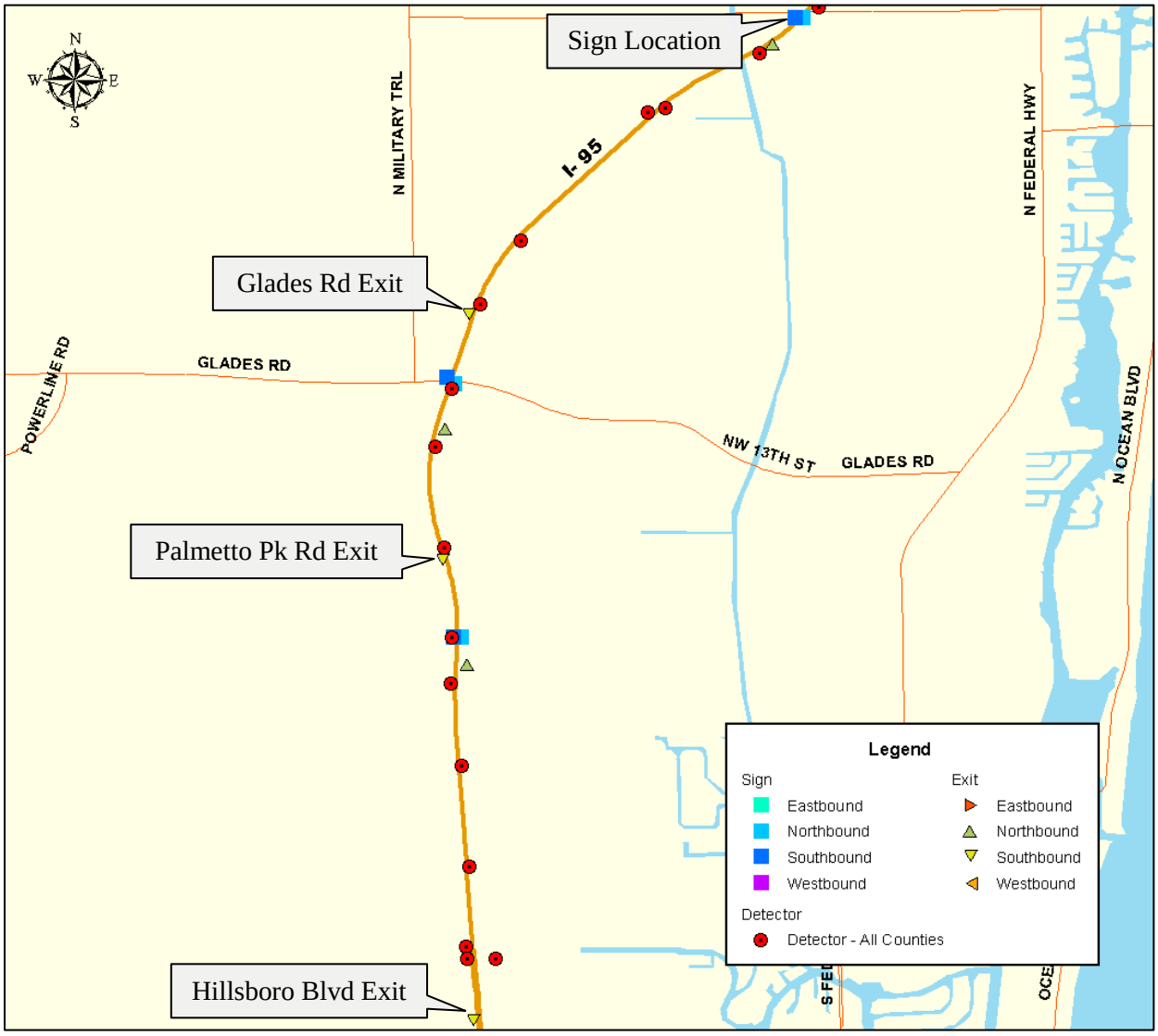
Sign Location: I-95 Southbound South of Atlantic Avenue (Palm Beach County)

Yamato Road: 1.5 miles; 4 detectors
Glades Road: 3.75 miles; 9 detectors
Palmetto Park Road: 6 miles; 12 detectors



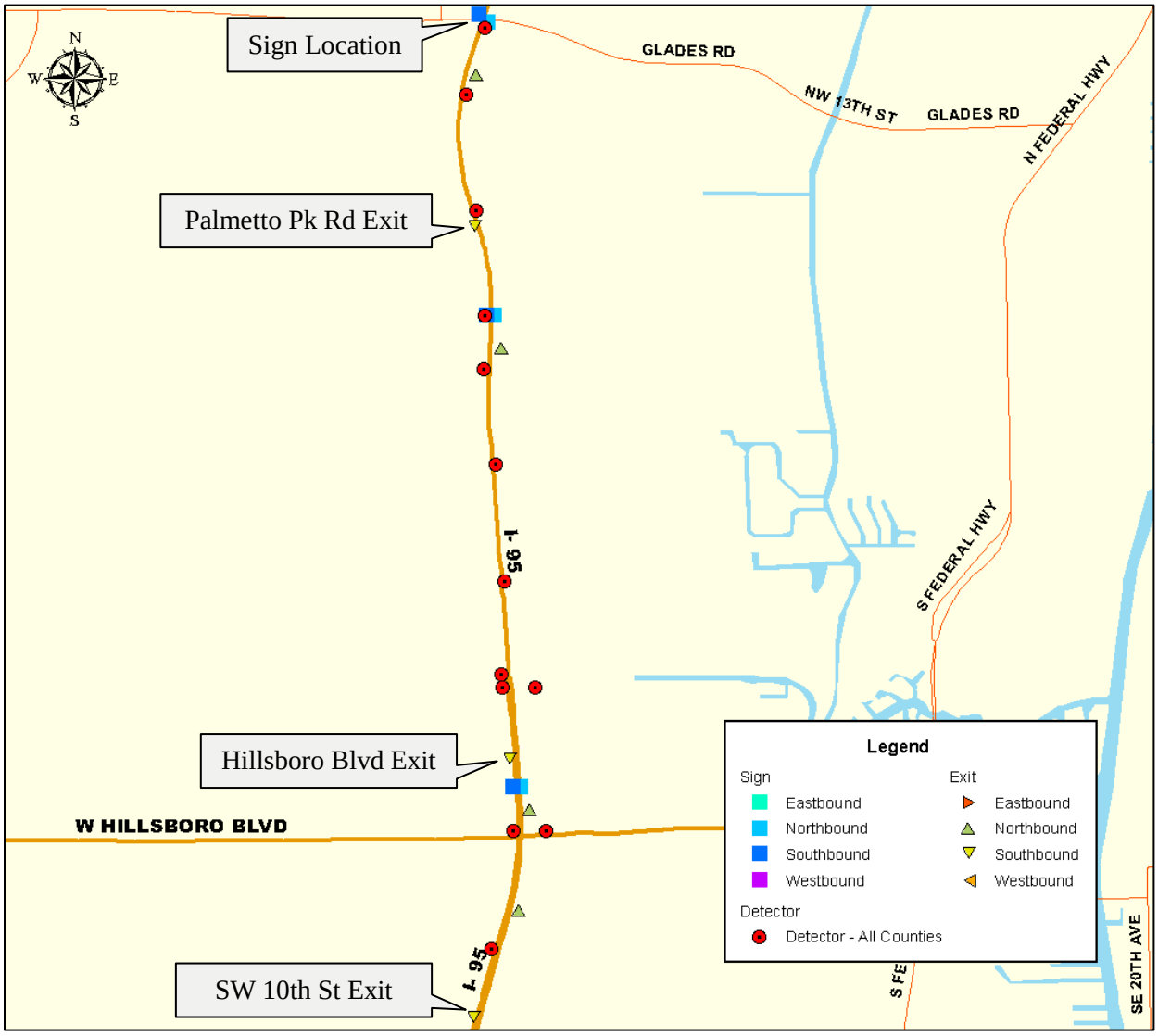
Sign Location: I-95 Southbound South of 51st Street (Palm Beach County)

Glades Road: 2.5 miles; 4 detectors
Palmetto Park Road: 3.5 miles; 7 detectors
Hillsboro Boulevard: 6 miles; 12 detectors



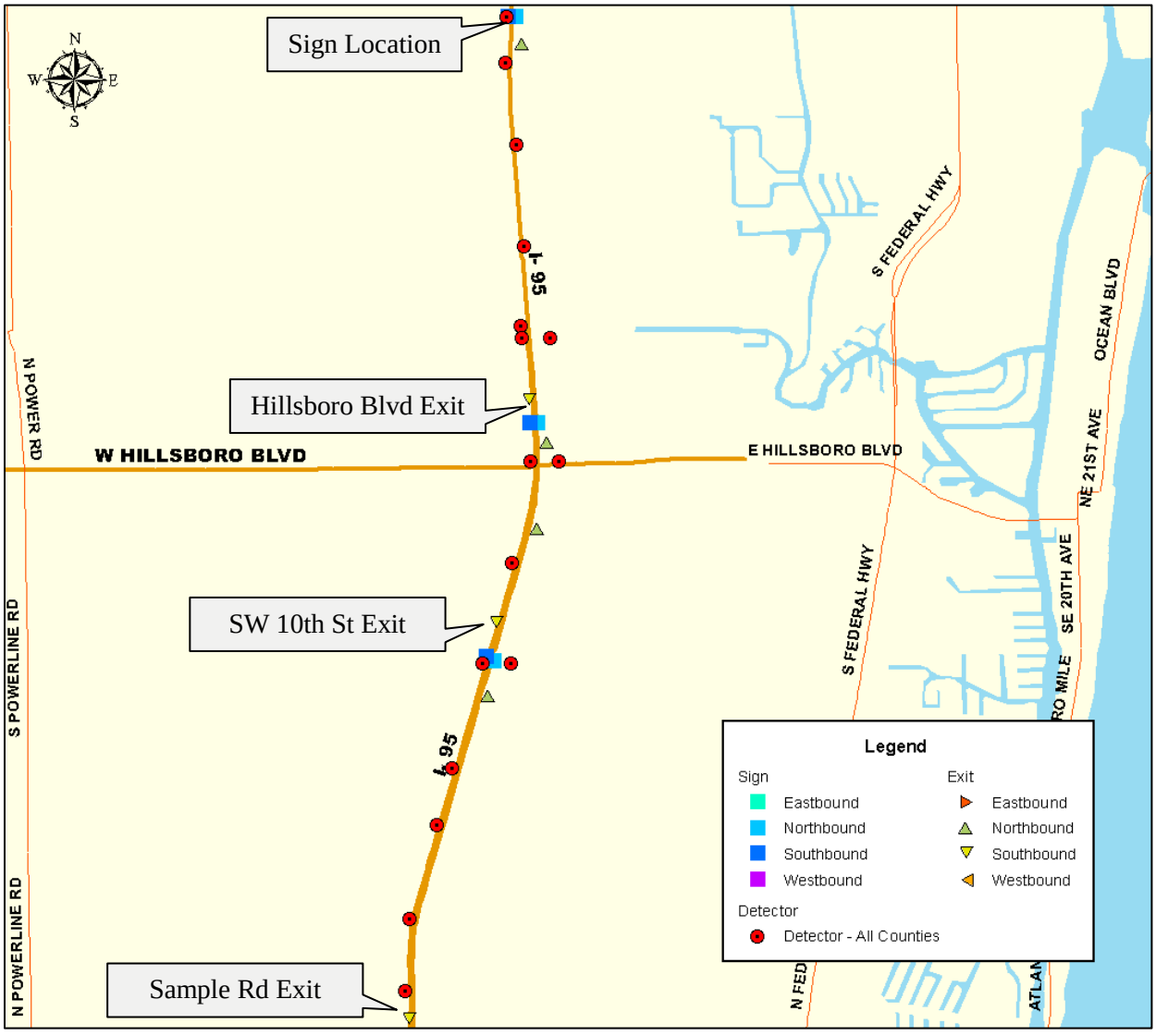
Sign Location: I-95 Southbound on Glades Road (Palm Beach County)

Palmetto Park Road: 1 mile; 3 detectors
Hillsboro Boulevard: 3 miles; 8 detectors
SW 10th Street: 4.25 miles; 10 detectors



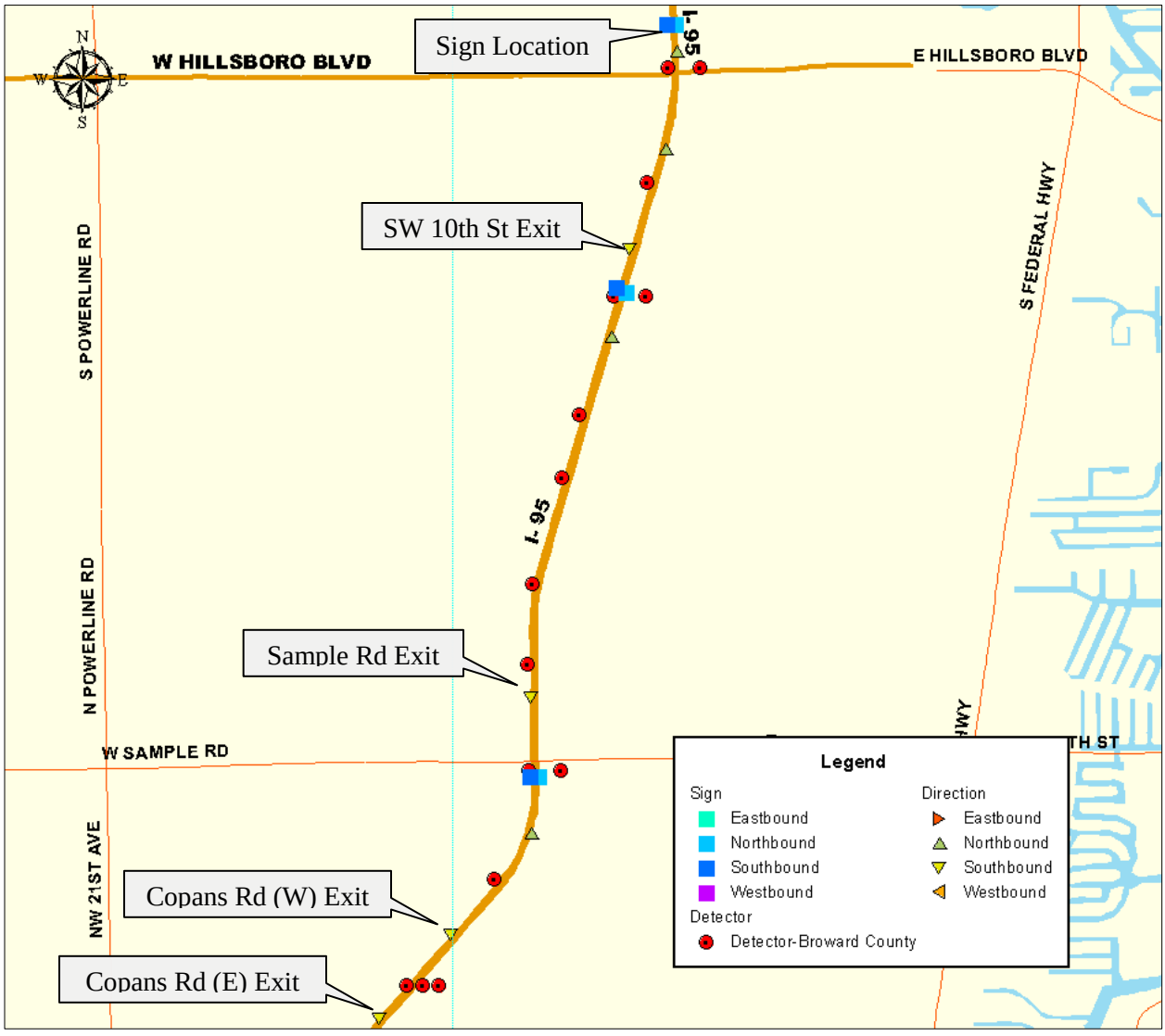
Sign Location: I-95 Southbound North of Hillsboro Boulevard (Palm Beach County)

Hillsboro Boulevard: 1.75 miles; 4 detectors
SW 10th Street: 3 miles; 6 detectors
Sample Road: 5 miles; 11 detectors



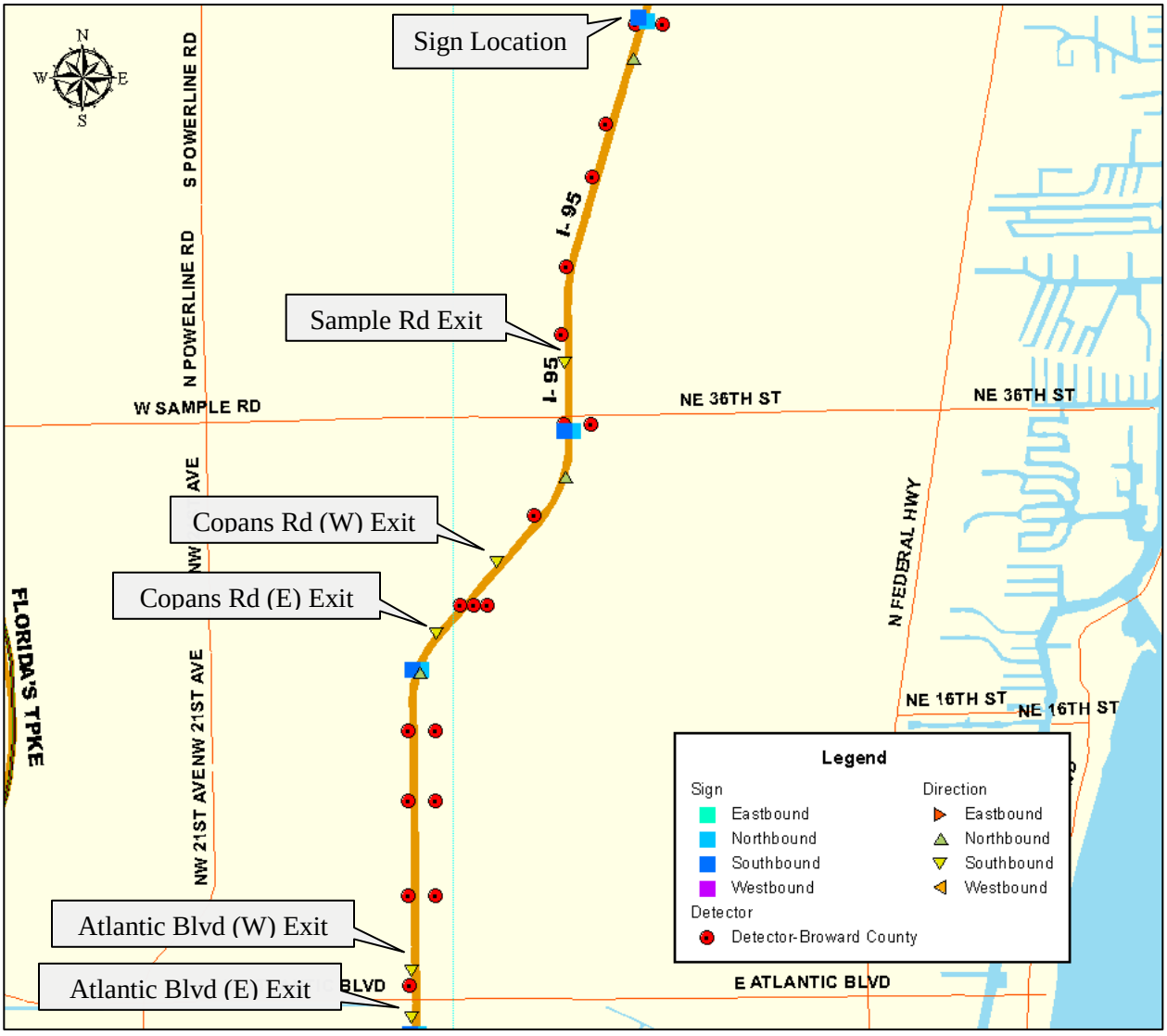
Sign Location: I-95 Southbound North of Hillsboro Boulevard (Palm Beach County)

SW 10th Street: 1 mile; 2 detectors
Sample Road: 3 miles; 7 detectors
Copans Road: 4 miles; 10 detectors



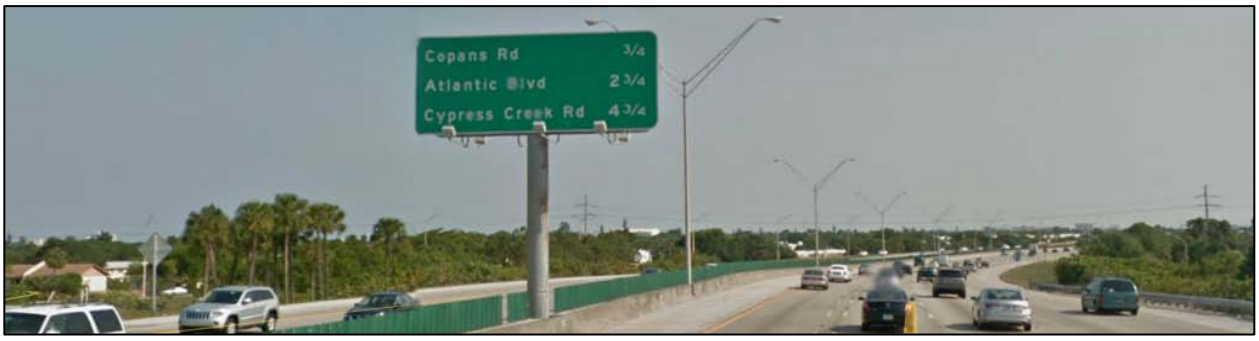
Sign Location: I-95 Southbound South of SW 10th Street Exit (Broward County)

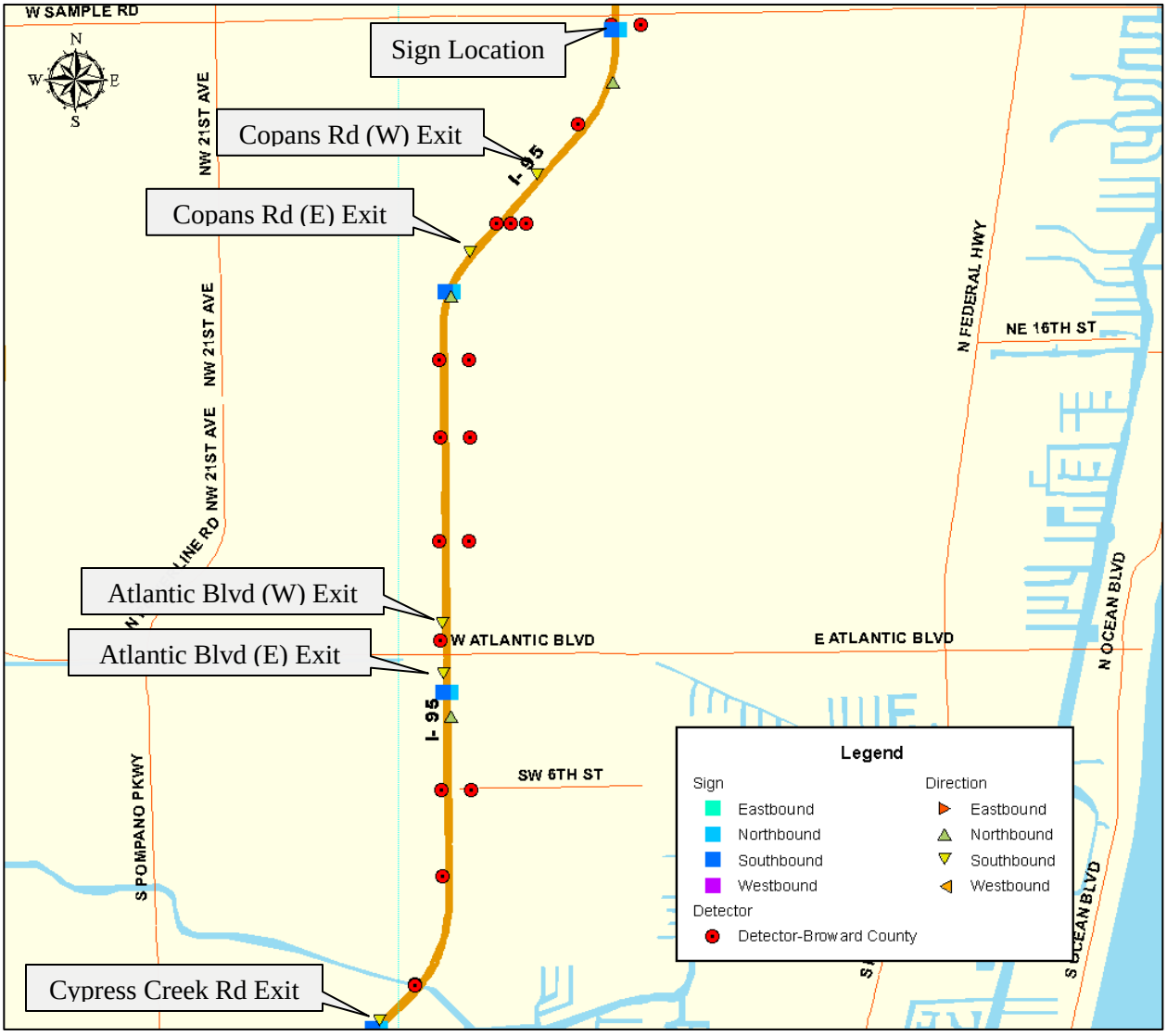
Sample Road: 1.75 miles; 5 detectors
Copans Road: 2.75 miles; 8 detectors
Atlantic Boulevard: 5 miles; 12 detectors



Sign Location: I-95 Southbound South of Sample Road (Broward County)

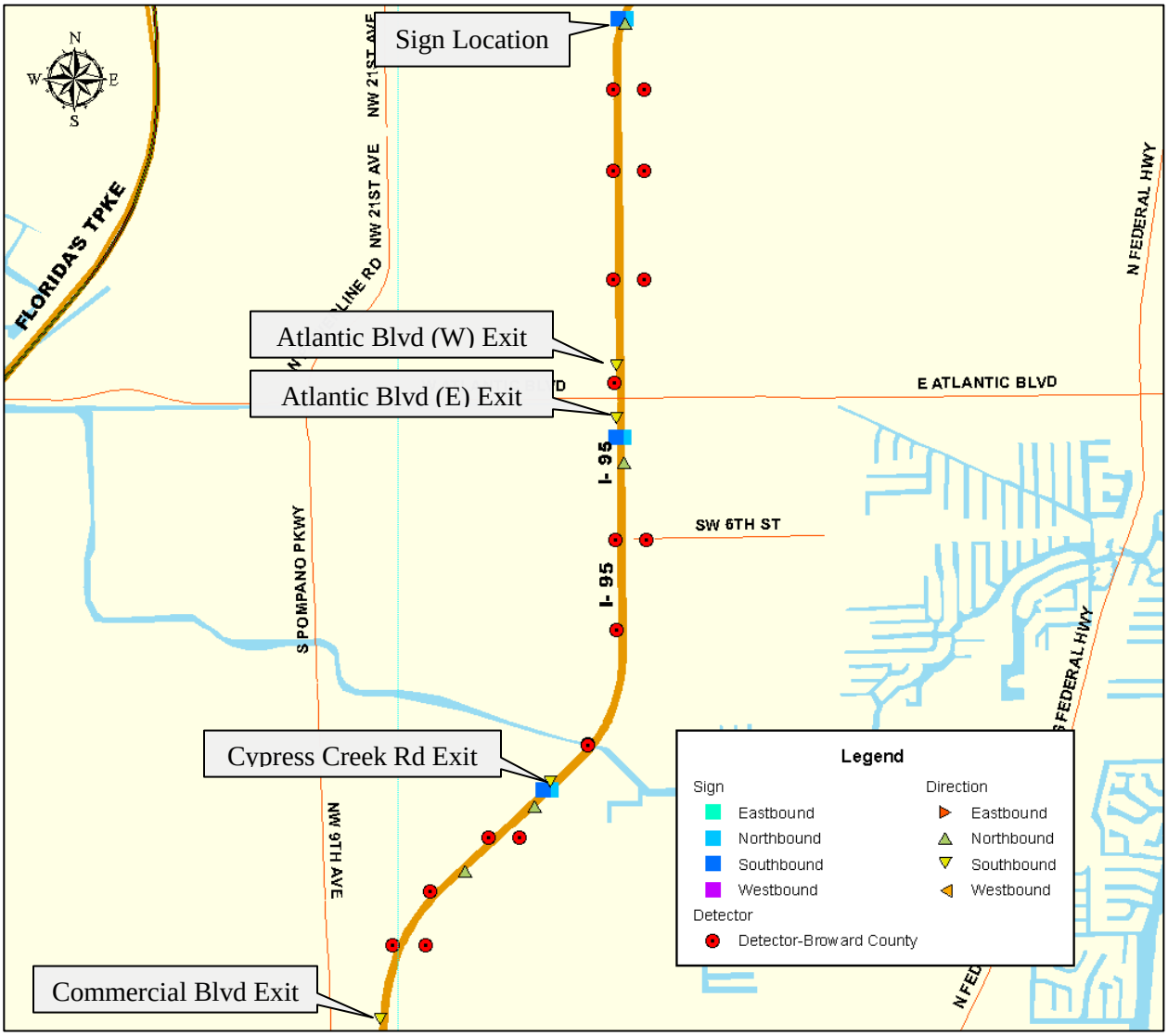
Copans Road: 0.75 miles; 2 detectors
Atlantic Boulevard: 2.75 miles; 6 detectors
Cypress Creek Road: 4.75 miles; 9 detectors





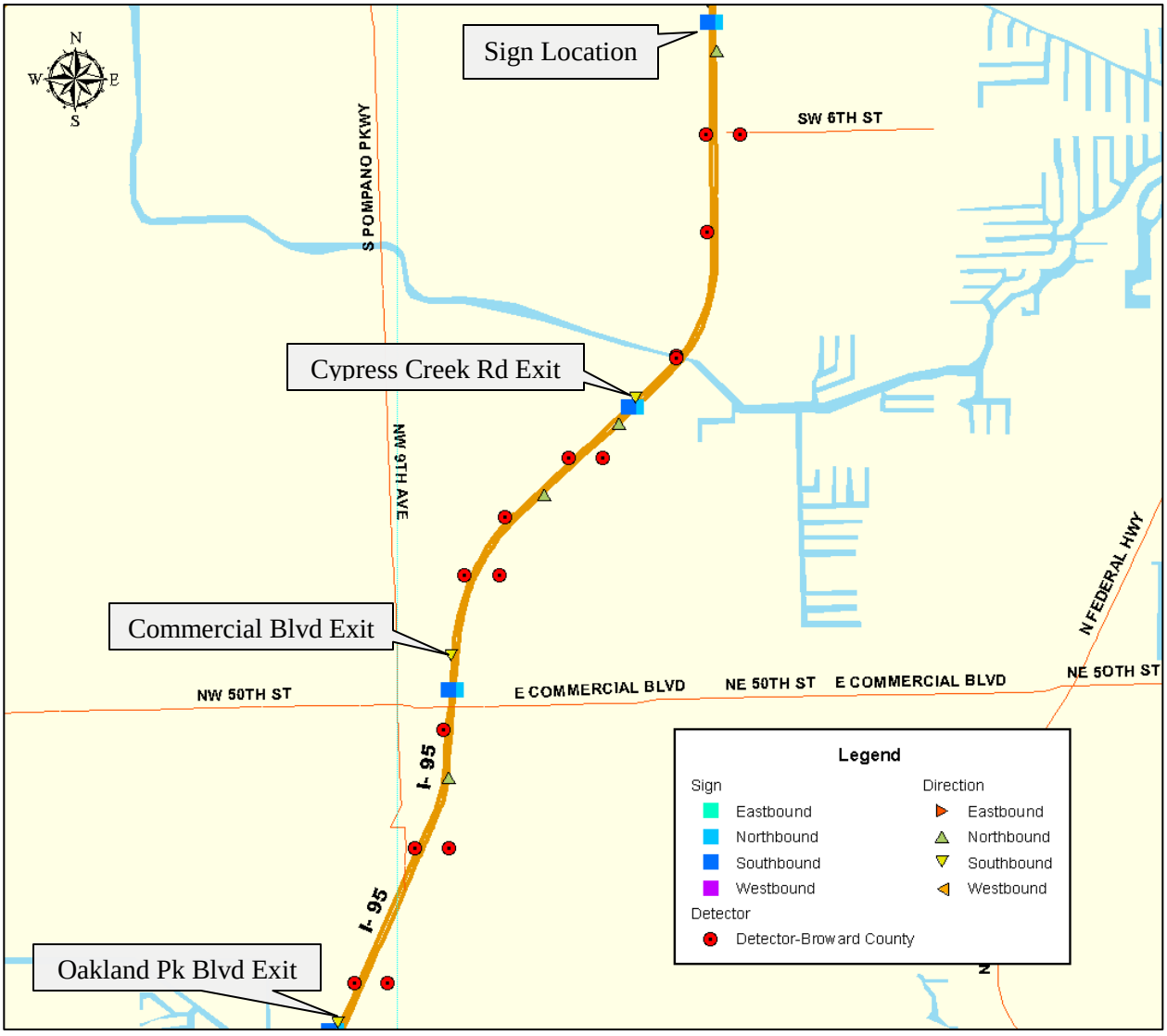
Sign Location: I-95 Southbound South of Copans Road (Broward County)

Atlantic Boulevard: 1.75 miles; 4 detectors
Cypress Creek Road: 3.75 miles; 7 detectors
Commercial Boulevard: 4.75 miles; 10 detectors



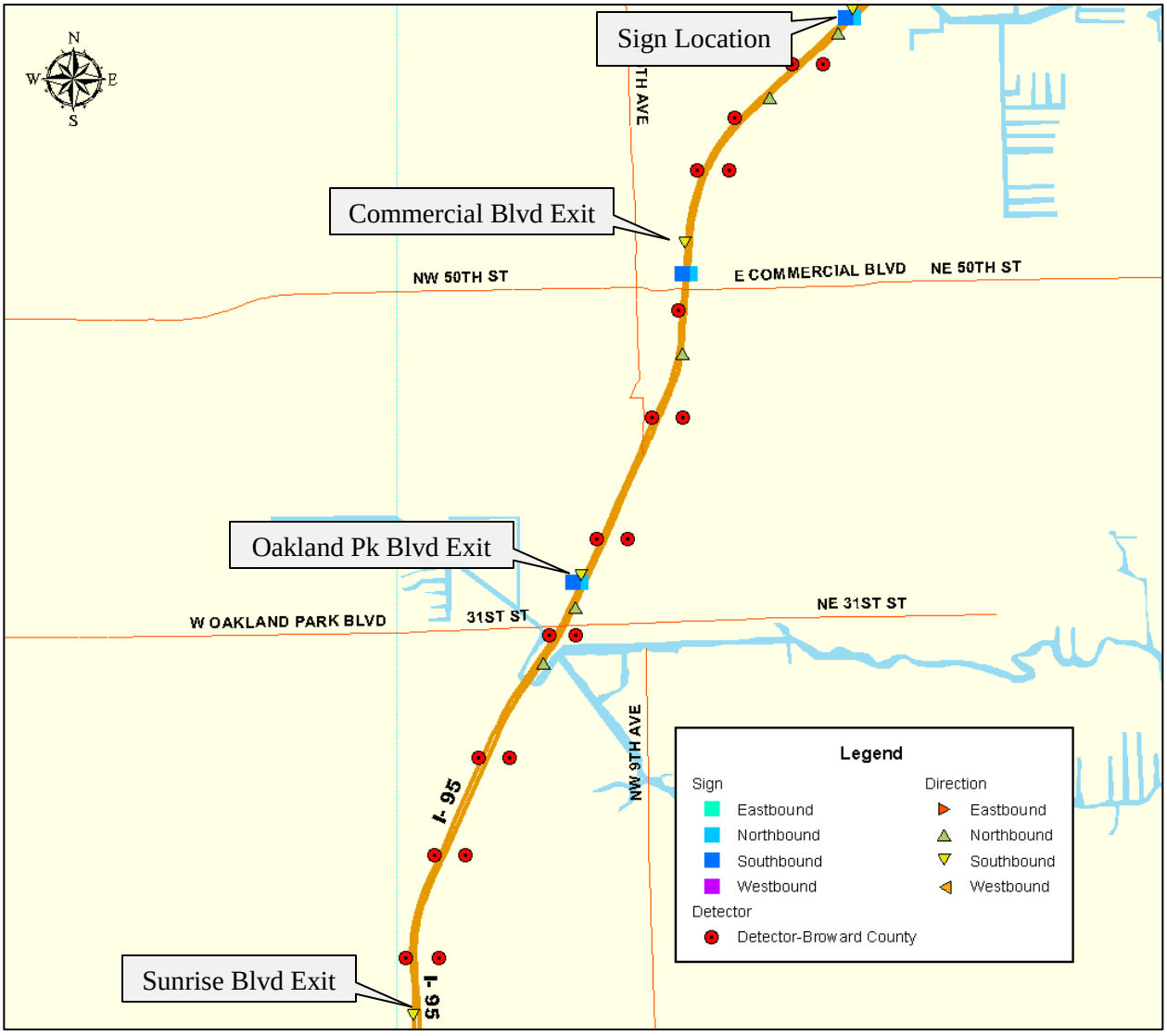
Sign Location: I-95 Southbound South of Atlantic Boulevard (Broward County)

Cypress Creek Road: 1.75 miles; 3 detectors
Commercial Boulevard: 3 miles; 6 detectors
Oakland Park Boulevard: 4.5 miles; 9 detectors



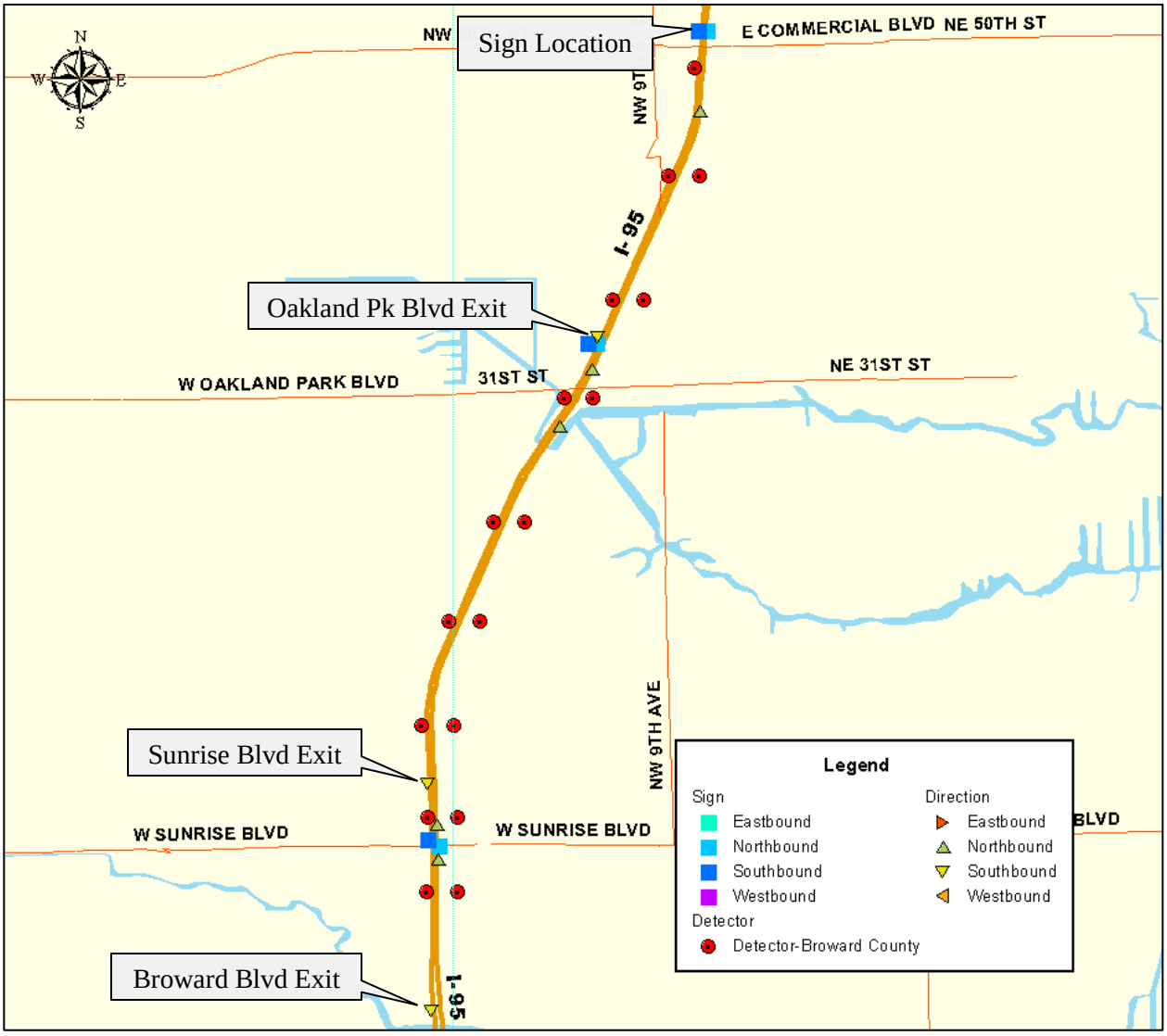
Sign Location: I-95 Southbound North of Cypress Creek Road (Broward County)

Commercial Boulevard: 1 mile; 3 detectors
Oakland Park Boulevard: 2.75 miles; 6 detectors
Sunrise Boulevard: 4.75 miles; 10 detectors



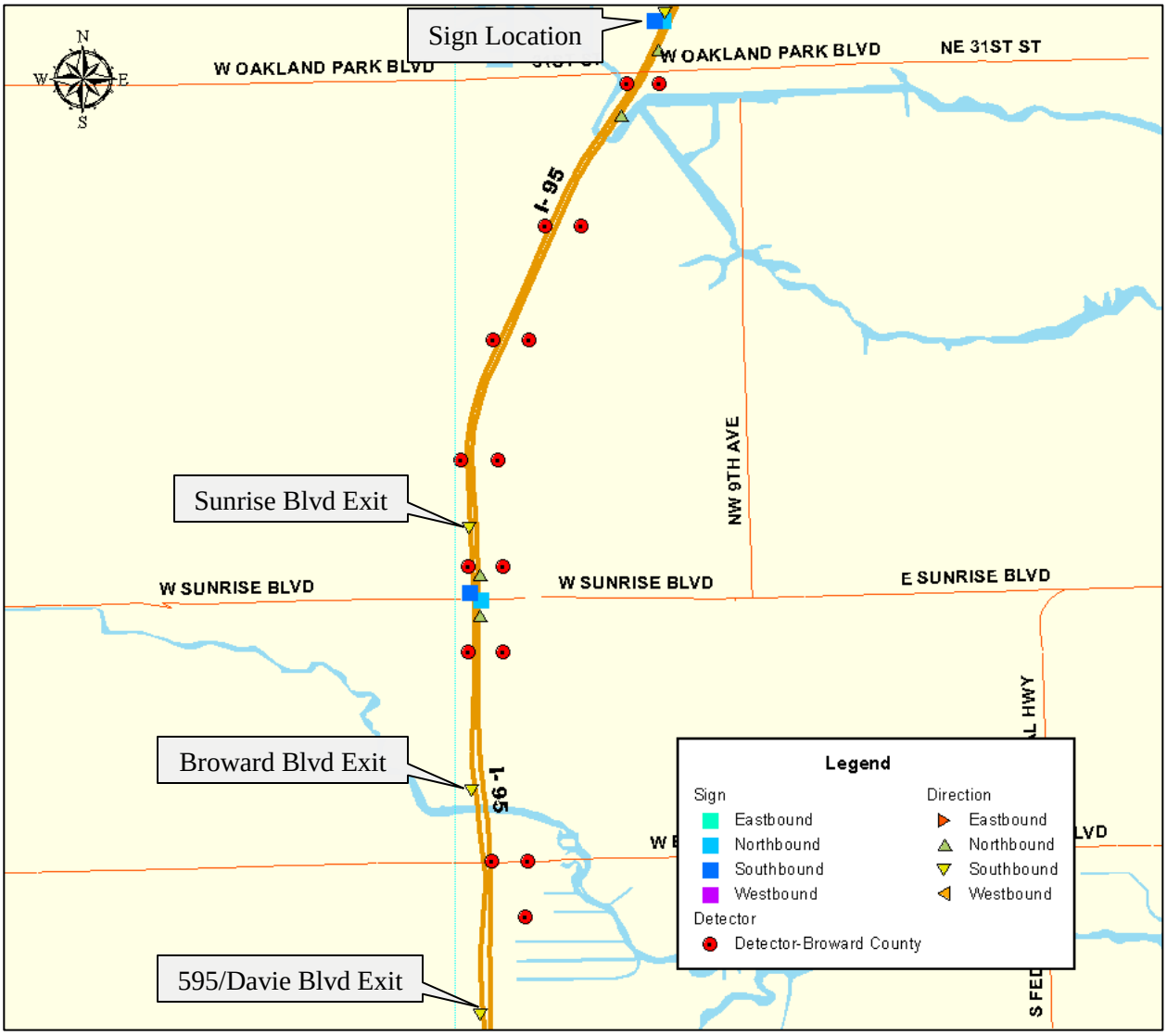
Sign Location: I-95 Southbound North of Commercial Boulevard (Broward County)

Oakland Park Boulevard: 1.5 miles; 3 detectors
Sunrise Boulevard: 3.75 miles; 7 detectors
Broward Boulevard: 4.75 mile; 9 detectors



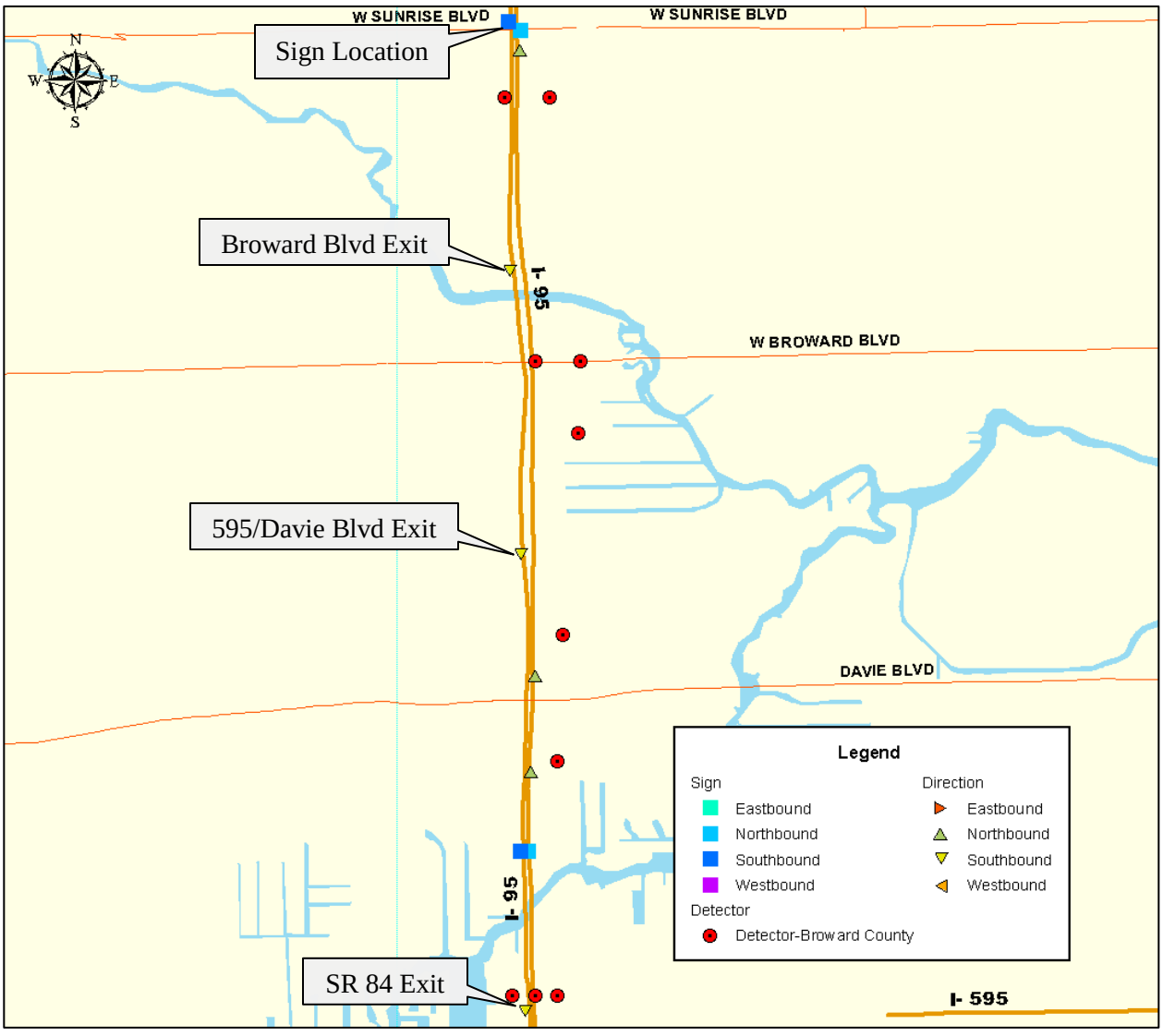
Sign Location: I-95 Southbound North of Oakland Park Boulevard (Broward County)

Sunrise Boulevard: 2 miles; 4 detectors
Broward Boulevard: 3 mile; 6 detectors
I-595/ Davie Boulevard: 4 miles; 8 detectors



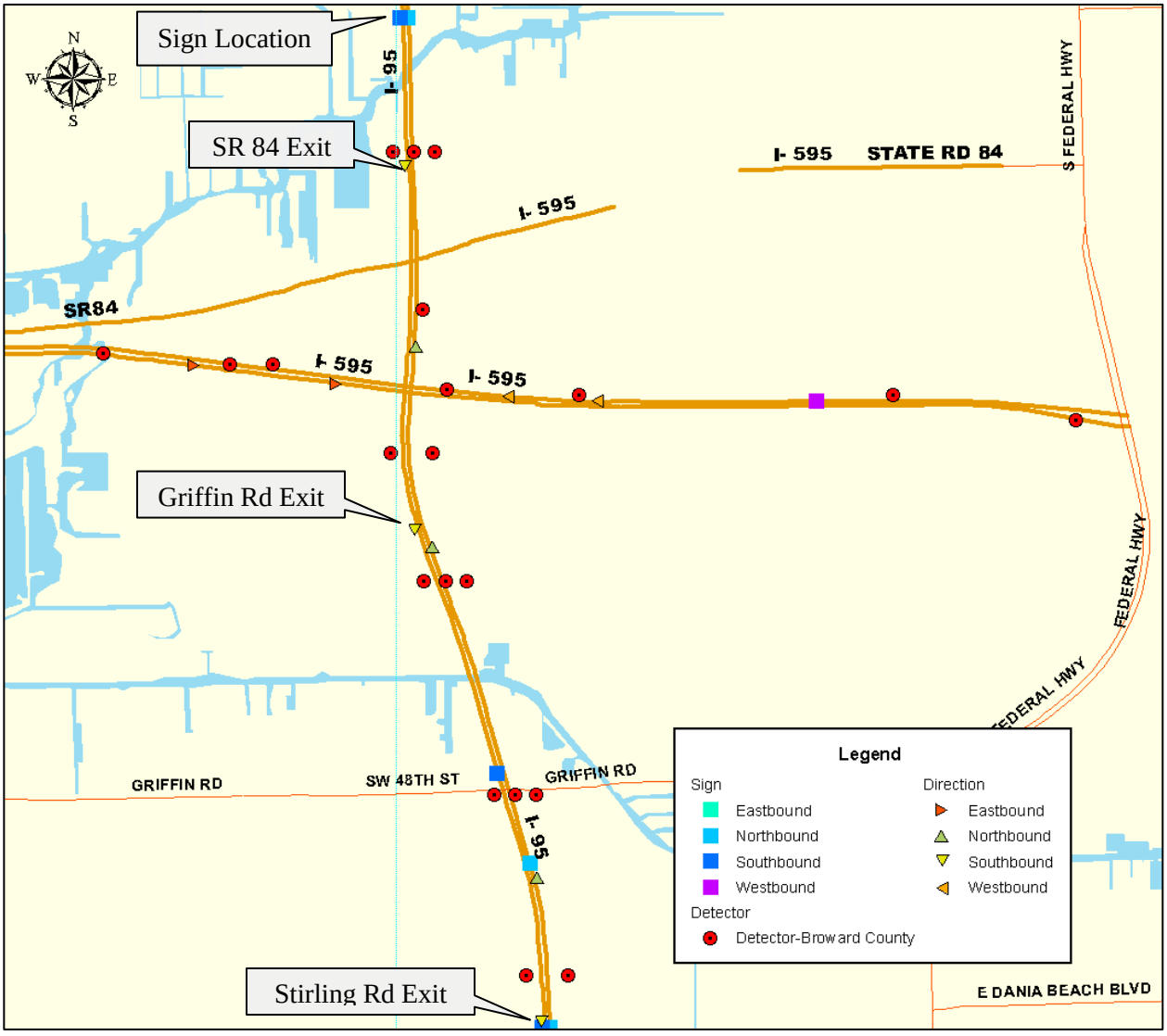
Sign Location: I-95 Southbound North of Sunrise Boulevard (Broward County)

Broward Boulevard: 0.5 mile; 1 detector
I-595/ Davie Boulevard: 1.5 miles; 3 detectors
State Road 84: 3 miles; 6 detectors in between



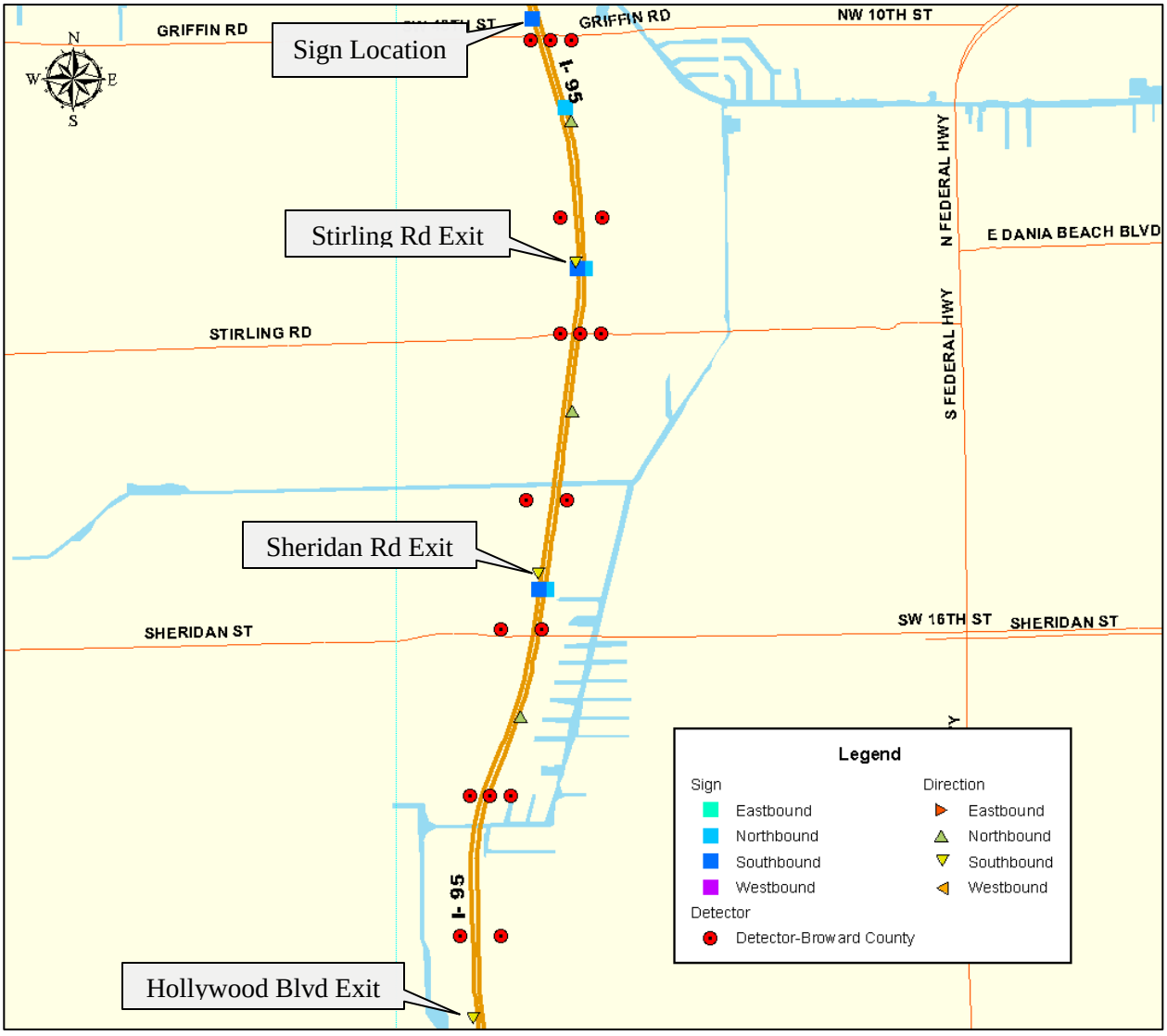
Sign Location: I-95 Southbound North of SR 84 Exit (Broward County)

State Road 84: 0.5 miles; 1 detector
Griffin Road: 1.75 mile; 3 detectors
Stirling Road: 3.5 miles; 6 detectors



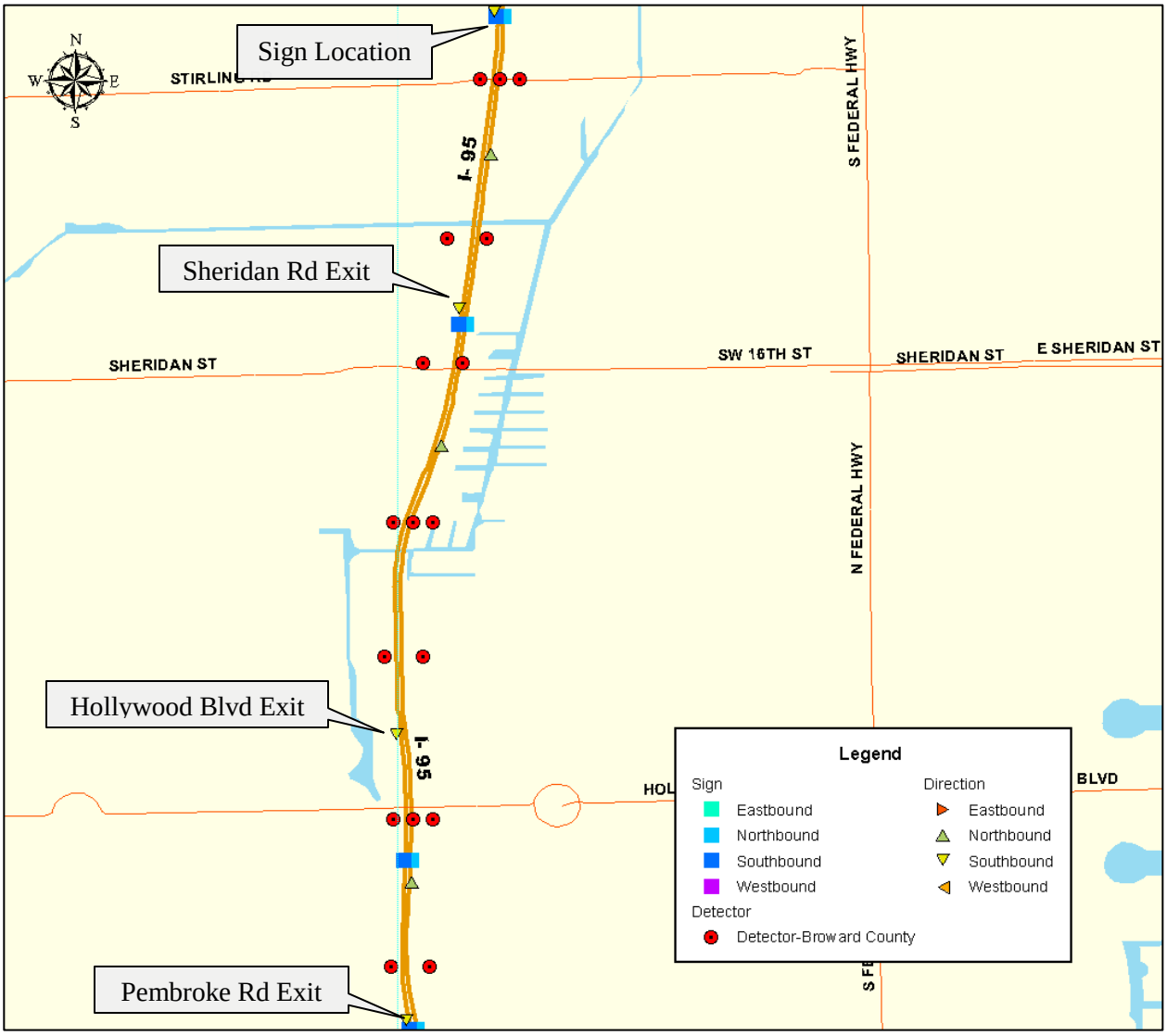
Sign Location: I-95 Southbound North of Griffin Road (Broward County)

Stirling Road: 0.5 miles; 2 detectors
Sheridan Street: 1.5 miles; 3 detectors
Hollywood Boulevard: 3.25 mile; 7 detectors



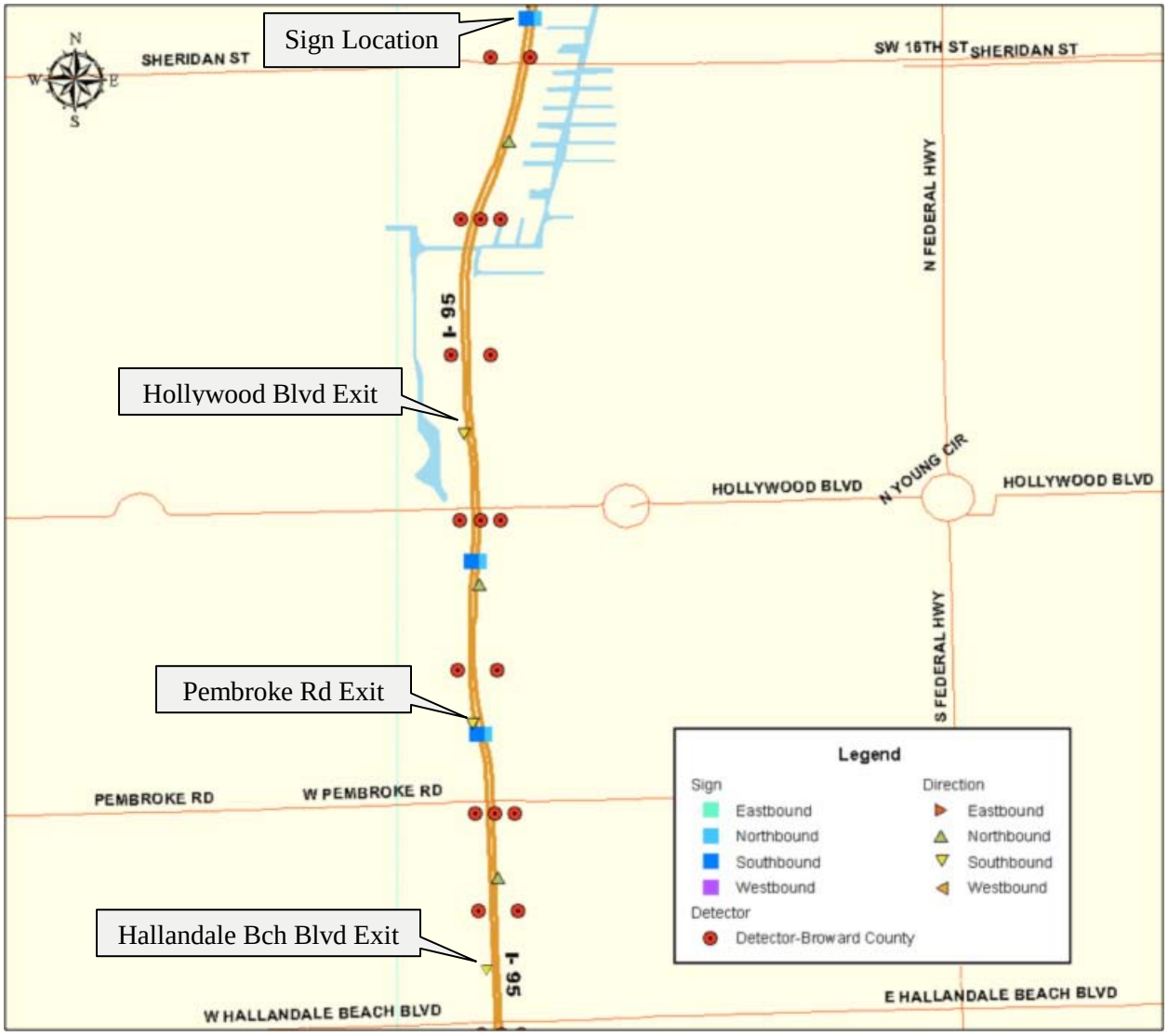
Sign Location: I-95 Southbound North of Stirling Road (Broward County)

Sheridan Street: 1 mile; 2 detectors
Hollywood Boulevard: 2.5 mile; 5 detectors
Pembroke Road: 3.5 miles; 7 detectors



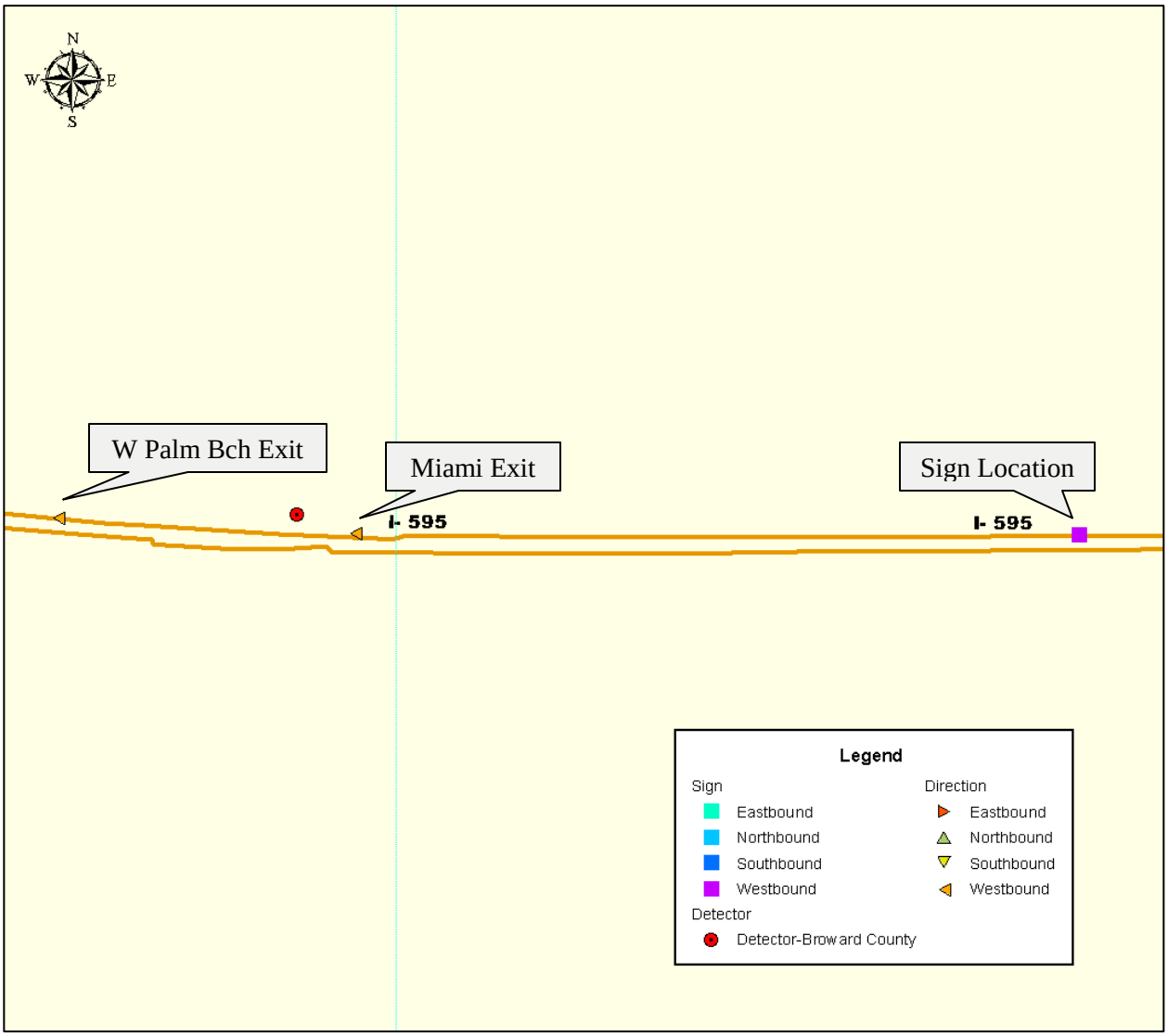
Sign Location: I-95 Southbound North of Sheridan Street (Broward County)

Hollywood Boulevard: 1.5 mile; 3 detectors
Pembroke Road: 2.5 miles; 5 detectors
Hallandale Beach Boulevard: 3.25 miles; 7 detectors



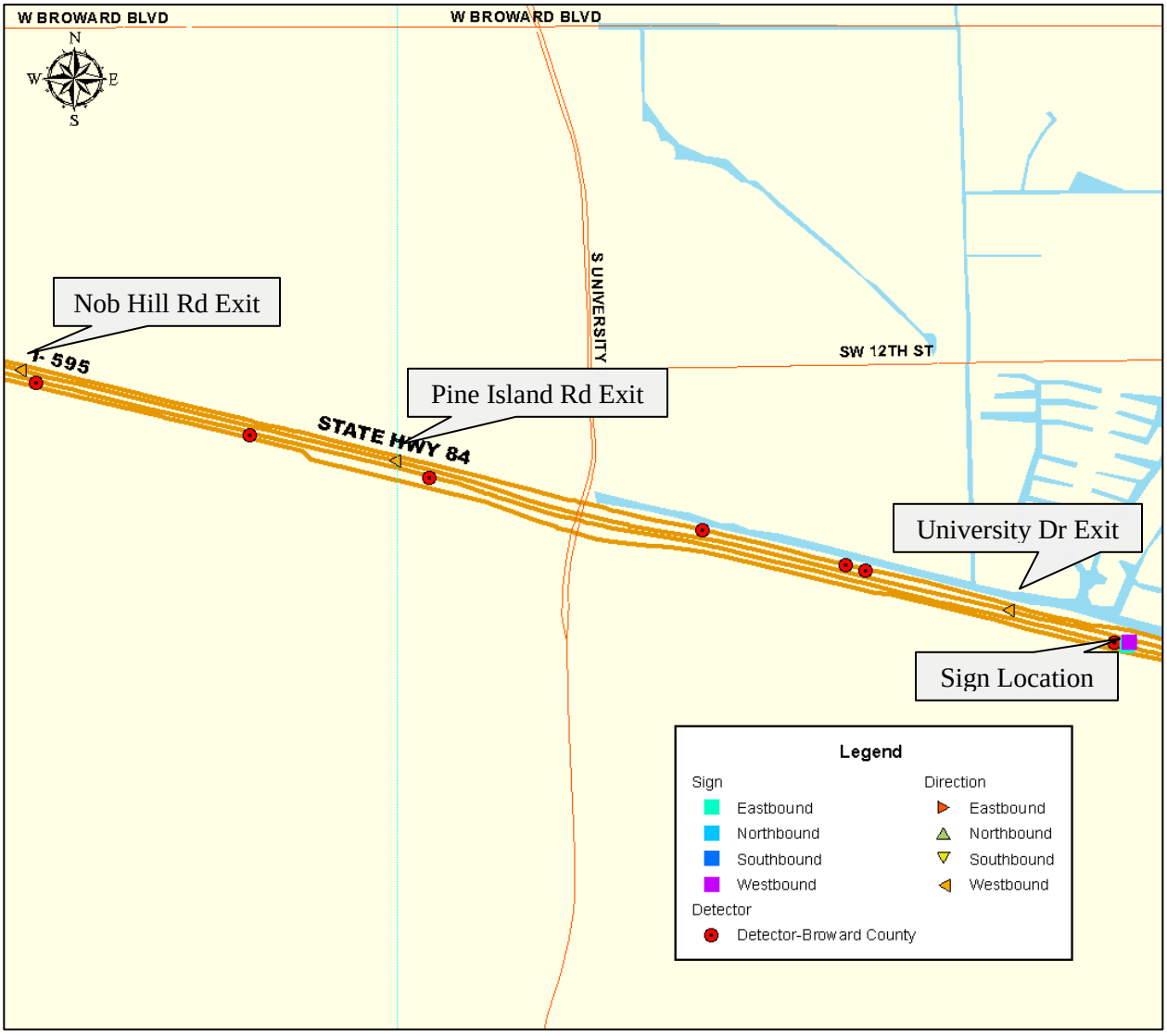
Sign Location: I-95 Westbound East of Miami Exit (Broward County)

Miami: 0.5 mile; No detector
West Palm Beach: 1 mile; 1 detector



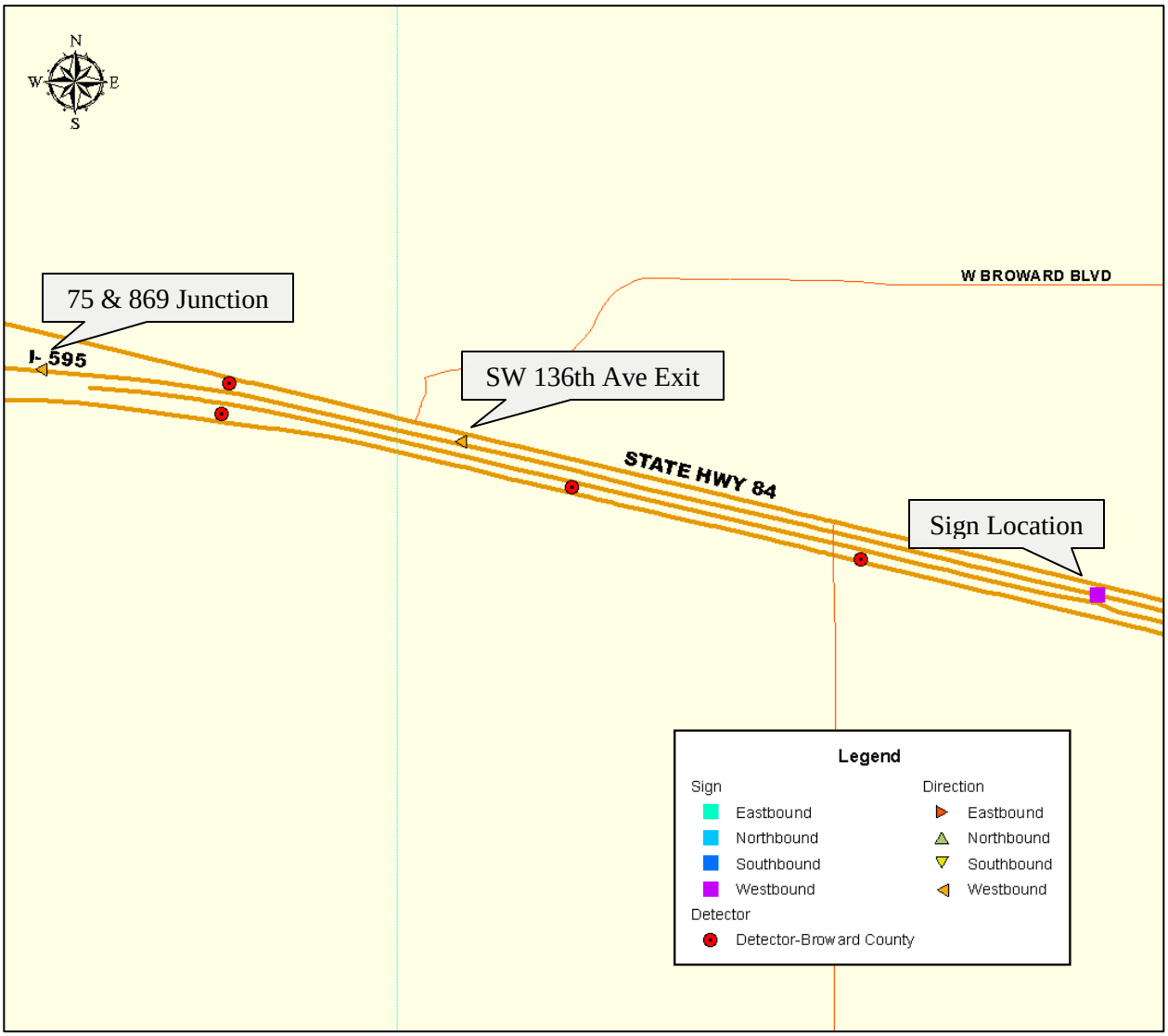
Sign Location: I-95 Westbound East of University Drive (Broward County)

University Drive: 0.25 mile; 1 detector
Pine Island Road: 2.25 miles; 5 detectors
Nob Hill Road: 3.25 mile; 7 detectors



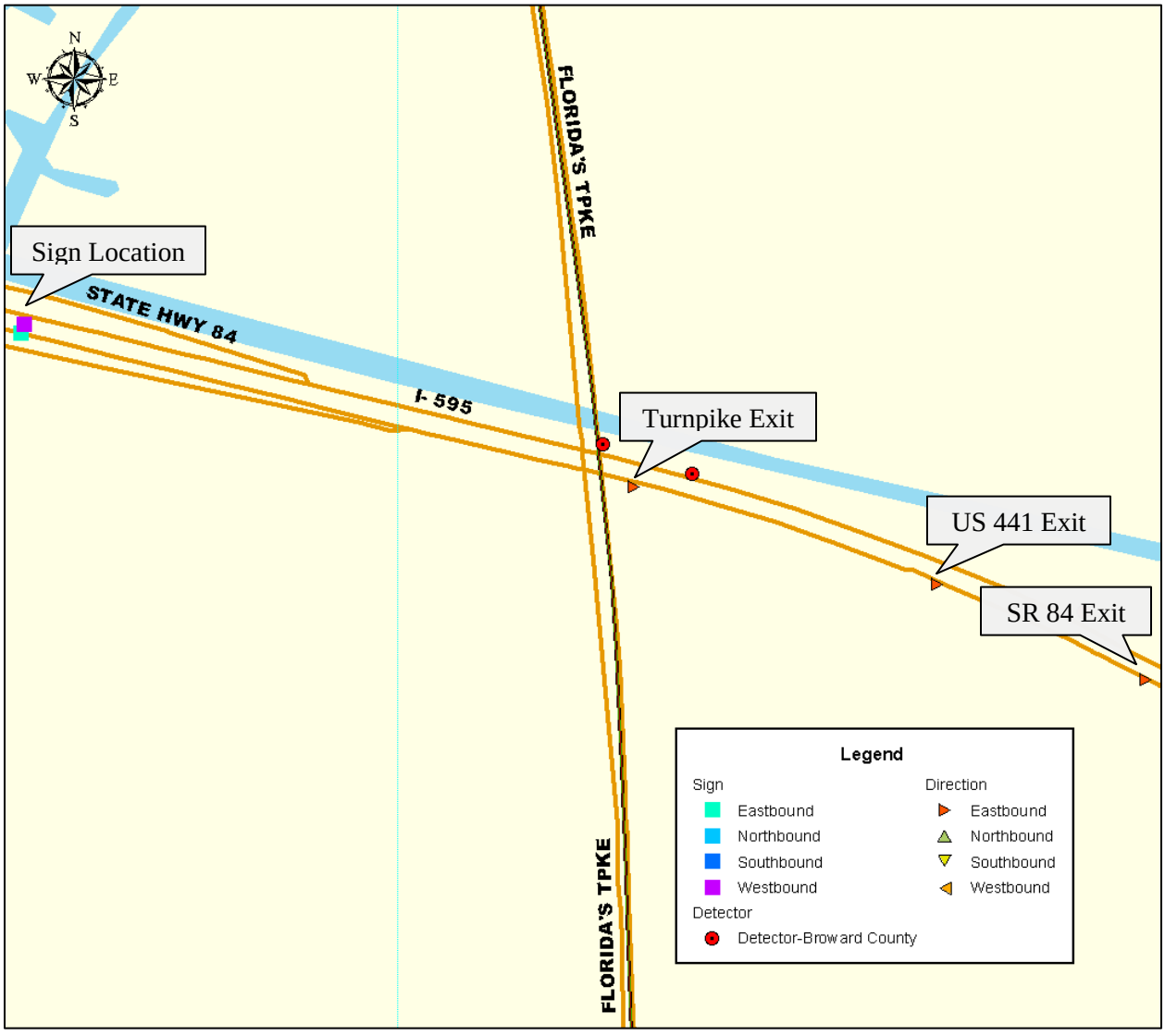
Sign Location: I-95 Westbound East of SW 136th Avenue (Broward County)

I-75/ State Road 869: 1.5 miles; 3 detectors
Southwest 136th Avenue: 1 mile; 2 detectors



Sign Location: I-595 Eastbound West of Turnpike (Broward County)

Turnpike: 0.75 mile; 1 detector
US 441: 1 mile; 1 detector
SR 84: 1.25 miles; No detector



Sign Location: I-595 Eastbound West of West Palm Beach Exit (Broward County)

Weast Palm Beach: 0.75 mile; No detector
Miami: 1.5 miles; 2 detectors in between