Technical Memorandum No. 2

Innovative Traffic Data Collection: Results of Field Test – Final Report

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Glossary

Latency - Latency is a direct measure of the "freshness" of travel time data. For example, if a segment of road being monitored for the purpose of collecting vehicular travel times is 10 miles long, then by the time an individual vehicle's travel time for that segment can be calculated (by comparing the time at which it passed sensor 1, against the time at which it passed sensor 2), conditions may have changed somewhere along the segment and the travel time information may be incorrect. In contrast, if the road segment is only one mile long, then there is a much smaller delay between the time the vehicle being monitored passes sensor 1 and the time it passes sensor 2. Consequently, the travel time data for that segment will be "fresher," and is more likely to be accurate than that collected for a longer segment

Leakage - Condition where vehicles are read by one probe sensor, but missed by the other, either because they have diverged from the roadway, or changed their lane of travel such that they cannot be detected by the second reader.

Matched Link Data – Travel time data stemming from a single transponder-enabled vehicle passing between a pair of Portable Roadside Transponder Readers (PRRs) deployed along a given segment.

Penetration – Total number of transponder reads as a percentage of total traffic volume at a given location during a set period of time.

Portable Roadside Transponder Reader (PRR) - Trailer-mounted transponder readers/antennas capable of being deployed to support transponder-oriented data collection at locations where no permanent transponder infrastructure exists.

Segment – Roadway between each pair of PRRs.

Telemetered Traffic Monitoring Site (TTMS) – Traffic monitoring sites operated by the Florida Department of Transportation's Statistics Office which collect detailed information, including traffic counts, vehicle classification, speed, and weight. Data from these TTMS sites is collected continuously and downloaded nightly via modem to the Transportation Statistics Office in Tallahassee.

1. INTRODUCTION

The Florida Intrastate Highway System (FIHS) is the most important strategic road system in the state. Carrying nearly one-third of the state's vehicular traffic on just three percent of its road mileage, the roughly 3,792-miles of limited-access roads, controlled access roads, and major arterials are the backbone of Florida transportation. As the Florida Department of Transportation (FDOT) moves to enhance its ability to manage and operate the FIHS, the need for accurate, timely, and reliable real-time traffic sensor data increases.

Between 1990 and 1999, the FIHS experienced a 40 percent increase in peak period congestion. Moreover, it is projected that by the year 2020, the FIHS will require the capacity to accommodate over 21 million residents and 80 million visitors per year. Vehicle Miles Traveled (VMT) by personal automobile and commercial vehicles are expected to increase by approximately 60 percent, while mileage associated with transit trips is projected to rise by another 40 percent. Due to this unprecedented demand for access to the FIHS, traditional infrastructure management programs focusing on roadway expansion will be insufficient to keep congestion within tolerable levels. As a result, in addition to roadway expansion programs, FDOT will be forced to pursue alternative techniques for managing and operating its roadway infrastructure. Included in these alternative techniques are:

- Advanced Traveler Information Systems (ATIS), to better inform the driving public of changing roadway, weather, and traffic conditions;
- Advanced Traffic Management Systems (ATMS), to ensure coordinated operations and active facilities management during peak periods of demand, and to support evacuation coordination during emergencies; and
- Archived Data Services (ADS), to support operations, performance evaluation, and transportation planning.

Although available traffic-monitoring methods and systems have the capacity to provide much of the data necessary to support the Florida Department of Transportation's (FDOT) traffic management and traveler information needs, gaps persist with regard to geographic coverage, accuracy, and dependability. Based on what has been learned regarding probe-oriented traffic data collection solutions, it is widely believed that significant opportunities may exist for these technologies to cost effectively complement, and in some cases replace, traditional traffic data collection resources.

This paper reports on research carried out on behalf of, and field-testing currently being conducted by the Florida Department of Transportation concerning the potential for utilizing in-vehicle transponders as the foundation for a probe-oriented data collection system to enhance the accuracy, timeliness, and reliability of real-time traffic data. For additional information concerning research carried out on the use of innovative traffic data collection technologies, see "Technical Memorandum No. 1 - Innovative Traffic Data Collection: An Analysis of Potential Uses in Florida," downloadable at: http://www.floridaits.com/PDFs/TM1_Innovative_Data_Collection_Analysis_V1.pdf

2. TRANSPONDER-BASED DATA COLLECTION FIELD TEST

2.1. SYNOPSIS OF FIELD TEST

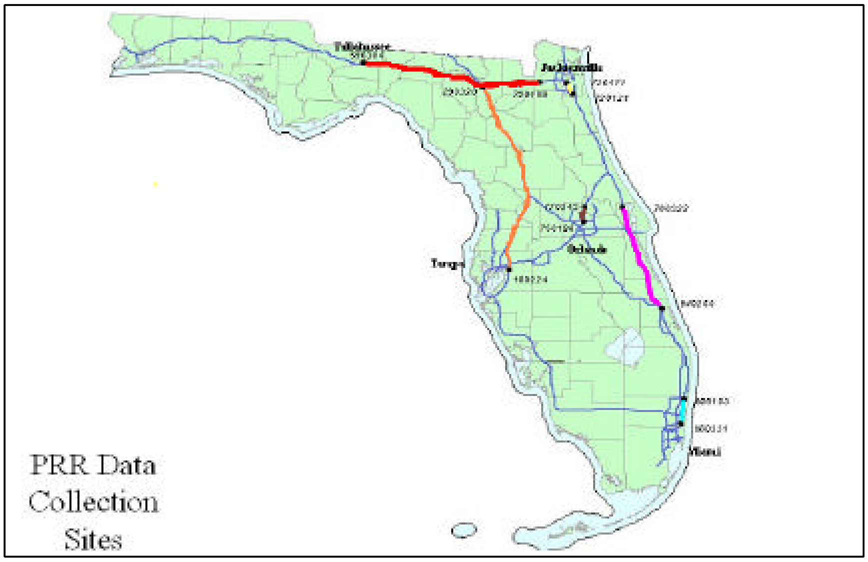
The purpose of this field test was to assess the penetration of transponders along non-tolled roads around the state in order to determine whether sufficient numbers of transponder-enabled vehicles were present to enable travel time data collection. To this end, FDOT ITS Office staff identified three urban and three rural corridors as desired locations for data collection:

Urban

- I-95 in Southeast Florida
- I-4 in the Orlando area
- I-95 in Jacksonville

Rural

- I-10
- I-75
- I-95



PRR Data Collection Sites

These corridors were selected based on a qualitative sampling plan, developed in conjunction with FDOT staff, aimed at balancing test-related efforts with existing resources. For each of these corridors, two Portable Roadside Transponder Readers (PRRs), owned and maintained by the Florida Turnpike, were deployed to gather transponder data along one direction of travel. PRRs are trailer-mounted transponder readers/antennas capable of being deployed to support transponder-oriented data collection at locations where no permanent data collection infrastructure currently exists. The roadway between each set of two PRRs is referred to in this report as a “segment.” For purposes of this study, a “matched link” is defined as travel time data stemming from a single transponder-enabled vehicle passing between both PRRs deployed along a given segment. Each PRR was deployed on a Monday evening, with data collection commencing on Tuesday morning at 6am and running continuously until Thursday afternoon/evening. This schedule was intended to provide of an average of approximately 60 hours of data for each PRR. For additional information on the function and operation of the PRRs, see Appendix B.

To maximize the benefits of field data collection, the PRRs were co-located with Telemetry Traffic Monitoring Sites (TTMS). The TTMS sites were utilized as a resource to provide the volume data necessary to determine vehicle penetration rates (for each site at which a PRR was deployed, penetration rate = transponder reads as a percentage of total volume). Data was collected in one direction of travel along each segment for three consecutive days, Tuesday through Thursday (consistent with standard data collection practices of the FDOT Statistics Office).

On each day of PRR operation, field staff conducted a minimum of one trip over the segment in a transponder-equipped “control” vehicle to enable the PRRs along that segment to record the vehicle’s presence. Field staff manually logged the time at which their “control” vehicle passed each PRR. This data was subsequently used to determine how well travel times calculated for the “control” vehicle based on transponder reads provided by the PRRs compared with actual travel times for the vehicle as recorded by field staff.

Overall, the primary goals of this field test were to determine:

- Current transponder penetrations along various non-tolled roadways across Florida; specifically, roadways where penetration might be sufficient to support travel time data collection
- Rules of thumb for reader spacing and determination of optimal link size:
  Smaller segments result in an increased number of matched links (reduced leakage), and reduced latency of data, but lead to increased costs.

Basic test data that we sought to collect included:

- Percentage of transponder-enabled vehicles identified vs. total volume along a segment
- Average number of matched links identified per minute along a segment
- Percentage of matched links composed of outliers (for the purpose of this report, an outlier should be considered to be a matched link resulting from a transponder-enabled vehicle passing one PRR and then diverging from the roadway being evaluated, returning to that roadway later in the day and passing the second PRR, thereby resulting in an extraordinarily high travel time for that vehicle between the two PRRs).
- Accuracy of travel time provided by system vs. actual travel time of control vehicle
- Travel time along segment(s) – Travel time of transponder enabled vehicles passing between both readers (All travel time data collected as part of this test was based on the movement of individual vehicles along the corridors involved during the various test periods. No average travel time data was recorded as part of this field test.).

Table 1 (below) provides more detailed information about the sites at which PRRs were deployed, the number of lanes of traffic at each site, the length of the segment created between each pair of PRRs, and the percentage of hours that each PRR was in operation/overlap of operation at each pair of sites. The column “Percentage of Hours in Operation,” indicates the amount of time (as a percentage of the total data collection period) during which a given PRR was collecting and storing data. “Overlap of Operation at 2 sites,” indicates the amount of time during which both PRRs along a given segment were in operation, and consequently the total number of hours during which matched link data could have been collected by that pair of readers.

Table 1 - PRR Deployment Sites and Data Collection Profile

Week of Test	PRR Location	Number of Lanes	Approximate Length of Segment	Percentage of hours in Operation	Overlap of Operation at 2 sites
April 15	I-4 (L. Mary)	3	12.6 miles	68%	~ 12 hours
April 15	I-4 (ORL)	4		42%	
April 22	I-95 (No.of (Ft.Lauderdale)	3	21.5 miles	94%	~ 51 hours
April 22	I-95 (Ft.Lauderdale)	5		73%	
April 29	I-95 (Brevard)	2	97 miles	97%	~ 61 hours
April 29	I-95 (St. Lucie)	3		98.5%	
May 6	I-75 (L. City)	3	175 miles	96%	~ 59 hours
May 6	I-75 (Tampa)	3		93%	
May 13	I-10 (Tallahassee)	2	143 miles	98%	~ 42 hours
May 13	I-10 (Jacksonville)	2		97%	
May 20	I-95 (Jax.)	3	N/A	98%	N/A
May 20	I-295 (Jax.)	2		98%	

Note: Testing during the week of May 20th was conducted on 2 different roads in the Jacksonville area, due to the fact that 2 TTMS sites along I-95 (necessary for collecting volume data) were not available. Consequently, data from this portion of the test was analyzed only to determine transponder volumes/penetration within the traffic stream.

2.1.1. TEST LIMITATIONS

Due to the nature of the transponder technology involved, the PRRs reliably read only those transponders in the two lanes closest to the spot at which each reader was deployed, and lack the ability to identify transponder-enabled vehicles according to their lane of travel (as a result, all data analysis is based on aggregate data for the right-most two lanes along each corridor). Additionally, visual observations by field staff indicate that although intermittent transponder reads did occur in the 3rd lane just outside the readers' effective range, the PRRs tended to miss transponders passing through the two lanes closest to them more often than they read those in that 3rd lane. As a result of these limiting factors, it is highly likely that the data collection system created for this test significantly underestimated the actual number of matched links that occurred along each corridor studied. Based on the application of simple probabilistic theory, it is estimated that the number of matched links recorded along each corridor during the various test periods was actually only a percentage of the total number of matched links created during those period (with the overall impact varying according to the number of lanes of travel at each data collection site). The impact of this hypothesis is as follows:

- I-4 – 33% of actual matched links represented by test data
- I-95 (Urban) – 27% of actual matched links represented by test data
- I-95 (Rural) – 66% of actual matched links represented by test data
- I-75 – 44% of actual matched links represented by test data
- I-10 – 100% of actual matched links represented by test data

Long segment lengths resulted in high percentages of outliers (25-30% on average).

2.2. FINAL RESULTS OF FIELD TEST

Table 2 outlines the results of FDOT's data collection field test. As the table indicates, significant penetrations of transponders were detected in Orlando along I-4, in and around Ft. Lauderdale along I-95, and in the Tampa area along I-75. For examples of how matched link data can be utilized to display changes in travel time along a single roadway over the course of a day, see Appendix A.

Table 2 - Field Test Results

Week of Test	PRR Location	Average Tag Reads/Hour	Average Traffic Vol./Hour	Average Penetration	Avg. Matched Links/Min
April 15	I-4 (L. Mary)	280	1706	16.4%	Approx. 1
April 15	I-4 (ORL)	472	2342	20.1%	
April 22	I-95 (No. of Ft. Lauderdale)	135	1444	9.5%	Approx. .23
April 22	I-95 (Ft. Lauderdale)	83	841	9.9%	
April 29	I-95 (Brevard)	37	546	6.5%	Approx. .07
April 29	I-95 (St. Lucie)	49	650	7.9%	
May 6	I-75 (L.City)	28	635	4.47%	Approx. .029
May 6	I-75 (Tampa)	59	640	9.3%	
May 13	I-10 (Tallahassee)	14	1151	.012%	Approx. .03
May 13	I-10 (Jacksonville)	11	956	.015%	
May 20	I-95 (Jax.)	21	1648	0.12%	N/A
May 20	I-295 (Jax.)	11	1389	.0079%	

2.2.1. DATA ACCURACY VERIFICATION

As mentioned in Section 2.1, field staff made daily trips along each segment, manually logging the time at which they passed each PRR. Doing so allowed for a comparative assessment of the travel time for their vehicle between the two PRRs against that calculated using data downloaded from the PRRs themselves. Results of this analysis indicate that the overall accuracy of PRR travel time calculations across the test was within an average of 1% of the actual travel times of transponder-enabled vehicles driven by field staff.

Table 3 – Difference Between Travel Times for Control Vehicle Calculated Using PRR-Data and Travel Time Manually Recorded by Field Staff

Segment	Length	Travel Time Difference
I-4 (Orlando)	12.6 miles	0.67%
I-95 (Ft. Lauderdale)	21.5 miles	0.446%
I-95 (Rural)	97 miles	0.67%
I-75 (Tampa/L. City)	175 miles	0.46%
I-10 (Tallahassee/Jacksonville)	143 miles	2.10%*
I-95 (Jacksonville)	---	---

*The difference in travel time of 2.1% is due to human error associated with recording of the time at which the control vehicle passed the PRRs located along I-10.

2.2.2. FIELD TEST - CONCLUSIONS

Based on information collected during this field test, the following lessons have been learned about the collection of transponder-based travel time data on non-tolled FIHS roads:

- Adequate penetrations along I-4 (Orlando) and I-95 (Broward County) indicate that suitable penetrations likely also exist in Miami and potentially Palm Beach (areas that are also close to networks of toll roads)
- Placing toll transponder readers too far apart results in latency and other data quality issues (e.g. increased numbers of outliers).
- It is likely that a full system deployment would require 100% lane coverage in order to ensure that a sufficient number of matched links are available for analysis. Failure to provide 100% lane coverage results in an unacceptable leakage of matched links between lanes.

As a consequence of the above, final conclusions of this field test suggest that:

1. If FDOT desires a statewide, travel time data collection system on the FIHS, multiple technologies will likely need to be used, e.g.:
   a. Transponders from the I-4 Corridor south (areas with higher transponder penetrations)
   b. License plate readers north of the I-4 corridor (areas with low transponder penetrations)
   c. Potentially utilize Pre-Pass transponders on trucks traveling along Commercial Vehicle corridors to collect supplemental travel time data.

2. More cost/performance data is needed to make more educated decisions concerning:
   a. Locations where transponder penetrations are sufficient for travel time data collection
   b. Rules of thumb for reader spacing/determination of optimal link size

2.3. NEXT STEPS

As stated in **FIELD TEST - CONCLUSIONS**, results of the initial transponder-based data collection field test indicate that although several viable options likely exist for assessing travel times along the FIHS, not all are appropriate to conditions in different portions of the state. As a result, multiple program delivery options will likely be needed for data collection in different areas. To move beyond the research stage, it will be necessary to develop a Concept Plan for the development and use of travel time data collection systems in Florida.

This Plan will:

- Establish a vision and purpose for travel time data collection, including how it will support operations, planning and traveler information applications;
- Determine the facilities for which travel time data will be collected, the density of coverage and the required quality parameters of the data;
- For each facility, utilize existing corridor plans developed by FDOT to assist in the selection of the technology or technologies to be used to collect travel time data along the corridors

involved. Determine the method of communication to be used to get data to the appropriate location(s) for real-time aggregation and analysis. Technology selection will be based upon the extent to which it supports the corridor concept, cost-effectiveness and implementation risk analysis; and,

- Contain a project architecture and concept of operations to ensure proper computing, storing, sharing and usage of data collected; Identify modifications to regional architecture/systems necessary to incorporate travel time data into local operations as desired.

To support development of a well-founded concept plan, additional research activities have been identified. These activities include:

1. Portable Roadside Transponder Readers (PRR) Follow-up tests – A second round of transponder volume tests is needed to obtain better resolution on transponder penetrations in certain areas. Candidates include the Tampa Bay, Miami-Dade, Palm Beach and SW Florida areas. Also, additional tests are needed to further refine FDOT's understanding of spacing issues related to the distance between readers and its impact on data latency and overall quality.

2. Use of Other Transponder Types for Travel Times in Florida – Over 200,000 commercial vehicles utilize HELP/Pre-Pass transponders for electronic clearance throughout the U.S., including in Florida. Over 7 million vehicles are equipped with EZ-Pass electronic toll collection transponders. With a vendor indicating willingness to provide at no cost a portable reader that can read both Pre-Pass and EZ-Pass transponders, a low-cost test will be conducted on I-75 and I-95 near the Georgia border (and possibly I-10 at the Alabama border) to determine the volume of vehicles that enter the state equipped with either or both of these transponders. Also, initial explorations will continue with HELP to determine whether current transaction volumes at various locations in Florida could support travel time data collection and, if so, can agreements be reached with HELP to enable this application.

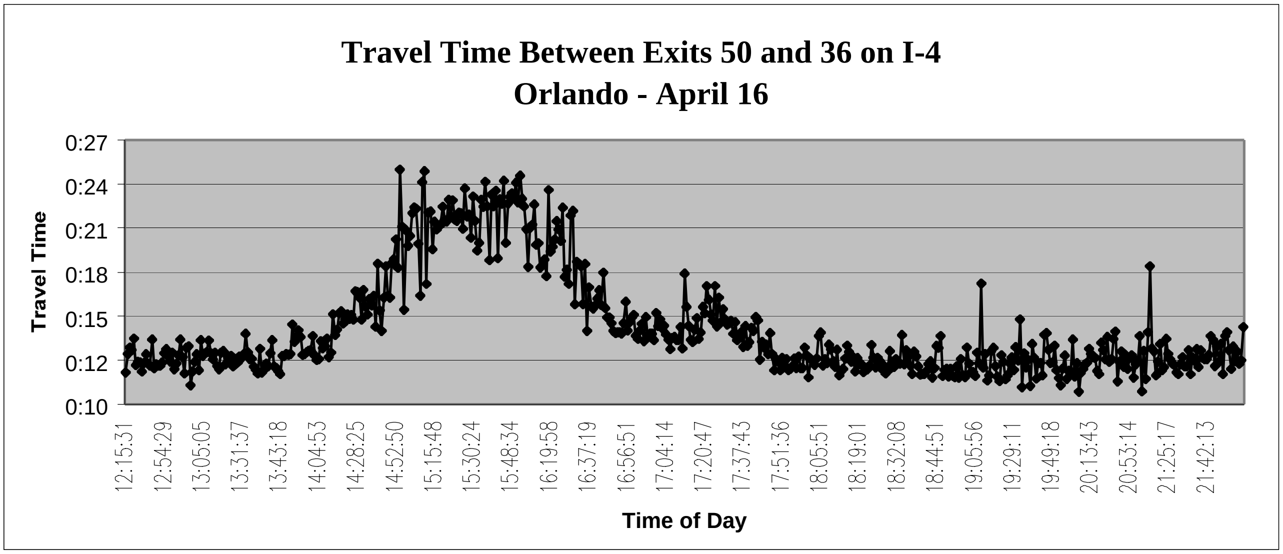
3. License Plate Reader (LPR) test bed(s) in the Jacksonville and Tallahassee areas – License plate readers (which offer data similar to that collected via the tracking of transponders, but without the need for toll tags) offer noteworthy promise for collecting travel time data, especially in areas with low penetrations of transponders. Consequently, LPR test bed(s) will be established along the I-95/I-10 corridors to assess the viability of this technology under Florida specific conditions. Aside from overall viability of the technology and refinement of reader spacing issues, this test will also seek to determine whether coverage of a single lane at each data collection point will yield accurate data. At present, LPR technology is utilized to support a range of applications, including: intersection control, traveler information systems, HOV lane enforcement, commercial vehicle weigh-in-motion (WIM) violation enforcement, border crossing security, parking access control, railroad crossing management, and work zone speed violation enforcement. Consequently, a number of proprietary license plate reader technologies are available from an assortment of vendors. As a result of this set of circumstances, specific functional requirements will need to be developed in order for FDOT to make the most appropriate technology/vendor selection to support this test.

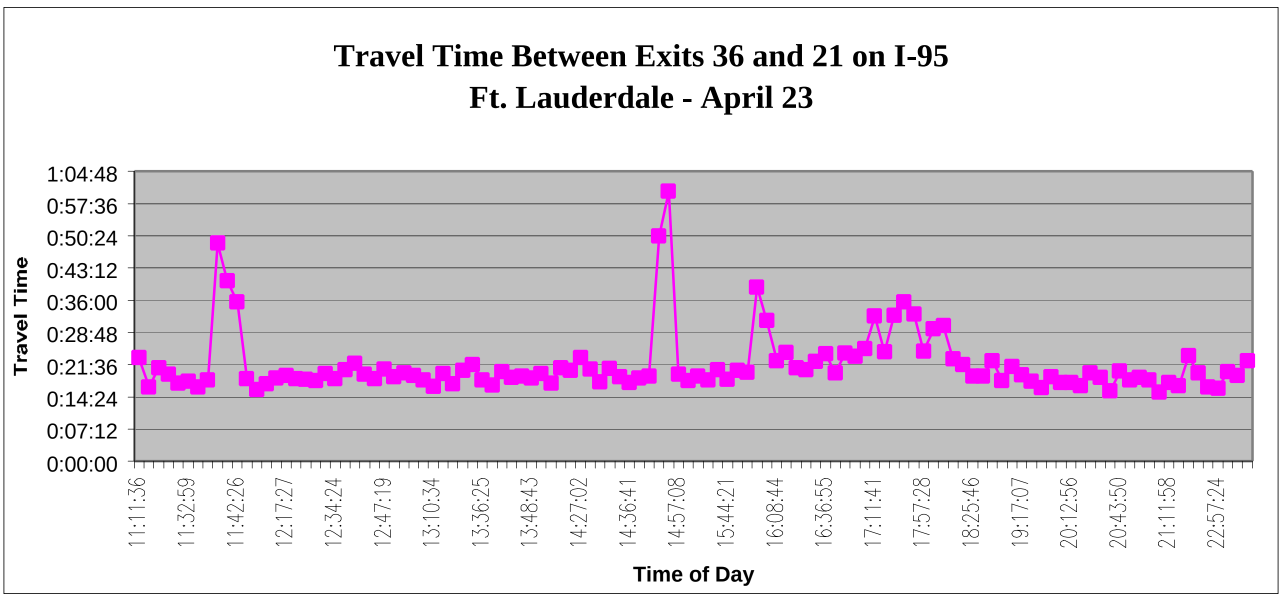
4. Pilot Implementation – FDOT will develop a pilot implementation project using either transponder readers or licenses plate readers. This pilot will seek to demonstrate the value of travel time data to travelers by providing travel time information for alternative routes near appropriate interchanges. Examples of alternative routes might include:

    - I-4 and SR 417 for traffic in the Orlando area
    - I-95 and Florida's Turnpike for intercity trips in the SE portion of the state

This test will calculate trip times on each road, communicating this information to travelers via DMS and/or HAR, thereby enabling travelers to make more informed route decisions.

APPENDIX A - EXAMPLES OF TRAVEL TIME* GRAPHS DEVELOPED USING TRANSPONDER DATA





*The above graphs depict travel time along the involved segment for each vehicle (excluding outliers) that traveled along that segment during the test period. No average travel times were recorded as part of this field test.

APPENDIX B – FUNCTION AND OPERATION OF THE PORTABLE ROADSIDE TRANSPONDER READERS

System Overview

The FDOT Portable Roadside Transponder Reader (PRR) is a transportable unit of automatic vehicle identification (AVI) electronics and support equipment designed to operate in the specified geographical environment of the SunPass project.

The PRR provides transponder traffic data on a given section of roadway. It is capable of identifying, time/date stamping, and storing a data record for each SunPass (or compatible - e.g., E-Pass) transponder, Type II, or Type III, as vehicles equipped with such transponders travel through a specific section of roadway. The PRR equipment supports the following applications:

- Measuring the volume of vehicles equipped with transponders on a specified roadway location over a period of time.
- Generating statistics for speed analysis, incident detection, origin destination studies, and other traffic management applications using the information gathered from a combination of one or more units at different locations.

The PRRs are complete, self-contained systems comprised of both hardware and software components. These components are mounted on an industrial strength trailer. The design of the trailer enables the PRR to be deployed at remote sites. After a PRR is deployed, its primary function is to obtain transponder information by reading each tag as it travels past the PRR.

The PRRs are designed to be deployed from the side of the roadway, or from the median, with the unit's antenna pointed toward the section of roadway from which the traffic information is desired. It is designed around a highway-ready trailer for ease of relocation. Deployment is a simple matter of towing the equipped trailer to a desired location, parking a safe distance off either side of the road, and setting up the equipment.

Operation of PRRs and Data Collection Process

For information concerning the set-up and usage of the PRRs, please refer to the "Portable Roadside Reader User Guide," (published by TransCore) available from Florida's Turnpike Enterprise.

To obtain a copy of the user's manual, please contact:
Name: Jennifer Farmer (Turnpike Operations)
Phone: (954) 975-4855 x. 1295
E-mail: jennifer.farmer@dot.state.fl.us

Illustration of a PRR with Antenna Deployed