Truck GPS Data for Freight Planning

presented to
Florida Model Task Force, Orlando

presented by
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Acknowledgements

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  - Frank Tabatabaee

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  - Jeff Short
  - Dave Pierce
  - Lisa Park
  - Dan Murray

- Graduate Students from University of South Florida
  - Aayush Thakur
  - Anissa Nur Irmania & Jonathan Koons
Background

- Significant growth in freight movement calls for improved freight planning and decision processes
- Major challenge: Inadequate data!
- Recent efforts to exploit technology for data collection
  - GPS-based automatic vehicle monitoring and location (AVM) & AVL) data

The ATRI-FPM Initiative

- Joint venture by ATRI and FHWA
- A national system for monitoring freight performance measures on key corridors
- Based on satellite data from trucking companies who use GPS technologies to monitor their fleet
Project Objectives

- Investigate the use of ATRI-FPM data for freight performance measurement and planning in Florida

- Develop methods for the following applications with the data
  
  1. Derive freight performance measures for Florida’s highways
  2. Derive a truck-trip database (from ATRI-FPM data) to understand the characteristics of truck travel in Florida
  3. Derive truck trip OD tables for the Florida Statewide Model
Freight Performance Measurement with ATRI-FPM GPS data

Contributors
Jeff Short, ATRI
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Lisa Park, ATRI

Speeds
Reliability measures
Congestion Measures
APPLICATIONS OF ATRI'S DATA FOR THE STATE OF FLORIDA

- Average Highway Speeds
- Reliability Measurements
- Analysis of Chokepoints
- Measures of Corridor Demand and Freight Activity Intensity
- Truck Flow Analysis
- Origin and Destination Estimates
- Other Analysis
Application One: Average Highway Speeds

- Data are processed through a series of software programs to generate measures.
- Those measures are plotted along a corridor map in a GIS environment.
- Data can be analyzed both in terms of space mean speed and spot mean speed.
Application One: Average Highway Speeds

Sample Study Area, I-95 Miles 24-48.
## Application One: Average Highway Speeds

### INTERSTATE 95 - FORT LAUDERDALE

**April - June 2010**

<table>
<thead>
<tr>
<th>SOUTHBOUND</th>
<th>Northbound</th>
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### Average Speeds by Hour, I-95 Miles 24-48
Application Two: Reliability Measures

For both space and spot mean speed calculations, relevant reliability measures include the Travel Time Index (TTI) and Planning Time Index (PTI).

TTI is the ratio of the average speed for a given highway segment at a particular time of day to the functional free flow speed of the same segment of highway.

PTI is the ratio of the “worst-case scenario” average travel speed for a given highway segment at a particular time of day to the functional free flow speed of the same segment of highway.
Application Two: Reliability Measures

Location of Study Corridors
### Application Two: Reliability Measures

**Travel Time Index and Planning Time Index for Eight Miami Corridors**

<table>
<thead>
<tr>
<th>Polyline</th>
<th>Freeway Section (sorted from most congested to least congested)</th>
<th>Length (mi)</th>
<th>Morning Peak (6a-9a)</th>
<th>Midday (9a-4p)</th>
<th>Evening Peak (4p-7p)</th>
<th>Average Peak Period</th>
<th>Morning Peak (6a-9a)</th>
<th>Midday (9a-4p)</th>
<th>Evening Peak (4p-7p)</th>
<th>Average Peak Period</th>
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<td>1</td>
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<td>12.2</td>
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<td>1.64</td>
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<td>1.18</td>
<td>1.39</td>
<td>1.27</td>
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<td>I-75 NB: SR 821 to I-595</td>
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<td>1.15</td>
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<td>5.96</td>
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<td>3.42</td>
<td>2.28</td>
<td>3.64</td>
<td>3.46</td>
</tr>
</tbody>
</table>
Application Three: Analysis of Chokepoints

- Analysis of chokepoints can offer a better understanding of when, where and possibly why, congestion is occurring.

- Study areas are often no more than 4 miles across, and are assessed in one hour increments.

- Further analysis would provide quantification of which segments or directions of an interchange have the worst congestion.
Application Three: Analysis of Chokepoints

2009 Bottleneck Analysis of 100 Freight Significant Highway Locations

Tampa, FL: I-4 at I-275

Bottleneck Summary
The bottleneck location is shown in Figure 1. The speed profile is shown in Figure 2.

- Average Speed: 45
- Peak Average Speed: 36
- Nonpeak Average Speed: 50
- Nonpeak/Peak Speed Ratio: 1.37
- Congestion Index: 260,041
- Ranking (out of 100): 49

Figure 1: Location Map

Average Speed by Time of Day
I-4 at I-275

Figure 2: Speed Profile

Bottleneck Analysis for I-4 at I-275 in Tampa from 2009 FHWA/ATRI Bottleneck Report
Application Four: Measures of Corridor Demand and Freight Activity Intensity

- Relative volume relationships between corridors.

- Freight Intensity Index: derived by dividing the number of position reads by the length of the segment.

- Data is indexed with the highest freight intensity receiving a value of 100.

- The FPM data can also be used to explore regional freight activities by determining the number of truck position data points contained within each county and dividing that figure by the length of the roadway segments in the county.
Application Four: Measures of Corridor Demand and Freight Activity Intensity

Freight Intensity Index for Florida, April-June 2010
Application Four: Measures of Corridor Demand and Freight Activity Intensity

Freight Intensity Analysis by County
Application Five: Truck Flow Analysis

- Identify freight movement trends between geographic areas
- Insight into what routes are taken between two locations

Sample of more than 1,000 trucks that originated in, or were traveling through, Miami on a given day; the traced paths after 7 days of truck movement are shown in red, as well as the percentage of the truck population that entered each state.
1,000 Trucks After 24 Hours
Same 1,000 Trucks After 48 Hours
Same 1,000 Trucks After 5 Days
Same 1,000 Trucks After 7 Days
Same 1,000 Trucks After 7 Days
Focus of Performance Measurement on Florida’s Strategic Intermodal System (SIS)
PM Peak Period Speeds on Florida’s SIS Highways
PM Peak Period Speeds on Florida’s SIS Highways
PM Peak Period Speeds on Florida’s SIS Highways
PM Peak Period Speeds on Florida’s SIS Highways
PM Peak Period Speeds on Florida’s SIS Highways
Bottleneck Analysis

![Graph showing Average Speed by Time of Day](image)

<table>
<thead>
<tr>
<th>Nonpeak/Peak Ratio</th>
<th>Nonpeak Average Speed</th>
<th>Peak Average Speed</th>
<th>Average Speed</th>
<th>National Ranking by Congestion Index</th>
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<tbody>
<tr>
<td>1.37</td>
<td>52</td>
<td>38</td>
<td>47</td>
<td>93</td>
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</tbody>
</table>
In-state truck routes in the data

Florida I-75 Freight Route Choice Illustration
In-state routes

- 4000 unique trucks that were on I-75 during a 1 week period (Oct 24-30)

**Florida I-75 Freight Route Choice**
Close-up of route patterns in Gainesville / Ocala region

Florida I-75 Freight Route Choice
1333 of the 4000 trucks crossed I-75 here

Florida I-75 Freight Route Choice
Of the 1333 trucks that crossed I-75 here, 949 took this route, 308 took this route, and 38 took this route.
Project Objectives

Investigate the use of ATRI-FPM data for freight measurement and planning in Florida

- Derive freight performance measures for Florida’s highways
- Derive a truck-trip database from ATRI-FPM data
  - Convert GPS data streams to truck trips, and analyze truck travel characteristics in Florida
  - Billions of GPS data points!
  - Needed to simplify the problem (Seasonality of truck flows)
- Derive truck trip OD tables for the Florida Statewide Freight model
Seasonality in the Florida Truck Count Data

Vehicle Count Station Locations in Florida

- Count Stations
- SIS Highway Network
Truck Counts by Month of the Year

Truck Flows in Florida (Counts for all Trucks) by Month

- Mean
- 95th Percentile
- 75th Percentile
- Median
- 25th Percentile
- 5th Percentile
Truck Counts by Month of the Year

Florida Truck Flows (Counts for Single Unit Trucks) by Month

Florida Truck Flows (Counts for Tractor-Trailers) by Month
Truck Counts by Day of Week

Florida Truck Flows (Counts for all Trucks) by Day of Week
Truck Counts by Day of Week

Florida Truck Flows (Counts for Single Unit Trucks) by Day of Week

Florida Truck Flows (Counts for Tractor-Trailers) by Day of Week

44
Conversion of GPS Data Streams to Truck Trips

- Seasonality analysis of the truck count data suggests
  - Seasonal variation not significant
  - Weekday vs. weekend differences

- Experience with one week of GPS data
  - Take all trucks that were in Florida at any time during 1 week
  - Start with GPS traces of those trucks within Florida (1.5 Million traces)
  - Then trace those trucks outside Florida as well (4.35 Million traces)
  - Initial results in next slides

- Next step: Derive trips from multiple weeks of data (2-3 months)
Examples of truck movements in the data

Legend
- Truck 1
- Truck 2
- Truck 3
- Florida Statewide Model TAZs
Distance vs. Time between Consecutive GPS Points: 1 Week GPS Data within and Outside Florida

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<tr>
<th>Distance between 2 consecutive points (in miles)</th>
<th>0 - 0.1</th>
<th>0.1 - 1</th>
<th>1 - 3</th>
<th>3 - 5</th>
<th>5 - 10</th>
<th>10 - 15</th>
<th>15 - 20</th>
<th>20 - 30</th>
<th>30-70</th>
<th>70-150</th>
<th>150-400</th>
<th>&gt; 400</th>
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<th>Cum%</th>
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<td>78.30%</td>
<td>91.57%</td>
<td>95.88%</td>
<td>99.50%</td>
<td>99.87%</td>
<td>99.97%</td>
<td>99.97%</td>
<td>99.99%</td>
<td>100.00%</td>
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</table>
Trips Extracted from 1 Week Data within Florida: Trip Length Distribution

-length distribution chart with a histogram showing the percentage of total trips against the length of the trip in miles. The chart includes a box plot with the 5th, 25th, 75th, and 95th percentiles. The mean is 29.83 miles, the standard deviation is 38.214, and the total number of trips (N) is 52,526.
Trips Extracted from 1 Week Data within Florida:
Trip Duration Distribution

Mean = 75.16
Std. Dev. = 79.93
N = 52,526
Trips Extracted from 1 Week Data within & Outside FL: Trip Length Distribution

Mean = 57.6
Std. Dev. = 75.408
N = 137,376
Trips Extracted from 1 Week Data within & Outside FL: Trip Duration Distribution

Mean = 112.86
Std. Dev. = 119.661
N = 137,378
Scatter Plots – Trip length vs. Trip duration

For 1-week dataset within Florida (52526 trips)
Speeds range from 5mph to 65mph

For 1-week dataset within & outside Florida (137378 trips)
Speeds range from 5mph to 70mph
Conversion of GPS Data Streams to Truck Trips

Next steps on deriving a truck trip database

- Validate and refine the algorithm
- Overlay the trips onto land-use GIS layers to refine trips data
- Derive trips from multiple weeks of data (2-3 months)
Project Objectives

Investigate the use of ATRI-FPM data for freight measurement and planning in Florida

• Derive freight performance measures for FL highways
• Derive a truck-trip database from ATRI-FPM GPS data
• Derive truck trip OD tables for the Florida Statewide Freight model
  • The trips derived from the GPS data is a sample (large sample)
  • Need a way to arrive at the population of truck flows
  • Exploring the use of different data sources and methods
    • The 100% truck count data, and OD estimation methods
    • Linking truck flows with commodity flows (e.g., Transearch)
    • Parcel/TAZ-level industry employment data
Thank You

Questions/Discussion
### Additional Slides (for Q&A)

<table>
<thead>
<tr>
<th>Task</th>
<th>Schedule</th>
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<tbody>
<tr>
<td>1. Review ATRI’s truck GPS (i.e., ATRI-FPM data) &amp; applications</td>
<td>May 2011 – Aug 2011</td>
</tr>
<tr>
<td>2. Review other data sources that ATRI-FPM data can supplement,</td>
<td>July 2011 – Oct 2011</td>
</tr>
<tr>
<td>and how ATRI-FPM data can be combined w/ other data sources.</td>
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<tr>
<td>4. Derive a truck trip database from ATRI’s truck GPS data</td>
<td>Nov 2011 – April 2012</td>
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<td>5. Analyze truck trip database to understand truck travel in FL</td>
<td>April 2012 – June 2012</td>
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<td>6. Investigate ways to relate commodity flows with truck flows</td>
<td>June 2012 – Oct 2012</td>
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<td>7. Derive a truck trip OD table for a reasonable level of geography</td>
<td>Sept 2012 – Dec 2012</td>
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<tr>
<td>8 and 9. Final research report, review by FDOT, and revisions</td>
<td>Dec 2012 – April 2013</td>
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Task 1: Review ATRI’s data and Applications (Complete)

- Review ATRI’s truck GPS data and applications
  - Materials describing the data
  - Review of the data in Florida
  - Synthesis of the data applications

- Meeting between USF, ATRI, and FDOT
  - Identify subsets of data for further applications
  - Identify the geographical/network/temporal scope for applications

- Other Administrative
  - Kick-off meeting
  - mechanism to transfer large datasets between ATRI & USF
  - Non-disclosure agreement between ATRI and USF
Task 2: Review other freight data sources that can be used in conjunction with ATRI’s truck GPS data (Complete)

• Data reviewed
  − Commodity flow data (e.g., Transearch, FAF)
  − Traffic counts, ITS data, local survey data

• Literature reviewed
  − Work with Freight GPS data
  − NCHRP/NCFRP reports
  − Freight-exclusive conference proceedings
  − Work within Florida (e.g., disaggregation of FAF)
Task 3: Derive Freight Performance Measures for the highway network in Florida (ongoing, ATRI is the lead)

- Performance measures
  - Speeds
  - Reliability measures
  - Congestion measures

- Geographical, network, and Temporal scope
  - Florida’s SIS network
  - Peak travel months
  - Different time periods of the day
Task 4: Derive a truck trip database from the ATRI-FPM data
(ongoing, USF is the lead)

- GPS data streams are being converted into “trips”
  - Identify trip end locations, determine non-congestion stops, stops at signals
  - Trip start and end times, trip distance, speed, dwell time

- Will result in the following:
  - Algorithms to convert the GPS data streams to truck trips
  - A truck trip database for Florida

Task 5: Analyze the truck trip database

- Analyze the truck trip travel characteristics such as trip distances, trip travel times, speeds, time of day, dwell time, etc.

- Compare the above characteristics to those from available truck trip data (e.g., survey data)
Task 6: Investigate methods to relate commodity flows with truck flows

- Develop relationships between commodity flows and truck flows at an aggregate-level for which both commodity flow and truck flow data is available
- The above relationships can be used to derive truck flows at a disaggregate level (using commodity flows at disaggregate level)
- Other methods being reviewed as well

Task 7: Derive a 2010 year truck trip OD table for the Florida Statewide model

Tasks 8 and 9: Final report, and revisions.
Deliverables

- Kick-off meeting
- Quarterly progress reports
- Technical Memorandum-1 (Review of the applications of ATRI data)
- Freight performance measures for FL
- Truck trip database for Florida
- Truck flow OD table for Florida
- Final research report
- Project closure meeting
# Project Schedule

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| Overall % Complete Projected | 20% | 40% | 11% | 17% | 23% | 28% | 36% | 29% | 42% | 66% | 59% | 55% | 58% | 62% | 69% | 71% | 77% | 82% | 87% | 92% | 99% | 100% |
| Overall % Complete Actual | | | | | | | | | | | | | | | | | | | | |
1. Trip length (tl) – Total spatial distance traveled by the truck between origin and destination
2. Trip time (tpt) – Total time taken to travel from origin to destination
3. Trip speed (tps) – Average speed of truck during the trip (tl/tpt)
4. Travel distance (td) – Spatial distance between two geographic (GPS) location records
5. Travel time (trt) – Time difference between two geographic (GPS) location records
6. Travel speed (tdw) – Average speed of truck between two GPS records (td/trt)
7. Origin dwell time (odwt) – Total time duration of stop at origin i.e. when the truck is not moving
8. Destination dwell time (sdwt) – Total time duration of stop at destination
9. Stop dwell time (sdw) – Stop duration at traffic stops
10. Total stop dwell time (tsdwt) – Total stop duration at traffic stops
11. Points motion (pm) – Number of GPS records skipped when truck is in motion
12. Points stop (ps) – Number of GPS records skipped when the truck is not moving or is at a stop
13. Points traffic stops (pts) – Number of GPS records skipped when truck is at a traffic stop

Variable descriptions:
- Points stop (pts): Number of GPS records skipped when the truck is not moving or is at a stop
- Points motion (pm): Number of GPS records skipped when truck is in motion
- Trip length (tl): Total spatial distance traveled by the truck between origin and destination
- Trip time (tpt): Total time taken to travel from origin to destination
- Trip speed (tps): Average speed of truck during the trip (tl/tpt)
- Travel distance (td): Spatial distance between two geographic (GPS) location records
- Travel time (trt): Time difference between two geographic (GPS) location records
- Travel speed (tdw): Average speed of truck between two GPS records (td/trt)
- Origin dwell time (odwt): Total time duration of stop at origin (when the truck is not moving)
- Destination dwell time (sdwt): Total time duration of stop at destination
- Stop dwell time (sdw): Stop duration at traffic stops
- Total stop dwell time (tsdwt): Total stop duration at traffic stops
- Points motion (pm): Number of GPS records skipped when truck is in motion
- Points stop (ps): Number of GPS records skipped when the truck is not moving or is at a stop
- Points traffic stops (pts): Number of GPS records skipped when truck is at a traffic stop
## Trips Extracted from 1 Week Data within Florida
### Trip length Vs. Trip Duration

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### Trips Extracted from 1 Week Data within & Outside FL

#### Trip length Vs. Trip Duration

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<th>3 - 5</th>
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