Estimation of Statewide Origin-Destination Truck Flows Using Large Streams of GPS Data: Application for Florida Statewide Model

presented by

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Background

- **Increasing importance of freight**
  - Impacting traffic operations, safety, highway infrastructure, port operations, and distribution center operations
- **Main challenges to mitigate the impacts**
  - Lack of adequate data on freight movement
    - Detailed origin-destination (OD) data
    - Truck travel times
    - Freight tonnage distribution by OD pairs
    - Truck trip stops and paths

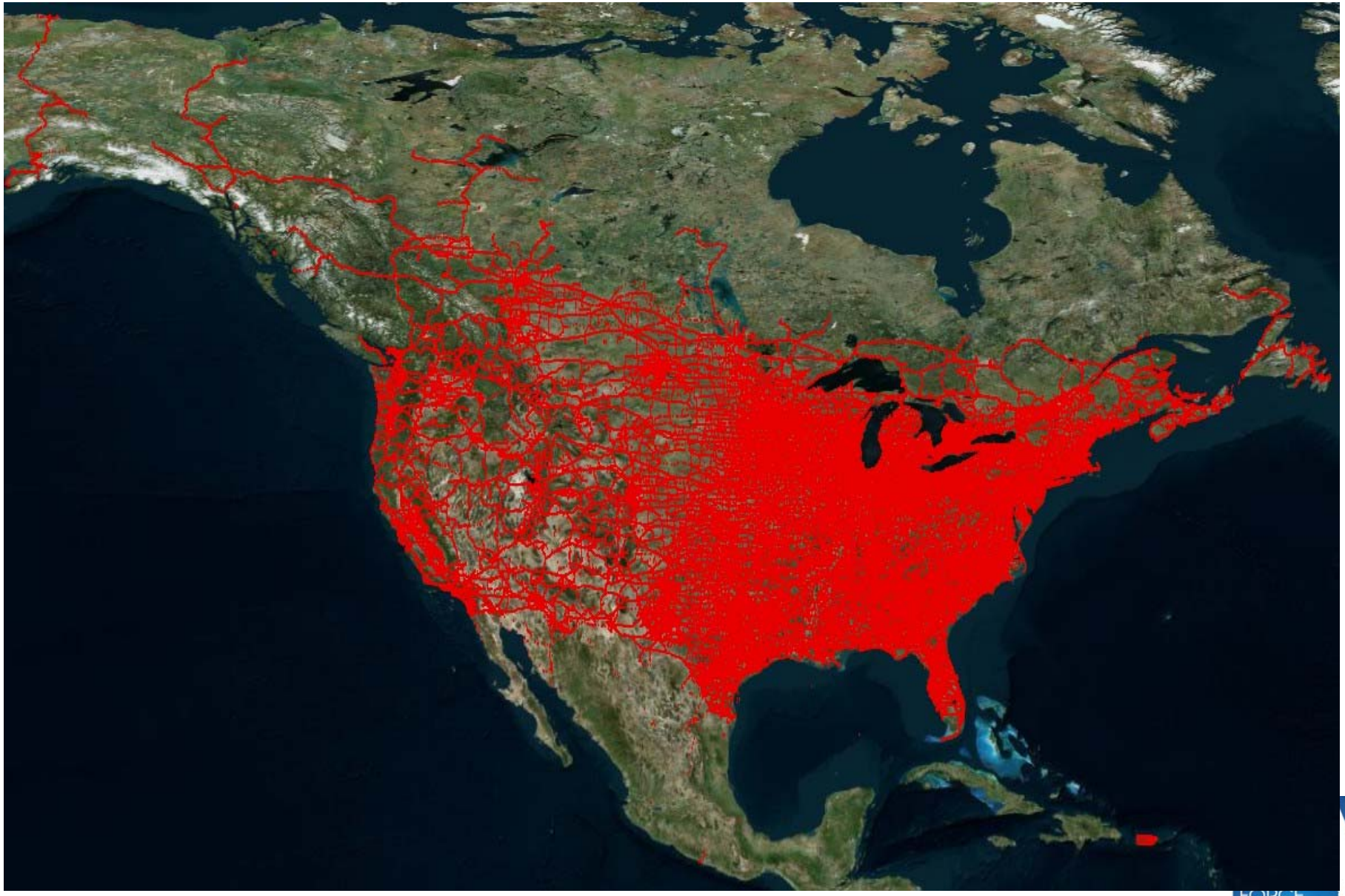
ATRI Data


- **More than 145 million GPS records of Florida centric truck movements during 4 months-March, April, May, and June-in 2010**

- **Each GPS record provides information on:**
  - Spatial and temporal location
  - A unique truck ID
  - A part of the data contains information on the spot speed (or instantaneous speed) and the direction of heading for each GPS data point

- **Some potential useful information not provided due to confidentiality:**
  - The businesses served
  - Truck type/axle configuration
  - Commodity being carried
  - The purpose of travel

ATRI Truck GPS Dataset – One Day



Current Research

- **Objectives**
  - Develop methods to convert ATRI's raw GPS data streams into truck trips
  - Assess ATRI's truck GPS data and its coverage of truck traffic in Florida
  - Derive statewide truck trip flow origin-destination tables for the Traffic Analysis Zone (TAZ)-level spatial resolution in the Florida Statewide Model (FLSWM)

GPS to Trip Conversion Algorithm

- **Steps:**
  - Sort GPS data for each truck ID into time series, in the order of date & time of GPS records
  - Identify potential trip-ends (origins/destinations) based on travel speed between consecutive records
  - Eliminate trip-ends in rest areas and other locations that are unlikely be pickup/delivery stops
  - Find circular (i.e., circuitous) trips and break each of them into multiple valid trips
  - Conduct additional quality checks and eliminate trips that do not satisfy quality criteria
- **A total of over 2.7 million truck trips**
- **Over 1.2 million of these trips were either within Florida or had one end in Florida**

How much flow is covered?

- **Truck types in ATRI data:**
  - The ATRI data is only a sample, but not necessarily representing a random population of the trucks in the state
    - Predominantly tractor-semitrailer combinations or larger trucks (or heavy trucks)
      - Class 8 to13 of FHWA's vehicle classification scheme
    - Data has a small proportion of trucks that are likely to be of FHWA classification 7 or below
    - Some heuristics were developed to classify the trucks into heavy trucks and medium trucks
      - The database was comprised of 169,714 unique truck IDs
      - Trucks that did not make at least one trip of more than 100 miles in a two week period were removed from the data
      - Trucks that made more than 5 trips per day were removed
      - 161,776 unique truck IDs were considered as trips made by heavy trucks that carry freight

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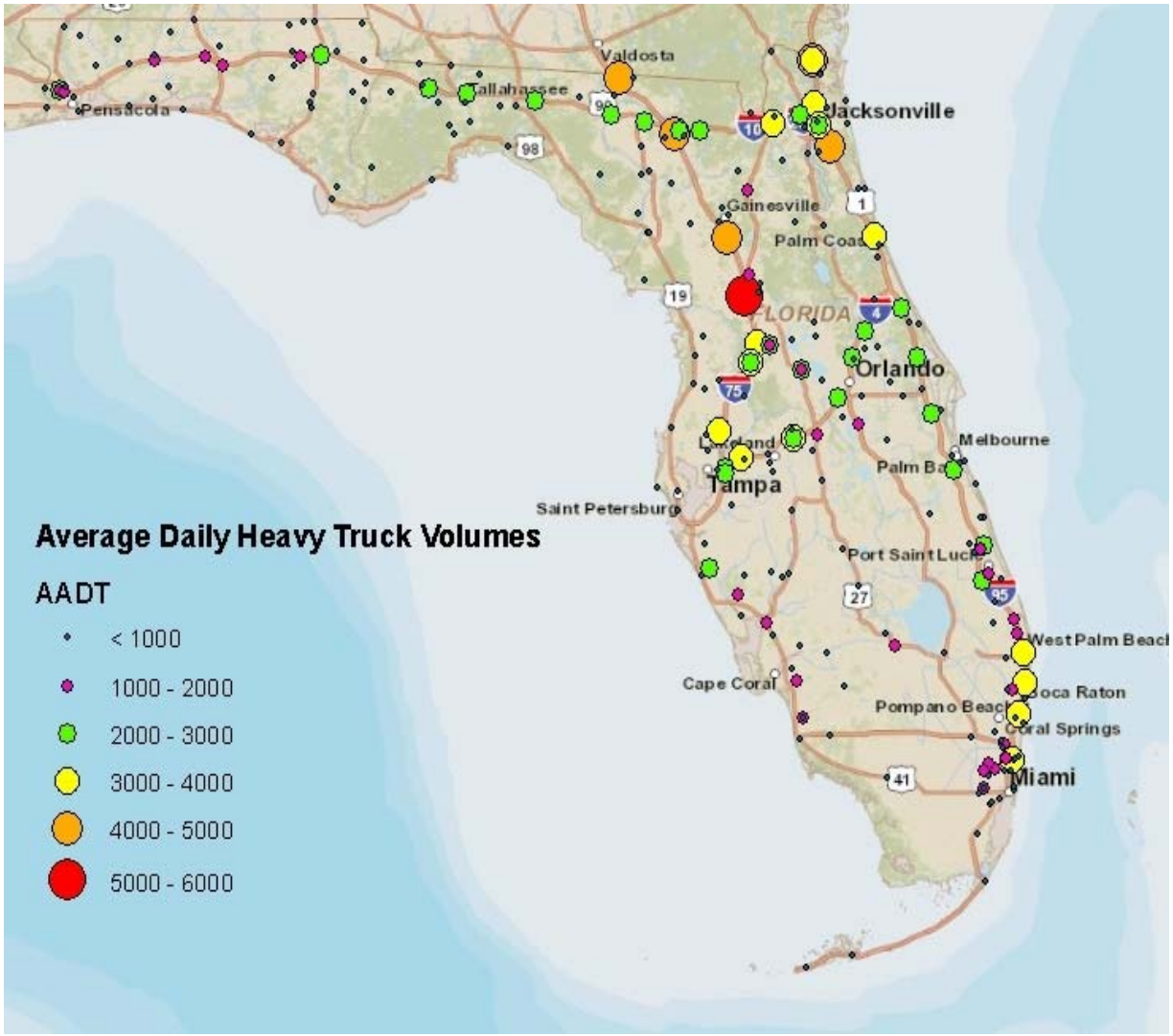
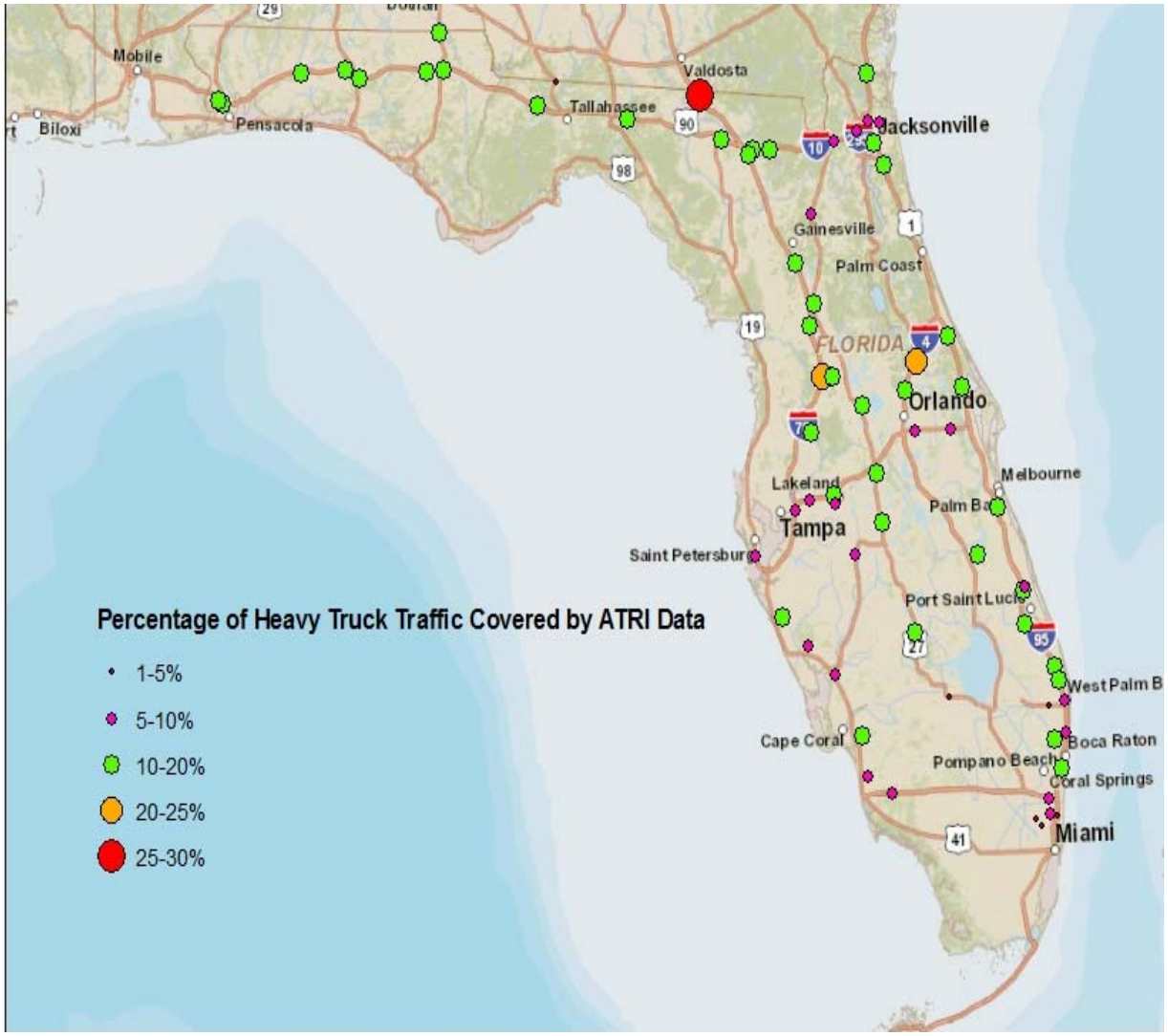
How much flow is covered?



Observed heavy truck traffic flows at different TTM sites in Florida

How much flow is covered?



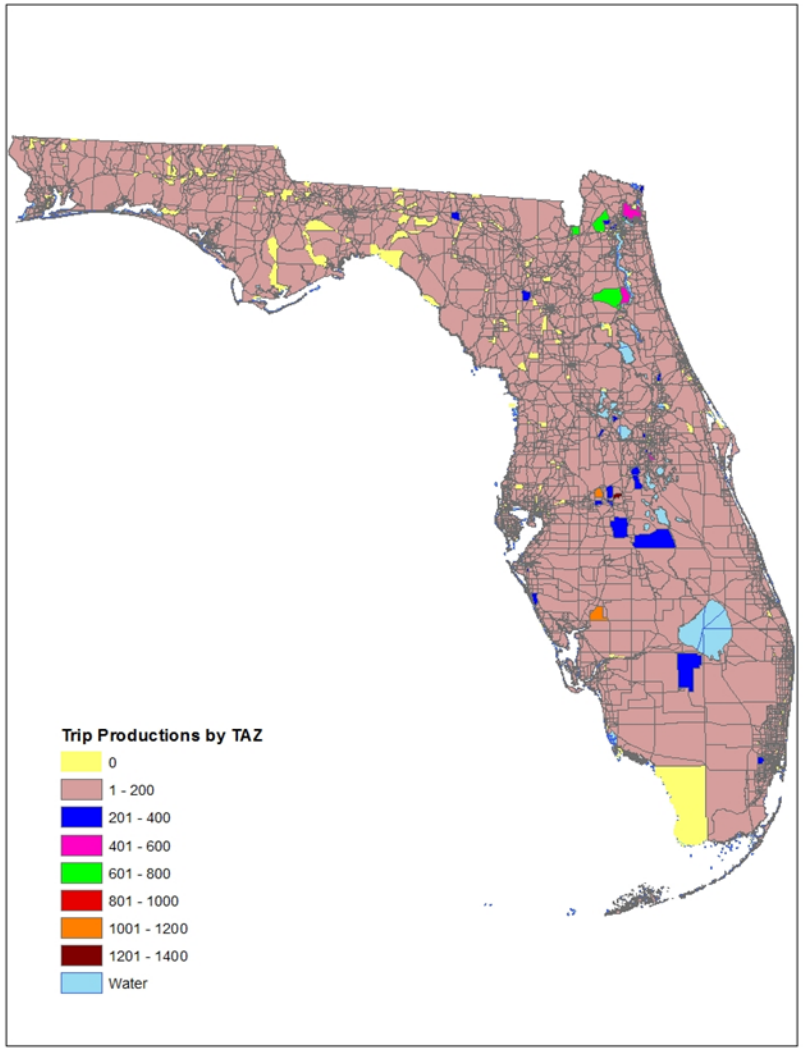
Percentage of observed heavy truck (classes 8-13) volumes represented by ATRI data at TTM sites in Florida during May 9–15, 2010

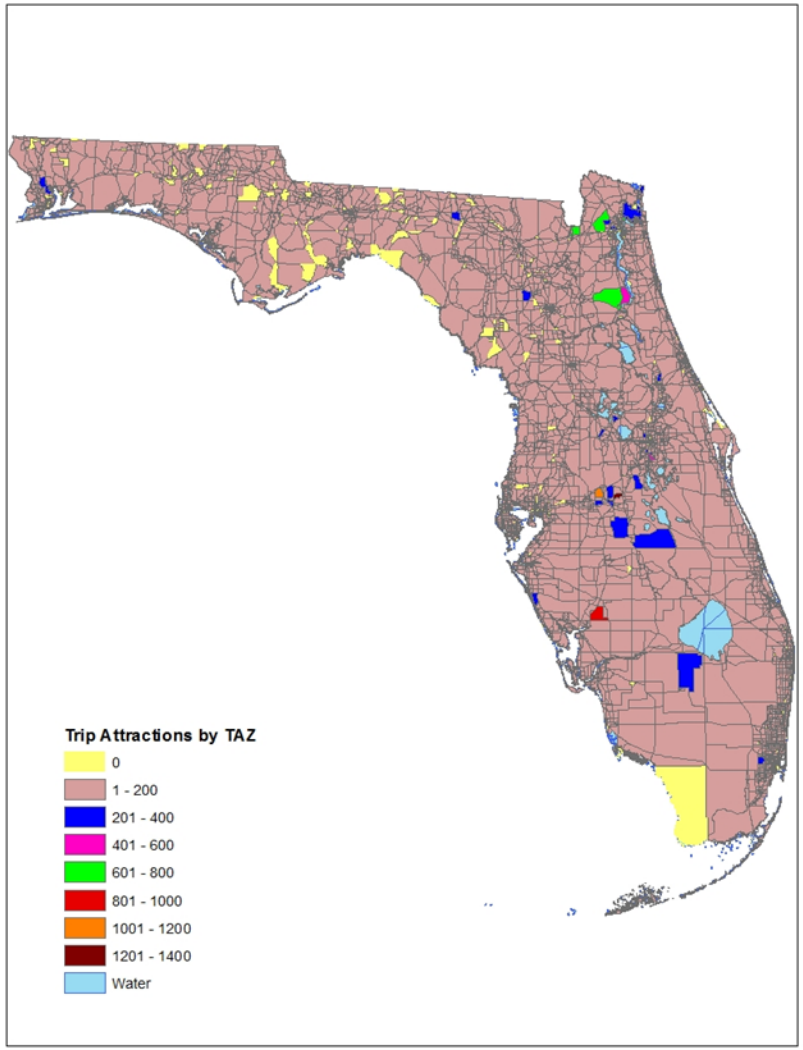
How much flow is covered?

Coverage of Heavy Truck Traffic Volumes in Florida in ATRI Data
(for One Week from May 9 to 15, 2010)

Facility Type	No. of TTM Traffic Counting stations	Observed Truck Traffic Volumes (Class 8-13) during May 9-15, 2010	Truck Traffic Volumes in ATRI data during May 9-15, 2010	% Coverage
Freeways & Expressways	29 (18.1%)	1,063,765 (65.6%)	111,608 (68.3%)	10.5%
Divided Arterials	64 (40.0%)	333,791 (20.6%)	30,472 (18.6%)	9.1%
Undivided Arterials	52 (32.5%)	101,066 (6.2%)	6,969 (4.3%)	6.9%
Collectors	8 (5.0%)	42,164 (2.6%)	5,127 (3.1%)	12.2%
Toll Facilities	7 (4.4%)	80,493 (5.0%)	9,291 (5.7%)	11.5%
Total	160	1,621,279	163,467	**10.1%**

Geographical Coverage of ATRI Data in Florida





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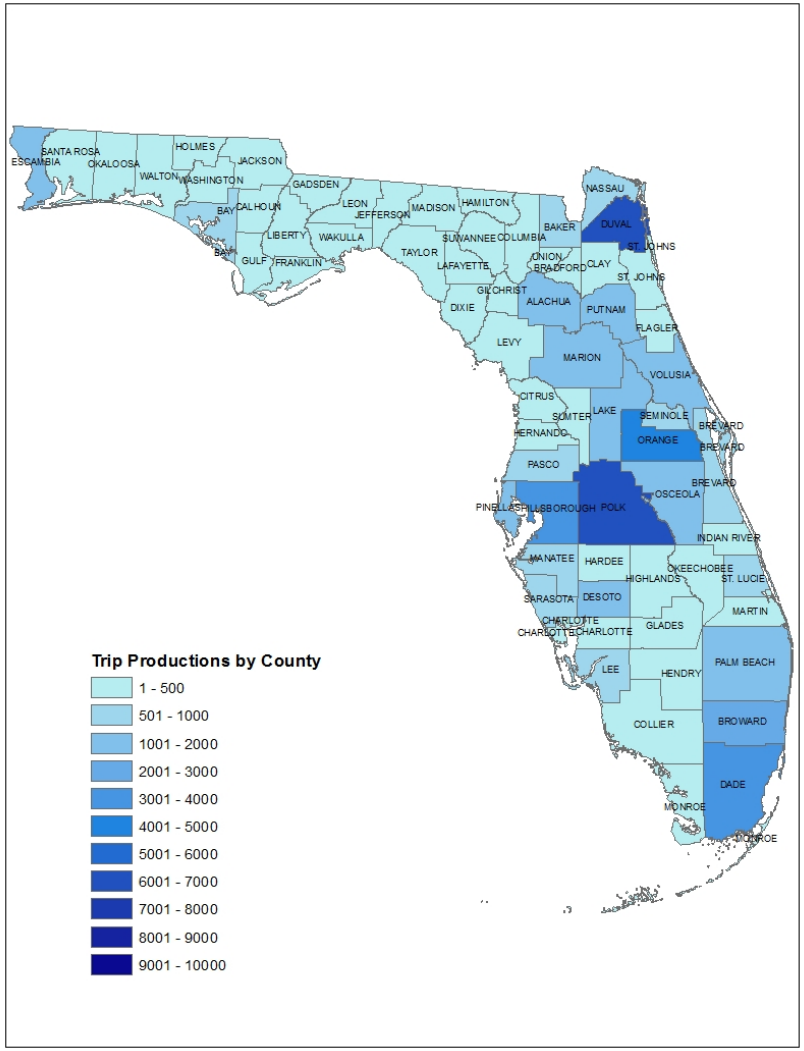
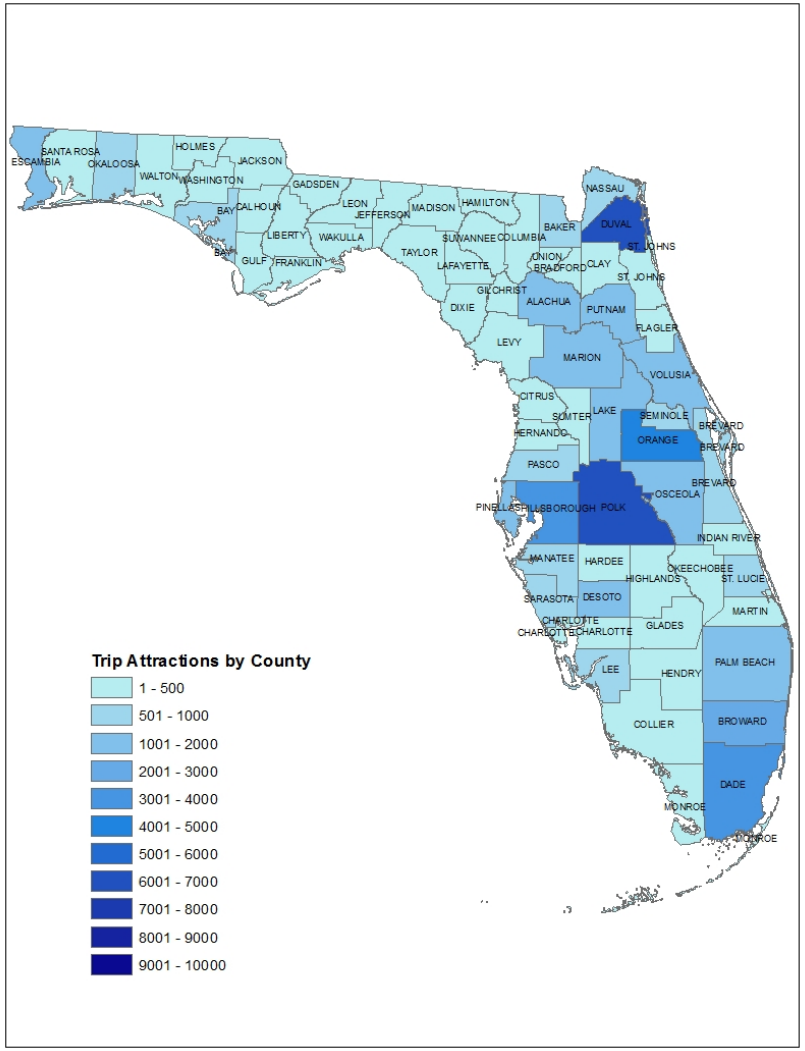




ORIGIN DESTINATION MATRIX ESTIMATION OF STATEWIDE TRUCK FLOWS

- The OD patterns from the raw data are from a sample of trips
- Sampling procedures are unknown (drawback of most probe data)
  - What proportion of the trucks are represented? Largely unknown
  - Representation of industries/commodities -- Unknown
  - Representation of axle configurations and carriers -- Known at only aggregate level
- Need to arrive at the population of truck flows
- Perform OD Matrix Estimation (ODME) to…
  - "Inflate" the sample OD table to a population OD table such that, when loaded onto the network, the resulting flows match with observed truck traffic counts at different locations.
  - Essentially "fuse" probe data with observed truck traffic count data

❑ Methodology

- ❑ ODME procedure embedded in the Cube software's Analyst Drive program

- ❑ An optimization problem that tries to minimize:
  - ❑ The difference between observed traffic counts and estimated traffic counts (from the estimated OD matrix), and
  - ❑ The difference between the seed matrix and the estimated OD matrix

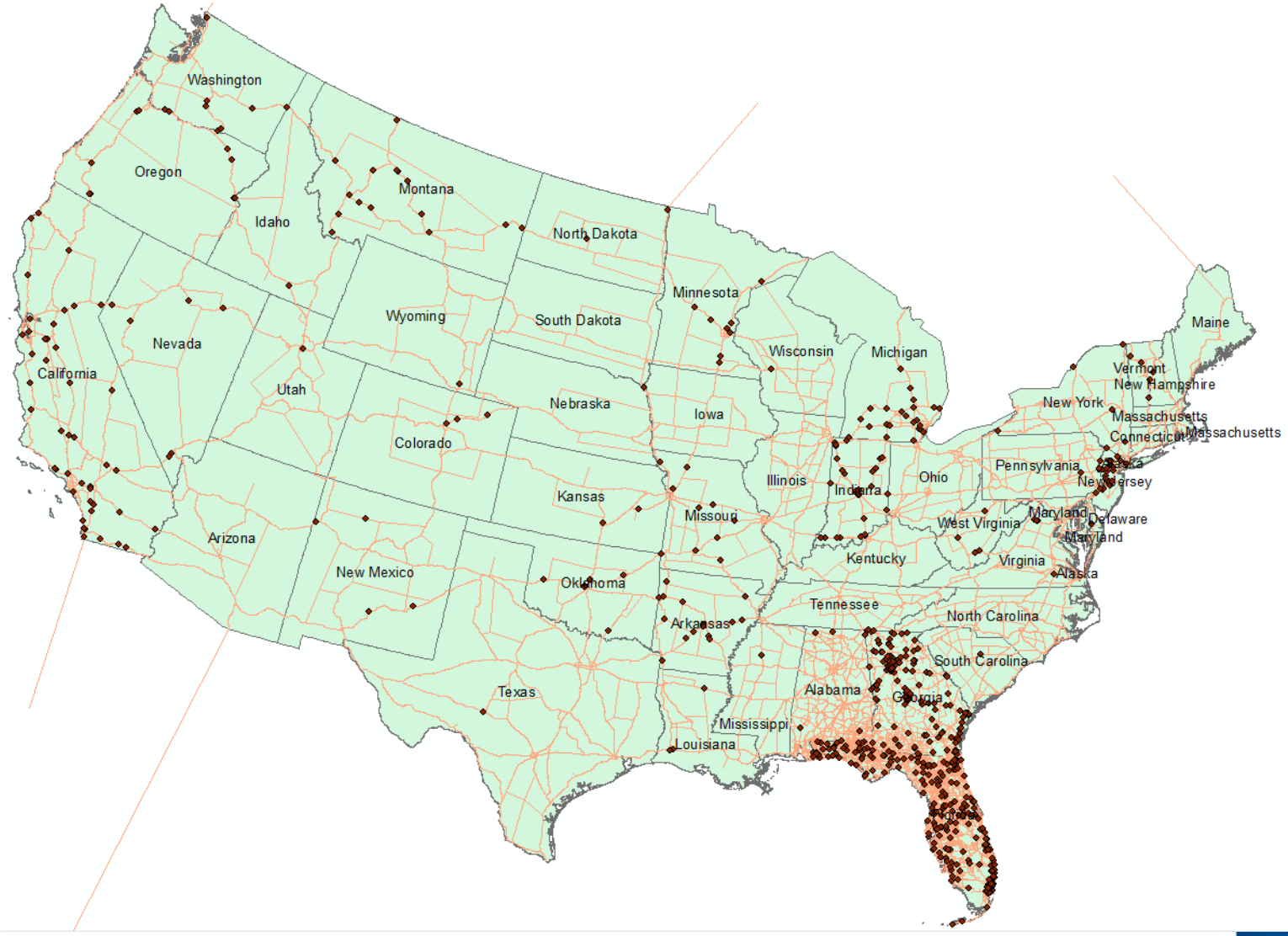
$$\arg\min_{X} \quad J(X) = F(AX - b) + G(X - X_0)$$

$$\text{subject to} \quad X \geq 0 \quad \text{and} \quad X_{lower} \leq X \leq X_{upper}$$

ORIGIN DESTINATION MATRIX ESTIMATION OF STATEWIDE TRUCK FLOWS

- **Inputs**
  - Seed matrix
    - Tractor-trailer combination trucks extracted based on heuristics
  - Other traffic flows (Passenger cars and non-freight trucks)
    - Inputs to Florida Statewide Model (FLSWM)
  - Network
  - Truck traffic counts
    - Florida: Florida DOT's Telemetered Traffic Monitoring Sites (TTMS)-413 locations
    - Georgia: Georgia DOT's Automated Traffic Recorder (ATR) locations
    - Outside Florida and Georgia: FHWA's vehicle travel information system (VTRIS) database (Overall 635 locations outside Florida)
  - Not the counts at all of these locations were used as input!

ORIGIN DESTINATION MATRIX ESTIMATION OF STATEWIDE TRUCK FLOWS



Truck traffic count locations

ORIGIN DESTINATION MATRIX ESTIMATION OF STATEWIDE TRUCK FLOWS

❑ Assumptions

- ❑ Seed Matrix:
  - ❑ In addition to heuristics to determine long haul Trips
    - ❑ Minimum trip length of 10 miles
    - ❑ Minimum trip length of 5 miles
    - ❑ Minimum trip length of 1 mile

- ❑ Zero cells in seed matrix (based on geographical coverage)
  - ❑ Assume OD pairs with zero-cells in the seed matrix do not have truck flows in reality
  - ❑ Alter only the zero-cells for OD pairs outside Florida to 0.01 to allow the possibility of truck flows between those OD pairs
  - ❑ Alter all zero-cells to 0.01, assuming that each zero-cell in the seed matrix is likely to have truck trips in reality

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ORIGIN DESTINATION MATRIX ESTIMATION OF STATEWIDE TRUCK FLOWS

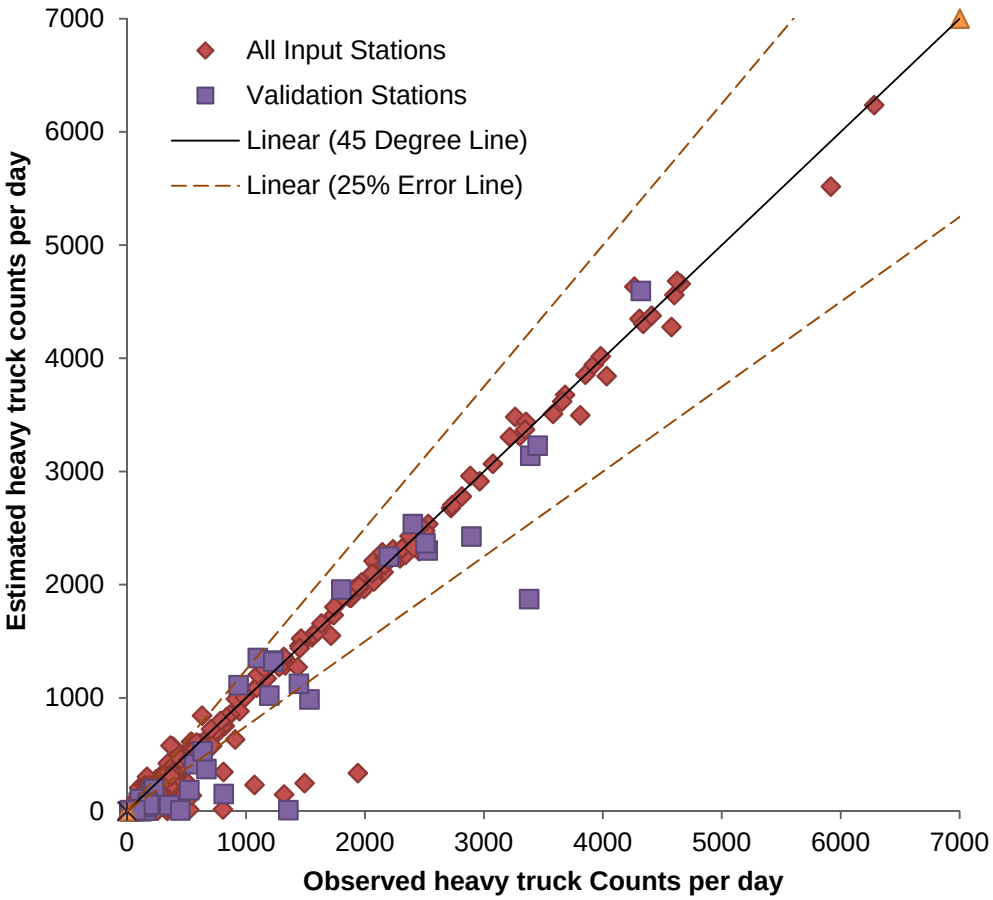
- **Assumptions**
  - Boundary conditions for cells in seed OD matrix
    - Lower bound equal to the seed matrix
    - No lower bound on the seed matrix
    - Lower bound equal to 0.7 of the seed matrix
    - An upper bound of 50 times the seed matrix
    - An upper bound of 100 times the seed matrix
    - No upper bound on the seed matrix

❑ Evaluation of Different Assumptions for ODME

- ❑ No upper bounds but a lower bound of 0.7 times the seed matrix on the estimated OD matrix
- ❑ Trips of at least 10 miles length
- ❑ Zero-cells in the seed matrix assumed to truly represent zero truck flows
- ❑ 4 months of truck trips between OD pairs were factored to one-day

ORIGIN DESTINATION MATRIX ESTIMATION OF STATEWIDE TRUCK FLOWS

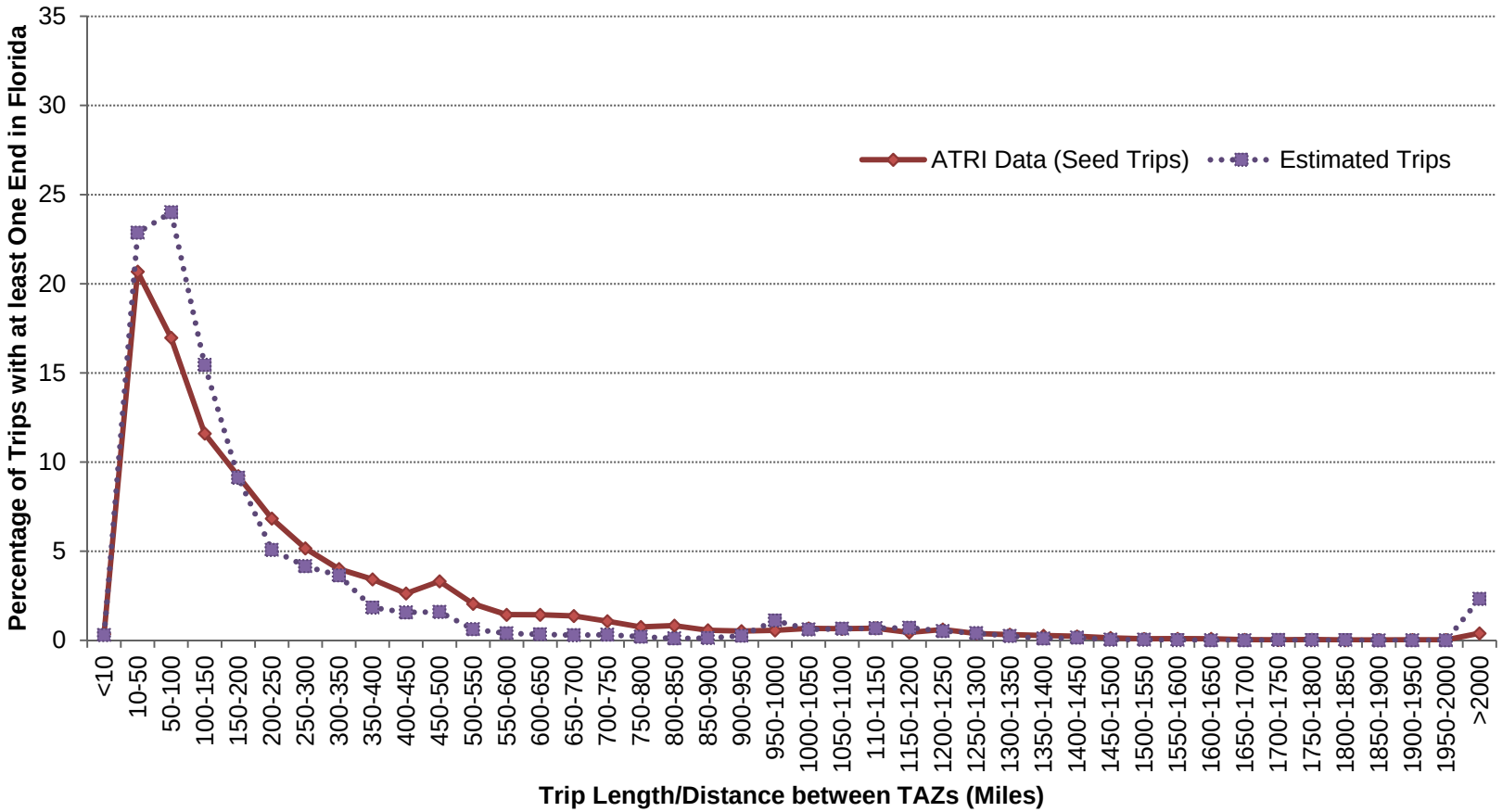
❑ ODME Results for One Set of Assumptions



Observed truck counts per day	RMSE for input stations (No. of input Stations)	RMSE for validation stations (No. of validation Stations)
20-100	70% (64 locations)	105% (11 locations)
100-500	47% (167 locations)	93% (14 locations)
500-1000	30% (38 locations)	49% (6 locations)
1000-7000	11% (96 locations)	25% (17 locations)
Total	20% (365 locations)	38% (48 locations)

Observed Vs. Estimated Heavy Truck Counts per Day at Different Locations in Florida

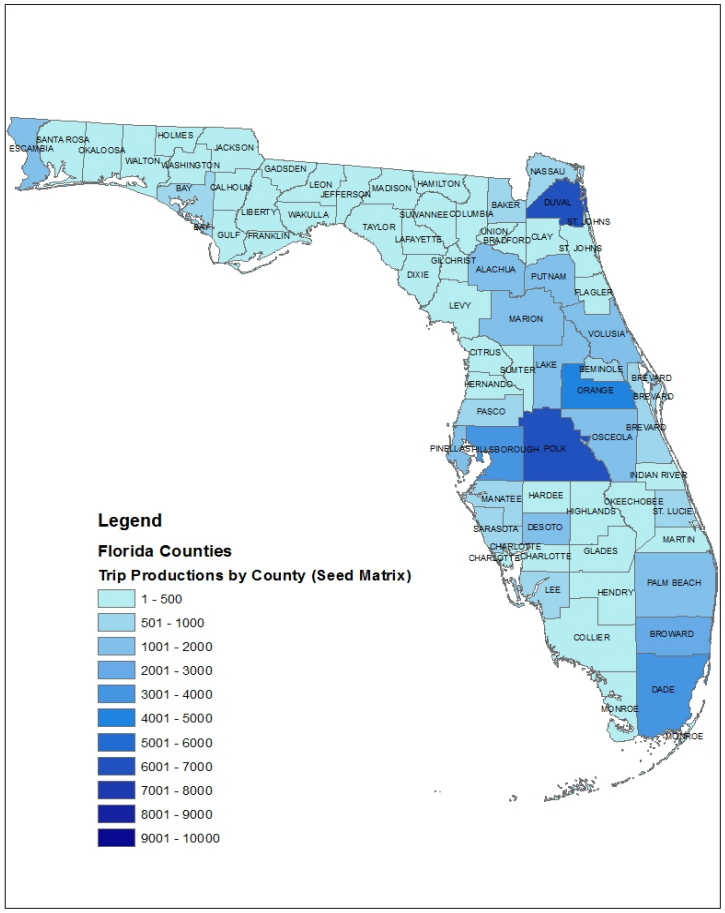
❑ ODME Results for One Set of Assumptions

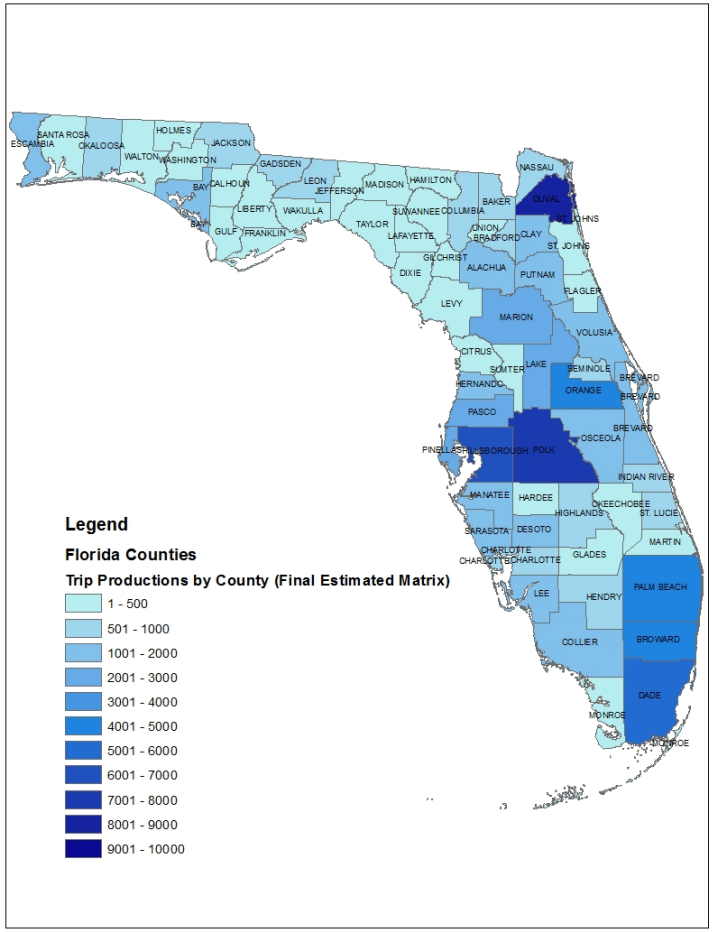


Trip Length Distributions of the Trips in the Estimated and Seed OD Matrices (OD pairs with at least one end in Florida)

ORIGIN DESTINATION MATRIX ESTIMATION OF STATEWIDE TRUCK FLOWS

- ODME Results for One Set of Assumptions





Comparison of Trip Productions by County between Seed OD Matrix and Estimated OD Matrix

Products from the Project

- Freight Performance Measures
  - Truck travel speeds by time-of-day for each mile on SIS highways
- A large database of truck trips within, to, and from Florida
- Analysis of truck travel characteristics in Florida
- Assessment of the coverage of truck traffic in Florida
- Exploratory analysis of truck routes and truck flows from ports
- Measurements of travel times & speeds between 1200 OD pairs
- Truck flow OD patterns at different geographies
  - FLSWM statewide TAZ level
  - County-level
  - State-level

- Final report available in FSUTMS website

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Thoughts for Way Forward

- This project focuses on statewide truck movements
  - The data predominantly comprises tractor-trailer trucks for long-haul movements
- There is an opportunity to use the data to extract truck travel patterns within a region
  - A small but useful portion of trucks in the data are smaller trucks, which are more likely to be local delivery trucks
  - ATRI's estimate: 11% of their database are trucks of class 7 or lower
- Most of the project focuses on generating data (truck trips, travel times, truck routes, etc.)
  - Using the generated data for further freight modeling and planning applications will be fruitful

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The time to repair the roof is when the sun is shining.

— John F. Kennedy

Thank you!

Questions???

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