Estimation of Truck Counts with Multiple Truckload Categories: A Data-Fusion Approach and a Case Study in Florida

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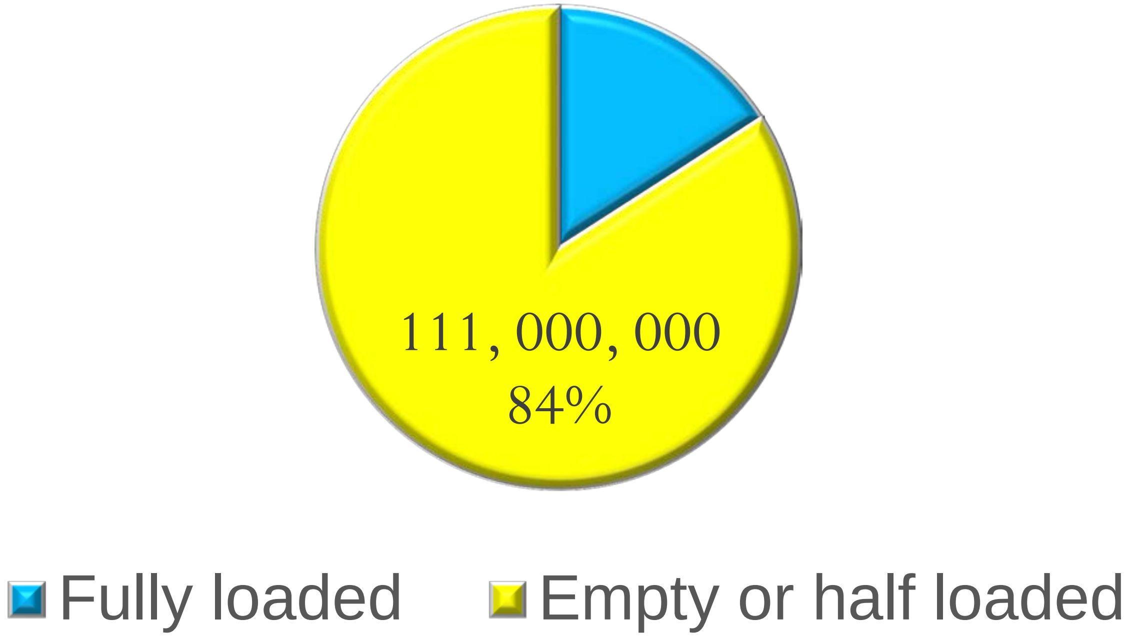
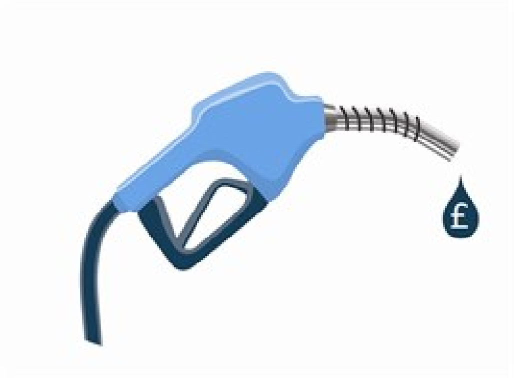
Empty Trucks

Truck trips in Florida in 2011





Waste fuel

Pollution

Pavement damage

Works on estimating truck counts

- A two-stage approach *by Jansuwan. et al.*
- Network flow methodology *by Mesa-Arango et al.*
- Dynamic and stochastic models *by Crainic* et al.

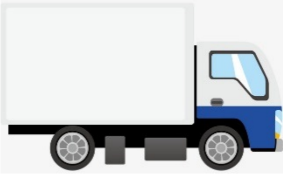
Half loaded or fully loaded?

Empty

Nonempty

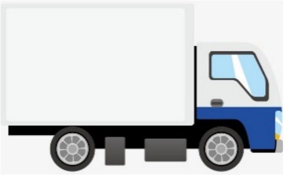
- We successfully estimated truck counts in different load categories

Three categories:



Load categories: Empty | Half loaded | Fully loaded

Five categories:



Load categories: 0-20% | 20-40% | 40-60% | 60-80% | 80-100%

Data

- 1: Truck Weights (n_{la}) and truck counts (n_a) on link a

Link ID	Vehicle weight (pounds)	Truck counts
7_9918	26060	11755

- 2: Commodity flows (m_w) and truck counts (n_w) between OD pair w

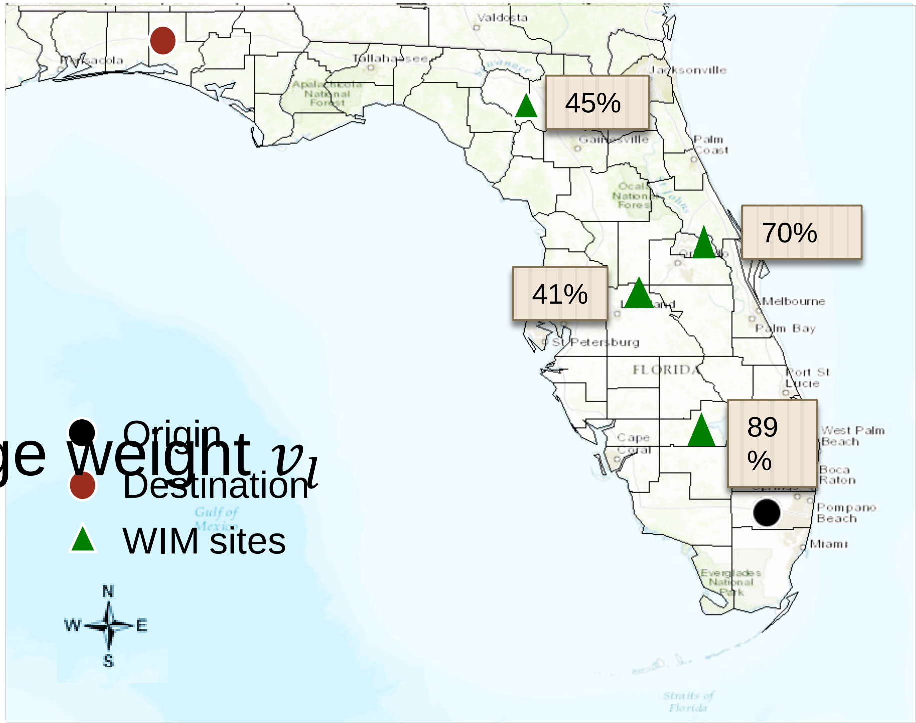
Origin-Destination	Commodity flows	Truck counts
319-323	36.68	1497

- 3: Path flows for freight trips p_{wa}

OD pair	Link ID	Percentage
319_359	18_9920	45%

- 4. Truck weight categories l and average weight v_l

Category no.	Weight range (kips)	Every weight (kips)
1	≤ 35	28.4
2	35 - 60	42.3
3	> 60	65.1



Variables to estimate

- y_{lw}: flow of category l trucks in between an OD pair w, $y_{lw} \geq 0, l \in L, w \in W$
- x_{la}: number of category l trucks passing through link a, $x_{la} \geq 0, l \in L, a \in A$
- ε_{la}: estimation error term

Objective function: *minimize the sum of squared errors with C_1 - C_5 being weight*

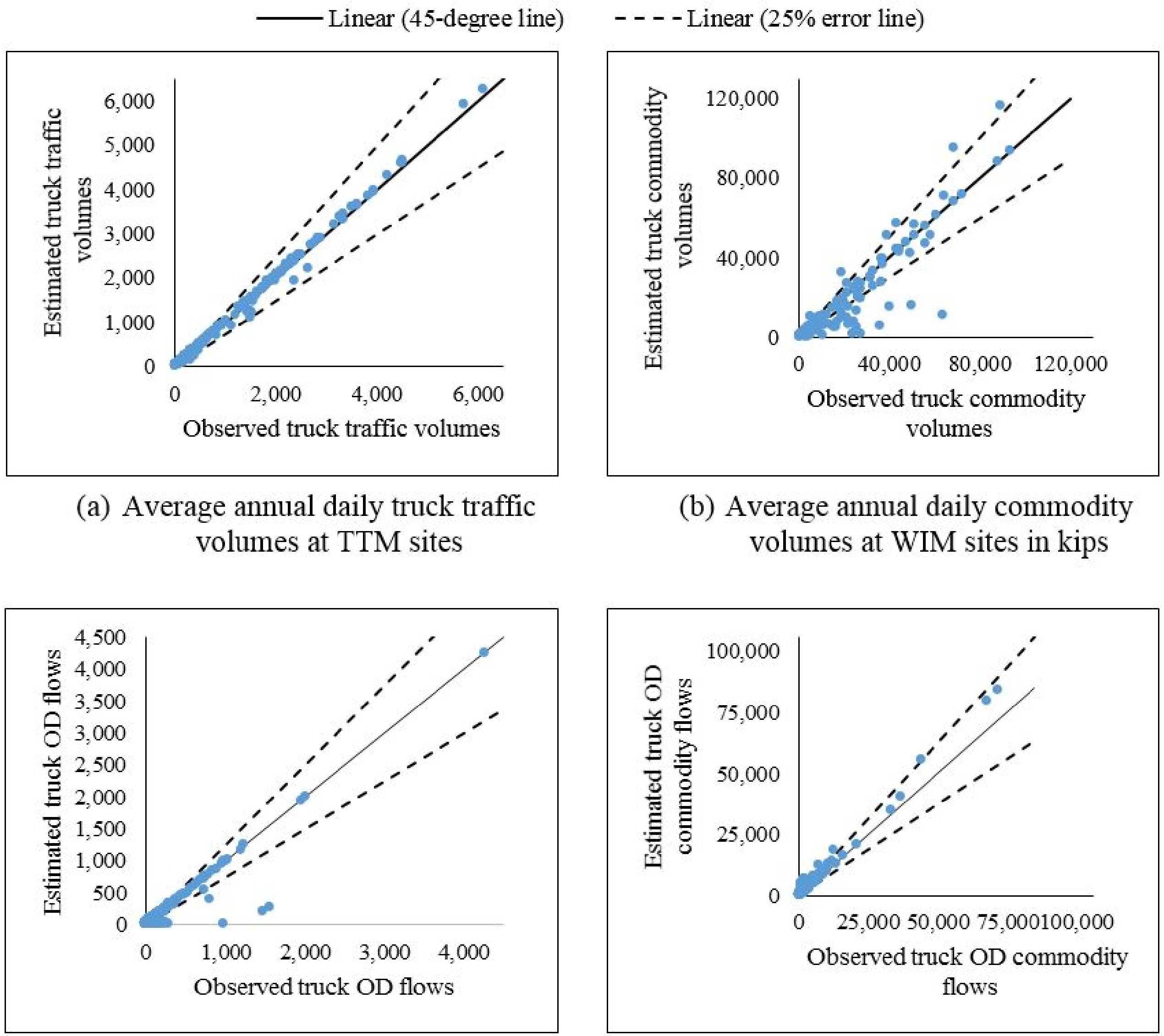
$$min_{x,y} \underbrace{\left[\sum_{l\in\mathcal{L}} \sum_{a\in A^{WS}} C_1(n_{la} - x_{la})^2\right]}_{\substack{Conservation\ of\ link\ flows \\ at\ WIM\ sites}} + \underbrace{\left[\sum_{a\in A^T} C_2\left(n_a - \sum_{l\in\mathcal{L}} x_{la}\right)^2\right]}_{\substack{Conservation\ of\ link\ flows \\ at\ TTM\ sites}} + \underbrace{\left[\sum_{w\in W^c} C_3\,(m_w - \sum_{l\in\mathcal{L}} y_{lw}\,v_l)^2\right]}_{\substack{Conservation\ of\ mass \\ at\ an\ OD\ pair\ level}}$$

$$+ \underbrace{\left[\sum_{w\in W^T} C_4\,(n_w - \sum_{l\in\mathcal{L}} y_{lw})^2\right]}_{\substack{Conservation\ of\ truck\ flows \\ at\ an\ OD\ pair\ level}} + \underbrace{\left[\sum_{a\in A^{WS}, l\in L} C_5\,{\varepsilon_{la}}^2\right]}_{\substack{Conservation\ of\ truck\ flows \\ at\ an\ OD\ pair\ level}}$$

Constraints

Subject to OD flow - link flow conversion:

$$\sum_{w\in W} y_{lw} p_{wa} = x_{la} + \varepsilon_{la}, l \in L, a \in \mathrm{A}$$



(a) Average annual daily truck traffic volumes at TTM sites

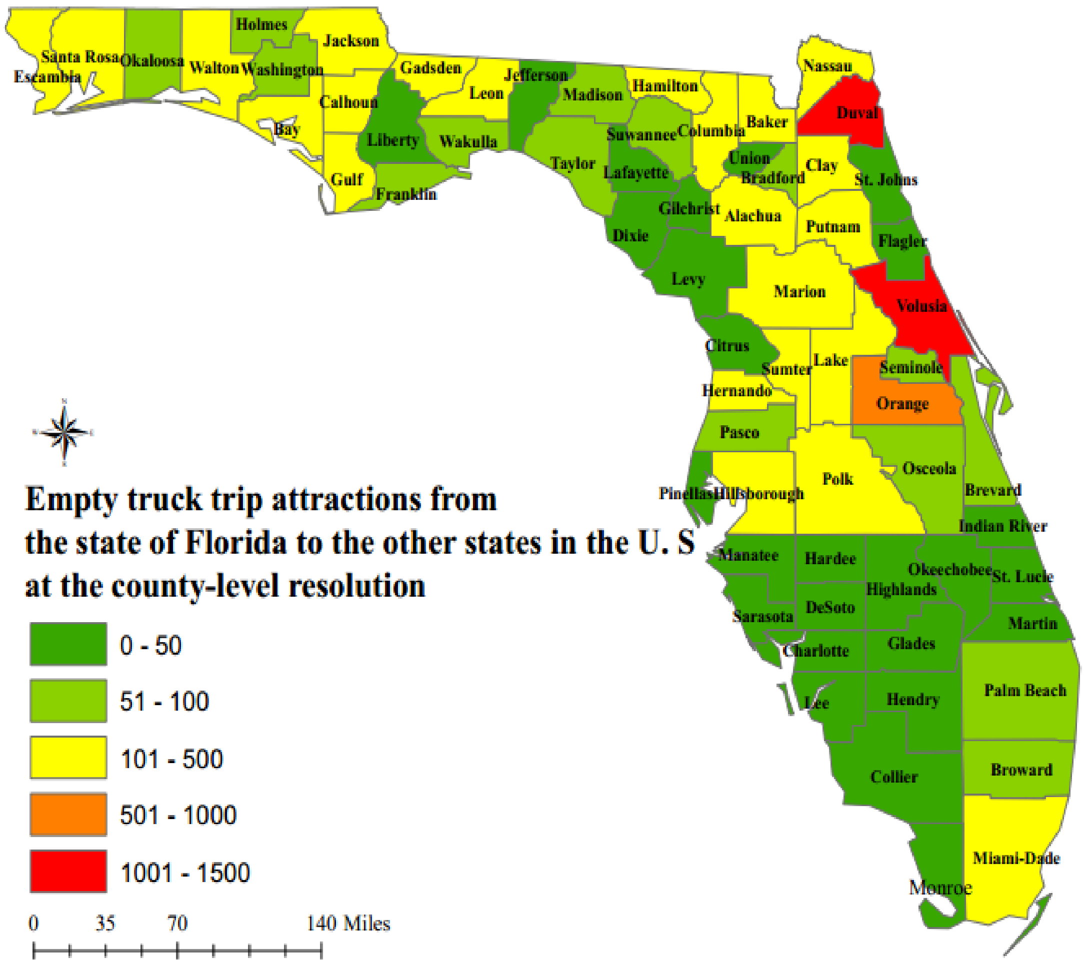
(b) Average annual daily commodity volumes at WIM sites in kips

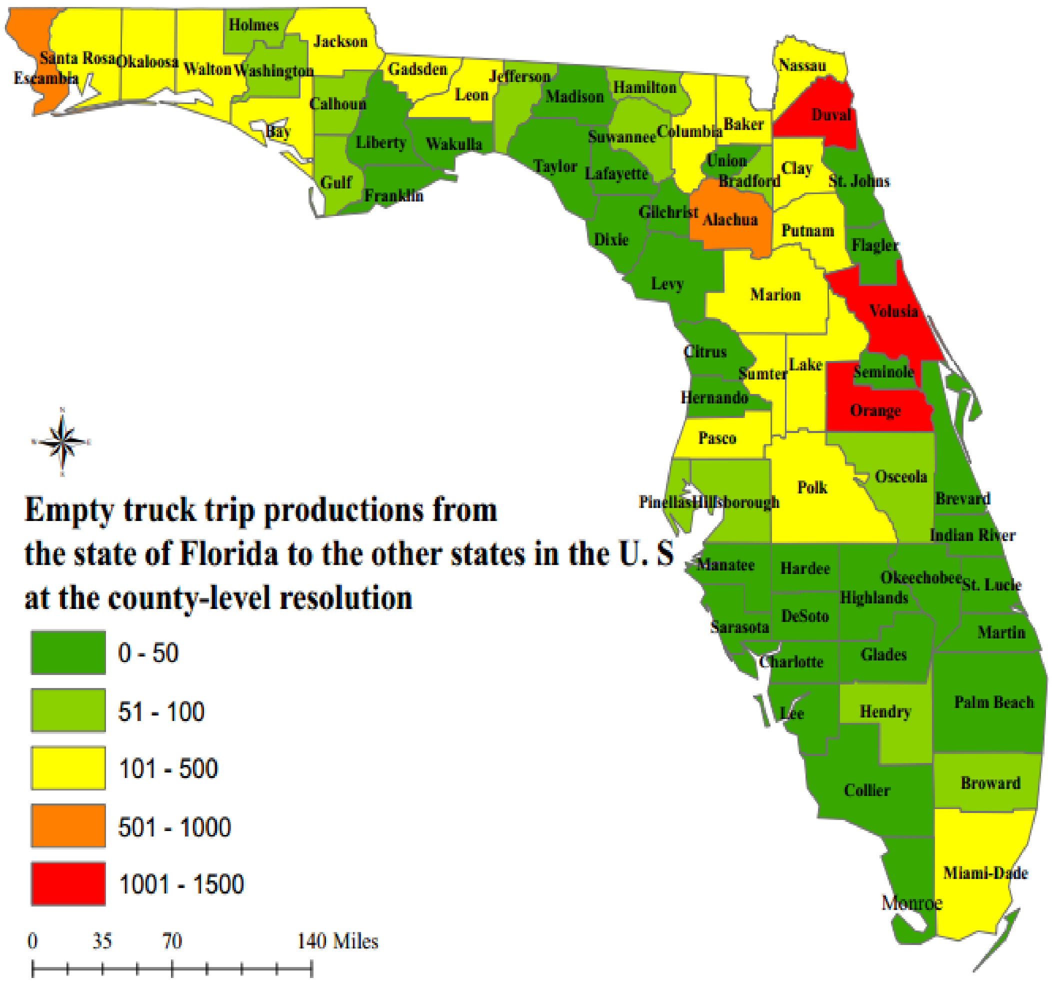
(c) Average annual daily truck flows between an OD pair

(d) Average annual daily commodity flows between an OD pair in kips

Observed versus estimated truck traffic volumes on links, truck OD flows, and commodity OD flows per day.

Empty truck flows between Florida and the other states in the US





- Conclusion:
  - Dividing truck weights into several categories
  - An nonlinear optimization model
  - Florida case study

- Acknowledgement

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Thank you!

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- Solver: Gurobi.

- Different sets for C's

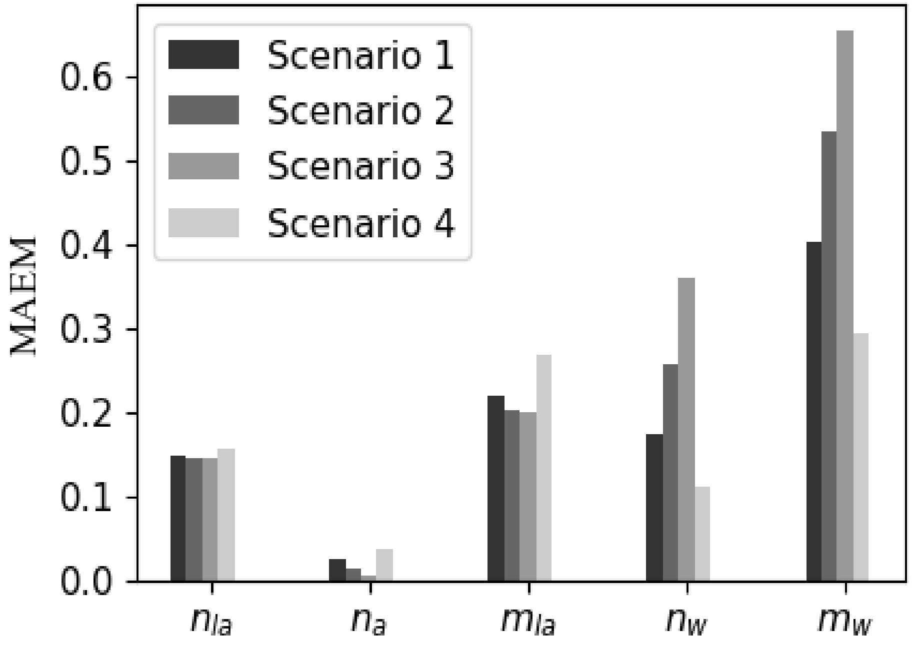
Weight	Scenario 1	Scenario 2	Scenario 3	Scenario 4
C1	1	10	**100**	1
C2	1	10	**100**	1
C3	1	1	**100**	1
C4	1	1	**1**	10
C5	1	1	**1**	10
C6	1	10	100	1

Mean of Absolute Error to Mean (MAEM)

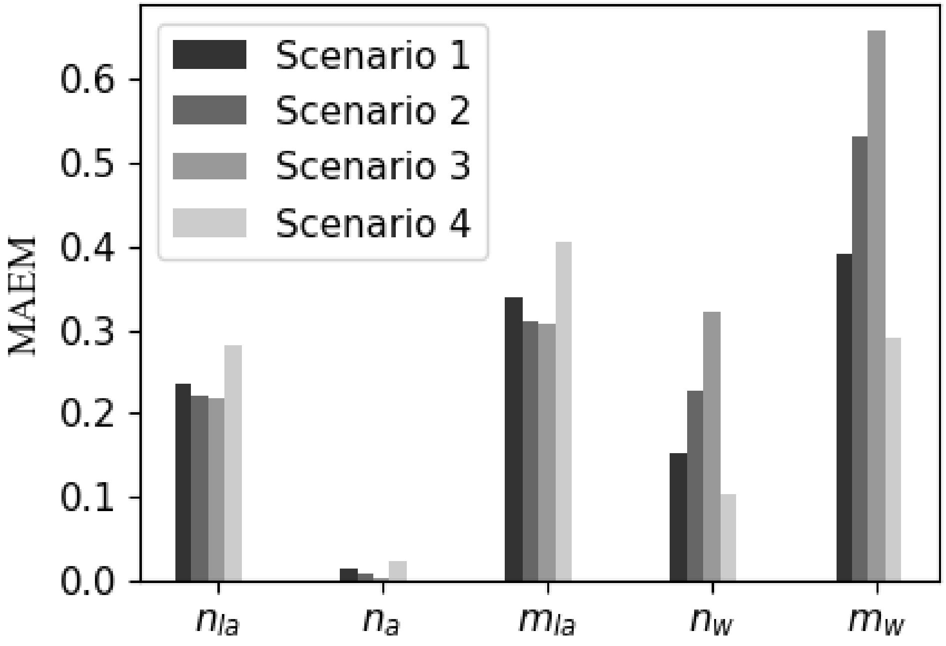
- Mean of Absolute Error to Mean:

$$MAEM(\hat{\theta}) = \frac{E[|\hat{\theta} - \theta|]}{\bar{\theta}}$$

where $E[|\hat{\theta} - \theta|]$ is the expected value of $|\hat{\theta} - \theta|$, $\hat{\theta}$ is the estimated value, θ is the observed value, and $\bar{\theta}$ is the mean of observed values.



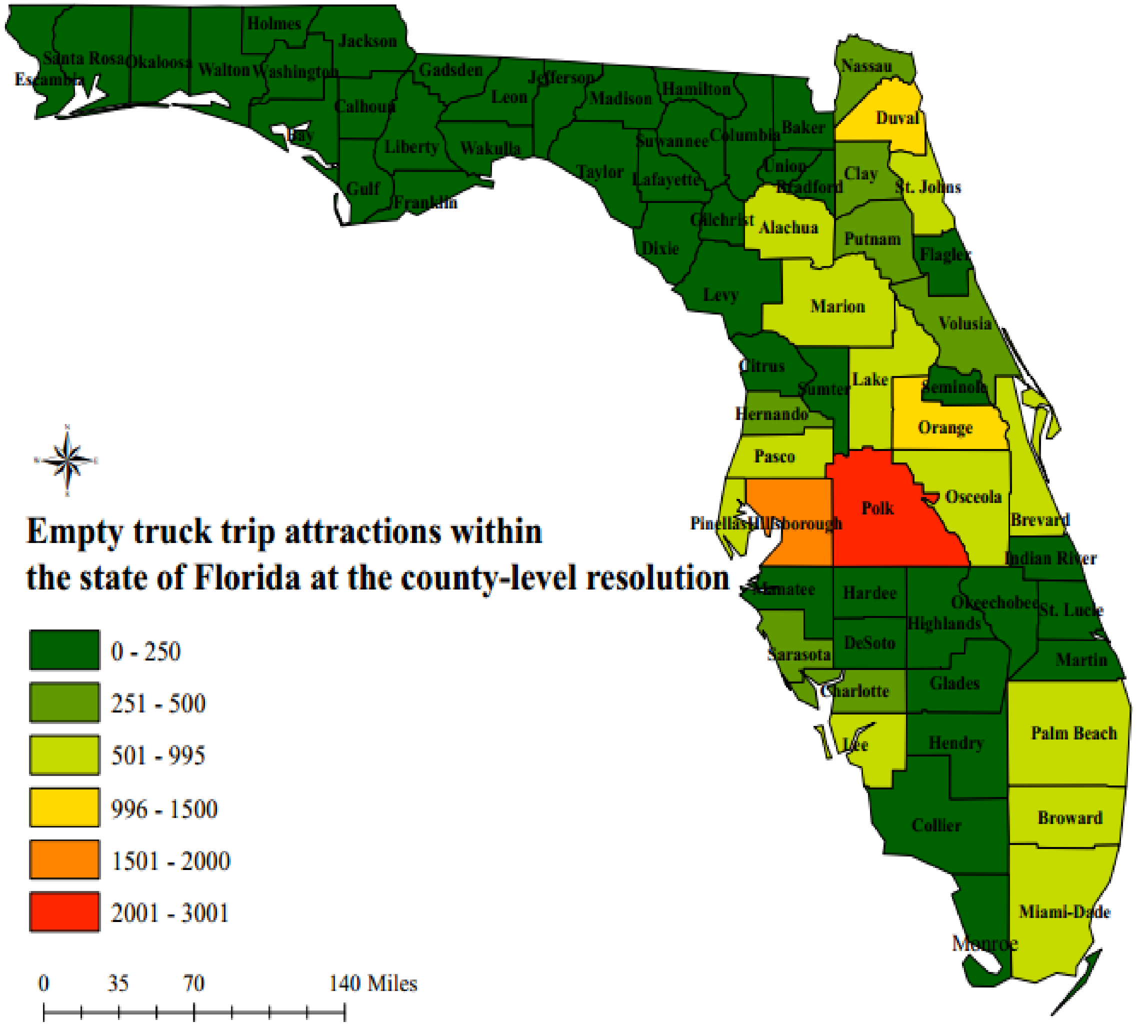
(a) Three Truck-weight Categories Model

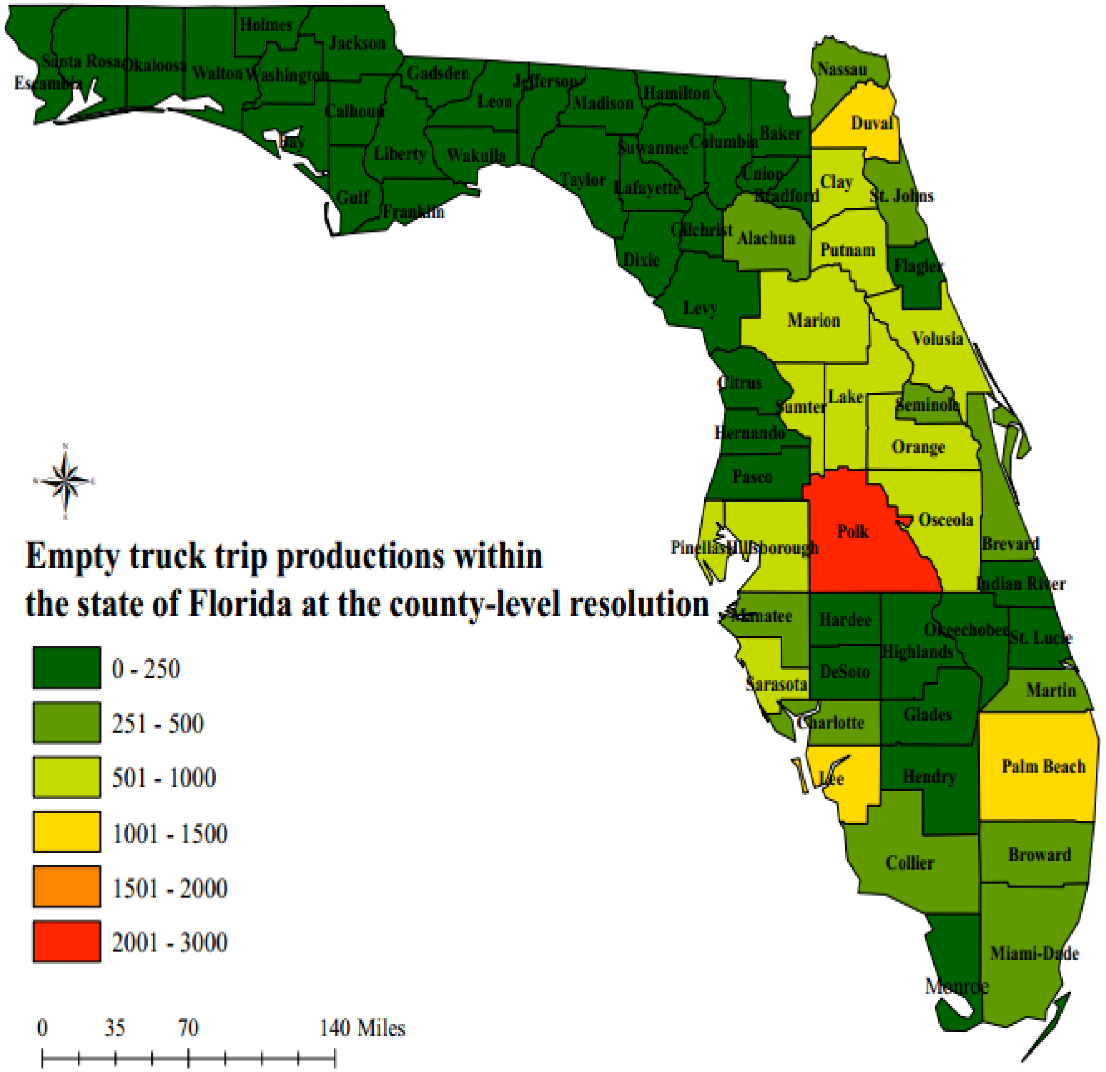


(b) Seven Truck-Weight Categories Model

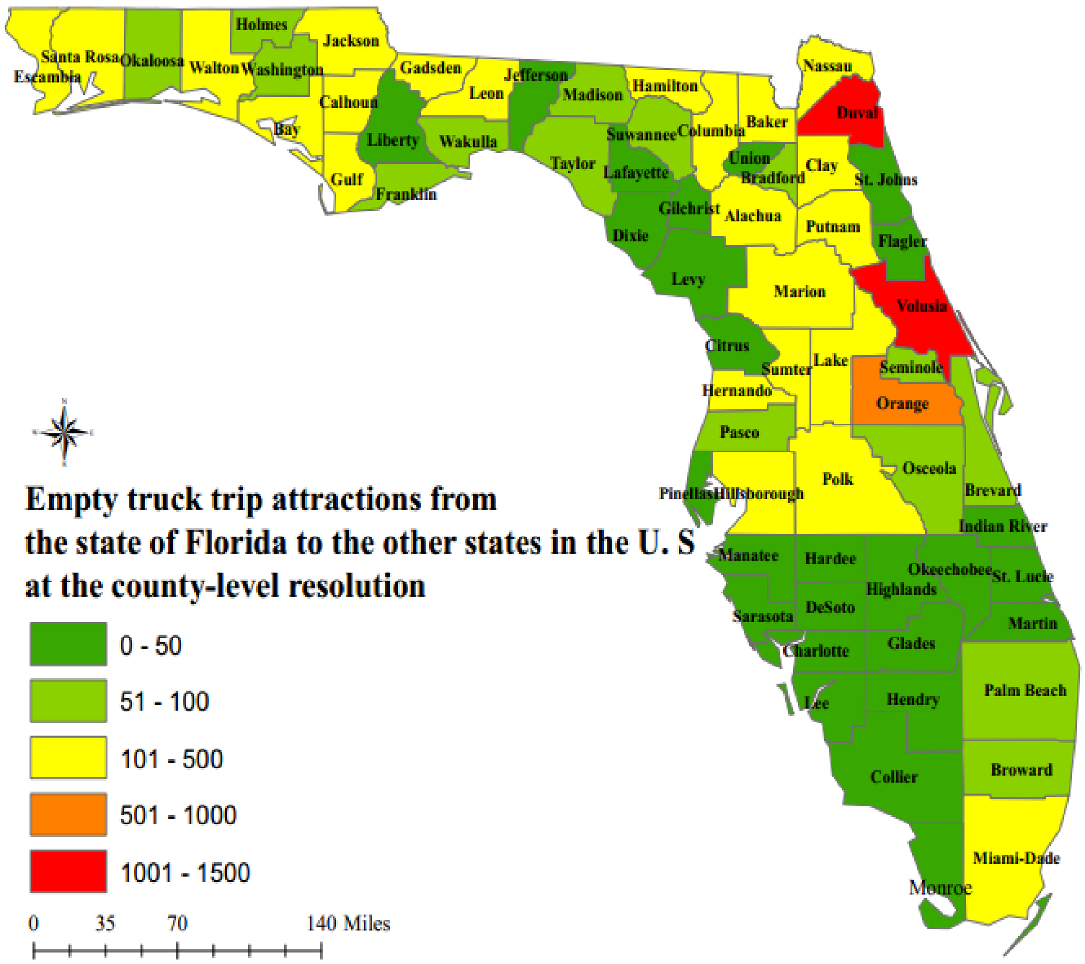
n_{la} - total number of category l trucks passing through link a
n_a - total truck flows on link a
m_{la} - total gross weight of category l trucks passing through link a
n_w - total truck flow between OD pair w
m_w - total commodity flow between OD pair w

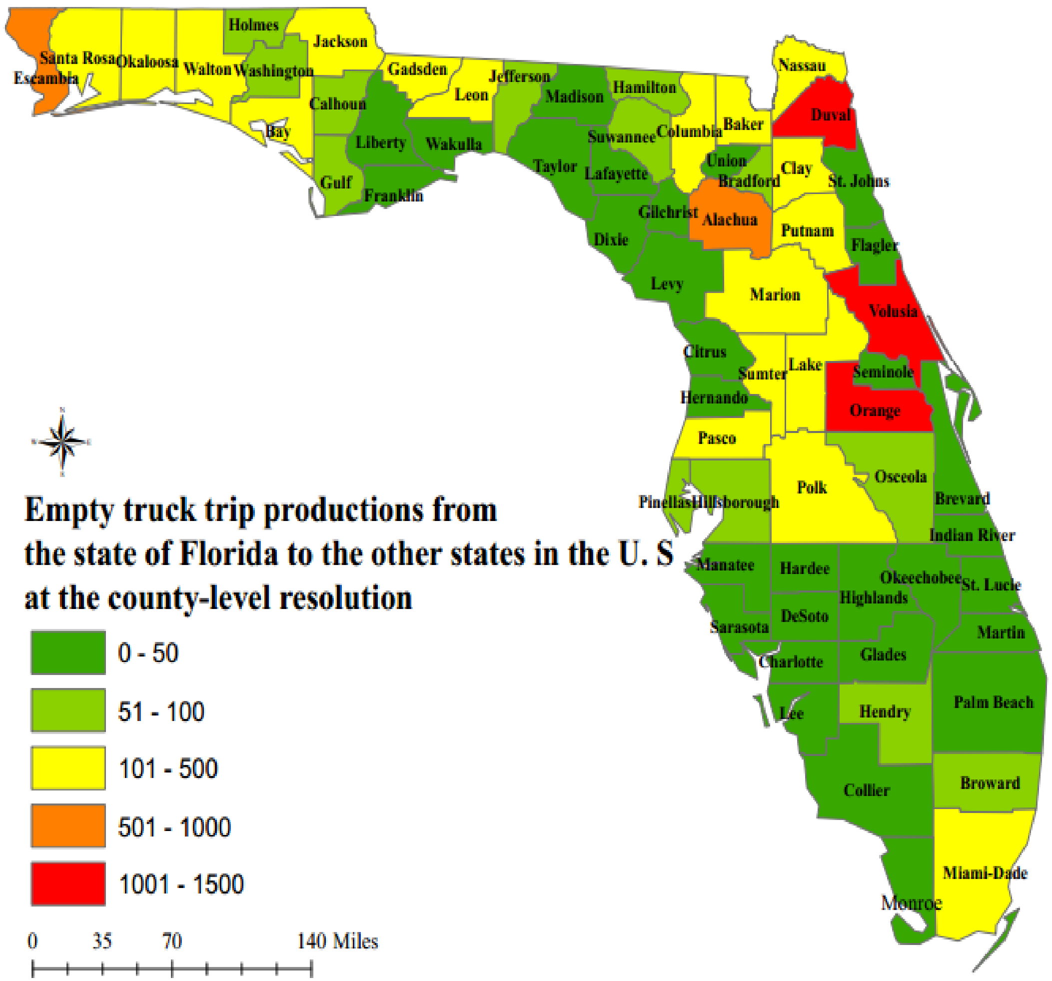
Average daily empty truck flows within Florida



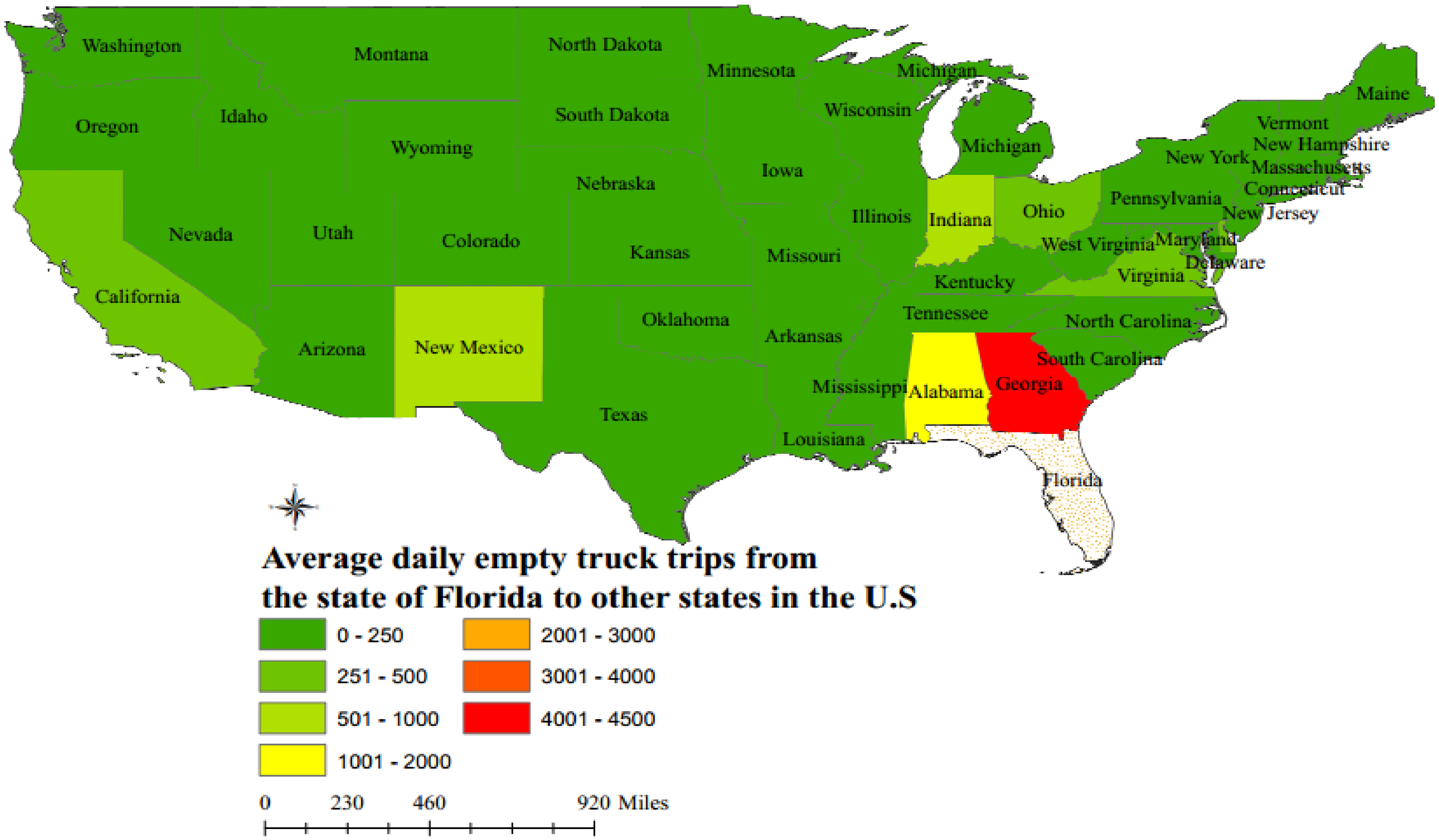


Empty truck flows between other states and Florida

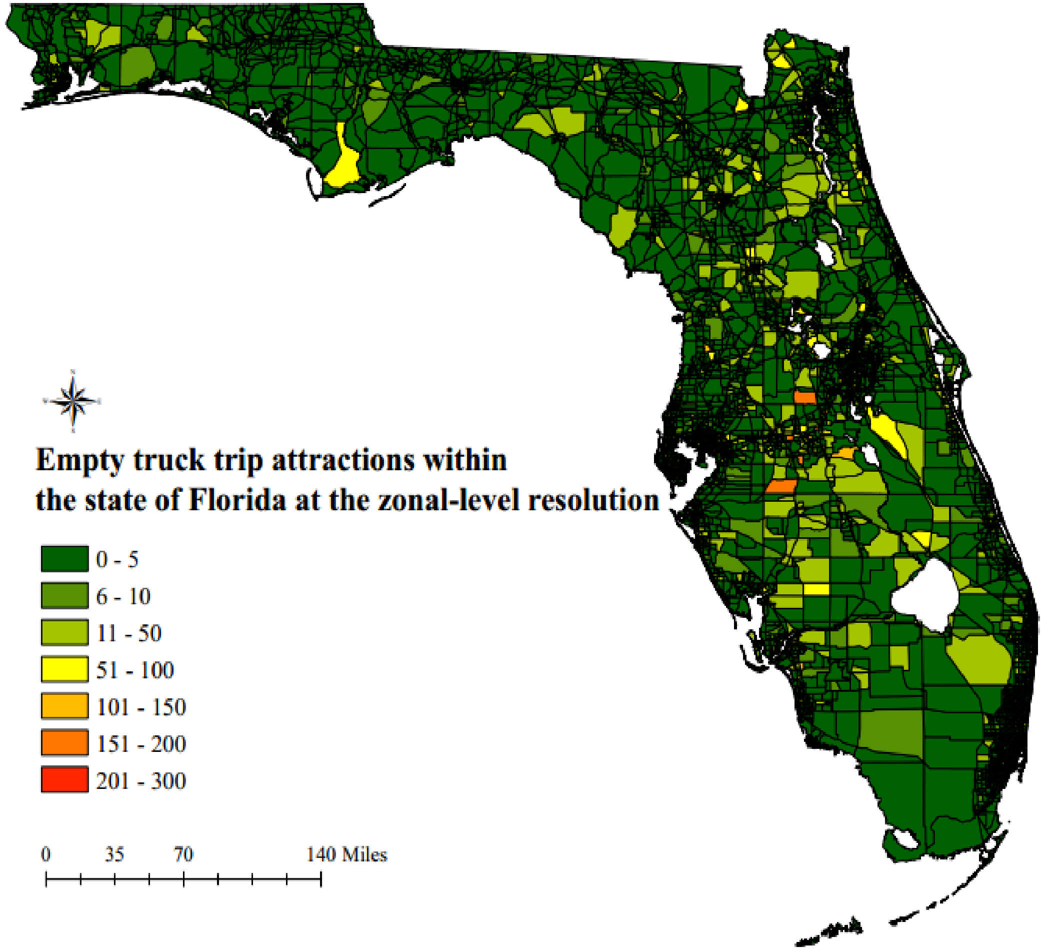


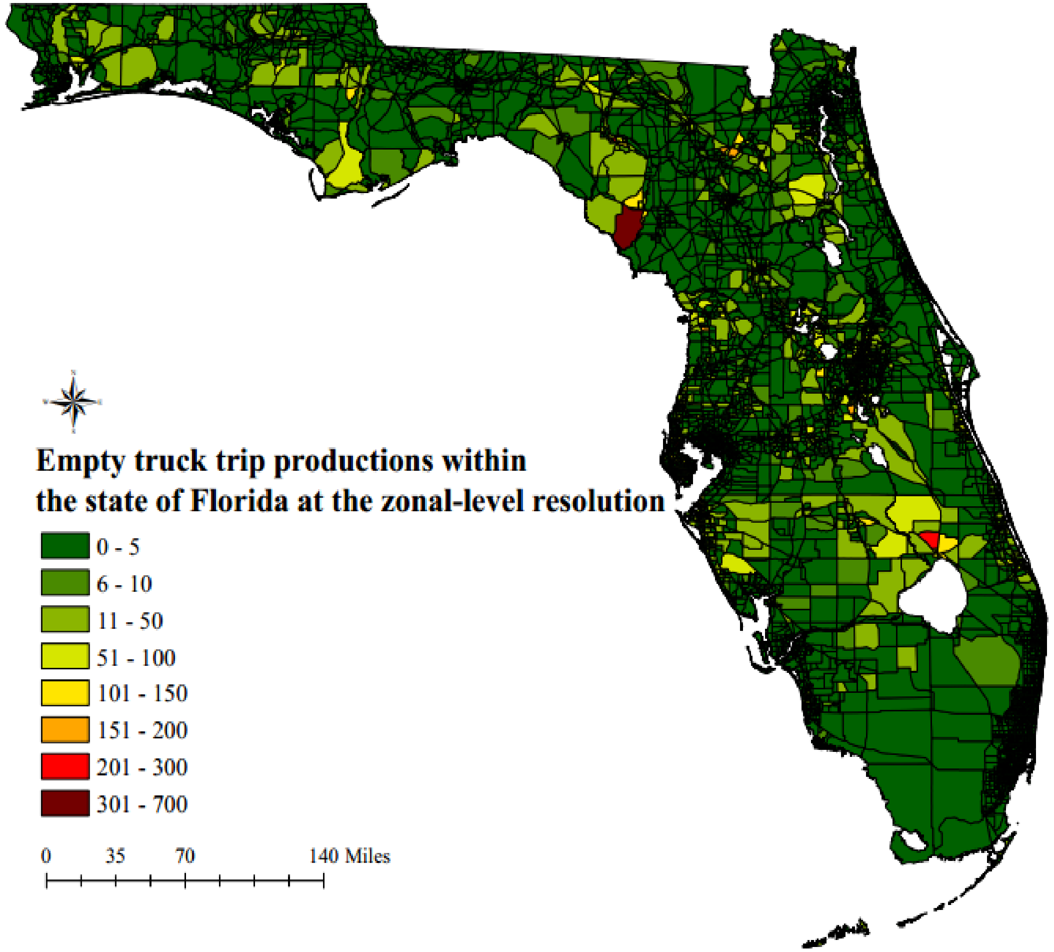


Estimated empty truck flows from Florida to other states in the US



Disaggregated empty truck flows within Florida





Estimated county level average daily empty truck trip attractions within Florida at SWTAZ level resolution

Estimated county level average daily empty truck trip productions within Florida at SWTAZ level resolution

Methodology- Disaggregation of truck flows to newest FLSWM TAZ level (Holguín-Veras and Patil, 2008)

Holguín-Veras, J., and G. R. Patil. A multicommodity integrated freight origin–destination synthesis model. *Networks and Spatial Economics*, Vol. 8, No. 2, 2008, pp. 309-326.

Estimated empty truck flows in TAZ level

Parameters:

- $k, \bar{k}$: OD pairs in TAZ level, $k, \bar{k}$ are in reverse direction
- a_k : observed truck flows
- $w, \bar{w}$: OD pairs in county level,$w, \bar{w}$ are in reverse direction
- p_w : in each OD pair w in county level, estimate empty truck flows of OD pair k as a proportion p of the corresponding truck flows of OD pair $\bar{k}$
- y_{0w}: empty truck flow in OD pair w

Variable:

- $\bar{b}_k$: estimated empty truck flows between OD pair k

- empty truck flows of OD pair k as a proportion p of the corresponding truck flows of OD pair $\bar{k}$.

$$\bar{b}_{\bar{k}} = p_w * a_k, \forall k \in w, \forall \bar{k} \in \bar{w}, \forall w, \bar{w} \in W$$

- sum of estimated empty truck flows $\sum_{\bar{k} \in \bar{w}} \bar{b}_{\bar{k}}$ should be equal to the estimated empty truck flows between OD pair

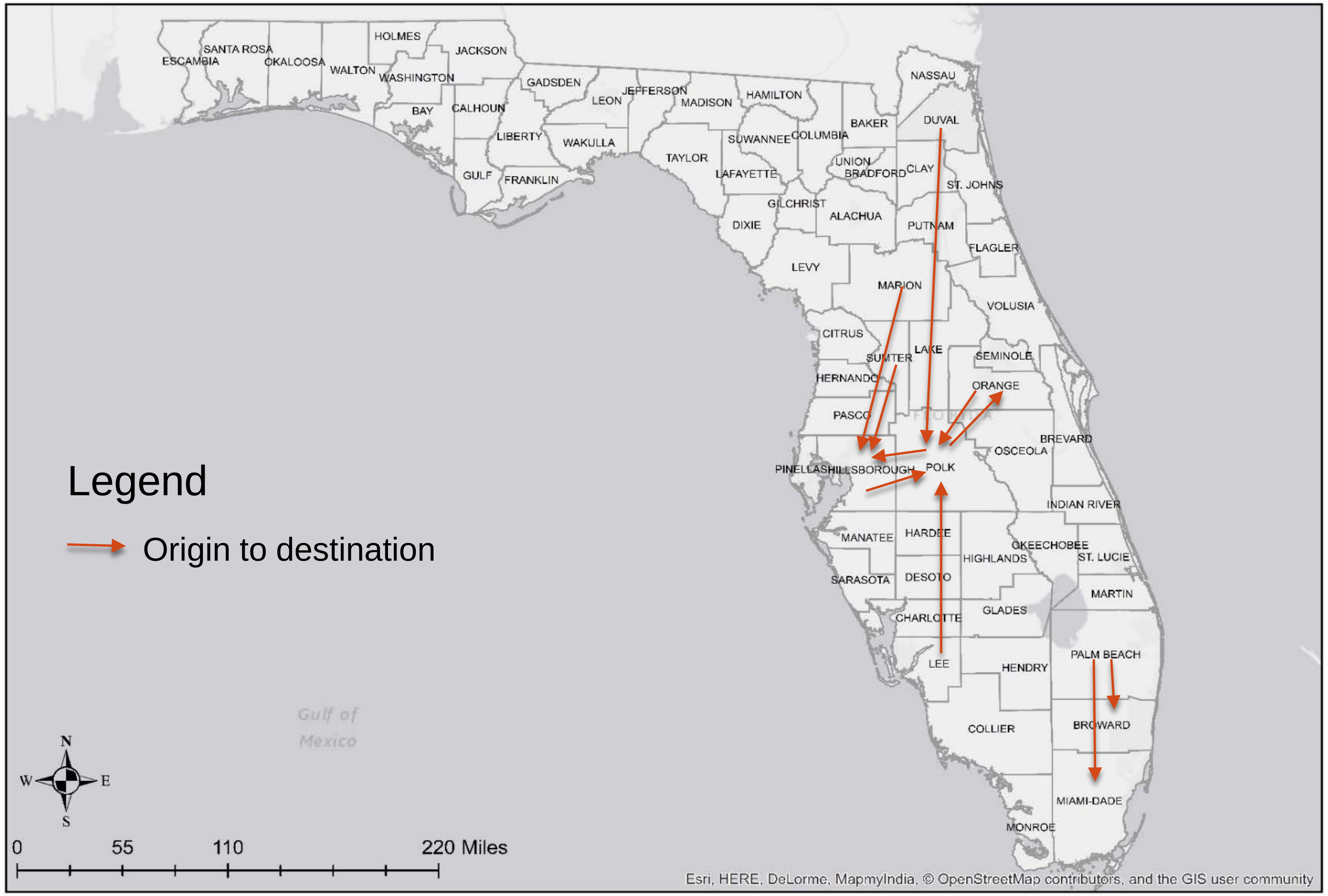
$$\bar{w} \sum_{\bar{k} \in \bar{w}} \bar{b}_{\bar{k}} = y_{0\bar{w}}, \forall \bar{w} \in W$$

- Union above equations and eliminate p_w:

$$\bar{b}_{\bar{k}} = y_{0\bar{w}} * a_k / \sum_{k \in w} a_k$$

Top 10 OD pairs within Florida with highest number of empty flows

Origin	Destination	Average daily empty truck flows
Polk	Orange	447.42
Hillsborough	Polk	311.69
Sumter	Hillsborough	311.27
Palmbeach	Broward	299.00
Palmbeach	Miami Dade	266.32
Orange	Polk	261.06
Lee	Polk	242.67
Duval	Polk	234.11
Marion	Hillsborough	232.22
Polk	Hillsborough	228.84



OD matrix of empty truck flows (deliverable format)

Origin zone \ Destination zone	1	2	3	4	5	6
1	175.37	0.98	0.00	1414.76	0.00	16.24
2	24.86	11015.72	3409.42	23643.44	13107.06	17295.67
3	0.00	7711.57	3730.46	10705.06	869.52	10351.20
4	514.71	14833.50	15086.26	51464.87	505.68	18441.74
5	0.00	12297.87	1055.78	4905.25	550.83	1144.43
6	0.00	18746.29	5225.65	13853.13	4673.33	22603.82
7	2239.04	51737.01	27705.42	111767.81	12362.30	65175.47
8	115.84	10912.60	794.89	13343.40	73.40	6368.06
9	289.42	2868.80	536.16	2346.72	98.89	4733.15

Top 1% OD pairs are highlighted in light red color