An Integrated Framework for Modeling Freight Mode Choice

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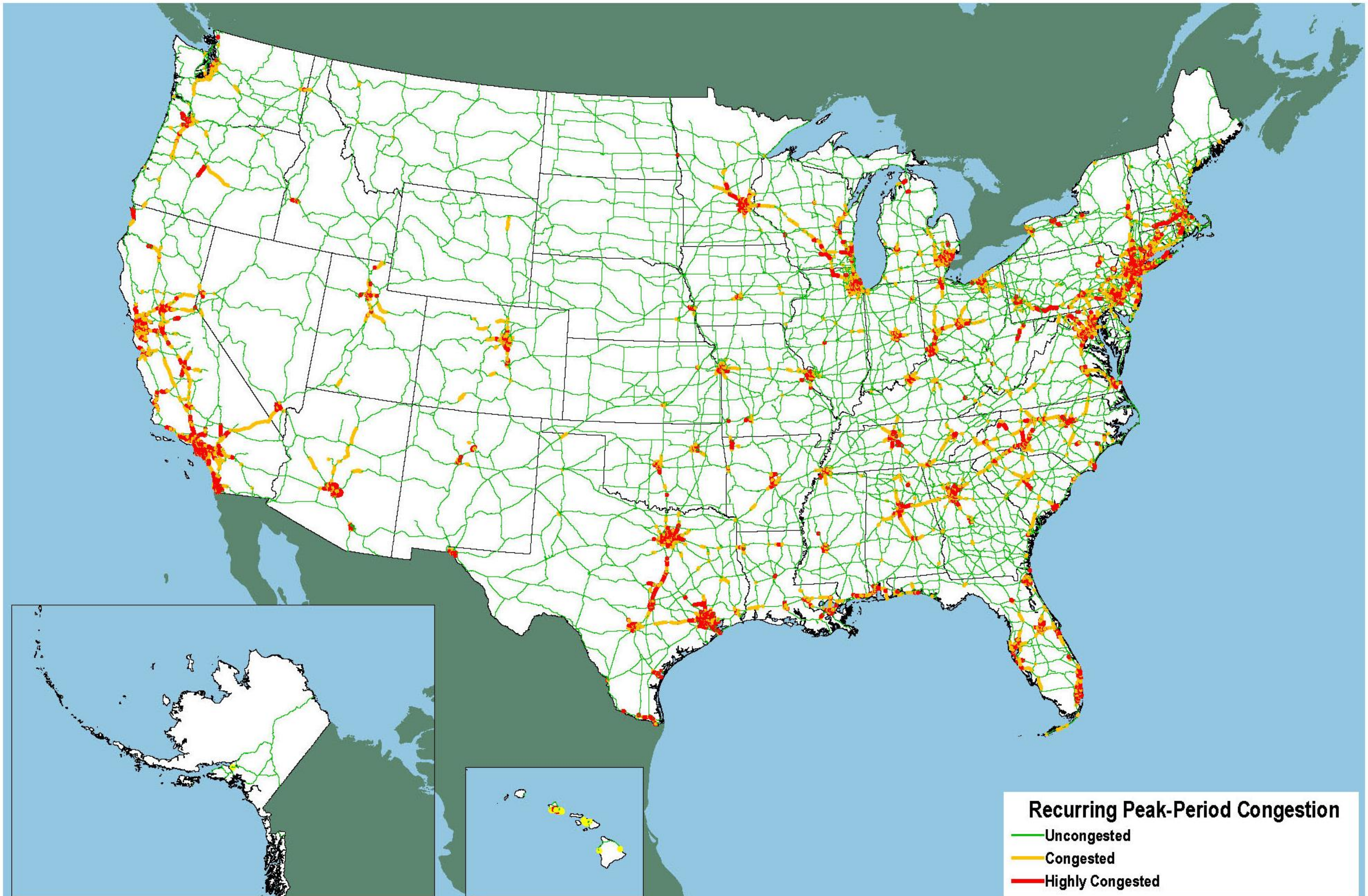
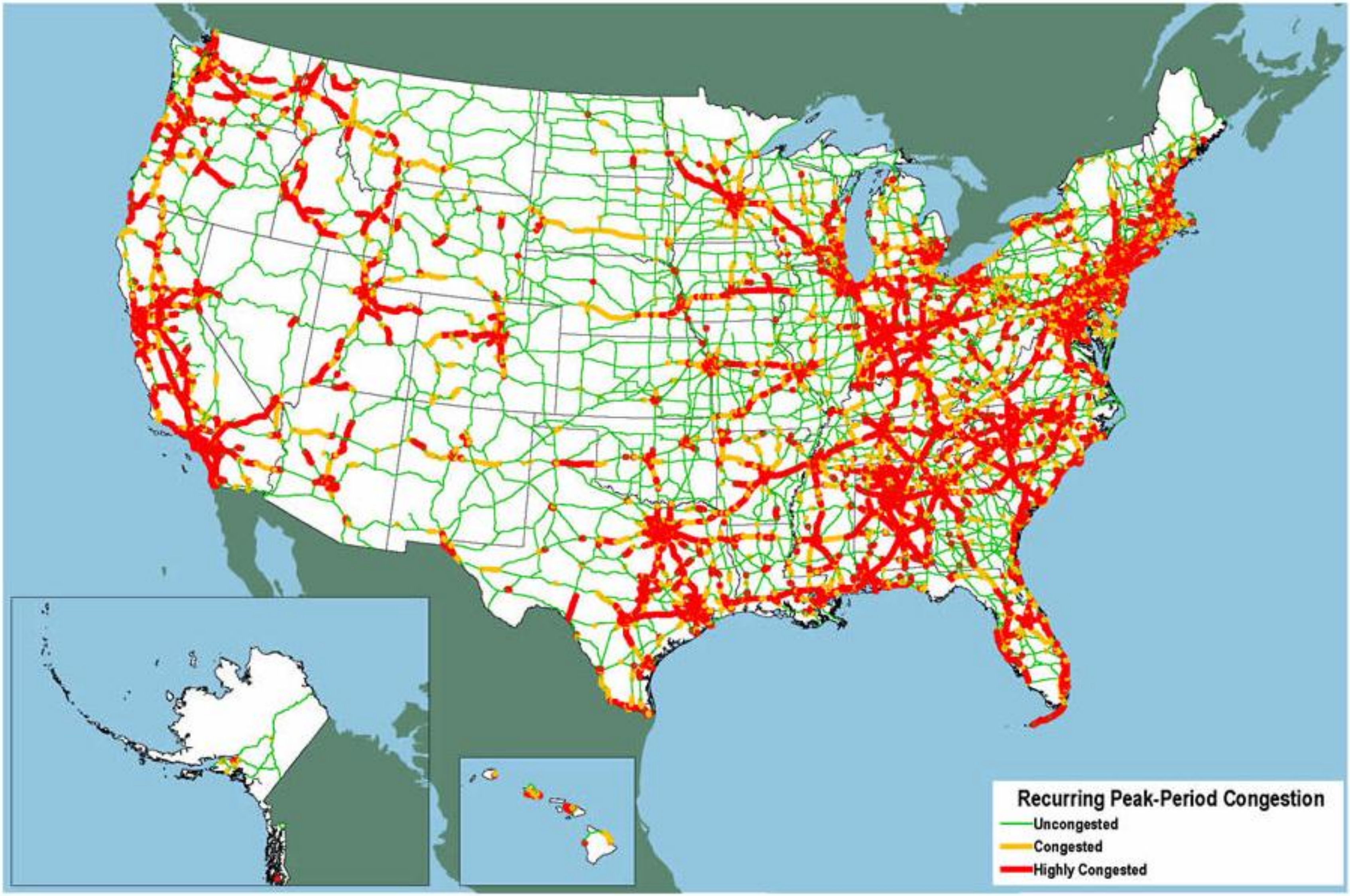
Background

- Growing awareness of freight system
- Thrust at federal, state and local level
- Maryland's freight transportation is estimated
  - To grow about 105% by 2035
  - 1.4 billion of total tons
  - 4.98 trillion of $ value transfer (108% increase from 2006)
- Sustainability of MD corridors to meet the future demand

National Peak Period Congestion-2007 (Freight)



National Peak Period Congestion-2040 (Freight)



Why Freight Mode Choice?

- Freight demand by mode varies by
  - Type of commodity
  - Value and size of commodity
- Travel characteristics near distribution centers
- Finer level geometric detail
- Detailed Origin-Destination analysis within Maryland
- Land use impact on freight flows
- LOS identification and project selection

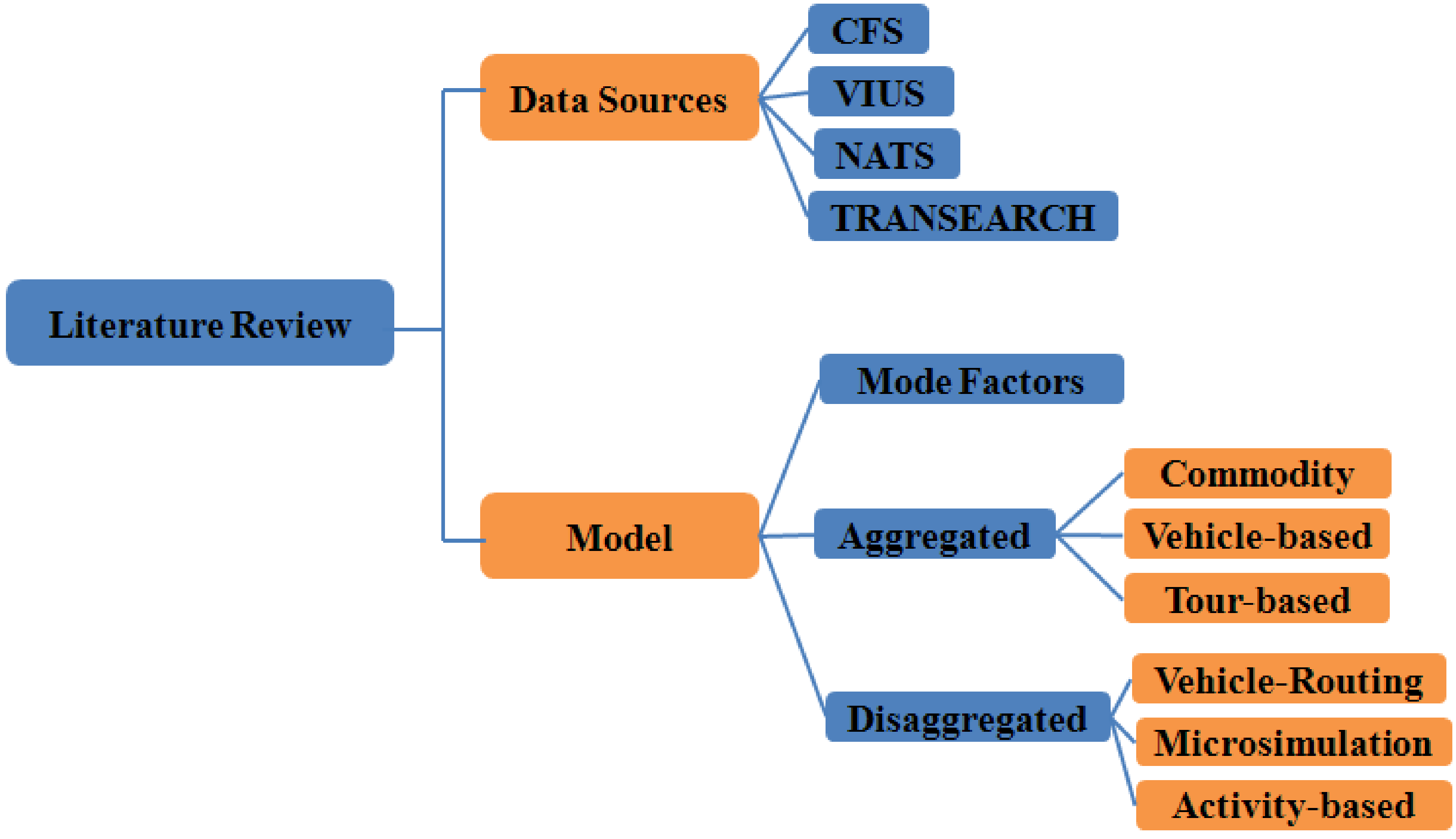
Objectives

- Develop methods to forecast freight shipments
  - By rail
  - By highway
    - Number of trucks
    - Time of day
  - Other
    - Multimodal
    - Other
- Capable of responding to external changes
  - Fuel price
  - New distribution centers
  - Tolling
  - Freight corridors

Mode Choice Factors

- Develop methods to forecast freight shipments
  - By rail
  - By highway
    - Number of trucks
    - Time of day
  - Other
    - Multimodal
    - Other
- Capable of responding to external changes
  - Fuel price
  - New distribution centers
  - Tolling
  - Freight corridors

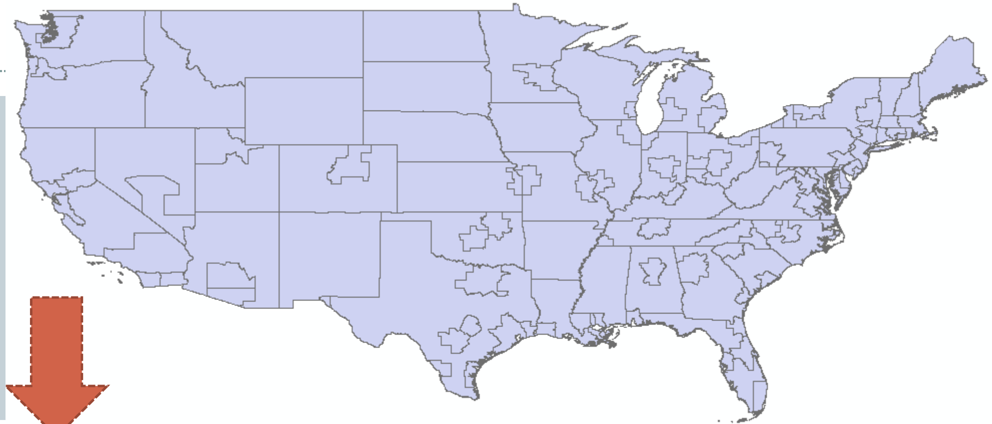
Literature Review Structure



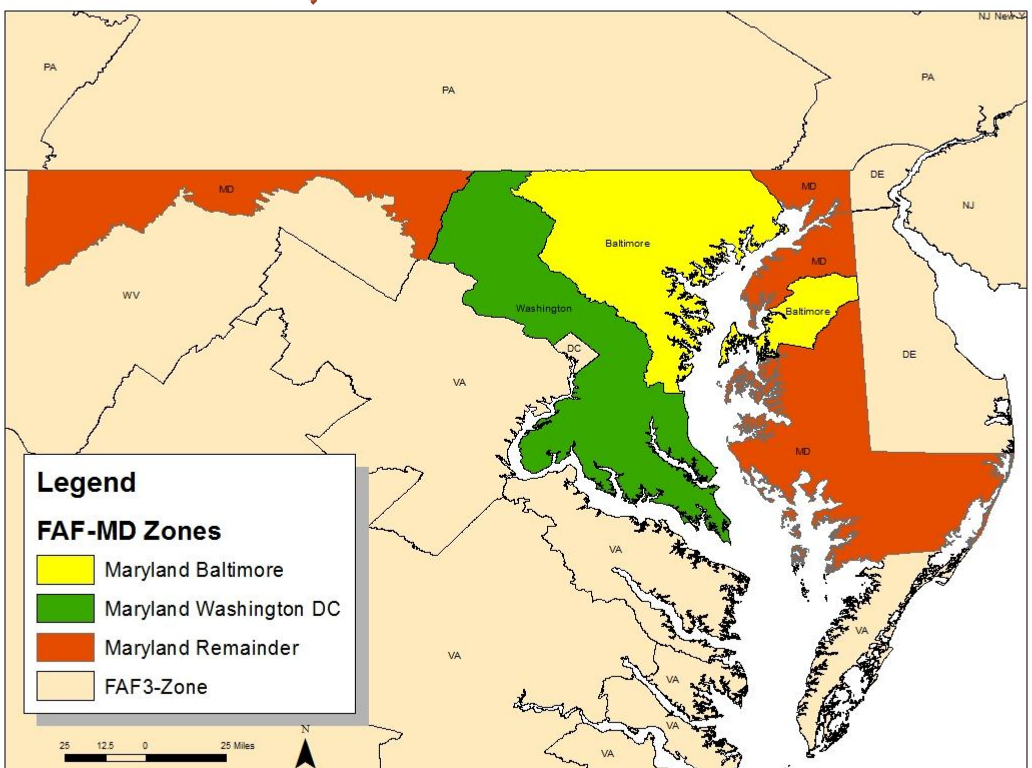
Data

- Available from Freight Analysis Framework (FAF)
  - Annual Macroscopic North American Freight Flow
  - Tons, Value, Distance, Commodity, Mode
  - Derive large scale long distance movements
- Not available from FAF
  - Through trips (route)
  - Short distance internal trips
  - Cost (fuel price, time)
  - Just in time delivery

FAF Zones



131 FAF Zones
123 nationwide
8 international



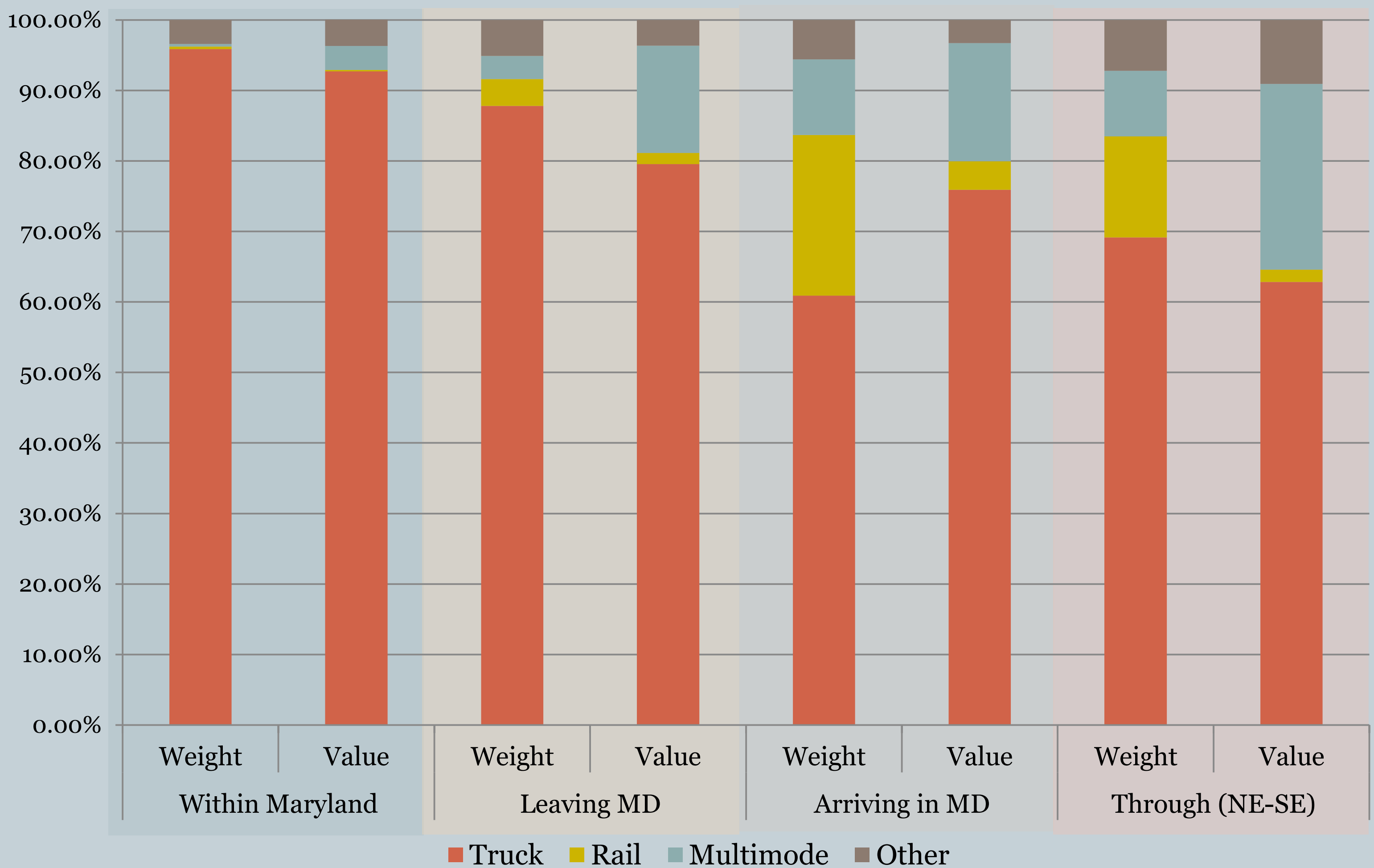
3 MD FAF Zones
- ✓ Baltimore-MD
- ✓ Washington-MD
- ✓ Remainder-MD

Freight in Maryland

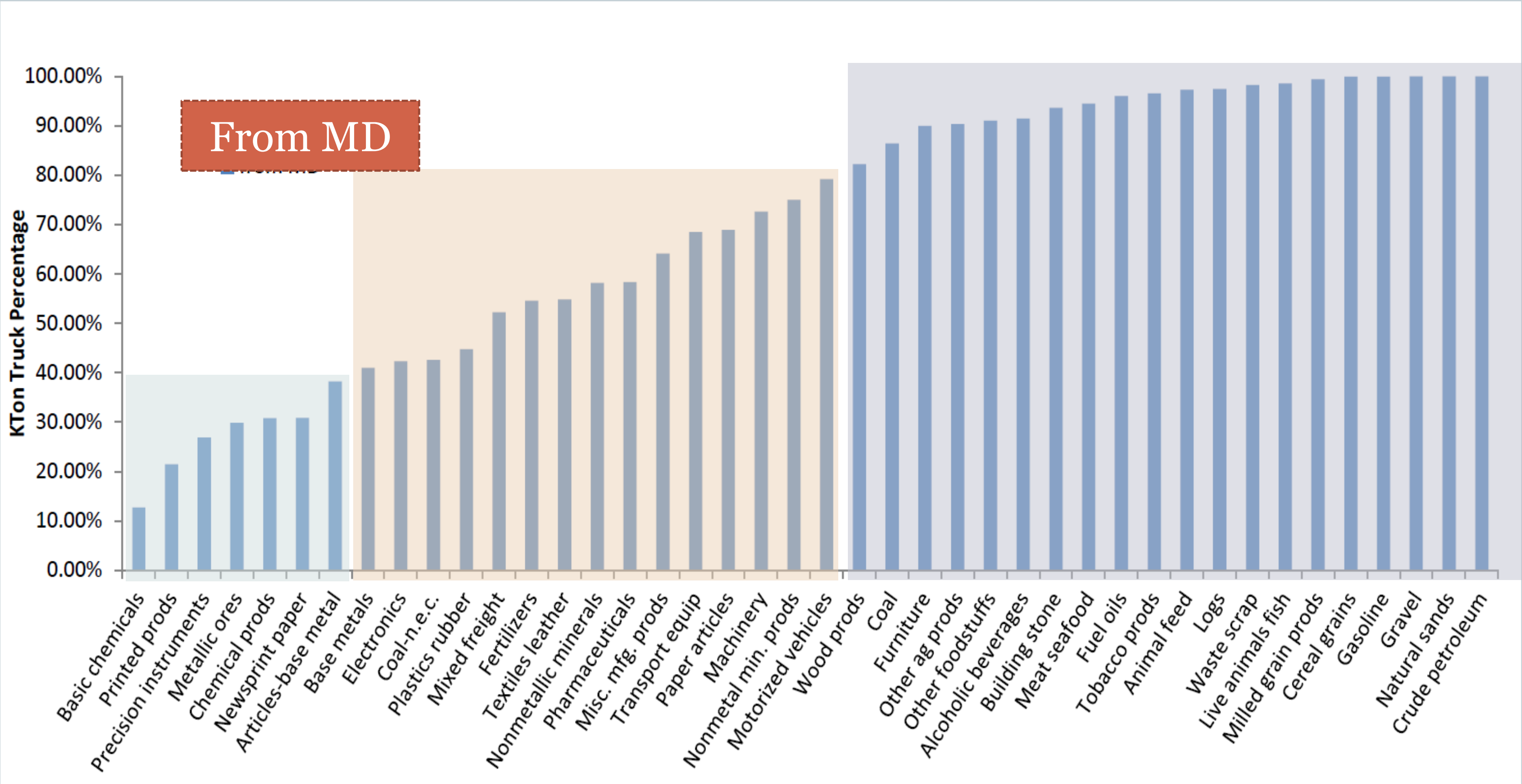
	Within MD	Leaving MD	Arriving in MD	Through (Northeast - Southeast)
Weight (million of tons)	135	84	91	52
Value (billion$)	92	113	169	177
Value/Weight (Thousand $/ton)	0.7	1.3	1.9	3.4

Northeast: CT, ME, MA, NH, NJ, NY, RI,VT
Southeast: FL, GA, NC, SC

External and Internal Trips By Mode



Commodities by Truck(From MD)

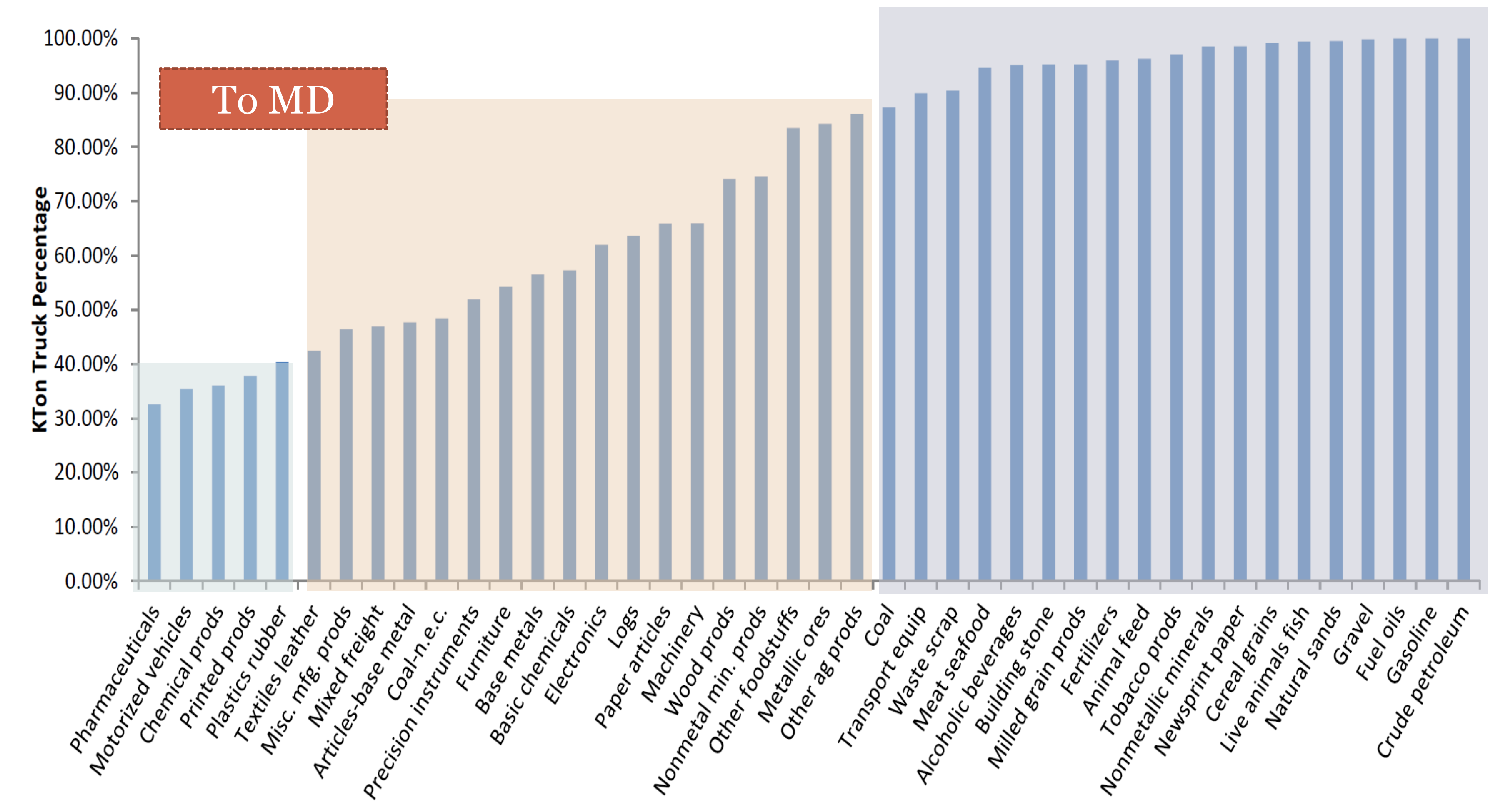


Lower Truck Percentage (<40%)

Medium Truck Percentage (41%-80%)

High Truck Percentage (>80%)

Commodities by Truck (To MD)

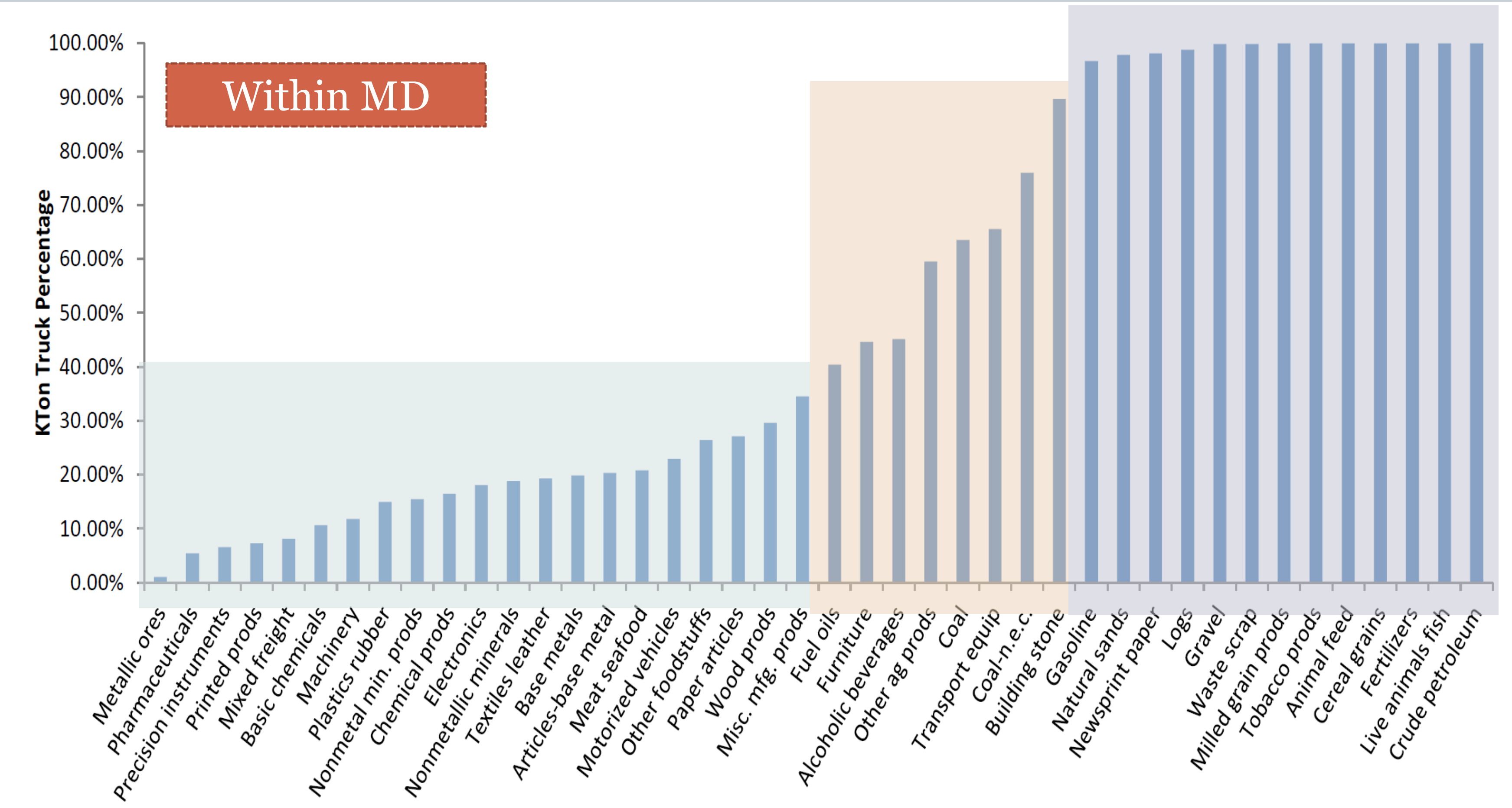


Lower Truck Percentage (<40%)

Medium Truck Percentage (41%-80%)

High Truck Percentage (>80%)

Commodities by Truck (Within MD)



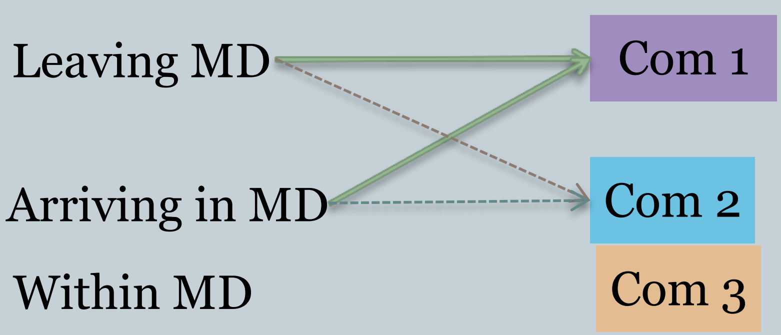
Lower Truck Percentage (<40%)

Medium Truck Percentage (41%-80%)

High Truck Percentage (>80%)

Proposed Model Structure

		From	To			From	To			From	To
1	Live animals fish	3	3	**15**	Coal	3	3	**29**	Printed prods	1	1
2	Cereal grains	3	3	**16**	Crude petroleum	3	3	**30**	Textiles leather	2	2
3	Other ag prods	3	3	**17**	Gasoline	3	3	**31**	Nonmetal min. prods	2	3
4	Animal feed	3	3	**18**	Fuel oils	3	3	**32**	Base metals	2	2
5	Meat seafood	3	3	**19**	Coal-n.e.c.	2	2	**33**	Articles-base metal	1	2
6	Milled grain prods	3	3	**20**	Basic chemicals	1	2	**34**	Machinery	2	2
7	Other foodstuffs	3	3	**21**	Pharmaceuticals	2	1	**35**	Electronics	2	2
8	Alcoholic beverages	3	3	**22**	Fertilizers	2	3	**36**	Motorized vehicles	2	1
9	Tobacco prods	3	3	**23**	Chemical prods	1	1	**37**	Transport equip	2	3
10	Building stone	3	3	**24**	Plastics rubber	2	1	**38**	Precision instruments	1	2
11	Natural sands	3	3	**25**	Logs	3	2	**39**	Furniture	3	2
12	Gravel	3	3	**26**	Wood prods	3	2	**40**	Misc. mfg. prods	2	2
13	Nonmetallic minerals	2	2	**27**	Newsprint paper	1	3	**41**	Waste scrap	3	3
14	Metallic ores	1	3	**28**	Paper articles	2	2	**43**	Mixed freight	2	2



4 models for different OD and Commodities

Proposed Method

- Aggregated analysis
- Using land use as the factor
- Logistic Regression Models

$$logit(P_{ij}) = X_{ij}\beta_j + \varepsilon_{ij}$$

- P_{ij} is the probability of Truck Tonnage share
- X_{ij} is the Info of distribution centers, highway/railway coverage, transportation/warehousing employment.

Proposed Model Structure

Summation of all group 1 tonnage from MD

	1	2	…	123
…				
…				
48	$w_{48.1}$	$w_{48.2}$		$w_{48.123}$
49	$w_{49.1}$			
50	$w_{50.1}$			$w_{50.123}$
…				

Summation of all group 1 truck tonnage from MD

	1	2	…	123
…				
…				
48	$T_{48.1}$	$T_{48.2}$		$T_{48.123}$
49	$T_{49.1}$			
50	$T_{50.1}$			$T_{50.123}$
…				

$$log\left(\frac{\frac{T_{o.d}}{w_{o.d}}}{1-\frac{T_{o.d}}{w_{o.d}}}\right) = X_{ij}\beta_j + \varepsilon_{ij}$$

$$=\beta_0 + \beta_1 Dist + \beta_2(DC_O) + \beta_3(DC_D) + \beta_4(Cov_O) + \beta_5(Cov_D) + \beta_6(Emp_O) + \beta_7(Emp_D) \ldots + \varepsilon_{ij}$$

Example: From MD group1

Parameter		Estimates	95% CI Lower	95% CI Upper	Wald Chi-Square	Sig.
(Intercept)	X0	.431	-2.580	3.442	.079	.779
Highway distance	X1	-.002	-.003	-.001	19.315	.000
# Origin zone truck center	X2	2.463	.417	4.508	5.569	.018
# Origin zone rail center	X3	-.164	-.272	-.055	8.766	.003
# Destination zone truck center	X4	.414	.108	.720	7.018	.008
# Destination zone rail center	X5	-.024	-.056	.007	2.265	.132
# Destination zone port center	X6	.286	-.075	.647	2.412	.120
# Destination zone Trans employment (10K)	X7	-.133	-.310	.044	2.160	.142

- The share of truck $P_t = \frac{\exp(y)}{1+\exp(y)}$
- $y = 0.431 - 0.002X1 + 2.463X2 - 0.164X3 + 0.414X4 - 0.024X5 + 0.286X6 - 0.133X7$

Example: From MD group1

Parameter		Estimates
(Intercept)	X0	.431
Highway distance	X1	-.002
# Origin zone truck center	X2	2.463
# Origin zone rail center	X3	-.164
# Destination zone truck center	X4	.414
# Destination zone rail center	X5	-.024
# Destination zone port center	X6	.286
# Destination zone Trans employment (10K)	X7	-.133

- For this group of commodities, the total truck share from MD is less than 40%.
- The truck percentage share decrease with longer distance between the Origin and Destination zone.
- The number of truck-truck centers in MD influence the truck share dramatically.
- More number of rail centers in MD reduce the truck share.
- Truck share is high to the destination zone with more truck and port oriented centers and less rail centers, and less transportation/warehousing employment.

Example: From MD group1

- The total group 1 commodity shipped from Baltimore (MD MSA) to Denver (CO CSA)
  - P_t=62.3%
- If there is one more port related distribution center in Baltimore
  - The truck share does not change.
- If there is one more truck center in Baltimore
  - P_t=95.1%
- If there is one more rail center in Baltimore
  - P_t=58.3%

Example: From MD group1

- If the Destination zone is Jacksonville (FL MSA)
  - Distance reduces from 1,591 m to 756m.
  - Employment reduces from 5.17 to 3.22 10K.
  - P_t=91.9%
- With one more port-truck distribution center in Baltimore
  - The truck share does not change.
- If there is one more truck center in Baltimore
  - P_t=99.3%
- If there is one more rail center in Baltimore
  - P_t=90.6%

Example: From MD group2

Parameter		Estimates	95% CI Lower	95% CI Upper	Wald Chi-Square	Sig.
(Intercept)	X0	.689	-.542	1.920	1.204	.273
Highway distance	X1	-.002	-.003	-.002	65.168	.000
# Destination zone rail center	X2	-.022	-.044	.000	3.676	.055
Destination zone Principal arterial percentage out of total highway and rail mileage	X3	3.660	.822	6.498	6.388	.011
# Destination zone Trans employment (10K)	X4	.112	.013	.210	4.956	.026

- For this group of commodities, the truck share from MD ranges from 40% to 80%.
- The characteristics in Maryland do not impact the truck share.
- The truck share only depends on the destination zone.
- The truck is preferred to the zones closer to Maryland, with less rail distribution centers, higher Principal Arterial roadway and more transportation related employments.

Example: To MD group1

Parameter		Estimates	95% CI Lower	95% CI Upper	Wald Chi-Square	Sig.
(Intercept)	X0	2.720	2.019	3.421	57.850	0.000
Highway distance	X1	-0.001	-0.001	0.000	3.981	0.046
# Origin zone port related distribution center	X2	-0.158	-0.373	0.058	2.060	0.151
Destination zone rail center percentage	X3	-2.020	-3.246	-0.794	10.431	0.001
# Origin zone Trans employment (10K)	X4	0.040	-0.023	0.102	1.565	0.211

- The percentage of rail oriented distribution centers in Maryland is negative related with the truck share.
- The truck share also depends on the origin zone # port related centers, transportation employments.
- The truck is preferred from the zones closer to Maryland, with less port distribution centers, and more transportation related employments.

Example: To MD group2

Parameter		Estimates	95% CI Lower	95% CI Upper	Wald Chi-Square	Sig.
(Intercept)	X0	3.055	1.351	4.760	12.340	.000
Highway distance	X1	-.002	-.003	-.002	54.749	.000
Origin zone percentage of rail miles out of total highway and rail mileage	X2	-3.576	-7.274	.123	3.590	.058
# Origin zone Trans employment (10K)	X3	.074	.000	.147	3.882	.049

- The characteristics in Maryland do not impact the truck share.
- The truck is preferred from the zones closer to Maryland, with more transportation related employments.

Choice Model for Rail

	Parameter	B	95% Wald Confidence Interval		Hypothesis Test
			Lower	Upper	Wald Chi-Square
Group1 Commodity from MD	(Intercept)	5.525	2.933	8.117	17.46
	Truck_dist	-0.001	-0.002	0	6.533
	D_Port	0.29	-0.002	0.582	3.783
	D_PAHwy_P	-12.539	-17.422	-7.655	25.324
Group2 Commodity from MD	(Intercept)	3.822	-0.862	8.506	2.557
	Truck_dist	-0.002	-0.003	-0.001	23.284
	D_truck	-0.228	-0.381	-0.075	8.536
	D_PAHwy_P	-14.252	-20.424	-8.08	20.486
Group1 Commodity to MD	(Intercept)	-2.339	-4.357	-0.32	5.158
	Truck_dist	-0.001	-0.002	0	6.233
	O_truck	-0.276	-0.461	-0.091	8.558
	O_rail	0.155	0.101	0.209	31.586
	D_TC_P	-6.958	-12.129	-1.787	6.954
Group2 Commodity to MD	(Intercept)	7.195	4.799	9.592	34.62
	Truck_dist	0	-0.001	-6.50E-05	5.541
	O_truck	0.127	0.008	0.246	4.349
	O_rail	0.044	0.019	0.069	11.756
	D_TC_P	-2.173	-3.488	-0.858	10.495
	D_RC_P	-5.759	-8.147	-3.372	22.361
	O_PAHwy_P	-8.946	-12.704	-5.188	21.774

Sensitivity Analysis Results

	Parameter		48	49	50
Group 1 from MD	# Origin zone truck center	X2	1.2314	1.209	1.0761
	# Origin zone rail center	X3	0.9763	0.9783	0.9904
	# Destination zone truck center	X4	1.0545	1.0498	1.0213
	# Destination zone rail center	X5	0.9966	0.9969	0.9986
	# Destination zone port center	X6	1.0384	1.0351	1.0152
	# Destination zone Trans employment (10K)	X7	0.9809	0.9825	0.9923
Group 2 from MD	# Destination zone rail center	X2	0.9930	0.9931	0.9928
	Destination zone principal arterial percentage out of total highway and rail mileage (1%)	X3	1.0115	1.0114	1.0120
	# Destination zone Trans employment (10K)	X4	1.0352	1.0349	1.0366
Group 1 to MD	# Origin zone port related distribution center	X2	0.9474	0.9713	0.9413
	Destination zone rail center percentage (1%)	X3	0.9934	0.9964	0.9926
	# Origin zone Trans employment (10K)	X4	1.0131	1.0069	1.0147
Group 2 to MD	Origin zone percentage of rail miles out of total highway and rail mileage (1%)	X2	0.9883	0.9883	0.9878
	# Origin zone Trans employment (10K)	X3	1.0242	1.0240	1.0252

Summary

- For Group 1 commodities, number of truck and rail centers will influence the percentage of tonnage carried by truck.
- For Group 2 commodities, the percentage of truck tonnage only depends on the characteristics of the opposite zones.
- The distance is a dominant variables related to truck share.
- The principal arterial highway and rail coverage in the opposite zones are related to truck share for group 2, not group 1.
- Number of transportation/warehousing employments in the opposite zones is significant.
- Variables such as highway and rail coverage in MD and employment in MD is not related.

Potential Applications

- Forecast of Future Freight Demand
- Expansion of the Port of Baltimore
  - Expansion of Panama Canal and Northwest passage
- Prevent Infrastructure Bottlenecks
  - Intermodal Facilities
  - Truck Distribution Centers
- Economic Analysis
  - Project selection
  - Dollars lost by not providing infrastructure

Thank You!