Freight Surveys and Modeling - Lessons from Toronto

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Freight Transportation Modeling

Why is Freight Relevant?

- Freight transportation is essential for economic development
- Freight flows grow with the economy and not necessarily with the population
- Freight role in economic resilience:
  - Supply chain disruptions – COVID 19
  - Shifting trade dynamics
  - Global events
  - Labor challenges
- Freight flows are increasing
  - Transportation infrastructure capacity
- Changing consumer behavior in urban areas

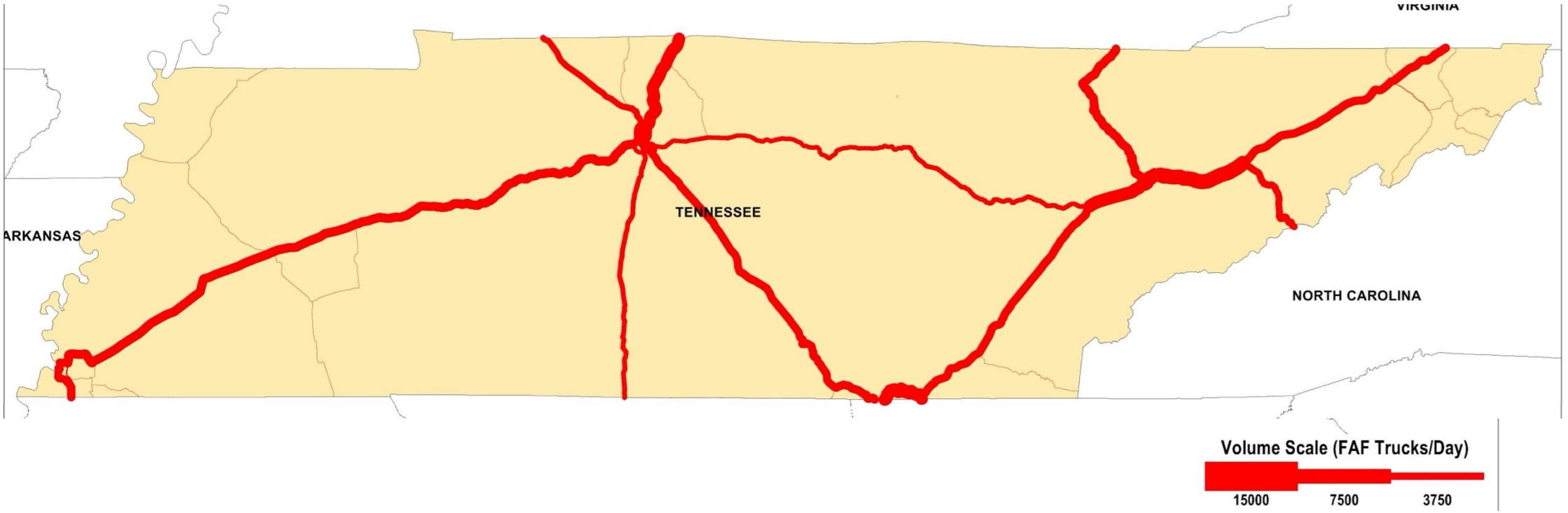
Why is Freight Relevant?

Table 3-1 Gross Output of Freight System–Dependent Industry Sectors: 2017–2023 (Billions of 2017 Chained Dollars)

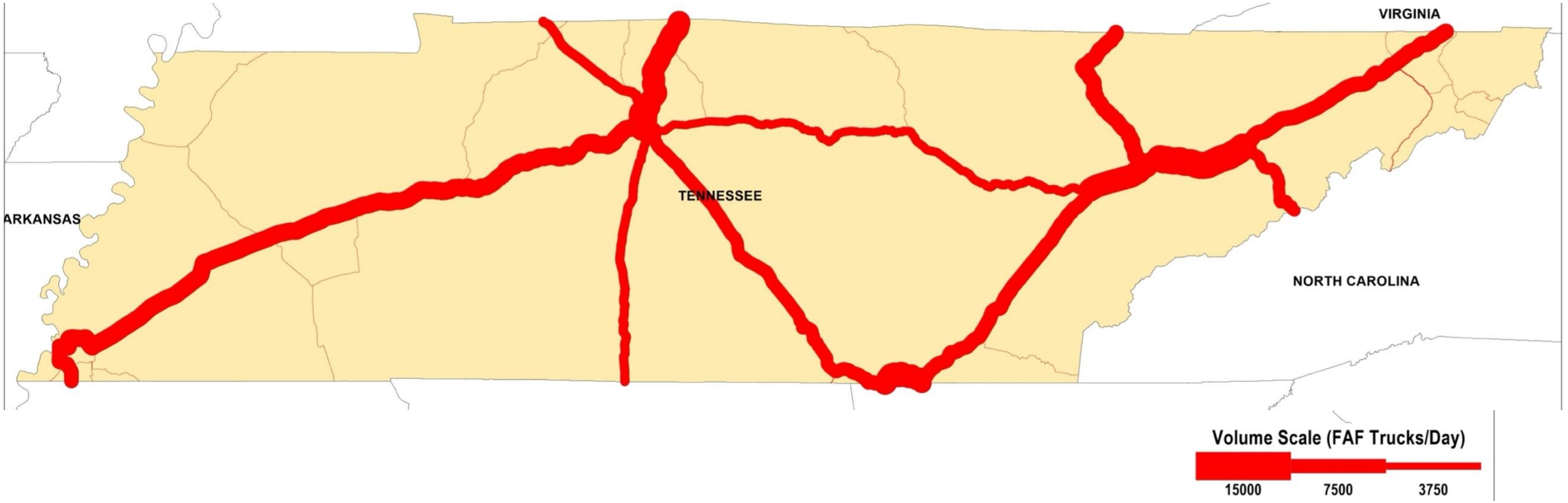
Industry sector*	2017	2018	2019	2020	2021	2022	2023
TOTAL	**13,768.1**	**14,181.9**	**14,165.9**	**13,446.8**	**14,177.3**	**14,231.4**	**14,301.3**
Agriculture, forestry, fishing, and hunting	448.9	447.2	440.1	454.5	454.8	434.8	444.5
Mining	462.8	536.2	568.2	471.8	501.7	531.9	539.8
Utilities	474.1	496.4	492.9	481.5	492.5	507.1	501.5
Construction	1,578.0	1,601.3	1,614.9	1,643.6	1,669.3	1,564.3	1,610.5
Manufacturing	5,676.6	5,786.4	5,724.7	5,335.3	5,498.2	5,541.9	5,629.0
Wholesale trade	2,053.9	2,115.5	2,089.1	1,986.7	2,203.5	2,198.7	2,068.5
Retail trade	1,846.9	1,914.6	1,932.0	1,931.2	2,089.5	2,092.2	2,163.4
Transportation and warehousing	1,226.9	1,284.3	1,304.0	1,142.2	1,267.8	1,360.5	1,344.1

Source: DOT Transportation Statistics Annual Report 2024

Truck Flows 2012



Truck Flows 2045



Why is Freight Different?

- More diversity than person travel (commodity type, truck types)
- Heterogeneity among industry types
- Business establishments vs. firms
- Decision-maker:
  - Passenger: individuals & households
  - Freight: businesses (shippers, carriers, receivers) - complex to determine who is making the decisions (vehicle type, shipment size)
- Growth rate is faster than for personal travel
- Willingness to pay does not depend on driver but on shipment

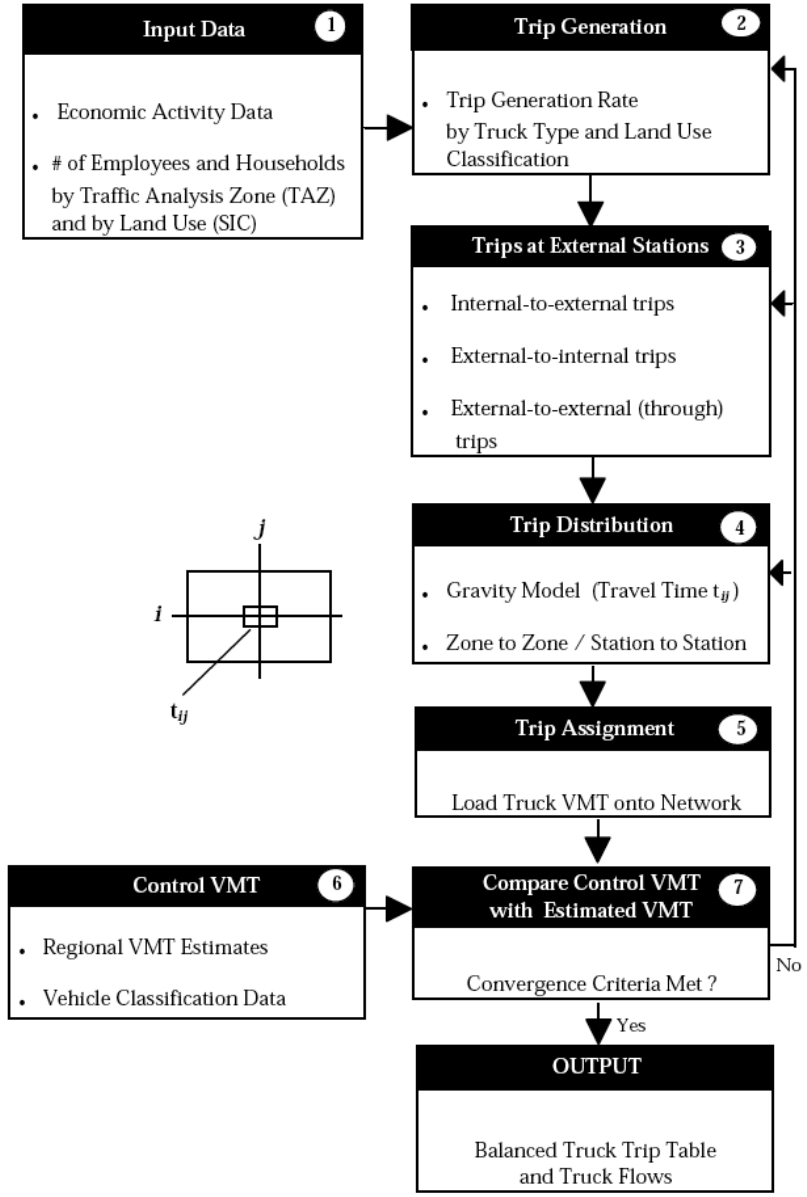
Why is Freight Different?

- Trucks contribute disproportionally to:
  - Congestion as they are slower moving vehicles and larger in size
  - Wear and tear on transportation infrastructure
  - Roadway safety conditions
  - Competition for curbside space - parking
  - Transportation Emissions
- Restrictions on using transportation infrastructure
- Changing freight trends
  - Same-day deliveries
  - Proximity logistics
  - New freight technologies

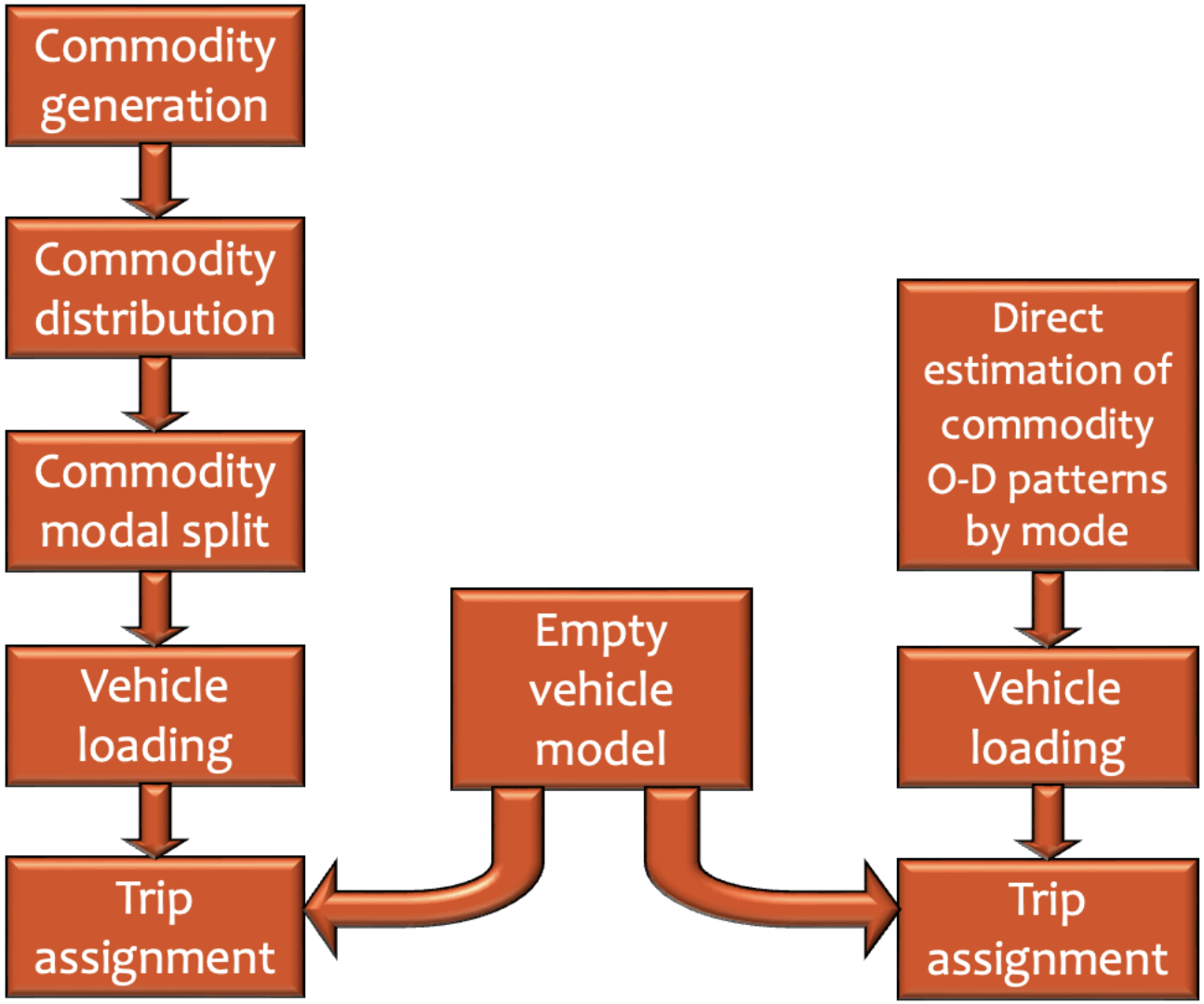
Freight Modeling - Overview

- Aggregate modeling
  - Trip-based modeling
  - Commodity-based modeling
- Disaggregate modeling
  - Tour-based modeling
  - Agent-based modeling

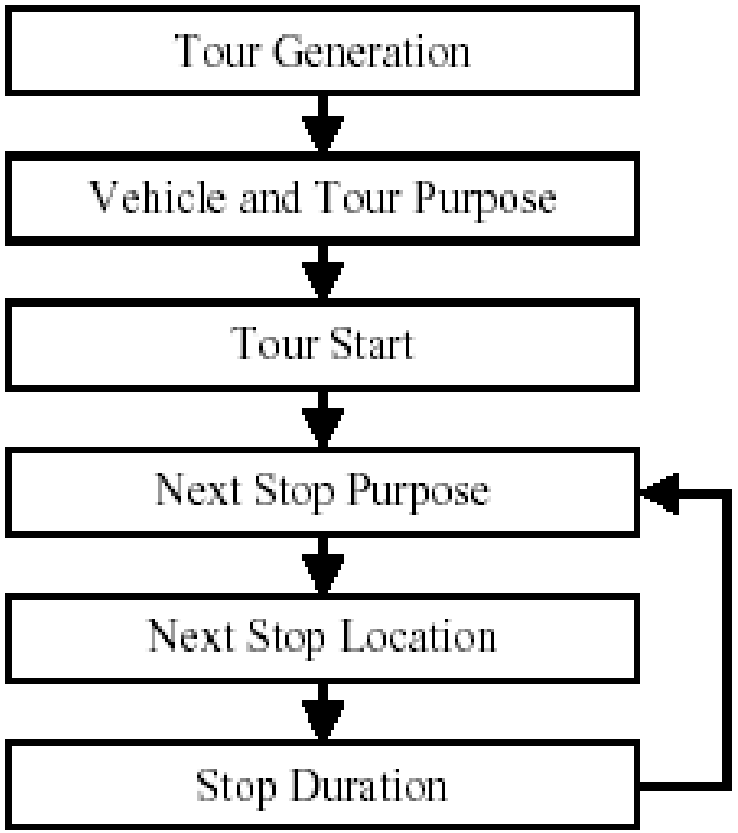
Trip-Based Models



Commodity-Based Models

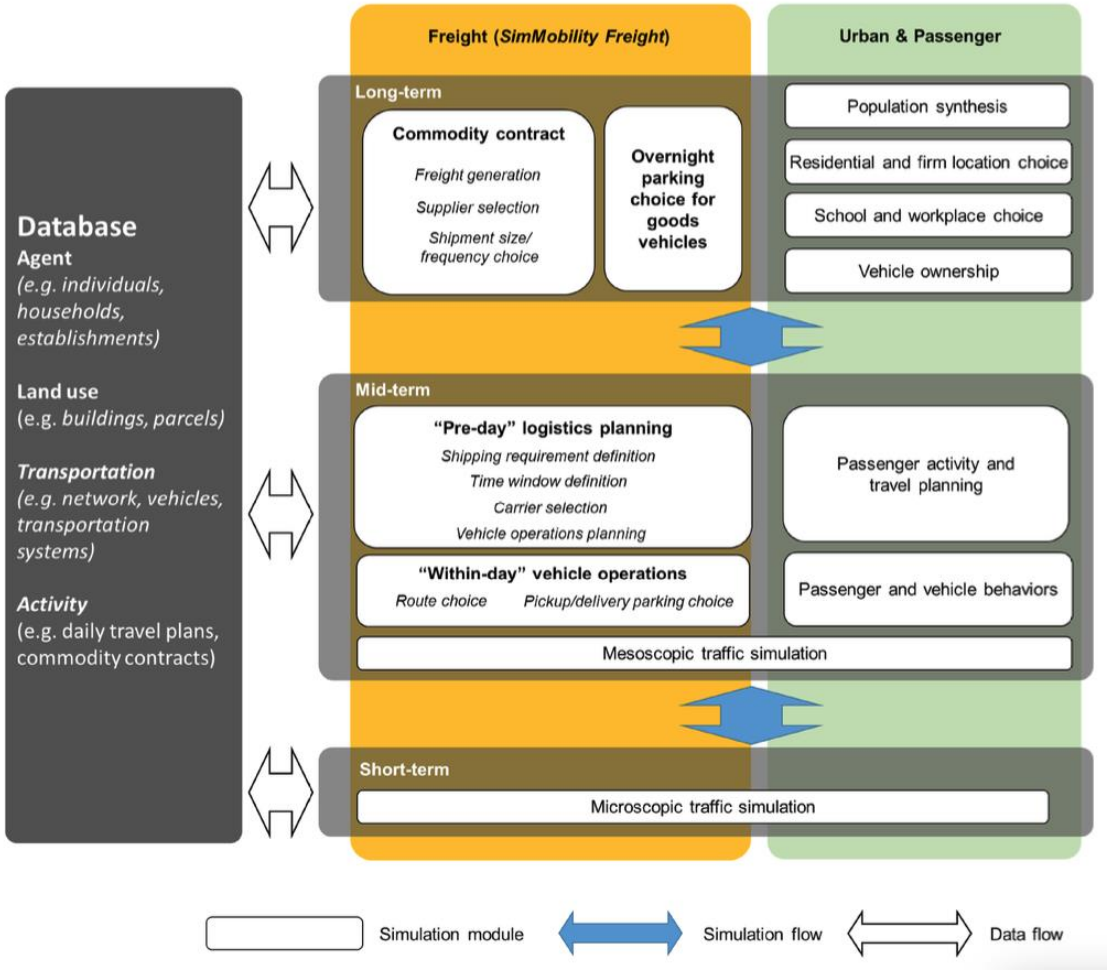


Tour-Based Models

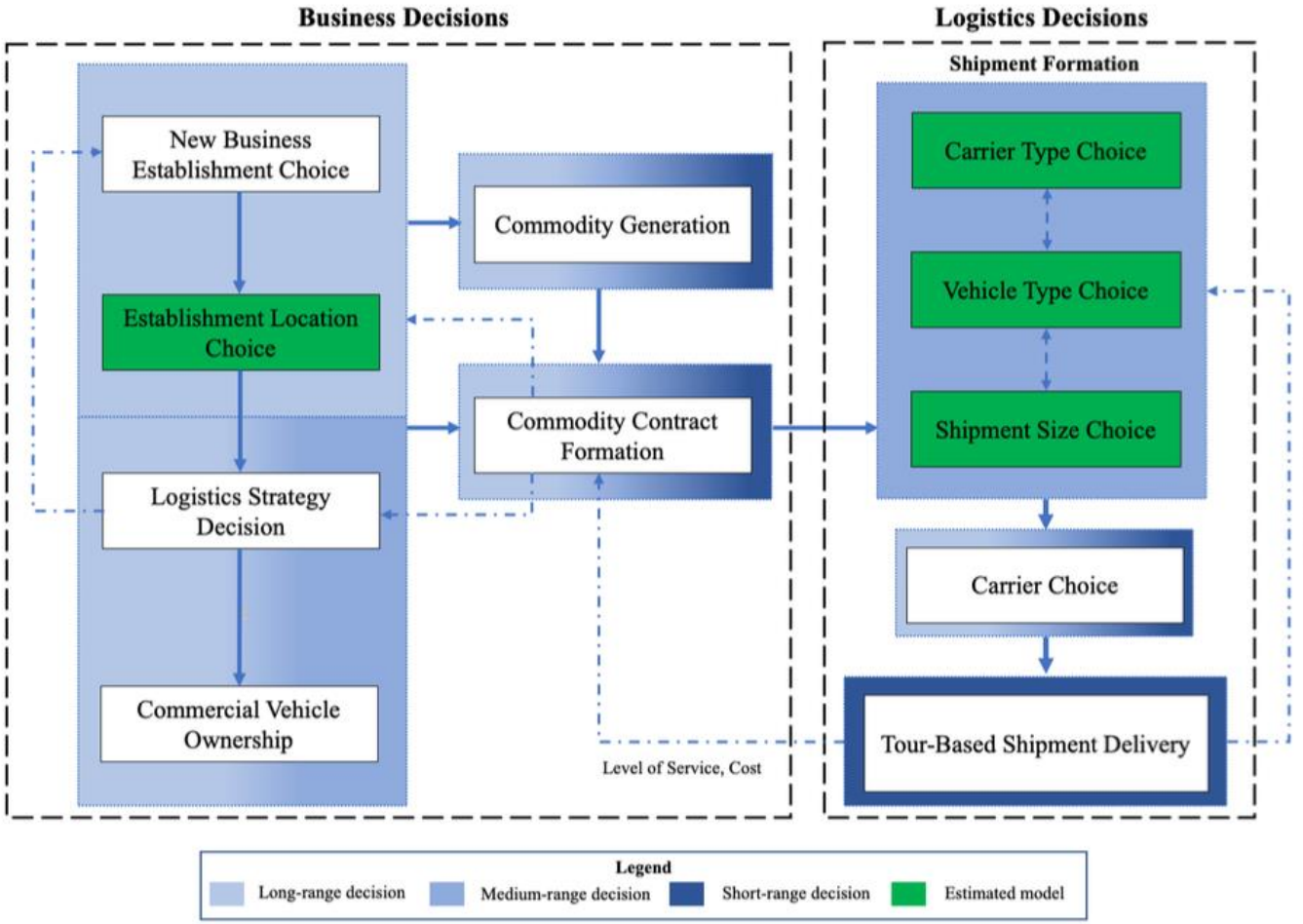


Hunt, J. D., & Stefan, K. J. (2007). Tour-based microsimulation of urban commercial movements. *Transportation Research Part B: Methodological*, *41*(9), 981-1013.

Agent-Based Models



SimMobility Freight (MIT)



Freight Business and Logistics Decisions Simulation (Ahmed, 2022)

Freight Modeling - Challenges

Trip-based models

- Limited representation of supply chains characteristics
- Limited policy analysis
- Most commonly used by public agencies - model development and operations

Agent-based models

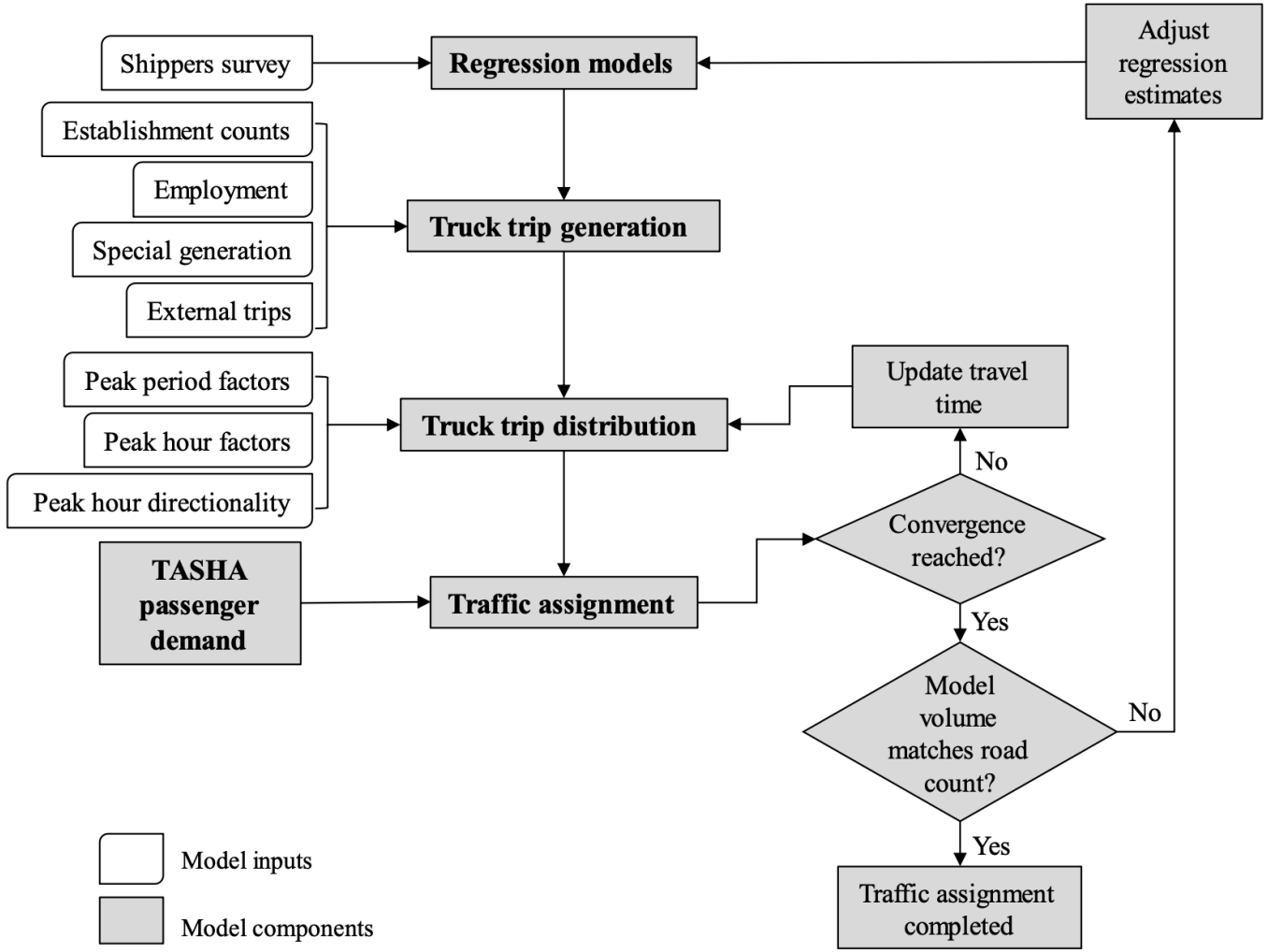
- Can represent complex supply chains and industry structure
- Data requirements
- Complex to maintain

Solution?

- Improve trip-based models by addressing shortcomings
- Representation of supply chain and industry structure
- Improved policy analysis

Toronto Freight Model

Toronto Freight Model



Chowdhury, T., Vaughan, J., Saleh, M., Mousavi, K., Hatzopoulou, M., & Roorda, M. J. (2022). Modeling the Impacts of Off-Peak Delivery in the Greater Toronto and Hamilton Area. *Transportation Research Record*, *2676*(10), 413-425.

Toronto Freight Model – Applications

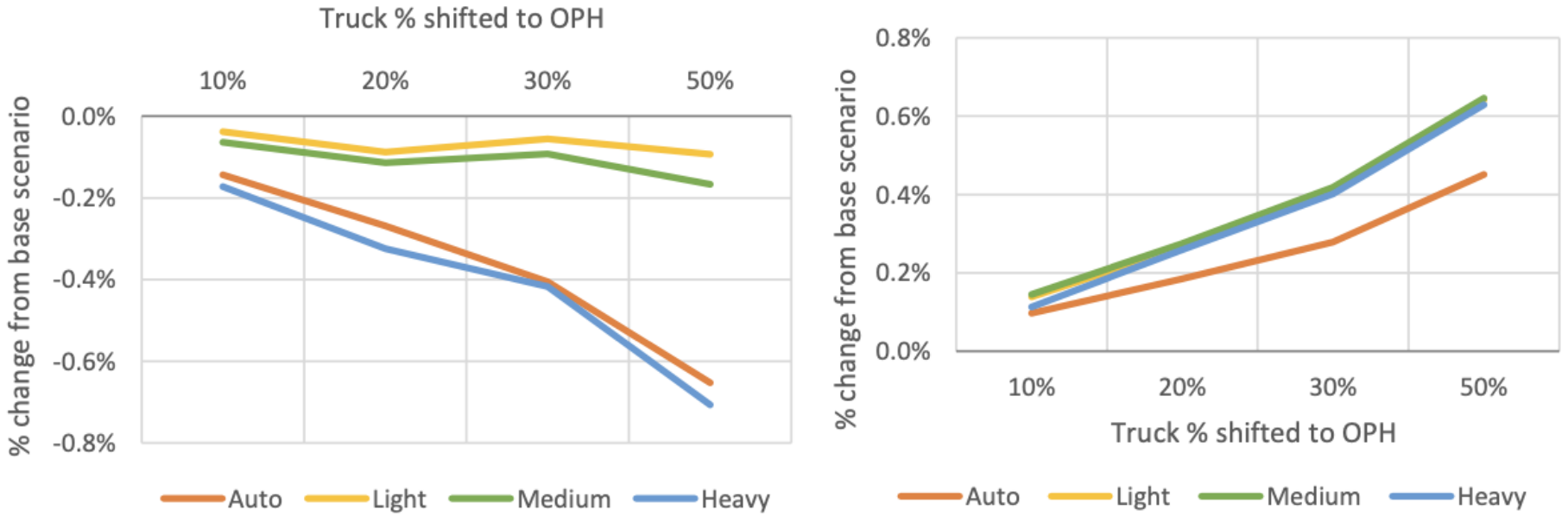
- Forecasting of freight flows
- Freight policy analysis
  - Off-peak deliveries
  - Freight automated vehicles
- Commercial vehicle parking*
- Electric-cargo tricycles for last-mile deliveries**

* Ghizzawi, Farah; **Ahmed, Usman**; Roorda, Matthew. Parking Patterns of Last-Mile Delivery Vehicles: A Comparison Between Light-Duty Trucks and Electric Cargo Tricycles in Downtown Toronto. *Under Review in Transportation Research Interdisciplinary Perspectives.*

** **Ahmed, Usman**; Xu, Junshi; Ghizzawi, Farah; Saeedi, Milad; Hatzopoulou, Marianne; Roorda, Matthew. Urban Goods Movement using E-Cargo Tricycle: A Pilot Study in Toronto. Working paper

Toronto Freight Model – Off-Peak Deliveries

- Shifting truck traffic to off-peak hours (12am – 6am)
- Industry: Retail Trade (RT), Wholesale Trade (WT), and Accommodation and Food Sector (AF)

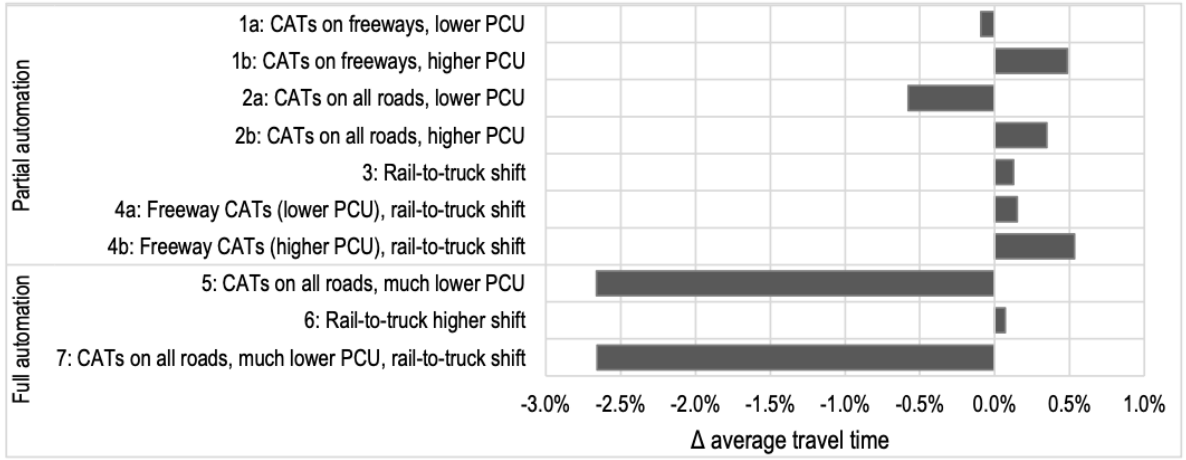


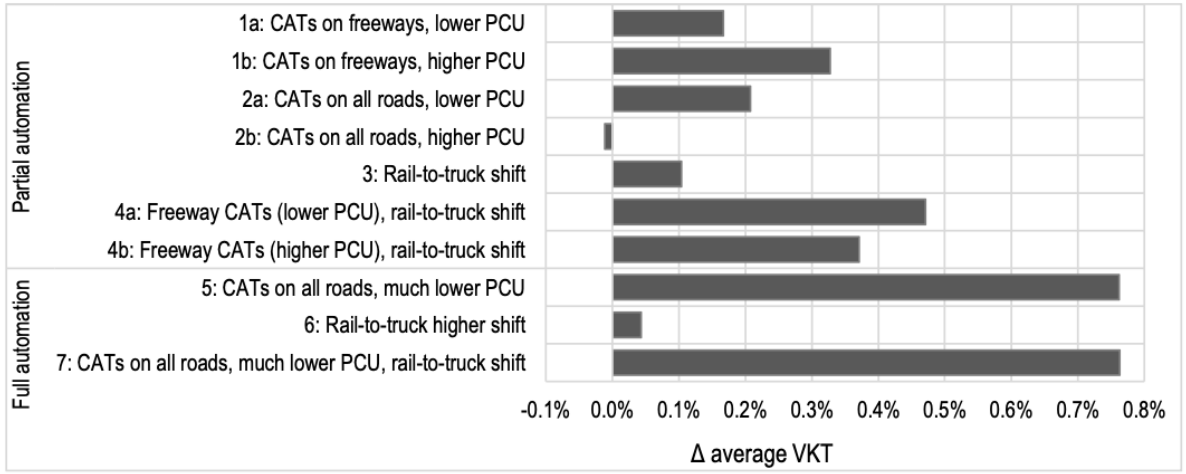
Change in average daytime (6 am- 7 pm) travel time (left) and travel speed (right)

Chowdhury, T., Vaughan, J., Saleh, M., Mousavi, K., Hatzopoulou, M., & Roorda, M. J. (2022). Modeling the Impacts of Off-Peak Delivery in the Greater Toronto and Hamilton Area. *Transportation Research Record*, *2676*(10), 413-425.

Toronto Freight Model – Freight Automated Vehicles

Scenario number	Scenario description	PCU change		
		Auto	Light	Medium & Heavy
	Partial automation (50% adoption)			
1a	Half of medium and heavy trucks on freeways are CATs with lower PCUs	-	-	−25%
1b	Half of medium and heavy trucks on freeways are CATs with higher PCUs	-	-	+10%
2a	Half of medium and heavy trucks on all roads are CATs with lower PCUs	-	-	−25%
2b	Half of medium and heavy trucks on all roads are CATs with higher PCUs	-	-	+10%
3	Modal shift (25%) from rail to long-haul truck	-	-	-
4a	Combine Scenarios 1a & 3	-	-	−25%
4b	Combine Scenarios 1b & 3	-	-	+10%
	Full automation (100% adoption)			
5	All trucks on all roads are CATs	-	−33%	−40%
6	Modal shift (50%) from rail to long-haul truck	-	-	-
7	Combine Scenarios 5 & 6, full truck automation	-	−33%	−40%
8	Full truck and passenger automation	−33%	−33%	−40%





Chowdhury, T., Vaughan, J., & Roorda, M. J. (2024). Modeling impacts of freight automated vehicles in the Greater Toronto and Hamilton Area. *Transportation Research Part A: Policy and Practice*, *184*, 104090.

Change in average travel time (top) and VKT (bottom) from baseline scenario, all vehicles (7 am – 11 pm)

Behavioral Elements for Future Modeling

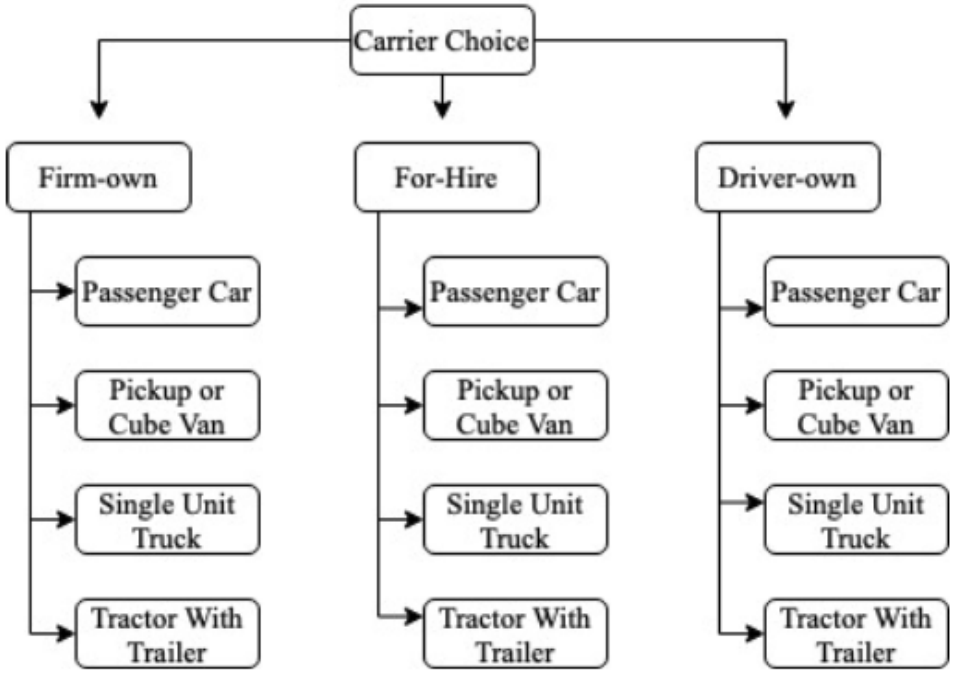
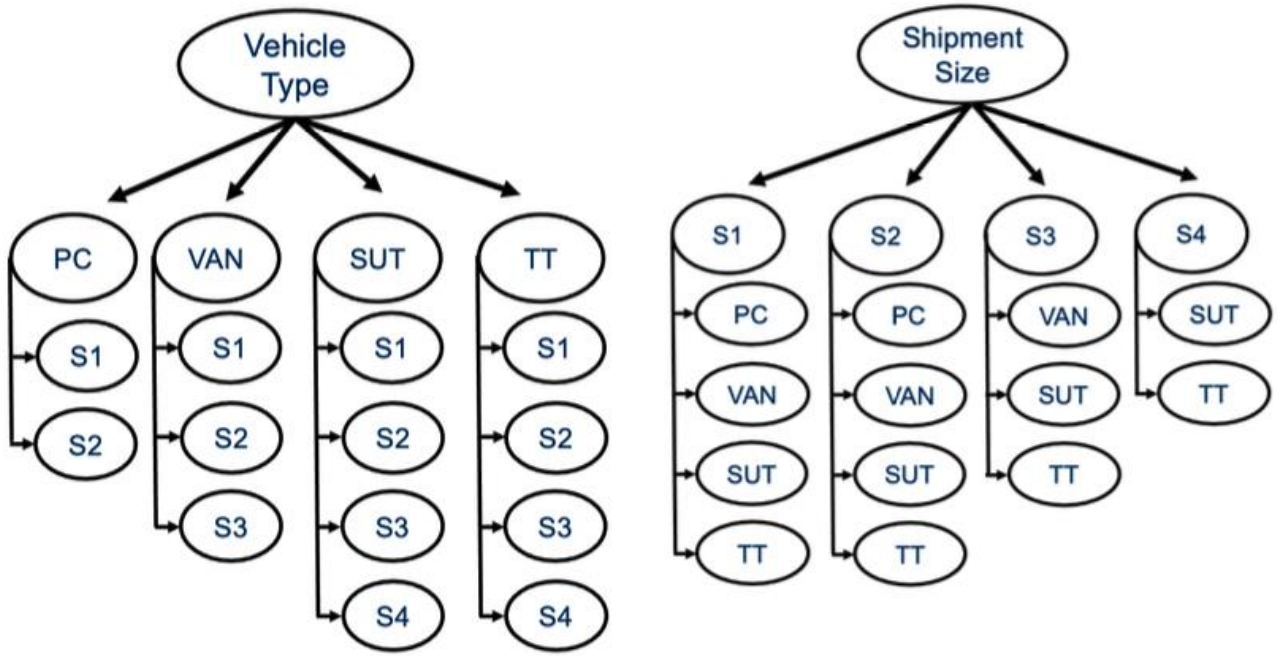


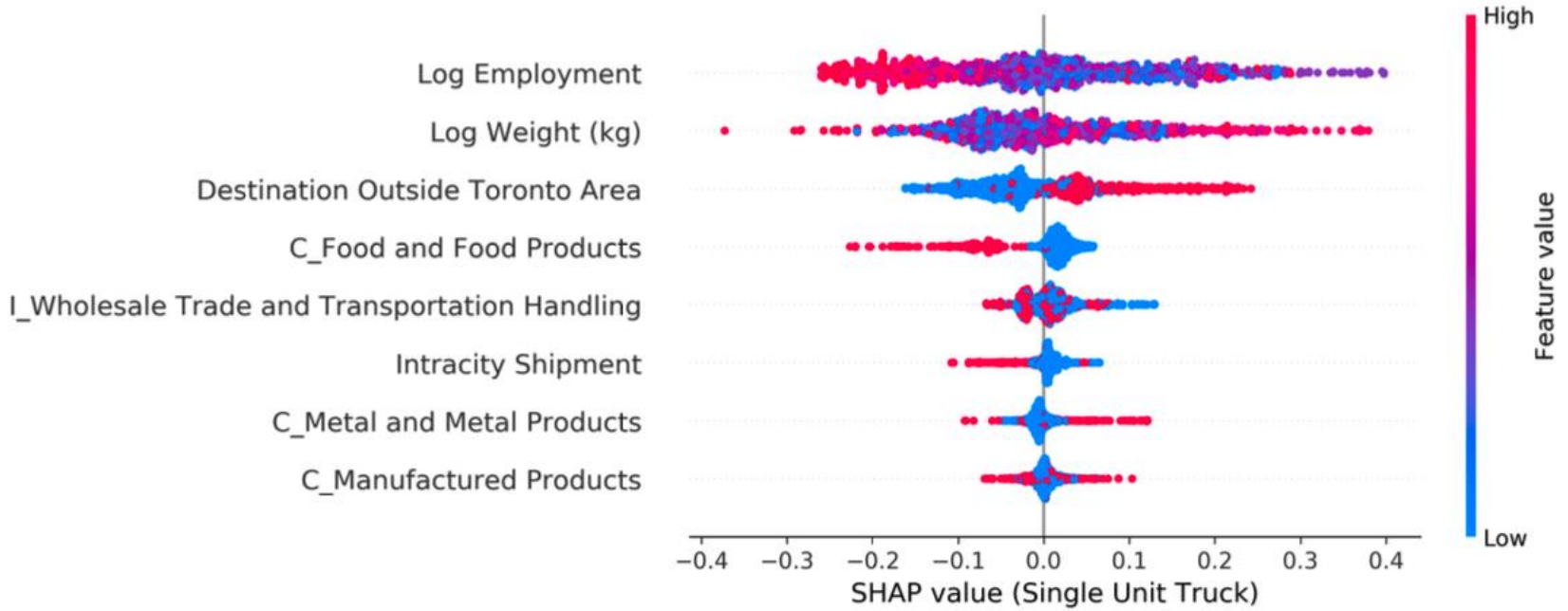
Figure 4.4: Nested logit model structure



Ahmed, Usman; Roorda, Matthew (2022). Modelling Carrier Type and Vehicle Type Choice of Small and Medium Size Firms. *Transportation Research Part E: Logistics and Transportation Review, 160, 102655.*

Ahmed, Usman; Roorda, Matthew (2022). Joint and Sequential Models for Freight Vehicle Type and Shipment Size Choice. *Transportation, 50(5), 1613-1629*.

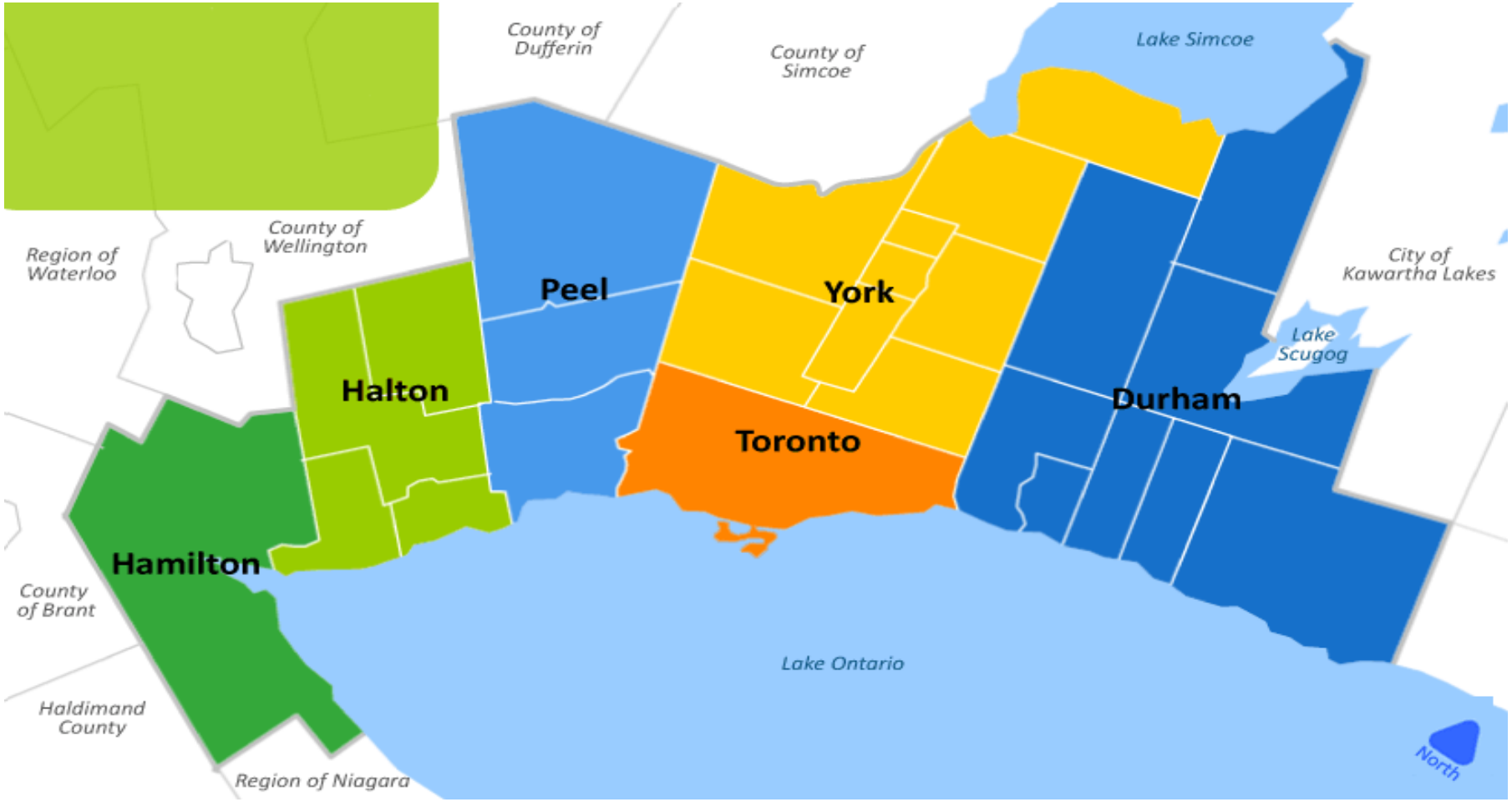
Behavioral Elements for Future Modeling



Ahmed, Usman; Roorda, Matthew (2022). Modeling freight Vehicle Type Choice Using Machine Learning and Discrete Choice Methods. *Transportation Research Record, 2676(2), 541-552.*

Toronto Commercial Travel Surveys

Commercial Travel Surveys in the GTHA



Commercial Travel Surveys in the GTHA

Survey	Year	Sample Size	Survey Method
Region of Peel	2006-2007	600	Mail-out-mail-back
Region of Durham	2009	500	Mail-out-mail-back
Greater Toronto and Hamilton Area	2012	1000	Mail-out-mail-back, phone interview, web-based
Greater Toronto and Hamilton Area	2023	876	Web-based, phone interview

Commercial Travel Surveys

- Company information: Industry type, employment, etc.
- Trip generation by vehicle type
- Shipments/services information
- Commercial vehicle ownership

Why Local Data Collection?

- Heterogeneity in trip generation:
  - City (land use)
  - Industry mix
  - Economic activity
- Establishment related information is not captured in other freight data sources such as the Freight Analysis Framework (FAF)

Amaral, Julia*; Holguin-Veras, Jose; Roorda, Matthew; … **Ahmed, Usman**; … Freight Trip Generation in Metropolitan Areas: An International Perspective. *Presented at the 104th Annual Meeting of Transportation Research Board, January 5-9, 2025, Washington D.C.*

Conclusions

Conclusions

- The new commercial travel survey showed significant:
  - Supply chain relationships
  - Intrafirm interactions
  - Deliveries to households
- Design of future commercial travel surveys
- These interactions are important to represent in urban freight modeling
  - Potential policy analysis implications

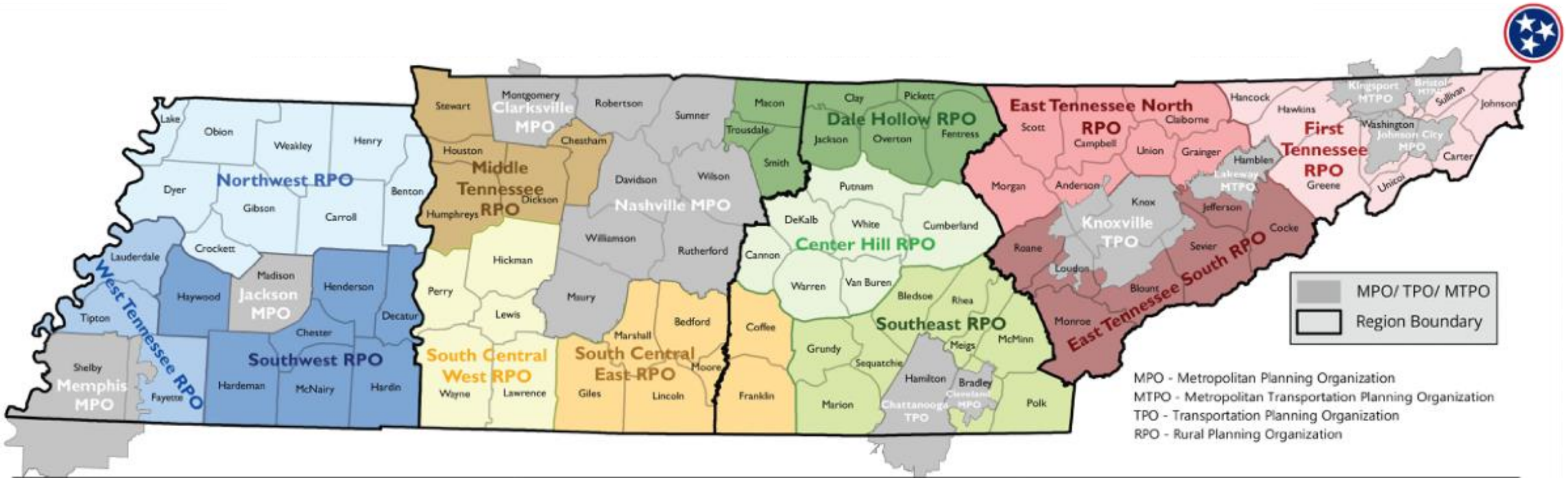
Freight Model for Tennessee MPOs

Freight Mode Share by Movement (Millions of Tons)

Modal Route	Inbound	Outbound	Intrastate	Through
Truck	66.34	66.34	55.44	5747.89
Water	22.73	6.04	1.37	1508.43
Rail	1.02	1.71		841.41
Air	0.42	0.58	0.01	7.75

Tennessee Statewide Multimodal Freight Plan 2023

Tennessee MPO/ TPO/ RPO



Why MPO Freight Model?

- Infrastructure investment decisions
- Policy testing
- Traffic congestion in urban cores and corridors
- Pavement wear and tear
- Roadway safety
- Commercial vehicle parking
- Impacts of disruptions

Why MPO Freight Model?

- Revenue generation (tolls)
- Impacts of new freight technologies
- Impacts of e-commerce
- Logistics clustering – freight efficient land use, logistics sprawl
- Port-related freight activity

MPO Modeling Approach

- Start with the new trip-based freight modeling approach.
  - Zonal level
  - Establishment level
- Model structure depends on the MPO - Memphis vs. Nashville
- Connect with national level freight flow modeling
- Conduct new establishment surveys
- Update the freight travel model
- Disaggregate modeling approach – agent-based modeling

RPO Modeling Approach

- Digital Twins based approach for freight planning
  - Integration with ongoing work at UTK
- Assessing freight efficiency and resiliency in rural regions across Tennessee
- Scenario-based simulations – impact of disruptive events
- Technology readiness
- Infrastructure investment decisions

THANK YOU

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