Tokyo University of
Marine Science and Technology

Massachusetts
Institute of
Technology

Agent-based freight simulation and its applications

Summer School of Behavior Modelling

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Outline

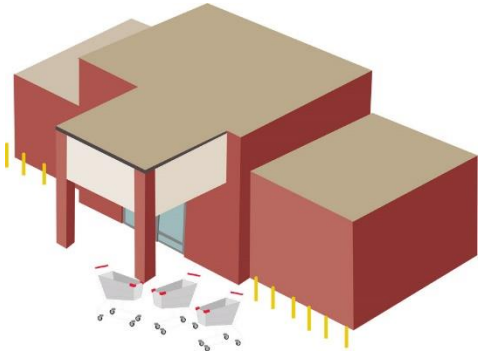
- Introduction
- SimMobility
- SimMobility Freight
- Applications
- Conclusion

Freight transport

- An integral component of the transportation system.
- Historically, behind in modelling compared with passenger.
- Complexity makes agent-based simulation challenging.
  - Various decision makers
  - Shipments vs. vehicle flows
  - Diversity in commodity type
    (e.g., parcels vs. construction materials)

Freight entities – examples

Source: picjumbo.com



Source: publicdomainq.net

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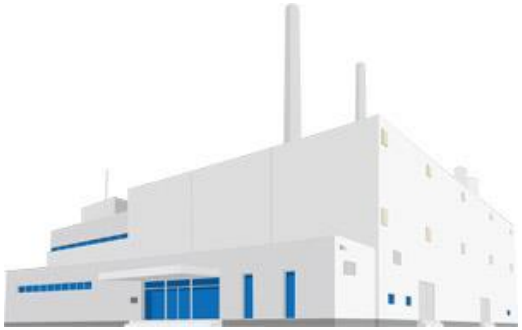


Source: publicdomainq.net

Source: publicdomainq.net

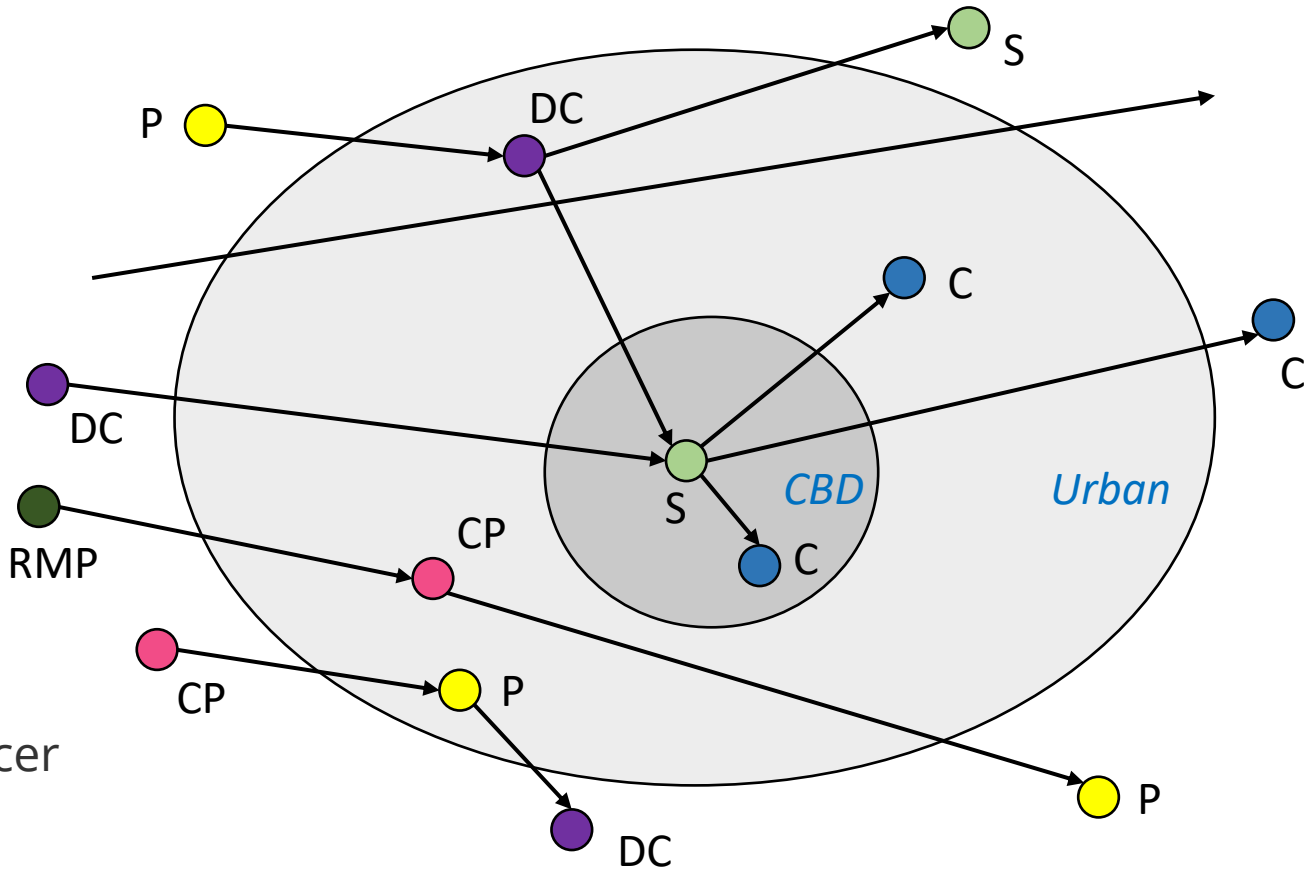
Freight entities – examples

Source: sg-reality.co.jp

Source: okinawayamato.co.jp

Source: picjumbo.com

Flows



C : Consumer
CP : Component producer
DC : Distribution center
P : Producer
RMS: Raw material supplier
S : Shop

Modified from Behrends et al. (2008)
https://www.tandfonline.com/doi/full/10.1080/03081060802493247

Motivations for modelling

- Increasing commodity flows
- E-commerce
- Last-mile deliveries
- Technological innovations
- Passenger-freight interactions

Freight model classification

Aggregate

- Factoring method (Link or OD)
- Truck model
- Four-step commodity model

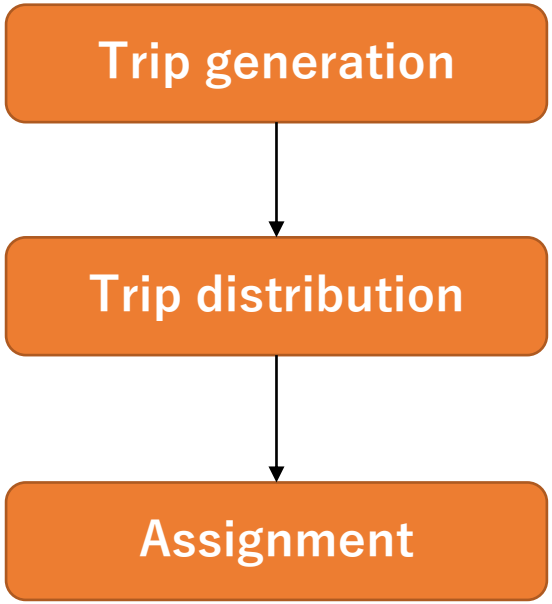
Disaggregate

- Vehicle touring model (without considering commodity flows)
- **Logistics model**
  - Buyer-seller matching, distribution channel, shipment size & inventory, mode choice, shipments-to-vehicle flows

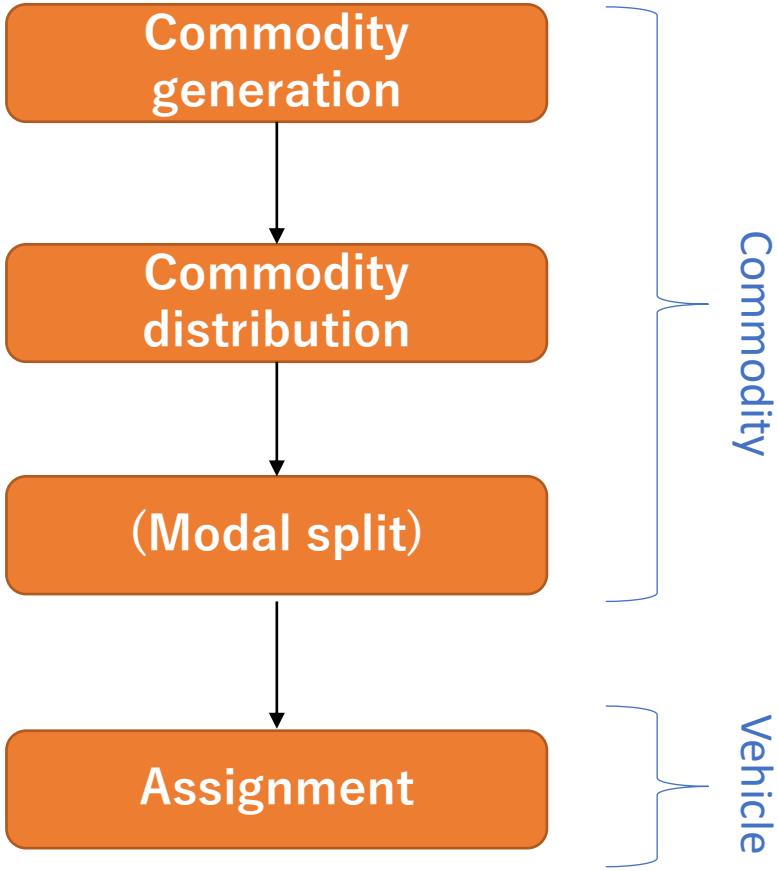
Modified from Chow et al. (2010) https://link.springer.com/content/pdf/10.1007/s11116-010-9281-1.pdf

Aggregate

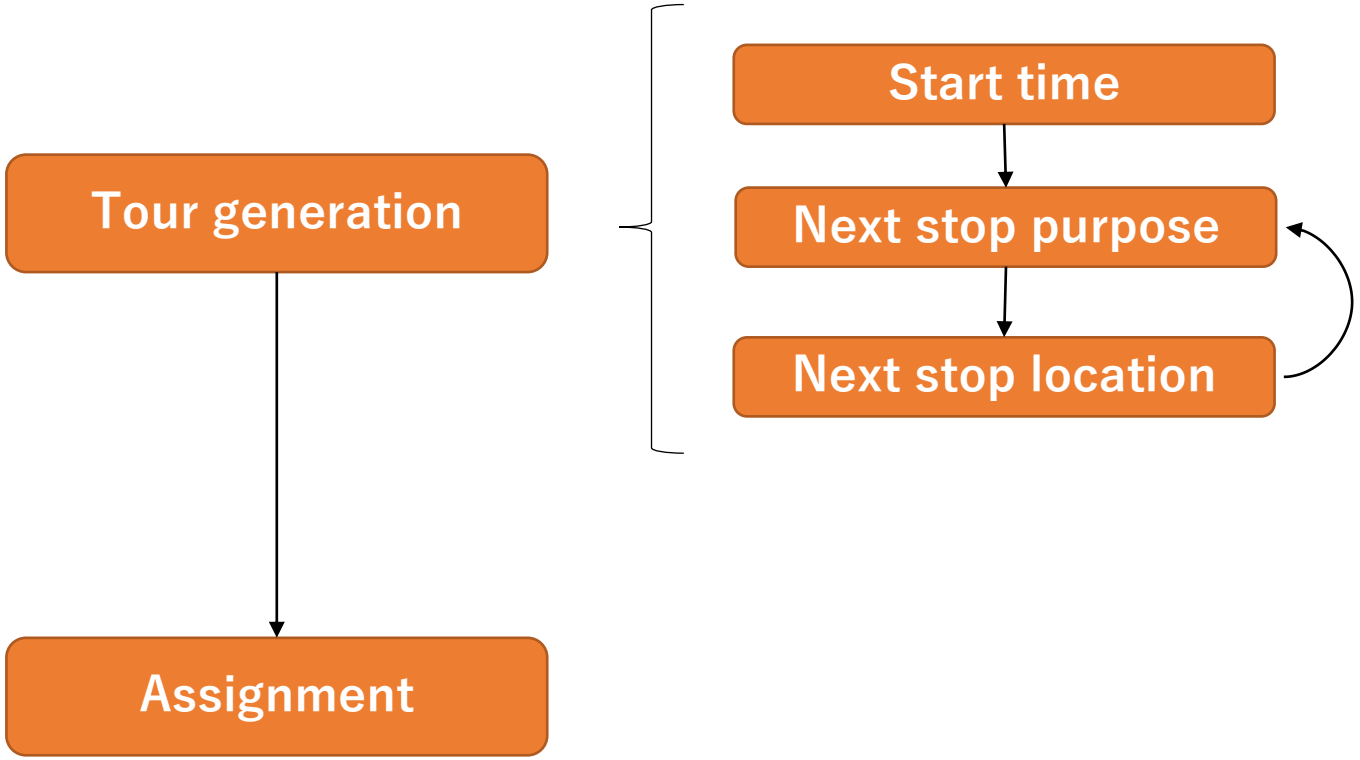
- Truck model



- Four-step model



Vehicle touring model



E.g., Hunt, J.D., Stefan, K.J., 2007. Tour-based microsimulation of urban commercial movements. Transport. Res. Part B: Methodol. 41 (9), 981–1013.

SimMobility

Sakai et al. “SimMobility Freight: An Agent-Based Urban Freight Simulator for Evaluating Logistics Solutions”, Travel Model Improvement Program (TMIP) Webinar - E-commerce Demand Analysis and Implementation in Urban/Regional Freight Transportation and Supply Chain Forecasting Models, October 29, 2020.

SimMobility: Overview

- **SimMobility**
  An agent-based demand and supply urban transportation simulation platform including passenger and freight (B-to-B & E-commerce)

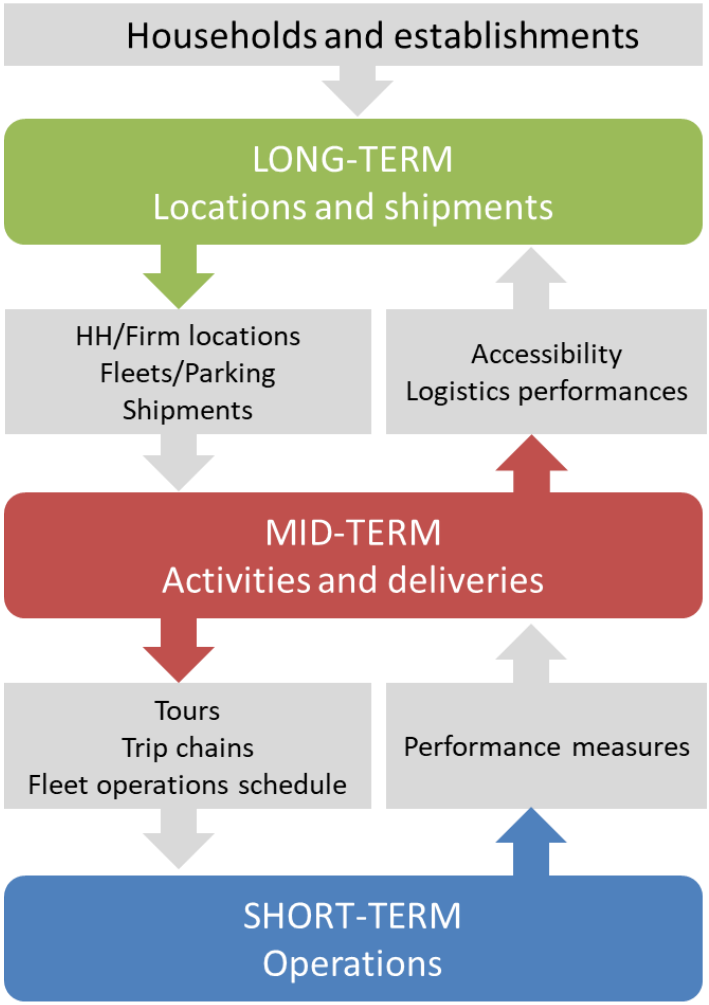
- **Key Features**

  - Temporal dimensions (long-term, mid-term, short-term)
  - ‘Smart’ mobility services (e.g., on-demand and shared)
  - Dynamic plan-action activity-based
  - Supply agents (inc. fleet/infrastructure management)
  - Open source

SimMobility agents

- **Demand**
  - Individuals
  - Households
  - Establishments/firms (shippers, receivers)
- **Supply**
  - Transit operators
  - Fleet operators/managers
    (on-demand services, taxis, freight carriers)
  - Network regulators
    (pricing, information, traffic control)
  - E-commerce vendors
  - Real-estate developers

SimMobility structure

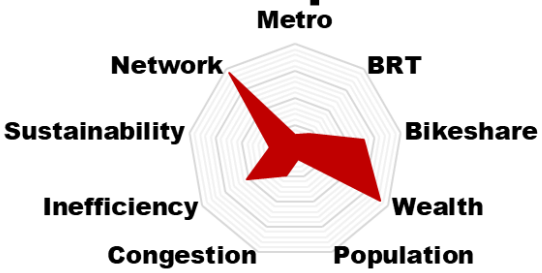


SimMobility applications

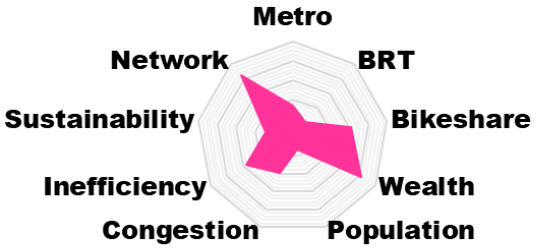
- New modes and services
- Traffic management
- Last-mile solutions
- Post-pandemic scenarios
- Disruptions
- Land-use
- Infrastructure

Prototype cities

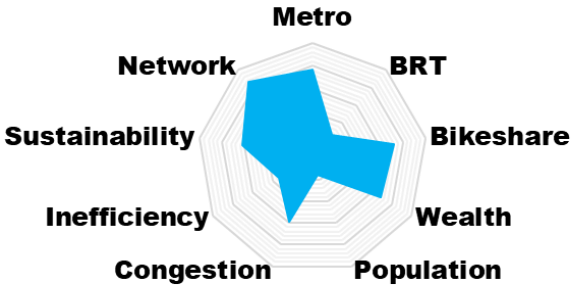
Auto Sprawl

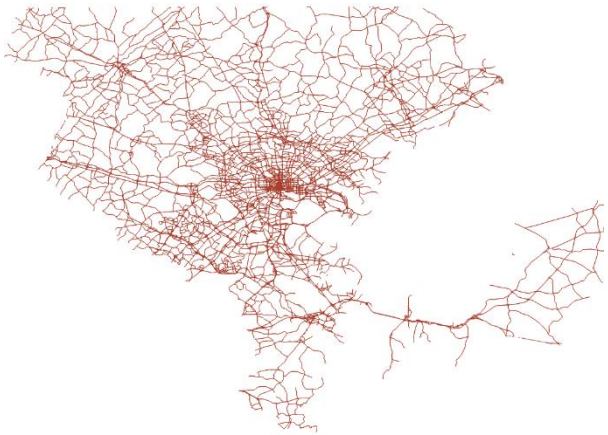


Auto Innovative

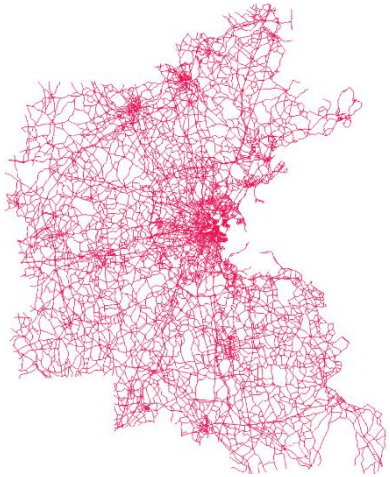


Innovative Heavyweight

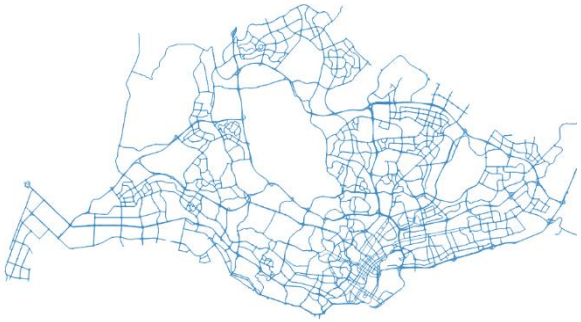




Baltimore



Boston



Singapore

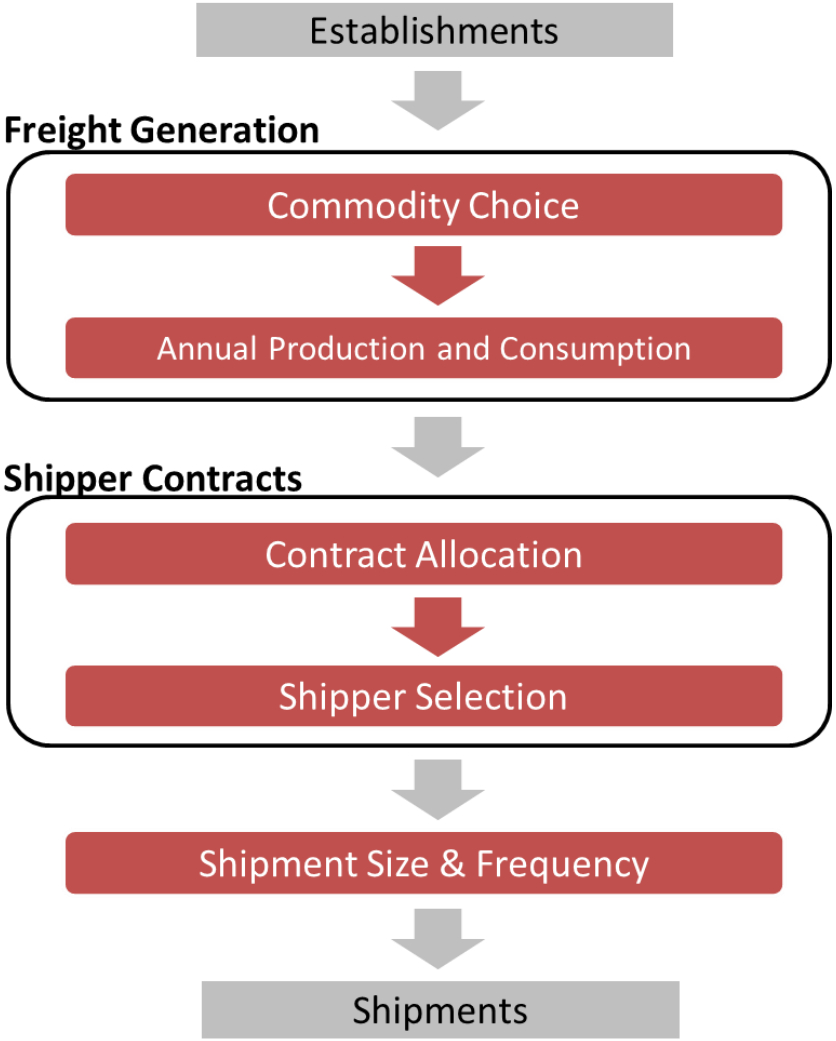
Urban Freight Modeling

Sakai et al. “SimMobility Freight: An Agent-Based Urban Freight Simulator for Evaluating Logistics Solutions”, Travel Model Improvement Program (TMIP) Webinar - E-commerce Demand Analysis and Implementation in Urban/Regional Freight Transportation and Supply Chain Forecasting Models, October 29, 2020.

Freight models

Long-term	Establishments/Fleets/Overnight Parking
	Shipments
Mid-term	Preday Logistics Planning
	Within-day Vehicle Operations
	Mesoscopic Traffic Simulation
Short-term	Microscopic Traffic Simulation

B-to-B shipments



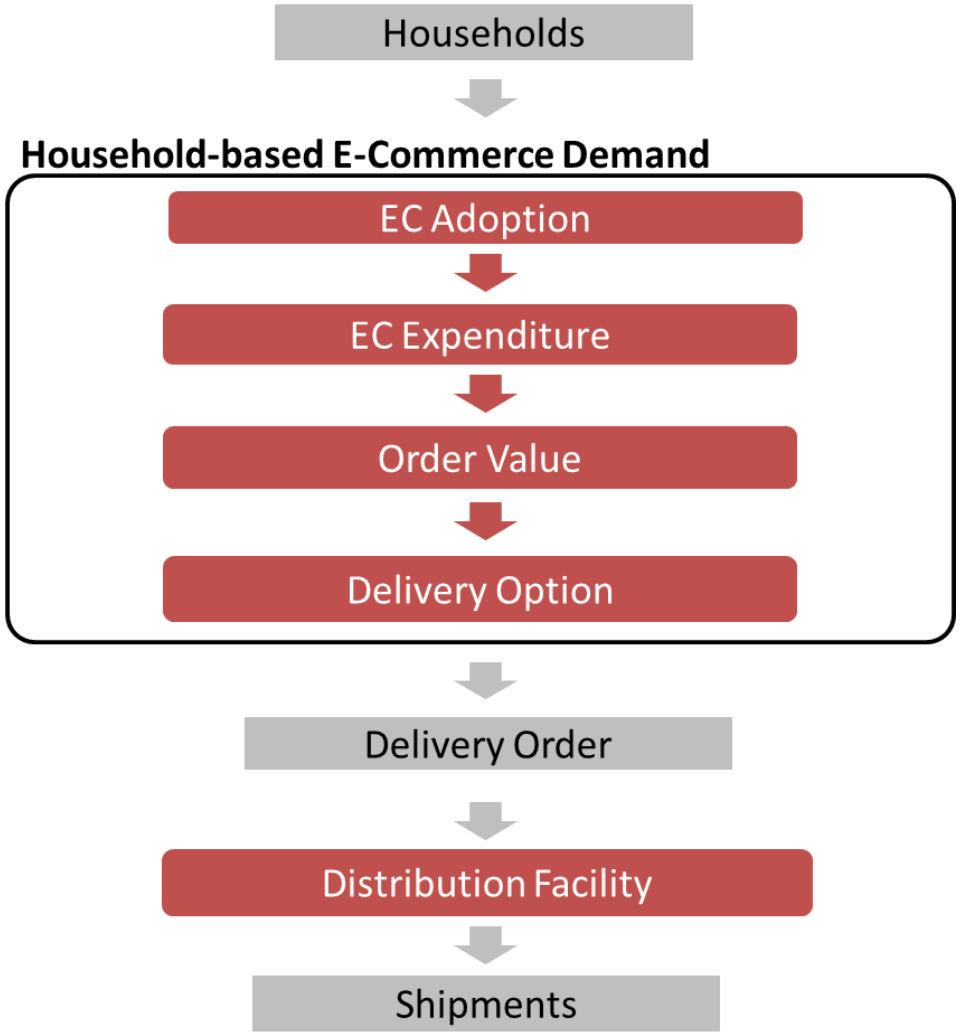
E-commerce demand

- E-commerce ***shipments*** to households
- ***Groceries***, ***HH Goods***, and ***Others***
- ***Demand*** (frequency, expenditure) is sensitive to ***delivery options*** (speed, fee, home delivery/pickup)

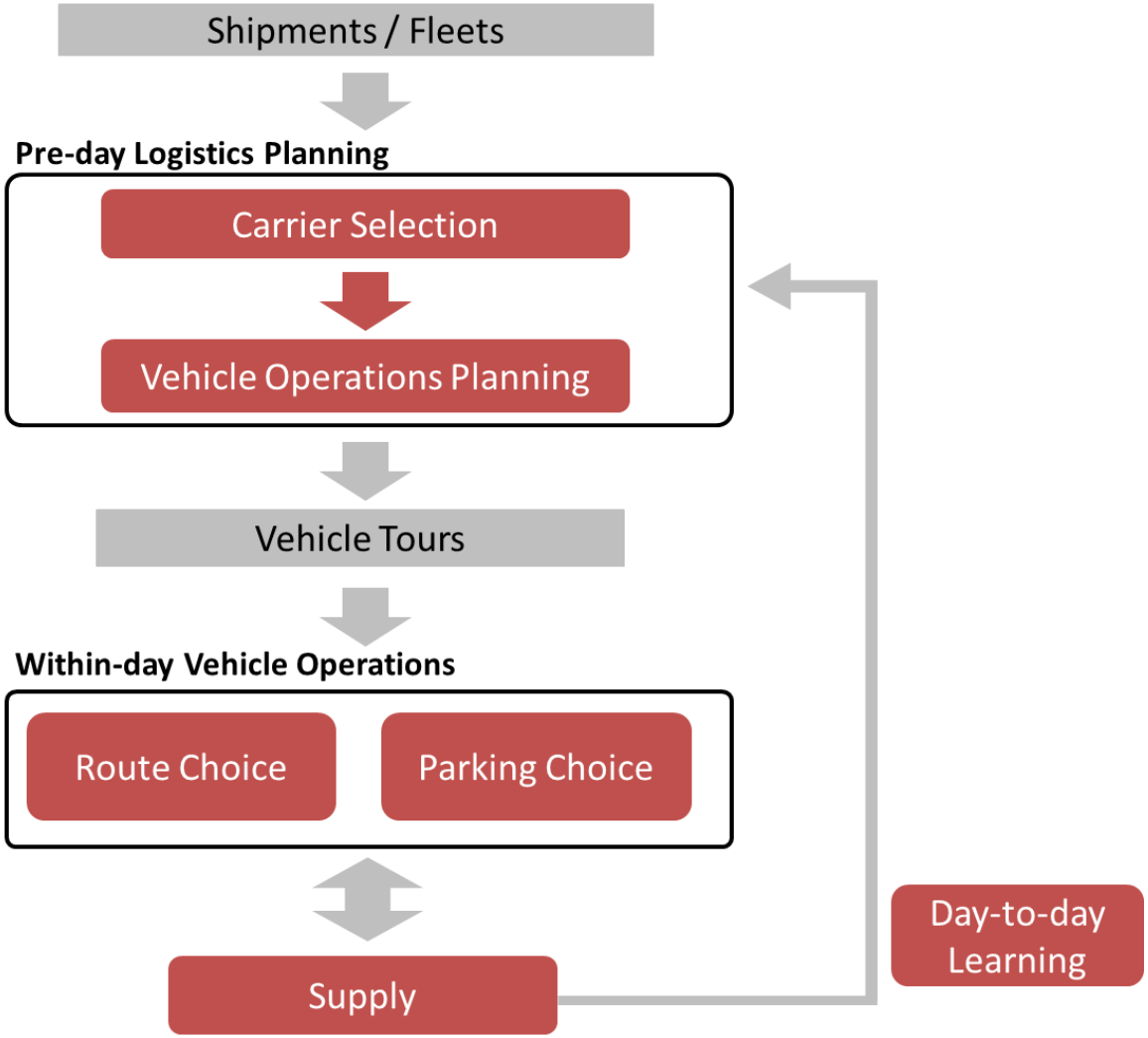
Example of Home Delivery Options

Option	Speed	Fee	Window	Time
1	2-5 days	US$0	No window	Daytime
2	One day	US$12	No window	Daytime
3	Same day	US$18	4 hr	Daytime and evening

E-commerce shipments

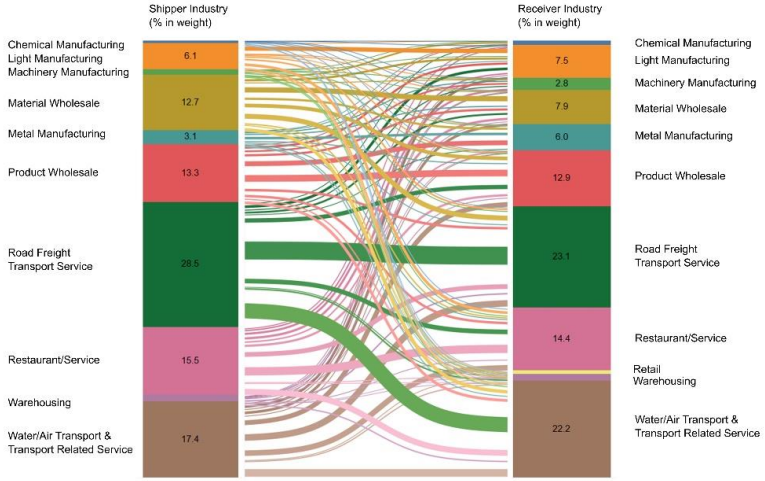


Freight Mid-term

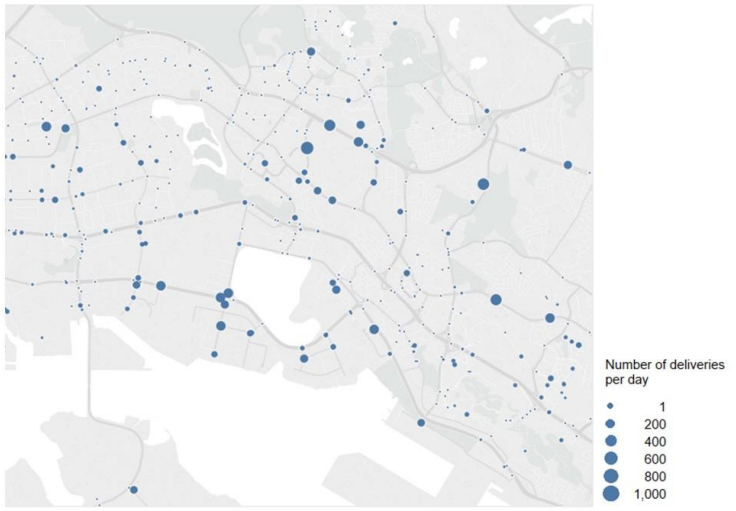


Illustrative outputs

Industry-to-industry

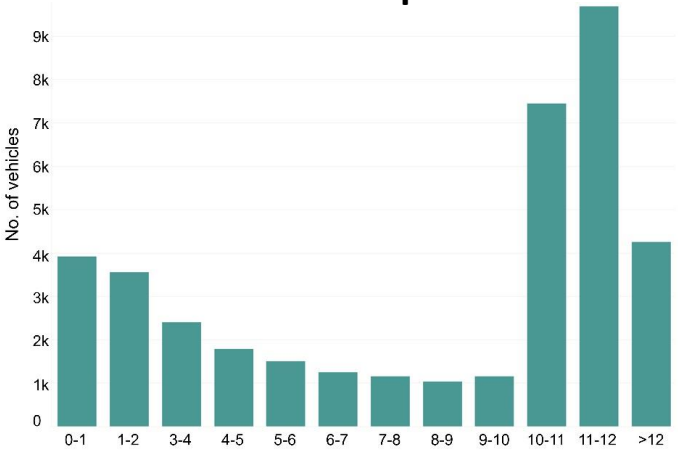


Delivery Locations



Zone-to-zone

Duration of Vehicle Operation



Source: Alho et al. (2021) https://link.springer.com/chapter/10.1007%2F978-981-15-8983-6_12

Applications

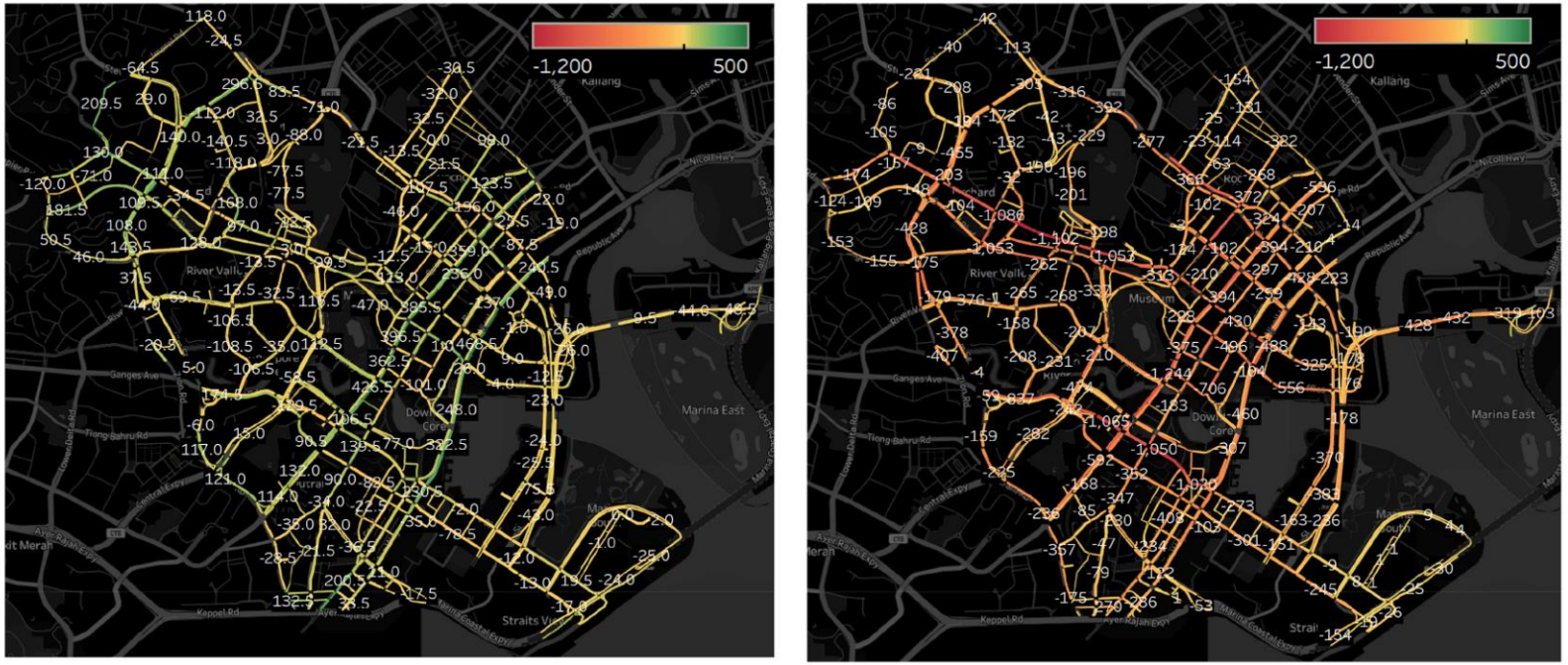
Recent applications

- Overnight freight vehicle parking
- Freight consolidation centres
- Route restrictions
- Congestion pricing
- Night/Off-peak deliveries
- E-commerce growth
- Freight-on-Demand

Policy analysis: Off-peak deliveries

Sakai et al. (2020). SimMobility Freight: An agent-based urban freight simulator for evaluating logistics solutions. Transportation Research Part E: Logistics and Transportation Review, 141, 102017.

- Study area: Singapore
- Restrict deliveries at CBD during the morning peak (7-10am)



Passenger vehicles

Goods vehicles

Fig. 11. Change in Traffic (PCU) in Singapore CBD during Morning Peak (7-10am) in Scn. B.

Policy analysis: Off-peak deliveries

- Peak-hour traffic at CBD decrease; however, through traffic increase (both pax and freight).

		7-10 am	
		Without policy	With policy
CBD	PCU-km (Diff. from Scn. Base)	-	-4.7%
	Average speed (km/hr.)[1)]	28.5	29.4 (+3.4%)
City	PCU-km (Diff. from Scn. Base)	-	-1.1%
	Average speed (km/hr.)	39.8	40.6 (+1.9%)

1) The average of the trips to the CBD.

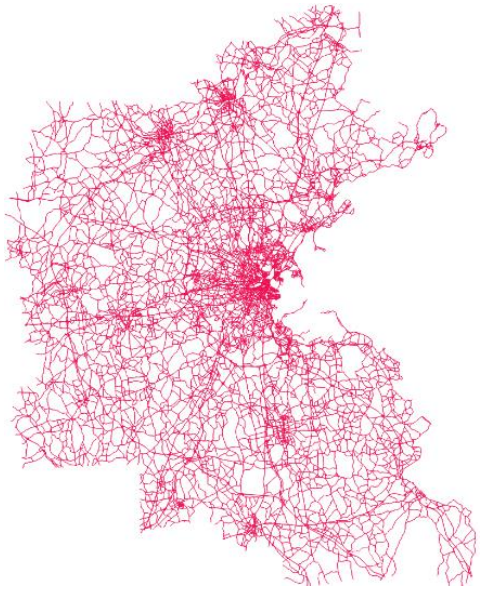
Demonstration: E-commerce demand

Sakai, T., Hara, Y. Seshadri, R., Alho, A., Hasnine, MS., Jing, P., Ben-Akiva, M. (2020) E-Commerce Delivery Demand Modeling Framework for An Agent-Based Simulation Platform. http://arxiv.org/abs/2010.14375

- Study area: Auto Innovative City (Boston, U.S.)
- Varying E-commerce adoption rate and pickup availability

Scenario setting (parentheses: change from Base)

Indicator		Base	S1	S2
• Adoption rate (%)	Groceries	16.6	28.7 (+70%)	28.7 (+70%)
	Household goods	45.8	68.7 (+50%)	68.7 (+50%)
	Others	60.9	73.0 (+20%)	73.0 (+20%)
• Pickup availability (%)	Groceries	7	40	60
	Household goods	7	30	45
	Others	7	20	30



Network in the Auto Innovative City

Demonstration: E-commerce demand

- Pickup availability curbs the delivery demand

Indicator		Base	S1		S2	
• No. of home deliveries (thousand)	Groceries	15.4	22.6	(+47%)	20.1	(+31%)
	Household goods	107.4	155.4	(+45%)	153.7	(+43%)
	Others	271.4	312.9	(+15%)	304.2	(+12%)
	Total	394.2	490.9	(+25%)	478.0	(+21%)
• No. of pickup orders (thousand)	Groceries	0.7	7.0	(+900%)	11.2	(+1500%)
	Household goods	2.8	20.7	(+639%)	34.7	(+1139%)
	Others	6.7	24.5	(+266%)	38.9	(+481%)
	Total	10.2	52.2	(+412%)	84.8	(+731%)

- Delivery traffic growth is not proportional to delivery growth

Indicator	Tour type	Base	S1		S2	
VKT (mil.)	Only e-commerce shipments	1.86	2.21	(+18.5%)	2.13	(+14.2%)
	Mixed (e-commerce & other parcels)	0.24	0.25	(+5.4%)	0.26	(+10.8%)
	Others	6.44	6.44	(+0.0%)	6.44	(+0.0%)
	Total	8.54	8.90	(+4.2%)	8.83	(+3.3%)

Solution analysis: Freight-On-Demand

Alho, A., Sakai, T., Oh, S., Cheng, C., Seshadri, R., Chong, WH., Hara, Y., Caravias, J., Cheah, L., Ben-Akiva, M. A Simulation-Based Evaluation of Impacts of Cargo-Hitching Applied to E-Commerce Using Mobility-on-Demand Vehicles. https://arxiv.org/abs/2010.11585

Coronavirus: Cabbies, private-hire car drivers turn to food and grocery deliveries

APR 18, 2020

Mr Toh Kian Seng has spent almost 25 years as a cabby driving passengers across the island, but these days, what is in his backseat ...

Taxi, private-hire drivers tapped to meet demand for food and grocery deliveries

MAR 30, 2020

Taxi and private-hire car drivers can now help make grocery and food deliveries, said Transport Minister Khaw Boon Wan yesterday in a Facebook post. The ...

Source: https://www.straitstimes.com/

- E-commerce deliveries
  - Increasingly on-demand
  - Smart solutions…leverage Mobility-On-Demand (MOD) capacity?

Solution analysis: Freight-On-Demand

- Potential deliveries by MOD vehicles:
  - how many deliveries can be handled?
  - time gap between request and pickup/delivery?

- Impact on passenger trips: how service levels may change when adding freight demand?

Solution analysis: Freight-On-Demand

- Singapore 2030
- MOD algorithm in SimMobility
  - Schedule solo and shared passenger rides
- Assign e-commerce shipments to previously committed and/or idle MOD vehicles

Scenario	Freight in MOD
MOD only (Base)	None
A	MOD shared
B	MOD shared and idle vehicles

Solution analysis: Freight-On-Demand

- Increase in requests handled by the MOD operator
  - Small change to MOD passenger service.

- Scenario
  - A: ~50% delivery demand with long waiting times
  - B: ~100% delivery demand with shorter waiting times

- Small reduction in total VKT observed

- Potential for emissions reduction by using electric MOD vehicles

Conclusion

- **SimMobility is:**
  - a comprehensive platform that jointly simulates passenger, B-to-B, and E-commerce flows
  - applicable to various types of policies, scenarios, & solutions

- Ongoing research:
  - Enhance E-commerce model (supply-side, trip/E-commerce interaction)
  - Post-pandemic scenarios
  - Application to other metropolitan areas

Thank you for listening

References

Overall

Takanori Sakai, André Alho, Peiyu Jing. “SimMobility Freight: An Agent-Based Urban Freight Simulator for Evaluating Logistics Solutions”, Travel Model Improvement Program (TMIP) Webinar - E-commerce Demand Analysis and Implementation in Urban/Regional Freight Transportation and Supply Chain Forecasting Models, October 29, 2020.

SimMobility

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SimMobility Freight & Applications

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