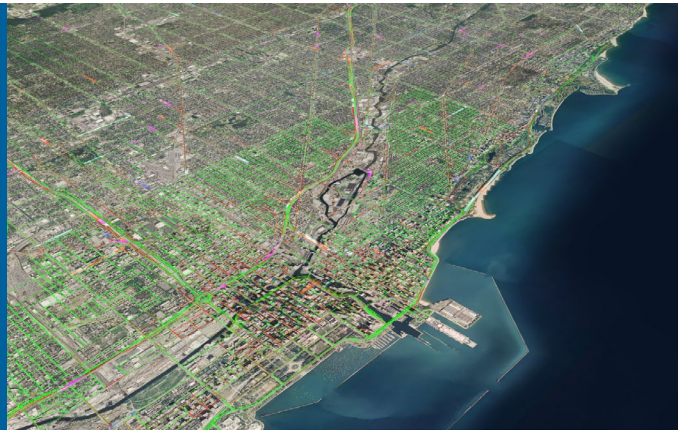
E-Commerce Impacts on Regional Travel and Energy Use:

Household Shopping and Parcel Delivery Tradeoffs

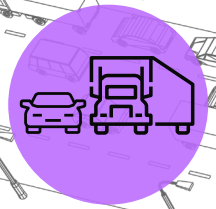


Monique Stinson[1], Annesha Enam[1], Amy Moore[2], Joshua Auld[1]
[1]Argonne National Laboratory
[2]Oak Ridge National Laboratory

FHWA Talking Freight Seminar
December 19, 2019

Transportation System is Being Disrupted

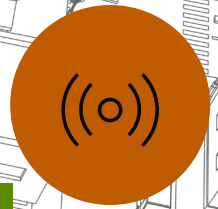
Vehicle Electrification



Passenger Movement

Traveler Behavior

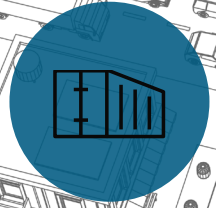
Connectivity



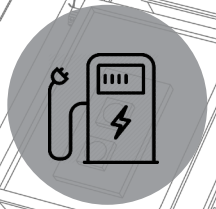
Shared Mobility

Automation

Goods Movement

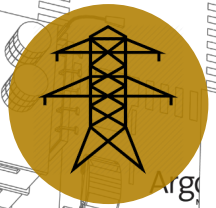


Charging Infrastructure



E-Commerce

Electric Grid



Today: Examine the Impacts of E-commerce on Regional Travel and Energy Consumption

Research Question

As traditional (physical) shopping trips

are replaced by

virtual (e-commerce) shopping “events”...

…what will be the net effect on regional Vehicle-Miles Traveled (VMT) and Fuel Use or Total Energy Consumption?

Scope

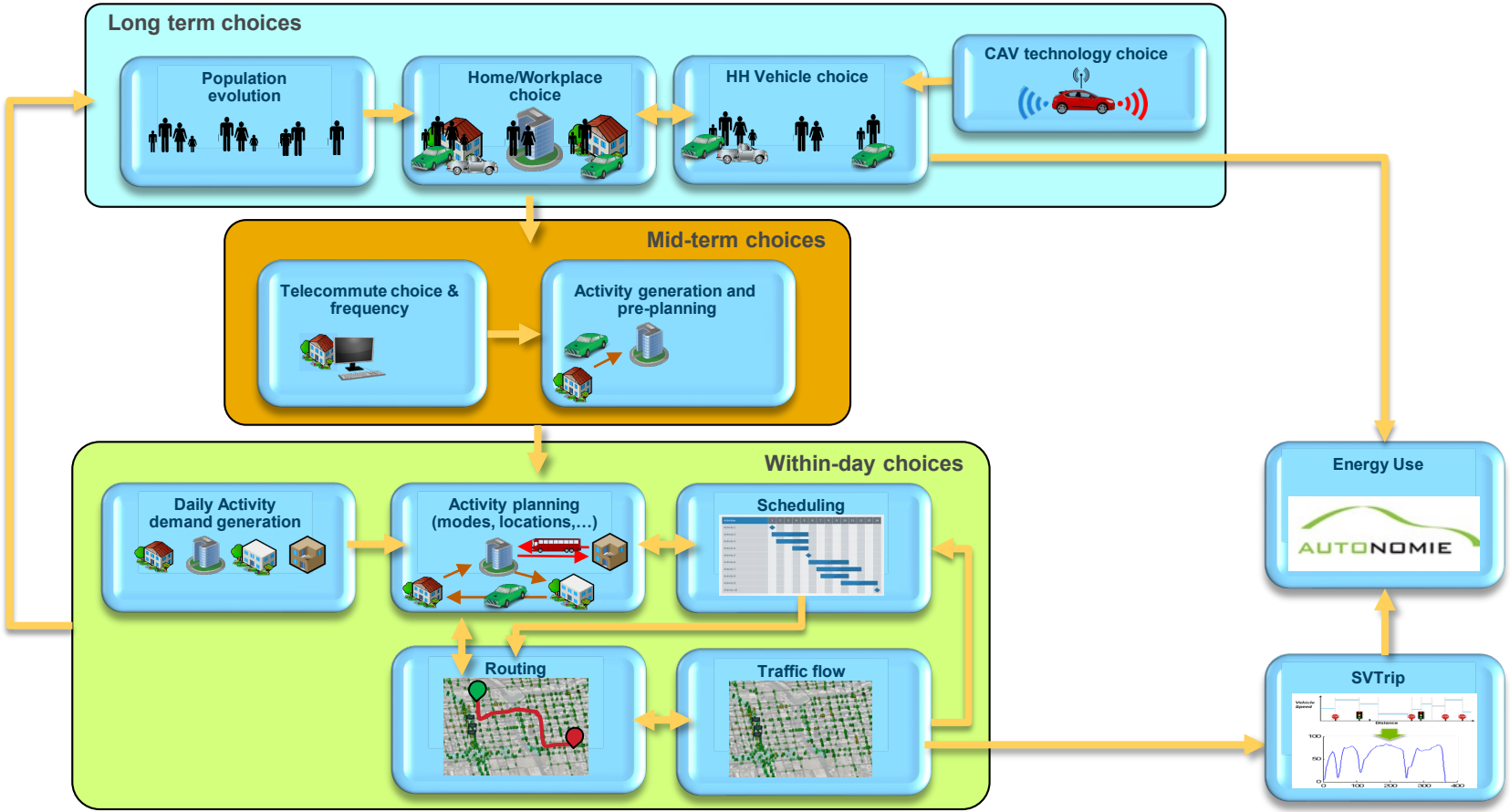
- Last-mile delivery
- Chicago Metropolitan Region:

APPROACH

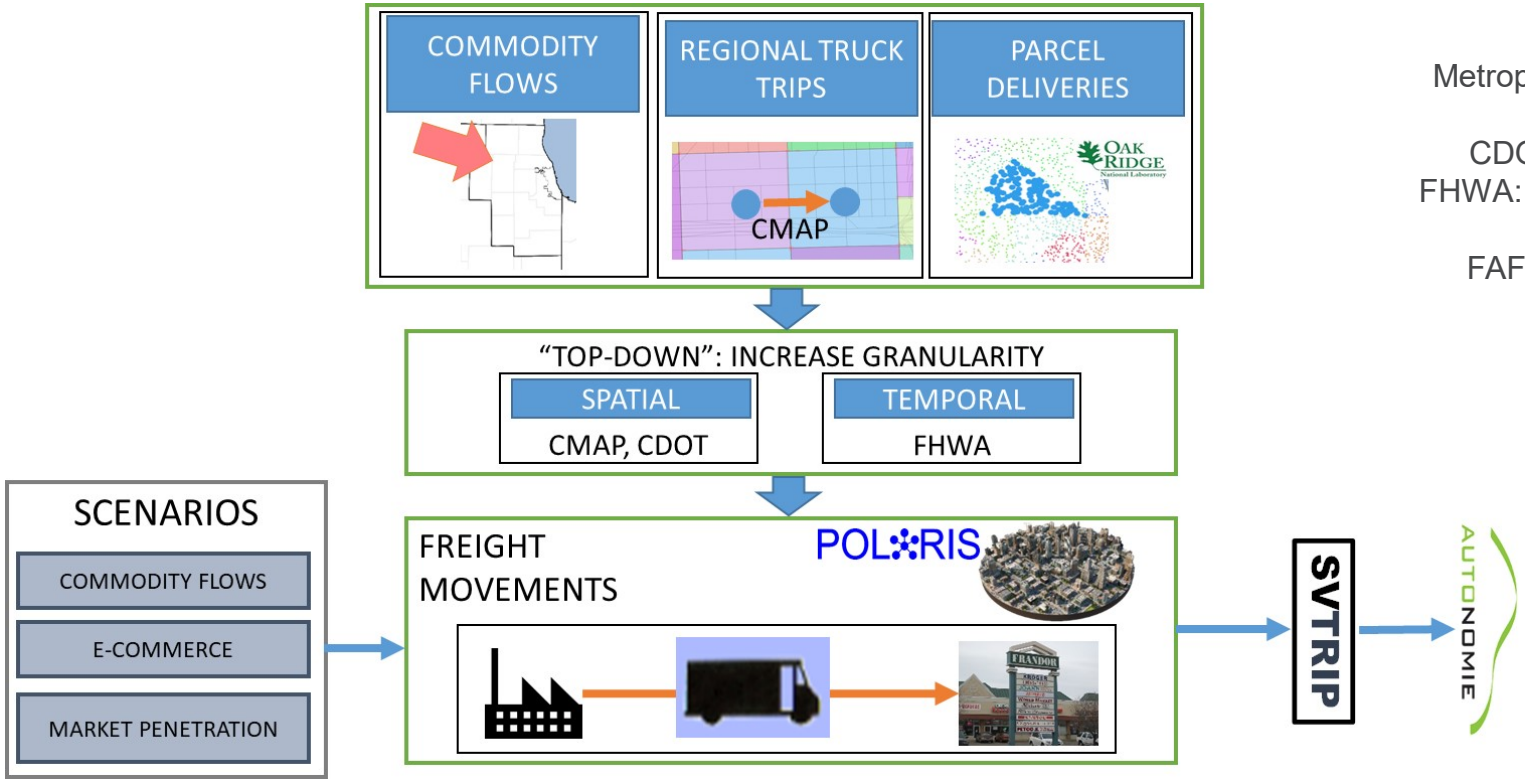
ACTIVITY-BASED TRAVEL DEMAND (ABM) AND DYNAMIC TRAFFIC ASSIGNMENT (DTA) MODELING

6

POLARIS…allows us to explore tradeoffs that individuals make in their travel decisions



Implemented Freight Model in POLARIS



CMAP: Chicago Metropolitan Agency for Planning
CDOT: Chicago DOT
FHWA: Federal Highway Administration
FAF: Freight Analysis Framework

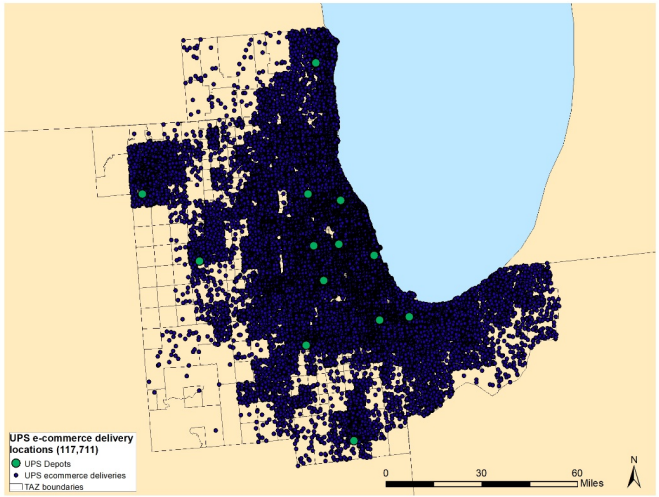
More details in Systems and Modeling for Accelerated Research in Transportation (SMART) Mobility *Multimodal Freight Capstone Report* (in progress)

Methodology to Assess E-Commerce Impacts

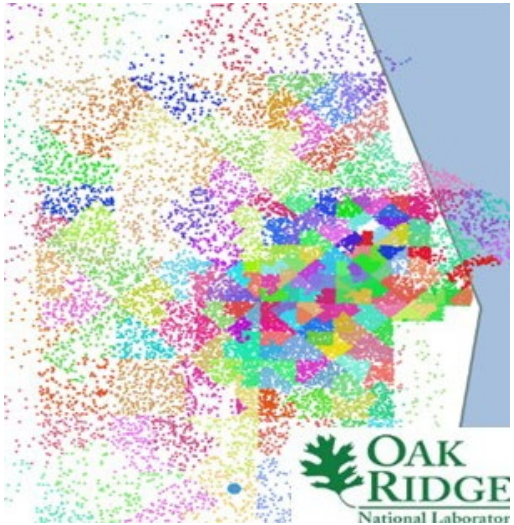
Step 1. Generate household delivery demand.
Step 2. Generate parcel delivery supply.

WholeTraveler survey data

E-commerce Demand: Household Behavioral Model



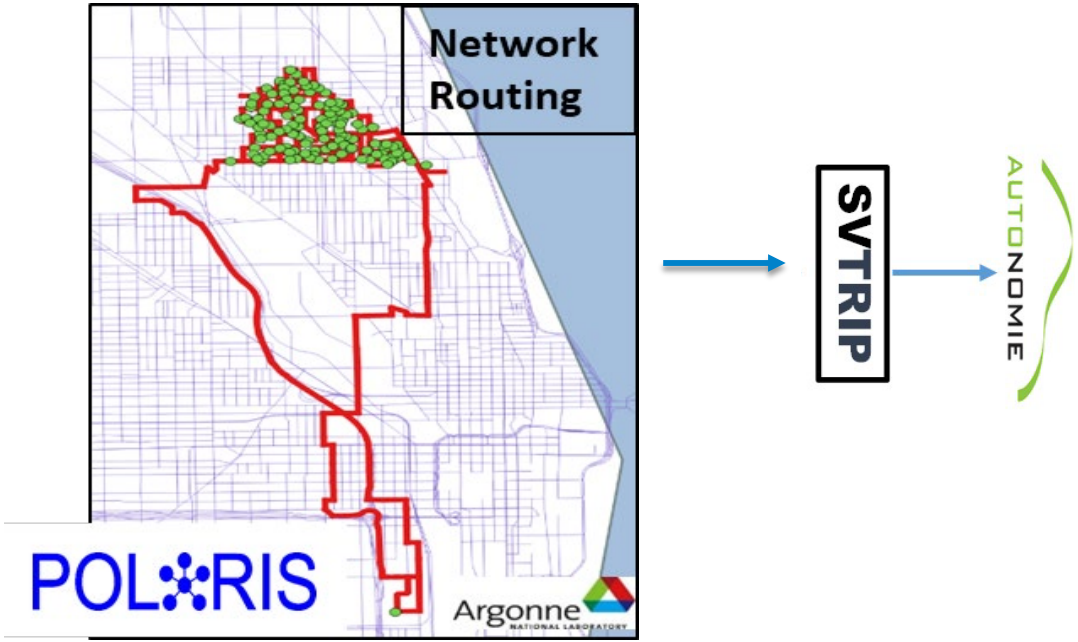
E-commerce Supply*: Parcel Truck Stop Sequence Model



*Efficient delivery system with 120 stops per tour.

Methodology to Assess E-Commerce Impacts

Step 3. Route delivery trucks in POLARIS.
Step 4. Compute vehicle-miles traveled (VMT) and energy use.



Household E-commerce Demand Behavioral Model

More e-commerce demand for households with:

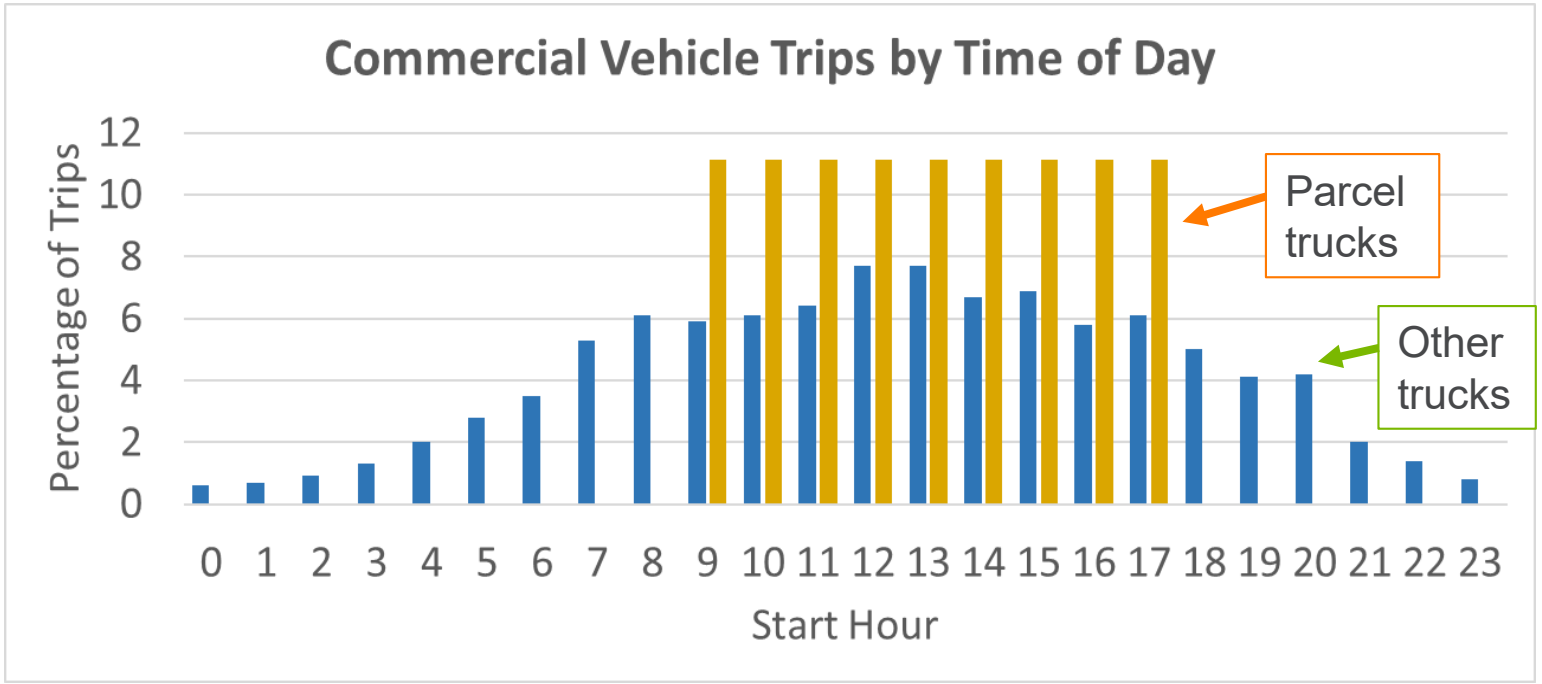
- Higher incomes
- More children (busier parents?)

Less e-commerce demand for households with:

- More vehicles
- Fewer adults
- Residence is walkable and/or relatively close to transit (high-density)

Binary Choice: Whether Participates in E-commerce or not		
Variables	Estimates	t-stat
Constant	-0.103	-1.64
# of HH Children	0.104	1.39
HH income less than 25k	-0.459	-2.33
HH income between 25k and 50k	-0.54	-3.37
HH income between 50k and 100k	-0.154	-1.41
HH income greater than 200k	0.355	3.32
Distance to nearest transit stop from home (in 100th of miles)	0.077	1.18
Ratio of Delivery to Retail Shopping		
Parameters to the latent propensity		
Constant	2.882	11.7
# of HH Adults	-0.146	-2.49
HH income greater than 200k	0.369	3.29
Walk Score (Range 0 to 10)	-0.057	-3
# of HH Vehicle	-0.18	-2.8
Threshold Parameters		
Theta 0	-ve Infinity	Fixed
Theta 1	0	Fixed
Theta 2	1.576	11.86
Theta 3	2.162	15.74
Theta 4	2.738	19.23
Theta 5	3.482	22.34
Theta 6	+ve Infinity	Fixed
Summary		
Number of Observations	971	
Final Log-likelihood	-1362.45	

Temporal Disaggregation* Algorithm



*The process uses data from: Chicago DOT Buildings Data, CMAP Land Use Inventory, and the FHWA Traffic Data Computation Method: Pocket Guide

Assumptions in Model Scenarios

Scenario	E-commerce Delivery Rate (Deliveries per week per household)	Vehicle & Powertrain Technology	Other Important Assumptions
Baseline	1	-	-
Short Term	3	**Baseline**, **BAU** (Business as usual), **VTO** Targets	Increased TNC Use
Long Term	5		2 scenarios: High TNC* Use & Low Private AV** Low TNC Use & High Private AV

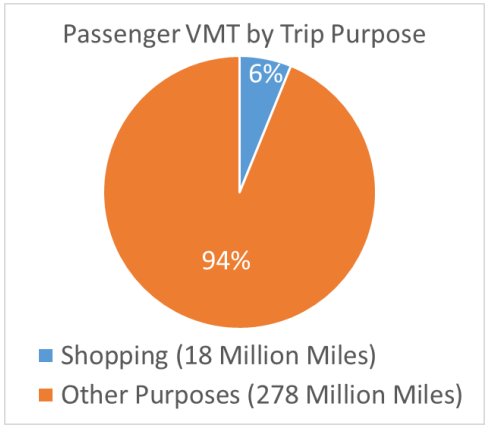
*Transportation network company
**Autonomous vehicle

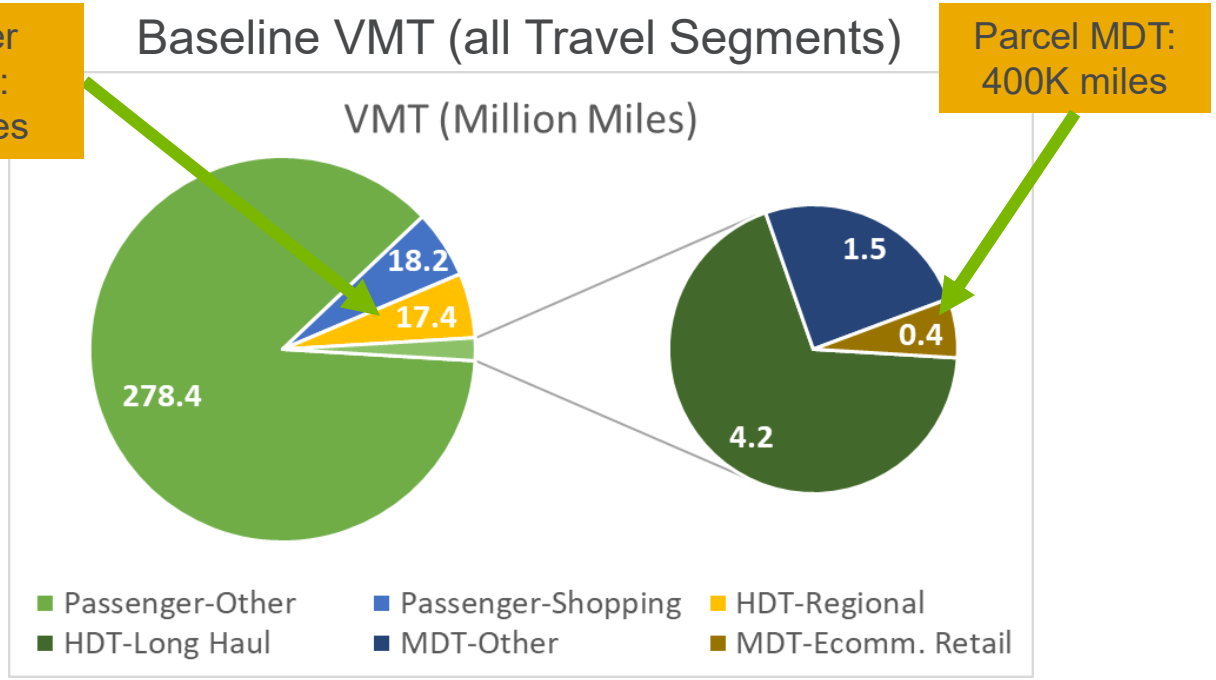
- Vehicle & Powertrain Technology: **Increasing levels of electrification** among passenger and commercial fleets
- Future growth in passenger and commercial trips due to **population growth** and **moderate commodity flow growth**

More details in SMART Workflow Capstone Report (in progress)

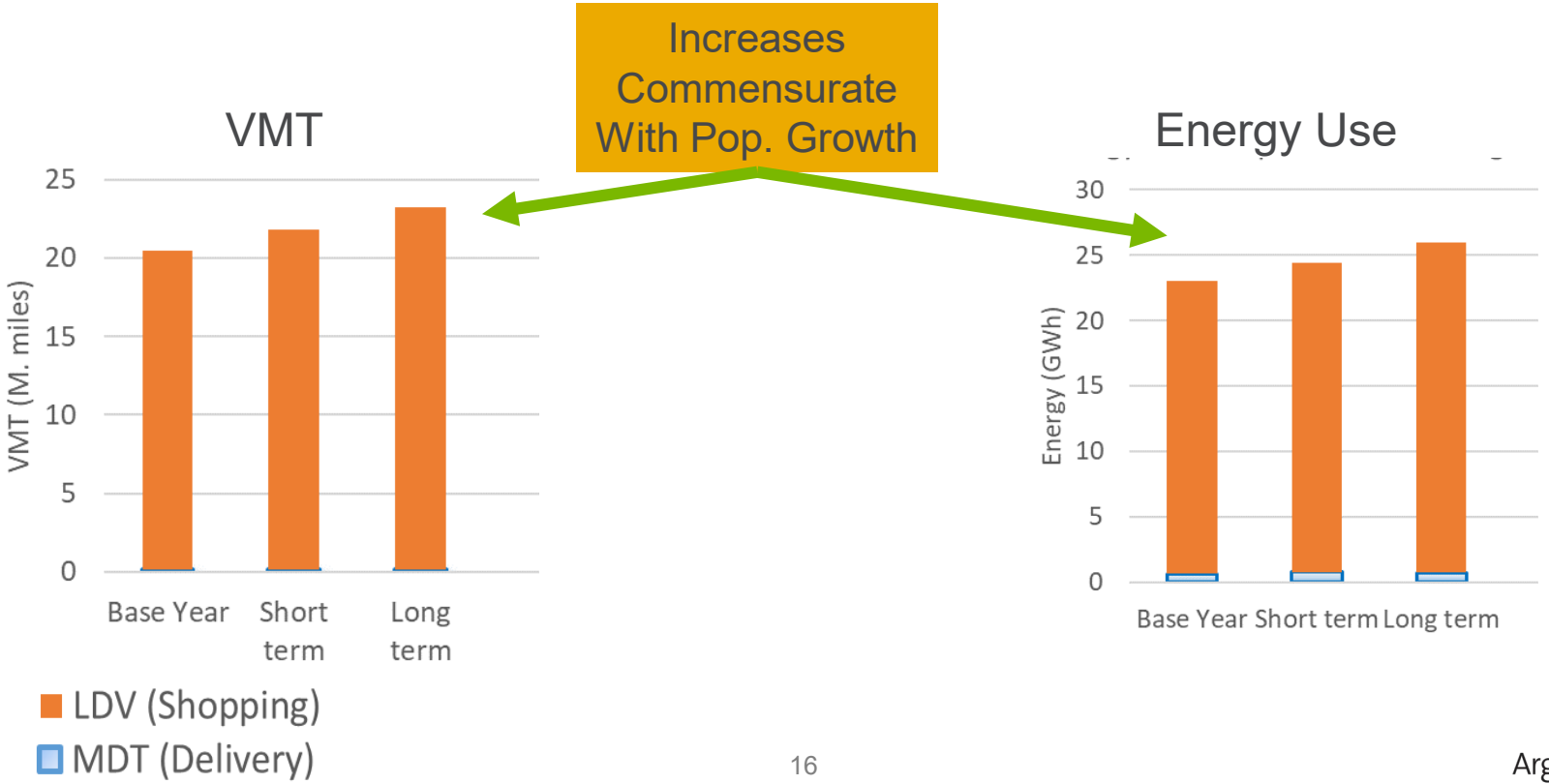
FINDINGS

Travel Segments in the E-commerce Analysis:
--Medium-Duty Parcel Delivery Trucks (MDT)
--Passenger Shopping Light-Duty Vehicles (LDV)





Slight Growth in VMT and Energy Use if E-commerce Rate Stays at 1 Delivery per Household per Week…



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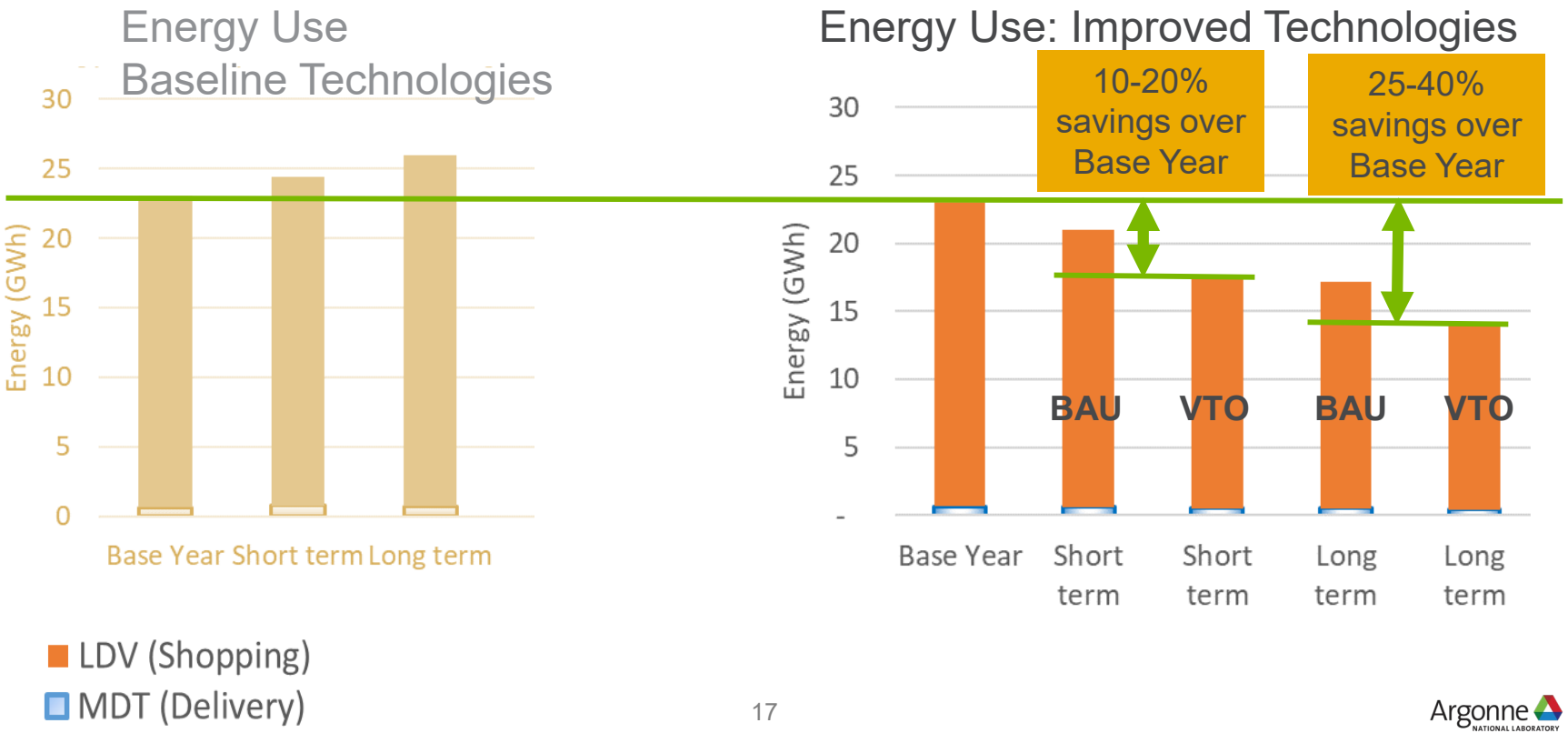
Ceteris Paribus (e.g., 1 Delivery per Household per Week), Vehicle Technology Improvements Can Greatly Reduce Energy Use



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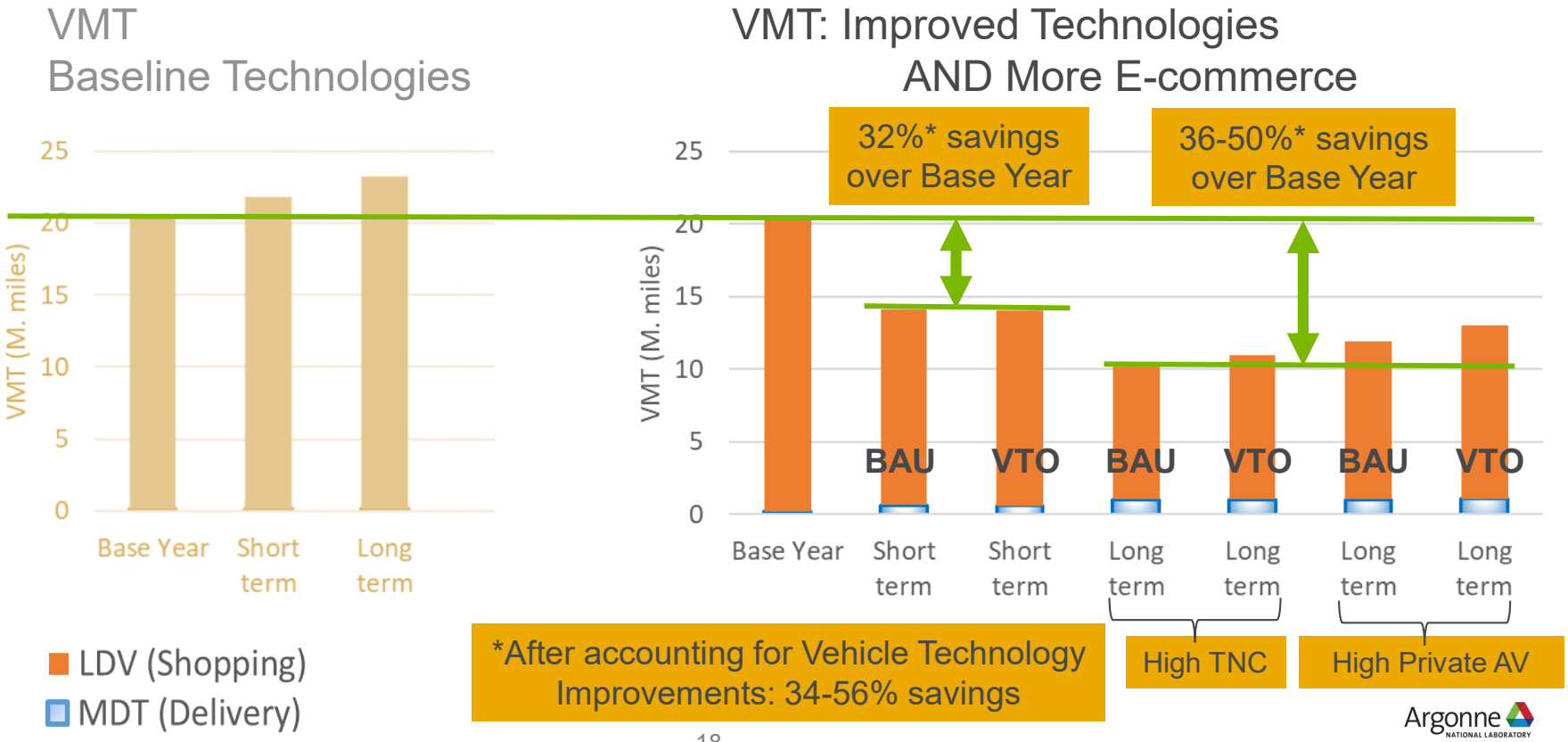
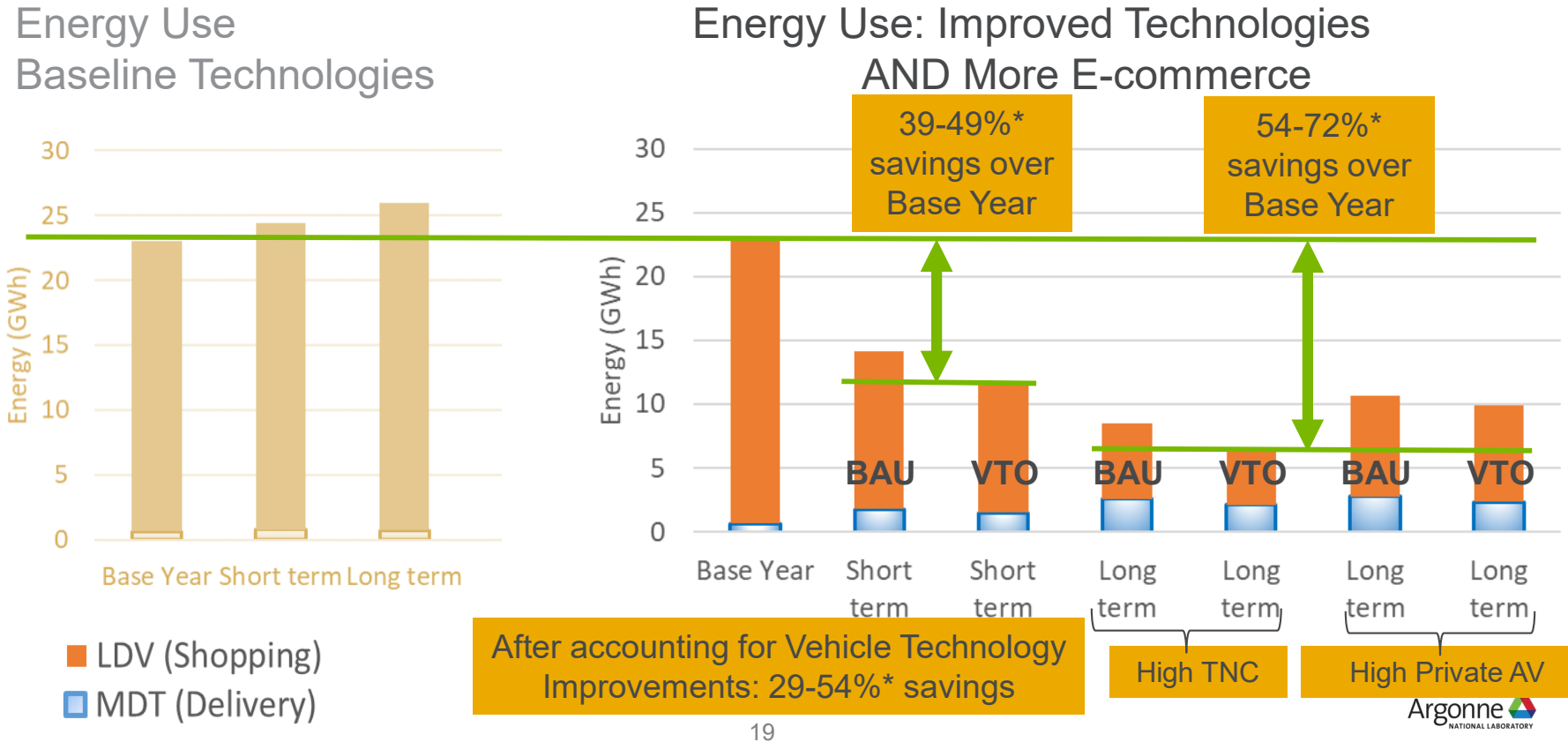
In a World with Increasing E-commerce, Parcel MDT VMT Grows by about 300-500%, but Total Last-Mile Retail VMT Decreases Significantly…

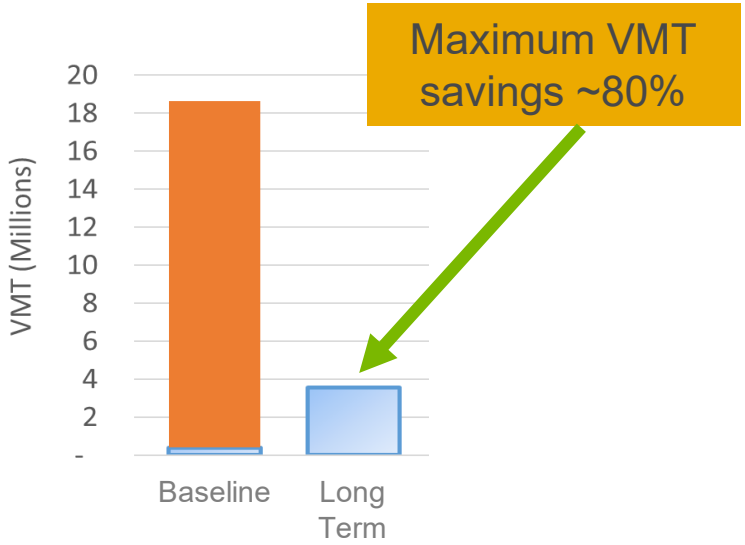


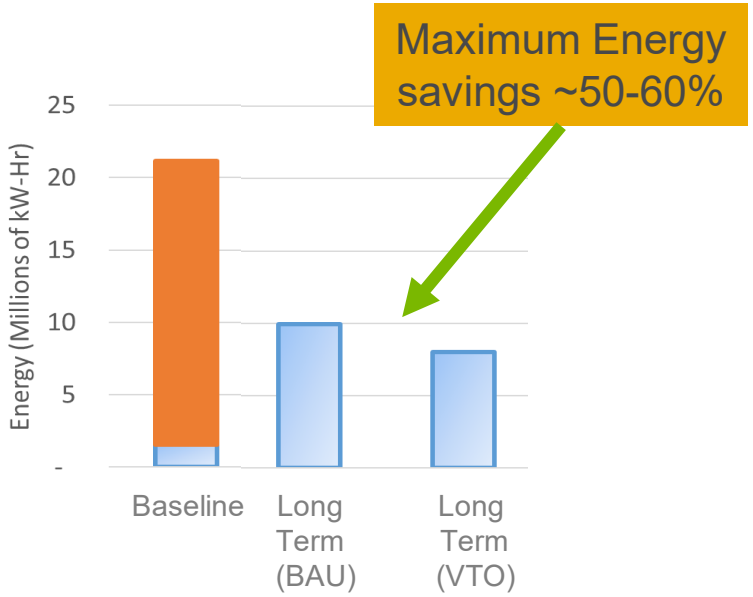
Energy Use is Likewise Significantly Reduced as E-commerce Increases…



A corner case*: E-commerce deliveries replace ALL household shopping trips…

*This case is from an earlier version of the model.





LDV (Shopping)
MDT (Delivery)

→ overall trend: efficient e-commerce system saves last-mile VMT & energy
→ room to improve truck efficiency

Why does this happen?

SHOPPING TRIP = 7 to 8 miles

(2017 NHTS)

DELIVERY TRIP **1 ADDED STOP = 0.4 mile**

CONCLUSION

Summary of Results

- Although e-commerce is expected to generate a large increase in last-mile delivery, an overall net reduction in VMT (34-56%) and energy use (29-54%) is estimated to occur after also accounting for shopping trip reductions and vehicle technology changes
- Overall results differ somewhat due to assumptions about the future, especially:
  - The market penetration of electrification technologies
  - Levels of TNC and Private AV use among passengers
    - High usage of Private AV may generate longer LDV shopping trips

For more information:

Citywide Impacts of E-Commerce: Does Parcel Delivery Travel Outweigh Household Shopping Travel Reductions?

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ABSTRACT

E-commerce has facilitated online ordering of goods by households in recent years. This technological advancement has disrupted shopping related transportation. While the National Household Travel Survey (NHTS [1]) finds that household shopping frequency has declined in the last 10-20 years, deliveries by parcel delivery trucks and vans [2] have increased. However, the net effect of these phenomena on overall trip making, vehicle-miles traveled (VMT) and fuel consumption has not been quantified. From a regional planning perspective, understanding the net effect is important for informing city policies—for example, in regards to land use and transportation planning.

The objective of this research is to address this gap. In this study, the net regional impact of e-commerce on transportation and fuel consumption is evaluated.

1 Introduction and Background

Generally speaking, city planning and policy measures aim to promote economic health, mobility, energy efficiency, and other desirable urban traits that enhance quality of life for residents. Access to shopping and low levels of congestion typically are considered desirable features in a metropolitan area.

In recent years, however, travel by motorized vehicles has grown to such levels that congestion is a top concern in many cities. At the same time, accessibility to shopping has been enhanced in a new way with the emergence of e-commerce, which has grown from less than 1% of US retail purchasing in 2000 to about 10% in 2018 [5]. Traffic by parcel delivery trucks, which transport deliveries from fulfillment centers and other e-commerce distribution points to homes and businesses, has grown

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doi>10.1145/3357492.3358633

See also:
DOE SMART *Workflow Capstone Report* & *Multimodal Freight Capstone Report*

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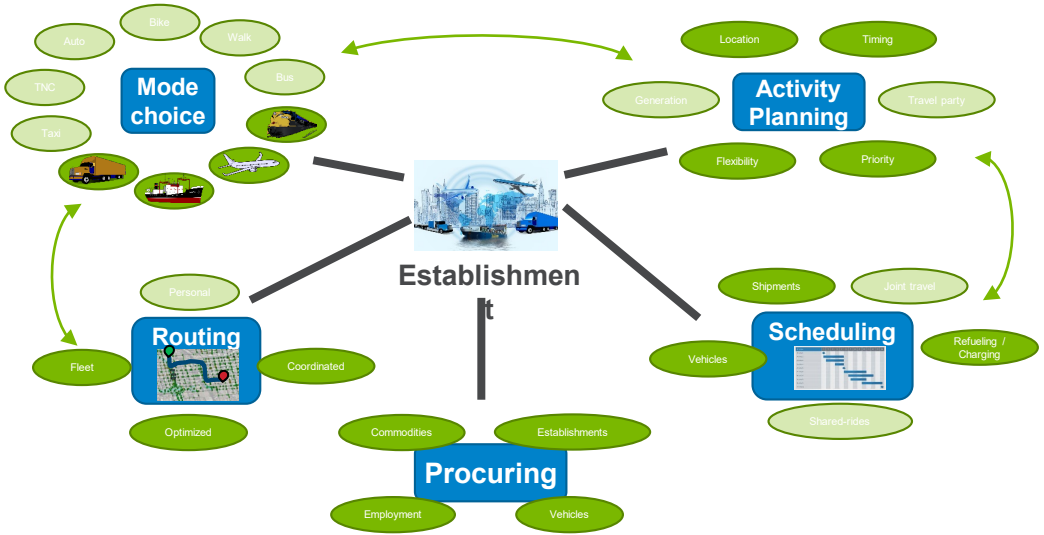
Next steps

Enhancements to the model:
Stinson, Auld, Mohammadian (Oct 2018).
"**An Agent-based Model of Freight Transportation with Emerging Trends in POLARIS**,"
VREF Urban Freight Conference, Gothenburg, Sweden.



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Detailed scenario assumptions

Scenario Group	Scenario	Component Technology	Long Haul Commodity Flow - CAGR (%)	E-commerce Deliveries per Household	Passenger vehicle retirement rate (%)	Passenger VOTT Factor
Baseline	Base0	Baseline	N/A	0.16 per day (about 1 per week)	0	1
Baseline Short Term	Base1	Baseline	1			
	Base2	Short term BAU				
	Base3	Short term VTO Targets				
Baseline Long Term	Base4	Baseline				
	Base5	Long term BAU				
	Base6	Long term VTO Targets				
A	A2	Short term BAU		0.4 per day (about 3 per week)	45	High
	A3	Short term VTO Targets			45	
B	B5	Long term BAU		0.7 per day (about 5 per week)	68	Low
	B6	Long term VTO Targets			75	
C	C5	Long term BAU			15	Low
	C6	Long term VTO Targets			20	