E-Commerce Impacts on Regional Travel and Energy Use: Household Shopping and Parcel Delivery Tradeoffs

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Presented at METRANS I-NUF 2019
Long Beach, California
October 16-18, 2019
Modeling Systemwide Travel for New Metropolitan Challenges…

Traveler decisions & transportation demand

Land use

Metropolitan area with built environment

Transportation supply
…Focusing Today on 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 Taveled (VMT) and Fuel Use or Total Energy Consumption?
Focus of This Study: Last Leg of the Journey to the Consumer

Not included:

Long-haul freight impacts

Secondary/outer distribution impacts:
APPROACH

ACTIVITY BASED TRAVEL DEMAND AND NETWORK SUPPLY MODELS
Test Case: the Chicago Metropolitan Region
POLARIS...allows us to explore tradeoffs that individuals make in their travel decisions
“Top-Down” Freight Model Implemented into POLARIS

COMMODITY FLOWS
REGIONAL TRUCK TRIPS
PARCEL DELIVERIES

“TOP-DOWN”: INCREASE GRANULARITY
SPATIAL
CMAP, CDOT
TEMPORAL
FHWA

SCENARIOS
COMMODITY FLOWS
E-COMMERCE
MARKET PENETRATION

FREIGHT MOVEMENTS

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

SVTRIP

Argonne National Laboratory
“Top-Down” Freight Model Implemented into POLARIS: Created Baseline Freight Trips

Spatial –Temporal Disaggregation Algorithm*

Zonal, Daily Commercial Vehicle Trips (Base Year)

3 trucks

Base-Year Truck Agents: Trips by Time of Day

Disaggregation

Source: Chicago Metropolitan Agency for Planning or CMAP

*The algorithm uses data from: Chicago DOT Buildings Data, CMAP Land Use Inventory, and the FHWA Traffic Data Computation Method: Pocket Guide
“Top-Down” Freight Model Implemented into POLARIS: Created Future Freight Trips

Spatial – Temporal Disaggregation Algorithm

...same process, but now add:

- Chicago Region Growth Rates

Zonal, Daily Commercial Vehicle Trips (Base, Future Years)

Disaggregation

Future-Year Truck Agents: Trips by Time of Day

Source: Chicago Metropolitan Agency for Planning or CMAP
Freight Analysis: “Top-Down” Approach:
Developed and Implemented Methodology to Assess E-Commerce Impacts

*Efficient Delivery Tours

**Base year:**
*Zone-Level*: Total Parcel Deliveries
*Stop-Level*: Random Delivery Locations
-> MDT Delivery Tours

WholeTraveler

Survey Data

SVTRIP
Agent-based Model: “Ground-up” Approach (In Progress)

Conceptual Overview

- **STRATEGIC**
  - B2B collaborations
  - Trade
  - Logistics capacity

- **TACTICAL**
  - Demand forecasting
  - Production
  - Procurement
  - Logistics preparation

- **OPERATIONAL**
  - Scheduling: vehicles, crews, tours
  - En-route decisions
Decisions and Actions of Individual Firms & Establishments (In Progress)

Mode choice
- Bike
- Walk
- Bus
- TNC
- Taxi

Activity Planning
- Location
- Timing
- Generation
- Travel party
- Flexibility
- Priority

Establishment
- Routing
  - Fleet
  - Personal
  - Optimized
  - Coordinated

Scheduling
- Joint travel
- Shipments
- Refueling / Charging
- Vehicles

Procuring
- Commodity
- Establishments
- Employment
- Vehicles

Procuring
- Commodity
- Establishments
- Employment
- Vehicles
Travel Segments in the Overall Analysis Include: Medium-Duty Trucks (MDT), Heavy-Duty Trucks (HDT) and Passenger-Shopping Light-Duty Vehicles (LDV)

Baseline VMT by Travel Segment

- VMT (Million Miles)
  - Passenger-Other: 18.2
  - Passenger-Shopping: 17.4
  - HDT-Regional: 1.5
  - MDT-Other: 0.4
  - MDT-Ecomm. Retail: 4.2
  - HDT-Long Haul: 278.4

Baseline MDT+HDT Share of VMT, Fuel

<table>
<thead>
<tr>
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<th>Model Result</th>
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<tbody>
<tr>
<td>VMT</td>
<td>8%</td>
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<tr>
<td>Fuel</td>
<td>36%</td>
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</table>

- Freight trucks have oversized impacts on regional travel:
  - HDT drives high fuel:VMT ratio (3.5:1)
## Assumptions in Model Scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Year</th>
<th>Commodity Flow Compound Annual Growth Rate (CAGR)</th>
<th>E-commerce Household Delivery Rate (Number of deliveries per week)</th>
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</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>2020</td>
<td>-</td>
<td>1</td>
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<tr>
<td>C</td>
<td>2040</td>
<td>Optimistic (1.3%)</td>
<td>3</td>
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<tr>
<td>B</td>
<td>2040</td>
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</table>

Additional assumptions regarding adoption of vehicle electrification technologies among passenger and commercial fleets

Finally, we focus on efficient delivery tours only (non-express)
FINDINGS
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

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<thead>
<tr>
<th>Variables</th>
<th>Estimates</th>
<th>t-stat</th>
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<tbody>
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<td>Constant</td>
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<tr>
<td># of HH Children</td>
<td>0.104</td>
<td>1.39</td>
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<tr>
<td>HH income less than 25k</td>
<td>-0.459</td>
<td>-2.33</td>
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<tr>
<td>HH income between 25k and 50k</td>
<td>-0.54</td>
<td>-3.37</td>
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<tr>
<td>HH income between 50k and 100k</td>
<td>-0.154</td>
<td>-1.41</td>
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<tr>
<td>HH income greater than 200k</td>
<td>0.355</td>
<td>3.32</td>
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<tr>
<td>Distance to nearest transit stop from home (in 100th of miles)</td>
<td>0.077</td>
<td>1.18</td>
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</table>

### Parameters to the latent propensity

<table>
<thead>
<tr>
<th>Variables</th>
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<tbody>
<tr>
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<td>11.7</td>
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<tr>
<td># of HH Adults</td>
<td>-0.146</td>
<td>-2.49</td>
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<tr>
<td>HH income greater than 200k</td>
<td>0.369</td>
<td>3.29</td>
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<tr>
<td>Walk Score (Range 0 to 10)</td>
<td>-0.057</td>
<td>-3</td>
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<tr>
<td># of HH Vehicle</td>
<td>-0.18</td>
<td>-2.8</td>
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### Threshold Parameters

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<tr>
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### Summary

- Number of Observations: 971
- Final Log-likelihood: -1362.45
Example tour after routing in a congested network

- 120 stops on average per tour
- Freight/delivery, passenger and service vehicles interact in the traffic simulation framework
- Total: 500,000 deliveries (base year) vs. 3.5M in Scenario B
Efficient E-commerce Delivery System Reduces VMT Related to Shopping...

...which is a large portion of the pie:

- Maximum VMT savings ~80%
- Passenger VMT by Trip Purpose
  - Shopping (18 Million Miles)
  - Other Purposes (278 Million Miles)
Likewise, Efficient E-commerce Delivery System Reduces Fuel Consumption Related to Shopping

However, maximum fuel, energy savings ~50-60% → not commensurate with VMT reduction → room to improve truck efficiency
CONCLUSION
Summary of Results

- Investigated net effect of e-commerce on VMT and energy use in the Chicago region
- Focused on efficient delivery tours and the final leg of the retail goods journey
- Based on analysis in the Chicago Metropolitan Area:
  - Efficient delivery tours generate significant savings in VMT over traditional, physical shopping trips
  - Energy savings are also substantial but vary considerably depending on market adoption of vehicle electrification technologies
Next Steps

- In progress
  - Testing additional future scenarios with new technology assumptions, e-commerce utilization rates, and commodity flow growth rates → paint broader picture of possible outcomes
  - Integrate long-haul and outer distribution

- Other extensions
  - Extended survey of e-commerce use among households and businesses
  - Include other last-mile delivery system options (e.g., delivery lockers) in modeling framework
ACKNOWLEDGMENTS

The submission has been created by UChicago Argonne, LLC, Operator of Argonne National Laboratory ("Argonne") and UT-Battelle, LLC, Operator of Oak Ridge National Laboratory ("ORNL"). Argonne, a U.S. Department of Energy Office of Science laboratory, is funded and operated under Contract No. DE-AC02-06CH11357. ORNL, a U.S. Department of Energy Office of Science laboratory, is funded and operated under Contract No. DE-AC05-00OR22725. The following Department of Energy project managers played a role in guiding this work: David Anderson and Prasad Gupte. The U.S. Government retains for itself, and others acting on its behalf, a paid-up, nonexclusive, irrevocable worldwide license in said article to reproduce, prepare derivative works, distribute copies to the public, and perform publicly and display publicly, by or on behalf of the Government.
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