REDUCING EMISSIONS IN URBAN DELIVERY SYSTEMS

Green Activity Zones Workshop
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CO2 Emissions in the U.S. (by end-use sector)

Transportation: 33%
Commercial: 19%
Residential: 22%
Industrial: 26%

Transportation-Related Greenhouse Gas Emissions

- Passenger Cars: 35%
- Light-Duty Trucks: 30%
- Medium- & Heavy-Duty Trucks: 20%
- Pipelines: 2%
- Rail: 2%
- Ships & Boats: 2%
- Aircraft: 8%
- Buses: 1%
- Motorcycles: 0%

Within the United States

- No low emissions zones
- Minimal federal regulations
  - Engines
  - Fuel economy
- Programs which motivate supply chain fuel efficiency
- Idling restrictions – state or county levels
Suggested strategies to reduce fuel consumption and emissions
(EPA SmartWay Transport Partnership)

- Idle reduction
- Improved aerodynamics
- Improved freight logistics
- Automatic tire inflation systems
- Single wide-base tires
- Driver training
- Low-viscosity lubricants
- Intermodal shipping
- Longer combination vehicles
- Reducing highway speed
- Weight reduction
- Hybrid powertrain technology
- Renewable fuels
Motivations to reduce emissions

• Often carrier driven
  • Reduce fuel and maintenance costs
  • Improve their sustainability profile
    • Company values
    • Customer demands

• Future regulations
Research at the University of Washington

- Several case studies using real-world partners
  - University mailing service
  - Grocery delivery service
- Examined various aspects of urban pickup and delivery systems
  - Emissions
  - Cost
  - Customer service
- Working with Anne Goodchild, Felipe Sandoval, and Erica Wygonik
Urban Pickup and Delivery Systems
University of Washington Mailing Service

- Pickup/delivery of internal campus mail, as well as U.S. Postal Service mail
- Fleet of 7 vehicles (heterogeneous)
- Serves 52 customers
- Travel on controlled access freeways, arterials, and residential streets

UWMS Customers. Great Seattle Area.
Model: Objective Function

- Typical Cost Model

\[
\begin{align*}
\text{Min} & \sum_{p \in P} \sum_{v \in V} \sum_{j \in N} \sum_{i \in N} C_{i,j}^{p,v} \times X_{i,j}^{p,v} \\
\text{Traffic Periods} & \text{Vehicles} \quad \text{Customers} \quad \text{Cost}
\end{align*}
\]

- Our Model

Cost per mile + Cost per hour + Emissions tax

\[
\begin{align*}
\text{Min} \sum_{p \in P} \sum_{v \in V} \sum_{j \in N} \sum_{i \in N} \left[ CO^v \times D_{ij} + CT^v \times T_{ij}^p + \text{TAX} \times EF^{p,v} \times D_{ij} \right] \times X_{i,j}^{p,v}
\end{align*}
\]
The trade-offs between cost, service quality, and emissions

Scenarios Tested Within the Model

- Base
- Improved
- Morning Consolidation & Afternoon Consolidation
- Single Deliveries
- Fleet Upgrade
The trade-offs between cost, service quality, and emissions

- Cost
- Service Quality
- Emissions

-50%  -30%  -10%  10%  30%  50%

Morning Customer Consolidation
Afternoon Customer Consolidation
Fleet Upgrade
Improved (Removing Driver Breaks)
Single Deliveries (Reduction in Frequency)
Conclusions: 

CASE STUDY

- Simple rerouting *reduces emissions and cost*
  - emissions: average reduction of 6%
  - cost: average reduction of 9%
- *UWMS fleet is underutilized:* fleet could be reduced from 7 vehicles to 4 vehicles
Conclusions:

**URBAN PICKUP SYSTEMS**

- Operational changes can reduce emissions while only increasing costs minimally, or not at all
- Cost and emissions savings can be found with service quality reductions
- Managers of small fleets of vehicles can use simple rules of thumb to improve emissions within vehicle routing
Grocery Delivery: Shared-use Transportation

- Any transportation service that combines multiple parallel trips into one
- Examples: vanpools, school buses, public and private transit, delivery services, airport shuttles
Research questions

1: Can CO$_2$ emissions be reduced if personal travel is replaced by delivery service for grocery shopping?

2: Can the type of service (provider-controlled or customer-controlled) affect the results?
Optimization Tools and Method

- Use ArcGIS Network Analyst tools to calculate cost, time, or emissions
- Depots: Grocery store locations
- Customers: 35-household samples (two types)
  - Provider-controlled (proximity-assigned)
  - Customer-controlled (randomly-selected)
- Each represents 1 truck’s worth of service
Two service types

Random selection

Proximity assignment
Routing of the two service types

Random selection

Proximity assignment
Influence on Distance Travelled

- Passenger Travel: Random Selection 8,804 feet/customer, Proximity Assignment 8,374 feet/customer
- Delivery Vehicle: Random Selection 1,453 feet/customer, Proximity Assignment 367 feet/customer
Influence on Distance Travelled

- Shared-use vehicle routing reduces VMT by 85-95 percent
- Personal vehicles travel the same distance regardless of regime
- Shared-use vehicles travel less when serving proximity-assigned customers
Influence on CO₂

![Bar chart showing the influence of CO₂ emissions for different service types and assignment methods.]

- **Passenger Travel**: Random Selection (0.595), Proximity Assignment (0.567)
- **Delivery Vehicle**: Random Selection (0.326), Proximity Assignment (0.079)

**Distribution of and Service Type for Customers**
Influence on CO₂

- Shared-use vehicle routing reduces CO₂ by 80-90 percent when serving proximity-assigned customers.

- CO₂ emissions are reduced by 17-75 percent when customers are randomly assigned.
Summary

- \( \text{CO}_2 \) emissions can be reduced if personal travel is replaced by delivery service for grocery delivery
- Larger \( \text{CO}_2 \) reductions are possible when delivery vehicles serve clustered customers (provider-controlled services)
In Closing

• Few government regulations concerning emissions
• Efforts to reduce emissions motivated by costs or company values
• Research shows emissions improvements
  • improved logistics
  • thinking beyond traditional goods movements