# REDUCING EMISSIONS IN URBAN DELIVERY SYSTEMS

Green Activity Zones Workshop

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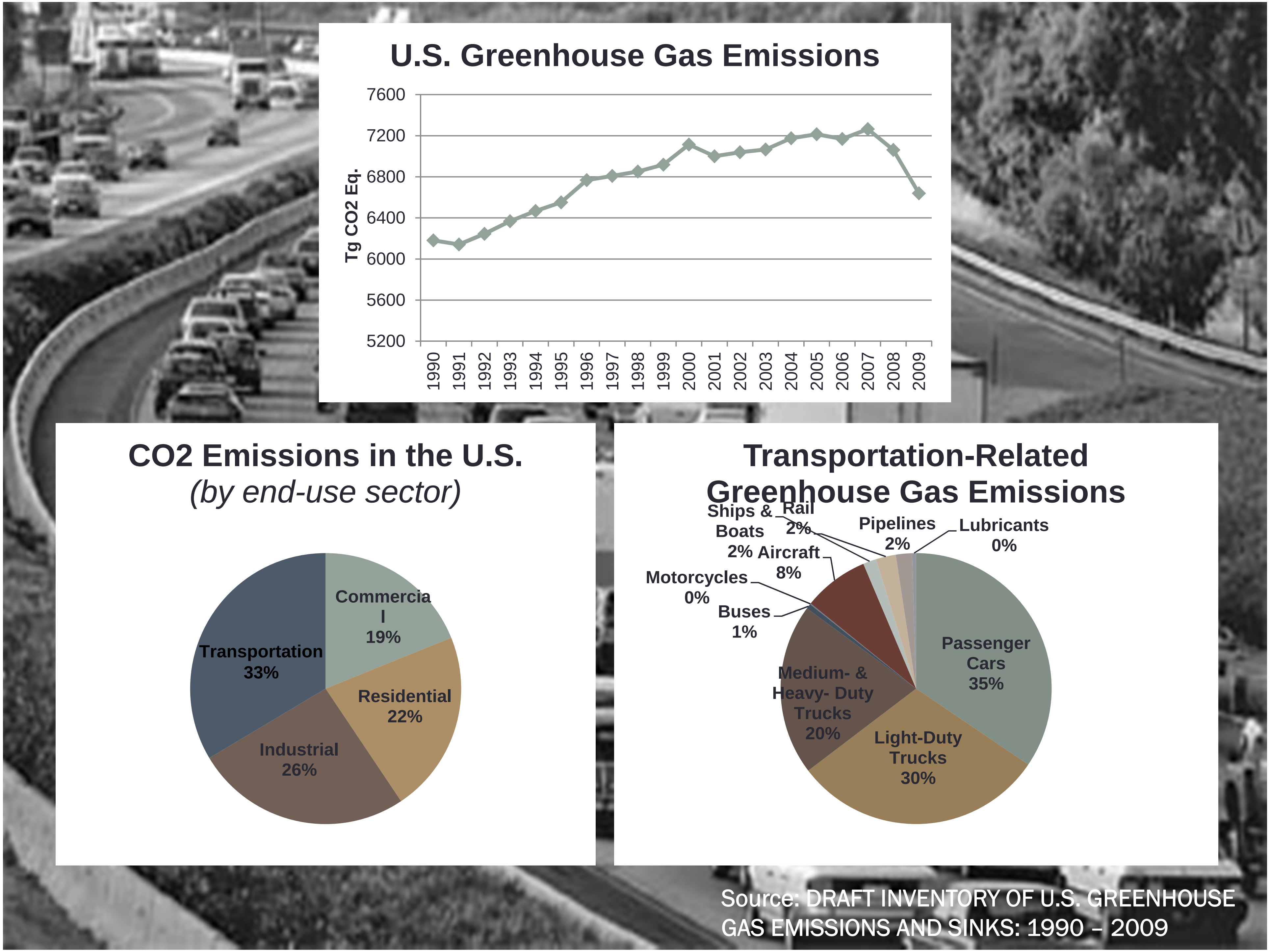

U.S. Greenhouse Gas Emissions
Tg CO2 Eq.
7600
7200
6800
6400
6000
5600
5200
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
CO2 Emissions in the U.S.
(by end-use sector)
Commercial 19%
Residential 22%
Industrial 26%
Transportation 33%
Transportation-Related Greenhouse Gas Emissions
Ships & Boats 2%
Rail 2%
Pipelines 2%
Lubricants 0%
Aircraft 8%
Motorcycles 0%
Buses 1%
Passenger Cars 35%
Medium- & Heavy- Duty Trucks 20%
Light-Duty Trucks 30%
Source: DRAFT INVENTORY OF U.S. GREENHOUSE GAS EMISSIONS AND SINKS: 1990 – 2009

# 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

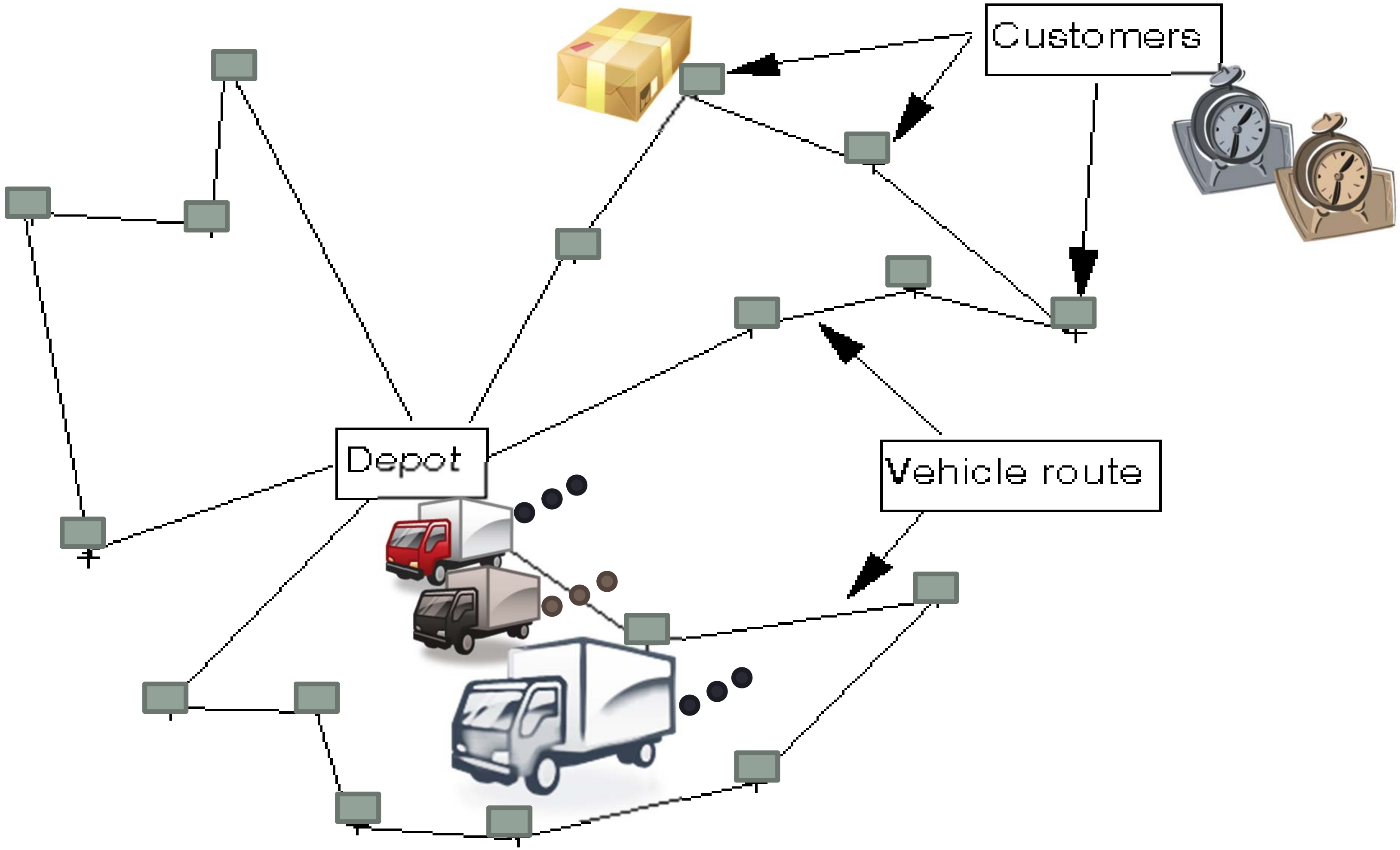
# Motivations to reduce emissions

- 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

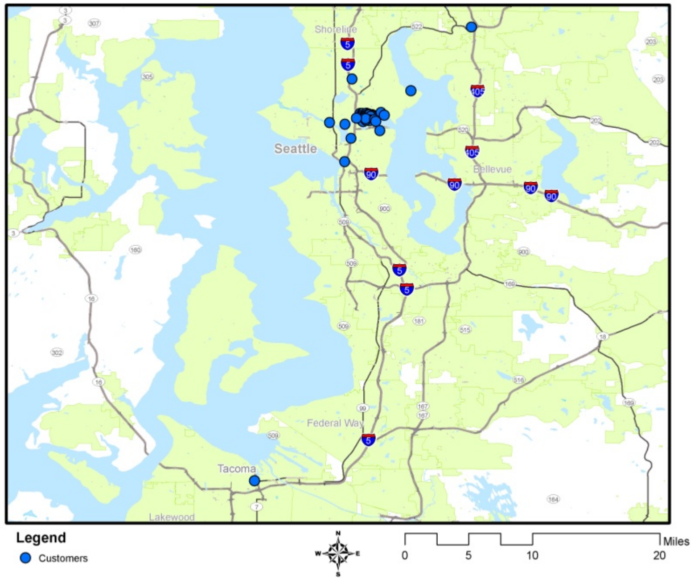
# Urban Pickup and Delivery Systems



# 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

Cost

$$\text{Min} \sum_{p \in P} \sum_{v \in V} \sum_{j \in N} \sum_{i \in N} C_{i,j}^{p,v} \times X_{i,j}^{p,v}$$

Traffic Periods Vehicles Customers

- Our Model

Cost per mile + Cost per hour + Emissions tax

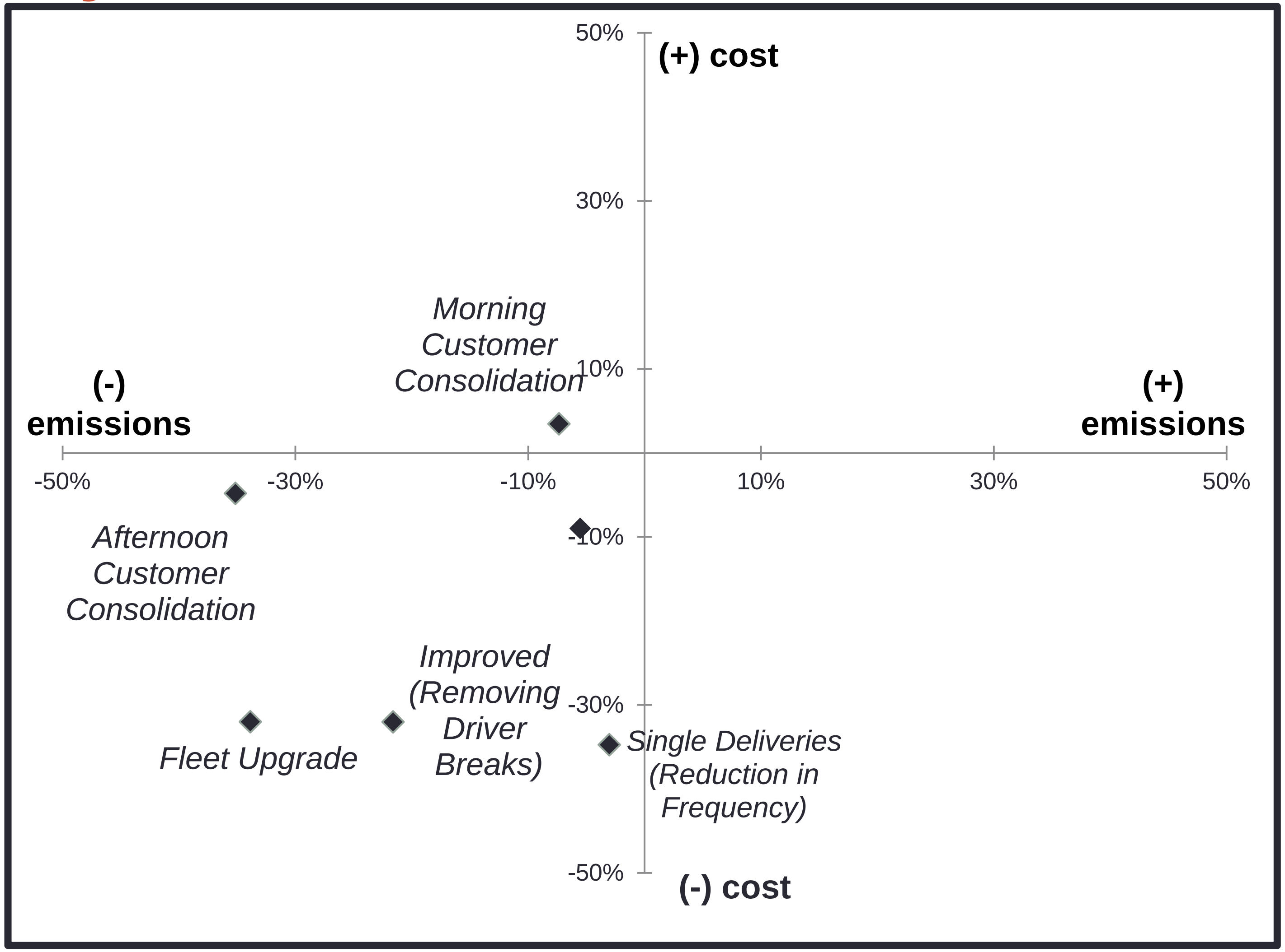
$$Min \sum_{p \in P} \sum_{v \in V} \sum_{j \in N} \sum_{i \in N} \left[ CO^{v} \times D_{ij} + CT^{v} \times T_{ij}^{p} + TAX \times EF^{pv} \times D_{ij} \right] \times x_{ij}^{pv}$$

# 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



# 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

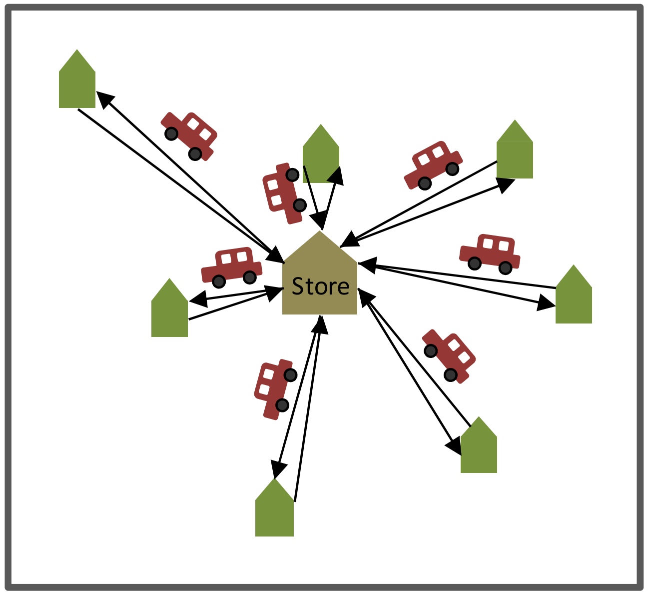
# Conclusions:
## *URBAN PICKUP SYSTEMS*

- 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 on simple rules of thumb to improve emissions within vehicle routing

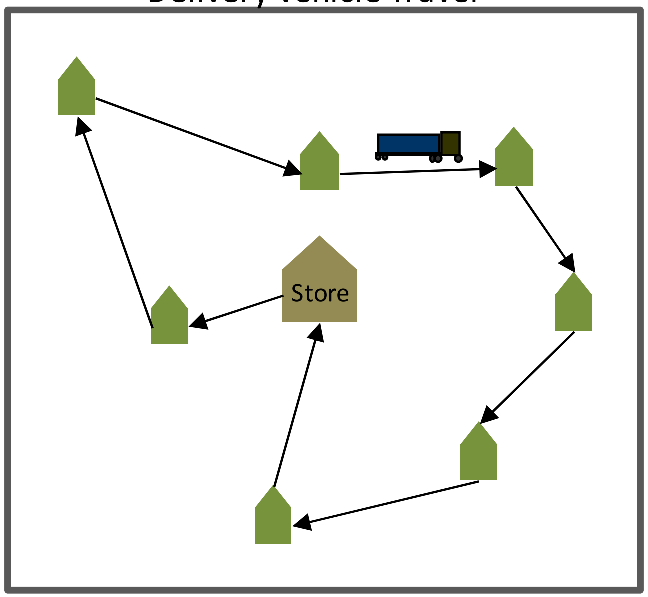
# Grocery Delivery: Shared-use Transportation

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

Personal Vehicle Travel




Delivery Vehicle Travel



# Research questions

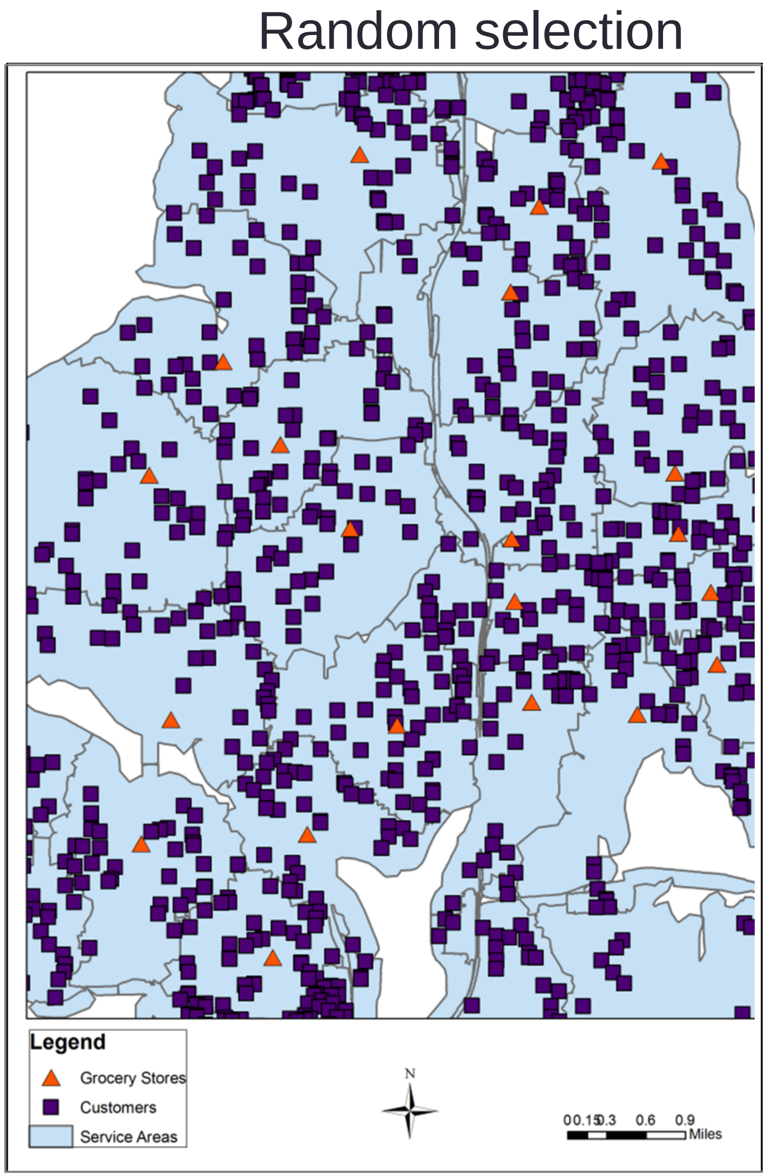
1: Can $CO_2$ emissions be reduced if personal travel is replaced by delivery service for grocery shopping?

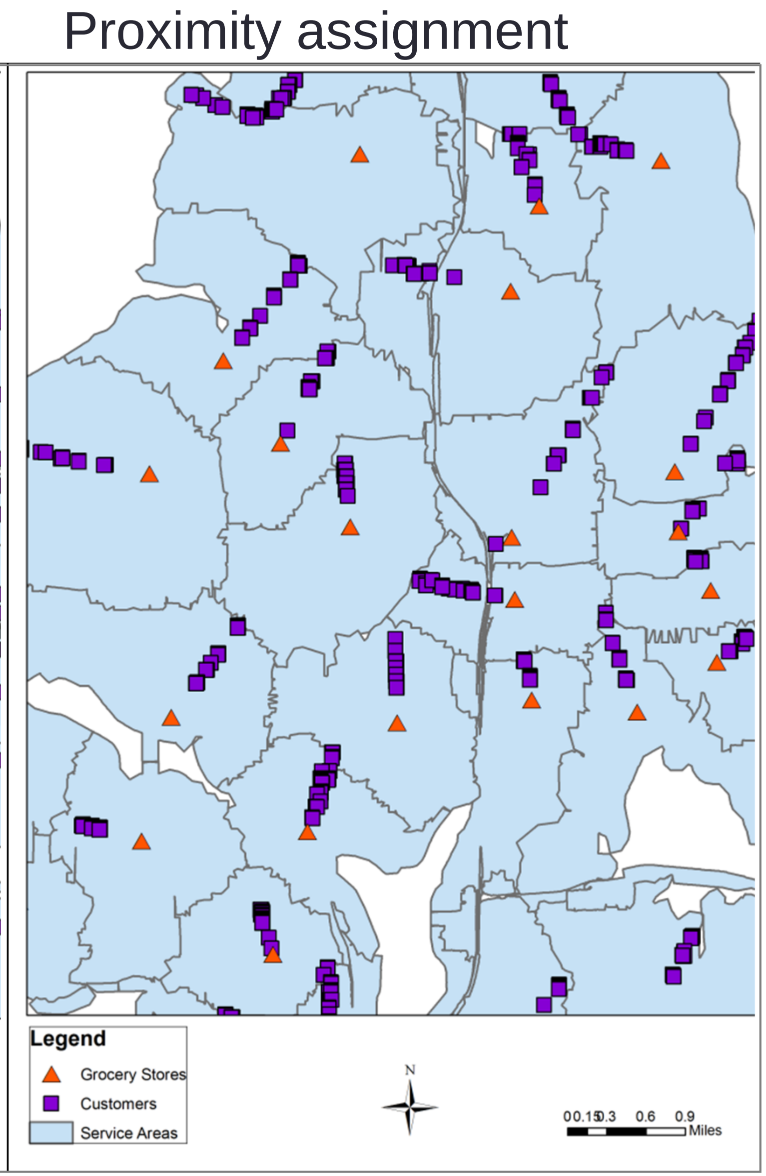
2: Can the type of service (provider-controlled or customer-controlled) affect the results?

# 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

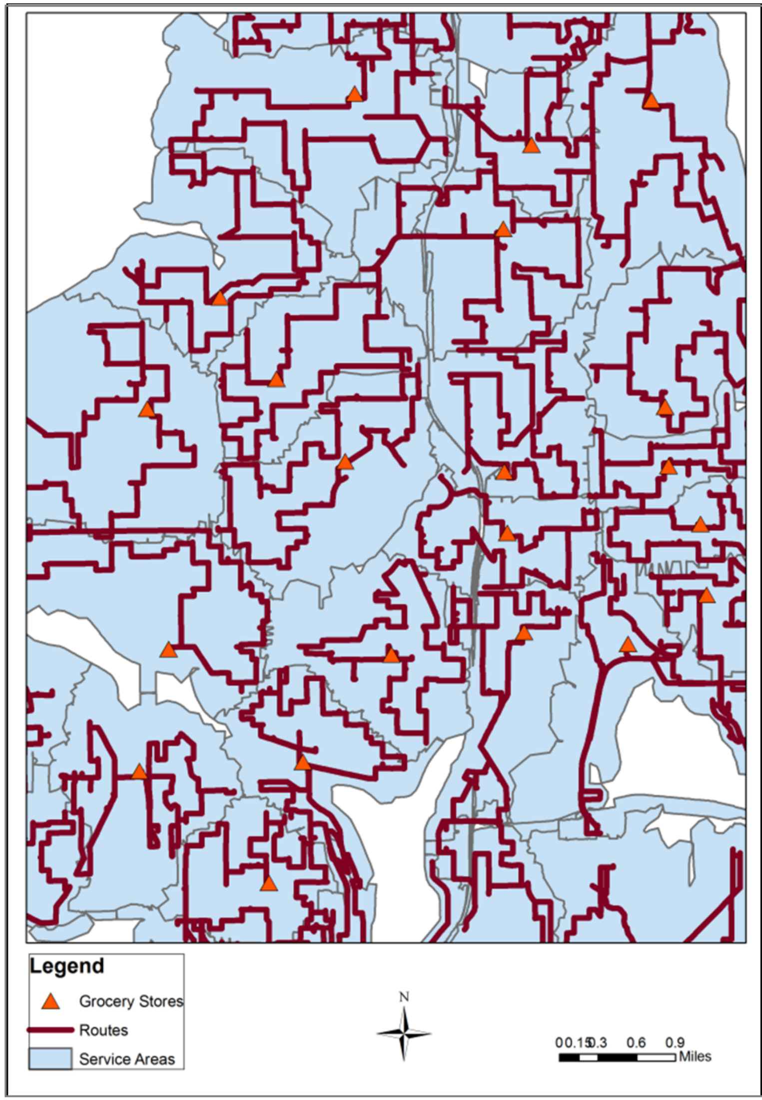
# Two service types



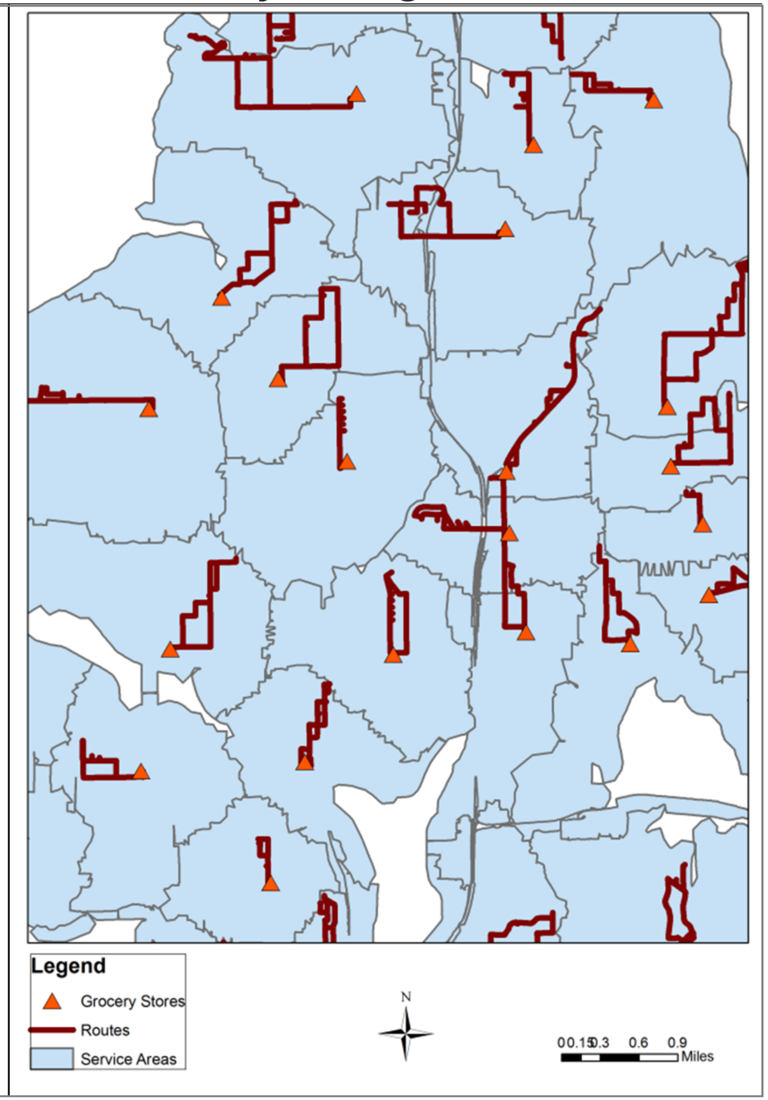



# Routing of the two service types

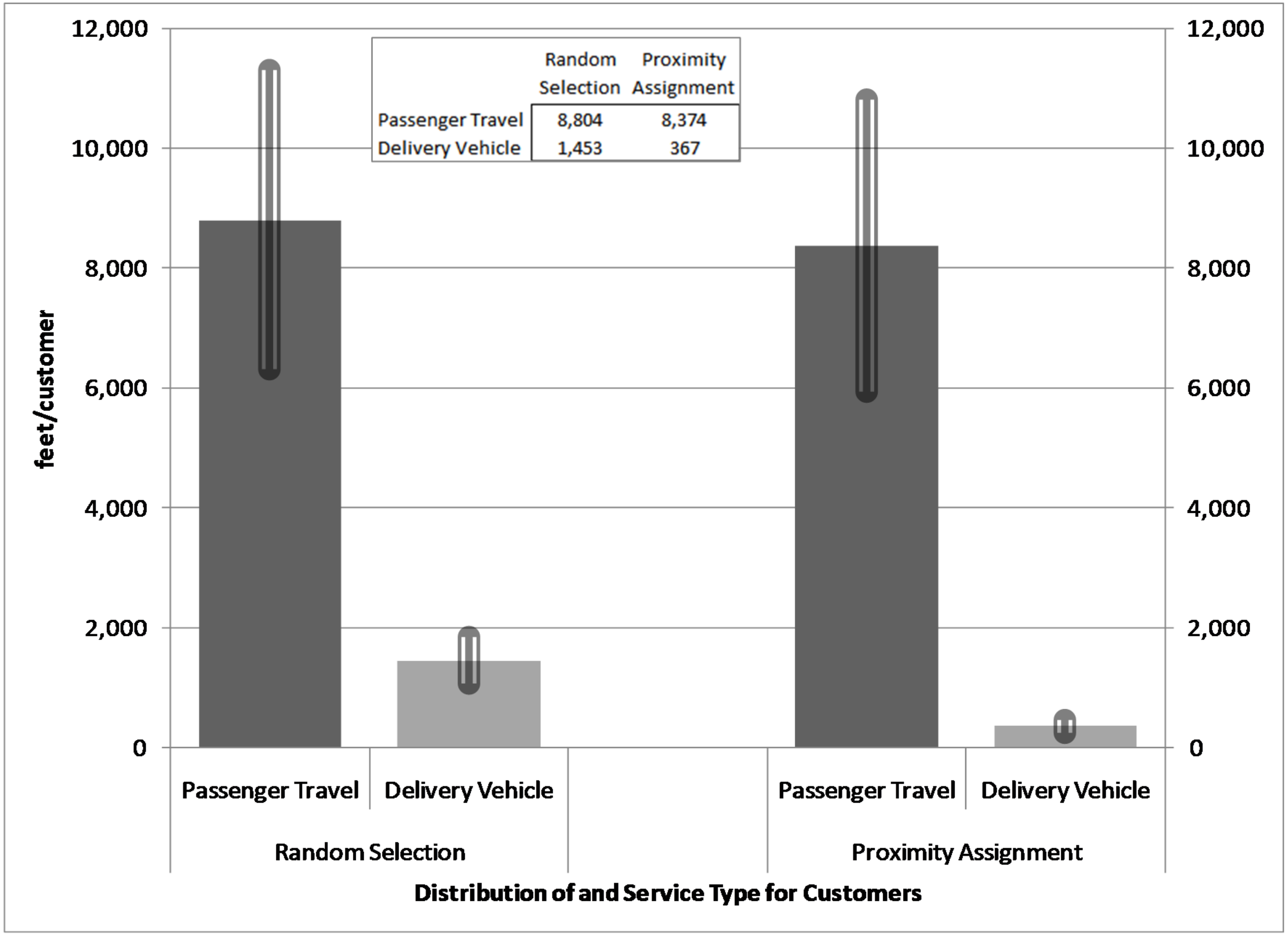
Random selection




Proximity assignment



# Influence on Distance Travelled

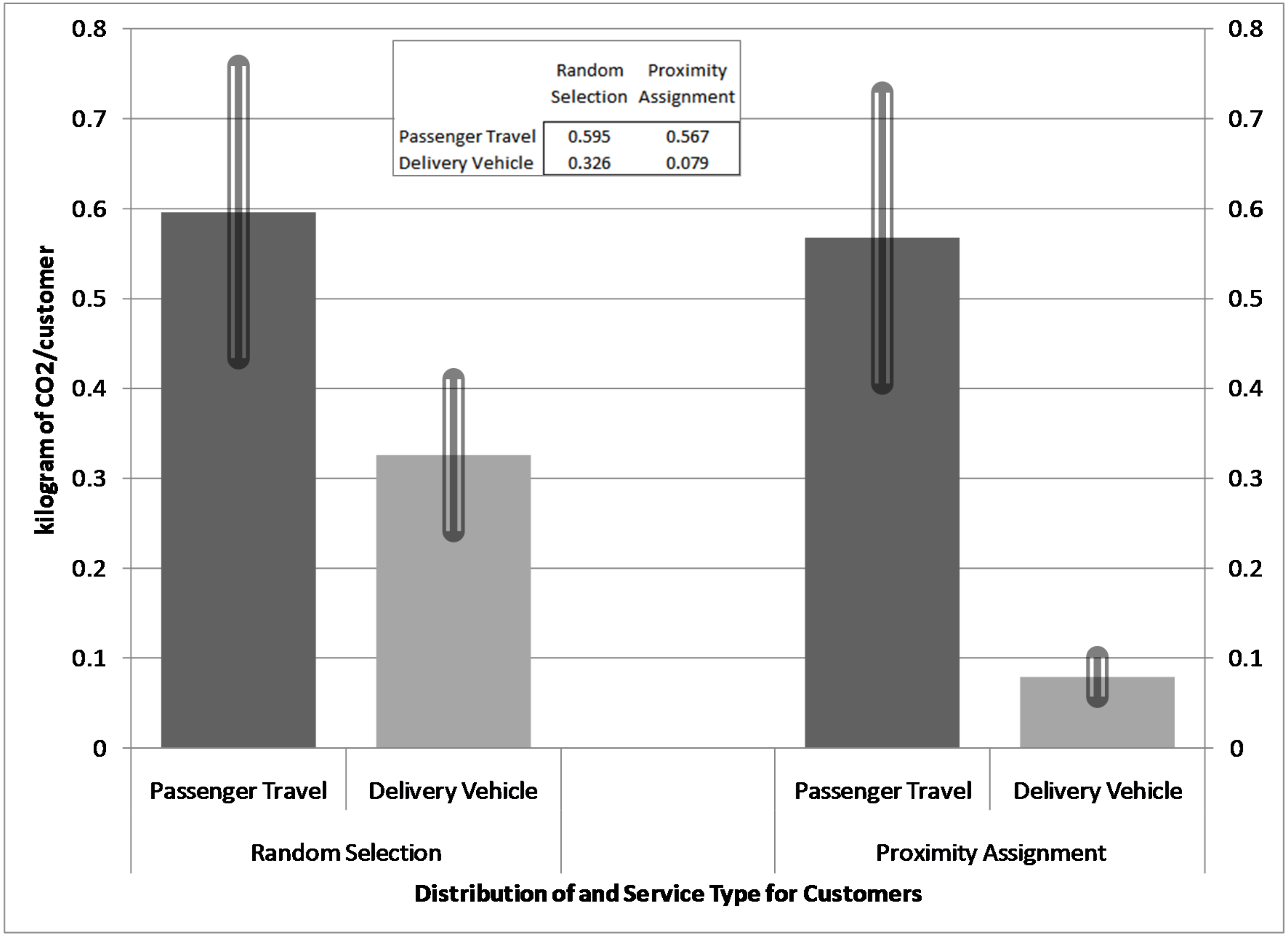



| | Random Selection | Proximity Assignment |
|---|---|---|
| Passenger Travel | 8,804 | 8,374 |
| Delivery Vehicle | 1,453 | 367 |

# 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 $CO_2$



# Influence on $CO_2$

- Shared-use vehicle routing reduces $CO_2$ by 80-90 percent when serving proximity-assigned customers
- $CO_2$ emissions are reduced by 17-75 percent when customers are randomly assigned

# Summary

- $CO_2$ emissions can be reduced if personal travel is replaced by delivery service for grocery delivery
- Larger $CO_2$ 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