Sustainable Freight

Contending with Increasing Freight Demand

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System of Interest

The freight system is multi-modal

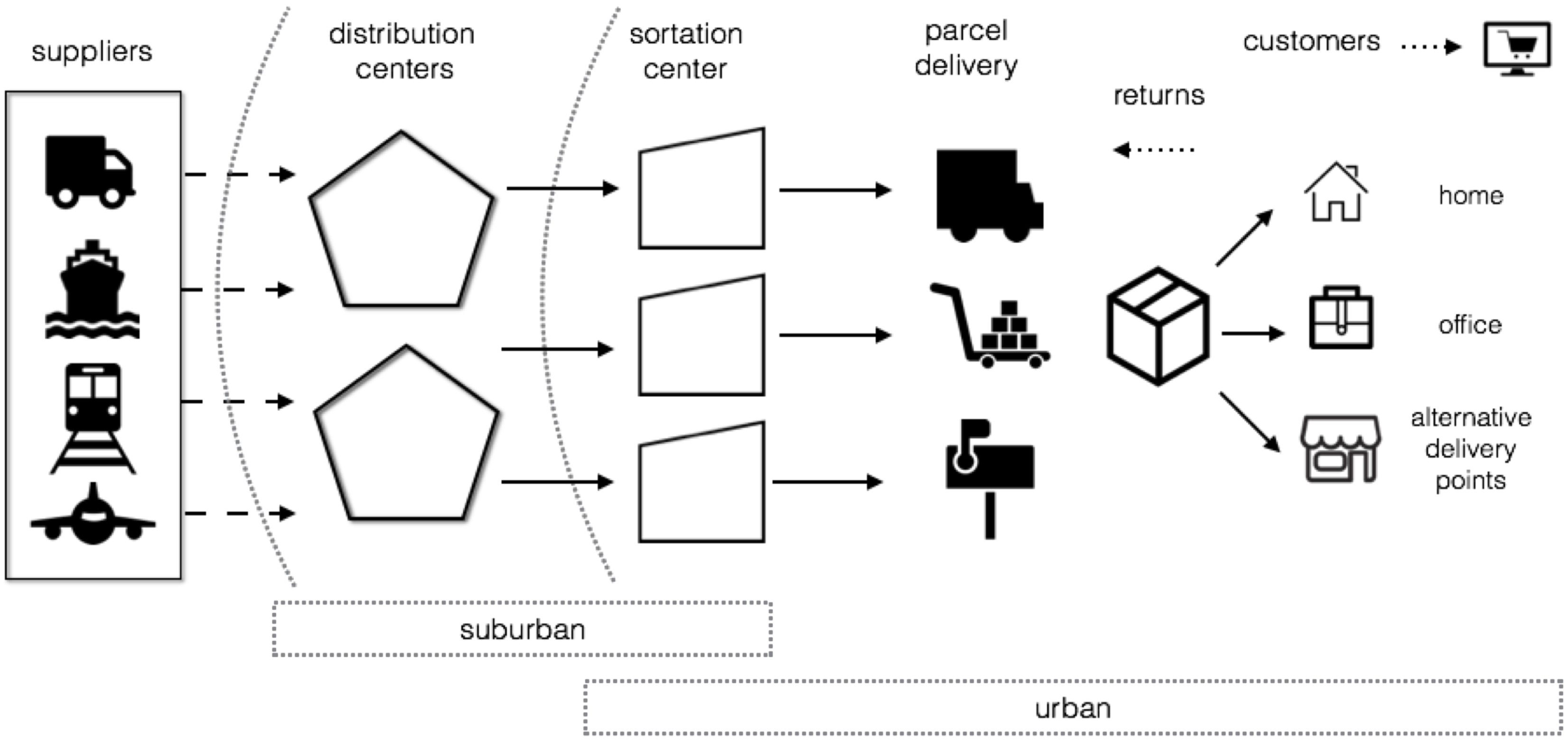
But…

The closer we are to the consumer…

Trucks dominate freight traffic

2 differences:

- Generation of cargo
- Generation of freight trips



In addition to commercial demand, residences and individuals generate freight traffic

Residential Demand is Growing

Online shopping market share has grown almost 30% since 2009

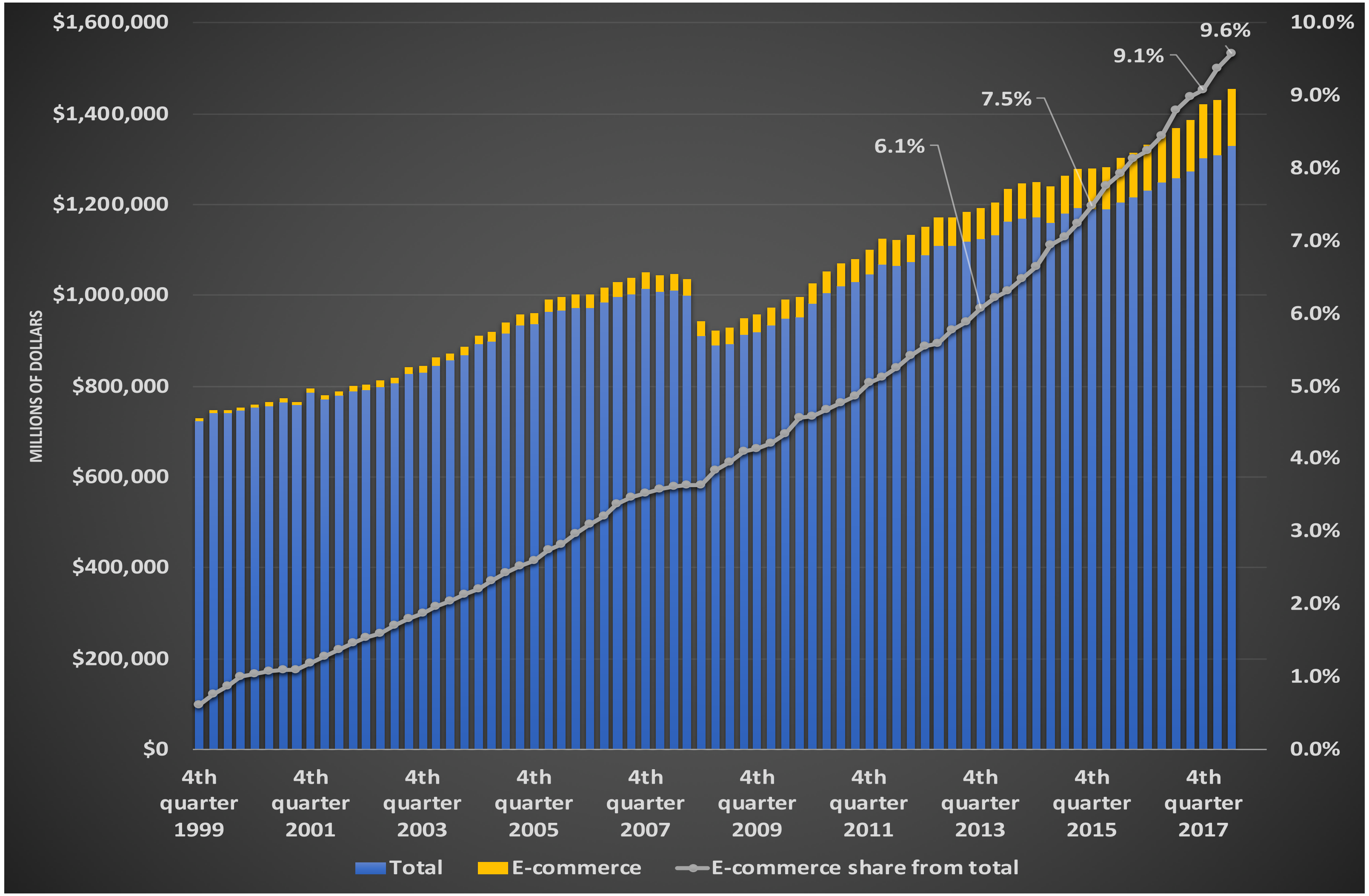
Today…

- 55% of the population shop online

During any given day…

- ~40% of the population shops
- 2-3% shop online

Retail and e-commerce quarterly sales 1993-2017



What is the Problem?

Basically…more freight traffic and the associated consequences…

This rapid increase:

- Generated by the market, and accentuated by consumers
- Disrupted the freight and logistics industries
  - Changes in the location of freight facilities (e.g., warehouses)
  - Changes in the location and concentration of demand
  - Changes in the retail landscape
  - Changes in inventory practices and distribution services
  - Put the system in steroids…
- Disrupted shopping practices
  - Changes in the shopping process (search, purchase, transport)
  - Tradeoff between individual's travel and deliveries
- Increased urban freight traffic
  - More congestion
  - More emissions
  - More energy consumed
  - More conflicts
  - More problems…

What are we doing?

AS SIMPLE AS THE **1-2-3** APPROACH

1. SOLVING RECURRENT PROBLEMS FROM THE PAST…
2. CONTENDING WITH THE NEW ISSUES…
3. ANTICIPATING THE FUTURE AND TRYING TO MITIGATE THE IMPACTS…

Understanding and Modeling Freight Practices

What is/are the:

- cargo?
- origins and destinations?
- Modes and vehicles?
- volumes?
- traffic?
- routes?
- costs?
- impacts?

This requires approaching the problem along the continuum

Supply ⟷ Demand

Demand

Estimating Demand and Evaluating the Impacts

Focus on commercial deliveries and online shopping

- Behaviors
- Travel

Research Methodology:

1. Estimated econometric models to determine the factors that affect shopping behavior using the American Time Use Survey (ATUS)
2. Evaluated complementarity or substitution effects between in-store and online shopping
3. Developed a behavioral-based shopping trip and urban delivery aggregate simulator
4. Estimated vehicle miles traveled and environmental emissions from shopping
5. Evaluated the impact of rush deliveries
6. Developed a breakeven analysis to compare in-store versus online shopping

Modeling Shopping Behaviors

Decisions about:

- Shopping or not?
- Shopping online or in-store?

Travel impacts:

- Complementarity effect
- Substitution effect
- Induced demand

- Heterogeneous shopping behaviors across different segments
- This effect is clearly different across two genders

Variable		Shop	In-store	Online
Gender	Female	+	-	+
Mobility	Difficulty in mobility	-		
Employment status	Unemployed	+		
Education Level	Secondary	+		
	Graduate	+		
Age group	Millennial	+		
	Generation X	+		
	Baby Boomers	+		
	Silent Generation	+		
Family Income	Low		-	+
	Lower Middle	+		+
	Median	+		+
	Middle Middle	+		+
	Upper Middle	+		
	High			+
Season	Fall		-	+
HH variables	Family Structure	-		
Control group	A single male in the house, belonging to generation Z, with no mobility related difficulty, having no education, is not in the labor force, living under poverty level, from Midwest. We observe this individual's shopping behavior during the summer.			

- Generalizing substitution or complementarity effects over the entire shopping behavior leads to aggregation bias
- The probability of shopping through one channel reduces when the individual had already shopped in the other

Evaluating the Environmental Impacts of Online Shopping

3 cases:

- All shopping in-store ("past")
- Omni-channel ("present")
- All online ("future?")

Different assumptions about shopping trips and delivery tours

Results for estimated tours of varying length and stops per tour substitution

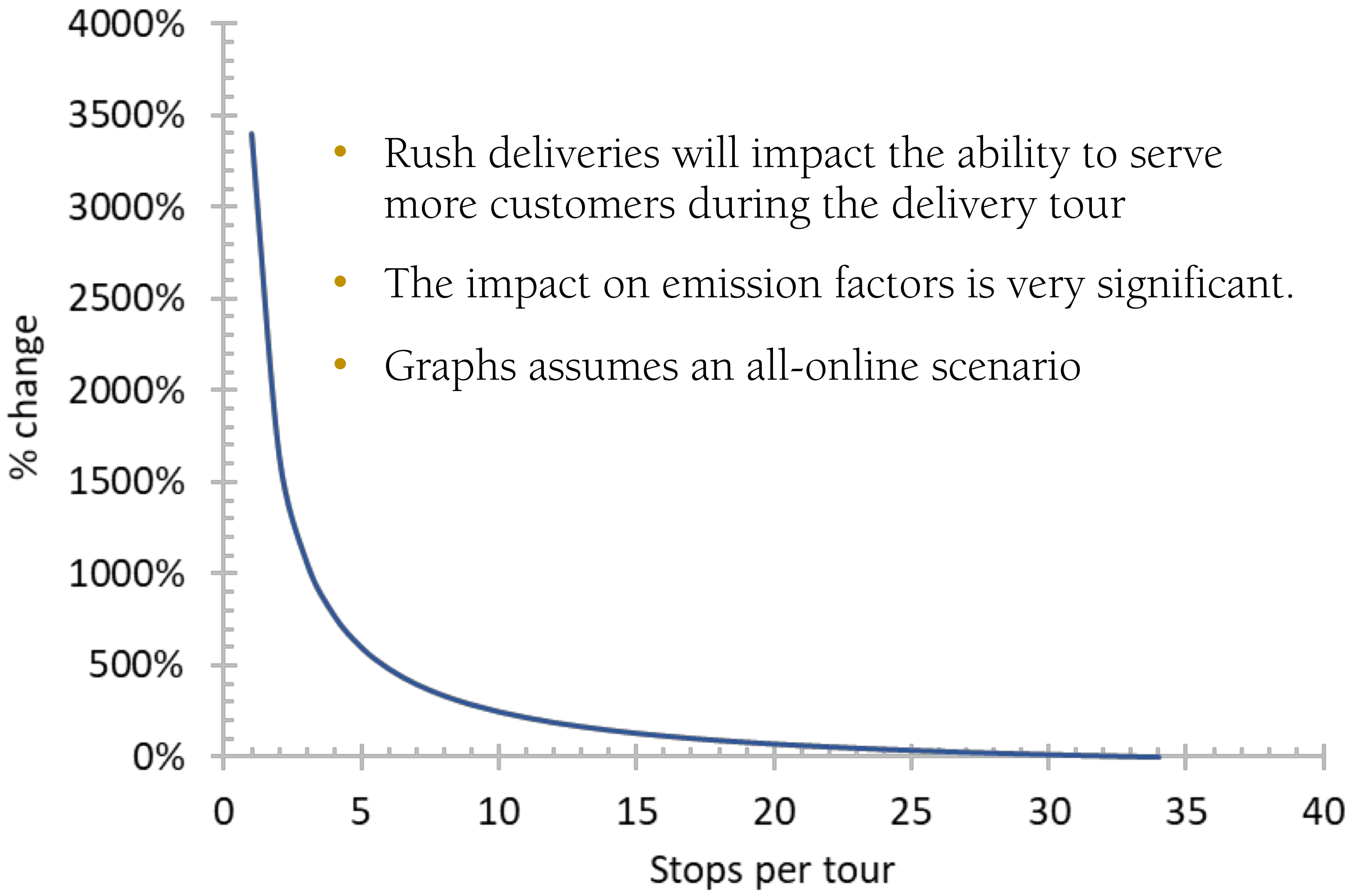
Implemented models in various cities

Parameters	Scenario	%Δ w.r.t. to SC in-store		
		FQC	MQC	TQC
VMT	Omni Channel	0%	1%	1%
	SC online	-92%	-88%	-81%
CO (kg)	Omni Channel	0%	1%	1%
	SC online	-91%	-88%	-80%
NO_x (kg)	Omni Channel	6%	9%	15%
	SC online	-16%	**20%**	**90%**
CO_2 (Metric ton)	Omni Channel	2%	2%	4%
	SC online	-75%	-64%	-42%
PM 10 (kg)	Omni Channel	3%	4%	6%
	SC online	-62%	-46%	-14%
PM 2.5 (kg)	Omni Channel	3%	4%	6%
	SC online	-62%	-46%	-14%
SO_x (kg)	Omni Channel	2%	2%	4%
	SC online	-75%	-64%	-43%
F/M/TQC:	First/Median/Third Quartile Delivery Distance			

Rush Deliveries are not Sustainable

Faster deliveries reduce time windows…

Deconsolidating the last mile



- Rush deliveries will impact the ability to serve more customers during the delivery tour
- The impact on emission factors is very significant.
- Graphs assumes an all-online scenario

Supply

Dealing with the Supply Side

Working with fleets:

- Zero and near zero emission
- Improved routing
- Alternative distribution network
- Automation

Diesel vehicles dominate the market

In the meantime, we can…

- Design them better (e.g., drivetrain, powertrain)
- Drive them better (e.g., eco-driving, eco-routing)
- Use them better (e.g., right sizing)
- Manage how they perform (e.g., geo-fencing)

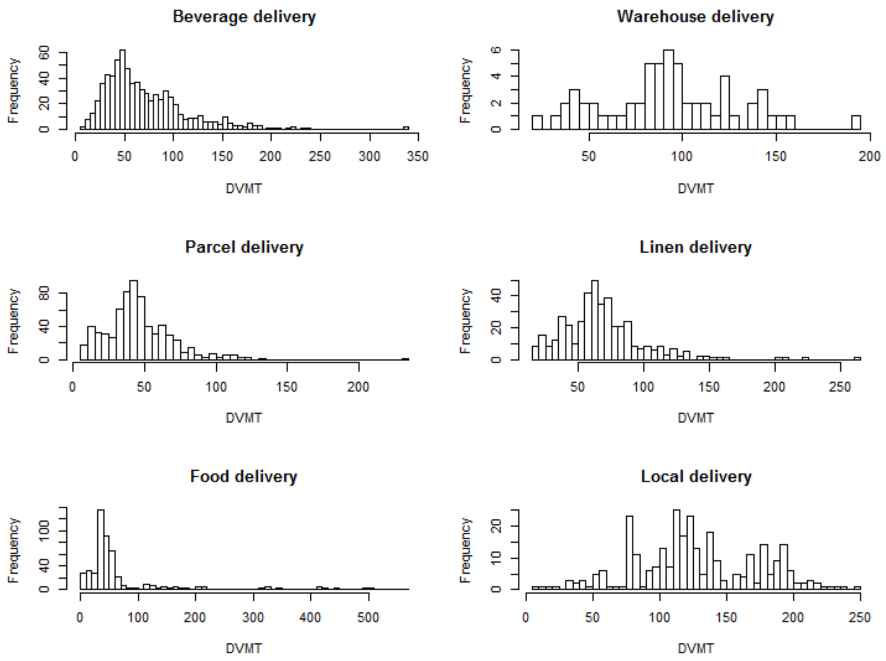
Or, we can…

- Replace them for zero emission vehicles
- Use them differently by changing our distribution networks
- Automate the system

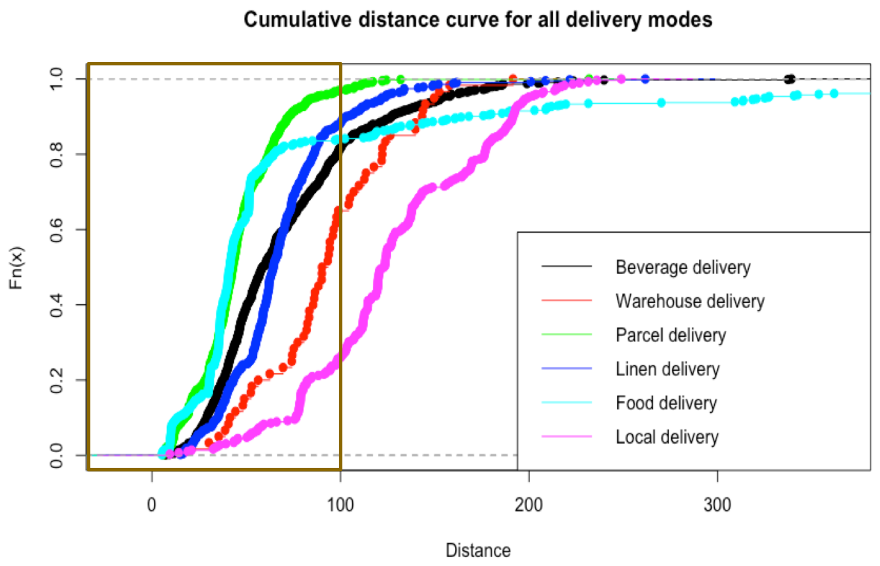
Evaluating Zero Emission Vehicles for Last Mile Distribution

Using aggregated GPS data from FleetDNA

Different last mile delivery vocations have different patterns



Parcel deliveries conduct a large number of stops per tour along shorter routes



ITS UCDAVIS INSTITUTE OF TRANSPORTATION STUDIES

UCDAVIS SUSTAINABLE TRANSPORTATION ENERGY PATHWAYS

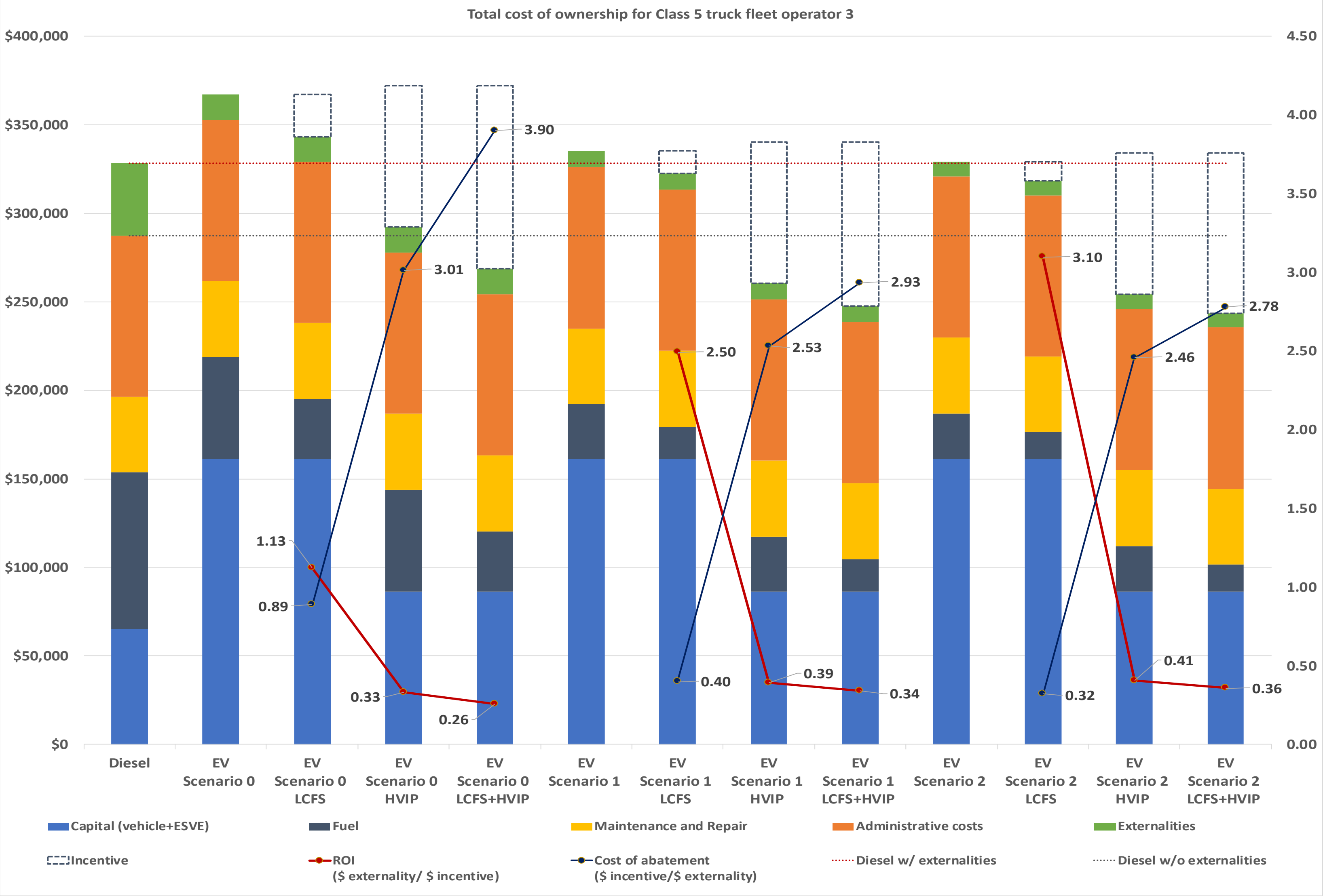
Total Cost of Ownership for Electric Trucks in Last Mile

Considering 3 scenarios based on Energy Efficiency Ratio (EER) assumptions

Consider:

- No financial incentives
- LCFS
- HVIP
- LCFS + HVIP

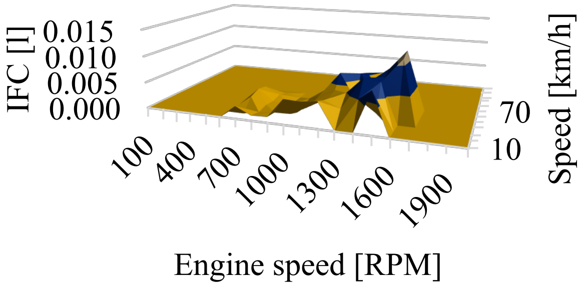
Class 5 truck for parcel deliveries

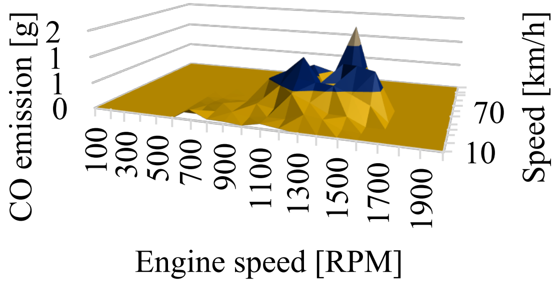


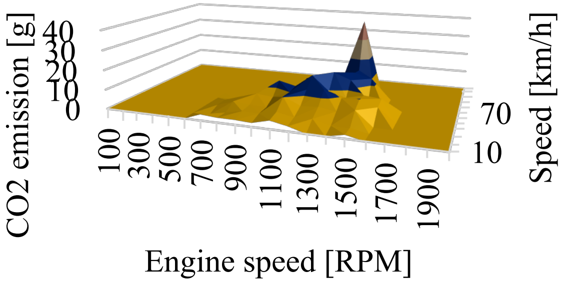
Eco-Routing

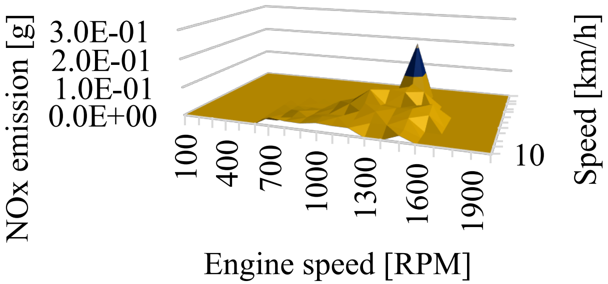
Based on empirical data, estimated:

- Drive cycles using different CPs
- Estimated models for each family of CP's operating pattern
- Developed a routing optimization algorithm to find eco-routes
- Different driving modes









	SFC [l/km]	EF CO2 [g/km]	EF CO [g/km]	EF NOx [g/km]
SFC	0.295	698.96	30.89	3.73
CO	0.325	695.71	29.22	3.86
CO2	0.366	630.76	32.16	3.39
NOx	0.352	683.88	34.27	3.25

$$Total\ cost = \beta_D D + \beta_T T + \beta_{FC} FC + \beta_{CO_2} CO_2 + \beta_{CO} CO + \beta_{NO_x} NO_x$$

Where,

$\beta_D = \$\ 0.2665\ per\ km^a$

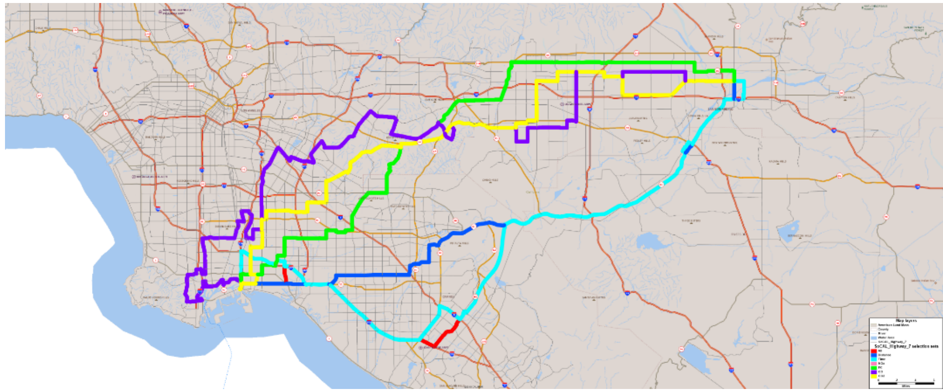
$\beta_T = \$\ 35\ per\ hour^a$

$\beta_{FC} = \$\ 1.051\ per\ litre^b$

$\beta_{CO_2} = \$\ 0.1966\ per\ kg^c$

$\beta_{CO} = \$\ 0.1763\ per\ kg^a$

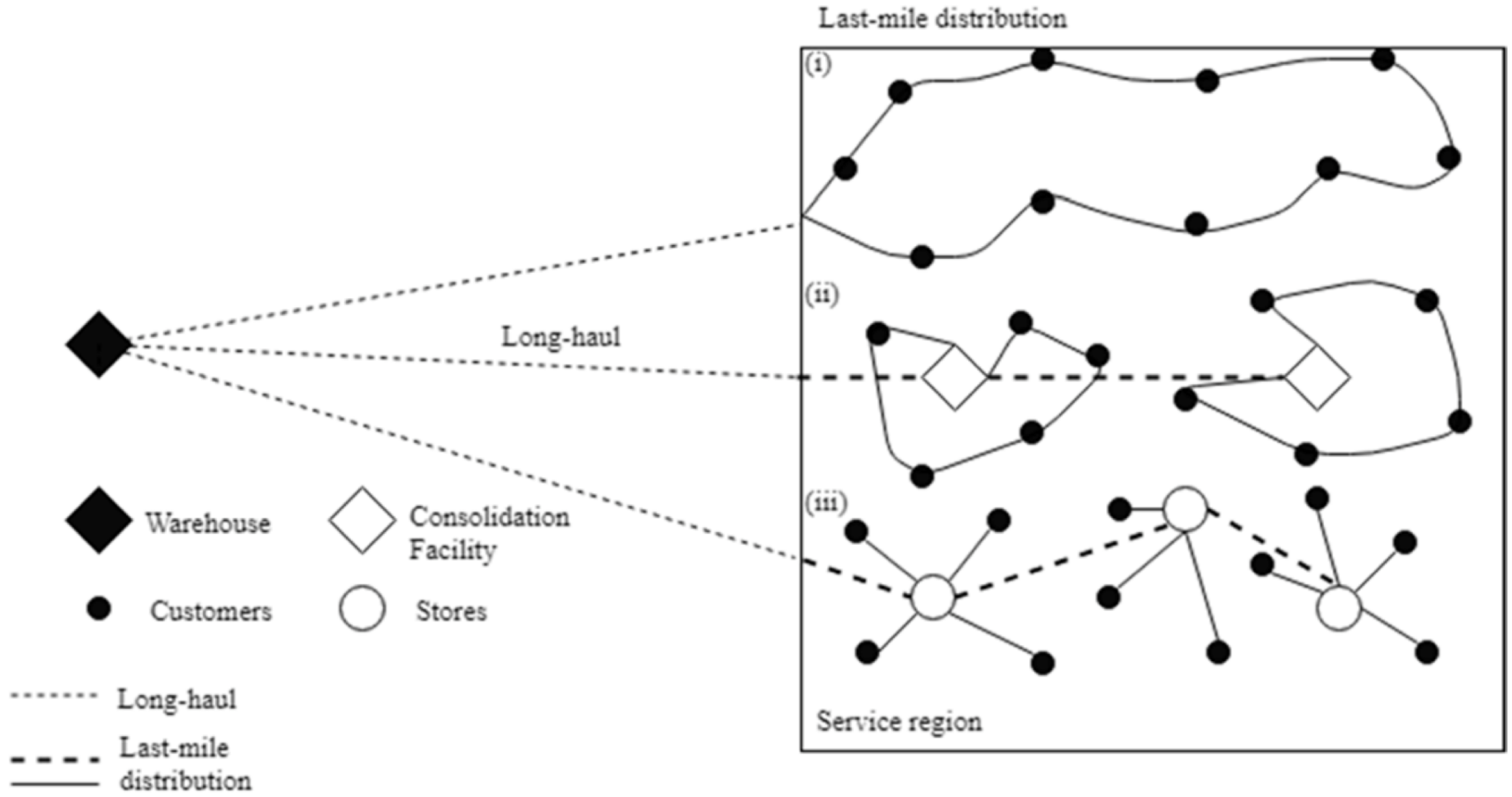
$\beta_{NO_x} = \$\ 70.43\ per\ kg^a$



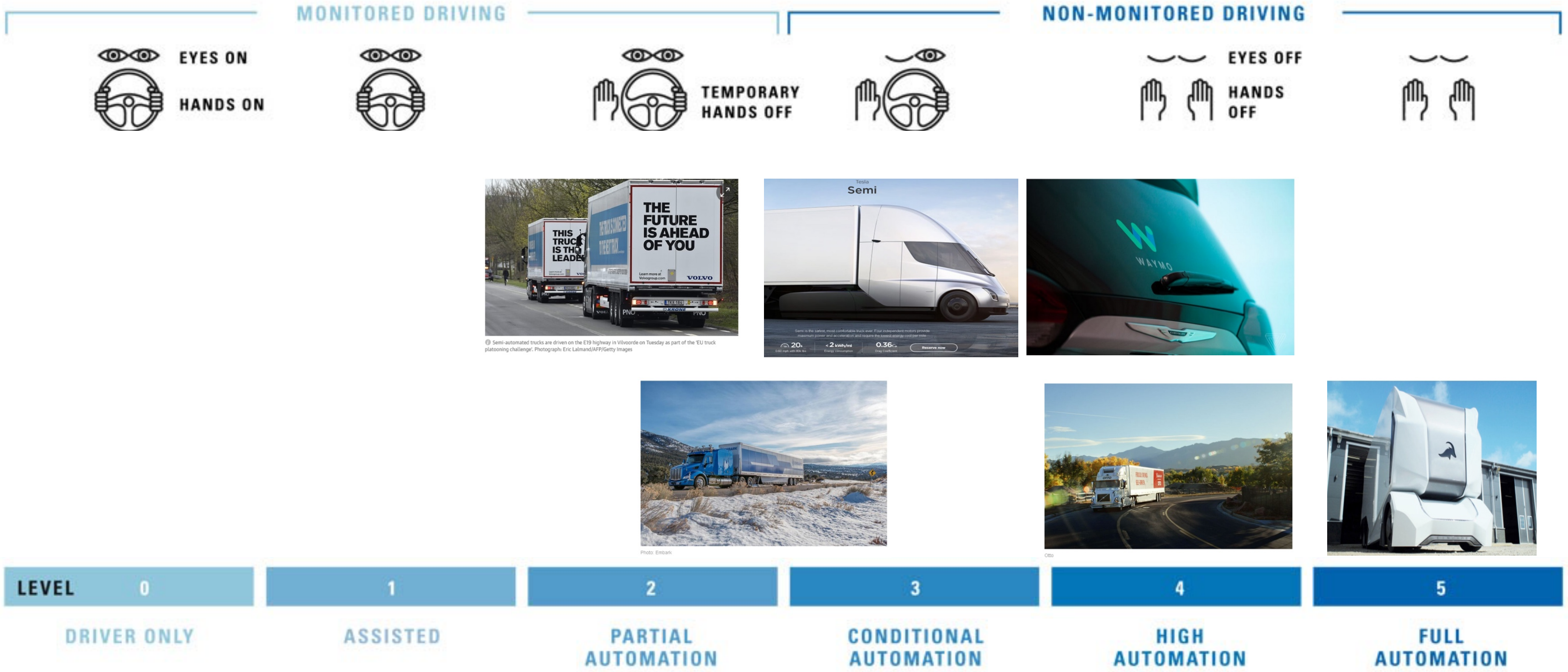
Evaluating Alternative Distribution Configurations

3 main strategies for mixed or full zero emission vehicle fleets:

- Delivery tours (from warehouse to destination)
- Using consolidation centers with various forms of final distribution (e.g., small electric vehicles, freight bicycles)
- Using alternative delivery locations (e.g., store or other pick-up/delivery points)



Automation for the Long Haul



https://medium.com/@yuchenluo/decoding-the-myth-of-self-driving-cars-and-the-competition-in-u-s-e2da6beb695c

Automation in the Last Mile

http://beta.latimes.com/business/autos/la-fi-hy-robovan-mercedes-20160907-snap-story.html
http://www.billbrucecommunications.com/article/jd-com-launches-robot-delivery-service-at-chinese-universities/

Questions!

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