Vehicle charging infrastructure for the future transportation system

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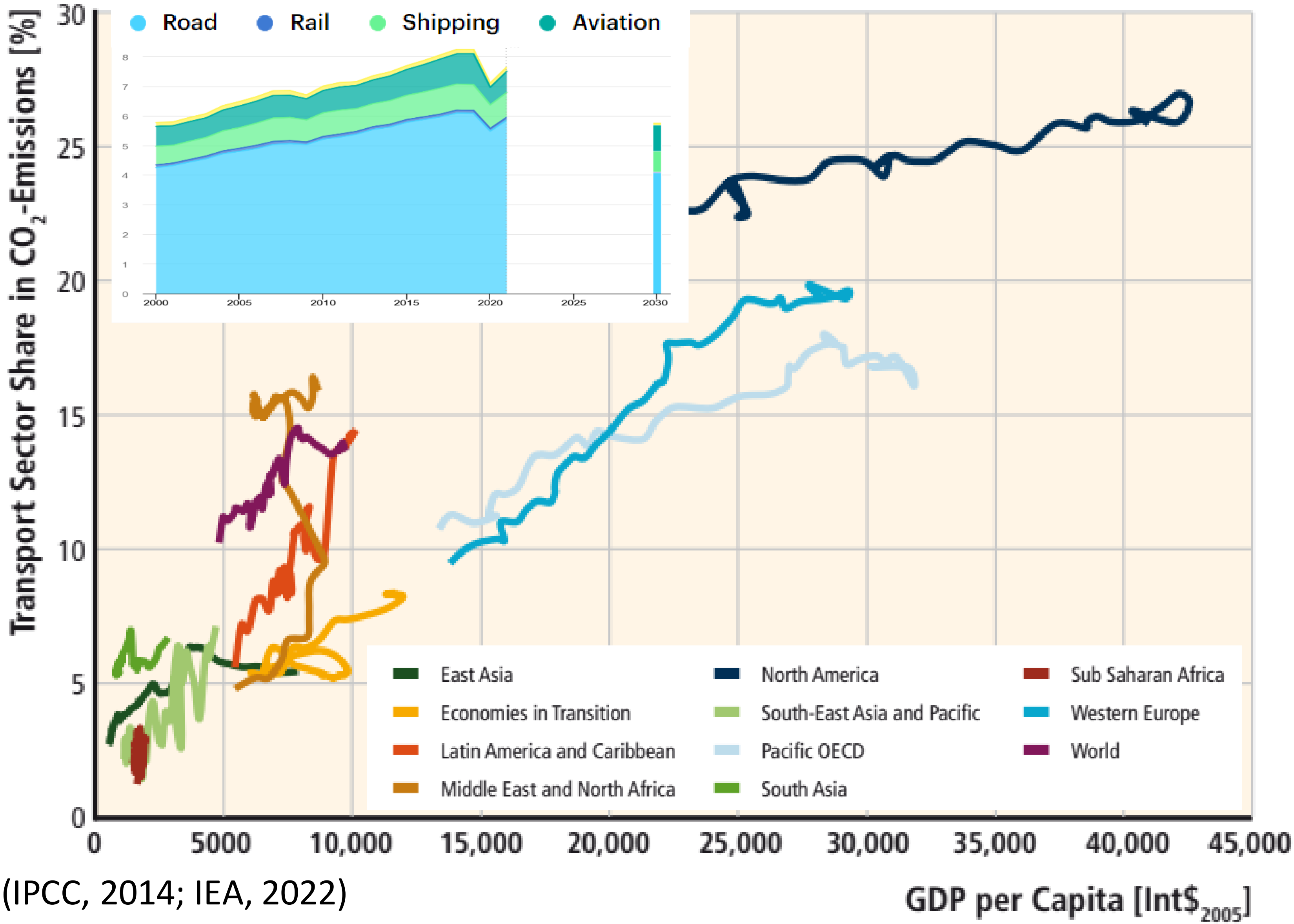
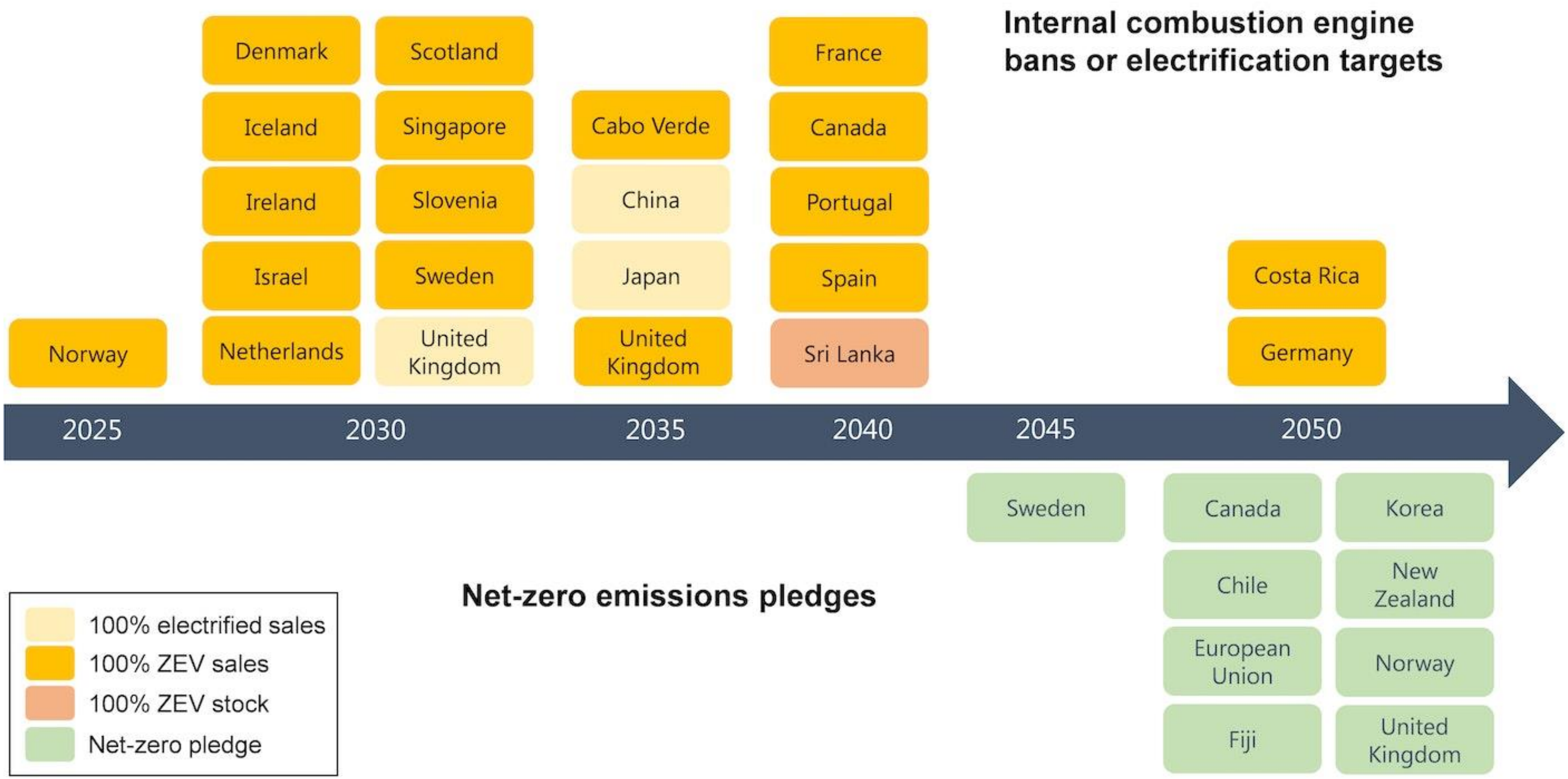
Existing transportation section is carbon intensive



(IPCC, 2014; IEA, 2022)

Many countries are incentivizing electric vehicle adoption to decarbonize road transport



(IEA, 2021)

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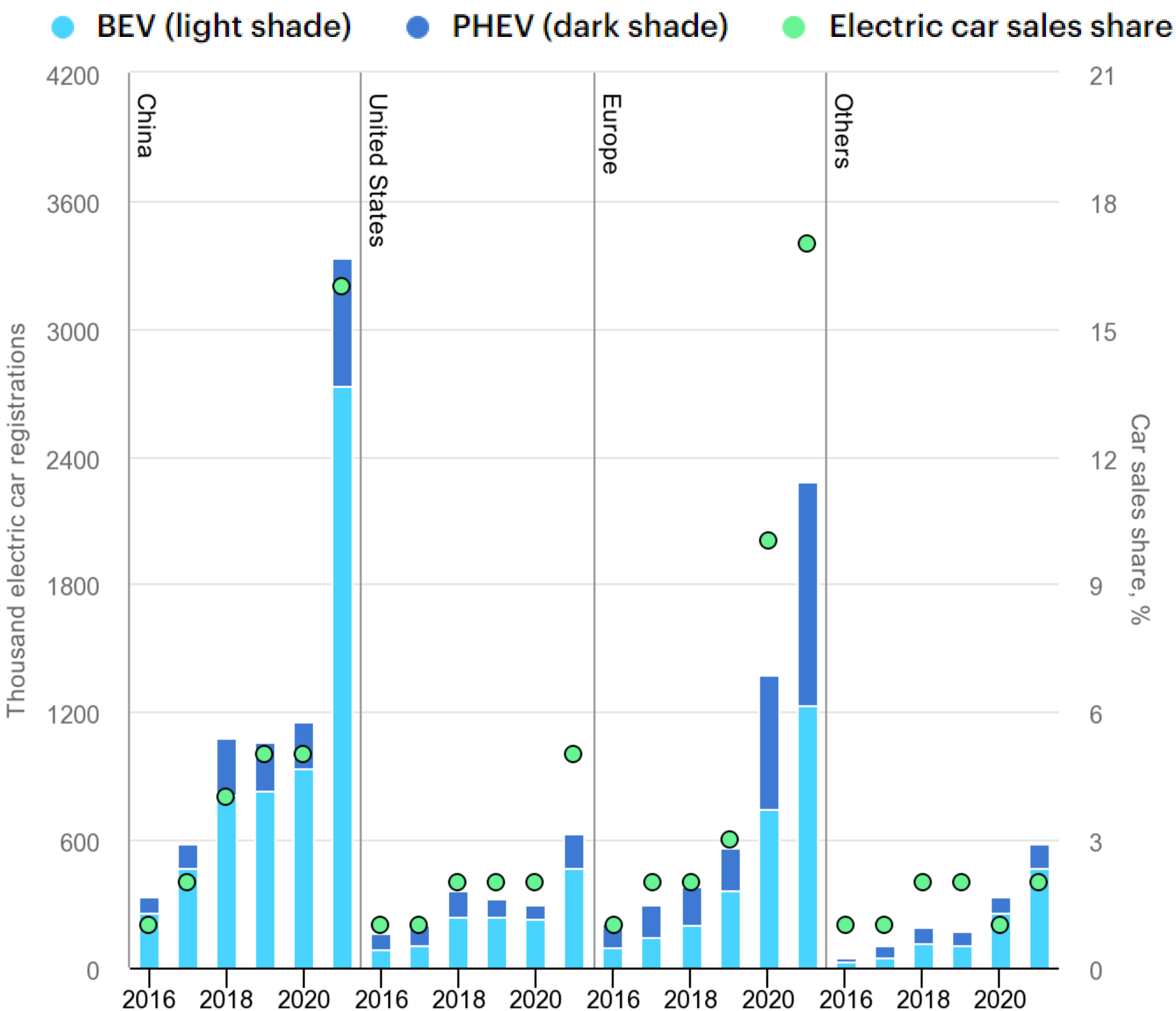
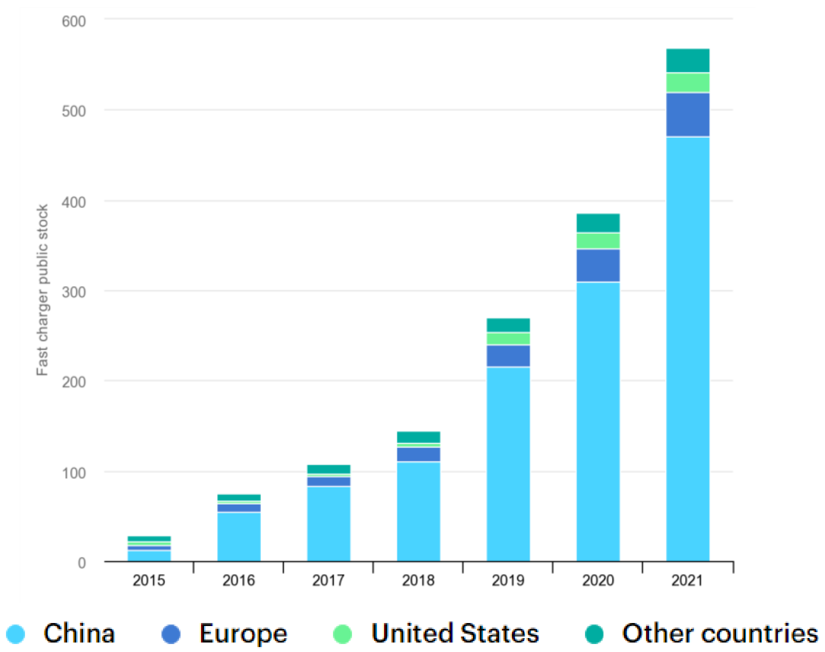


(IEA, 2022)

Building public charging infrastructure to support EV adoption is critical

Dream

Number of EV Fast Charging Stations World Wide



Reality

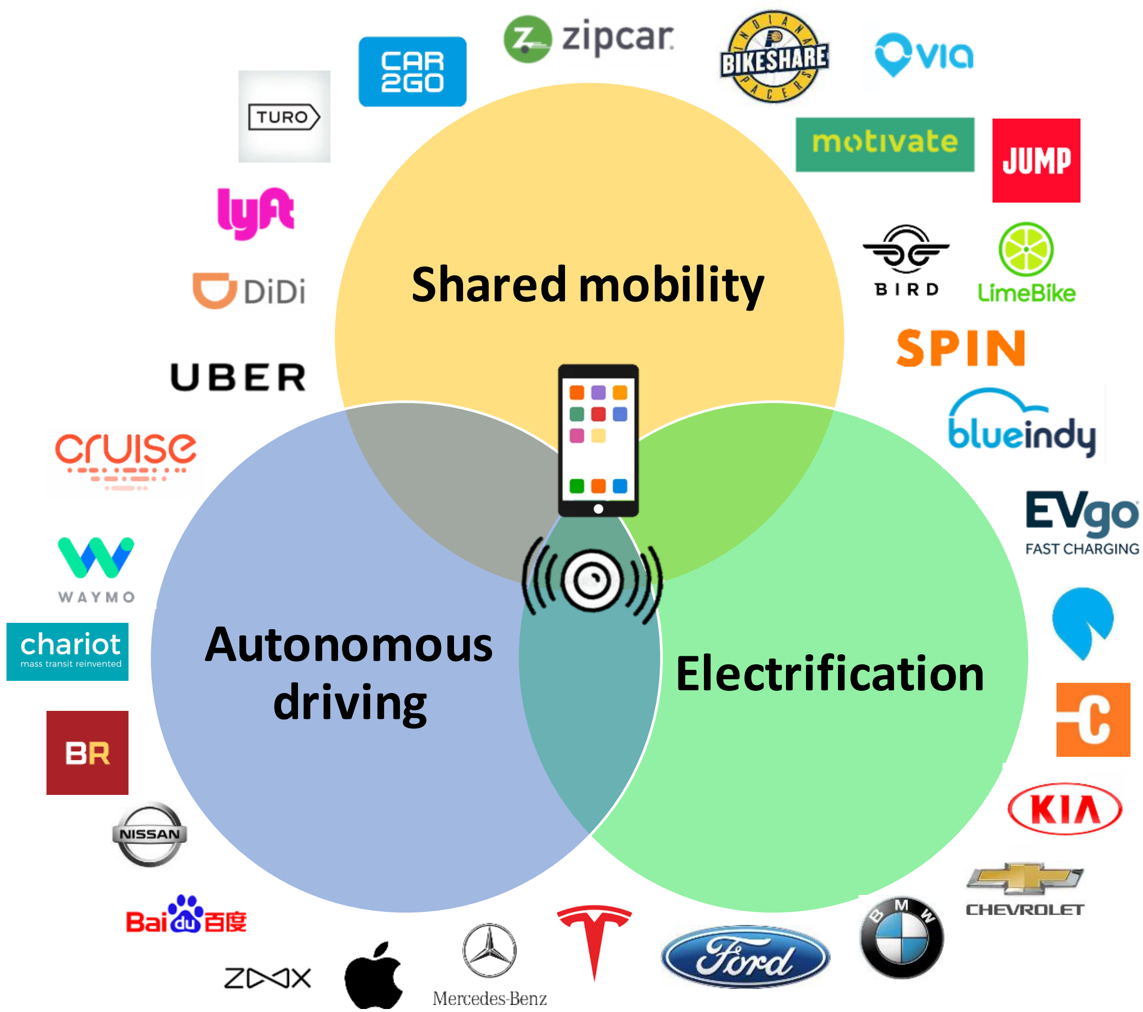
Empty charging stations

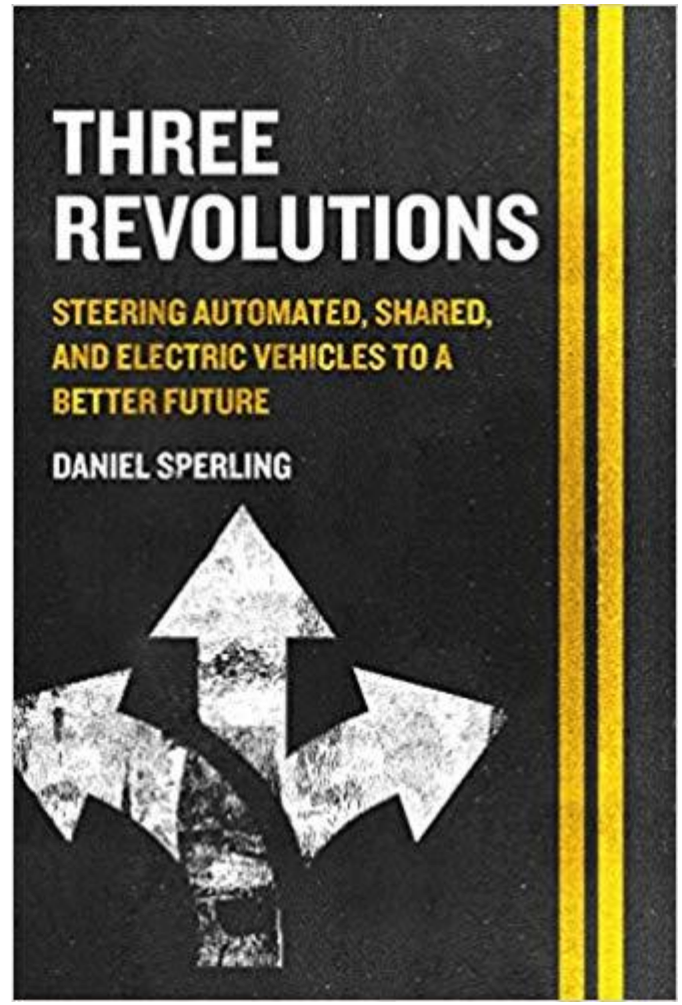
- a waste of public resources

http://english.cri.cn/11354/2014/03/21/3441s818546.htm

(IEA, 2022)

Electrification is not the only "revolution" that is happening in the transportation sector





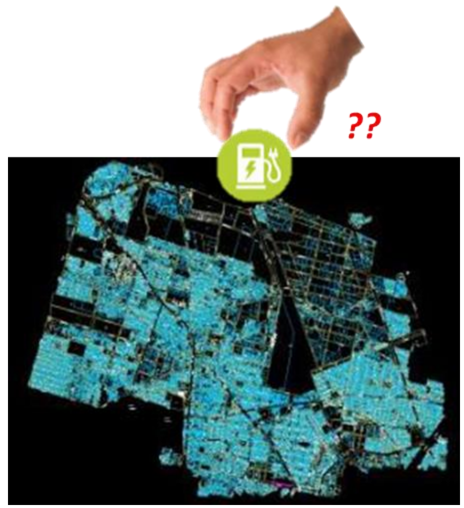
Different sharing and autonomous driving adoption pathway may need different charging infrastructure

Electric Vehicles

- Home charging
- Destination charging

- Flexible charging schedule and location
- Reduced fleet size

- Increased charging demand
- Reduced parking time
- Reduced fleet size



Autonomous Vehicle

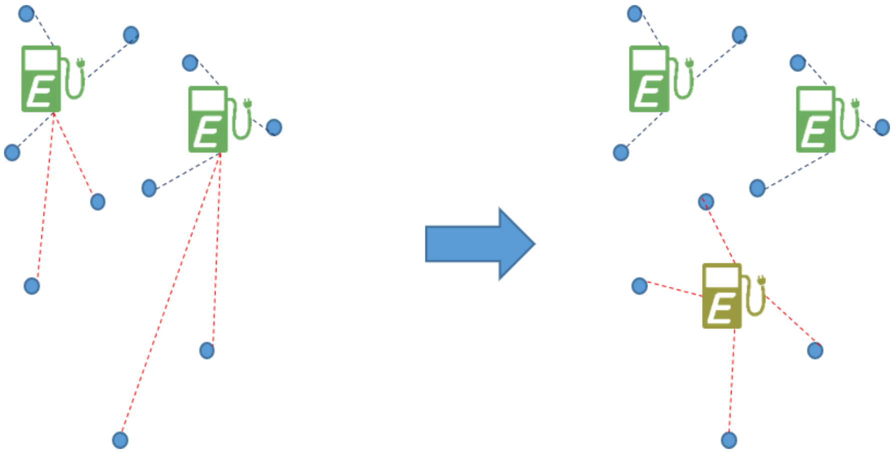
Service availability

Service availability

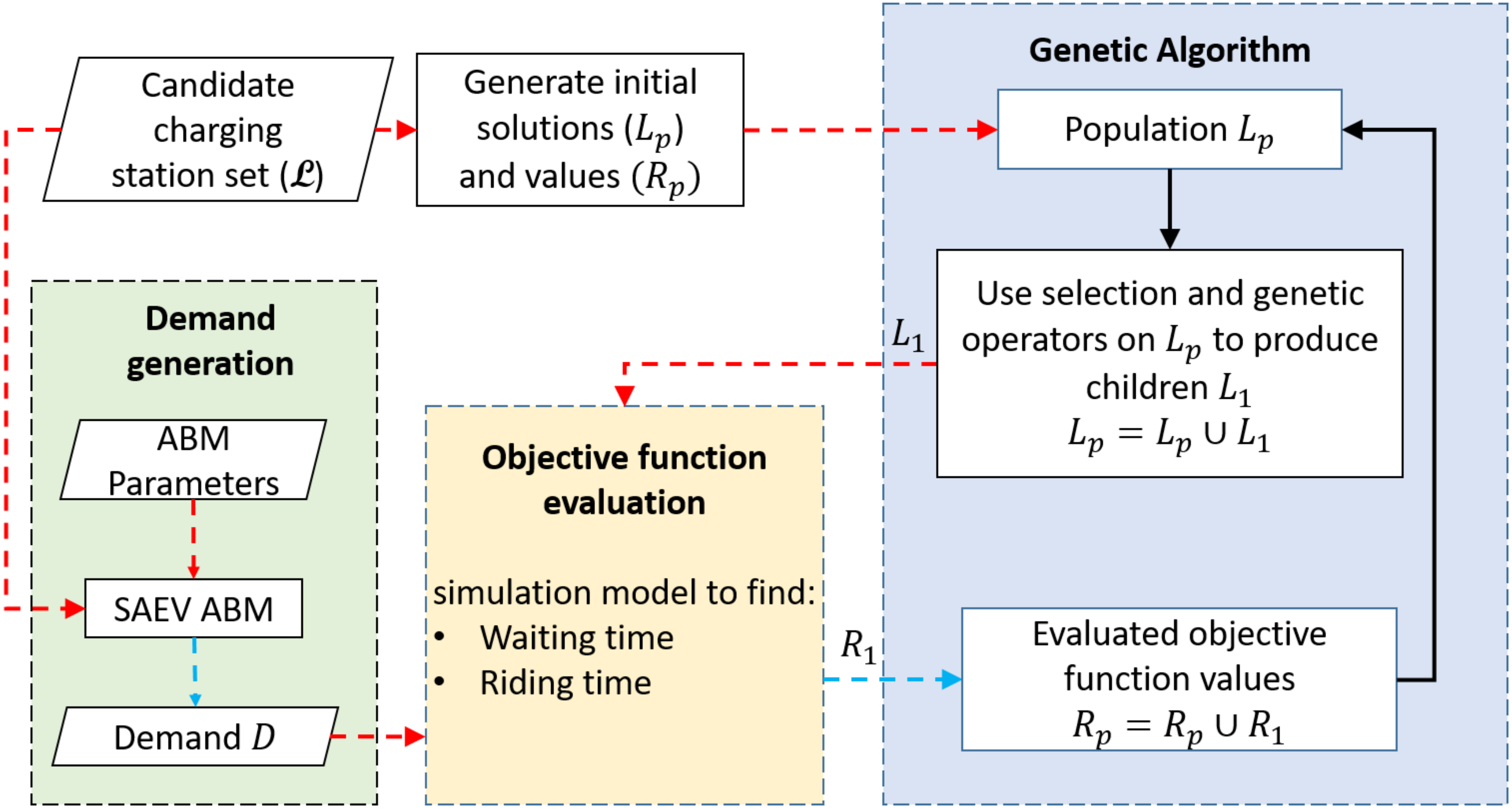
Ride Sharing

Key elements to consider in charging station siting

- Charging is different from refueling
- Optimizing station capacity while siting charging station
- Multi-period development of charging infrastructure
- Tradeoffs between adding a new charging station vs. upgrading existing ones need to be evaluated
- Queueing at charging stations
- Budget is often limited

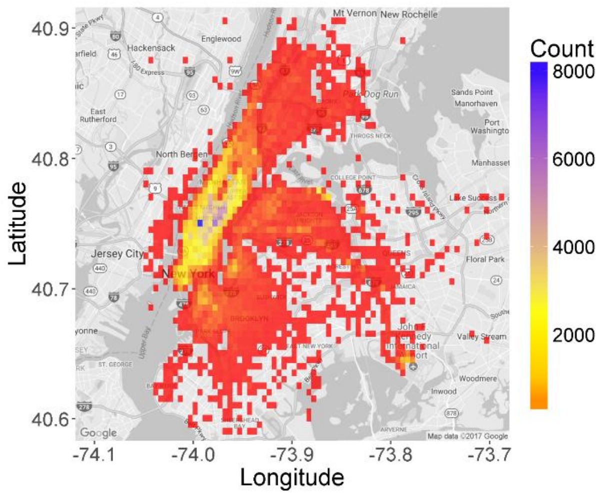


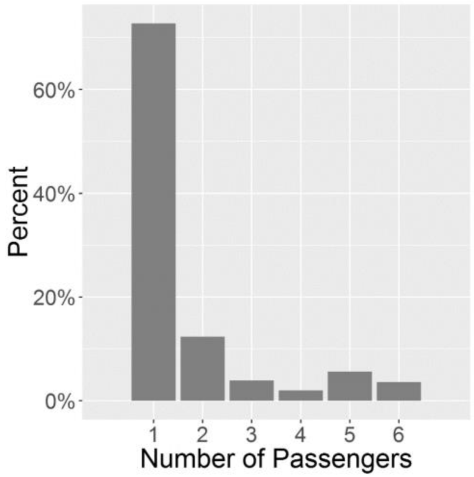
Integrated simulation and optimization model to site charging stations



Case study: Siting charging station for NYC taxi fleet

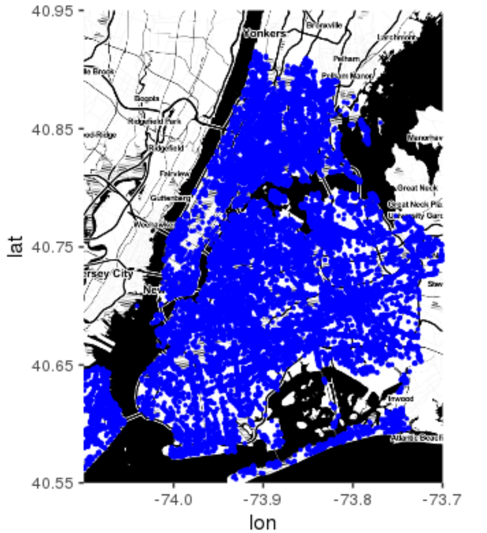
- High demand (474,000 trips/day)
- High sharing potential
- Parking lots for potential charging development
- Build new stations vs. expand existing





Three development pathways:

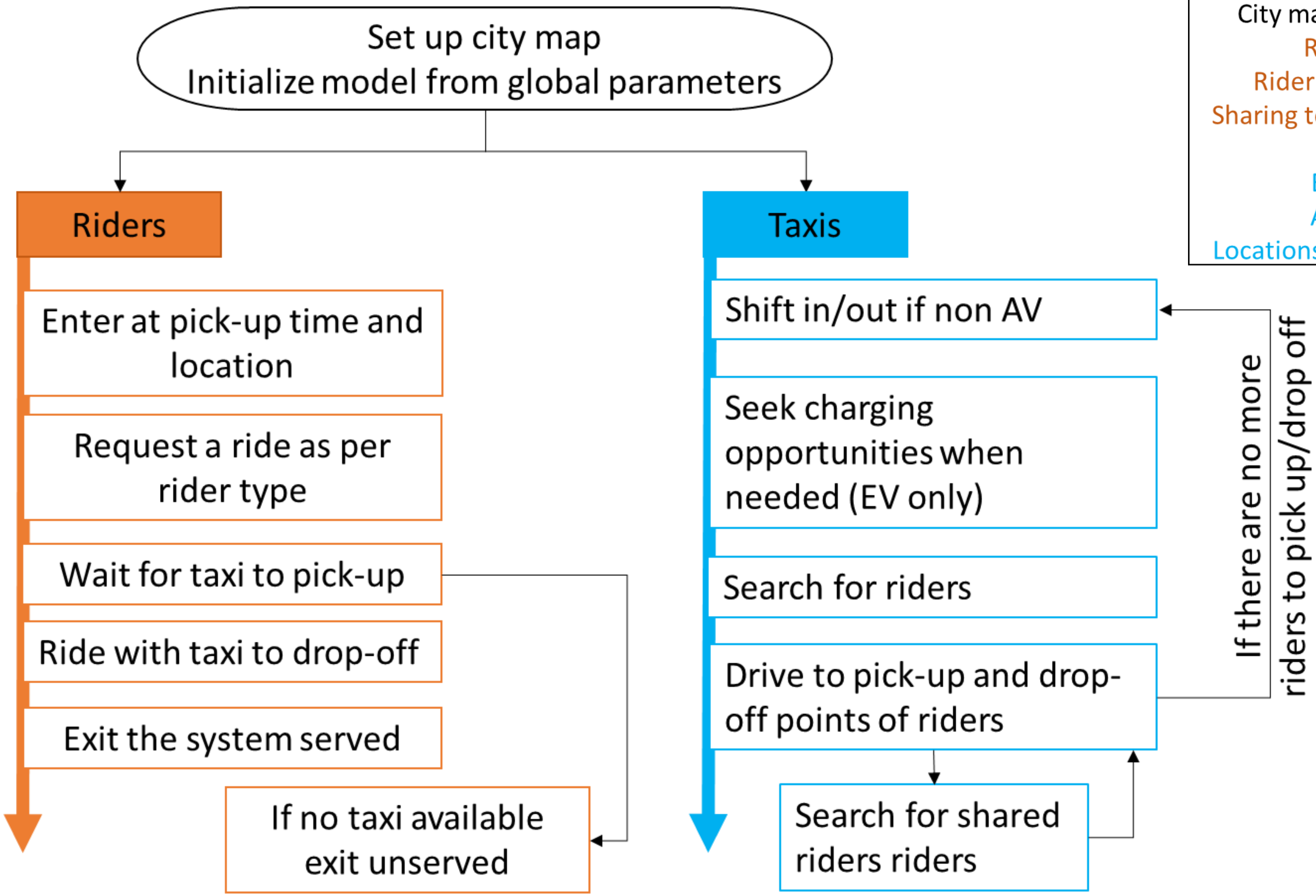
- Case P (present): traditional fleet (no sharing, no AV) with increasing EV adoption
- Case F (future): shared autonomous taxis with increasing EV adoption
- Case M (mixed): switch halfway



Parking lots in NYC : 20714

Lokhandwala, M., & Cai, H. (2020). Siting charging stations for electric vehicle adoption in shared autonomous fleets. *Transportation Research Part D: Transport and Environment*, 80, 102231.

Preference and Parameterized Shared Autonomous Electric Vehicles (PP-SAEV) model



Global Parameters
City map / route network
Rider data set
Rider type distribution
Sharing tolerance distribution
Fleet size
EV Adoption
AV Adoption
Locations of charging stations

Optimization model to site charging stations

Objective:

Minimize : $T_W = \sum_{i=1}^{N}(T_{Q_i} + T_{T_i} \times 2)$ … total wasted time

Subject to :

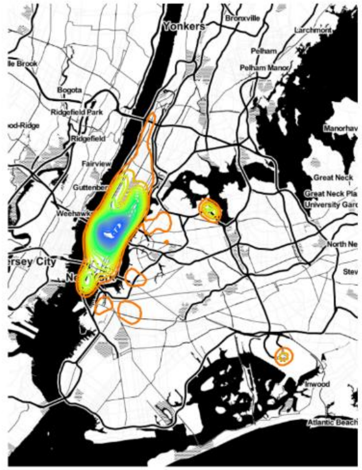
- New charging station locations : selected from parking lots
- Old Charging station locations
- Parking lot capacity
- Budget constraint : $C_{new}N_{new} + C_{upg}N_{upg} \leq B$

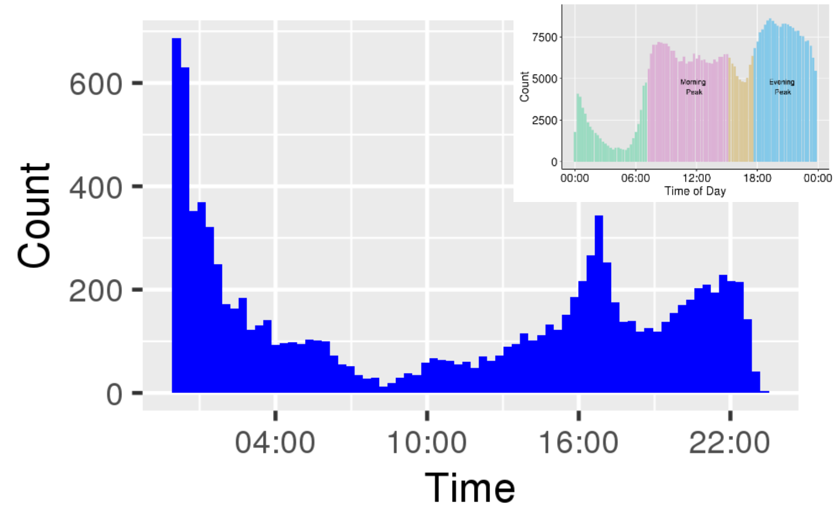
(cost of new satiations and new ports under budget)

T_W - total wasted time in charging (function of CS location)
T_{Q_i} - time spent by taxi i in queue (function of CS location)
T_{T_i} - time spent by taxi for a round trip to the charging station
C_{new}; N_{new} - cost to build up a previously un-electrified parking lot and place 1 charging station; Number of parking lots chosen
C_{upg}; N_{upg} - cost to add additional charging stations at a parking lot that has been electrified; Number of added parking stations. $C_{new} = 2C_{upg}$

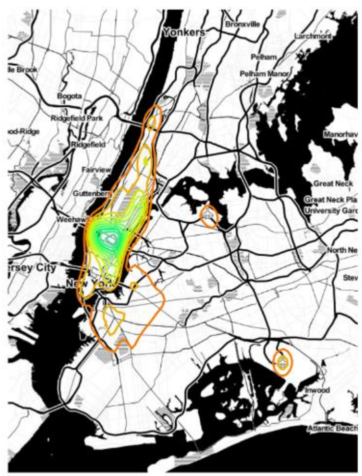
Autonomous driving and sharing will change spatial and temporal charging demands

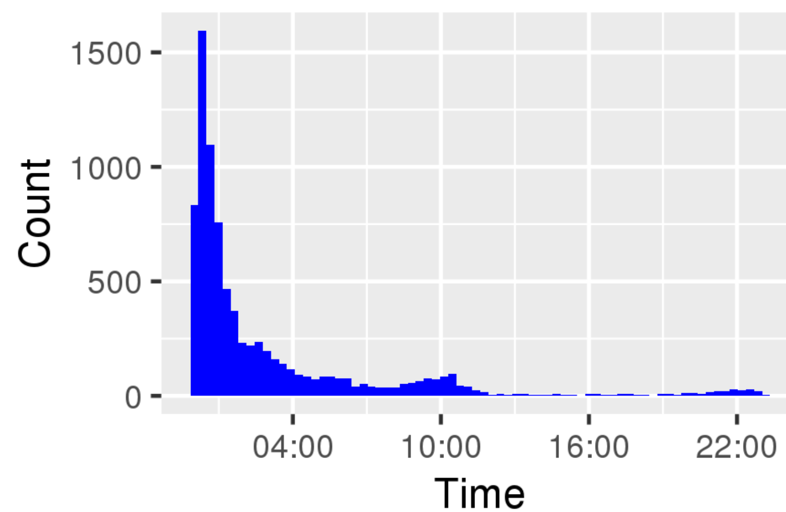
Traditional fleet with 100% EV adoption (13500 taxis)

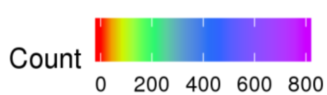




Shared autonomous fleet with 100% EV adoption (5500 taxis)







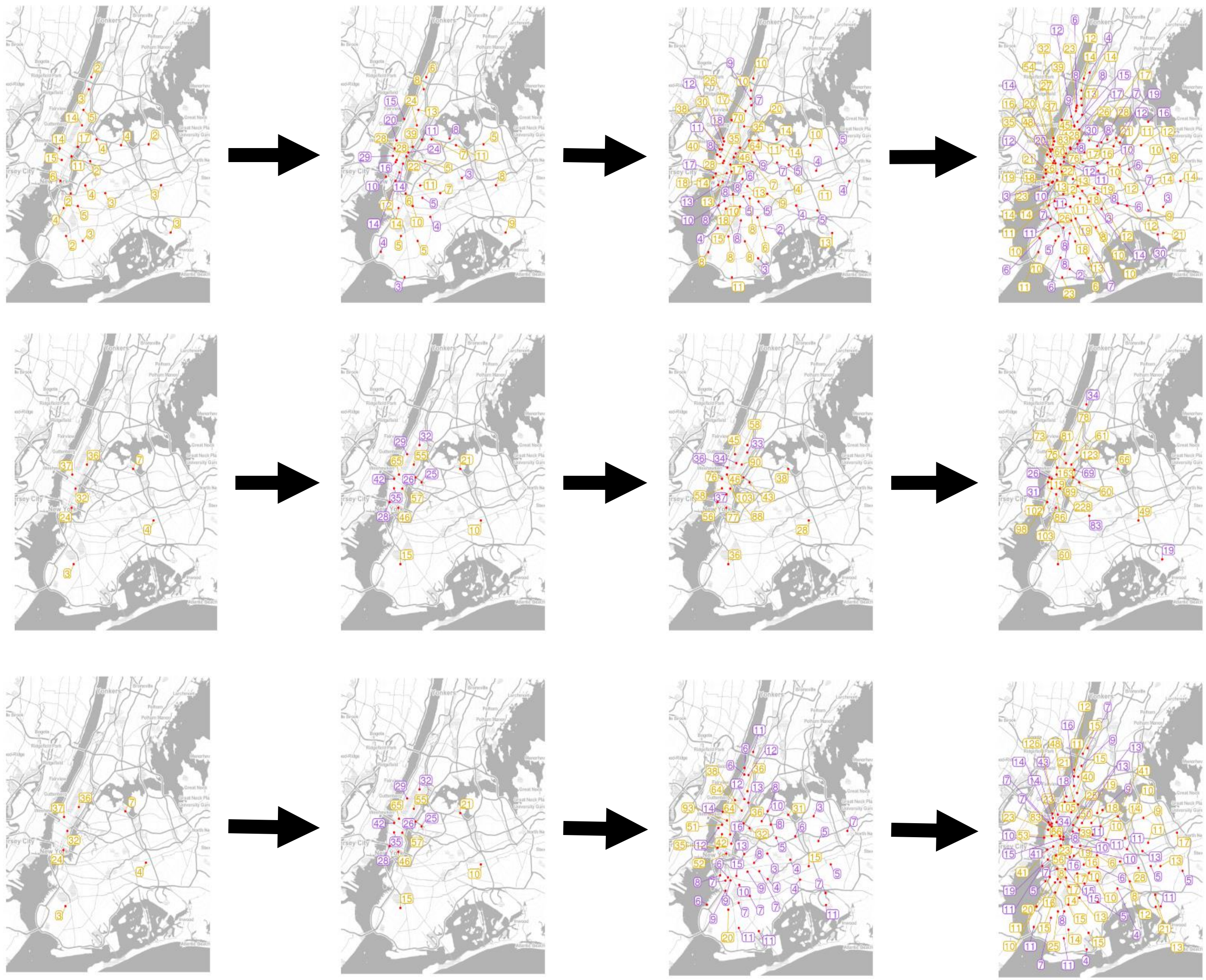
Charging infrastructure development needs to consider the emerging trend of sharing and autonomous vehicle use

EV = 10% | EV = 40% | EV = 70% | EV = 100%

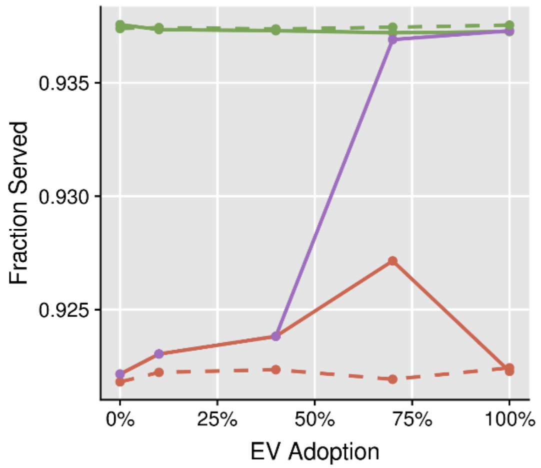
Shared autonomous fleet

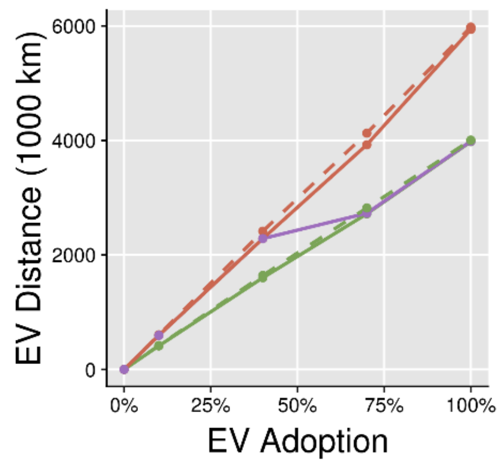
Traditional fleet

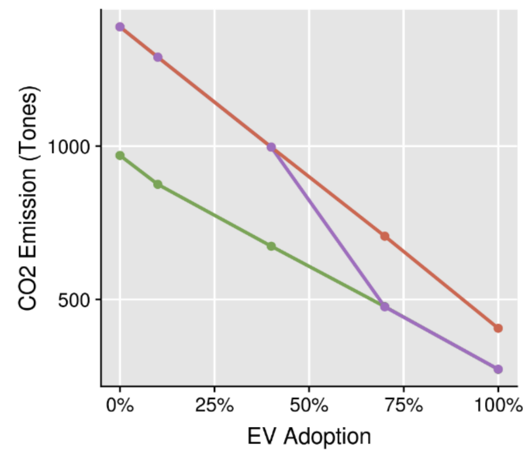
Mixed development

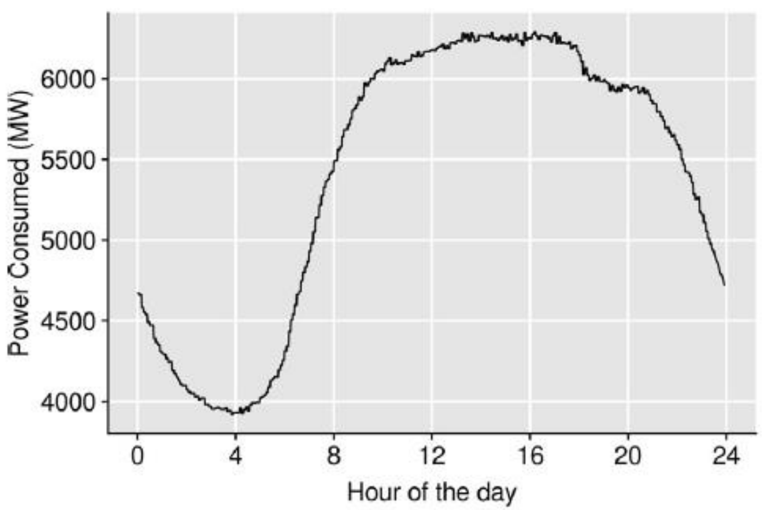


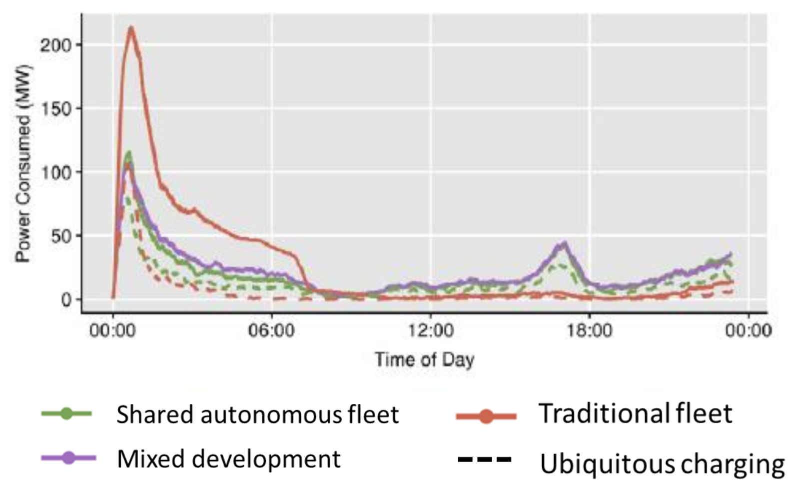
Optimal charging was able to support similar level of system performance











Conclusions

- Different development pathways do have different charging infrastructure needs
- Electrifying the taxi fleet did not significantly impact service level
- Shared autonomous fleet has advantages in reducing vehicle-miles-driven and carbon emissions
- The proposed modeling framework can also be used to study other fleets

Urban Sustainability Modeling & Analysis Research Team (uSMART)

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Motivation

- Half of the global population now lives in urban areas
- Can emerging technologies improve urban sustainability?
- The power of "Big Data" and high performance computing

What do we do?

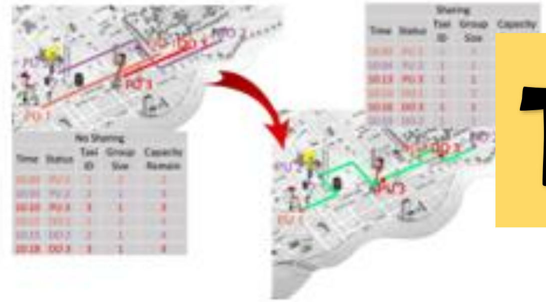
- Our research interests include energy-water nexus, emerging transportation systems, energy policy, sustainable consumption.

How?

- Agent-based modeling
- Life cycle assessments
- System dynamics
- Big data analytics
- Geospatial Information System
- Optimization

Ride Sharing Systems

- The average vehicle occupancy rate is 1.6
- Sharing rides can reduce energy use and emissions



We have built an agent-based simulation model and used the New York Taxis as a test case to study the advantages and disadvantages of ride sharing using shared autonomous taxis using agent based modeling.

Energy Efficiency of Drone Delivery Systems

- Drones are geeing more and more popular!
- A potential solution to the "last mile" problem
- How to design and operate a truck + drone system?

We are developing optimization models to study how to design and operate a truck and drones system to most energy efficiently deliver all packages.

Optimal Battery Size for Electric Vehicles

- EVs with larger batteries are more expansive
- Different EV models have different battery sizes
- How big a battery do I/you need?

Thank you!!!

Autonomous Vehicle Systems

- Self-driving cars are coming!
- What changes will they bring?

We are evaluating the optimal fleet size in a shared autonomous vehicle (SAV) system to satisfy known travel demands and evaluate the tradeoffs between fleet size and environmental performance.

Impact of Eco-Labels

- What information goes into consumer's decision making?
- Are eco-labels (e.g., USDA Organic) promoting sustainable consumption?

e eye-tracking glasses to real-world consumer or data during their ng to study the eneness of eco-labels.

Bike Sharing Systems

- How are shared bikes used?
- Are they making the cities more sustainable?

We are analyzing trip data from bike sharing programs in 8 U.S. cities. Integrating multiple data sets from different sources, we aim to estimate the primary transportation modes replaced by bike sharing. We conducted a Monte Carlo simulation to determine the replaced mode based on several factors such as trip purpose, trip distance, and accessibility of public transit service.

Interested in Being Involved?

- Checkout our website (scan the QR code)
- Contact Dr. Cai via email (Please include your resume)