Public Transportation Equity

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College of Engineering

XI

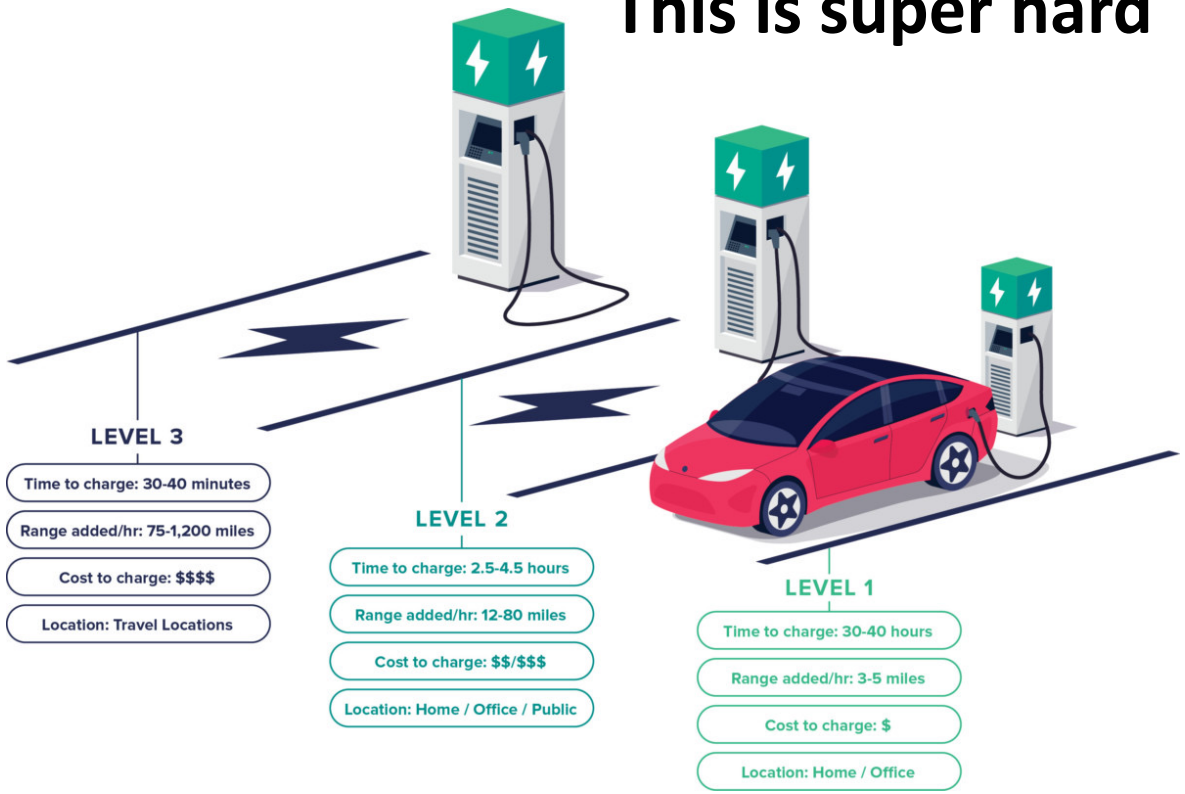
what is public transportation equity

Public transportation equity refers to the fair and just distribution of public transportation services and benefits among different communities and populations. It focuses on ensuring that all individuals, regardless of their socioeconomic status, race, ethnicity, age, or physical ability, have equal access to and opportunities for using public transportation systems.

Achieving public transportation equity involves addressing disparities in transportation access, affordability, quality, and availability. It recognizes that transportation is a critical factor in people's ability to access employment, education, healthcare, social services, and other essential opportunities.

Two cases of public transportation for today

This is super hard

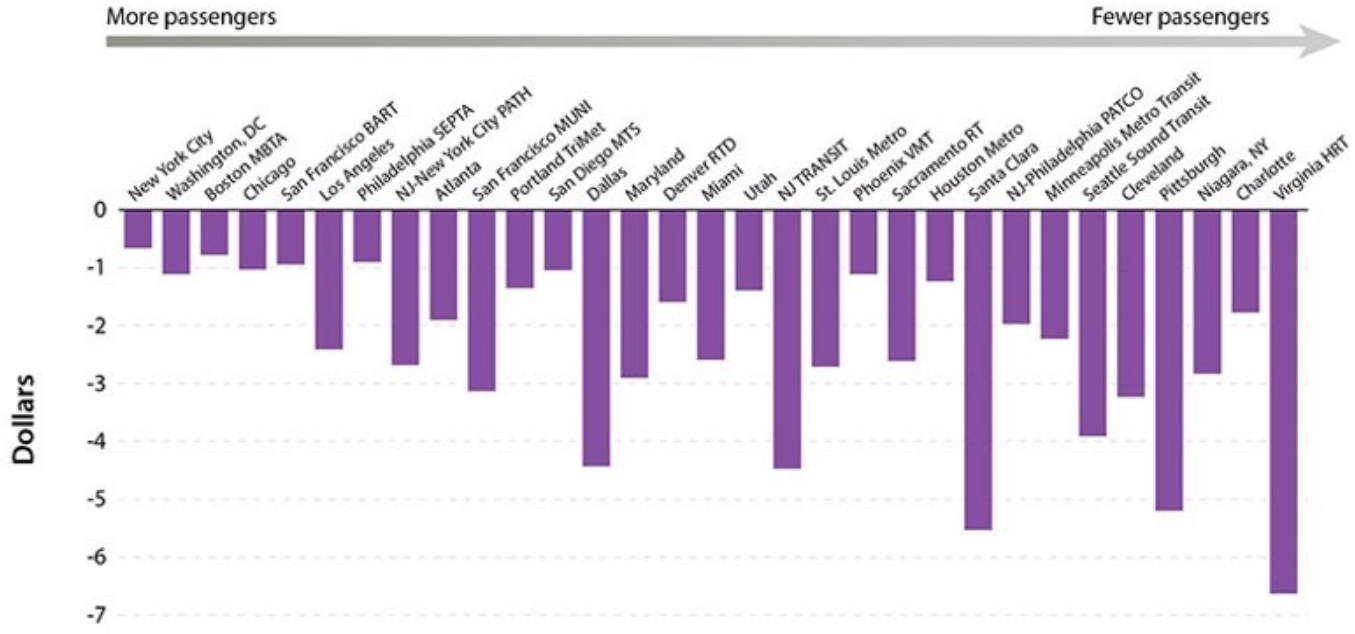


Public transit in general

FIGURE 4.

Average Loss per Passenger Ride by U.S. Metro Rail System, 2013

Although operating costs exceed fare revenue for nearly all metro systems, larger metro systems tend to lose less money per passenger ride than do smaller systems.



Source: Department of Transportation (2015d).
Note: "Average loss per passenger ride" is calculated by subtracting total operating expenses from revenue collected from fares, and dividing this difference by the number of unlinked passenger trips, where each line change is a separate trip. "Metro rail systems" refers to heavy or light rail operated in urban areas. In cities and regions where both light and heavy rail are operated by the same system, the values for operating expenses, fare revenue, and passenger trips are combined. Metro rail system names shown above are abbreviated in some cases to enhance readability. For more details, including the full names of the metro rail systems, see the technical appendix.

THE HAMILTON PROJECT
BROOKINGS

Cost-effectiveness and **financial burden** are of **top-most concerns for transit agencies**

Maximize Ridership
Subject to Limited Resources

Working with Transit/Paratransit Agency

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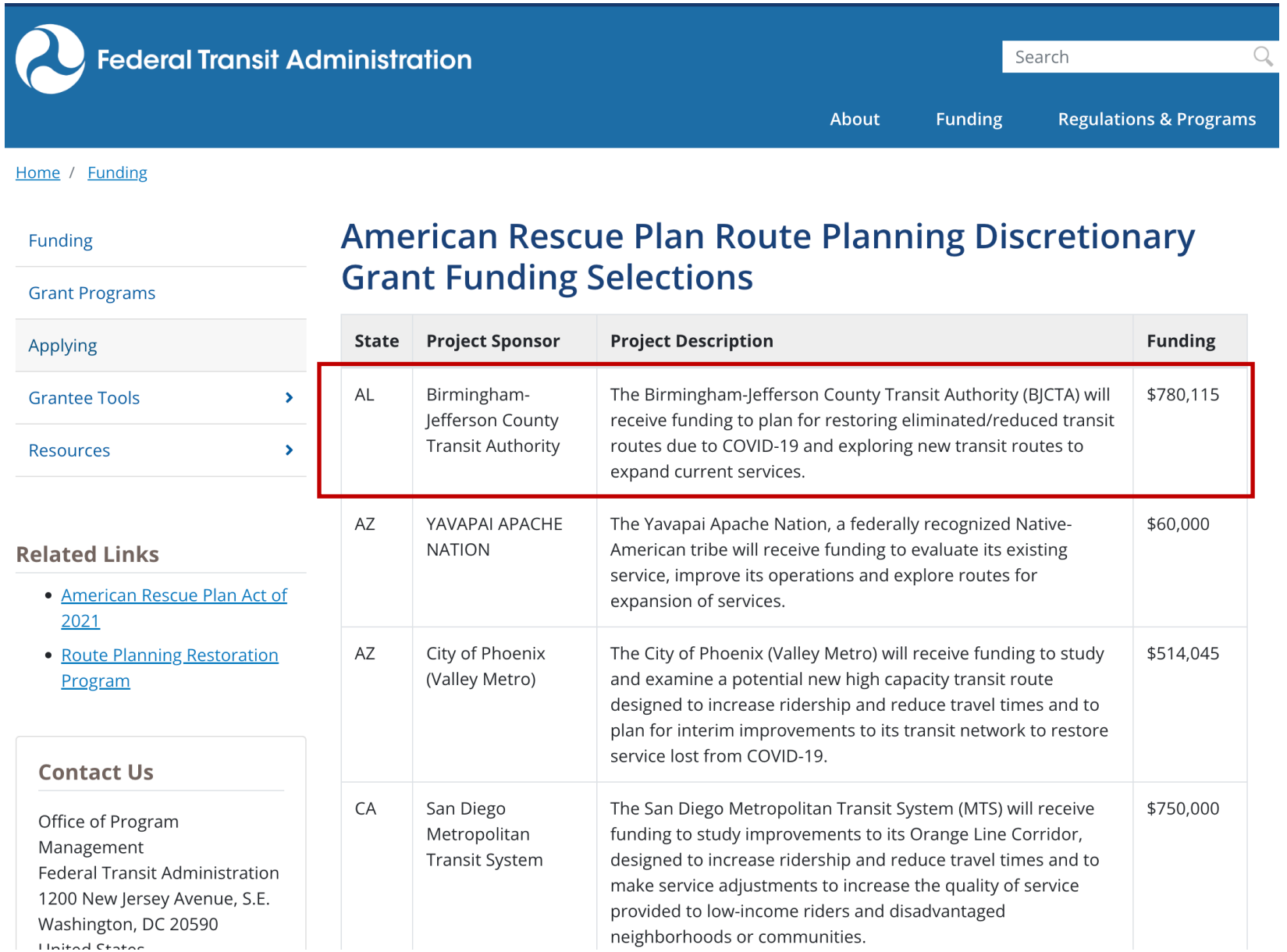
Public Transportation COVID-19 Research Demonstration Grant Program Selected Projects

State	Project Sponsor	Project Description	Funding Amount
AL	Alabama Department of Transportation	The Alabama Department of Transportation will receive funding to work with 10 transit agencies, nine of them rural, to design solutions that improve cleaning protocols, respond to and mitigate exposure and develop contactless fare payment systems to improve operations and restore public confidence during the COVID-19 public health emergency.	$300,000
AR	Rock Region Metropolitan Transit Authority (METRO)	Rock Region Metropolitan Transit Authority in Little Rock, Arkansas, will receive funding to purchase portable UVC light disinfectant systems for use in its fleet to combat the spread of COVID-19 and help ensure a safe environment for operators and riders while strengthening public confidence in transit.	$288,750
AZ	City of Tucson	The City of Tucson, Arizona, will receive funding to upgrade SunTran's fare payment systems to allow riders to use mobile and other touchless fare payment options and install automated wheelchair securing systems on buses to allow riders to secure themselves, reducing contact with operators and improving mobility, confidence, and independence.	$600,000

Working with Transit/Paratransit Agency



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- American Rescue Plan Act of 2021
- Route Planning Restoration Program

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Office of Program Management
Federal Transit Administration
1200 New Jersey Avenue, S.E.
Washington, DC 20590
United States

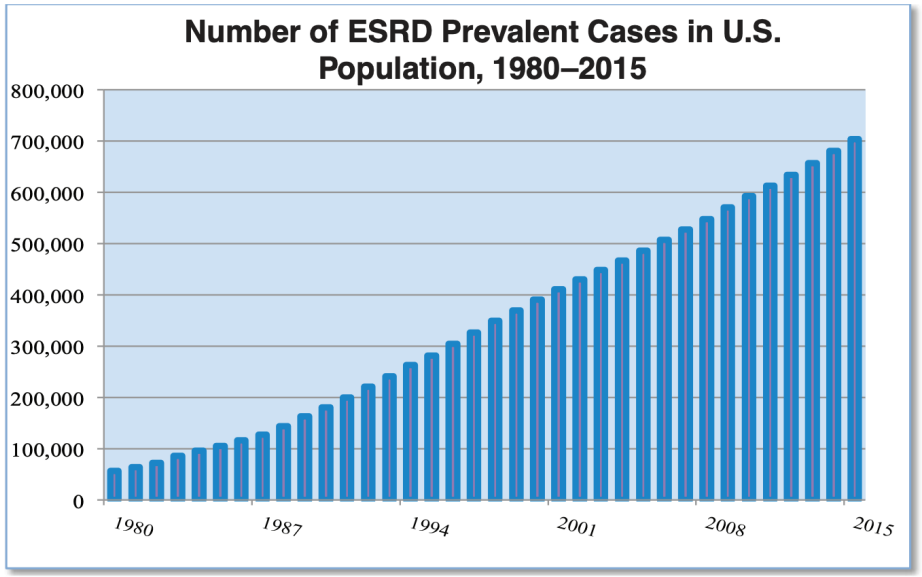
American Rescue Plan Route Planning Discretionary Grant Funding Selections

State	Project Sponsor	Project Description	Funding
AL	Birmingham-Jefferson County Transit Authority	The Birmingham-Jefferson County Transit Authority (BJCTA) will receive funding to plan for restoring eliminated/reduced transit routes due to COVID-19 and exploring new transit routes to expand current services.	$780,115
AZ	YAVAPAI APACHE NATION	The Yavapai Apache Nation, a federally recognized Native-American tribe will receive funding to evaluate its existing service, improve its operations and explore routes for expansion of services.	$60,000
AZ	City of Phoenix (Valley Metro)	The City of Phoenix (Valley Metro) will receive funding to study and examine a potential new high capacity transit route designed to increase ridership and reduce travel times and to plan for interim improvements to its transit network to restore service lost from COVID-19.	$514,045
CA	San Diego Metropolitan Transit System	The San Diego Metropolitan Transit System (MTS) will receive funding to study improvements to its Orange Line Corridor, designed to increase ridership and reduce travel times and to make service adjustments to increase the quality of service provided to low-income riders and disadvantaged neighborhoods or communities.	$750,000

Working with the community

- We worked with a local paratransit agency
  - ADA-compliant service complements fixed-route transit
  - An essential connector between disadvantaged population group and healthcare services

ClasTran serving Jefferson, Shelby and Walker County in Alabama

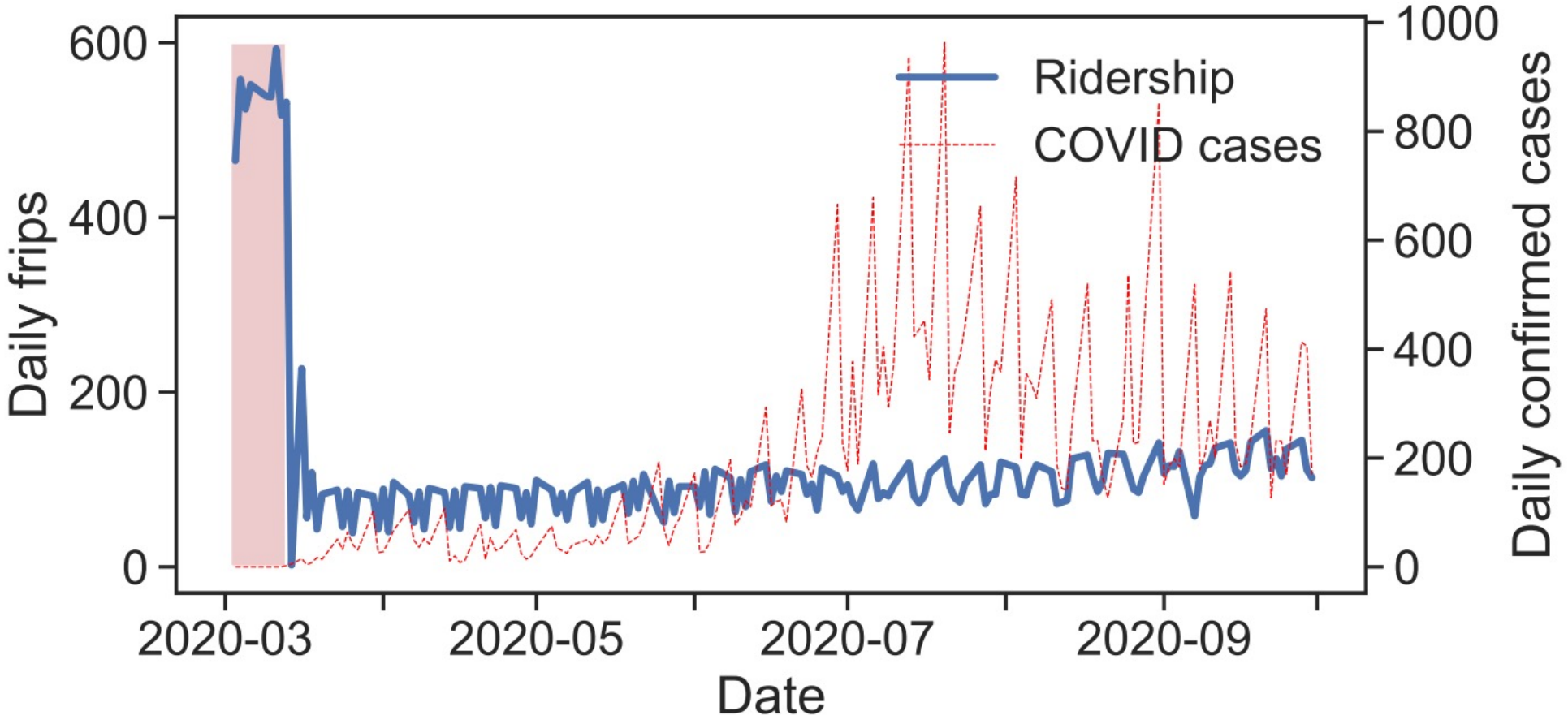


ESRD: End-Stage Renal Disease (*Source: TCRP report 203*)
139 million annual trips needed ⇔ 70 million by transit/paratransit

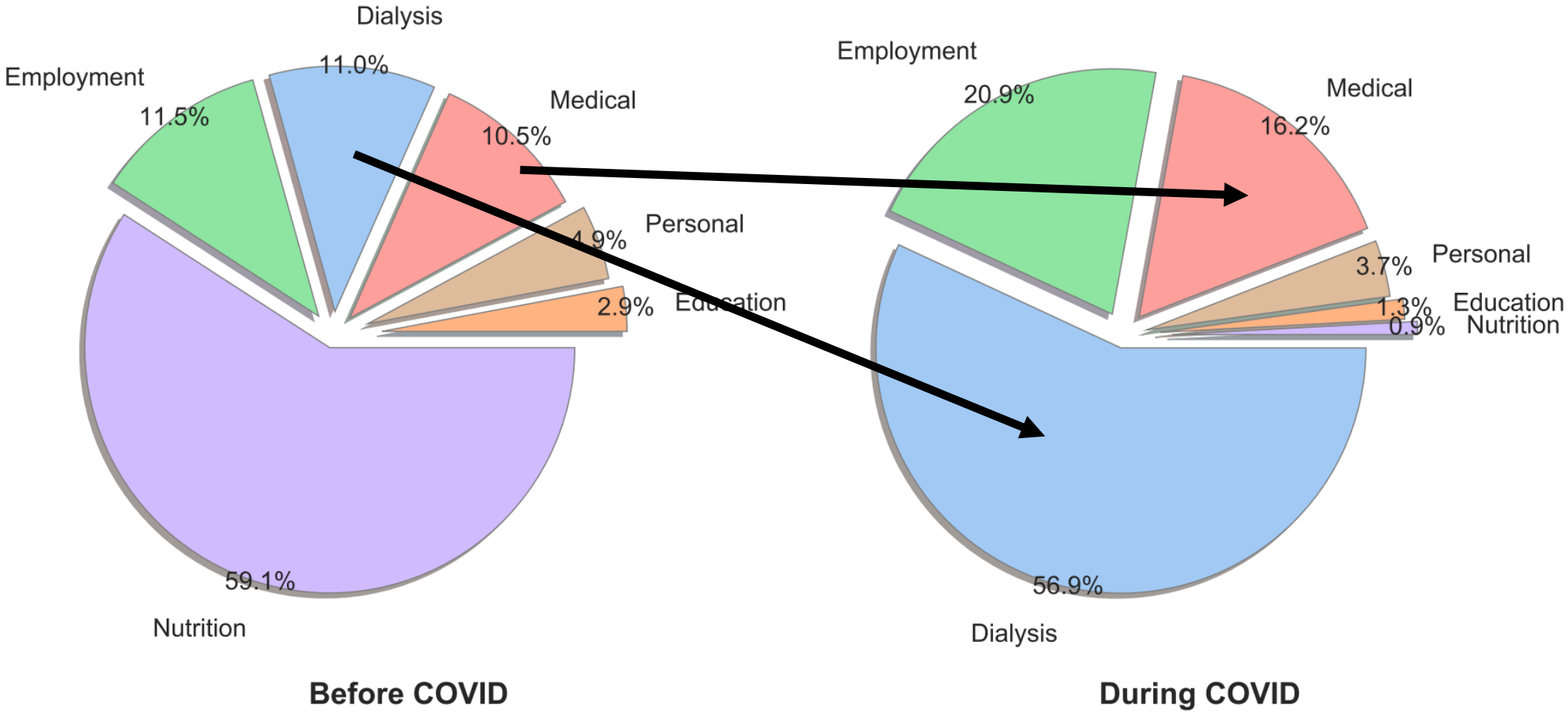
Nie, Q., Qian, X.*, Guo, S., Jones, S., Doustmohammadi, M., & Anderson, M. D. (2022). Impact of COVID-19 on paratransit operators and riders: A case study of central Alabama. ***Transportation research part A: policy and practice***, *161*, 48-67.

Working with the community

Half-year data in 2020



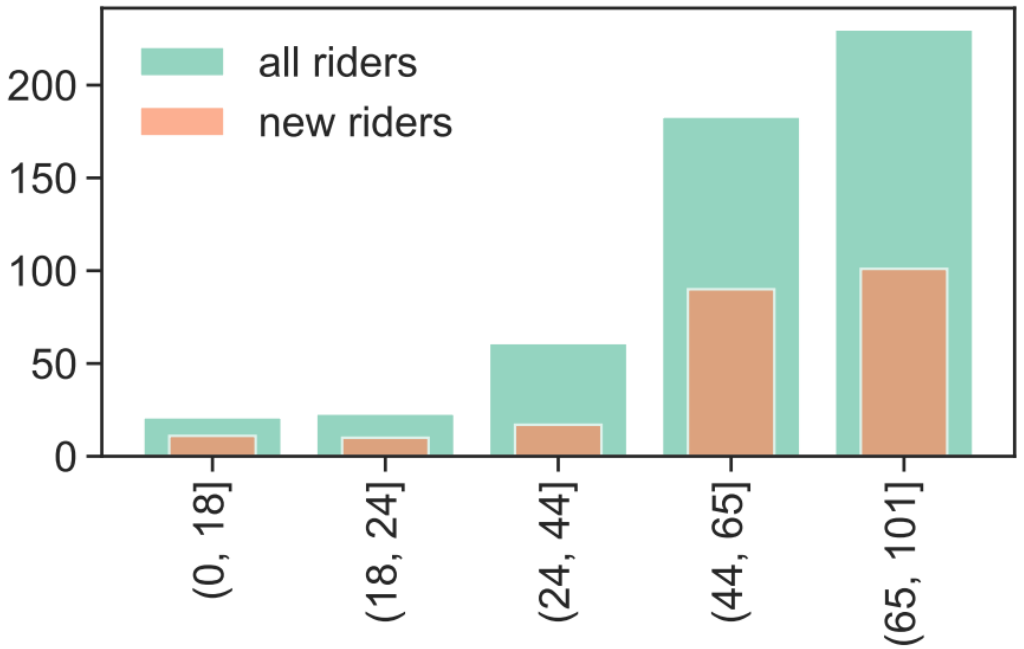
Change of Functionality



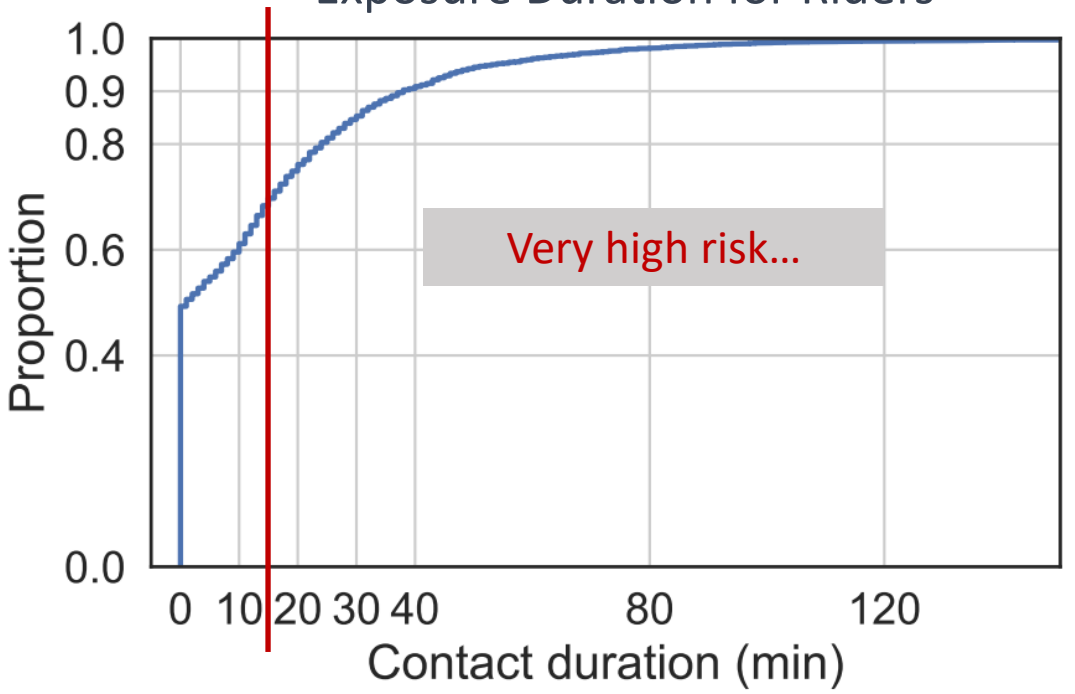
Elastic demand → Inelastic demand

Change of Functionality

Riders' Age Distribution



Exposure Duration for Riders



Recommendations for COVID-19 Close Contacts

Have you been in close contact with someone who has COVID-19? You were a close contact if you were less than 6 feet away from someone with COVID-19 for a total of 15 minutes or more over a 24-hour period (excluding K-12 settings).

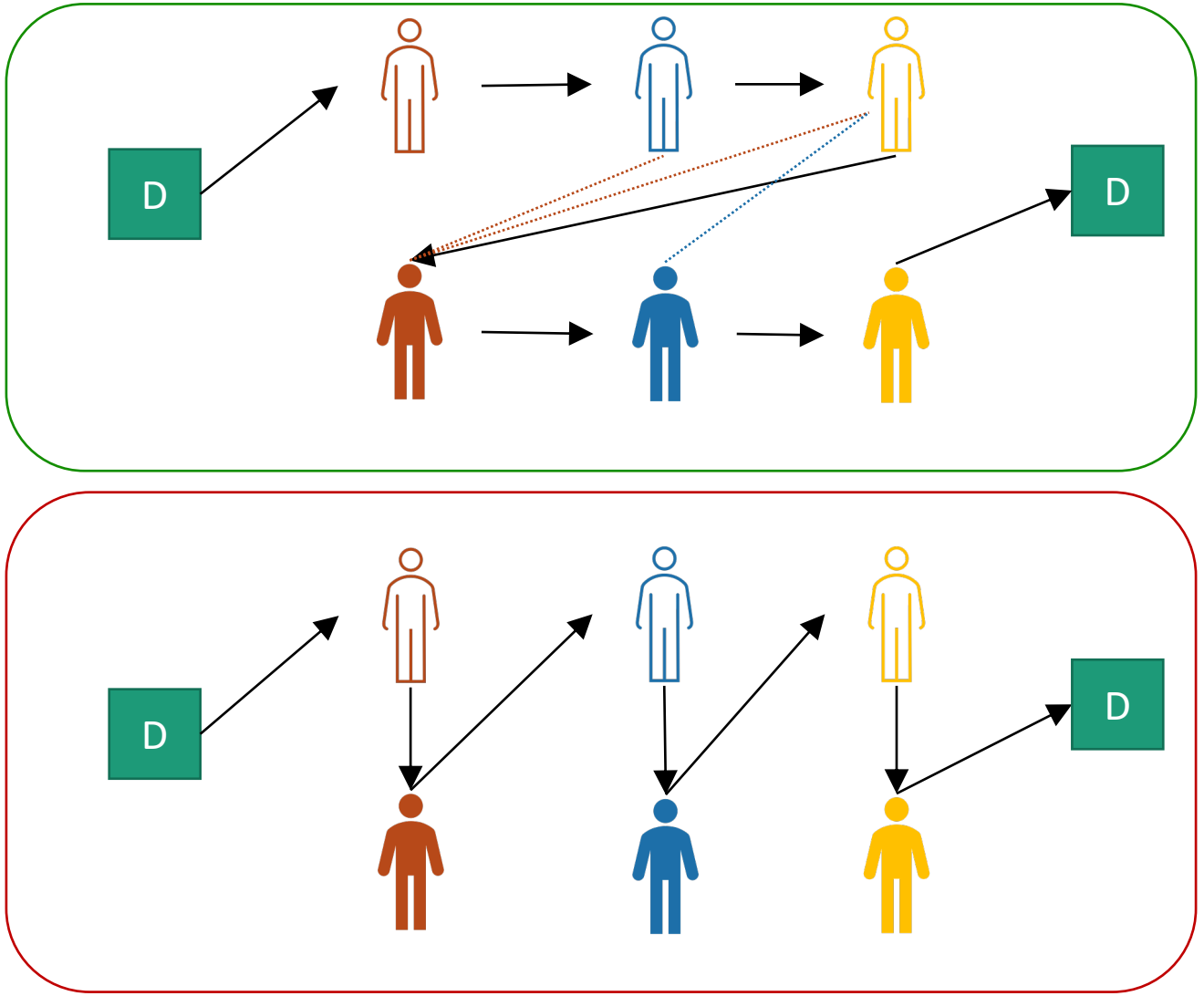
Need to minimize transmission risk!

The underlying transportation problem

- **Ridesharing:** boost efficiency and save cost
- Dial-a-ride problem (DARP)
  - Special case of pickup-and-delivery problem with time window (PTPDW)
  - Location and request time of O&D
  - Max capacity
  - Maximum ride length
  - Extensively studied
- Philosophy challenged during COVID-19

Efficiency vs Transmission Risk?

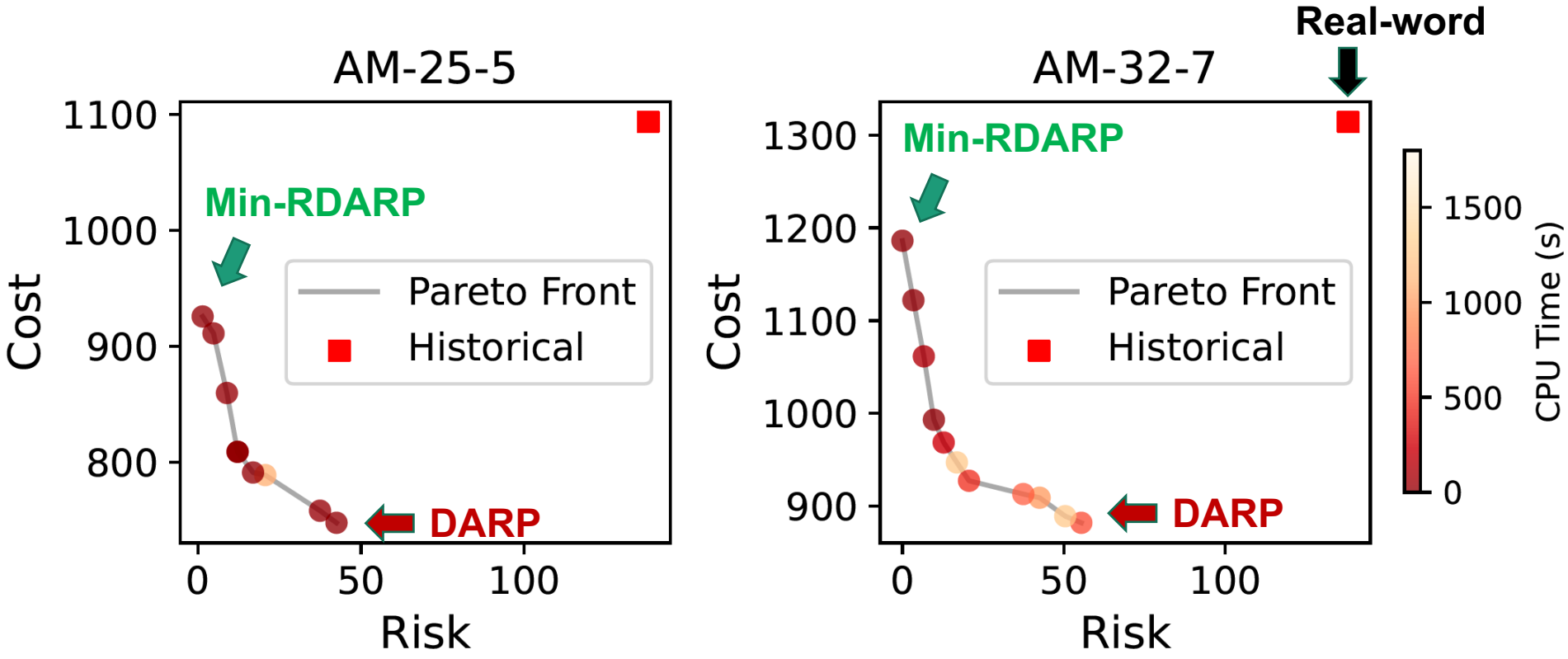
Model



Pick-up

Drop-off

Pareto Front

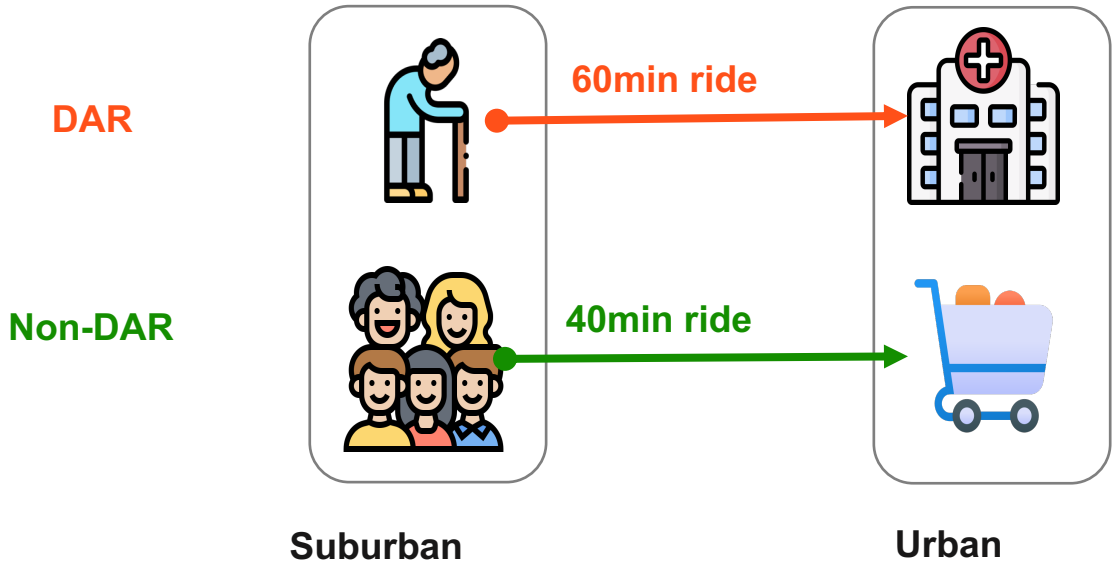


Real-world routes: higher cost w/ excessive exposed risk

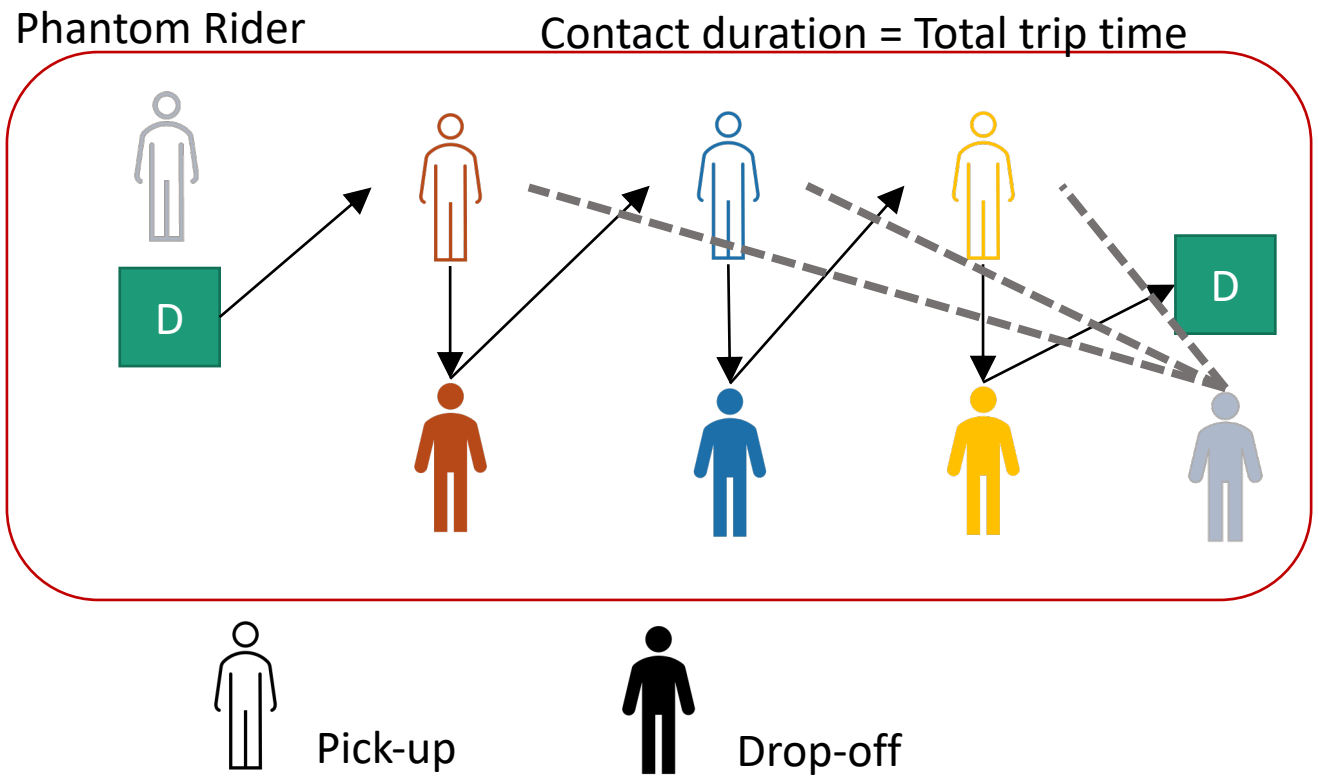
DARP: cost-minimizing solution **Min-RDARP**: risk-minimizing solution

Generalization- Equity-aware DARP

- The Equity-of-Travel (EoT) emerges if a disadvantaged rider (DAR) receives a different level of service compared to other less-disadvantaged riders.



Generalized Model

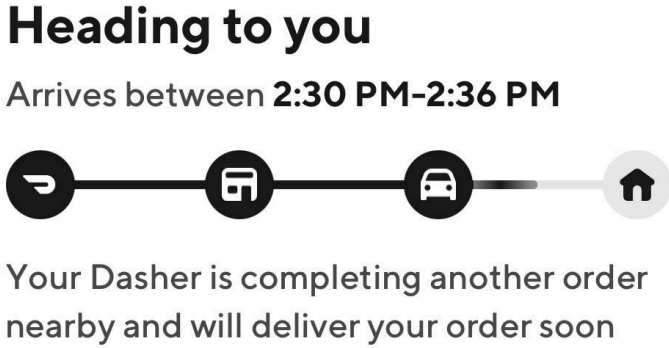


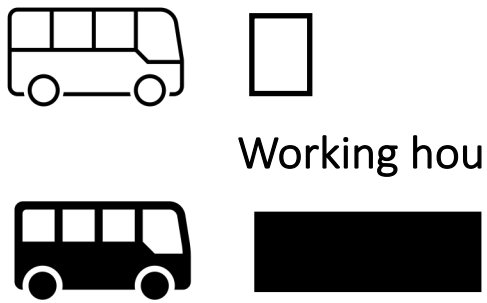
Adding a `Fake Rider' who contacts with everyone else

A one-stop solution for Equitable DARP

Service safety/equity for ridesharing

Service equity for food delivery





Working hours

Workload balancing

Transportation for disadvantaged group

Equity-aware route planner for serving disadvantaged riders with demand responsive transport

Shuocheng Guo[1], Xinwu Qian[1,*] & Steven Jones[1]
{sguo18, xinwu.qian, steven.jones}@ua.edu
1. The University of Alabama, USA

Background & Introduction

Demand responsive transport (DRT)

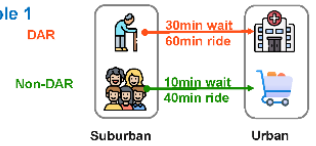
- Flexible-route on-demand transit
- Door-to-door service in lower-density areas [NADTC, 2022]
- Satisfying essential mobility needs for disadvantaged groups:
  - Seniors
  - People with disability (PWD)
  - People for non-emergency medical needs (PNEM)

Equity issue in the DRT operation receives little attention.

Real-world evidence of Equity-of-Travel (EoT)

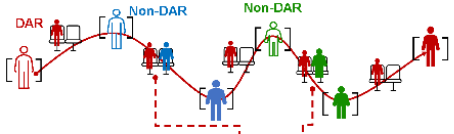
The EoT emerges if a disadvantaged rider (DAR) receives a different level of service compared to other less-disadvantaged riders.

Example 1



A DAR suffers much longer waiting and ride time than the non-DAR on the trips from suburban to urban area.

Example 2



During the COVID-19 pandemic, a senior citizen travelling for dialysis is reported to get **overly exposed** compared with other non-DAR co-riders (Nie et al., 2022).

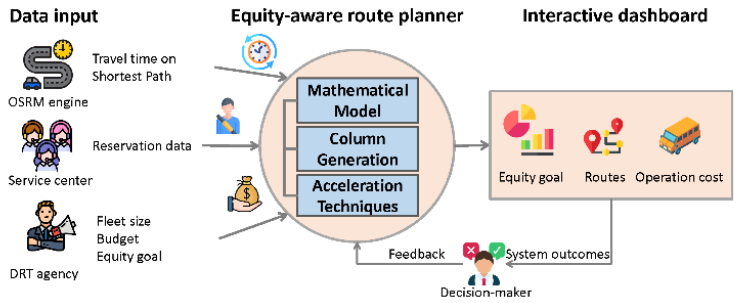
Our Contribution

- Among the first to provide ***customized routing strategies*** given ***heterogeneous traveler characteristics.***
- ***Sets of EoT routing strategies*** with different weights of EoT goals are provided for the DRT operator to ***choose a sweet spot to balance*** the cost- and EoT-optimal solutions.
- ***State-of-the-art solution algorithm*** is designed to efficiently give an EoT routing strategy, e.g., 1hr for 55 pax.

Framework of the Equity-aware route planner

We develop **an end-to-end product** including:

- Data input: basic info + personal info (optional) for customized service
- Equity-aware route planner: first-of-its-kind tool to consider equity goals
- Iterative dashboard: sets of routing strategies for better decision-making



Mathematical model:

- Equity-aware Dial-A-Ride-Problem (DARP) (Cordeau and Laporte, 2007)
- Bi-objective optimization problem: cost + equity goal: more challenges than DARP.

$$\min_{x} \left\{ \sum_{k\in\mathcal{K}} \sum_{i\in\mathcal{N}} \sum_{j\in\mathcal{N}} t_{ij} x_{ij}^{k}, \max_{i\in\mathcal{P}} (H_i) \right\}$$

Total travel time (cost) Min-Max EoT metric

Cost vs Equity?

- Column generation method and serveral acceleration techniques are implemented to effectively solve the Equity-aware DARP.
- We extended the traditional labeling algorithm by designing a linear-time algorithm to incorporate the equity measures, e.g., exposed risk and detour rate (for more technical details, see Guo et al., 2022.)

Broader applications:

- Wheelchair-accessible fleet
- Paratransit
- Dial-a-ride service
- Micro-transit
- Flexible transit
- Food delivery
- Supply chain
- More...

Food delivery for fresh produce/hot food

Patient transportation

Load balancing for food delivery

Supply chain management

Real-world examples

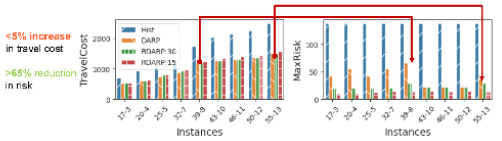
Outcomes

- Equitable level of service, e.g., detour ratio, ride time, …
- Load balancing for DRT/ paratransit/dial-a-ride fleets
- Disparity of contracting diseases during pandemic (our case)

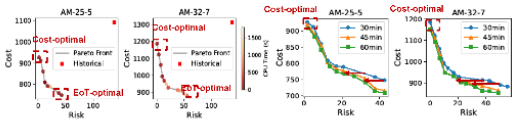
Case Study

- **Real-world paratransit operation** in Birmingham, AL.
- **Equity goal:** minimizing the risk of getting COVID-19 among different groups of populations, e.g., age, pre-existing condition, etc.
- Problem size: 17 pax with 3 veh to 55 pax with 13 veh

Significant risk mitigation with slight compromise of cost

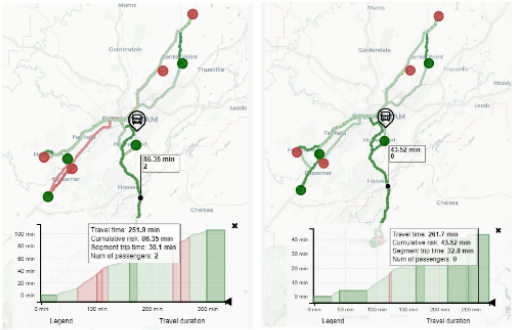


Pareto Front: detailed trade-off between cost and risk



Comparison with historical routes Less restrictive time windows

Iterative dashboard: real-time EoT measures and location



Historical routing solution EoT-optimal routing solution

Reference:
1. National Academies of Sciences, Engineering, and Medicine and others. Ada paratransit and other demand-responsive transportation services in small to midsized transit agencies, 2022.
2. National Aging & Disability Transportation Center. Ada & paratransit, 2021, Source: https://www.nadtc.org/about/transportation-aging-disability/ada-and-paratransit/. Accessed July 2021.
3. Qifan Nie, Xinwu Qian, Shuocheng Guo, Steven Jones, Mehrnaz Doustmohammadi, and Michael D Anderson. Impact of covid-19 on paratransit operators and riders: A case study of central alabama. *Transportation research part A: policy and practice*, 2022.
4. Jean-Fran, cois Cordeau and Gilbert Laporte. The dial-a-ride problem: models and algorithms. Annals of operations research, 153(1):29–46, 2007
5. Shuocheng Guo, Iman Dayarian, Xinwu Qian, and Jian Li. A branch-cut-and-price algorithm for a dial-a-ride problem with minimum disease-transmission risk. *arXiv:2205.05324*, 2022.

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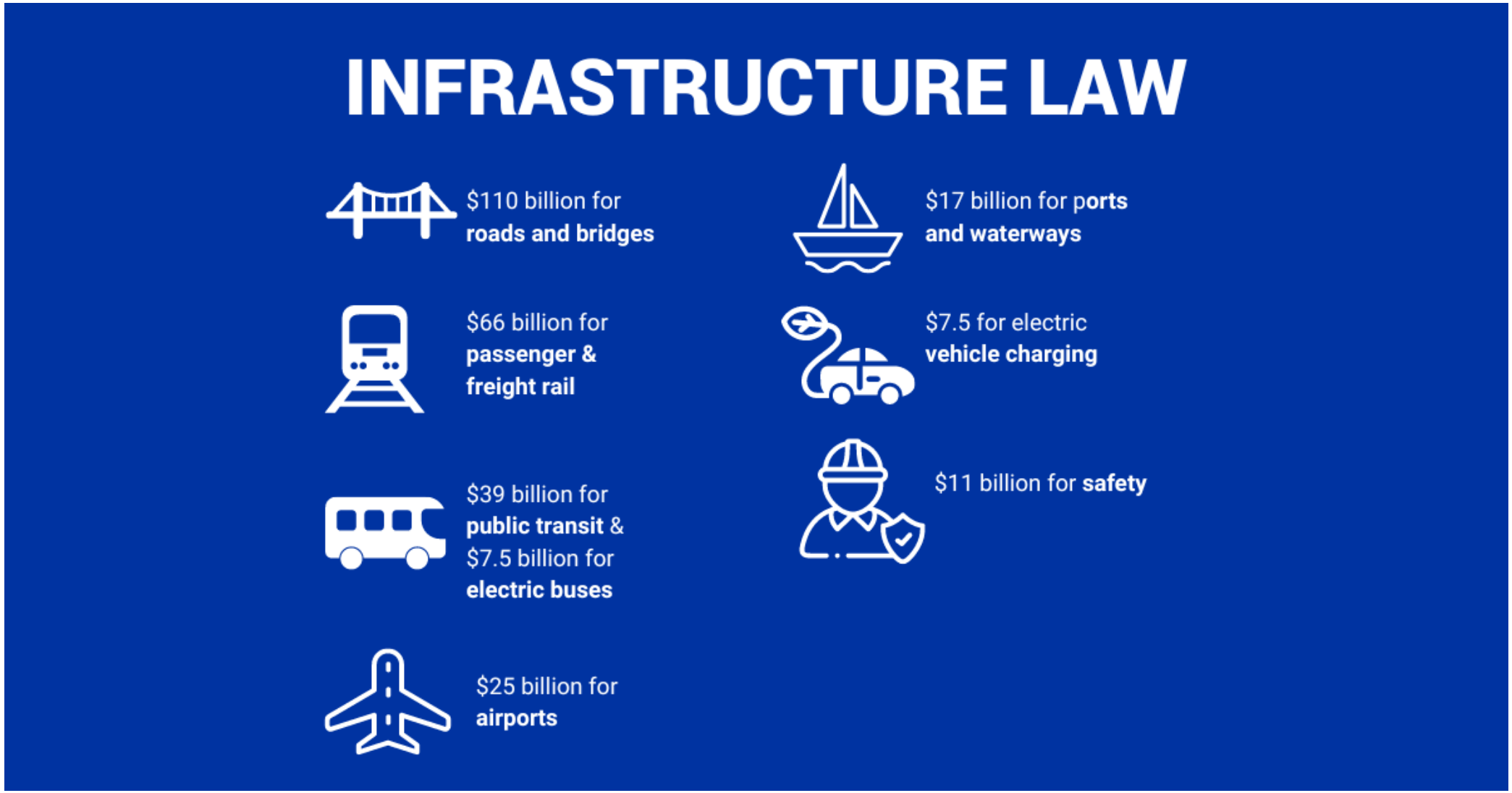
Preprint

Dashboard: Historical routes

Dashboard: EoT-Optimal routes

Public Charging Station

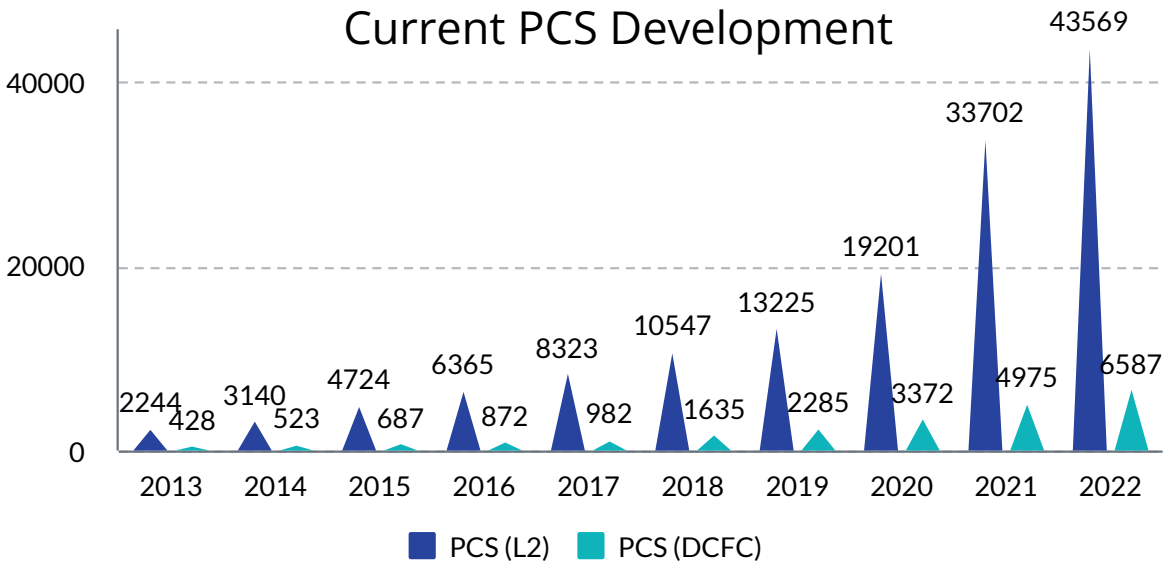


Why Public Charging Stations (PCS) ?

New EV Charging Stations by 2030 under the BIL

500,000

New EV Sale by 2030



6.7%
EV Penetration in 2022

63%
Single Family House

55%
Detached Garage

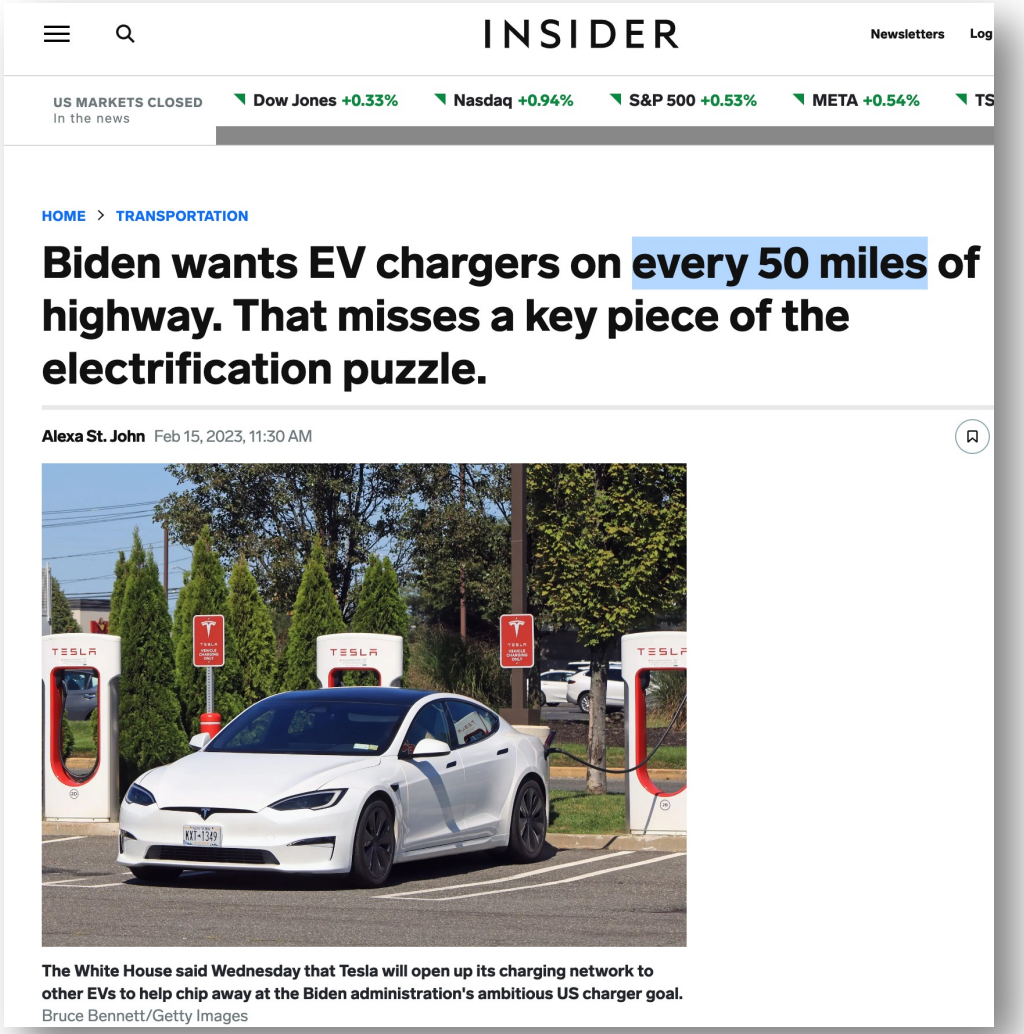
Convenient for EV users with home-charging, Essential for those without

Is anything missing in our planning?

Great….

- But do we understand EV users?
- How should we plan charging stations?
- What do we need in order to plan the charging station?

How do we deploy charging stations?



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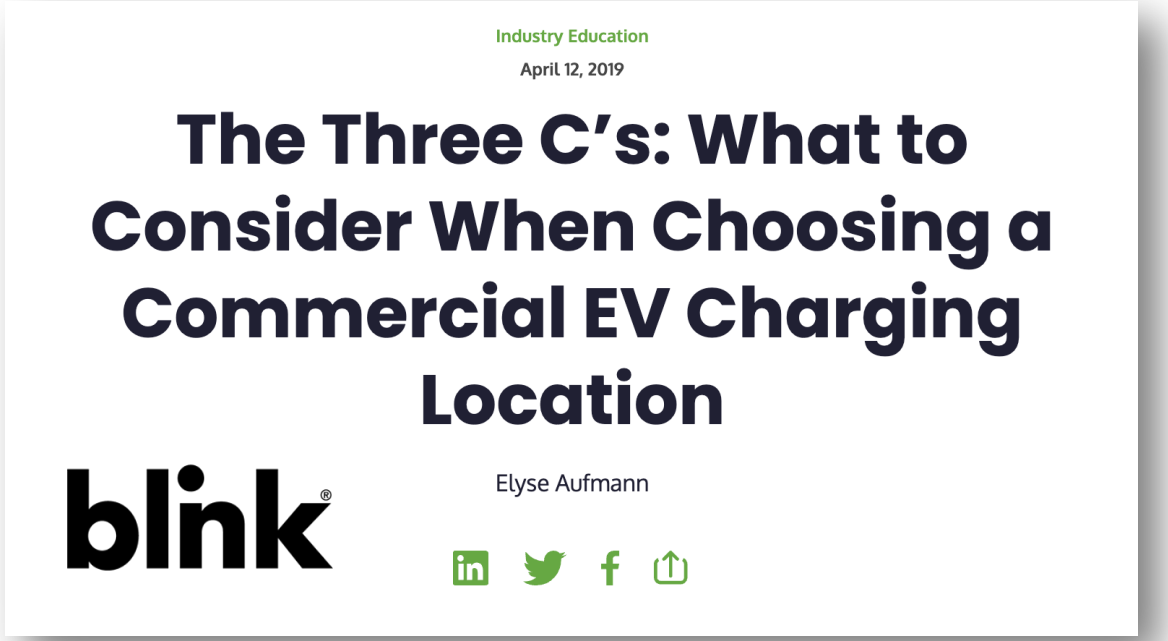
HOME > TRANSPORTATION

Biden wants EV chargers on every 50 miles of highway. That misses a key piece of the electrification puzzle.

Alexa St. John Feb 15, 2023, 11:30 AM

The White House said Wednesday that Tesla will open up its charging network to other EVs to help chip away at the Biden administration's ambitious US charger goal.
Bruce Bennett/Getty Images



Industry Education

April 12, 2019

The Three C's: What to Consider When Choosing a Commercial EV Charging Location

blink®

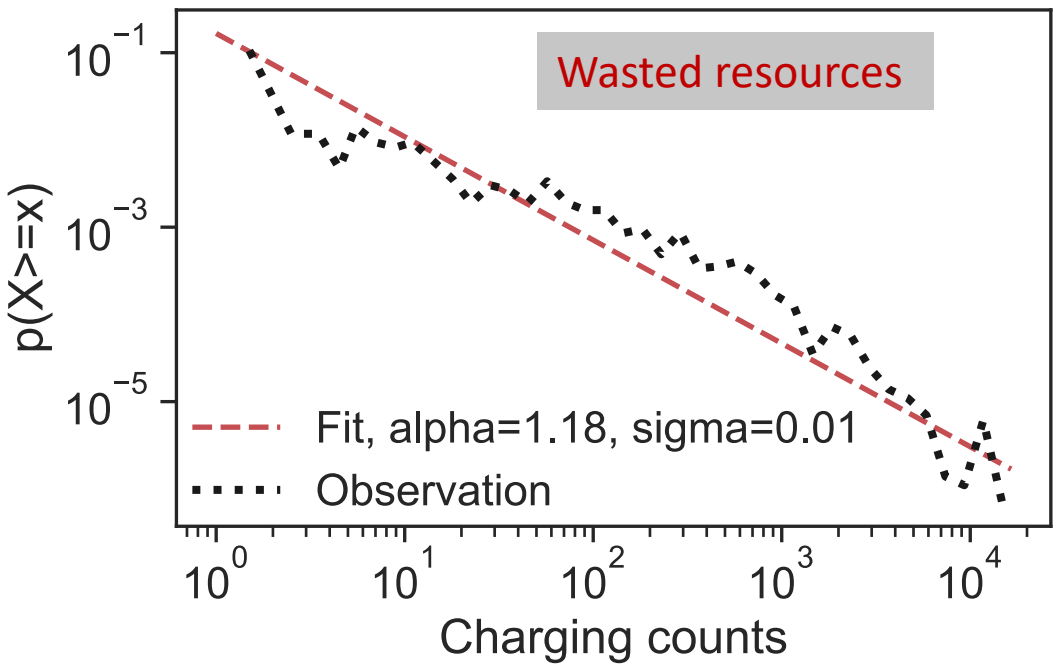
Elyse Aufmann

Convenience, Cost and Clientele

One-way decision only

How were PCSs utilized in the real-world?

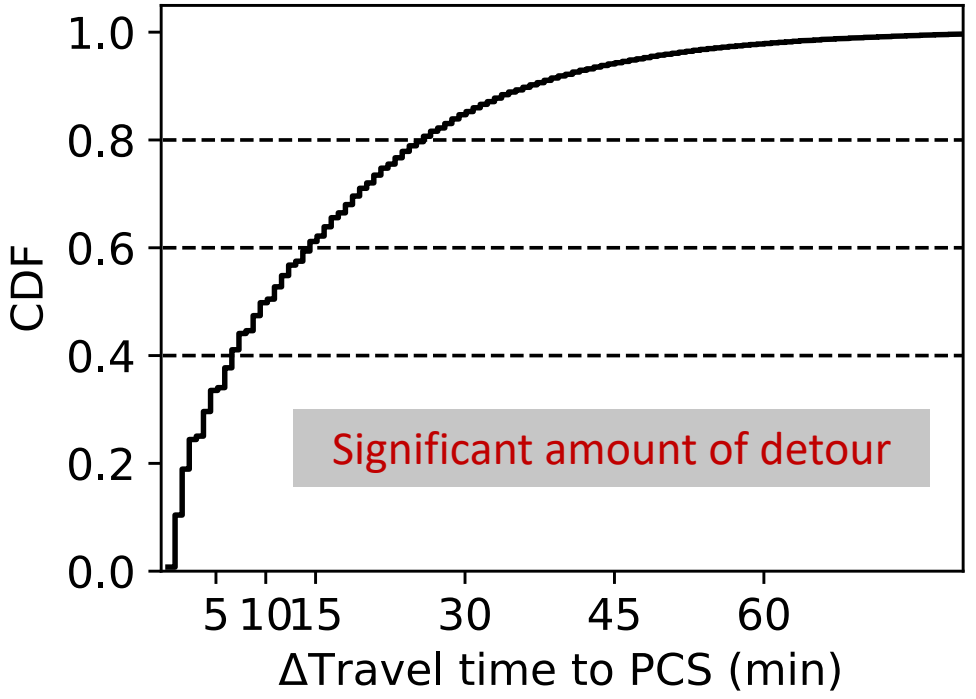
We mined one month of trajectory from 20,000 electric taxi drivers using 425 PCSs



Distribution of daily charging demand across all PCSs

6% of PCSs served over 50% of charging demand

35% of PCSs used <10 times a day



Additional Travel Time to get to the selected PCS

Why do they detour?

1) Maximize Utility or 2) Habit?

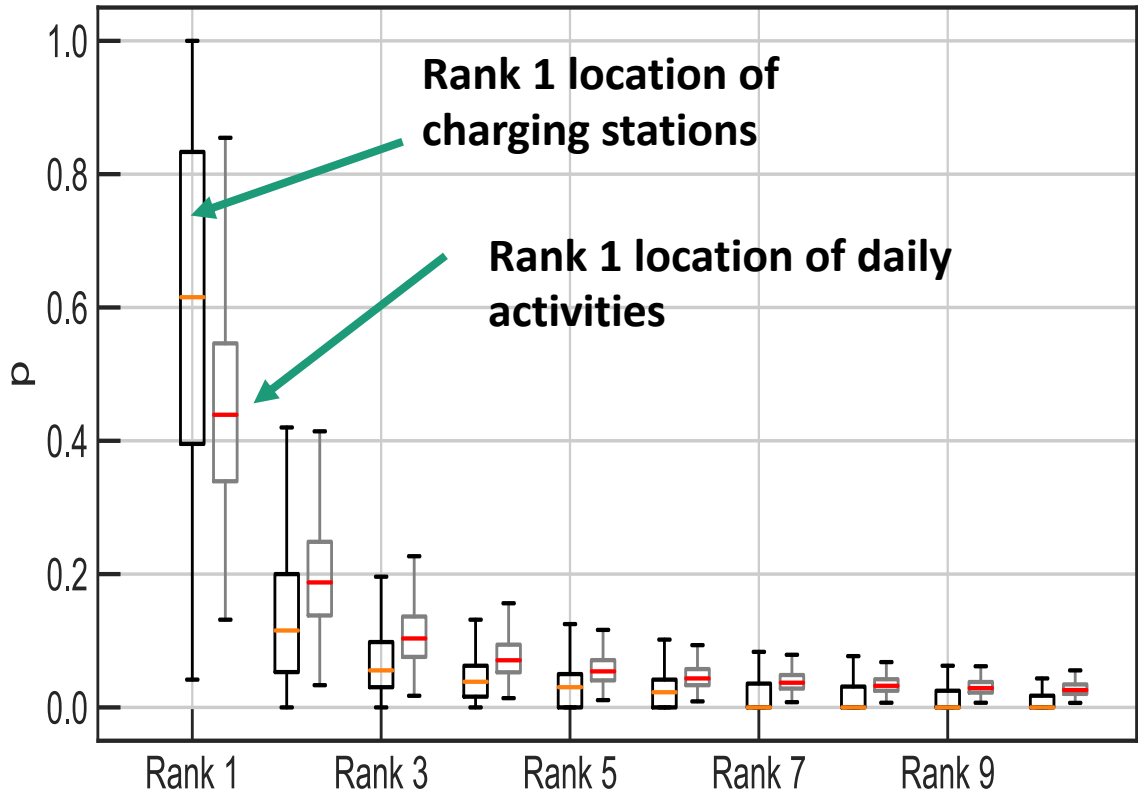
Lei, T., Guo, S., Qian, X.*, & Gong, L. (2022). Understanding charging dynamics of fully-electrified taxi services using large-scale trajectory data. ***Transportation Research Part C: Emerging Technologies***, *143*, 103822.

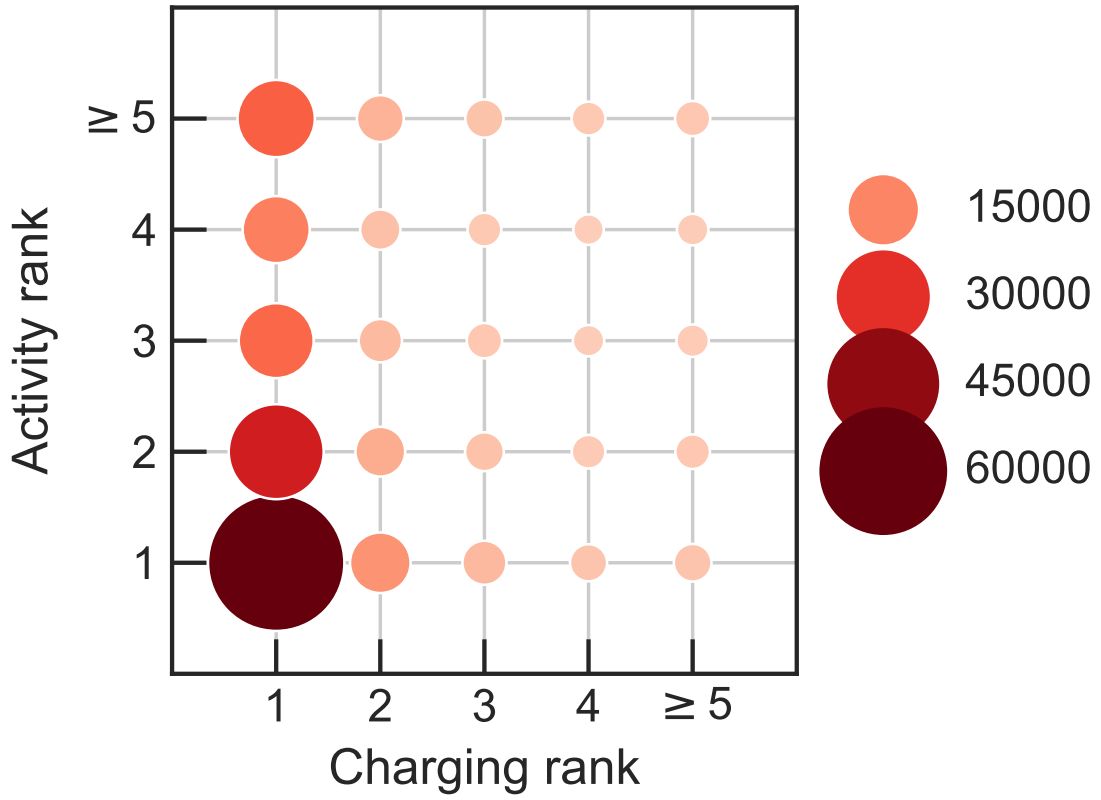
Charging at a Public Charging Station: A travel decision or a social activity?

A motivating question

When deciding between two candidate charging stations, will one choose
(1) a standalone Tesla Supercharger 2 minutes away, or
(2) a slower charging station that is 5 minutes away, but is adjacent to a Starbucks shop?

Two quick facts on charging demand





How are we deploying charging stations?

To answer, we need to explore:

- Who has access to public charging stations?
- How access to stations is related to access to activities?
- What are the underlying deployment strategies?

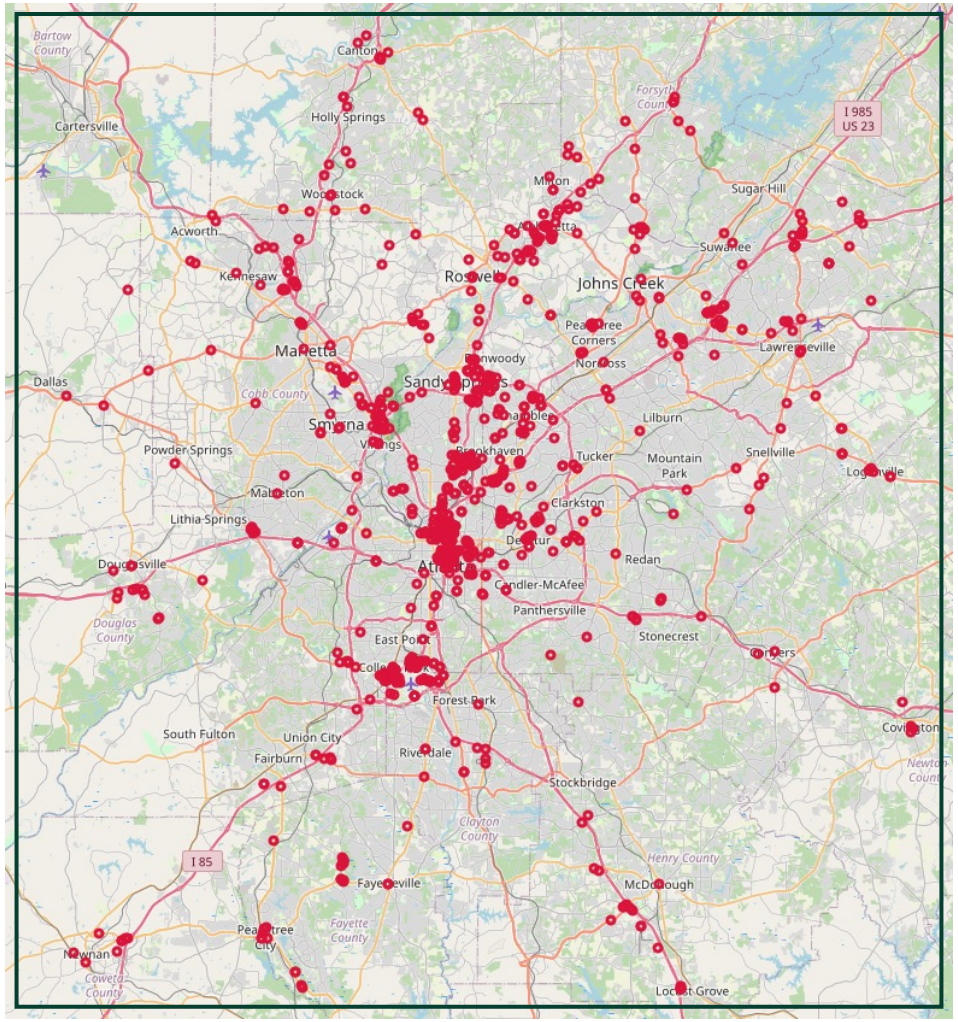
Question:

- Is there a general trend across metro areas in the US?

Data

For 10 metropolitan areas across the US:

- Location of the available public charging stations as of June 2023 (AFDC)
- Sociodemographic status of census block groups (ACS)
- Location of places and activities (SafeGraph POI)
- Road network (OpenStreetMap)charging stations



public charging stations in Atlanta, GA

The multidimensional nature

Opportunities nearby charging stations

Census block group's (CBG) access to charging stations

From your neighborhood to the nearest charging stations

Accessibility from charging station to nearby CBGs

All the CBGs that are near this station

Charging induced activities

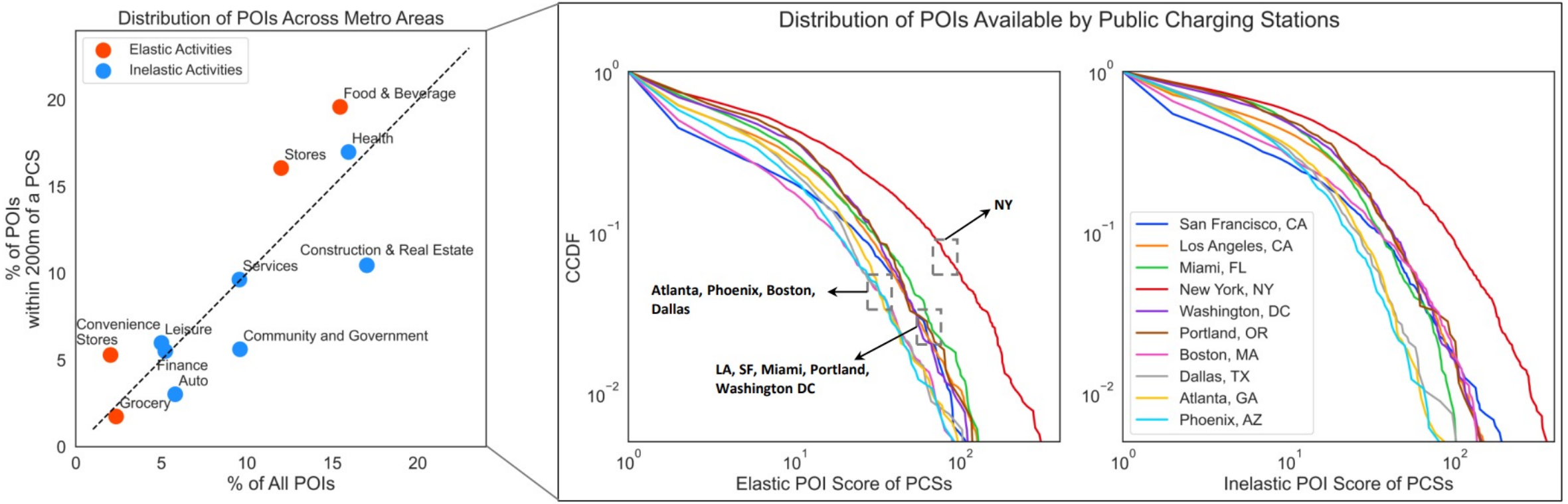
If my goal is to find a charging station but great to find something to spend the time

Activity induced charging

If my goal is to do the activity, while it is great to find a charging station…

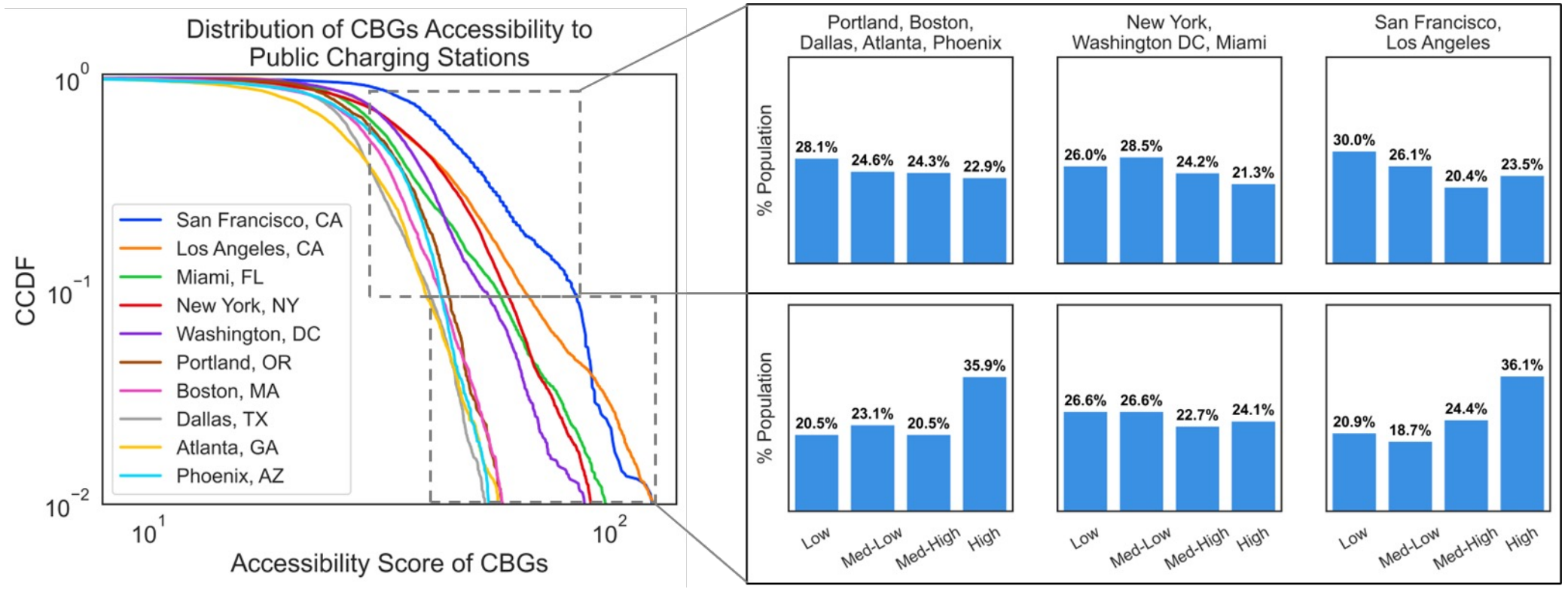
Activities near charging stations

We compare how likely can we find things to do around public charging stations



Accessibility from CBG to charging stations

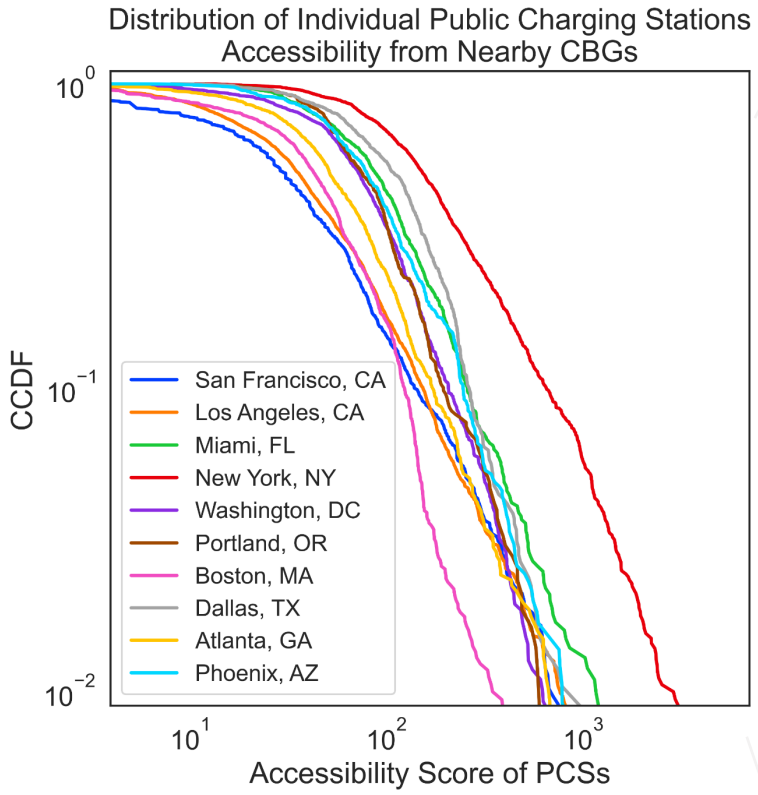
The standard measure of accessibility from each CBGs in terms of distance



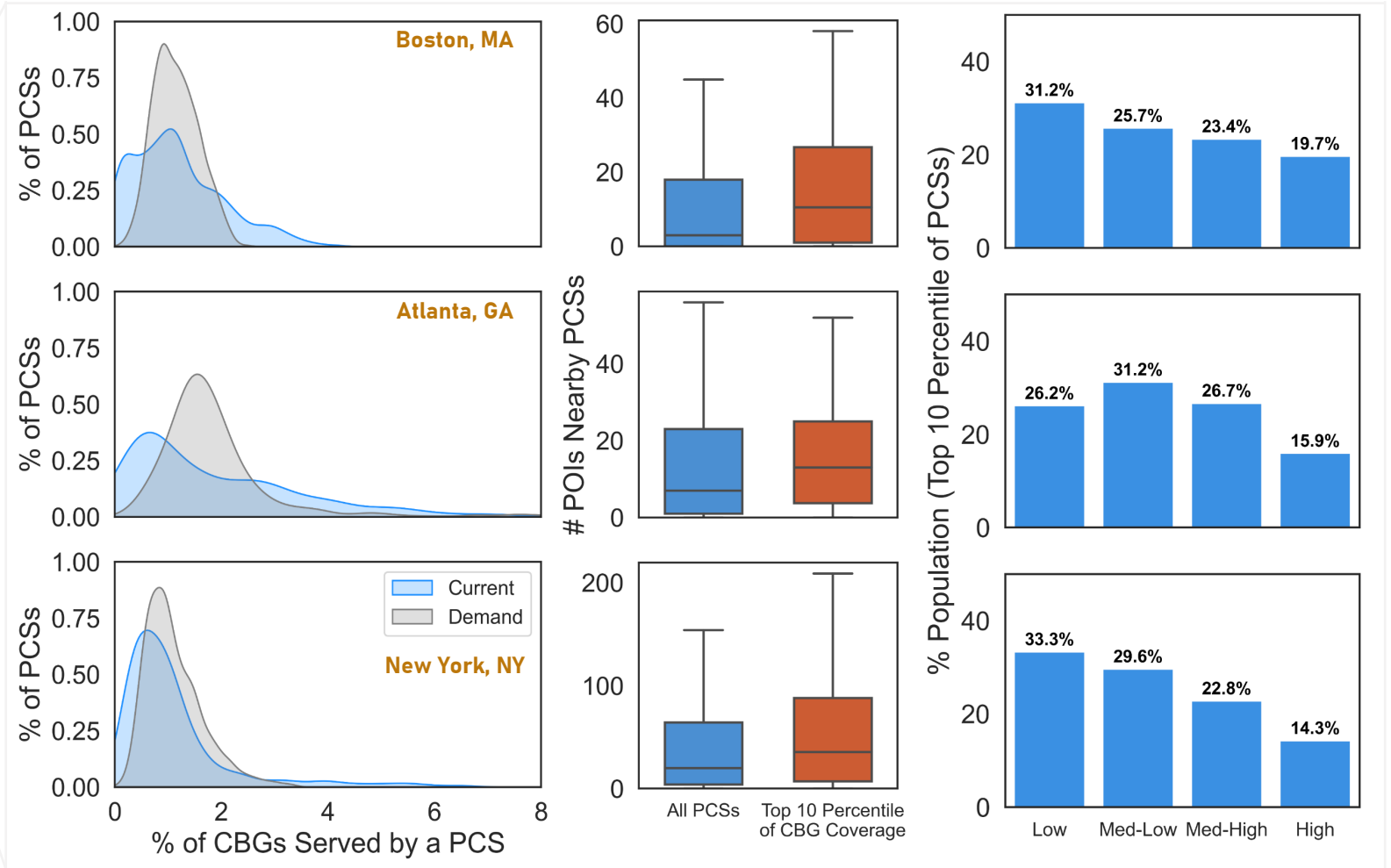
higher level of EVSE adoption

Income distribution

The other way: from stations to CBGs



Those stations are not equally important



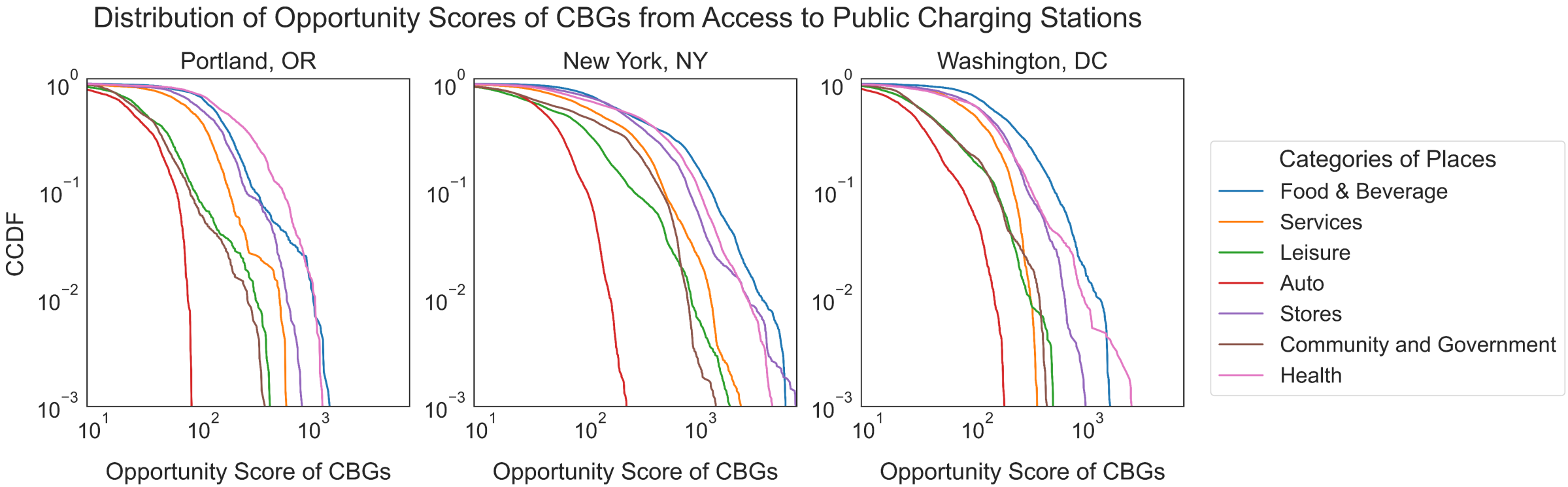
Population coverage Vs. baseline

POISs

Income distribution

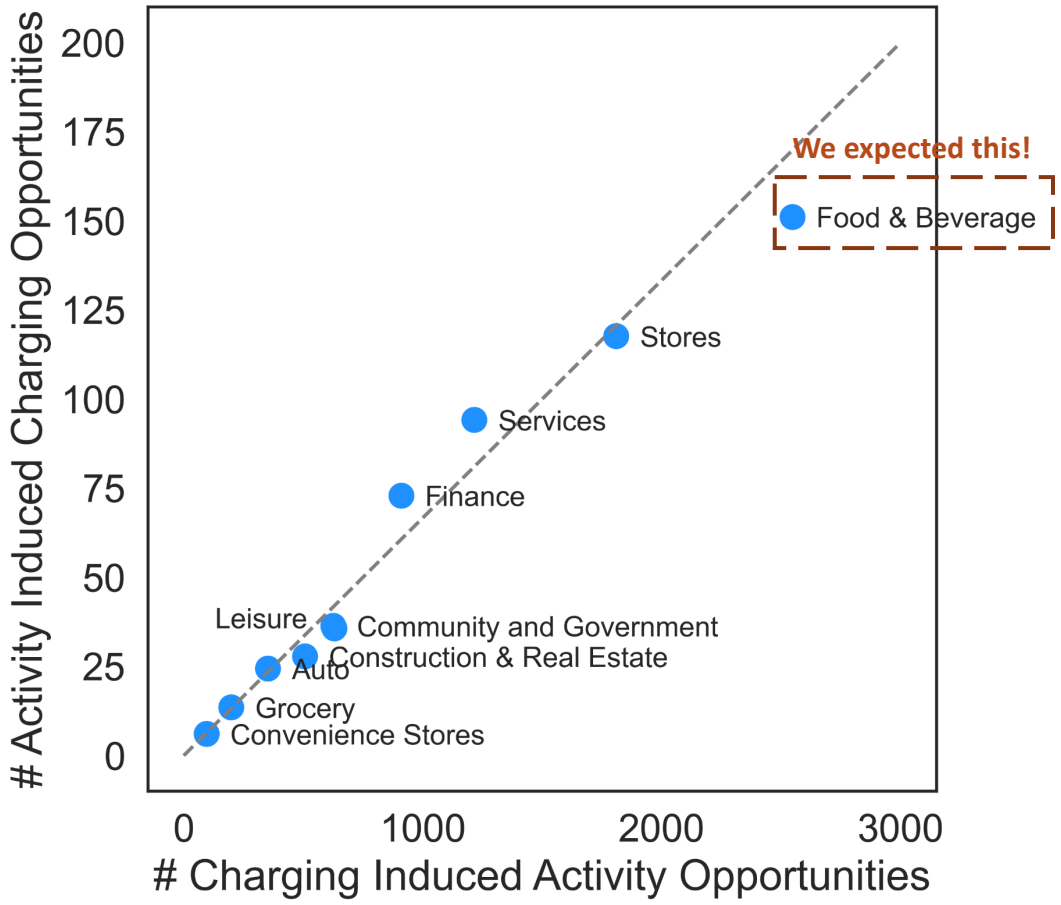
Charging Induced Activities

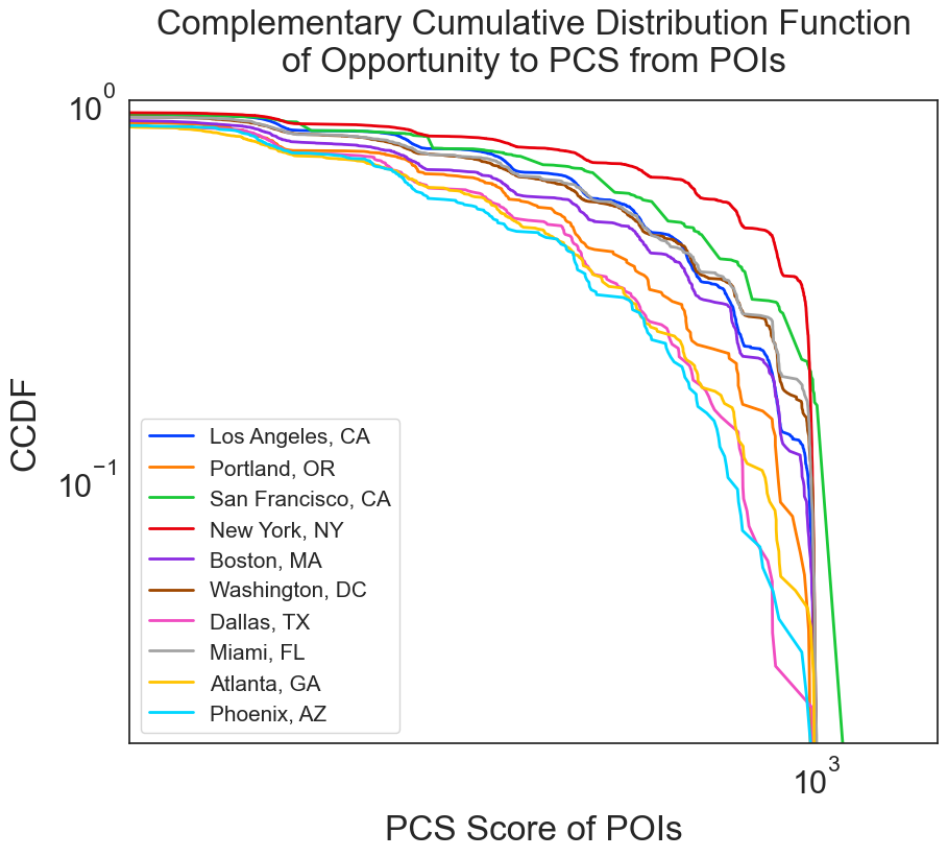
Activities that are available to EV users by accessing to their nearby stations



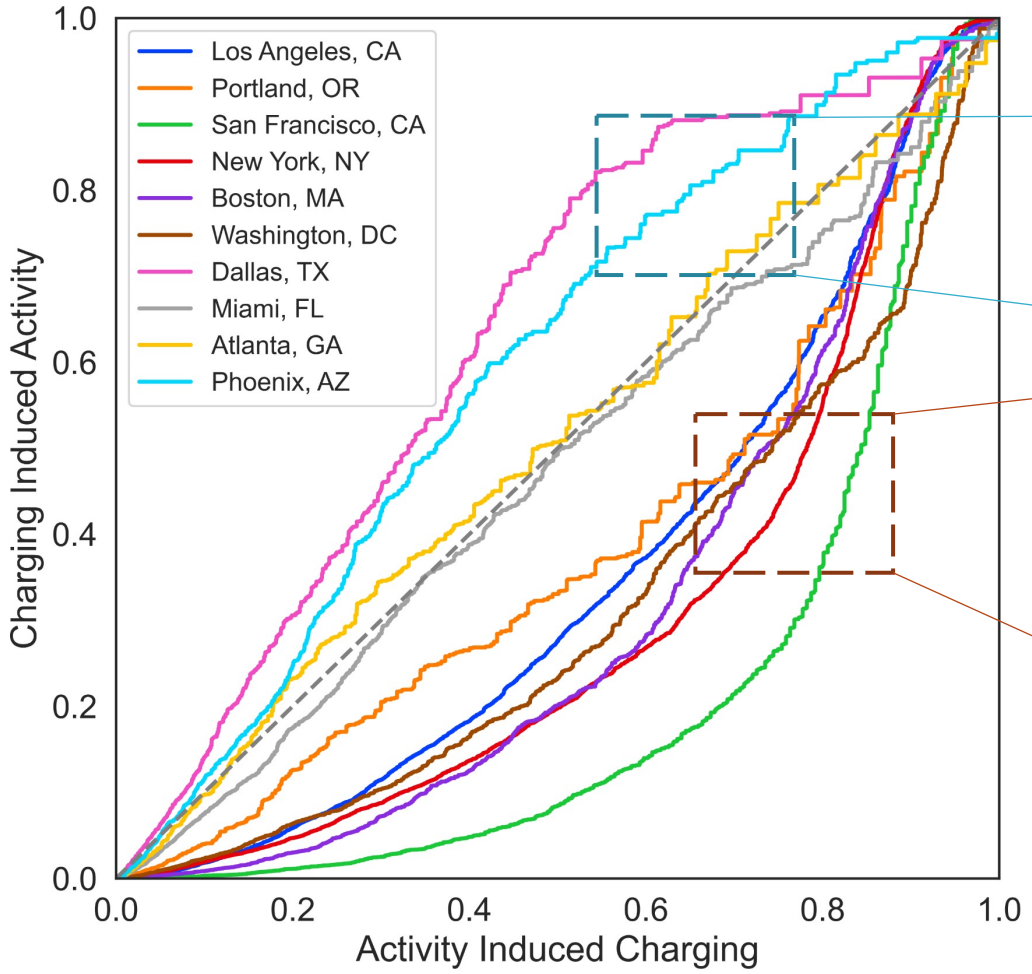
Activity Induced Charging

Charging opportunities that are available to EV users by accessing to their nearby activities





Can we observe a trend?



Two sides of PCS deployment:

- \- EV users face inconvenience while finding suitable charging facilities that align with their preferred activities.
- \+ But they will likely find something to do while charging

+ Most EV users can conveniently charge their vehicles while engaging in their preferred activities.

- But difficult for other users when their activities are less aligned with charging stations

Charging deployment scenarios

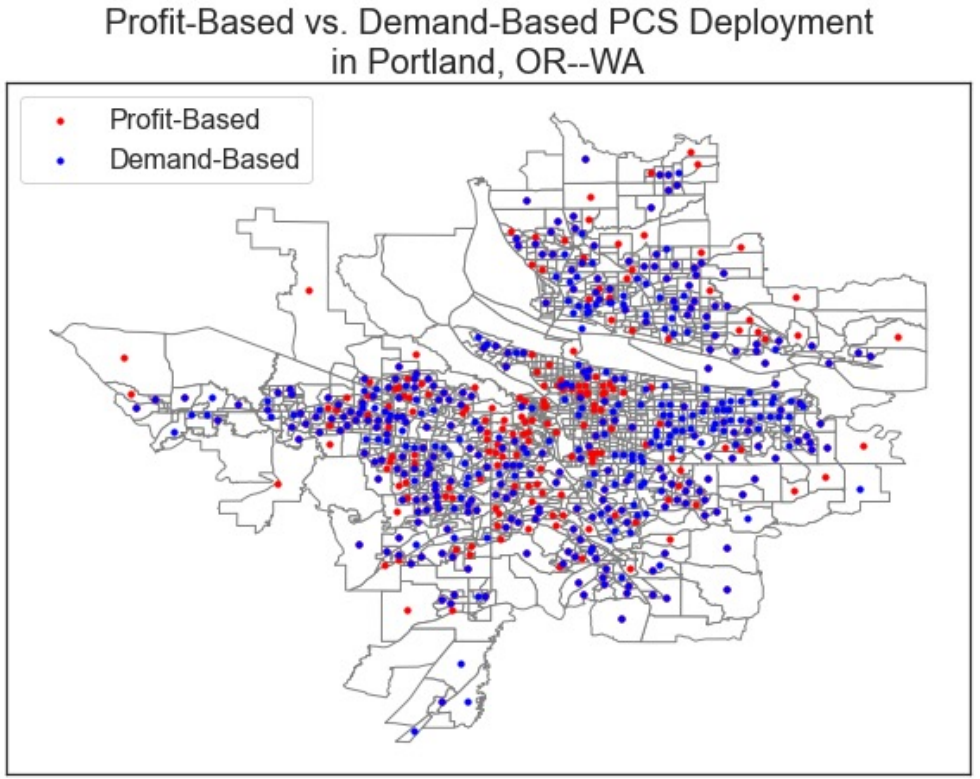
Redistributing the stations across the metro area:

1. Spatially uniform
   without any specific criteria

2. Demand-based
   prioritizing areas with higher population

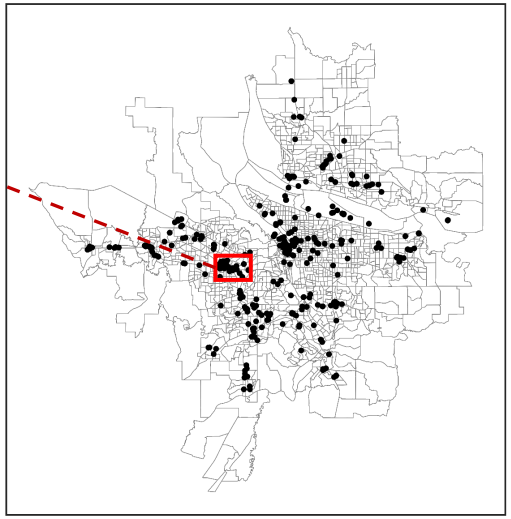
3. Profit-based
   prioritizing areas with higher income

4. Equity-based
   considering the accessibility of block groups to charging stations

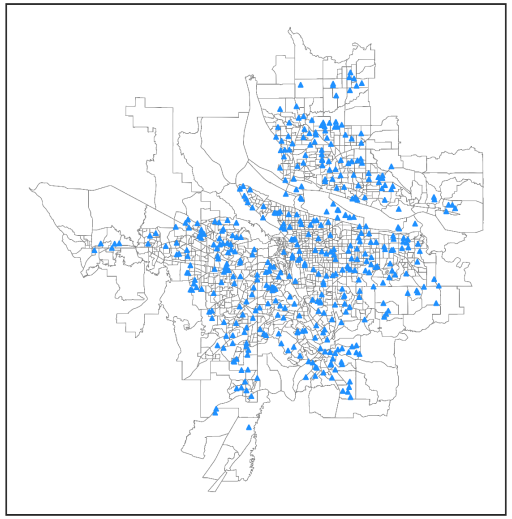


Charging Station Deployment Scenarios for Portland, OR

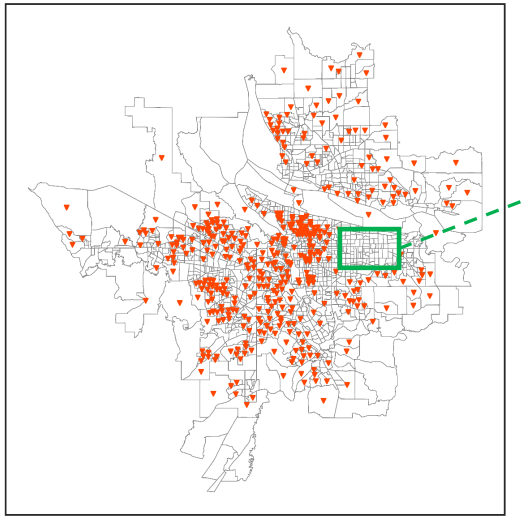
Current



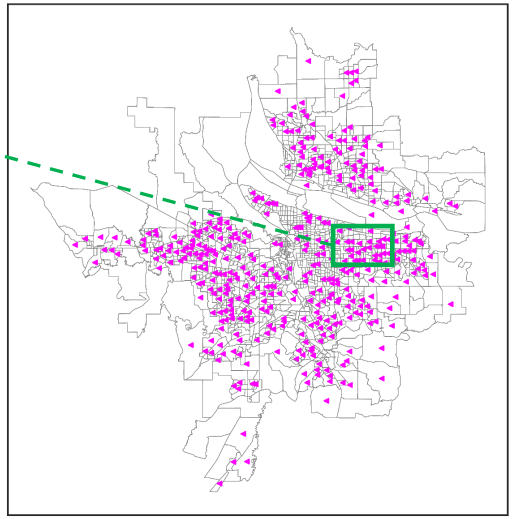
Random



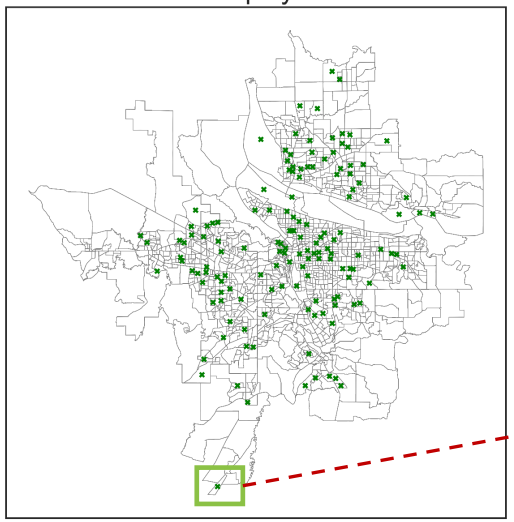
Profit-based



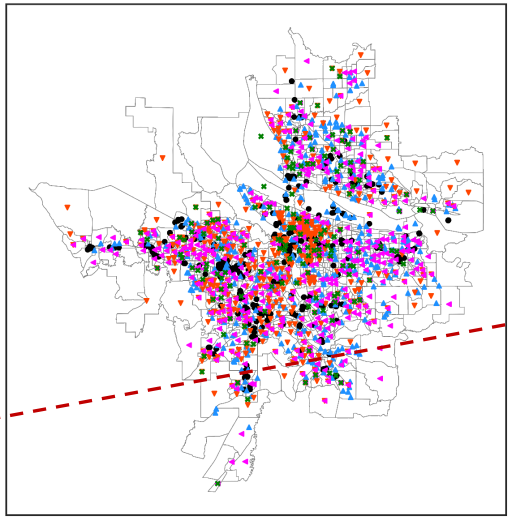
Demand-based



Equity



All Scenarios



very high number of stations very close to each other

large area without any station (because of lower relative income)

same area which has a high coverage now

focused on areas with high population while considering the accessibility of the others

Charging deployment scenarios

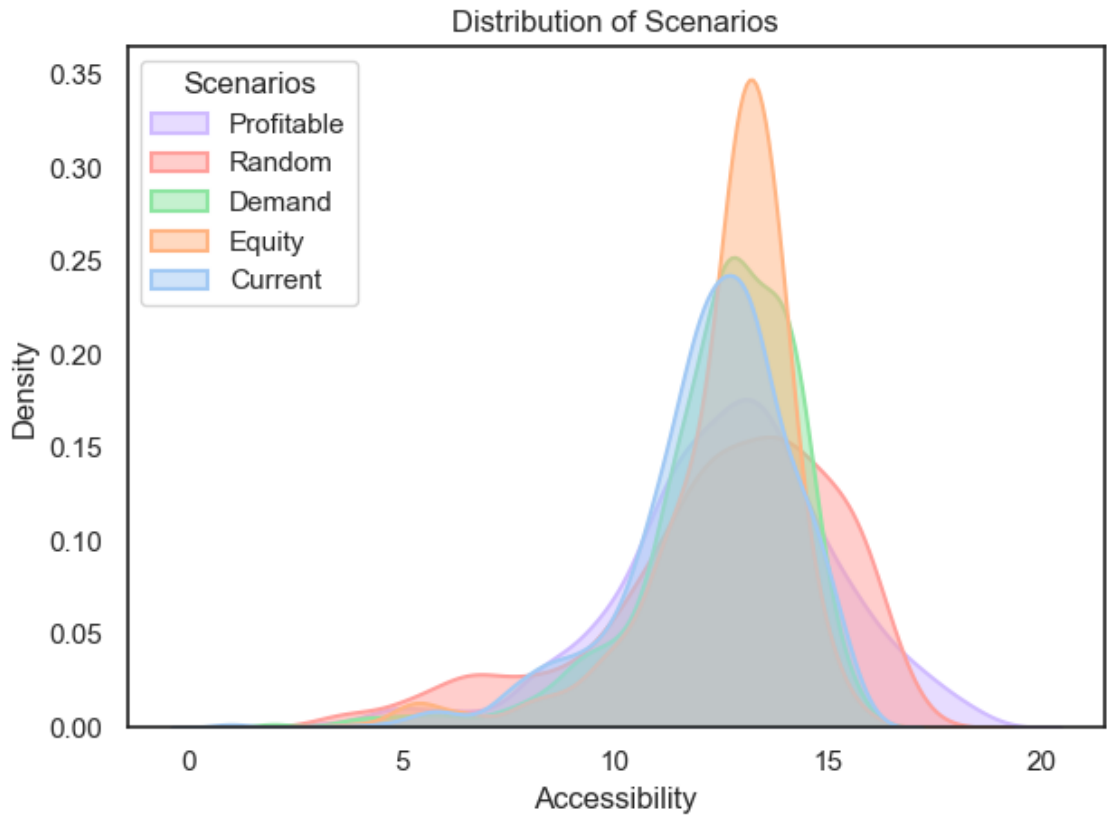
What is the underlying strategies
(which scenario is the closest to current layout in terms of access to charging stations)

Uniform
- Atlanta, GA
- Phoenix, AZ
- Portland, OR

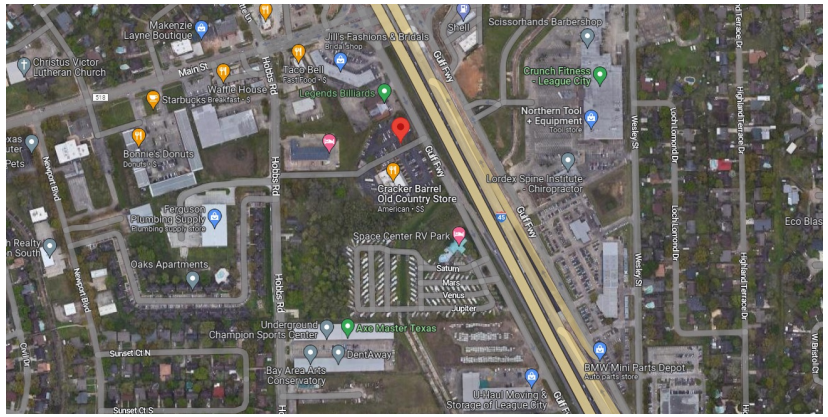
Demand-based
- Los Angeles, CA
- San Francisco, CA
- Washington, DC

Profit-based
- New York, NY
- Boston, MA
- Miami, FL

Equity-based
- Dallas, TX



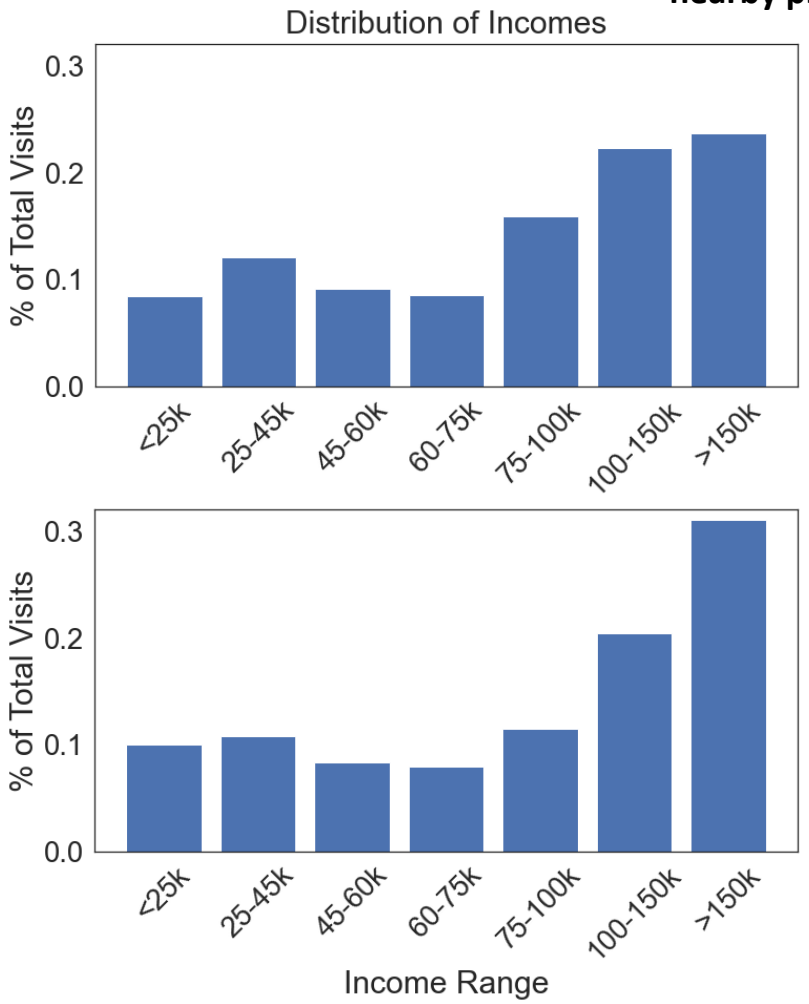
A single PCS can change the nearby area!



- **Jan. 2019**
- **Jan. 2022**

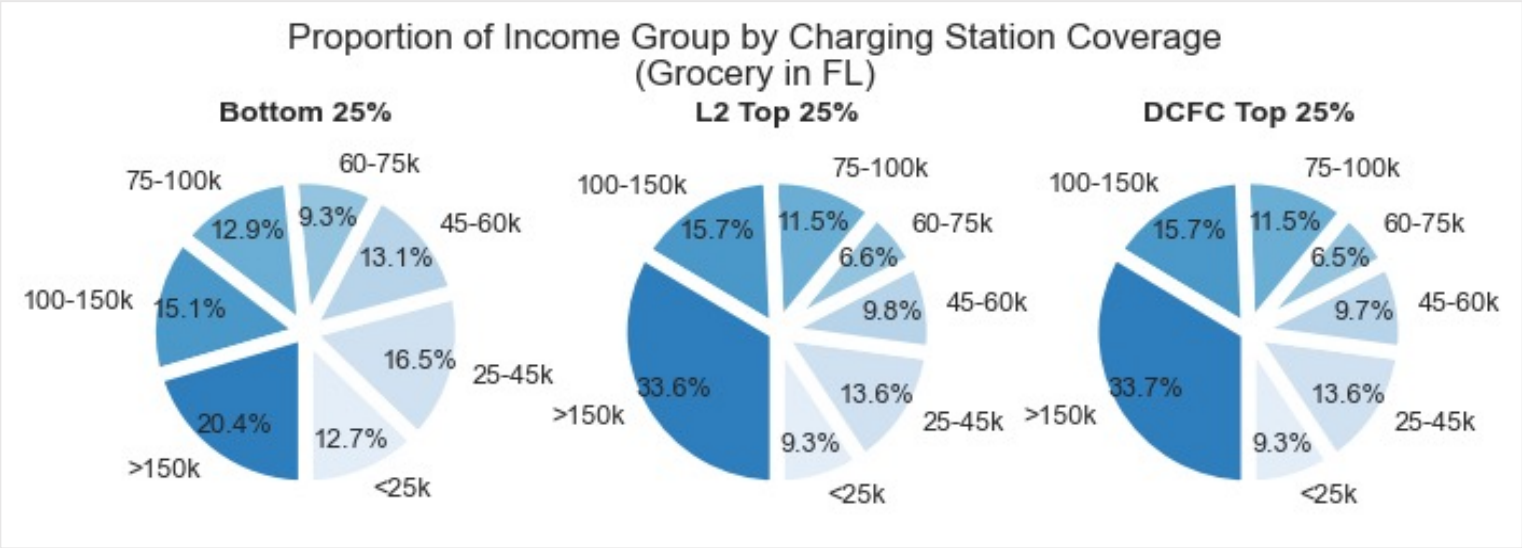
League City, TX 77573

Who visits the nearby places?

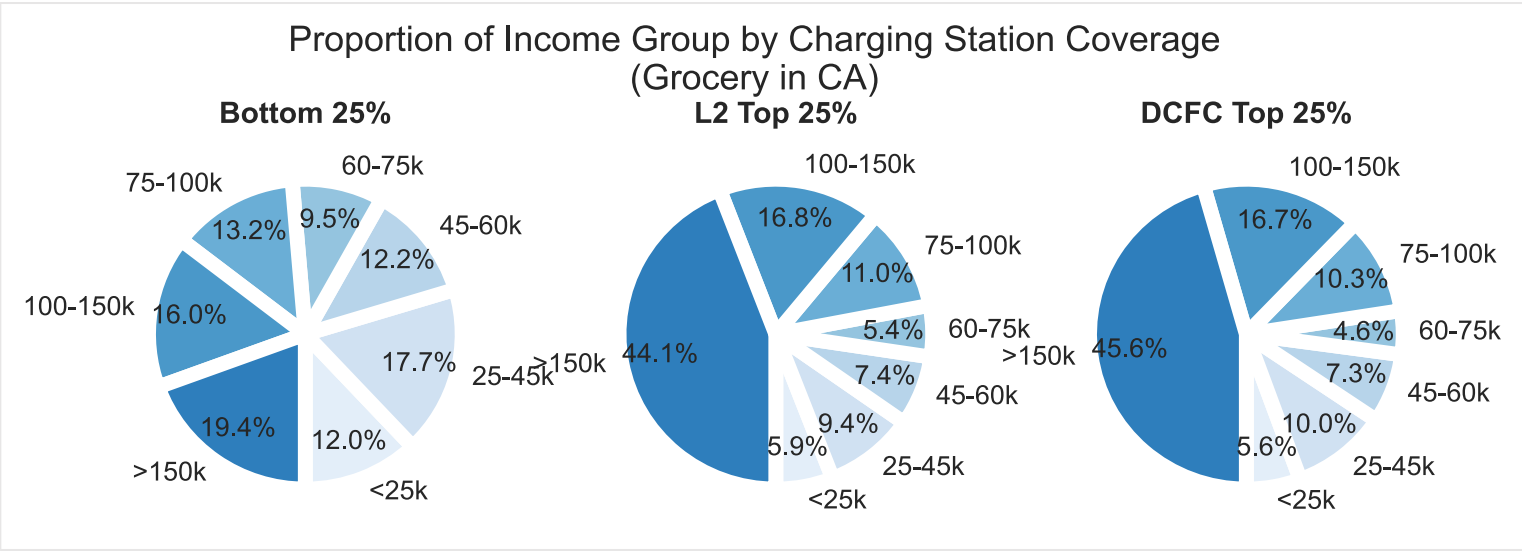


Who Visits the Nearby Places?

Grocery Stores,
FL
(2,755 PCSs)



Grocery Stores,
CA
(14,132 PCSs)



Which Brands Are Associated With Charging Stations?

Short Answer: Less affordable brands that attract higher income customers

- For grocery places in Florida (by end of 2022):

Highest PCS coverage*

(%50.0)

(%28.6)

(%28.6)

Lowest PCS coverage*

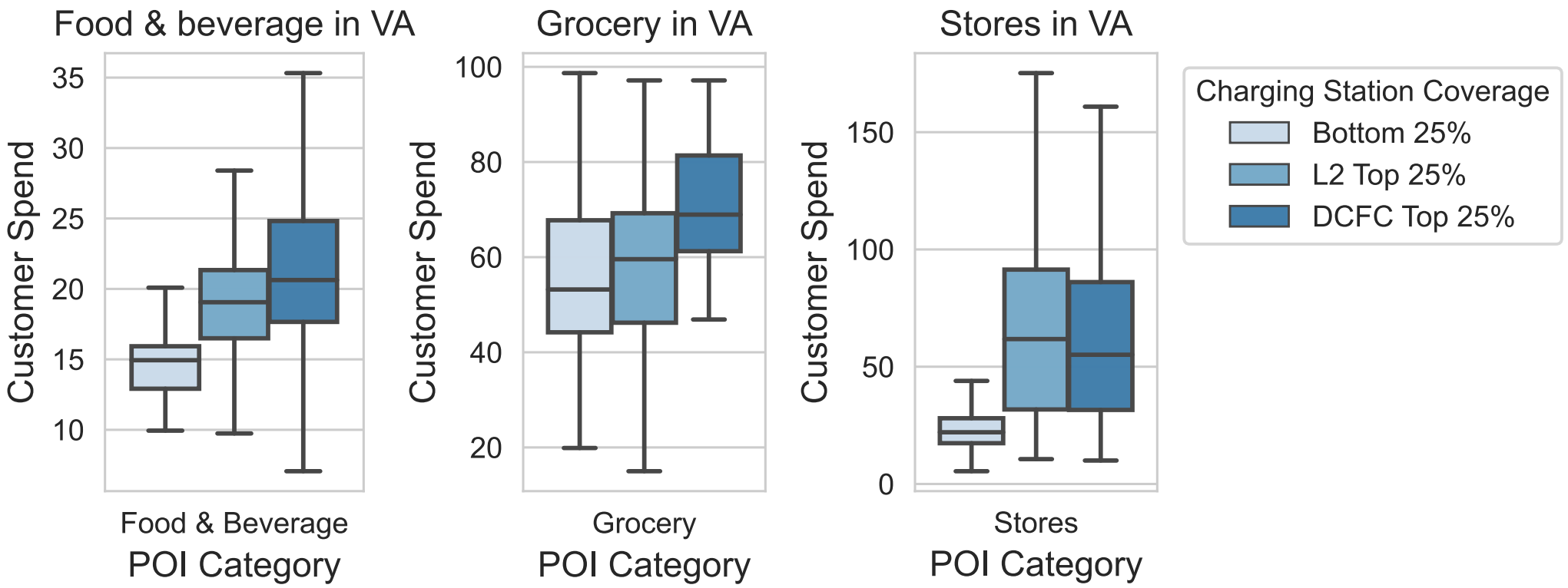
(%4.4)

(%7.8)

(%5.5)

*% of locations within 200 meters of a PCS

How much do people pay at the POIs?



What will be the hidden cost for using an EV?

Thank You!

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Xinwu Qian

July 2023