Emissions and Equality: Optimizing Car Locations for Colorado Car Share

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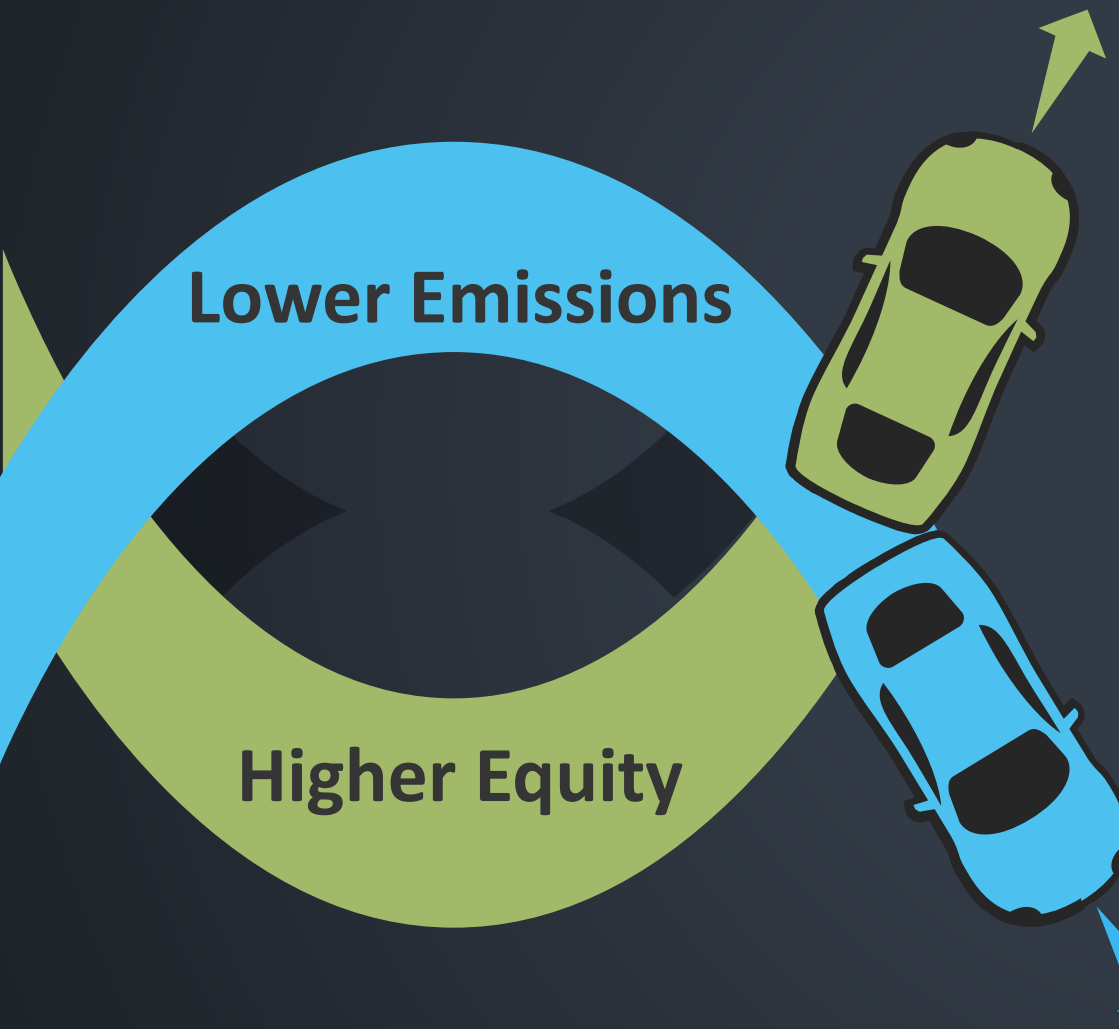
What is car sharing and why we want more?

Car sharing programs allow for people who don't need a car daily to use a shared one.



Cost savings

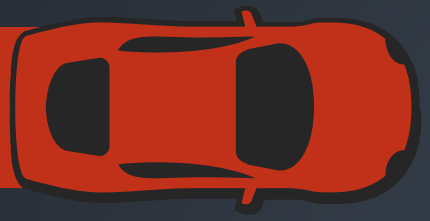
- Saves money on parking, maintenance, gas, and insurance.
- Subsidised rates for low-income individuals
- Multiple vehicle options available

Emissions reduction

- New model electric or fuel-efficient vehicles
- Each vehicle added replaces 9-13 personal cars
- Members reduce the amount they drive overall
- Less vehicles allows for a more walkable/bikeable city

About Colorado Car Share

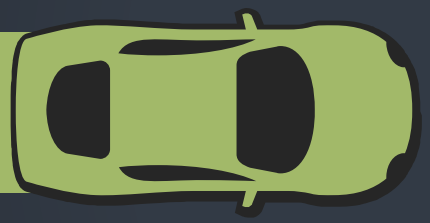
Non-Profit



Colorado Based

- Founded in 1997 in Boulder Colorado
- In 2006 were approved as a 501(c)(3) entity
- Currently the only nonprofit carshare in Colorado
- In 2010, awarded federal funding (CMAQ) to expand fleet

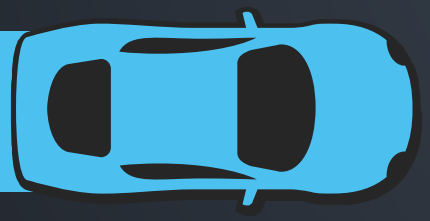
Lower Emissions



Environmentally Friendly

- Reduces the total number of vehicles on the road
- Increases the number of electric vehicles in CO

Equity

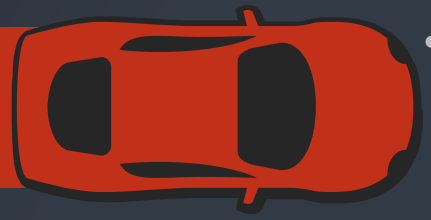


Flexibility and Cost

- Cars are fully insured for $1,000,000 in liability
- Allows for foreign driver's licenses – Rare in CO
- Significantly lower cost than owning a personal vehicle
- Subsidized pricing for low-to-middle income members and CU Boulder students

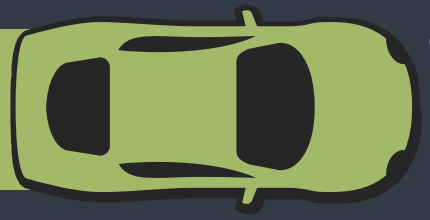
What are we doing?

Optimizing Growth



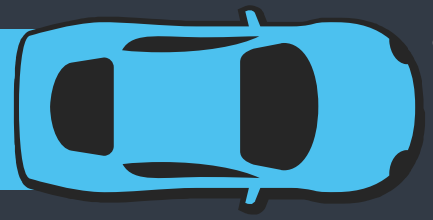
- Choosing optimal locations for new vehicles increases the impact per vehicle added.

Population Density



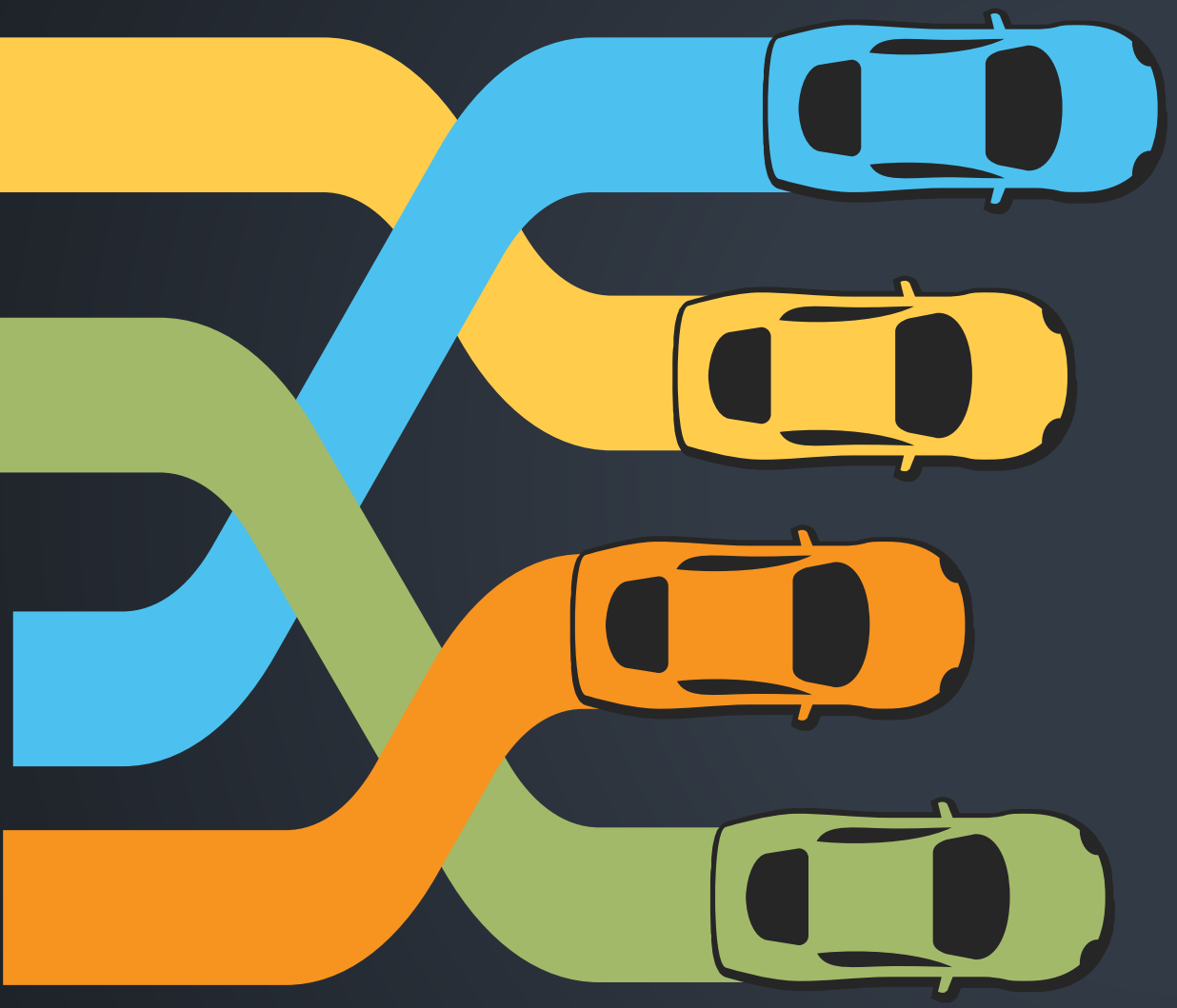
- Our basic model uses population density to factor in population and area when determining new vehicle locations.

Adaptability



- By weighting the model to target specific groups, we can prioritize subsets of the total population.

Model Varieties



No vehicle access

Forces people to spend more money, more time, or both to perform everyday tasks.

Cost-Burdened

Anyone who spends more than 1/3 of their income on housing costs.

Poverty

Annual income under $18,255 a year for an individual.

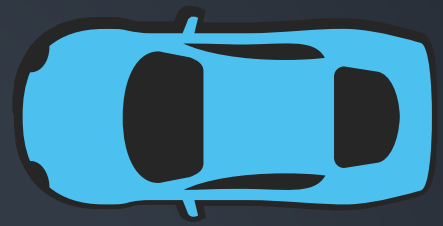
Renters

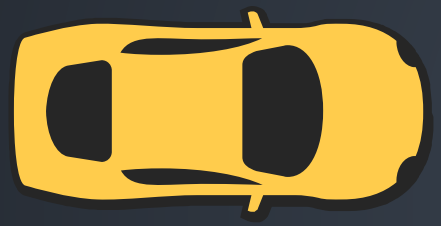
People who rent instead of own their primary residence.

Final Model Choices

Pyomo

We used the Pyomo package to build and solve our IP in Python.



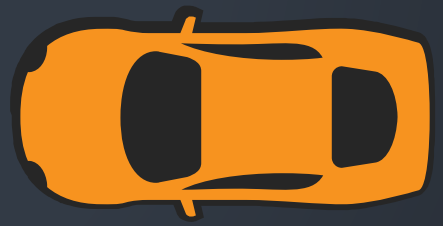


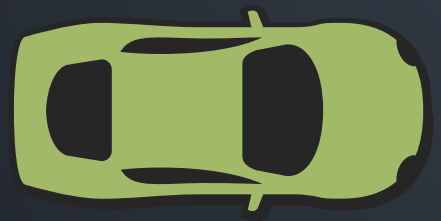
Dictionaries

We had to pull our data from the dataframe and create dictionaries for Pyomo to use it.

Solver

We used Gurobi to solve the IP.





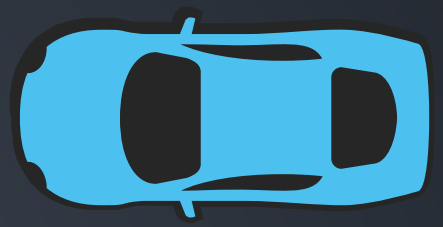
Github link

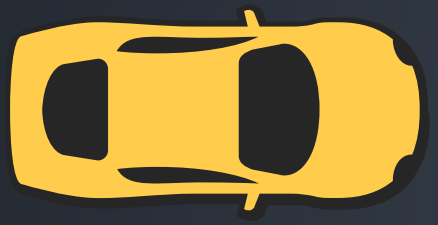
https://github.com/pgmath/Emissions-and-Equality

Data Cleaning

Data sources

Our data was sourced from the City of Denver and is based on Denver ACS data. The current vehicle locations were from Colorado Car Share's public site



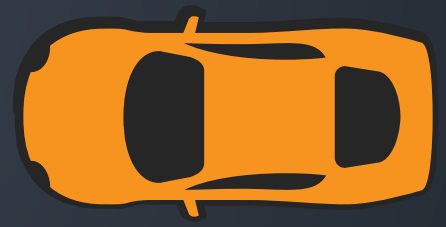


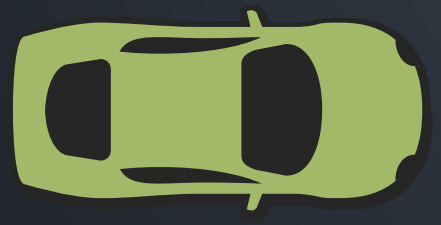
Current vehicle data

We manually took the current car locations for CCS and noted how many were in each tract

Data Frames

Used Python to merge data frames from the ACS data with the vehicle location data





Weighting selection process

Basic regression led to the intial weights chosen, future weights would be based on funding stipulations

Model Inputs

- Set: R the set of all census tracts in Denver under consideration. $i = 1 \dots n$
- Variable: x_i The number of cars to add to census tract i $\forall i \in R$.
- Parameter: t_i. The number of cars currently in census tract i $\forall i \in R$.
- Parameter: p_i The population density of census tract i $\forall i \in R$.
- Parameter: w_i Weighting based on model variation for census tract i $\forall i \in R$.
- Parameter: c The total number of cars to be added.
- Parameter: $m = \max\left(\frac{t_i}{p_i}\right)$ $\forall i \in R$ such that $p_i \neq 0$.
- Parameter: ℓ An upper bound on the number of cars added to any one tract.

Objective function and constraints

Our objective function is given by

$$\max \sum_{i \in R} w_i \cdot p_i \left(t_i + x_i\right)$$

subject to the constraints:

$$\sum_{i \in R} x_i \leq C,$$

$$t_i + x_i \leq m \cdot p_i, \text{for all } i \in R,$$

$$x_i + t_i \leq \ell \text{ for all } i \in R,$$

and the variable constraints:

$$x_i \geq 0, x_i \in \mathbb{Z}.$$

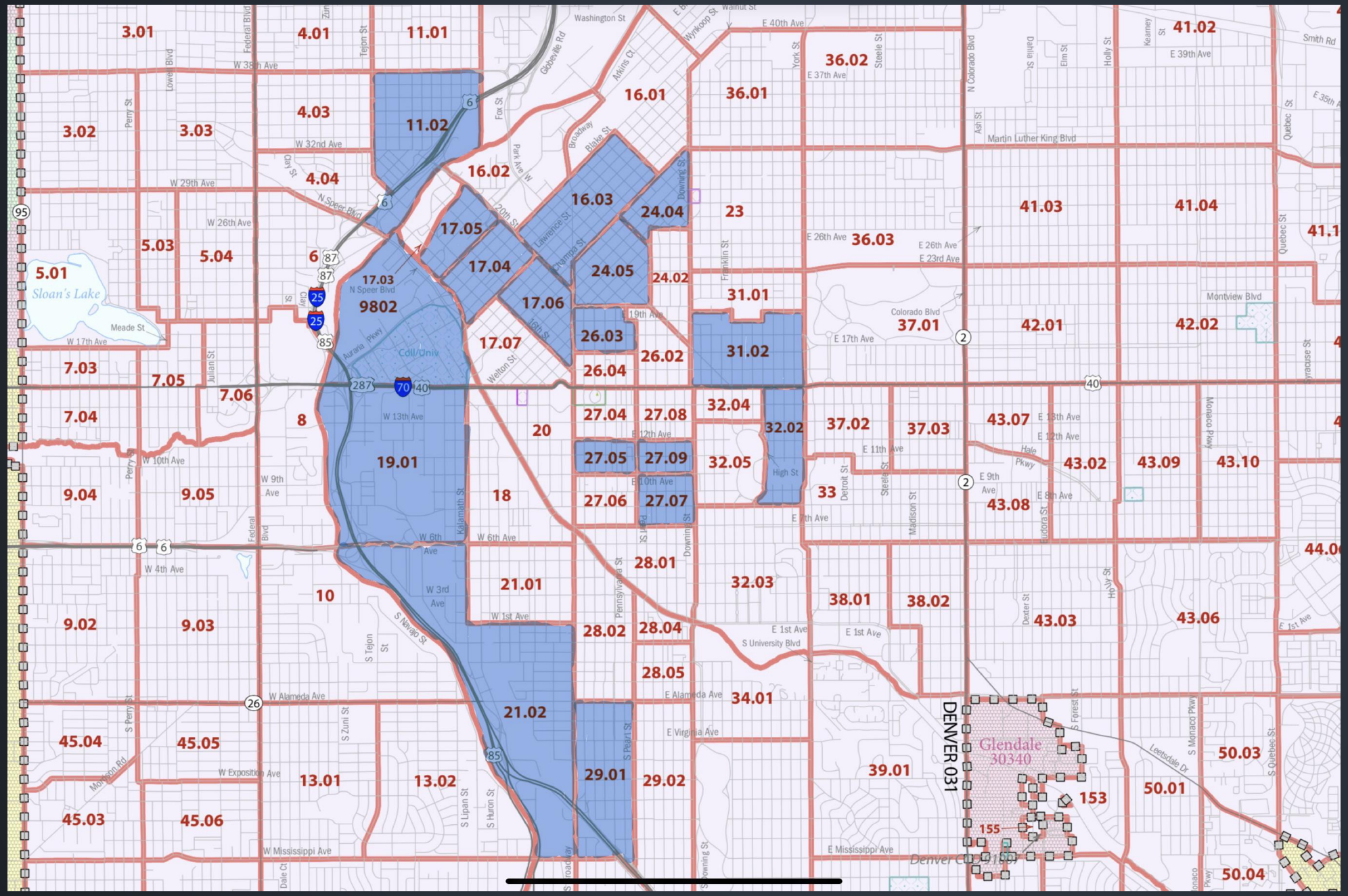
Obective

The objective function optimizes car locations using a weight (w_i), population density (p_i), and current car locations (t_i), for all given regions.

Constraints

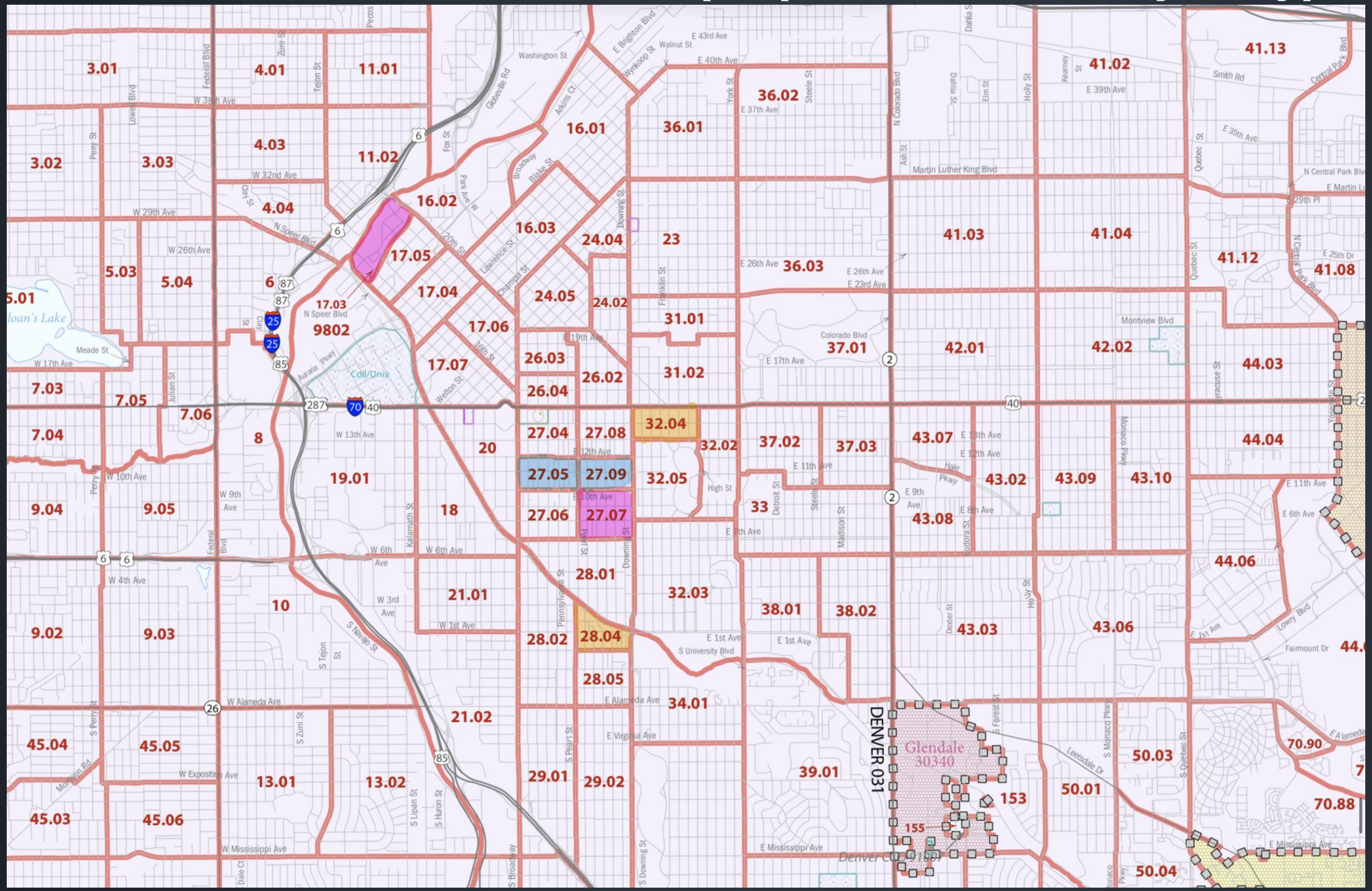
We choose the number of cars to be added (C). We then use combination of existing vehicles, population density, and a flat limit to spread out the expansion among multiple areas.

Current CarShare Locations



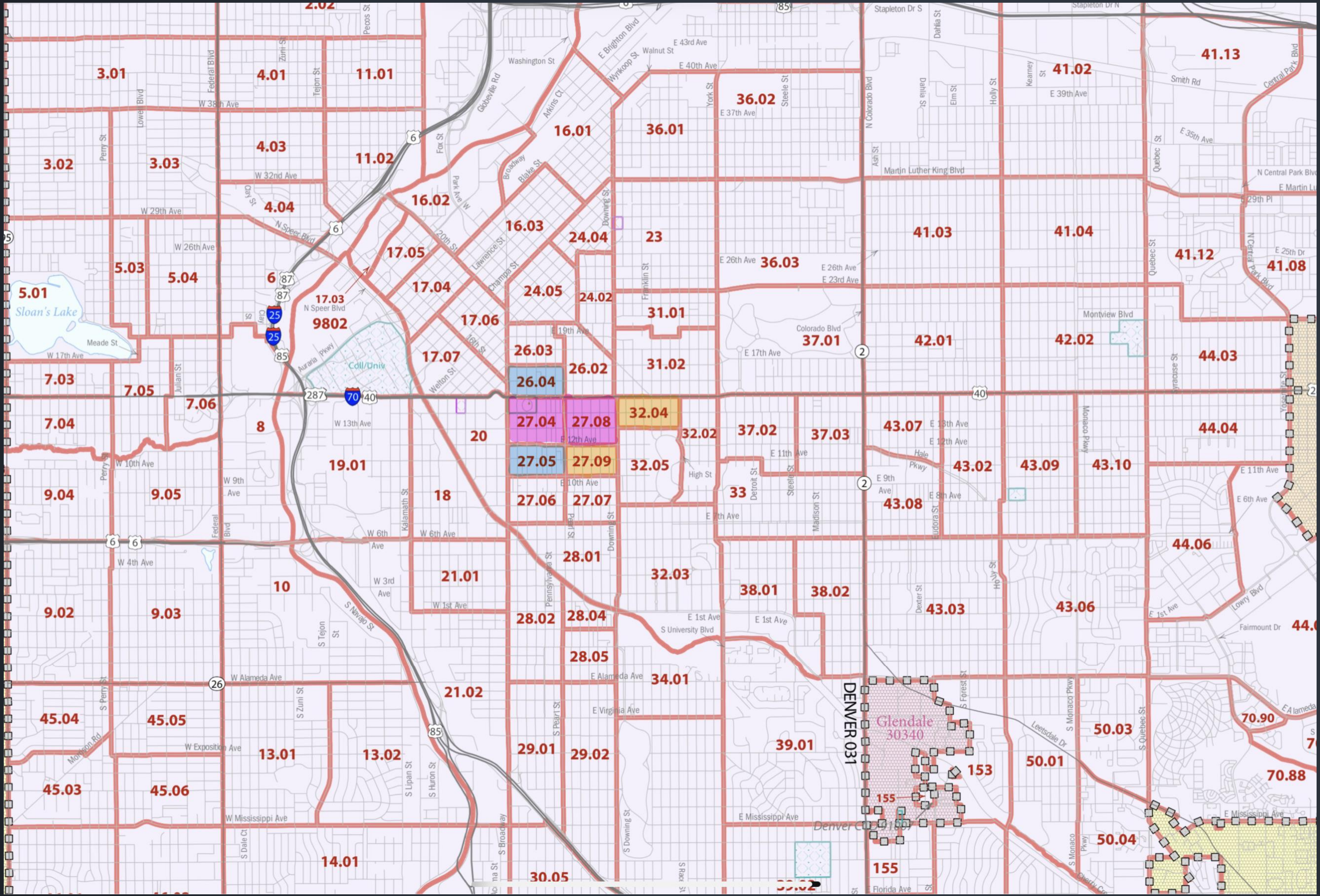
- Regions shaded in blue are tracts which currently contain cars

Basic Model (Population Density only)



- Blue areas are tracts the model selected when we used 9 cars
- Pink areas are tracts the model selected when we used 18 cars
- Orange areas are tracts the model selected when we used 27 cars

No Vehicle Access



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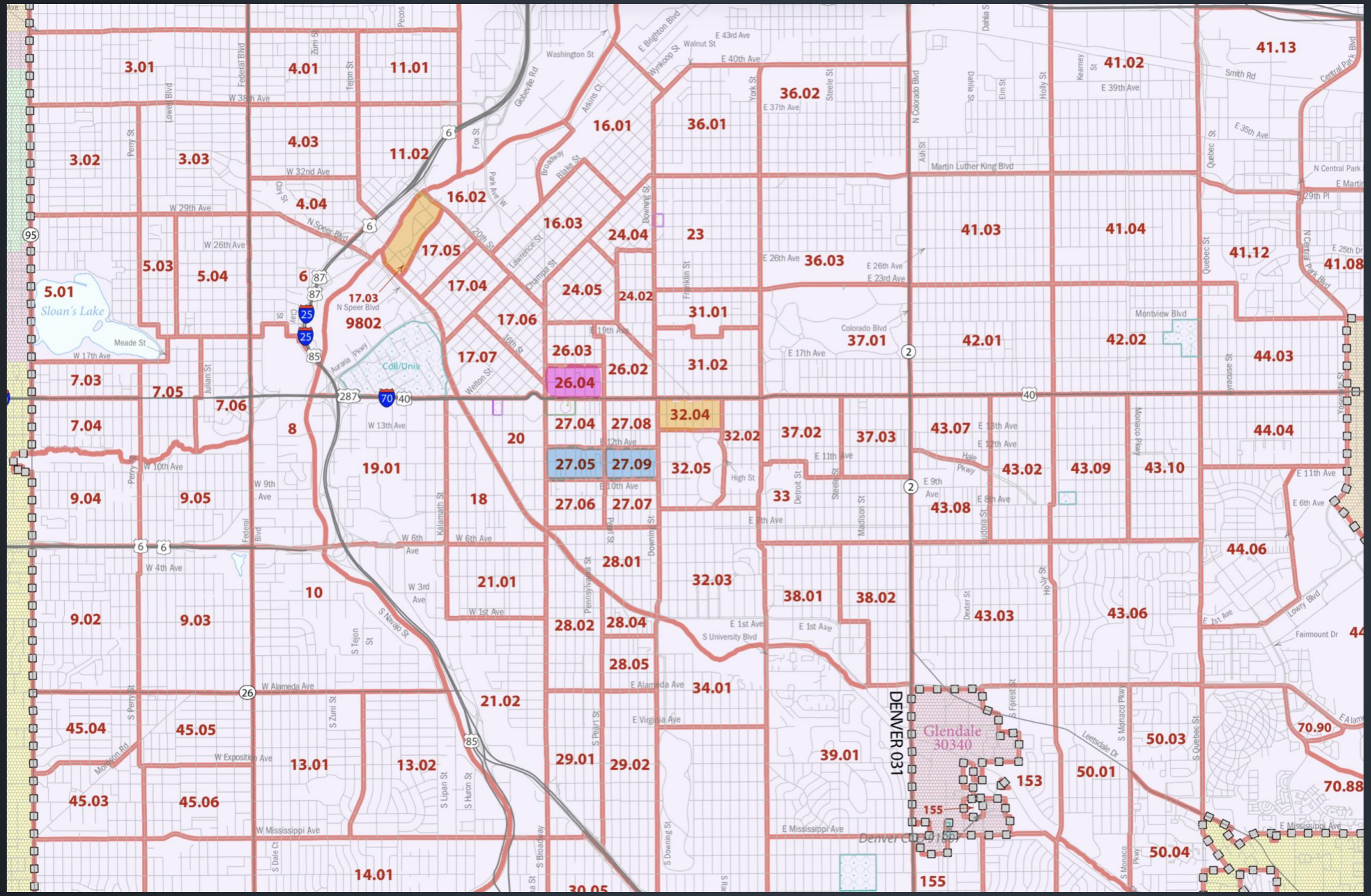
Cost-Burdened



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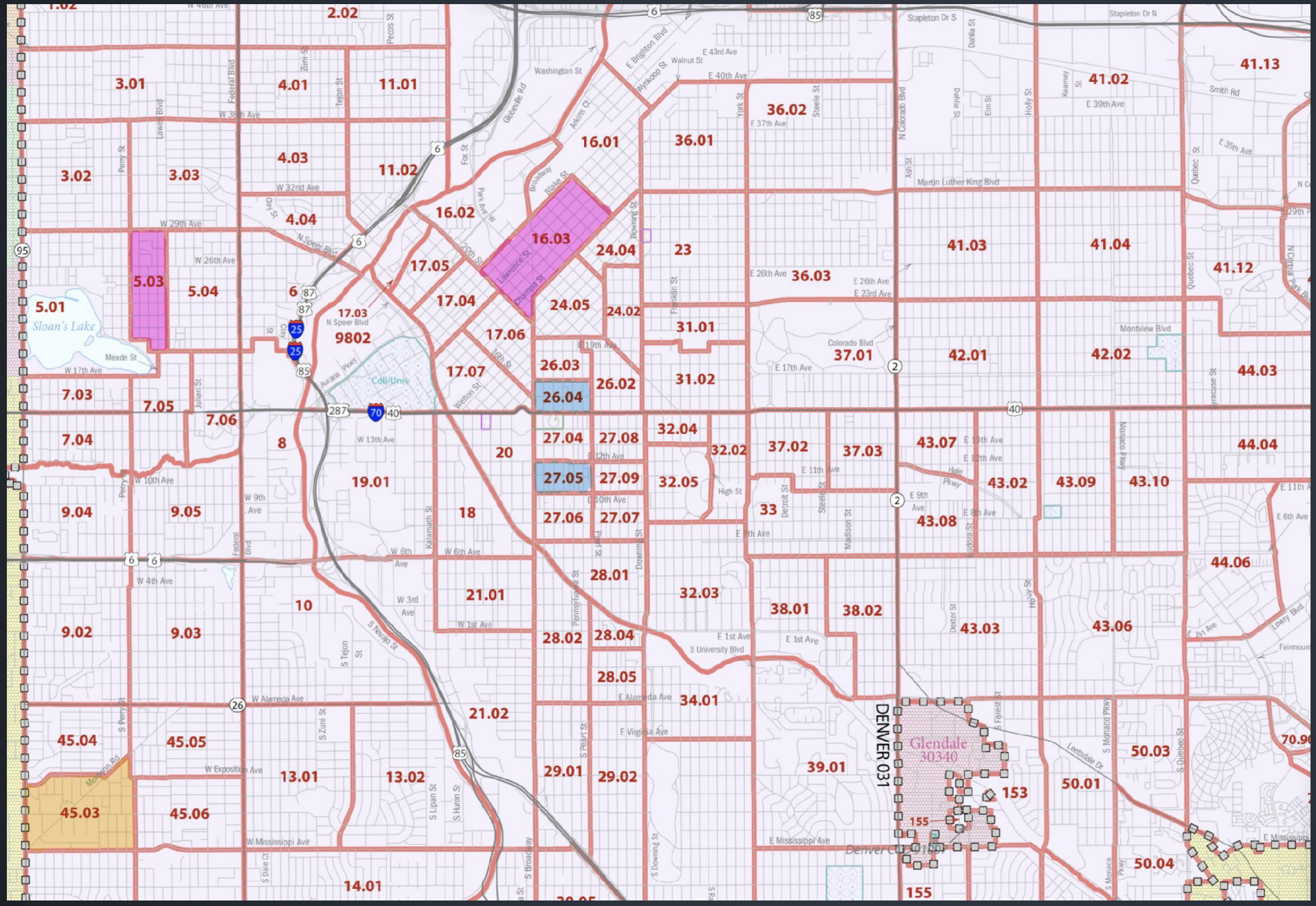
Poverty



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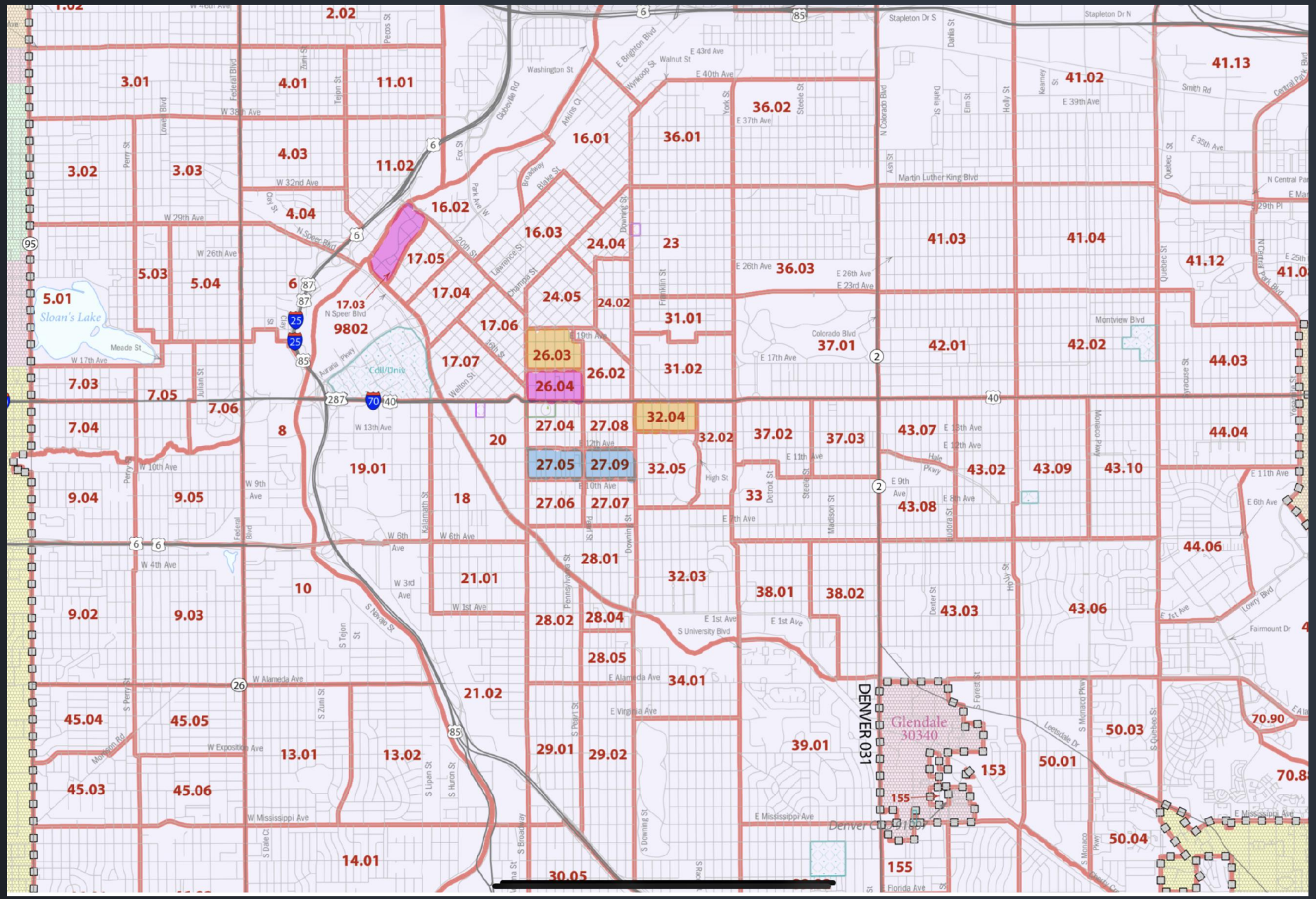
Renters



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Policy From Initial Data

Struggles with Current Policy

- Dedicated charging-capable spaces are difficult to get permits for compared to non-electric ones
- No funding for expansion outside of low-income communities

Policy Suggestion from initial tests

- Every tested iteration of the model adds vehicles to census tract 27.05
- We recommend the city help find locations for several cars in or near this tract
- Work with Xcel Energy to use funding allocated for charging capable carshare spaces in this region to pay for added spots

Additional Policy Suggestions

Struggles with Current Policy

- Dedicated charging-capable spaces are difficult to get permits for compared to non-electric ones
- No funding for expansion outside of low-income communities

Possible Policy Changes

- Add new charging capable spaces when road or sidewalk work is already being done
- Incentivize dedicated spaces near or in new housing builds
- Work with city zoning to add more spots for carshare programs where they will help most such as low-to-middle income communities
- Work with Xcel and companies who have charging stations aroud Denver to expand charging infrastructure in Denver while adding spaces

Next steps and Open Questions

Possible Model improvements

- Factor in region size and/or neighboring regions
- Test weighting the spread constraint
- Test multiple weights at once

Open Questions

- What are the most important factors to consider when funding carshare expansions?
- Would it be better to group or cluster similar tracts to highlight areas of the city to focus on?
- Is it best to use a combination of weights to determine locations?

Sources and Credits

- Data sources: census.gov, Denver Open Data Catalog, Colorado Car Share, driveelectriccolorado.org, and Google Maps.
- Slide templates and graphics from www.presentationgo.com allowed for educational and commercial use.
- Model written in Overleaf Latex Editor.