title page

TABLE OF CONTENTS

INTRODUCTION #

- STUDY AREA DESCRIPTION
- PROPOSAL DESCRIPTION

EXISTING + PROPOSED ZONE CONDITIONS #

EXISTING NETWORK CONDITIONS #

ACCESSIBILITY #

VEHICLE ACCESS MODEL #

TRIP GENERATION MODEL #

GRAVITY MODEL #

MODE CHOICE MODEL #

ESTIMATING TRANSIT RIDERSHIP #

INTRODUCTION: STUDY AREA DESCRIPTION

Our team has an interest in exploring the relationship between density and travel behavior. With a total population of c people, we selected the Denver-Lakewood-Aurora MSA both out of interest in exploring a western urban area but also because the MSA has a relatively low density: about 347 people per square mile (for context, the Boston-Cambridge-Newton MSA has a density of about 1,386 people per square mile). Unless otherwise noted, all data presented here has been pulled from Social Explorer, which uses the 2019 ACS 5-year Survey.

The principal cities of our MSA have higher densities, however. Denver has a density of 4,603 people per square mile, Lakewood has a density of 3,604 people per square mile, and Aurora has a density of 2,392. The low density of the MSA is likely due to the fact that much of its 8,345 square-mile area consists of rural land. Four of the ten counties in the MSA (Clear Creek, Gilpin, Park, and Elbert) are rural, located in the Rocky Mountains or on the southeastern edge of the MSA reaching into the plains. Combined, these four counties have an area of 4,590 square miles, more than half of the MSA. If we exclude these four counties, the new total population would be 2,832,969 and the new density would be about 754 people per square mile, more than double the original density. We will consider the entire MSA moving forward, but may nuance our proposal by focusing on the more urban counties of the MSA. The map below, from ESRI Business Analyst, shows the density distribution of the MSA by census tracts. The tracts near the center of Denver and Aurora are more dense than the tracts on the peripheries.

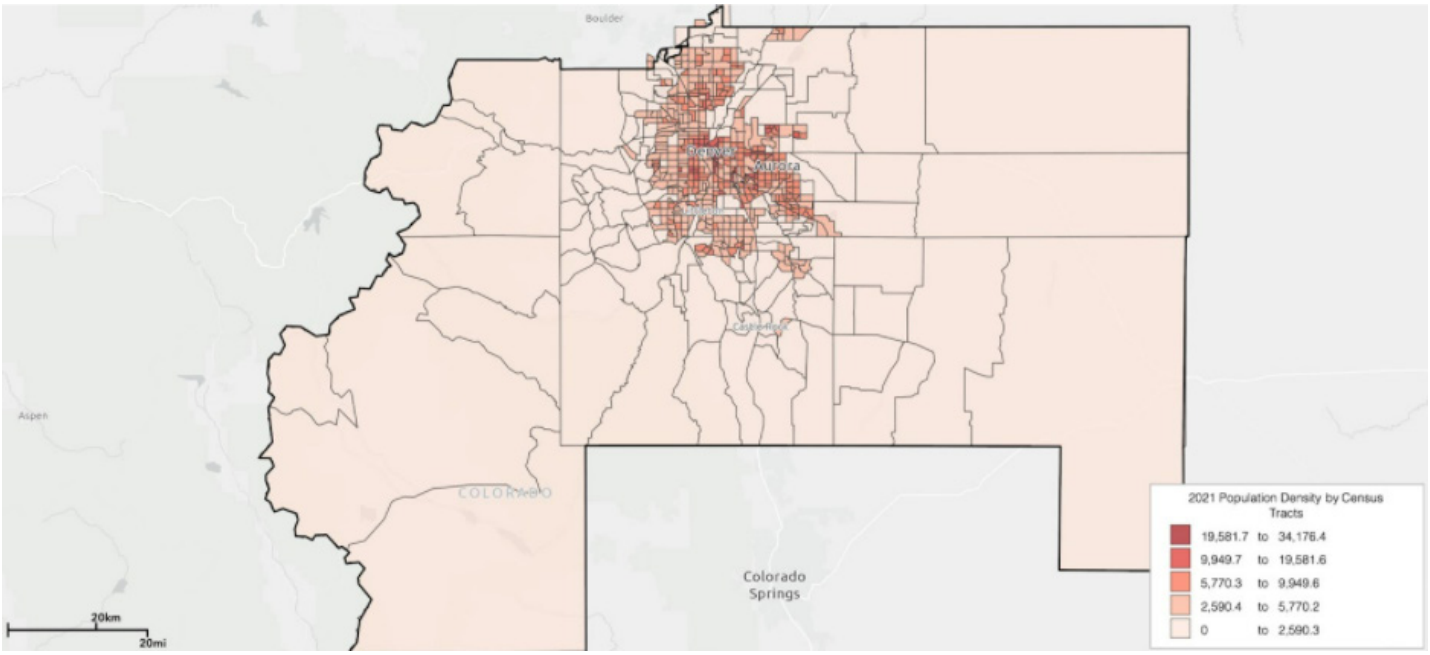

Figure 1: Population Density by Census Tract

The map below is zoomed in on the three principal cities and the density distribution by census tracts both in the cities and their surroundings.

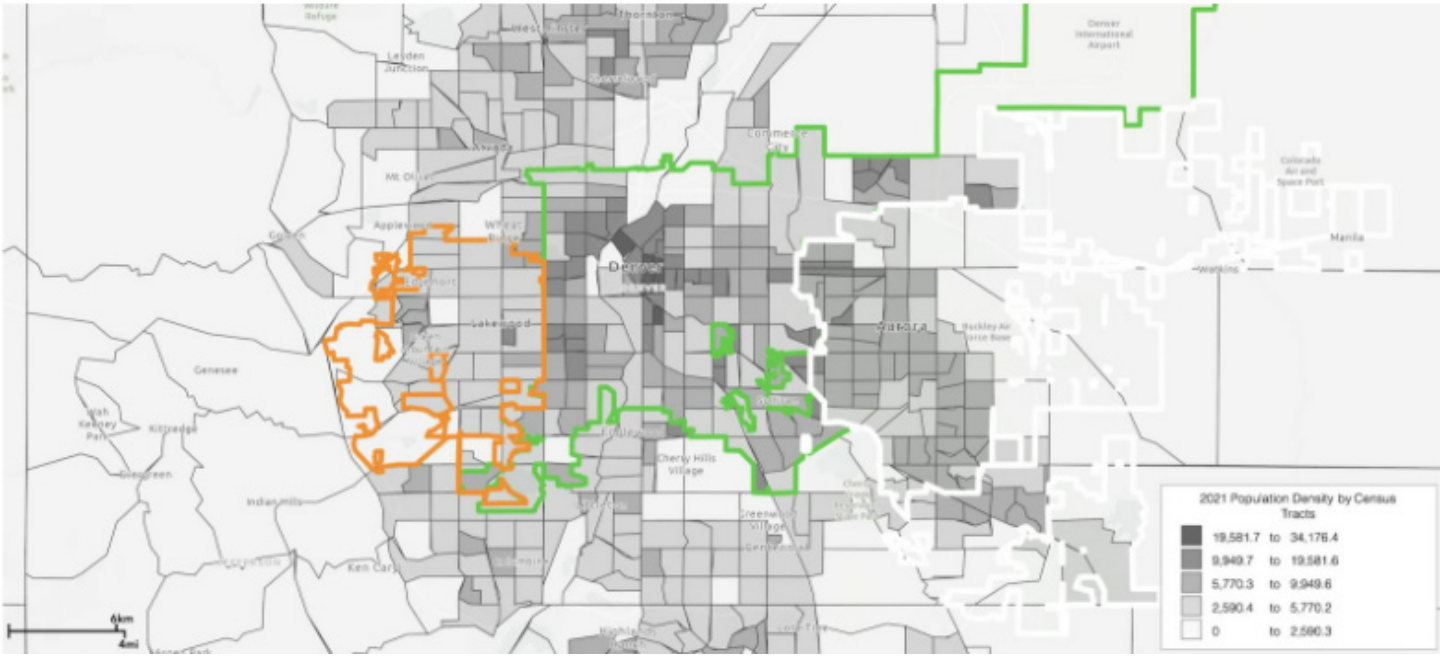

Figure 2: Population Density by Census Tract with Principal Cities Outlines

The MSA population has a median age of 36.5 years, with about 23% of the population under 18 years old and 13% above the age of 65. About 64% of the MSA identifies as white, 23% identify as Hispanic (including one or more or races), 5.5% identify as non-Hispanic Black, and 4.2% identify as non-Hispanic Asian.

With regards to employment and income, only 3.72% of the population is unemployed. The per capita income is $41,988 and the median household income is $79,664. About 30% of the population has a household income less than $50,000.

Among the working population that is 16 years old or older, the average commute to work lasts 28 minutes and driving remains the most common form of transportation to work with 75.26% of the population reporting driving alone to work. Another 8.42% work from home, 8.12% carpool, and only 4.27% use public transit. Only 2.19% of the population walks to work and less than 1% reported biking to work.

Since we will be looking at increasing density, it's important to note that the average household size is 2.57 people. It may be assumed that adding housing units to a tract will increase the population by that many residents per household. The MSA has 1,112,126 households and about 61% of those are married couples. Of the 1,173,990 housing units in the MSA, about 95% of them are occupied, and 64% of those are owner occupied. The median house value is at $380,900 and the median gross rent is $1,380. According to the Zillow Home Value Index, the typical home value in Denver as of December 2021 was $593,289 (an increase of nearly 19% over the last year), while in Aurora and Lakewood the typical home was valued at $479,349 and $590,585 respectively.

The majority of residential land in each principal city is zoned for single family or single unit development. Each city has a spectrum of residential development ranging from single-family to multi-family, with specific allowed development of two- or three-family units or ADUs in some

instances.
Three major interstate highways cut through the MSA: I-25 runs north-south through the center of the MSA, I-70 runs east-west, and I-76 comes from the northeast towards the center of the MSA merging into I-70. Two toll roads, C-470 and E-470, form a ring road around the peripheries of Denver, Lakewood, and Aurora, allowing drivers to circumvent the city center. E-470 connects drivers directly to Denver International Airport (DIA). The Regional Transportation District (RTD) is the public transit agency that provides light rail and bus service to the region. Investment in redeveloping the Union Station area of downtown Denver over the last several years has improved access to the light rail in that area, although many areas are still not served by light rail. Additionally, a new line providing direct service to DIA has met ridership demand for direct transit to the airport from downtown.

PROPOSED CONDITIONS DESCRIPTION

We are interested in adding housing density to tracts across the MSA. We will add this density by increasing maximum Floor-to-Area-Ratios in multi-family residential zoned districts. Given the variety of population and unit density across the area, we are proposing a scaled increase in FARs.

This scaled approach is outlined as such:

- FAR < 3 = 50% increase
- FAR 3-5 = 25% increase
- FAR 5-8 = 15% increase
- FAR 8-10 = 10% increase
- FAR > 10 = 5% increase

Our proposal will assume that new FARs will be maximally used, adding 2.57 persons to the tract per additional unit. We will assume new units will average 1,000 SF. We will assume each story is 10' unless otherwise noted by a city's code.

Arvada:
Arvada has 10 residential zone district types, our proposal will focus on three multifamily residential districts (R6, R13, and R24). These districts are named based on how many units are allowed per acre (6, 13, or 24) and all have a maximum height restriction of 35 feet (3 stories). Based on the housing type (townhome vs. multiplex) the maximum building coverage percentage ranges from 55%-100%. Based on these restrictions, these zones can have a FAR ranging from 1.65 to 3. A 50% increase would result in a new FAR range of 2.475 to 4.5.

Aurora:
Aurora has 6 residential zone district types, our proposal will focus on two multifamily residential districts (R-3 and R-4). R-3 has a maximum height restriction of 45 feet (4 stories), R-4 is 65 feet (6 stories). There are no coverage or open space requirements in Aurora. R-3 has a current FAR of 4 and R-4 has a current FAR of 6. R-3 will increase by 25% to 5 and R-4 will increase by 15% to 6.9.

Centennial:
Centennial has 3 residential zone district types, our proposal will focus on the Urban Residential District (RU). RU has a maximum height restriction of 30 feet (3 stories). Centennial requires a minimum of 15% open space. RU has a current FAR of 2.55. RU will increase by 50% to 3.825.

Denver:
Denver has a fairly complex zoning code. There are three zone districts that include multi-family zoning: Suburban Neighborhood Context, Urban Edge Neighborhood Context, and General Urban Neighborhood Context. Within the Suburban Neighborhood Context, there are 5 multi-unit zones (S-MU-3, S-MU-5, S-MU-8, S-MU-12, S-MU-20). Within the Urban Edge Neighborhood Context, there is 1 multi-unit zone (E-MU-2.5) Within the General Urban Neighborhood Context, there are 5 multi-unit zones (G-MU-3, G-MU-5, G-MU-8, G-MU-12, G-MU-20). The number at the end of each zone indicates the number of permitted stories.

Suburban Neighborhood Context has a maximum of 50% building coverage. This makes current maximum FARs for each zone and updates per our proposal as follows:
S-MU-3: current FAR 1.5 -> increase of 50% to 2.25
S-MU-5: current FAR 2.5 -> increase of 50% to 3.75
S-MU-8: current FAR 4 -> increase of 25% to 5
S-MU-12: current FAR 6 -> increase of 15% to 6.9
S-MU-20: current FAR 10 -> increase of 5% to 10.5

Urban Edge Neighborhood Context has a maximum of 37.5% building coverage. This makes current maximum FAR for the zone and update per our proposal as follows:
E-MU-2.5: current FAR 0.94 -> increase of 50% to 1.41

General Urban Neighborhood Context has a maximum of 50% building coverage. This makes current maximum FARs for each zone and updates per our proposal as follows:
G-MU-3: current FAR 1.5 -> increase of 50% to 2.25
G-MU-5: current FAR 2.5 -> increase of 50% to 3.75
G-MU-8: current FAR 4 -> increase of 25% to 5
G-MU-12: current FAR 6 -> increase of 15% to 6.9
G-MU-20: current FAR 10 -> increase of 5% to 10.5

Thornton:
Thornton has 5 residential zone district types, our proposal will focus on the Multifamily District (MF). MF has a maximum height restriction of 60 feet (6 stories). Thornton has a maximum site coverage of 60%. MF has a current FAR of 3.6. MF will increase by 25% to 4.5.

Westminster:
Westminster has 7 residential zone district types, our proposal will focus on two multifamily districts (R3 and R4). Both R3 and R4 have a maximum height restriction of 35 feet (3 stories) and a maximum site coverage of 30%. R3 and R4 have current FARs of 0.9. Both will increase by 50% to 1.4.

EXISTING + PROPOSED ZONE CONDITIONS

The Denver-Lakewood-Aurora MSA is home to 2,892,066 residents. Our analysis reveals that the majority of this population surrounds the Downtown Denver Area, as highlighted by the small size of census tracts (which are usually home to 1,000-8,000 residents). The increased square footage of census tracts outside the central area indicates the lessened population density outside the central downtown.

Figure 3: Existing Population per Tract

Our proposal adds households and therefore population to multi-family zones across several jurisdictions. As seen below, this proposal affects some municipalities and tracts within them more than others. Rather than the existing peak population near 12,500, some of these proposed tracts have close to 40,000 residents.

Figure 4: Proposed Population per Tract

The MSA has just over 1,000,000 households. The existing distribution of households aligns with population, where there are high numbers of households in the small tracts near downtown and then a maintenance or decrease of household number for much larger tracts. Here we do see a bigger differentiation between western and eastern suburbs, where western tracts seem to have more households, even if there populations were fairly similar to their eastern counterparts.

Figure 5: Existing Households per Tract

Our proposal adds a significant number of households, evident through the jump in the legend. Tracts were household dense around 7,000 units in the existing conditions, while now some see upwards of 15,000 units. Similar to the proposed population, these increases are especially apparent in a few tracts.

Figure 6: Proposed Households per Tract

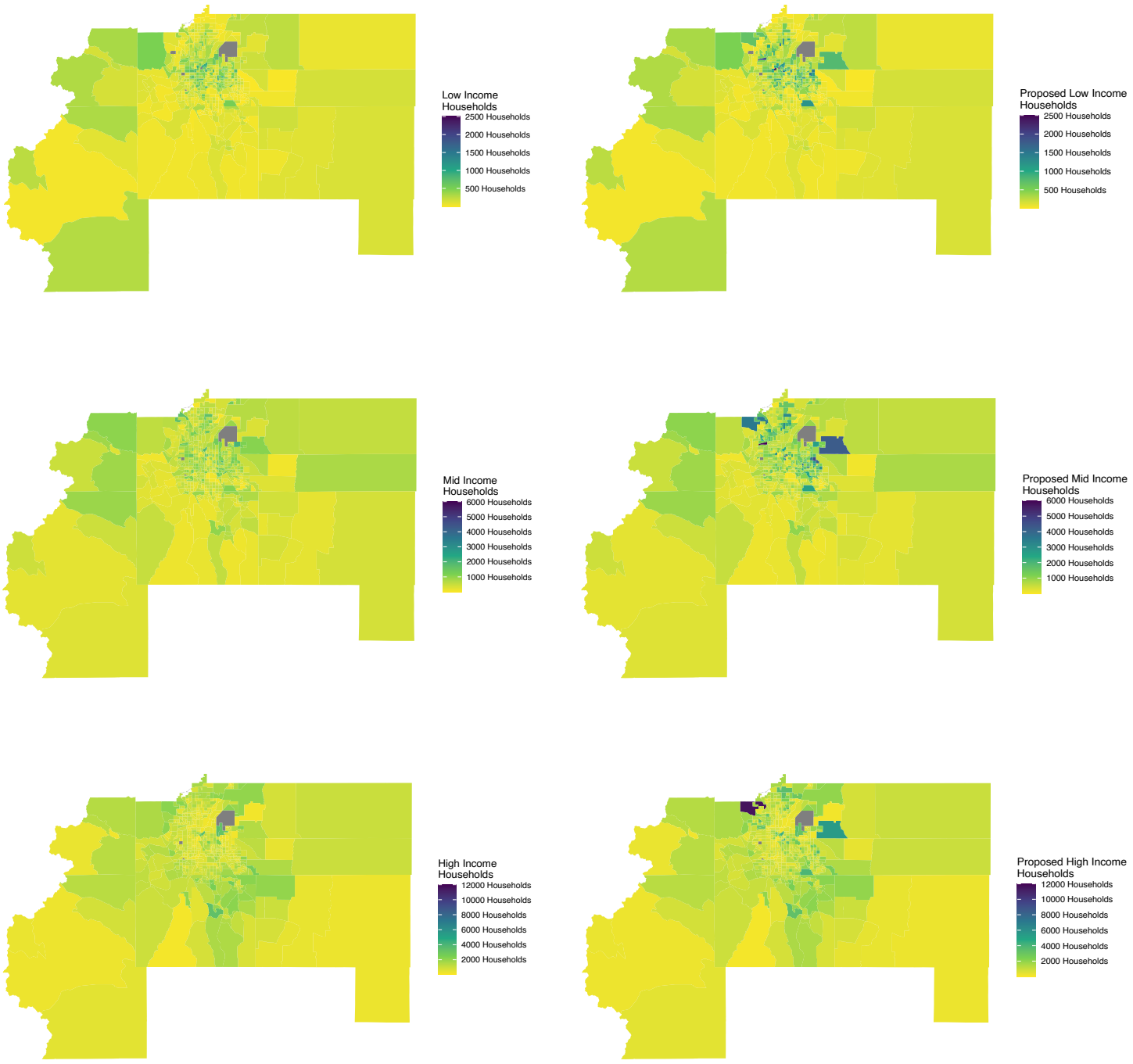

Figure 7: Existing (left) versus Proposed (right) Low, Mid, and High Income Households

The six maps above show low, mid, and high income households across the MSA tracts in existing conditions, the left column, and after our proposal, on the right. The ratios of low to mid to high income households stay the same per our assumptions, so the change in maps reveals the tracts which overlay multi-family zoning, and therefore received household increases.

Unsurprisingly, the majority of households that do not have a vehicle available are near downtown, where street networks are more walkable or bikable, or where there are transportation options available. Even so, zero car households are fairly rare, even in tracts with close to 1000 car-free households, they only make up about 10%.

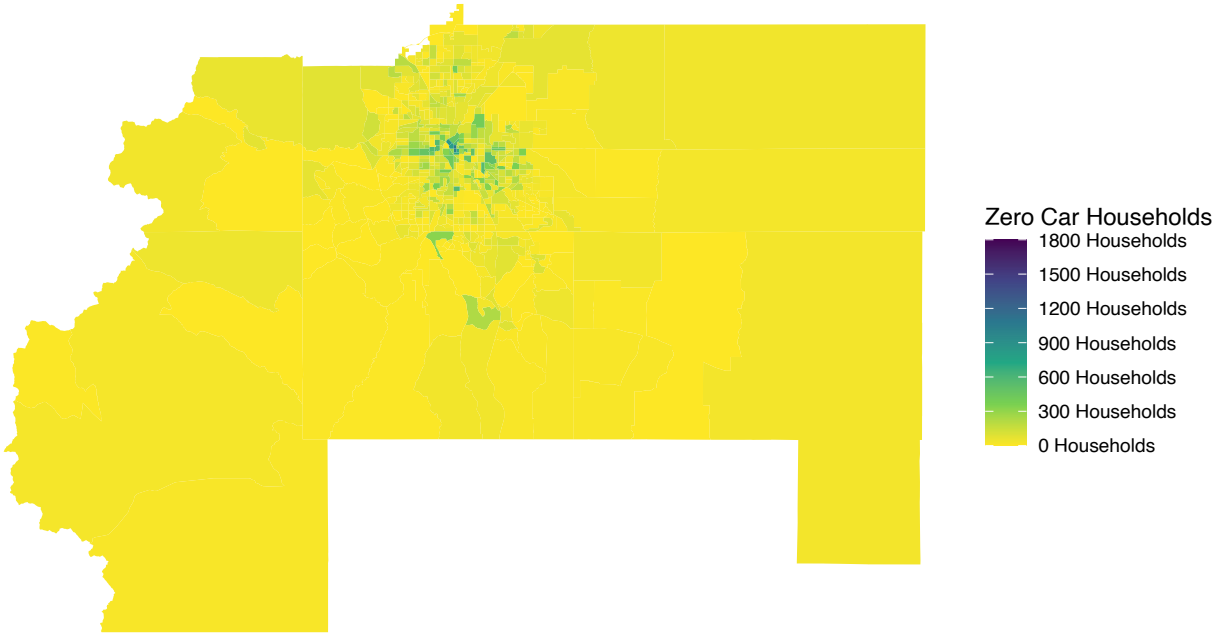

Figure 8: Existing Households with No Vehicles Available

Our proposal maintains the percentage of zero-car to car-available households. Because more central jurisdictions tend to have more multi-family zones, we see the increase in zero-car households in the core of the MSA.

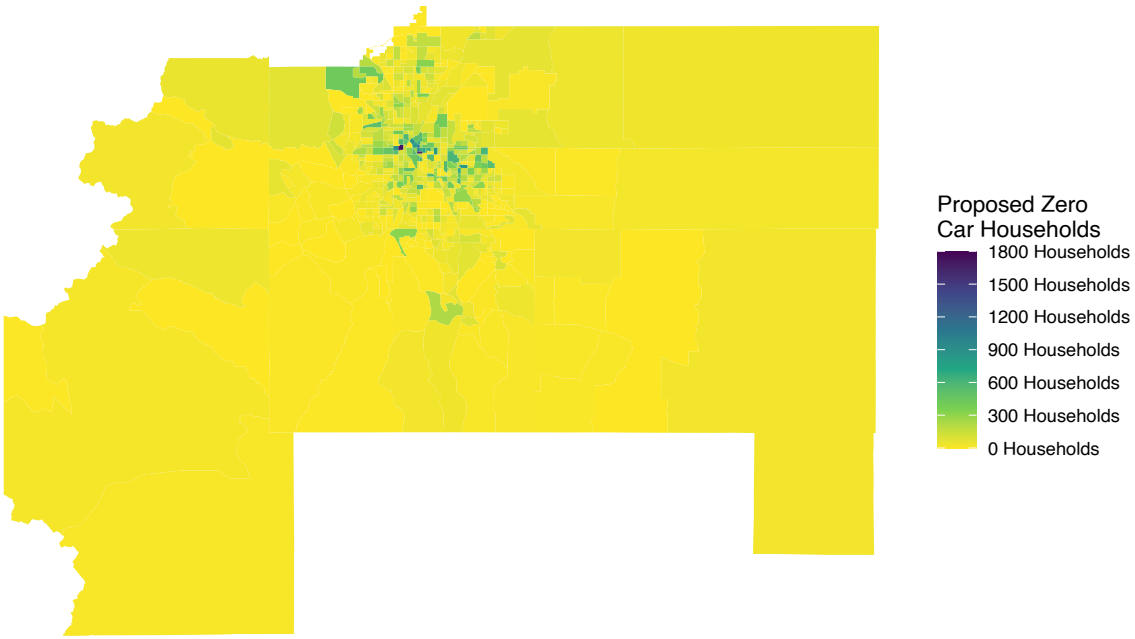

Figure 9: Proposed Households with No Vehicles Available

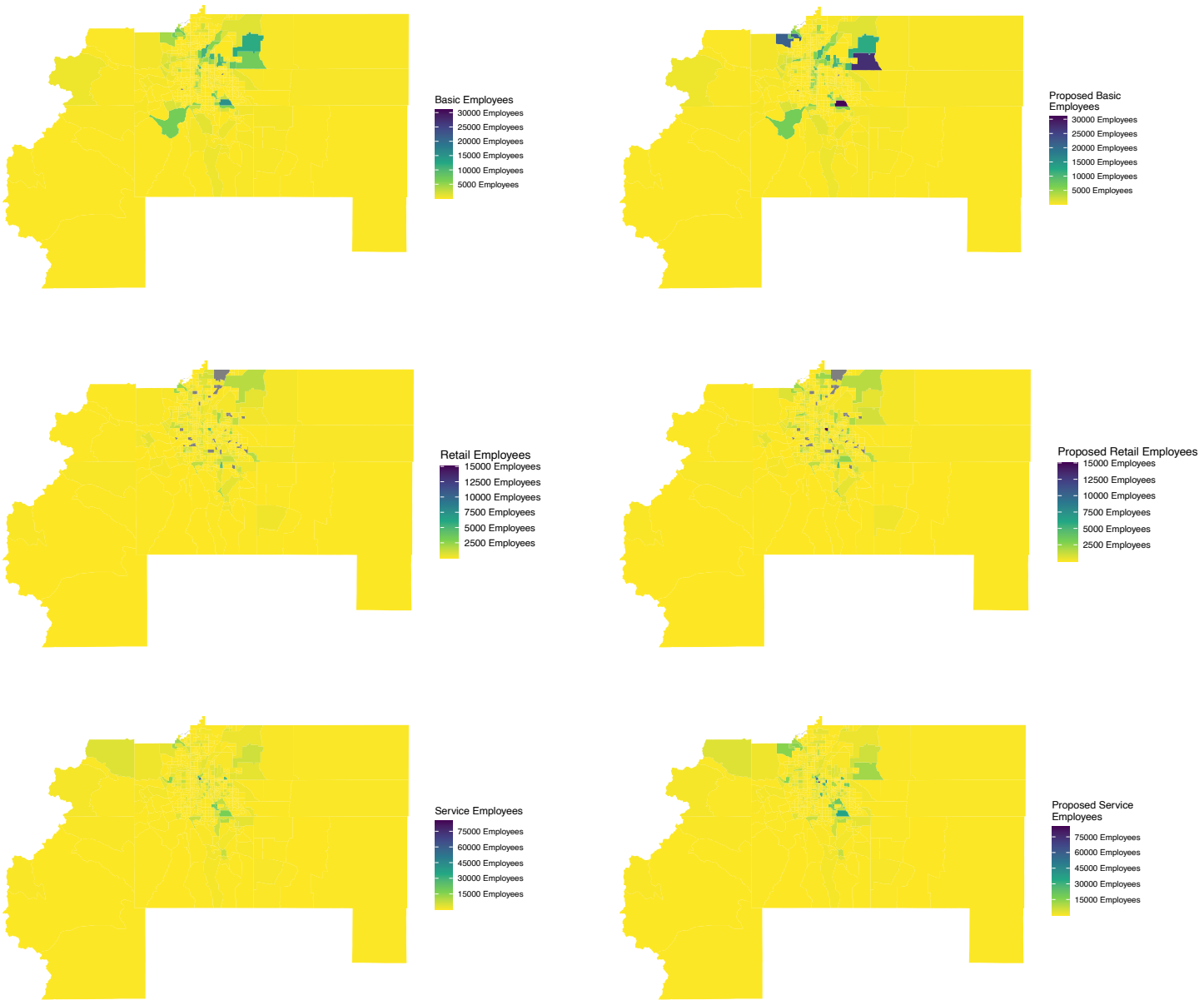

Figure 10:Existing (left) versus Proposed (right) Basic, Retail, and Service Employees.

The six maps above show basic, retail, and service employees across the MSA tracts in existing conditions, the left column, and after our proposal, on the right. The ratios of basic to retail to service employees stay the same per our assumptions, so the change in maps reveals the tracts which overlay multi-family zoning, and therefore received household increases.

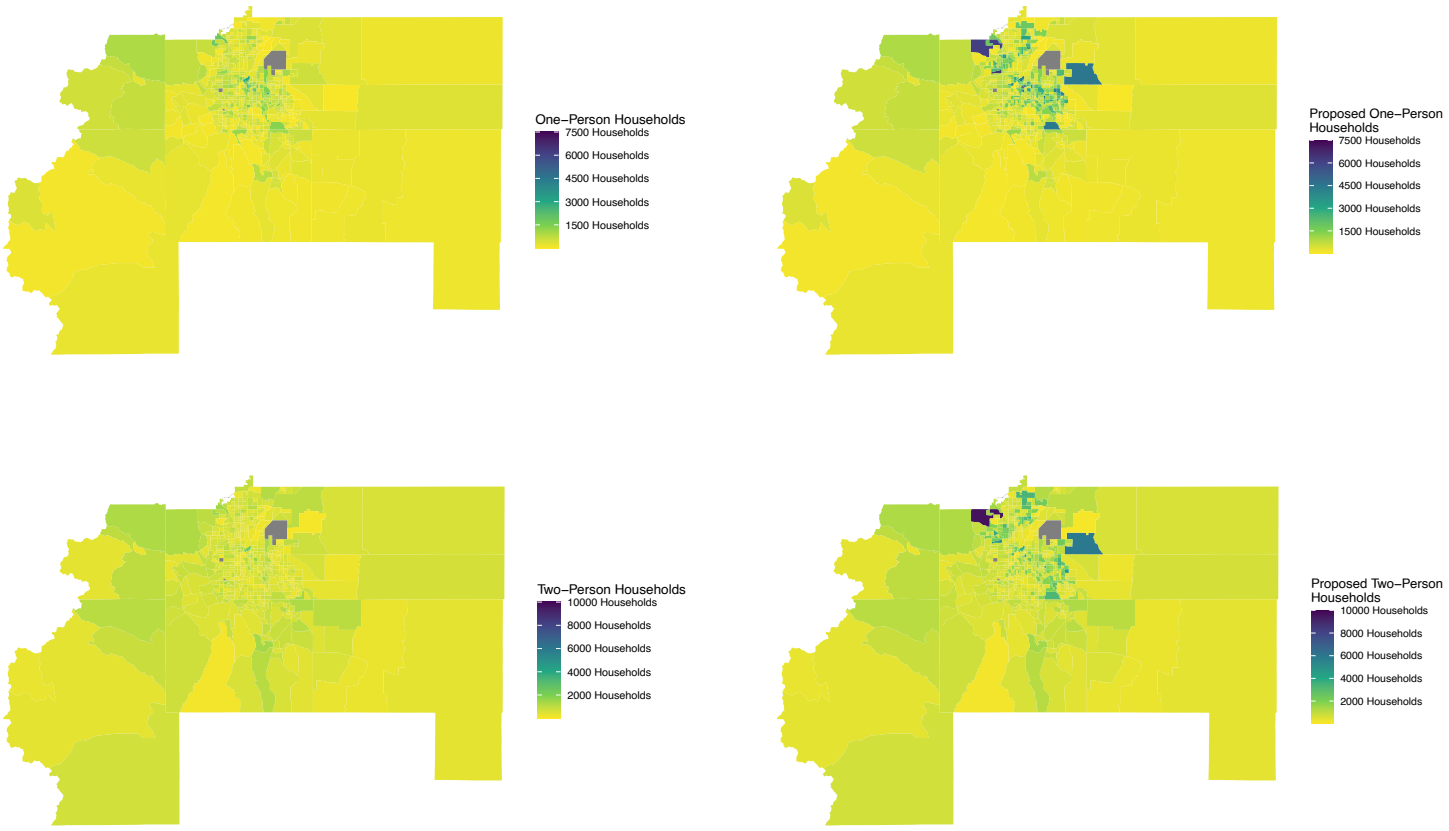

Figure 11: Existing (left) versus Proposed (right) One and Two Person Households

The four maps above show one and two person households across the MSA tracts in existing conditions, the left column, and after our proposal, on the right. The ratios of one and two person households compared to total households stay the same per our assumptions, so the change in maps reveals the tracts which overlay multi-family zoning, and therefore received household increases. Given our proposal is adding solely multi-family units, we chose to designate these households as one or two person only, no larger.

Existing Conditions Summary of Variables:

Variable <chr>	Average <dbl>	Standard deviation <dbl>	Median <dbl>
basic_emp	623.03871	1638.8601	108.0
hh_income_high	946.97267	524.0082	842.0
hh_income_low	224.30064	184.9907	166.0
hh_income_mid	620.93730	347.1401	574.0
housing_units	1891.84887	802.4370	1812.0
nocar	99.72669	134.5266	50.0
oneperson_hh	506.17846	402.5089	407.0
population	4660.38585	1946.3886	4448.5
retail_emp	244.48871	431.7376	90.5
service_emp	1609.03065	3735.2709	583.0
twoperson_hh	615.06431	272.7655	584.5

11 rows

Variable <chr>	Average <dbl>	Standard deviation <dbl>	Median <dbl>
new_basic	798.4101	2424.0003	127.2663
new_hh_income_high	1149.3486	836.6467	971.3750
new_hh_income_low	287.2174	288.1387	192.4000
new_hh_income_mid	810.7390	705.2310	610.5000
new_nocar	125.0116	185.1424	57.5000
new_oneperson_hh	820.7401	921.2454	481.5000
new_retail	329.4870	771.9666	115.0492
new_service	2265.3940	5943.0249	654.5000
new_total_housing_units	2315.5785	1520.4037	1997.7050
new_total_tract_population	6112.9770	4447.0253	4978.5000
new_twoperson_hh	948.2001	820.1789	700.0000

11 rows

In addition to spatial comparison, we wanted to pull out some summary statistics for our existing versus proposed conditions. Aside from a useful tool to compare averages before and after, we find it interesting how large the standard deviations are and how different the medians are from the averages. These are likely influenced by the great variation in tract size and zoning type across the MSA.

EXISTING NETWORK CONDITIONS

As shown by the clustering of census tracts below, high density tracts are concentrated in or near Denver's downtown. Knowing this, we chose to evaluate travel times from the tract with the most jobs in downtown, to illustrate the characteristics of the street and transit networks.

As shown by the following maps, within two hours, cars are the only mode that can reach the full extent of the MSA from downtown. Although transit is present, comparing these travel times to bicycles indicates that it may not be the most robust or efficient system given their isochrones are not that varied.

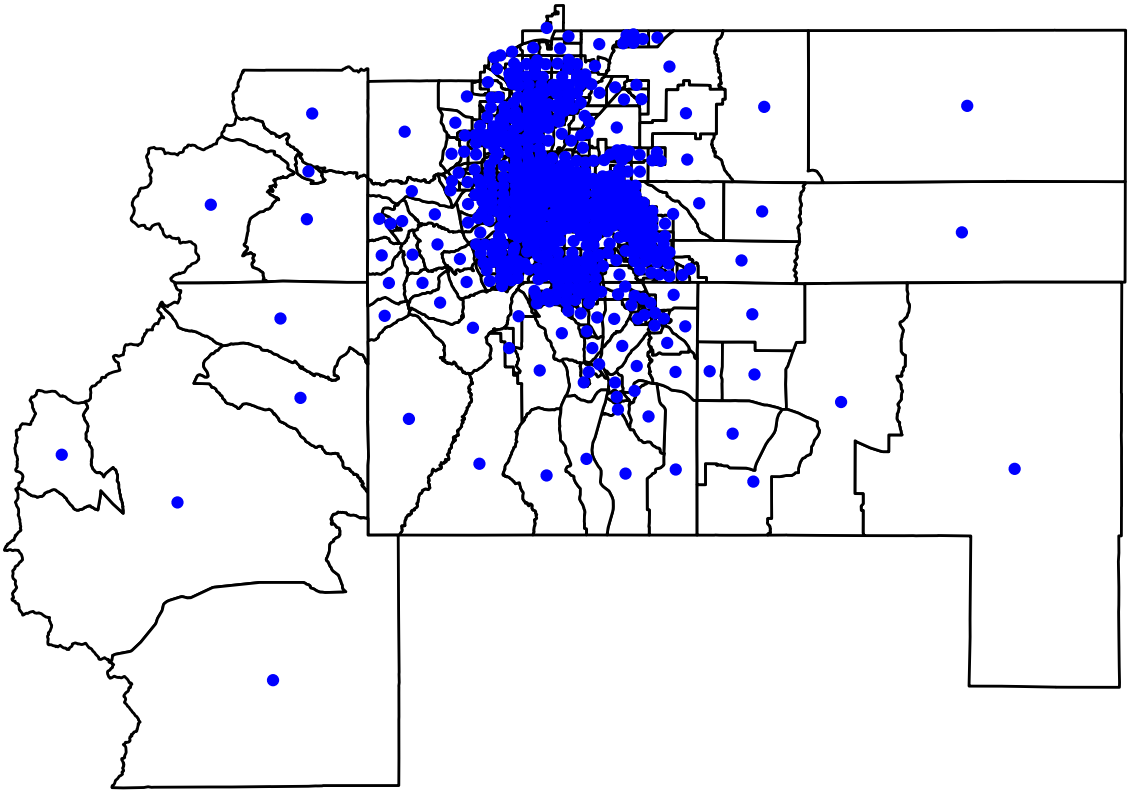

Figure 12: Denver-Aurora-Lakewood MSA Census Tracts with Centroids

Figure 13: Car Travel Times

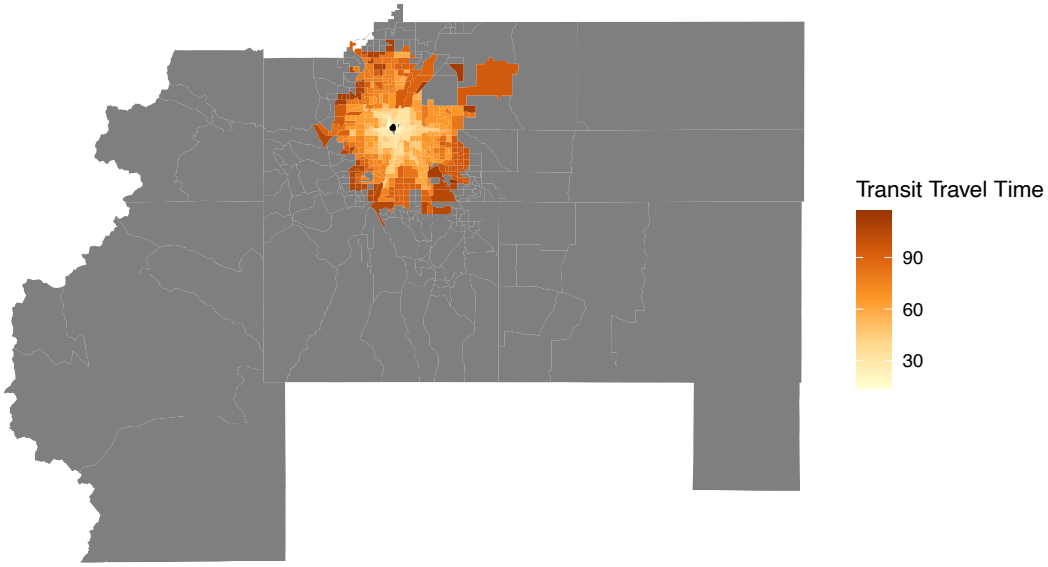

Figure 14: Transit Travel Time

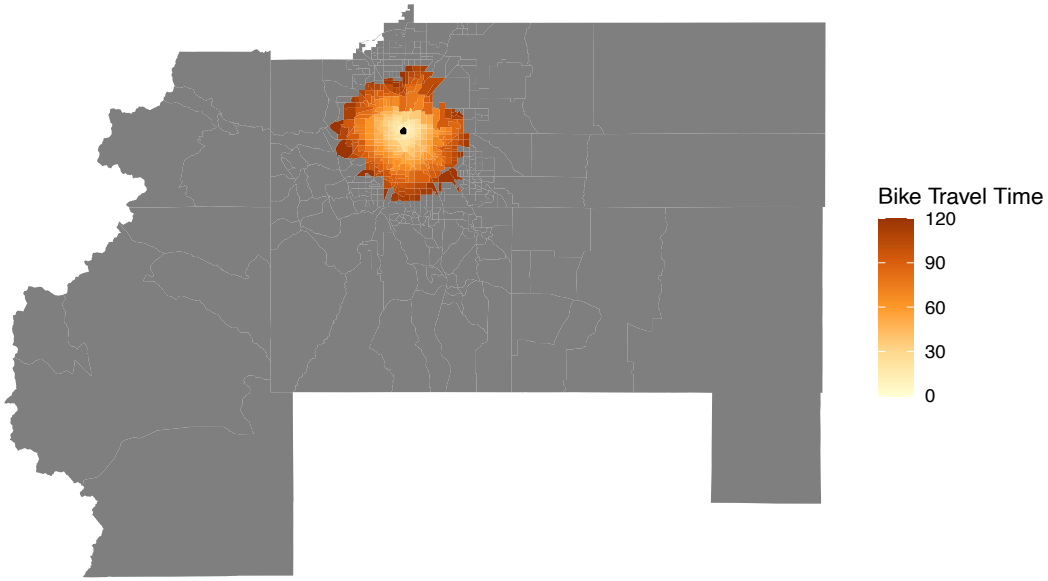

Figure 15: Bicycle Travel Time

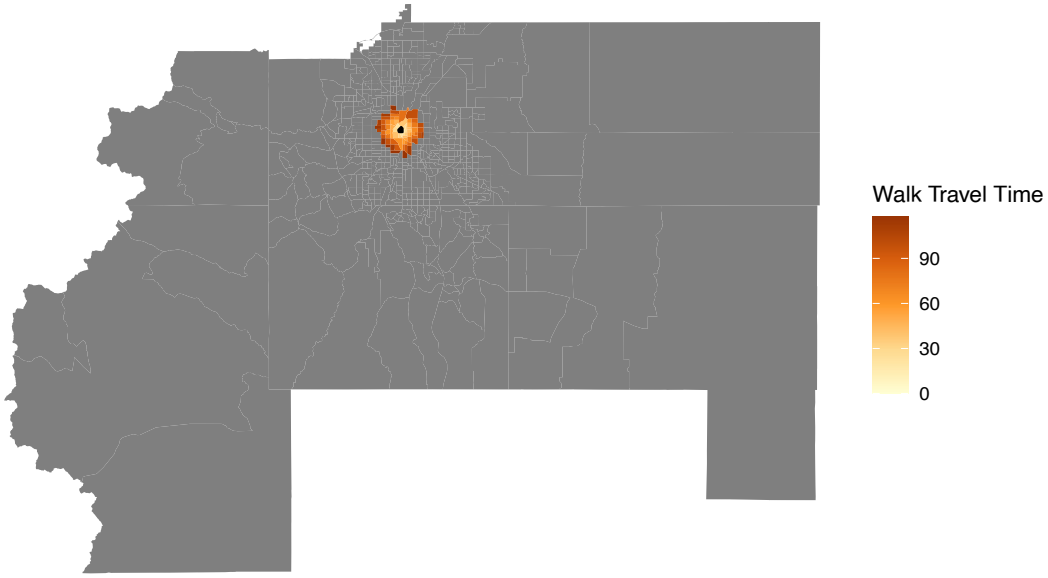

Figure 16: Pedestrian Travel Time

ACCESSIBILITY TO JOBS

While jobs are currently concentrated in Denver's central areas, we hope that our proposal will further increase this concentration, leading to an increased number of jobs with short travel times from most residents and possibly leading to higher transit usage.

As shown by our maps, the increases in both residents and jobs in these central areas will lead to an increase of jobs in the central, more transit rich areas of Denver, thus improving the transit to car job accessibilty ratio.

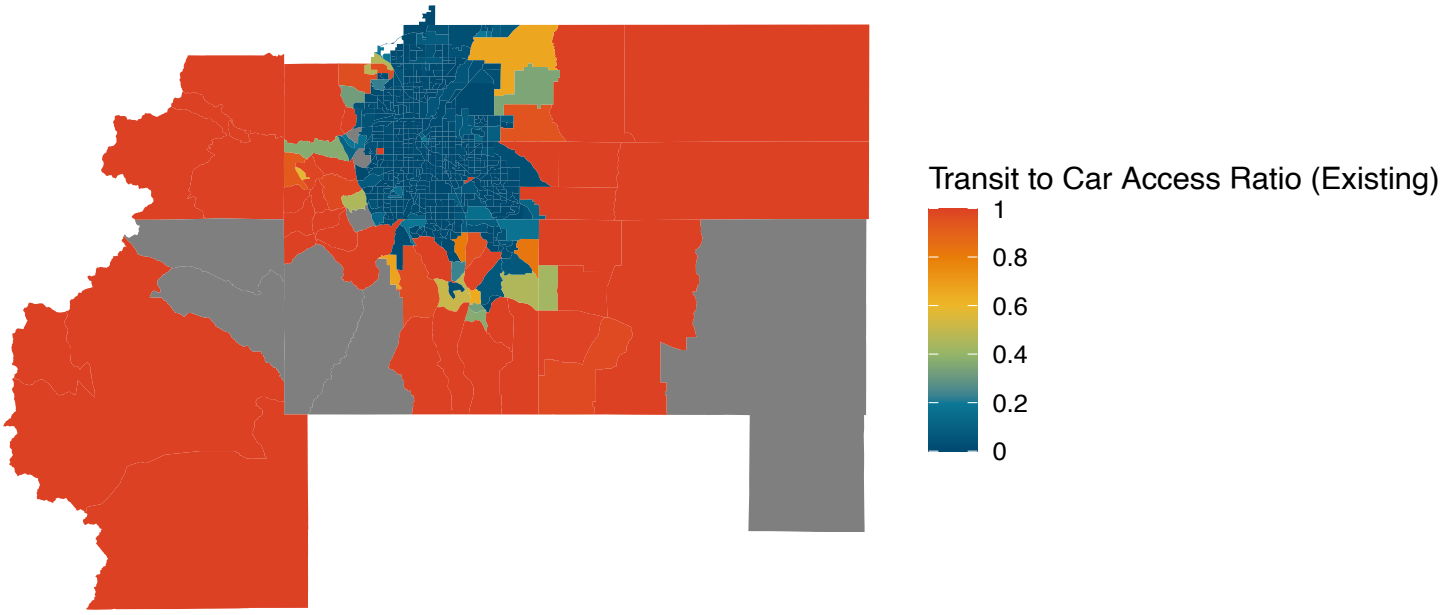

Figure 17: Denver-Aurora-Lakewood MSA Existing Transit to Car Job Accessibility Ratio

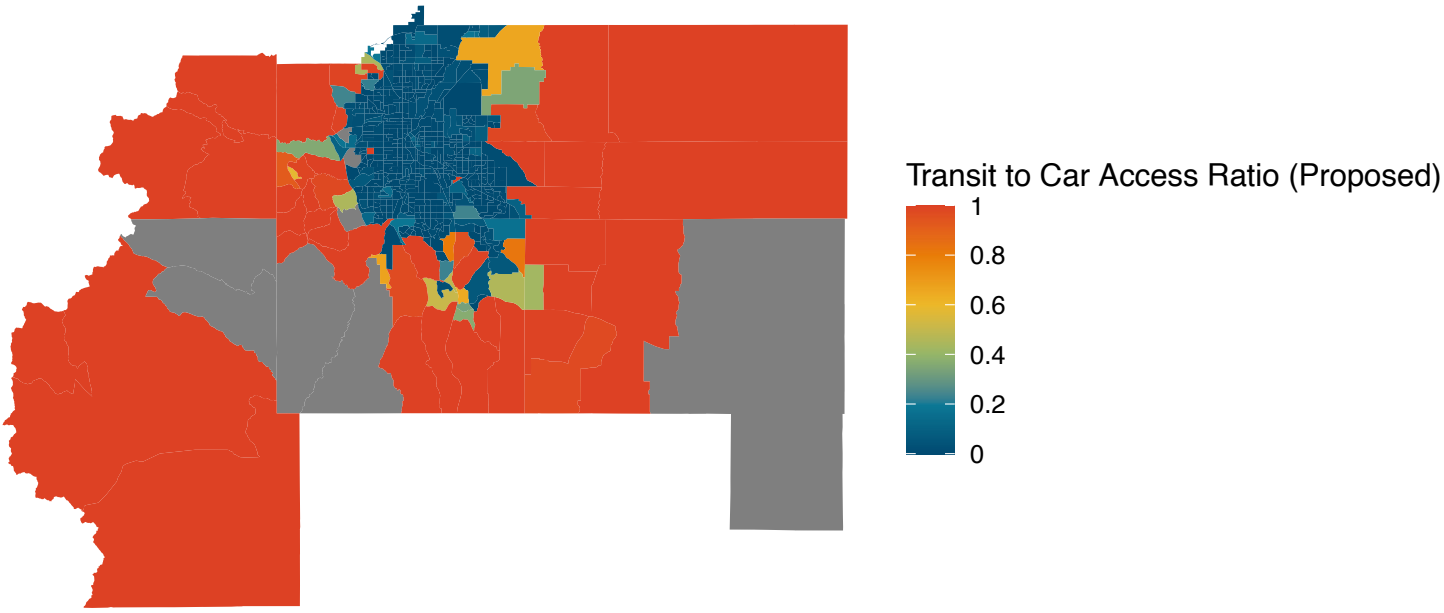

Figure 18: Denver-Aurora-Lakewood MSA Proposed Transit to Car Job Accessibility Ratio

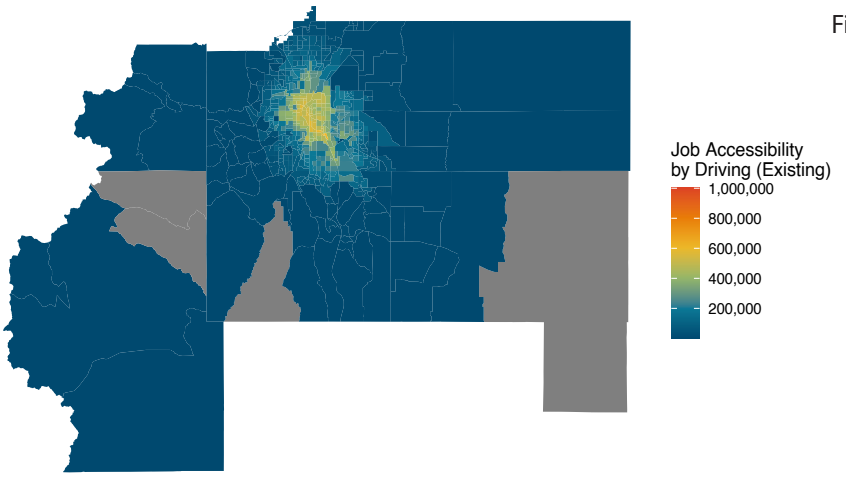

Figure 19: Existing Job Accessibility by Driving

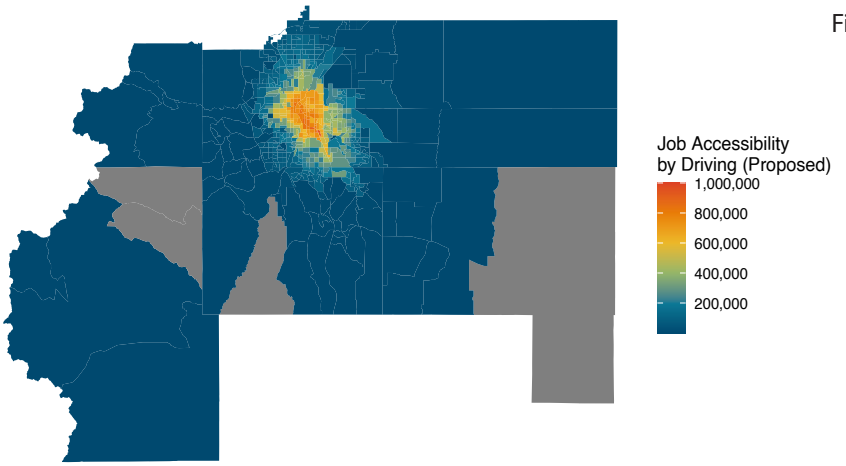

Figure 20: Proposed Job Accessibility by Driving

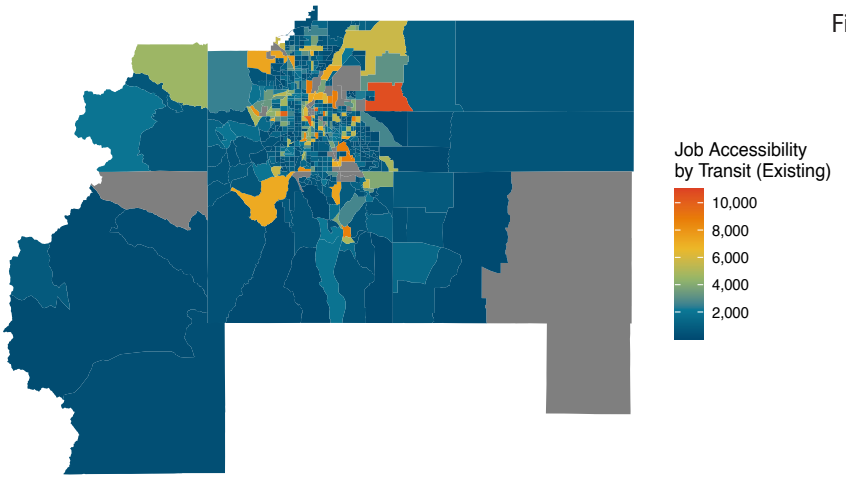

Figure 21: Existing Job Accessibility by Transit

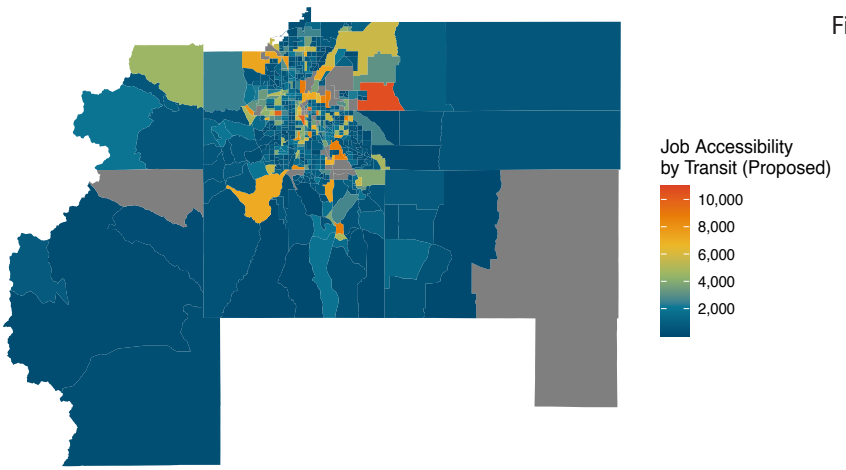

Figure 22: Proposed Job Accessibility by Transit

ESTIMATING VEHICLE OWNERSHIP UNDER PROPOSED CONDITIONS

The next step in creating our model is estimating the percentage of zero-vehicle households in each census tract under proposed conditions based on the data from our existing conditions. We initially considered four factors that might predict vehicle ownership: household size (1- to 2- persons per household), households that were low-income, households that were high-income, and the transit-car accessibility ratio. Our proposed conditions involve increasing FAR in multifamily residential zones, which tend to have smaller household sizes so we chose to only select small households. A household's level of income tends to predict whether they own a vehicle or not, and the transit-car accessibility ratio might predict vehicle ownership if more jobs are accessible by transit than by car.

We began by comparing each variable to car ownership in our existing conditions to understand the relationship between them.

Figure 23 suggests that as the share of small households increases in a tract, so does the share of zero-vehicle households.

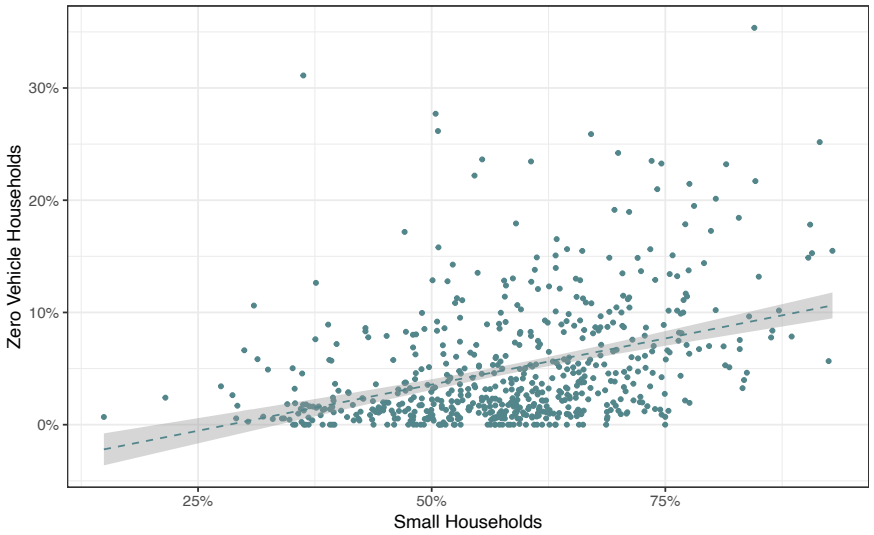

Figure 23: Share of Small Households and Zero-Vehicle Ownership

Figure 24 suggests that as the share of low-income households increases in a tract, so does the share of zero-vehicle households.

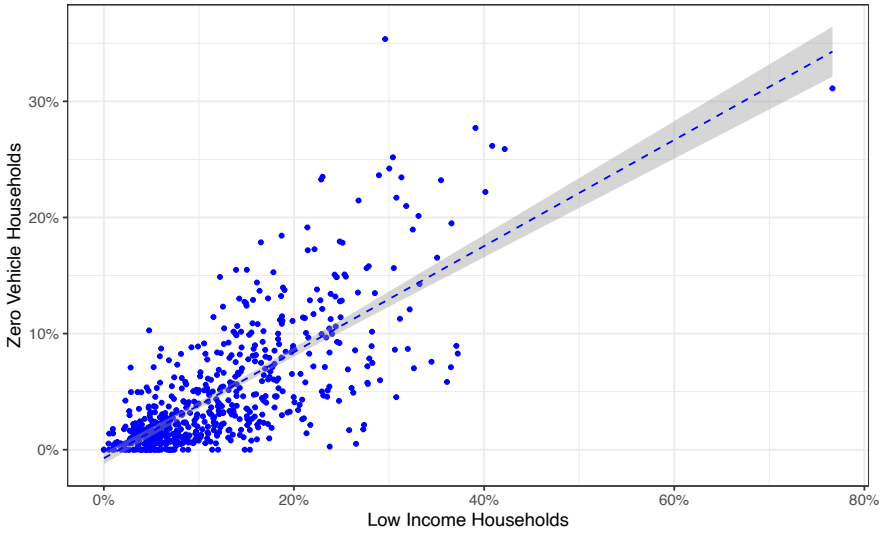

Figure 24: Share of Low-Income Households and Zero-Vehicle Ownership

Figure 25 suggests that as the share of high-income households increases in a tract, so the share of zero-vehicle households decreases.

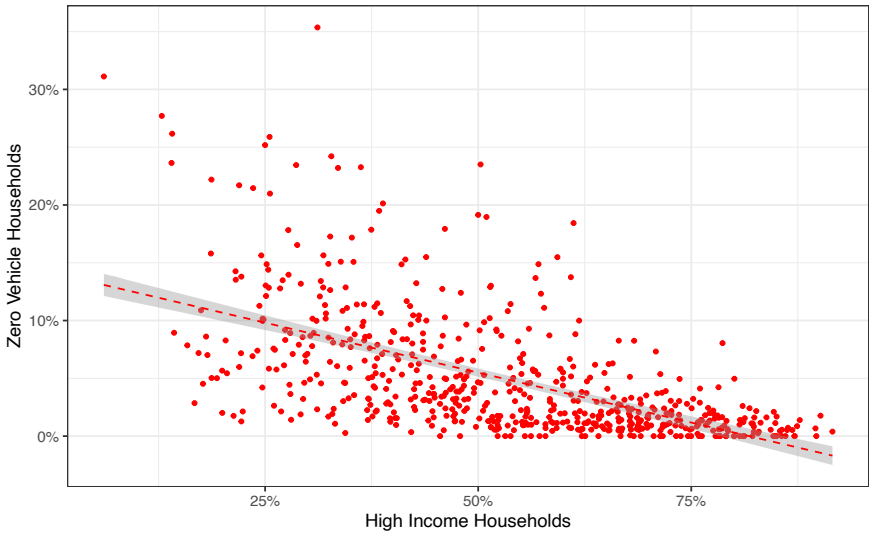

Figure 25: Share of High-Income Households and Zero-Vehicle Ownership

Figure 26 suggests that a lower transit-car accessibility ratio of a tract, meaning that fewer jobs are accessible by transit, is related with a smaller share of households with zero vehicles. In other words, when more jobs are accessible by car than by transit, then households tend to have more cars.

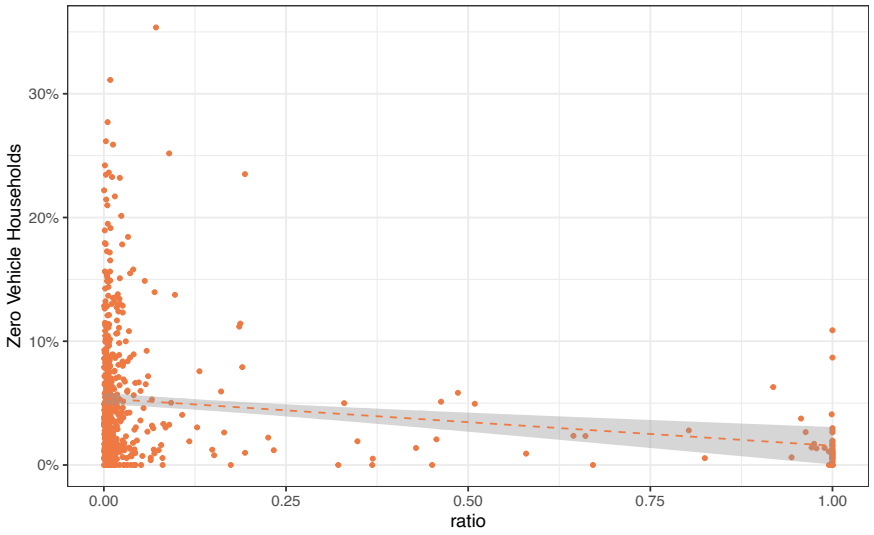

Figure 26: Transit-Car Accessibility Ratio and Zero-Vehicle Ownership

These four variables start to paint a picture of who might own a car: households that are larger, have higher incomes, and that can access more jobs by car than by transit are more likely to own a car.

The next step was to run a regression model to determine which variables were significanly related to car ownership.

We estimated a linear regression model (Model 1) using all four variables and found that only household size and low-incomes were significant ($p < 0.001$). The R^2 value was 0.59.

We estimated a second model keeping only these two variables and found that neither the p-values nor the R^2 values changed. Model 2 was more parsimonious and just as predictive as Model 1.

	Model 1	Model 2
(Intercept)	-0.07 ***	-0.06 ***
	(0.01)	(0.01)
pct_smol_hh	0.09 ***	0.09 ***
	(0.01)	(0.01)
pct_lo_inc	0.45 ***	0.42 ***
	(0.03)	(0.02)
pct_hi_inc	0.02	
	(0.01)	
ratio	-0.00	
	(0.00)	
N	610	610
R2	0.59	0.59

*** p < 0.001; ** p < 0.01; * p < 0.05.

Figure 27: Model 1 and Model 2

Last, we applied Model 2 to our proposed condition factors to predict zero-vehicle ownership under our proposed small household size and low-income conditions. Figure 28 shows a map of the tracts in the Denver MSA by the share of households that we predict have zero-vehicles.

The results are intuitive. Multi-family residential zones tend to be near the center of Denver and that is where we see a concentration of tracts with greater shares of zero-vehicle households.

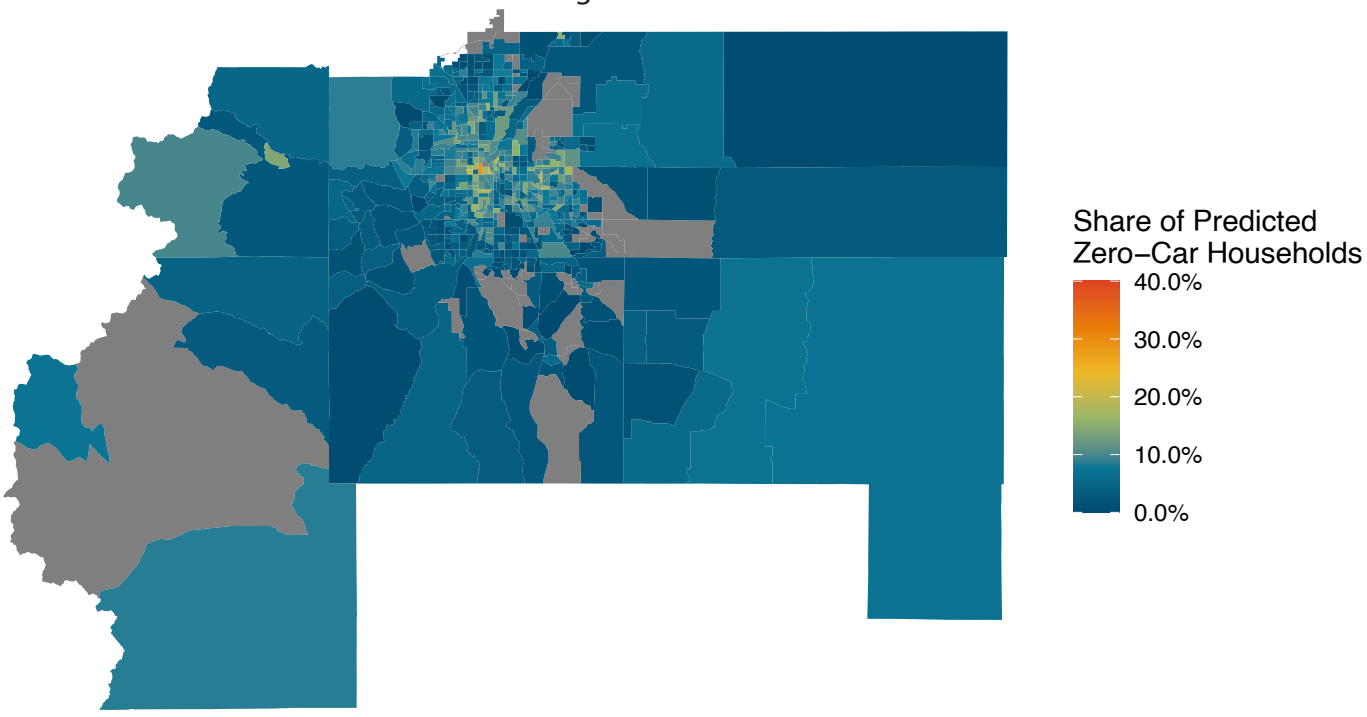

Figure 28: Predicted Share of Zero-Vehicle Households by Tract

ESTIMATING TRIP GENERATION

This week focused on estimating the household-level trip production model for home-based work (HBW), home-based other (HBO), and non-home based trips (NHB). We first estimated a household-level regression model for each type of production type, then choosing the most significant variable alone, to see if a reduced model would be preferred. These results are shown here.

	Full model		Reduced model	
(Intercept)	1.28 ***	(p = 0.00)	1.63 ***	(p = 0.00)
zero_veh_TRUE	0.06	(p = 0.83)		
size_two	0.26	(p = 0.22)		
inc_levels_low	-1.01 **	(p = 0.01)	-0.97 **	(p = 0.01)
inc_levels_mid	-0.69 *	(p = 0.03)	-0.60	(p = 0.08)
N	185		251	
R2	0.11		0.05	

*** p < 0.001; ** p < 0.01; * p < 0.05.

Figure 29: Home Based Work (HBW) Model Summary

The regression model for home-based work trips indicates that trip counts are most affected by low income households. We chose income levels for the reduced model, though because our R^2 then drops but the low income level coefficient changes only slightly, we are choosing the full model to move forward.

	Full model		Reduced model	
(Intercept)	2.21 **	(p = 0.00)	2.11 ***	(p = 0.00)
zero_veh_TRUE	0.16	(p = 0.84)		
size_two	1.89 ***	(p = 0.00)	2.02 ***	(p = 0.00)
inc_levels_low	-0.49	(p = 0.63)		
inc_levels_mid	0.14	(p = 0.84)		
N	185		188	
R2	0.13		0.13	

*** p < 0.001; ** p < 0.01; * p < 0.05.

Figure 30: Home Based Other (HBO) Model Summary

The regression model for home-based other trips indicates that trip counts are most affected by household size. We chose household size for the reduced model, and this is a better fit, with our R^2 staying constant and our two person household coefficient increasing.

	Full model		Reduced model	
(Intercept)	1.97 ***	(p = 0.00)	3.09 ***	(p = 0.00)
zero_veh_TRUE	0.18	(p = 0.71)		
size_two	0.41	(p = 0.29)		
inc_levels_low	-1.41 *	(p = 0.01)	-2.07 ***	(p = 0.00)
inc_levels_mid	-0.06	(p = 0.91)	0.11	(p = 0.88)
N	185		251	
R2	0.09		0.04	

*** p < 0.001; ** p < 0.01; * p < 0.05.

Figure 31: Non-Home Based (NHB) Model Summary

The regression model for non home-based trips indicates that trip counts are most affected by low income households. We chose income levels for the reduced model, though because our R^2 then drops but the low income level coefficient drops less signficantly, we are choosing the full model to move forward.

After determining our preferred models and balancing our number of trip productions and trip attractions, we are left with a distribution of trip counts by tract across our study area. These are visualized below.

Figure 32: Home Based Work (HBW) Trips by Census Tract

The figure above shows home-based work trip productions - we see that there are a handful of tracts that have a significant number of household trips. We see a peak in some downtown census tracts, maybe those who travel back and forth to their homes more frequently during the day.

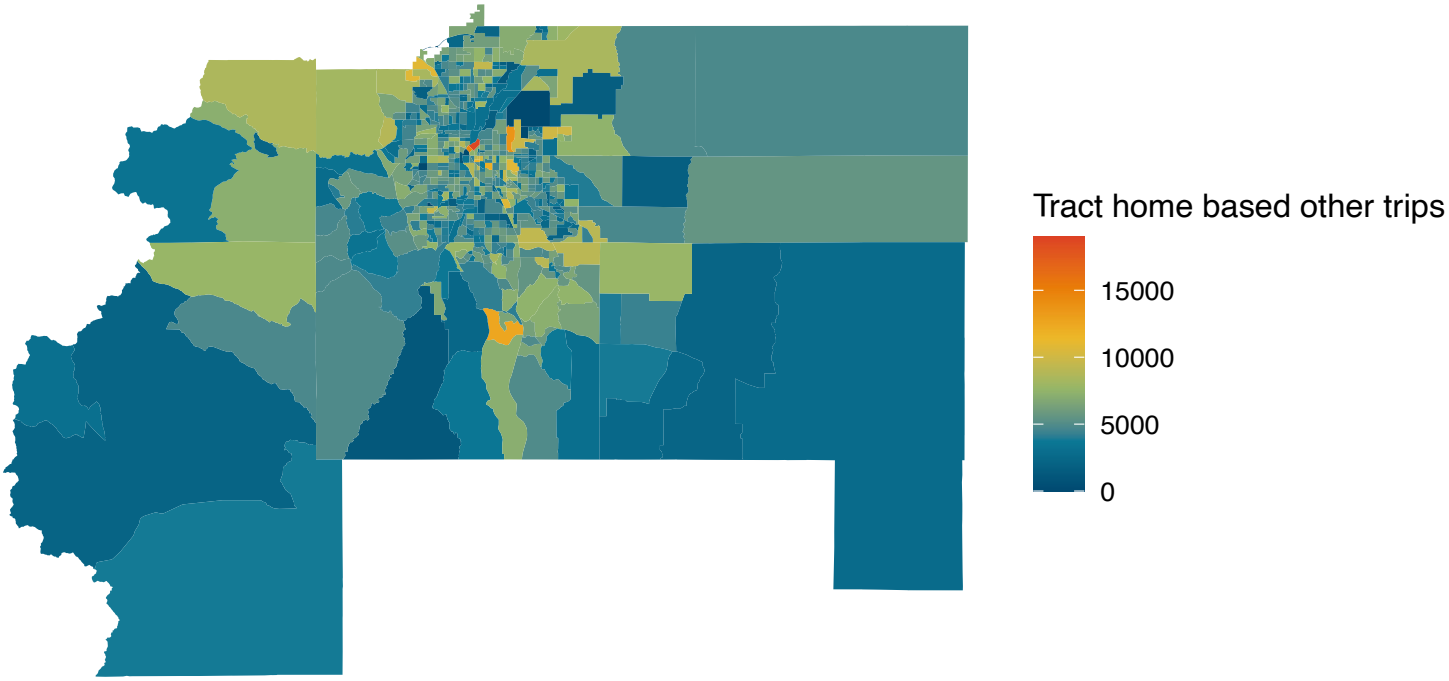

Figure 33: Home Base Other (HBO) Trips by Census Tract

Home-based other trip productions are show above - we see similar relationships between tracts here but with higher total counts.

Figure 34: Non-Home Based (NHB) Trips by Census Tract

Non-Home Based trips have a similar relationship to the others as well. Red and orange tracts must have high levels of residential and non-residential productions.

Figure 35: Home-Based Other (HBO) Trip Attractions

Finally, we looked at trip attractions. Red and orange tracts here indicate areas where there are a lot of opportunities that draw households outside of work commitments. The bright orange tract on the west, for example, is almost entirely state park.

ESTIMATING TRIP DISTRIBUTION

The next part of our model is to estimate trip distribution between zones. Using data from the National Household Travel Survey we were able to calculate the average travel time by trip purpose (for HBW, HBO, and NHB trips). The average travel time, in minutes, is shown below for each travel purpose.

purpose <chr>	avg_time <dbl>
HBO	17.88936
HBW	22.78287
NHB	19.37754

Then, using a gamma function and friction factors for MPOs categorized as Large MPO 1 by the NCHRP 716, we estimated trip distribution between all zones. We used a tolerance of 1% in our gamma function, meaning that the distribution of travel flows between origins and destinations will be within 1% of our target values of all trips generated. We did this for both our existing conditions as well as our proposed conditions. The below graphs illustrate the convergence of travel flows for each of trip purpose (HBW, HBO, and NHB) for each condition

Existing Conditions

Proposed Conditions

Home-Based Work (HBW) Trips

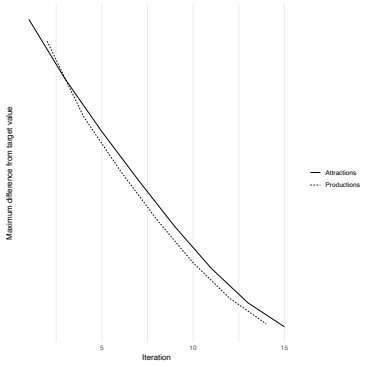

Figure 36: HBW Travel Flow Convergence

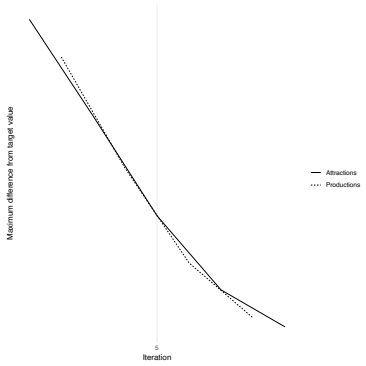

Figure 37: HBW Travel Flow Convergence

Home-Based Other (HBO) Trips

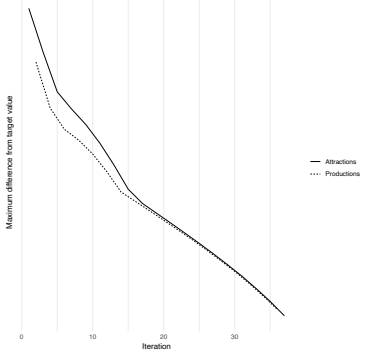

Figure 38: HBO Travel Flow Convergence

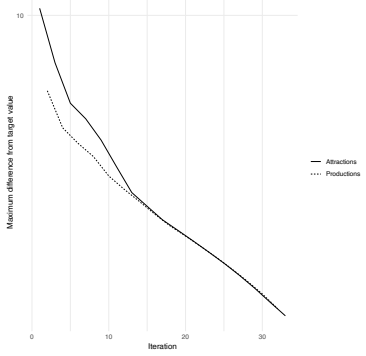

Figure 39: HBO Travel Flow Convergence

Non-Home-Based (NHB) Trips

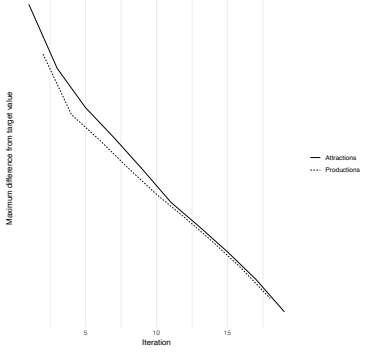

Figure 40: NHB Travel Flow Convergence

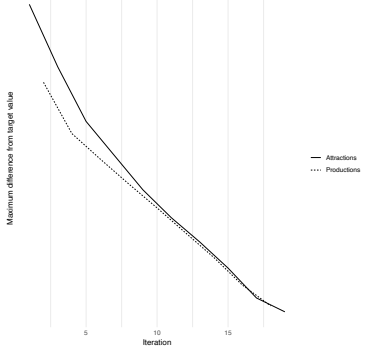

Figure 41: NHB Travel Flow Convergence

Each travel purpose reached convergence within 1% of our target values with relatively few iterations of the gamma function, with HBO travel flows in the existing conditions requiring the most iterations at just under 40 of them.

Next we visualize the change in travel flows for each trip purpose between the existing conditions and the proposed conditions. For each map, we selected the top five census tracts that had the highest number of trip attractions, and in some cases the same census tract appeared twice in the top five. There are noticeable differences in travel flows between existing and proposed conditions. The top five attracting tracts vary within each trip purpose and between conditions

Existing Conditions

Proposed Conditions

HBW Travel Flows

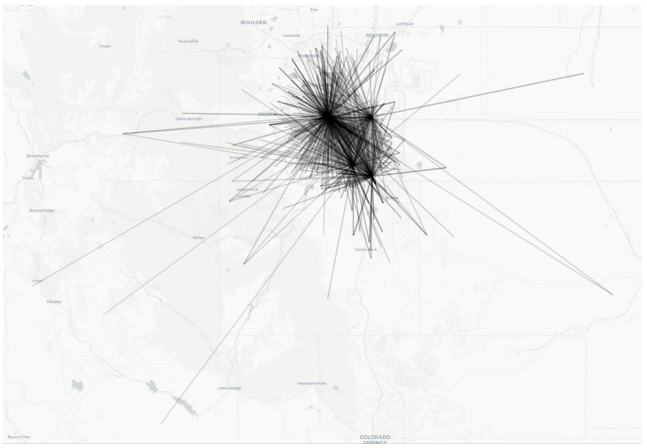

Figure 42: HBW High-Attraction Tracts

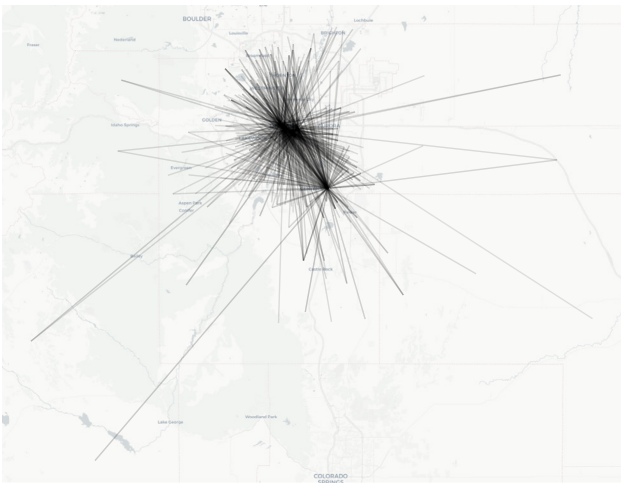

Figure 43: HBW High Attraction Tracts

HBO Travel Flows

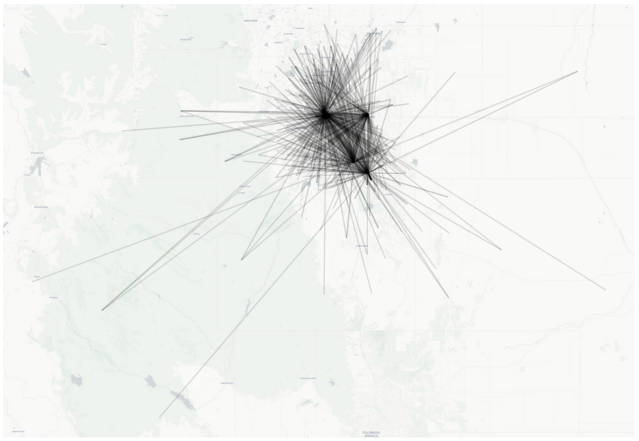

Figure 44: HBO High-Attraction Tracts

Figure 45: HBO High-Attraction Tracts

NHB Travel Flows

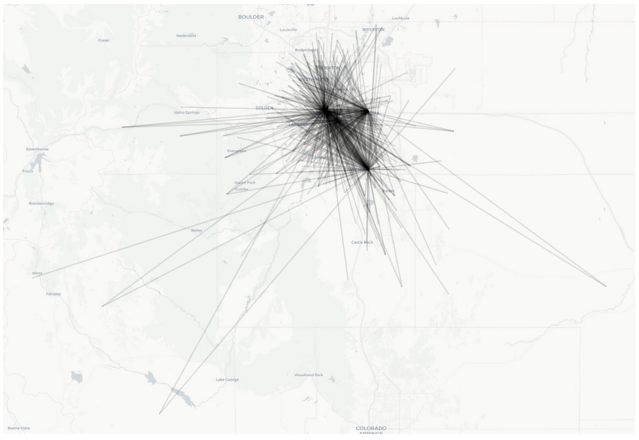

Figure 46: NHB High-Attraction Tracts

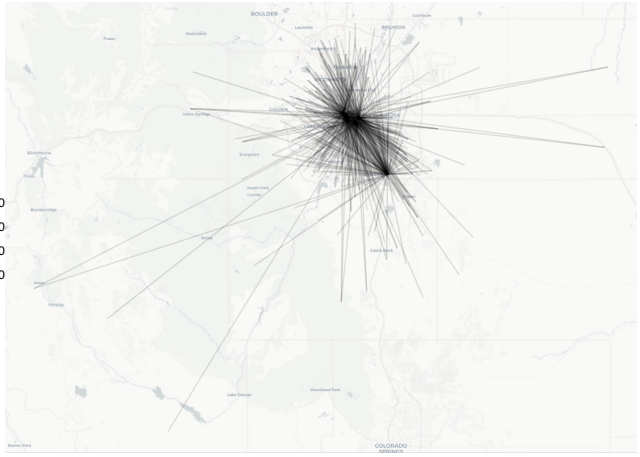

Figure 47: NHB High-Attraction Tracts

Last, we visualize the percent change in travel flows for each trip purpose and between existing and proposed conditions. For ease of understanding the percent change in trip attractions we selected the census tract that had the highest trip attractions for each purpose. It is clear from the maps below that the increase in population due to increased FAR in multifamily zones will alter trip distribution between census tracts in the Denver MSA.

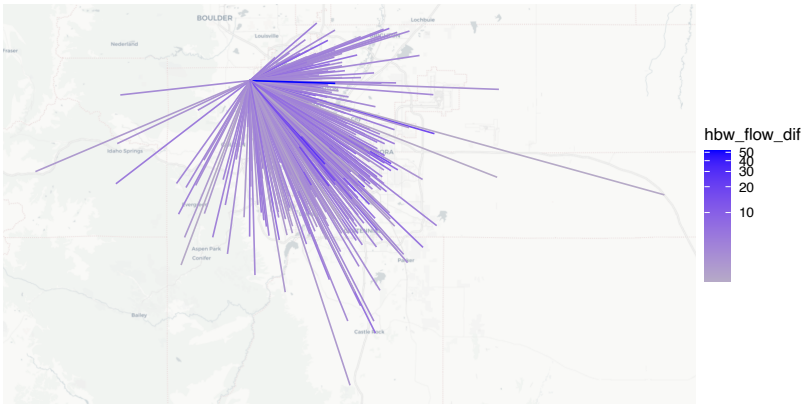

Figure 48: This map shows the percent change in HBW travel flows between existing and conditions at the census tract with the highest number of trip attractions.

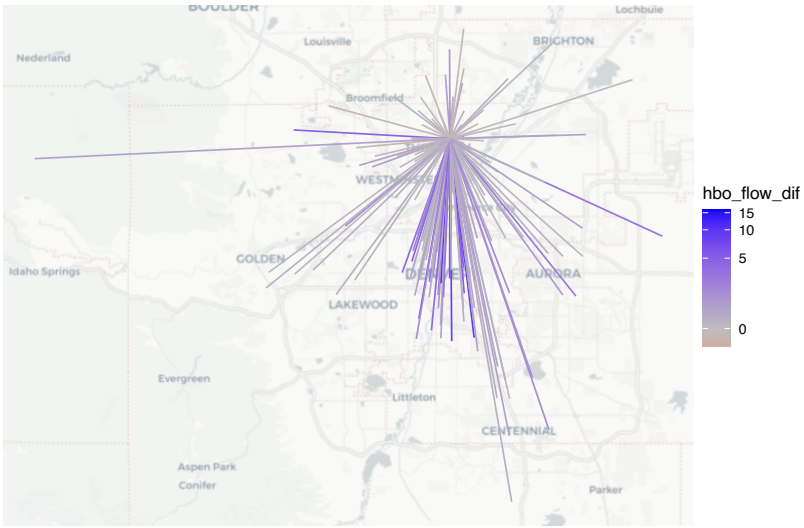

Figure 49: This map shows the percent change in HBO travel flows between existing and conditions at the census tract with the highest number of trip attractions.

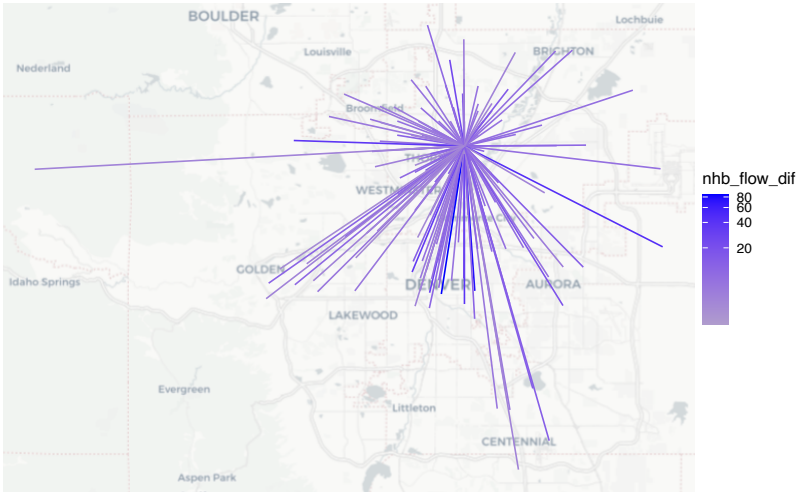

Figure 50: This map shows the percent change in NHB travel flows between existing and conditions at the census tract with the highest number of trip attractions.

ESTIMATING MODE CHOICE

We next attempt to estimate the mode choices of the region's residents based on NHTS data for different kinds of trips. We first look at trip costs for both driving and transit:

$1.46

per transit ride

$0.05

per minute to operate a car

Using NCHRP 716 models, we calibrated our models to match regional mode shares for home based work trips, home based other trips and non home based trips.

purpose <chr>	pct_bike <dbl>	pct_SOV <dbl>	pct_HOV <dbl>	pct_transit <dbl>	pct_walk <dbl>
HBO	0.026272691	0.3302818	0.47781811	0.0212728996	0.144354538
HBW	0.024568409	0.7231060	0.09841425	0.0605980889	0.093313214
NHB	0.012593283	0.3380101	0.53307667	0.0219190213	0.094400883
NHB_model_alt 1	0.001639956	0.2984797	0.69004925	0.0003734353	0.007806478
NHB_model_alt 2	0.010926420	0.3282241	0.52671641	0.0313527679	0.099141201

Figure 51: This table is an example of the calibration process where our "non-home based mode share" is calibrated to the NHTS regional mode share data

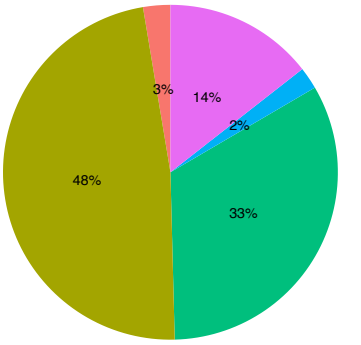

Figure 52: Mode share for home-based other trips

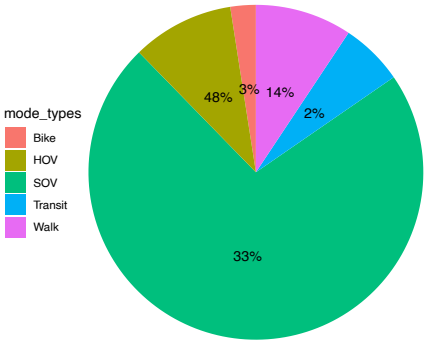

Figure 53: Mode share for home-based work trips

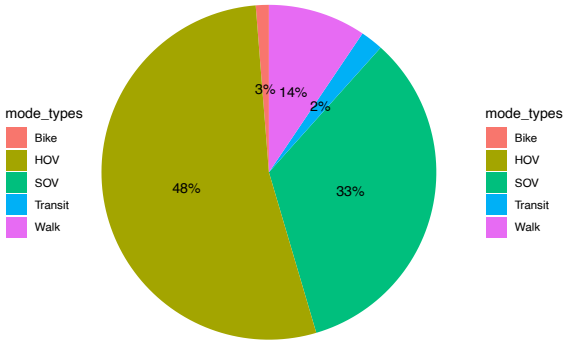

Figure 54: Mode share for non-home based trips

Our model tended to slightly overestimate trips by single occupany vehicle, heavily overestimate trips by high occupancy vehicles, slightly underestimated transit and heavily underestimated active (walking and biking) trips.