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CHAPTER 4 SUPPORTING DOCUMENTATION—TRANSPORTATION IMPACT ANALYSIS

Travel Demand Modeling Methodology, Assumptions, and Results Technical Report

Emerging Mobility Impacts Study: Travel Demand Modeling Methodology, Assumptions, and Results

draft technical report

prepared for

Colorado Department of Transportation

prepared by

HDR and Cambridge Systematics, Inc.

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draft technical report

Travel Demand Modeling Methodology, Assumptions, and Results

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Executive Summary

This study is the first of its kind in Colorado. One of the objectives of the study is to estimate the travel impacts of emerging and shared mobility modes in the state of Colorado. It should be noted that there is high uncertainty in the estimates due to a lack of data as some of these emerging mobility options, particularly TNCs and carsharing, are new and changing considerably over a relatively short period of time.

The study focused on six types of emerging and shared mobility modes:

- TNCs
- Taxis,
- Non-peer carshare,
- Peer carshare,
- Rental cars, and
- Residential deliveries.

Considering that estimating travel for these emerging mobilities has never been done before in Colorado, the first step involved a literature review and data gathering. Where local data was not available, data from other parts of the country were reviewed and translated or adjusted to account for Colorado characteristics like population and travel.

After a review of the data available, vehicle trips and vehicle-miles traveled (VMT) were estimated for each of the study's six modes. It should be noted that the VMT estimates are those vehicle miles on the road today; this study did not look at a number of other metrics such as net increases or decreases because of the modes available or how much of the VMT is substituting for other modes of travel. This study focused on gathering any data available on number of person or vehicle trips, average trip length (with and without passengers, where relevant), and the resulting total VMT.

Travel in Colorado

The Colorado Statewide Travel Demand Model (StateFocus) forecasts all personal travel made by every Colorado resident, plus commercial truck travel and visitor travel to or from Denver International Airport (DEN). The model forecasts travel for an average fall/spring weekday. The activity-based model's development relied on the 2010 Front Range Travel Counts Survey for information on Colorado resident's travel behavior as well as traffic counts and transit ridership to validate the model.

A wealth of data is used as input to the model in order to explain travel in the region. This includes information on people, households, schools, and employment (socioeconomic data); road, nonmotorized, and transit networks (transportation supply); and other characteristics of the region. Outputs of the model include number of trips by mode and total VMT. Currently available forecast years include a base year (2015) and future years for 2030 and 2045. For this study, data from the 2015 and 2030 scenarios were utilized to understand socioeconomic characteristics of the population, travel behavior choices, and estimates of the total travel in Colorado. The following table provides some key metrics used in this study based on data input or output from the model.

MPO	Population		Personal VMT (1,000s)		Total VMT (1,000s)	
	2018	2030	2018	2030	2018	2030
DRCOG	3,326,689	4,058,025	71,103	86,013	81,908	99,165
NFRMPO	580,625	766,748	11,720	16,505	13,145	18,437
PPACOG	732,811	892,270	13,242	17,205	14,942	19,395
PACOG	166,198	200,731	3,052	4,094	3,400	4,528
GVMPO	157,583	202,337	2,651	3,763	2,887	4,087
NonMPO	731,659	854,354	22,432	30,687	24,696	33,549
Statewide	5,695,564	6,974,465	124,201	158,268	140,978	179,162

Notes: A 2018 model scenario does not exist. Travel estimates were interpolated between 2015 and 2030 and adjusted to account for current 2018 population estimates from the Census.
Total VMT includes personal travel and commercial truck travel.

A recent effort to enhance StateFocus included the addition of a TNC mode, which can be optionally included in model runs. Given insufficient data to re-estimate the model for TNCs, data collected prior to and during this study, along with professional judgment, was used to reasonably calibrate the model based on borrowed sensitivities to various factors (such as time, cost, and auto availability in the household) that influence the choice to use TNCs or other modes. However, a lack of observed data of TNCs in Colorado means that this model cannot be validated but it can be used as a tool for analysis.

TNCs

In light of the growing popularity of TNCs in major metropolitan areas and the fact that TNCs can no longer be considered a fringe mode of transportation, it is important to investigate how TNCs, such as Uber and Lyft, are affecting congestion—are they reducing congestion by complementing transit and reducing car ownership in major cities, or are there other effects? TNCs have been shown to be correlated to traffic congestion in cities like San Francisco[1] and Denver[2] in recent studies. TNCs represent a relatively new mode of transportation, but one that is demonstrably shaping and modifying extant transportation and mode choice trends.

It is very common to run into data availability issues when dealing with TNC research and application. Due to the proprietary nature of the data protected by the companies that operate such vehicles, it is not common for city planners and demand modelers to have access to this data in as transparent a way as any other public or privately operated transportation mode. A few research studies have overcome this challenge by making use of different data collection methods. Additionally, household travel surveys and recently released publicly-available TNC data at a disaggregate level provide another picture of TNCs in America. The primary sources of data used in this study to estimate TNC travel in Colorado include:

[1] Castiglione, J., Roy, Sneha, et.al. (2019).The Effect of Transportation Network Companies on Congestion in San Francisco. TRB.

[2] Henao, Alejandro. Impacts of Ridesourcing-Lyft and Uber-on Transportation Including VMT, Mode Replacement, Parking, and Travel Behavior. University of Colorado at Denver, 2017.

- 2015 and 2017 Puget Sound Regional Council (PSRC) Household Travel Survey,
- 2017 National Household Travel Survey (NHTS),
- 2018 publicly available TNC trip data from Chicago,
- A 2016 study by Alejandro Henao and Wesley Marshall in which the researcher became a TNC driver and collected both survey-based data, as well as, TNC trip characteristics spread across various spatial geographies within Denver, and
- A 2018 study by Fehr & Peers that estimated TNC VMT for several large urban regions across the county, in comparison to the total VMT for those regions.

After assessing the available data, this information was applied to Colorado, by a variety of different approaches, in order to approximate a reasonable range of estimated TNC travel. Those efforts resulted in the following estimates for TNCs in Colorado:

- 38,000 to 119,000 daily TNC vehicle trips, with a best estimate of 63,000;
- An average passenger trip length of 7 miles (observed values ranged from 3 to 8 miles); and
- Deadheading travel (travel while waiting for TNC rider and travel to pick up a rider) of 40% (values ranged from 20%-50%) of the total TNC VMT per trip.

Assuming approximately 63,000 vehicle trips and 12 miles a trip (including deadheading) results in approximately 750,000 VMT, with a low estimate of 450,000 and a high estimate of 1,400,000 VMT per day in 2018.

To forecast TNC travel in 2030, expected population and employment growth and the current trajectory of rapidly increasing TNC usage were two important considerations. Recent TNC data released for Seattle show a rapidly increasing number of TNC trips per day. While it is expected that the use of TNCs will continue to increase, it is unclear where the level of saturation may occur. Several different approaches were implemented to estimate TNC travel in 2030, the primary estimates included:

- Application of StateFocus, which resulted in the same mode share (or propensities) estimated today in Colorado – an estimate of **81,000 vehicle trips**;
- Assuming an increase in TNC market will result in mode shares observed today in the Chicago region today, where the density today is similar to the forecasted density of Denver in 2030 – an estimate of **315,000 vehicle trips**; and
- Assuming an increase in TNC market in Colorado will result in mode shares observed today in San Francisco, as an example of attainable TNC travel but much higher than experienced in Colorado or many other places in the county – an estimate of **850,000 vehicle trips**.

These analyses led to an estimated 81,000 to 850,000 TNC vehicle trips per day in Colorado in 2030, with a best estimate of 315,000 vehicle trips. Assuming the same average trip length and deadheading), estimates for 2030 TNC VMT range from 950,000 to 10 million. This translates to

approximately 0.5% to 5% of forecasted 2030 total VMT. This wide range of impacts underscores the need for better data and a better understanding of who, where, when, and why people use TNCs.

Taxis

Taxis have been regulated in Colorado for a long time. Subsequently, reliable data of taxi travel is available from the Colorado Public Utilities Commission (PUC) and was provided for years 2013-2017. The data provided reveals an average of 5,500 vehicle trips per day in 2017 and an average passenger trip length of 4.8 miles. The PUC advised researchers for this study to assume the total taxi miles traveled are double the paid miles. This results in an estimate of 53,000 daily VMT by taxis today.

While researchers are confident that this is a reasonable estimate of taxis in Colorado, it should be noted all taxi providers who reported to the PUC were in the Denver metro region. Taxis do exist outside of Denver but the PUC suspected that they did not meet a threshold requiring reporting. Considering the population outside of the Denver region, taxi trips were increased by 28%[3] to account for potential unreported taxi travel, a high estimate of taxi travel in Colorado.

Assuming approximately 5,500 to 7,000 vehicle trips and 10 miles a trip (including deadheading) results in approximately 55,000 VMT, with a high estimate of 70,000 VMT per day in 2018.

To forecast taxi travel in 2030, a few approaches were utilized to estimate the range of future possibilities:

- Taxi trips will continue to decline at its currently observed rate, which would result in zero taxi trips before 2030; and
- Taxi travel will increase proportionally with expected growth in travel in Colorado (25% between 2018 and 2030), applied to the best and high estimates of taxi travel today.

These assumptions lead to an estimated zero to 8,700 taxi trips per day in Colorado in 2030, with 6,900 vehicle trips as the best estimate, which is a tiny percentage of forecasted 2030 VMT.

Carshare

Carshare, today, is one of the newer popular emerging modes in the shared economy. The main purpose of carsharing is to share a personally owned car or a fleet of cars with multiple users in an on-demand basis for a relatively shorter period of time. The renters, and owners, of the cars are two end nodes of supply and demand of the network of car renting service, and carsharing companies this demand and supply using a app-based network. Carsharing service can be classified in two different classes considering the characteristics of the car owners. These are (i) non-peer carsharing service and (ii) peer-to-peer (p2p) carsharing service.

Little to no data on carsharing in Colorado was available at the time of this report. Some studies of non-peer carsharing (particularly car2go and Zipcar services) were available for other locations. Limited studies of peer carsharing were available but were not locally specific or very current considering the rapidly evolving business models for the companies.

[3] A 28% increase represents the population in 2018 that's outside the DRCOG region but has taxi service (NFRMPO and PPACOG regions) divided by the total population in all regions with taxi service (DRCOG, NFRMPO, and PPACOG).

The primary sources of data used in this study to estimate carshare travel in Colorado include:

- 2015 PSRC Household Travel Survey and 2017 NHTS;
- Online news articles and reports about carsharing in Colorado;
- A 2016 study (Martin and Shaheen (2016)) assessment of the impacts of car2go on vehicle ownership, modal shift, vehicle miles traveled, and greenhouse emissions in 5 American cities;
- Studies from Portland State University (Dill, et al (2016)) based on surveyed vehicle owners and renters using the Getaround platform;
- A study by University of California, Berkeley (Shaheen et al. (2018)) study that surveyed users of multiple P2P carsharing operators, collecting behavioral statistics including monthly trip frequency and monthly spending on P2P carsharing;
- A University of California, Berkeley (Stocker et al. (2016) study that conducted a survey to better understand the impact that carsharing has on college member travel behavior; and
- Estimates of fleet size for carsharing apps in Colorado by manually counting the average number of vehicles available on an average weekday.

The PSRC and NHTS surveys asked respondents how often they use carsharing services. Analysis and application of that data to Colorado resulted an estimated range of 4,100 to 21,000 carsharing person trips per day, or 2,000 to 10,000 carsharing vehicle trips today, assuming an average vehicle occupancy of 2.08 (as estimated from NHTS data). As described below, the lower end of this range is reasonable compared to estimates of non-peer plus peer carsharing. **The higher end of this range, 10,000 vehicle trips, with a high estimate of 50 miles per day, results in a high estimate of 500,0000 VMT for all carsharing today**.

Application of PSRC survey data to 2030 population forecasts for Colorado results in a high estimate of approximately **55,000 vehicle carsharing trips in 2030. Assuming the same high 50 mile VMT per day estimate results in a high estimate of 2.8 million VMT for carsharing in 2030 in Colorado.**

Non-peer Carshare

Non-peer carshare operators in Colorado today include car2go[4] and Zipcar. These two companies have very different business models:

- car2go includes a floating network of vehicles that can be dropped off anywhere within its service boundaries and lend themselves to shorter duration rentals; and
- Zipcar includes a network of vehicles that are picked up and dropped off at specific location and are often used for longer duration rentals.

[4] It should be noted that, at the time of writing this report, car2go was canceling its services in Colorado on October 31, 2019.

The car2go fleet was reported as 340 vehicles in Denver in 2017[5] with a customer base of 48,000 in 2018[6]. Martin and Shaheen (2016) estimated 5 customer trips per vehicle per day with average trip lengths ranging 3.4 to 4.1 miles and repositioning travel ranging from 3% to 17% of total fleet VMT, the higher end being for SmartCar fleets requiring electric charging. A local news article reported the average trip length of car2go trips in Colorado was 6.83 in 2018[7]. Assuming 340 vehicles with 5 trips each per day, an average trip length of 6.83 miles, and 3% of vehicle fleet VMT for repositioning, **1,700 vehicles trips and 12,000 VMT are estimated per day for car2go**.

The Zipcar fleet was estimated to be 55 vehicles across Colorado in 2019. Stocker et al. (2016) estimated the average VMT per reservation was approximately 50 miles but this included reservations for more than one day so the average amount of travel in one day is unknown but likely a lower. Considering that the Zipcar model is more similar to the peer carshare model (in terms of having to return the vehicle to a specific place and lends itself to longer rental durations), the same assumptions of average trip length were assumed for both. It is unclear how often vehicles are rented. Based on information provided by various peer carsharing studies and professional judgement, a 15-mile per day trip length, which is about the same mileage an average person drives an average day, was assumed here. Because vehicles are returned to specific space, and with no better information, no repositioning VMT was assuming. With these assumptions, **50 vehicle trips and 1,000 VMT are estimated per day Zipcar**.

Without historical trend data or better information about future use of non-peer carsharing, an assumed increase proportional to expected growth in travel in Colorado (25% between 2018 and 2030) results in an estimated **2,500 vehicles trips and 20,000 VMT for non-peer carsharing in Colorado in 2030.**

Peer Carshare

The primary operators for peer carsharing in Colorado include Getaround and Turo; researcher's manual estimates of their available fleet sizes were 100 and 200, respectively. Very little is known about how often these vehicles are rented or their durations or miles traveled. A Portland State University study estimated the number of trips on peer carsharing vehicles to be 0.4 trips per day, on average. Some rentals can be short-term (an hour) or long-term (multiple days). Given the lack of data, as noted above in the Zipcar trip length assumptions, a 15-mile average trip length (per reservation per day) for was assumed here. To check for reasonableness, a researcher of this study's individual vehicle rental history on a peer carsharing platform was mined and revealed an average of 0.5 reservations per day and an average rental duration of 19 hours[8], suggested that a longer average VMT estimate may not be unreasonable.

Assuming 300 available vehicles on any given day and 0.4 trips per day results in a best estimate of **100 vehicle trips per day**. Due to the uncertainty of average trip length, a range of 15 to 50 miles per day was assumed, resulting in **1,800 to 2,700 VMT per day for peer carsharing in 2018**. It should be noted that there is high uncertainty in these estimations due to lack of recent or local data.

[5] https://www.denverpost.com/2017/06/15/car2go-mercedes-denver/

[6] https://www.thedenverchannel.com/news/local-news/car2go-in-denver-more-users-longer-trips-since-switching-to-mercedes-benz

[7] https://www.thedenverchannel.com/news/local-news/car2go-in-denver-more-users-longer-trips-since-switching-to-mercedes-benz

[8] This average duration of 19 hours is per reservation and includes multi-day rentals.

Without historical trend data or better information about future use of peer carsharing, an assumed increase proportional to expected growth in travel in Colorado (25% between 2018 and 2030) results in a best estimate of **200 vehicles trips and 3,600 VMT for non-peer carsharing in 2030 in Colorado.**

Car Rentals

Car rentals, like taxis, have existing in Colorado for a long time. Since 2010, every car rental is charged a $2 per day fee that is collected by the state and reported by the Department of Revenue. Subsequently, reliable data for car rentals is available online for years 2010-2018. The data provided reveals to an **average of 47,600 daily vehicle rentals per day in 2018**. It is unknown how much, on average, a rental car is driven per day. The only known estimate available at the time of research was the 2017 NHTS data that estimated **an average of 66 miles per day** for those trips reported by car rental or carshare. Applying these assumptions, **3.1 million VMT is estimated for car rentals**.

To forecast car rentals in 2030, the historical data from 2010 to 2018 made available by the Department of Revenue was used to estimate the linear relationship over time for car rentals and resulted in an estimated **76,400 car rentals per day in 2030**. Assuming the same 66 miles per day travel, **5 million VMT is estimated for car rentals in 2030.**

Given the uncertainty in average VMT per day, low and high estimates of car rental travel was bracketed by 25-mile (an average car rental trip length from NHTS) and 150-mile (the industry standard maximum) per day assumptions. This results in **ranges of 1.2 to 7 million VMT in 2018 and 1.5 to 12 million VMT in 2030**.

Residential Deliveries

Residential deliveries for this analysis included third-party restaurant delivery, online grocery delivery, and parcel delivery of goods purchased online. Little to no quantifiable data on residential delivery in Colorado was available at the time of this report. Therefore, primarily anecdotal data were used to inform the analysis.

Third-Party Restaurant Delivery

For 2018, 4,190 restaurants were assumed to be partners with one of the major third-party restaurant delivery firms such DoorDash, Grubhub, or Uber Eats. The number of daily orders per restaurant was guided by a restaurant owner suggesting that he averaged about ten orders per day as a result of joining one of the third-party restaurant delivery platforms.[9] Thus, an average of eight orders per day was assumed in the analysis. For the average trip length, a conservative 5 miles per delivery was assumed including deadhead. **In 2018, approximately 33,780 third-party restaurant deliveries were made daily. Total VMT would be 168,900.**

For 2030, a compound annual growth rate (CAGR) of 20 percent was assumed based on market research conducted by UBS Bank.[10] While this growth assumption is very aggressive, some of the other assumptions used in the estimates may provide an offset to the conservative numbers used in the analysis such as the average trip length which implicitly seems short (5 miles including deadhead) or the average number of orders of eight. **In 2030, using the same average trip length and average number of orders per restaurant as**

[9] https://www.apnews.com/36be30dc1c944101a310bef3e79eca7a

[10] https://www.aol.com/article/finance/2018/07/02/ubs-online-food-delivery-could-be-a-dollar365-billion-industry-by-2030-here-are-the-winners-and-losers-from-that-mega-trend/23473052/

was assumed for 2018, deliveries would almost increase tenfold to 301,186. VMT would increase to 1,505,930 in 2030.

Online Grocery Delivery

Online grocery delivery estimates were developed based on the assumption that typical household trip-making characteristics to the grocery store would also apply to online grocery purchases and deliveries. Using an assumption that households on average make 1.5 trips to the grocery per week,[11] the number of households (2,296,481) in Colorado for 2015 was multiplied by the average of 1.5 grocery trips. Based on these assumptions, there are 3,444,122 grocery trips made in the state during any given week. Dividing this value by 7 gives an estimate of 492,017 daily grocery trips. The United States currently lags other developed countries with online grocery purchases at 3 percent which suggests approximately **14,760** grocery deliveries, assuming they are all delivered and not picked up. The average trip length traveled by customers to a grocery store is 4 miles.[12] **Assuming this distance would likely be the same distance as driven by an employee in delivering groceries, there would be approximately 118,804 VMT (including deadhead) in 2018.**

For 2030, the assumption was made that online grocery purchase and deliveries would triple from 3 percent to 9 percent which would still put Colorado behind the United Kingdom and South Korea today where some estimate put online grocery purchases as high as 15 percent. **Using the 2030 estimates for households in Colorado of 2,950,775 and a 9 percent share, there would be 56,908 residential grocery deliveries and 341,447 VMT in 2030.**

Parcel Delivery

Residential deliveries for online shopping were estimated using the 2017 National Household Travel Survey (NHTS) and research conducted by Dr. John-Paul Rodrigue. The 2017 NHTS data for Colorado suggests 2.37 online purchases per month that were delivered. Converting this monthly figure to a daily value results in 0.095 average deliveries/person/day. For an estimate of 2018 daily residential deliveries, the average of 0.095 deliveries /person/day was multiplied by Colorado's 2015 population of 5,452,000, giving an estimate of **517,700 daily parcel deliveries and 277,750 VMT.**

For 2030, an annual growth rate of 17 percent per year for three years[13] to 2020 was assumed, followed by a flat growth rate from 2020 to 2030. Therefore, any growth between 2020 and 2030 would be due to the increase in Colorado's population. Using the 2030 population of 6,892,000 with Rodrigue's growth rate assumptions for three years, there would be **1,048,154 daily parcel deliveries and 562,341 VMT**.

Summary of Residential Delivery

Adding the residential deliveries from third-party restaurant delivery, on-line grocery delivery, and parcel delivery, there would be a total of 566,240 residential deliveries and 563,734 VMT in 2018. For 2030, the estimate for total residential deliveries is 1,406,187 and 2,523,227 VMT.

[11] https://www.creditdonkey.com/grocery-shopping-statistics.html

[12] http://couponsinthenews.com/2016/11/17/how-far-will-you-drive-to-get-your-groceries/

[13] Rodrigue, J.P., Residential Parcel Deliveries: Evidence from a Large Apartment Complex. Final Report, March 2017. Metro Freight Center of Excellence, Department of Global Studies & Geography, Hofstra University, Hempstead, New York, USA.

Summary

Any number of social, economic, or regulatory changes could substantially impact any or all of these modes of travel, but it's important to understand how they are operating today and what range of future may lay ahead for these modes, Colorado's residents and visitors, the state's transportation infrastructure, and the environment.

The analyses presented in this report represents the average miles on the road today and their potential by 2030. These efforts have not accounted for a number of factors, including but not limited to the following:

- Any miles on the road by these modes that are substitutions for other vehicle travel;
- Any suppressed travel as a result of these options being available;
- Any induced travel as a result of these options being available; and
- Any impacts of one mode on another in the future.

Estimates for number of vehicle trips and total VMT per day are provided by mode below.

Travel Metric	Emerging Mobility Mode	Today (~2018)			Share of Travel		
		Best Estimate	Low	High	Best Estimate	Low	High
Vehicle Trips	TNCs	63,000	38,000	120,000	0.7%	0.4%	1.3%
	Taxis	5,500	5,500	7,100	0.1%	0.1%	0.1%
	Non-peer Carshare	1,800	n/a	10,000	0.0%	n/a	0.1%
	Peer Carshare	100			0.0%		
	Car Rentals	47,600	47,600	47,600	0.5%	0.5%	0.5%
	Residential Deliveries	n/a	n/a	n/a			
	Total Vehicle Trips for Emerging Mobilities	**120,000**	**90,000**	**185,000**	**1.3%**	**1.0%**	**2.0%**
	Total Vehicle Trips in CO	9,071,000					
VMT	TNCs	748,000	448,000	1,440,000	0.5%	0.3%	1.0%
	Taxis	53,200	53,200	68,100	0.0%	0.0%	0.0%
	Non-peer Carshare	25,700	n/a	503,500	0.0%	n/a	0.4%
	Peer Carshare	58,000			0.0%		
	Car Rentals	3,153,000	1,190,000	7,140,000	2.2%	0.8%	5.1%
	Residential Deliveries	564,729	564,729	564,729	0.4%	0.4%	0.4%
	Total VMT for Emerging Mobilities	**4,602,629**	**2,257,929**	**9,716,329**	**3.2%**	**1.6%**	**6.9%**
	Total Statewide VMT	140,980,000					

Notes: Car Rentals are estimated as daily rentals, not individual trips.

Travel Metric	Emerging Mobility Mode	Today (~2018)			Share of Travel		
		Best Estimate	Low	High	Best Estimate	Low	High
Vehicle Trips	TNCs	315,000	81,000	850,000	1.9%	0.5%	5.0%
	Taxis	6,900	0	13,300	0.0%	0.0%	0.1%
	Non-peer Carshare	2,200	0	56,600	0.0%	0.0%	0.3%
	Peer Carshare	200	0		0.0%	0.0%	0.0%
	Car Rentals	76,400	60,600	81,500	0.5%	0.4%	0.5%
	Residential Deliveries						
	Total Vehicle Trips for Emerging Mobilities	400,000	140,000	1,000,000	2.4%	0.8%	5.9%
	Total Vehicle Trips in CO	16,969,000					
VMT	TNCs	3,700,000	950,000	10,000,000	2.1%	0.5%	5.6%
	Taxis	66,700	0	127,600	0.0%	0.0%	0.1%
	Non-peer Carshare	16,000	0	2,800,000	0.0%	0.0%	1.6%
	Peer Carshare	3,600	0		0.0%		
	Car Rentals	5,060,700	1,515,000	12,225,000	2.8%	0.8%	6.8%
	Residential Deliveries	2,523,227	2,523,227	2,523,227	1.4%	1.4%	1.4%
	Total VMT for Emerging Mobilities	11,000,000	5,000,000	28,000,000	6.3%	2.8%	15.4%
	Total Statewide VMT	179,162,000					

Source: Car Rentals are estimated at daily rentals, not individual trip.

1.0 Overall Approach

As required by Colorado Senate Bill 19-239, one of the objectives of the study was to estimate the travel impacts of six emerging and shared mobility modes in the state of Colorado:

- Transportation Network Companies (TNCs),
- Taxis,
- Non-peer carshare,
- Peer carshare,
- Car rentals, and
- Residential deliveries.

A literature review and data collection effort identified available published statistics or open source data specific to the study's six modes. The resulting set of data and information included the following:

- Household survey data,
- Disaggregate TNC data from cities outside of Colorado,
- Published studies and reports, and
- Local data provided by the Denver International Airport, the Public Utilities Commission, and the Colorado Department of Revenue.

Furthermore, local providers were contacted to provide locally-specific data. However, local providers did not respond or did not provide detailed data that could be used to validate estimates of trips or vehicle miles traveled (VMT) by mode in Colorado. A list of the data and studies available to researchers at the time of this report is provided in **Appendix A.1**.

After review and analyses of collected data and information, vehicle trips and VMT were estimated for the six modes. It should be noted that the **VMT estimates are those vehicle miles on the road**. This study did not conduct analyses of a number of other metrics, such as net increases or decreases in travel due to the availability of these modes. This study focused on estimating the number of vehicle trips, average trip length (with and without passengers, where relevant), and the resulting total VMT as it is today and forecasted for 2030.

Assumptions and Limitations

To the researchers' knowledge, no one has attempted to estimate total number of trips or VMT for these modes of travel in Colorado. It should be noted that there is **high uncertainty in many estimates because of a lack of data** as some of these emerging mobility options are new and changing considerably over a relatively short period of time. Similarly, data on residential delivery was extremely limited since the behaviors of firms and drivers are not as widely understood and/or available compared with information on consumers. In the absence of directly observed data to validate estimates, a number of assumptions were made and are stated in this report. Some of these assumptions include the following:

- In the absence of local data, trip-making characteristics were **borrowed from other cities or regions**. It is recognized that things like average trip length and mode shares may differ between Colorado and these other places. Adjustments were made to account for Colorado's population and travel characteristics when reasonable and when there was adequate detail or data to make those adjustments.

- This study **does not account for any suppressed or induced VMT** as a result of these services being available. Because of this assumption, the total VMT for the state does not change in any estimates of VMT. Below are a couple of examples that demonstrate emerging mobilities' potential for suppressed or induced VMT.
    - A study by Martin and Shaheen (2016), estimated suppressed VMT in different cities. In this study, about 7% to 10% of carshare members reported not owning a car because of access to carshare. The VMT from those suppressed vehicles were estimated in different cities; the lower bound ranging from 1,290-1,867 and the upper bound ranging from 5,161-7,467 miles per year per customer.
    - A study by Henao (2017) in the Denver region estimated that TNC trips account for about 25% of all trips that would have occurred on non-motorized modes of travel like walk or bike and about 36% of counterfactual transit trips.
- This study does not account for any potential changes in the regulatory environment for these modes in the future. Similarly, there may be a number of social, cultural, or economic changes in the future that may impact these mobility providers or the public's preferences in using them.
- Without better data, estimates have not been provided at a detailed level of geography which might better measure varying impacts to the transportation system. For example, it is likely that TNC travel is higher in Central Business Districts and urban regions of the state where congestion is higher and the impacts of additional trips would be more pronounced. For example, additional delays experienced by Colorado residents due to disruptive impacts of TNC pick-ups and drop-offs in urban or congested areas is not addressed or measured in this study. Similarly, trip-making has not been estimated by time of day where, for some emerging modes, trips may be much more frequent in the peak, congested times of day, increasing the delay to (and emissions from) other drivers on the road.

These assumptions lead to limitations when interpreting the estimated baseline results. Due to lack of data and subsequent varying degrees of confidence in estimates, a range of trips and VMT are provided for each of the modes. These ranges should be acknowledged when interpreting results for various fee scenarios, which are solely based on the best estimates provided in this report.

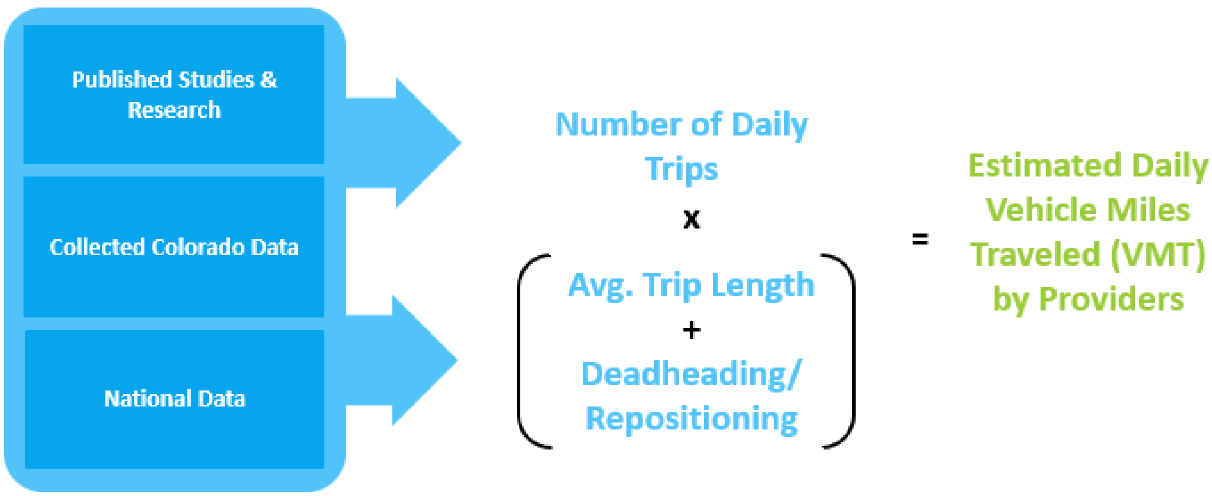
Overall Methodology

The methodological approach to estimating trips and VMT include the following steps:

1. Obtain any local data on trip-making for emerging mobility providers.
2. In the absence of local data, obtain data from providers in other states.
3. Modes for which there is a significant lack of data, and subsequently, high uncertainty in estimates, a number of methodologies were employed to estimate trips and VMT. The purpose of this was to decrease the level of certainty if results were similar even though the methods and data sources for estimation were different.

Figure 1.1 graphically presents the methodology, which involves taking all data collected for this study and estimating best estimates, along with low and high ranges where appropriate, for number of daily trips, average passenger trip length, and deadheading or repositioning to estimate total daily VMT for each emerging mobility mode. Given the lack of available local data, any data available was analyzed in the context of Colorado as well as several efforts to check "reasonableness" of estimates. These efforts often utilized "back-of-the-envelope" type calculations to ensure results are reasonable compared to other regions where data was available.

Figure 1.1 Methodology for Estimating Trip and VMT for Emerging Modes



Source: Cambridge Systematics, Inc.

2.0 Total Travel in Colorado

The Colorado Statewide Travel Demand Model (StateFocus) forecasts all personal travel made by every Colorado resident, plus commercial truck travel and visitor travel to or from Denver International Airport (DEN). The model forecasts travel for an average fall/spring weekday. The development of the statewide model was based on the Denver Regional Council of Governments (DRCOG)'s activity-based model but expanded to cover the entire state of Colorado, relying on 2010 Front Range Travel Counts Survey for information on Colorado resident's travel behavior as well as traffic counts and transit ridership to validate the model. Recent enhancements to the model allow a user to optionally evaluate the impact of connected autonomous vehicles (CAVs) as well as evaluate TNCs as a mode choice option.

A wealth of data is used as input to the model in order to explain travel in the region. This includes information on people, households, schools, and employment (socioeconomic data); road, nonmotorized, and transit networks (transportation supply); and other characteristics of the region. Outputs of the model include number of trips by mode and VMT for every resident. Currently available forecast years include a base year (2015) and future years for 2030 and 2045. For this study, data from the 2015 and 2030 scenarios were utilized to understand socioeconomic characteristics of the population, travel behavior choices, and estimates of the total travel in Colorado. **Table 2.1** and **Table 2.2** provide some key metrics used in this study, based on data input or output from the model.

Table 2.1 Colorado Population and Employment

MPO	Population			Employment		
	2015	2018	2030	2015	2018	2030
DRCOG	3,173,230	3,326,689	4,058,025	1,949,893	2,083,043	2,438,474
NFRMPO	539,221	580,625	766,748	296,331	321,235	393,528
PPACOG	699,417	732,811	892,270	364,562	397,440	495,150
PACOG	159,032	166,198	200,731	71,508	75,332	84,220
GVMPO	147,786	157,583	202,337	76,121	81,292	95,059
NonMPO	707,446	731,659	854,354	402,344	427,019	489,400
Statewide	5,426,132	**5,695,564**	**6,974,465**	3,160,759	**3,385,360**	**3,995,831**

Source: Cambridge Systematics, Inc.
2015 and 2030 socioeconomic data is directly from the model. 2018 socioeconomic data was interpolated between the two model years and adjusted to match total population and employment in 2018 as reported from the Census and Colorado State Demographer's Office, respectively.

Table 2.2 Colorado Trips and VMT

MPO	Person Trips (1,000s)			Personal VMT* (1,000s)			Total VMT* (Personal + Truck Travel) (1,000s)		
	2015	2018	2030	2015	2018	2030	2015	2018	2030
DRCOG	11,136	11,895	14,934	67,376	71,103	86,013	77,594	81,908	99,165
NFRMPO	1,872	2,042	2,723	10,524	11,720	16,505	11,822	13,145	18,437

MPO	Person Trips (1,000s)			Personal VMT* (1,000s)			Total VMT* (Personal + Truck Travel) (1,000s)		
	2015	2018	2030	2015	2018	2030	2015	2018	2030
PPACOG	2,424	2,568	3,143	12,251	13,242	17,205	13,829	14,942	19,395
PACOG	530	560	679	2,791	3,052	4,094	3,118	3,400	4,528
GVMPO	505	545	706	2,373	2,651	3,763	2,587	2,887	4,087
NonMPO	2,346	2,455	2,889	20,368	22,432	30,687	22,482	24,696	33,549
Statewide	18,813	**20,065**	**25,075**	115,684	**124,201**	**158,268**	131,432	**140,978**	**179,162**

* VMT reported here is assigned network VMT, meaning, the VMT on the roads within each region.

Source: Cambridge Systematics, Inc.
2015 and 2030 travel data is directly from the model. 2018 travel data was interpolated between the two model years and adjusted by a factor of 2018 interpolated population and the observed population from Census data.

3.0 TNC

In light of the growing popularity of TNCs in major metropolitan areas and the fact that TNCs can no longer be considered a fringe mode of transportation, it is important to investigate whether TNCs, such as Uber and Lyft, live up to their stated vision of reducing congestion by complementing transit and reducing car ownership in major cities. TNCs have been shown to be correlated to traffic congestion in cities like San Francisco[14] and Denver[15] in recent studies. TNCs represent a seemingly fledgling mode of transportation, but one that is demonstrably shaping and modifying extant transportation and mode choice trends.

TNCs in concept and operation are analogous to taxis but differ variedly from them, owing to their sheer numbers and in terms of trip and user characteristics. Several metropolitan cities (e.g. New York) have historically evaded the unchecked rise of taxis operating within their boundaries by a variety of means like stringent safety and insurance laws, and cordon-based medallion limits. This separation of commercial enterprises from private entities that had provided a method of identifying and regulating commercial transactions from private trips are redundant in the sharing economy. To this end, a literature review was conducted on published studies concerning TNC data. The following studies provide a deeper insight into the trip patterns and travel footprint of TNCs by either introducing or making use of highly disaggregate network-wide TNC data.

- San Francisco (Castiglione, J., Roy, S., et.al., 2019) - A before-and-after assessment between 2010 conditions where TNC activity was assumed to be negligible and 2016 conditions when they were not. The study concluded that 15% of intra-San Francisco vehicle trips in 2016 were made by TNCs. TNCs were estimated to be 52% of the increase in vehicle hours of delay (VHD) and 47% of the increase in VMT between 2010 and 2016.

- Chicago (Roy, S., 2019[16]) – A study in review that compares TNC trip characteristics to those of taxis by tracing changes in these metrics across two points in time – a five month period in the years 2013-2014 and 2018-2019. Both the TNC and taxi dataset comprise of trip start and end census tracts, actual trip length, trip time-of-day, travel time, and trip fare. One additional data item in the TNC trip dataset is whether the trip was pooled.

- Chicago (Momtaz, S. 2019[17])– Trip generation models was estimated by Cambridge Systematics based on Chicago and New York City TNC data from 2018. Trips for different times of day were estimated based on spatial characteristics like population and employment density for each participating census tract. This study was under TRB review at the time of this report.

[14] Castiglione, J., Roy, Sneha, et.al. (2019).The Effect of Transportation Network Companies on Congestion in San Francisco. TRB.

[15] Henao, Alejandro. Impacts of Ridesourcing-Lyft and Uber-on Transportation Including VMT, Mode Replacement, Parking, and Travel Behavior. University of Colorado at Denver, 2017.

[16] Roy, S., Komanduri, A., Proussaloglou, K. (2020 – In publication) Evolution of ride-hailing and ridesharing in Chicago: 2013-2018, Transportation Research Record - 2020

[17] Momtaz, S., Lemp, J., Komanduri, A., Roy, S. (2020 – In Review) Quantifying the Impact of App-Based Ride Share Systems: Findings from NYC and Chicago, Transportation Research Board -2020

- Denver (Henao, A., Marshall, 2016[18]) – In this study carried out in 2016, the researcher became a TNC driver and collected both survey-based data as well as TNC trip characteristics spread across various spatial geographies within Denver. Pooled trips were identified and separated from non-pooled TNC trips, and a relational database between user characteristics and trip metrics was created to produce exploratory insights within the data. Deadheading/cruising distances and time, pickup and drop-off destinations, trip lengths, fares, and passenger wait times were recorded as trip characteristics.

- Multiple Cities (Fehr & Peers, 2019[19])– In a 2019 study, Fehr & Peers combined data from the Highway Performance Monitoring system and that obtained from Uber and Lyft to calculate the percentage share of VMT generated by TNCs as a fraction of the total regional VMT. Spatial boundaries of the study differentiated between the core county as well as the high-level regional boundaries. A low and high range of total TNC VMT was calculated assuming drivers used both the platforms to search for rides. This analysis also differentiated between deadheading miles and ridesharing miles.

Other reviewed studies are provided in **Appendix A.1**.

3.1 Data

It is very common to run into data availability issues when dealing with TNC research and application. Due to the proprietary nature of the data protected by the companies that operate such vehicles, it is not common for city planners and demand modelers to have access to this data in as transparent a way as other public or privately operated transportation mode. A few research studies have overcome this challenge by making use of different data collection methods. Additionally, household travel surveys and recently released publicly-available TNC data at a disaggregate level provide another picture of TNC travel.

National Household Travel Survey

The National Household Travel Survey (NHTS) is a periodic national household travel diary survey used to assist transportation planners and policy makers who need comprehensive data on travel and transportation patterns in the United States. The NHTS serves as the nation's inventory of daily travel. Data is collected on daily trips taken by households and individuals in those households, over a 24-hour period, and includes:

- Purpose of the trip (work, shopping, social, etc.);
- Means of transportation (car, walk, bus, subway, etc.);
- Travel time of trip; and
- Time of day/day of week.

This data is collected for all trips, modes, purposes, and trips across the country, urban and rural. **Table 3.1** presents the available options for means of transportation, or mode, for each trip. **Table 3.2** presents the

[18] Henao, Alejandro, and Wesley E. Marshall. "The impact of ride-hailing on vehicle miles traveled." Transportation (2018): 1-22.

[19] Fehr & Peers. *Estimated TNC Share of VMT in Six US Metropolitan Regions*. Memorandum to Uber, August 2019. https://www.fehrandpeers.com/what-are-tncs-share-of-vmt/

resultant weighted mode shares of all trips in Colorado and Nationwide as well as the reported number of (unweighted) samples. **Figure 3.1** provides the trip length distribution for taxi/rideshare trips, as well as the average trip lengths for the persons' travel (this would not include any deadheading).

Table 3.1 2017 NHTS Mode Options

NHTS Mode Options	Mode Group
Walk	Walk
Bicycle	Bike
Car	Drive
SUV	Drive
Van	Drive
Pickup truck	Drive
Golf cart/segway	Drive
Motorcycle/moped	Drive
RV (motor home, ATV, snowmobile)	Drive
School bus	School bus
Public or commuter bus	Transit
Paratransit/dial-a-ride	Transit
Private/charter/tour/shuttle bus	Transit
City-to-city (Greyhound, Megabus)	Transit
Amtrak/commuter rail	Transit
Subway/elevated/light rail/street car	Transit
Taxi/limo (including Uber/Lyft)	Taxi/rideshare
Rental car (including Zipcar/car2go)	Car rental/carshare
Airplane	Other
Boat/ferry/water taxi	Other
Other	Other

Source: Cambridge Systematics analysis of 2017 National Household Travel Survey

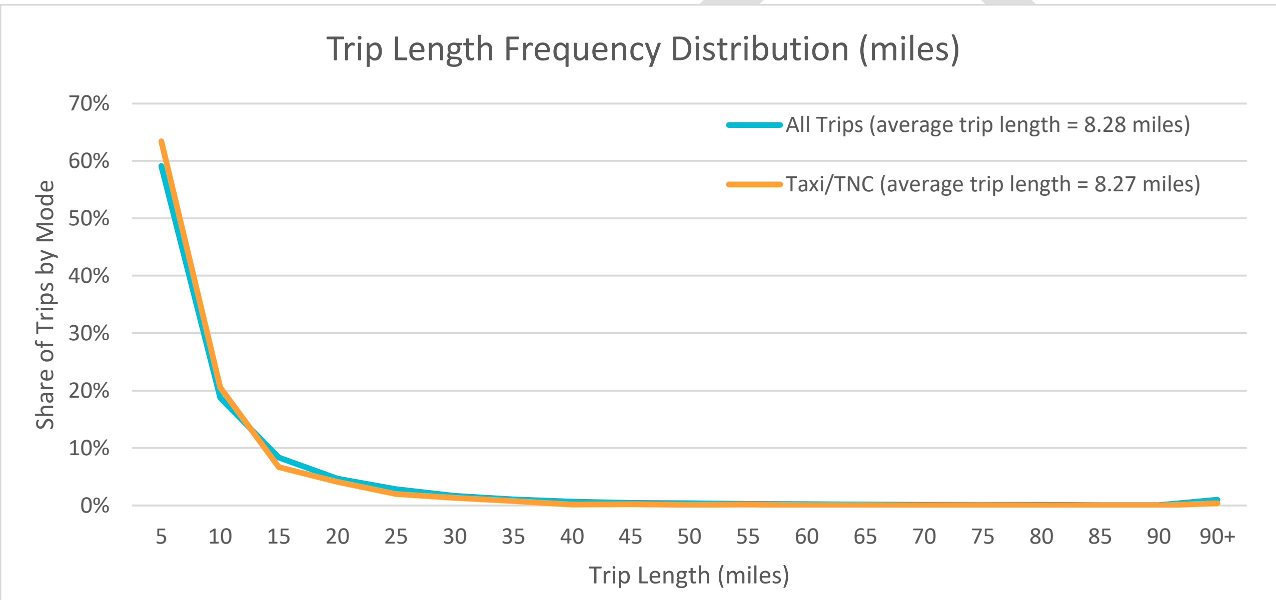
Table 3.2 NHTS Mode Shares, Weekday Trips

Mode Group	Colorado				Nationwide			
	Unweighted		Weighted		Unweighted		Weighted	
	Trips	Mode Share	Trips (1,000s)	Mode Share	Trips	Mode Share	Trips (1,000s)	Mode Share
Drive	2,008	82%	3,727,954	80%	611,563	86%	212,416,071	81%
Transit	43	2%	109,949	2%	11,257	2%	8,540,211	3%
Walk	285	12%	560,391	12%	61,311	9%	27,924,091	11%
Bike	54	2%	92,980	2%	6,150	1%	2,521,074	1%

Mode Group	Colorado				Nationwide			
	Unweighted		Weighted		Unweighted		Weighted	
	Trips	Mode Share	Trips (1,000s)	Mode Share	Trips	Mode Share	Trips (1,000s)	Mode Share
School bus	21	1%	40,935	1%	10,998	2%	6,778,131	3%
Taxi/rideshare	7	**0.29%**	12,771	**0.28%**	1,852	**0.26%**	1,225,293	**0.47%**
Car rental/carshare	16	**0.65%**	20,936	**0.45%**	1,486	**0.21%**	511,949	**0.20%**
Other	21	1%	66,276	1%	4,638	1%	1,857,125	1%
Total Trips	2,455		4,632,192		709,255		261,773,945	

Source: Cambridge Systematics analysis of 2017 National Household Travel Survey

Figure 3.1 Taxi/TNC Trip Length (NHTS)



Source: Cambridge Systematics analysis of 2017 National Household Travel Survey

In additional to the typical household travel survey trip data, the following question was asked of respondents (those of at least 16 years of age):

> *"In the past 30 days, how many times have you purchased a ride with a smartphone rideshare app (e.g., Uber, Lyft, Sidecar)?"*

Table 3.3 summarizes the responses to that question for Colorado residents as well as the entire dataset, nationwide. It may seem that more Colorado residents have used rideshare within the last month than the nationwide average; however, the low sample size of only 940 persons in Colorado should be noted as a limitation in extrapolating these results to the entire state.

Table 3.3 NHTS Rideshare App Use in Past 30 Days

Rideshare App Use (Times per Month)	Colorado				Nationwide			
	Unweighted		Weighted		Unweighted		Weighted	
	Persons	Percentage	Persons	Percentage	Persons	Percentage	Persons	Percentage
0	833	88%	4,104,196	87%	246,551	93%	276,271,841	92%
1	33	4%	159,777	3%	4,942	2%	6,245,758	2%
2	28	3%	149,163	3%	4,413	2%	6,128,432	2%
3	14	1%	85,646	2%	1,779	1%	2,544,664	1%
4	7	1%	44,332	1%	1,612	1%	2,485,143	1%
5	12	1%	70,933	2%	1,456	1%	2,458,909	1%
6	3	0%	21,384	0%	769	0%	977,803	0%
7+	12	1%	80,622	2%	2,376	1%	4,017,215	1%
Total	942		4,716,053		263,898		301,129,765	
Overall Average per Person			**0.01455**				**0.01126**	

Source: Cambridge Systematics, Inc. analysis of 2017 National Household Travel Survey

PSRC Household Travel Survey

The Puget Sound Regional Council (PSRC) conducts a regional household travel survey. This regional travel study aimed to obtain detailed information about the socioeconomic, demographic and travel behavioral traits existing in the region. The survey also obtained data about responder attitudes towards ride-sourcing services, values, attitudes, technology ownership and adoption, and future intended use of autonomous vehicle technologies apart from the regular socioeconomic and activity travel characteristics.

In 2015 and 2017, the survey asked how often the respondent uses ridesharing and carsharing. The response variables were ordinal in nature, namely: ‘I never do this’, ‘I do this, but less than once a month’, ‘I do this 1-3 times a month’, ‘I do this 1 day per week’, ‘I do this 2 or more days per week’. A study by Dias et al. (2017)[20] made use of the 2015 household travel survey and estimated the propensity of the survey responder to fall among one of these categories by regressing the indicator variables using a multivariate probit modeling method. The variables found significant in determining the frequency of use of carshare and/or TNCs were age, education level, employment type, smartphone ownership, household size, average income, and number of vehicles owned by their respective households.

Colorado Statewide Model: StateFocus

A recent effort to enhance the Colorado Statewide Model, StateFocus, included the addition of a TNC mode, which can be optionally included in model runs. At the time of that effort and this study, there was not sufficient data to re-estimate mode choice with TNCs nor was there sufficient data to fully calibrate the model. However, based on the data collected prior to and during this study effort the model was reasonably

[20] Dias, Felipe F., Patrícia S. Lavieri, Venu M. Garikapati, Sebastian Astroza, Ram M. Pendyala, and Chandra R. Bhat. "A behavioral choice model of the use of car-sharing and ride-sourcing services." Transportation 44, no. 6 (2017): 1307-1323.

calibrated to an estimated number of TNC person trips in the state as well as some characteristics of TNC users and their trip characteristics.

Many of the studies reviewed revealed common characteristics on TNC users[21] including higher education, higher income, younger, urban or high-density residents, and those with no vehicles in the household. Little consistent information is available, to the authors' knowledge, on the types of trips that are being made with TNCs. Rayle et. al. (2014)[22] noted that the survey of San Francisco ridesourcing users oversampled social and leisure trips, thus conclusions on prevalence of TNC trips by purposes based on that data are not recommended. A survey from MAPC[23] in Boston revealed three most popular activities for TNC trips originating from home: work, entertainment, and social visit. **Table 3.4** and **Table 3.5** provide some quantitative details of those studies' results.

[21] Dias, F. et.al. (2016). A Behavioral Choice Model of the Use of Car Sharing and Ride-sourcing Services. TRB

[22] Rayle, Lisa, Susan A. Shaheen, Nelson Chan, Danielle Dai, and Robert Cervero. App-based, on-demand ride services: comparing taxi and ridesourcing trips and user characteristics in San Francisco. No. UCTC-FR-2014-08. Berkeley, CA: University of California Transportation Center, 2014.

[23] Metropolitan Area Planning Council (MAPC). *Fare Choices. A Survey of Ride-hailing Passengers in Metro Boston*. An MAPC Research Brief. February 2018. http://www.mapc.org/wp-content/uploads/2018/02/Fare-Choices-MAPC.pdf

Table 3.4 Characteristics of TNC Users (Person Characteristics)

Study	Universe	Gender		Education				Age							
		Male	Female	High school or less	Some College	College Degree	Graduate Degree	18-25	26-30	31-35	36-44	45-54	55-64	65-74	75+
Blynn et. al. (2017)[24]	Share of TNC Users	57%	43%	6%	28%	49%	16%	27%	31%	21%	16%	4%	2%		0%
Grahn et. al. (2018)[25]	Share of TNC Users							15%		21%	13%	8%	5%	3%	1%
	NHTS Population	49%	51%	28%	31%	23%	18%								
	Share of TNC Users	52%	48%	9%	21%	37%	33%								
Rayle et. al. (2014)[26]	San Francisco Residents	51%	49%		46%	33%	21%	11%		22%	16%	14%	12%	7%	7%
	Share of TNC Users	60%	40%		16%	54%	27%	16%		57%	19%	6%	1%	0%	0%
Clewlow and Mishra (2017)[27]	Share of Population that are TNC Users	20%	23%	11%	14%	25%	28%		36%				60%		4%
2017 NHTS	Share of TNC Users, nationwide	54%	46%												

[24] Blynn, K, Sarriera, J. M., Escovar-Alvarez, G., Alesbury, A., Scully, T., Zhoa, Jinhua. *To Share or Not To Share: Investigating the Social Aspects of Dynamic Ridesharing*. 2017. TNC presentation, 17-03910.

[25] Grahn, R., Harper, C., Hendrickson, C., Qian, Z., Matthews, H. S. *Socioeconomic and Usage Characteristics of Transportation Network Company Riders*. 2019. TRB 2019 Annual Meeting. Paper No. 19-04584.

[26] Rayle, L., Shaheen, S., Chan, N., Dai, D., Cervero, R. *App-Based, On-Demand Ride Services: Comparing Taxi and Ridesourcing Trips and User Characteristics in San Francisco*. University of California Transportation Center (UCTC) Working Paper. November 2014.

[27] Clewlow, R., Mishra, G. S. *Disruptive Transportation: The Adoption, Utilization, and Impacts of Ride-Hailing in the United States*. UC Davis Institute of Transportation Studies. October 2017. Research Report UCD-ITS-RR-17-07. https://itspubs.ucdavis.edu/wp-content/themes/ucdavis/pubs/download_pdf.php?id=2752

Table 3.5 Characteristics of TNC Users (Household Characteristics)

Study	Universe	Household Income						Number of Vehicles in the Household		Vehicle Occupancy (number of passengers)		
		Less than $30k	$30k-$50k	$50k-$75k	$75k - $100k	$100k-$125k	$125k+	0	1+	1	2	3+
Blynn et. al. (2017)	Share of TNC Users	22%	24%	25%	13%		17%					
Grahn et. al. (2018)	Share of TNC Users											
	NHTS Population	19%	21%	16%	13%	10%	18%					
	Share of TNC Users	11%	13%	13%	13%	11%	37%					
Rayle et. al. (2014)	San Francisco Residents	26%		22%	13%		38%	31%	69%			
	Share of TNC Users	9%		23%	18%		38%	43%	57%			
Clewlow and Mishra (2017)	Share of Population that are TNC Users	15%		20%			58%					
	Share of TNC Users							40%				
2017 NHTS	Share of TNC Users, nationwide							32%	68%			
Henao et. al. (2017)	Share of TNC Users, nationwide									74%	18%	9%

Note: There are some differences in reported data of TNC trips by the trip-makers household income in terms of the income breakpoints.

The model was enhanced by adding a TNC mode choice option in the tour and trip mode choice models. The TNC mode options are TNC1 (ride alone), TNC2 (shared[28] TNC ride with two persons), and TNC3+ (shared TNC ride with three or more persons). **Figure 3.2** provides the StateFocus tour mode choice structure with TNCs. The model is sensitive to the following person or trip characteristics, as it relates to the TNC option:

- Trip purpose and time of day,
- Household income,
- TNC travel time and cost, and
- Availability of vehicles in the household.

Sensitivities to each of these components was estimated based on those from other modes and then calibrated to match TNC trip and rider characteristics.

Figure 3.2 Tour Mode Choice Structure

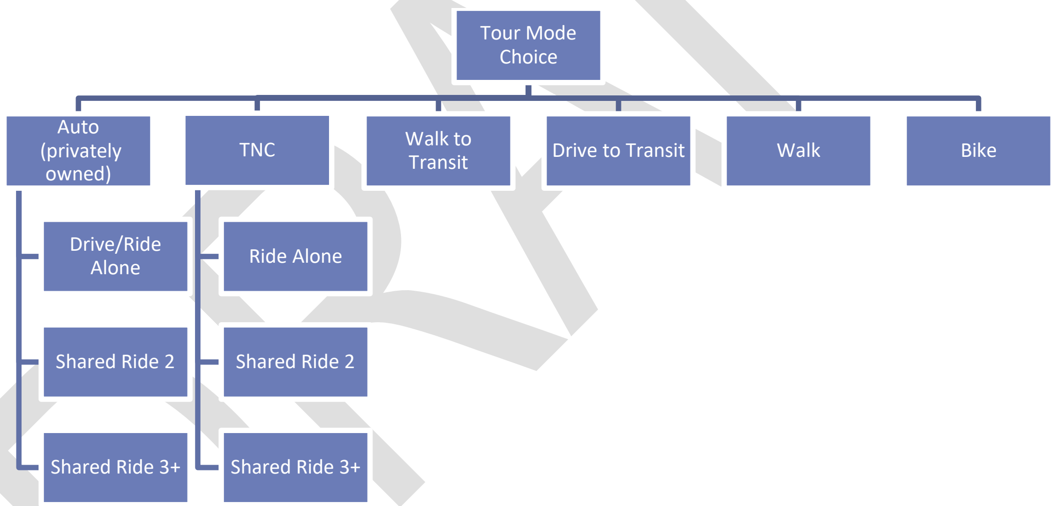


Table 3.6 provides the calibration targets and model results for StateFocus, as of the time of this report. Note that the intention of developing these model enhancements was to create a framework for analyzing TNC as a mode of travel. It is expected that the model will be updated as needed and as new data becomes available. Modeled TNC trip length was compared to the data sourced by Henao for his research by driving TNCs in the Denver region, and results of that comparison are provided in **Figure 3.3**. The modeled average person trip length for those using TNCs was 5.30 miles, and the average TNC vehicle trip length was 6.36 miles, which is very similar to the average vehicle trip length reported by the Denver-based study at 7 miles.

[28] Note that the model currently only includes TNC shared rides when they are shared with members of their household. The model does not account for "pooling" (also referred to as dynamic ridesharing or dynamic carpooling as a mobility option), meaning the service matches riders with other riders dynamically.

Table 3.6 StateFocus TNC Calibration Targets and Results

TNC Modes [1]	Target [2]	Modeled Result	Auto Ownership	Target [3]	Modeled Result	Household Income	Target [4]	Modeled Result
TNC1	74%	70%	No cars	19%	21%	< $25k	19%	28%
TNC2	18%	21%	Cars < drivers	15%	11%	$25k - $75k	26%	20%
TNC3+	8%	9%	Cars >= drivers	66%	68%	$75k - $100k	12%	17%
						$100k - $150k	13%	15%
						$150k+	30%	20%

Source: Cambridge Systematics, Inc.

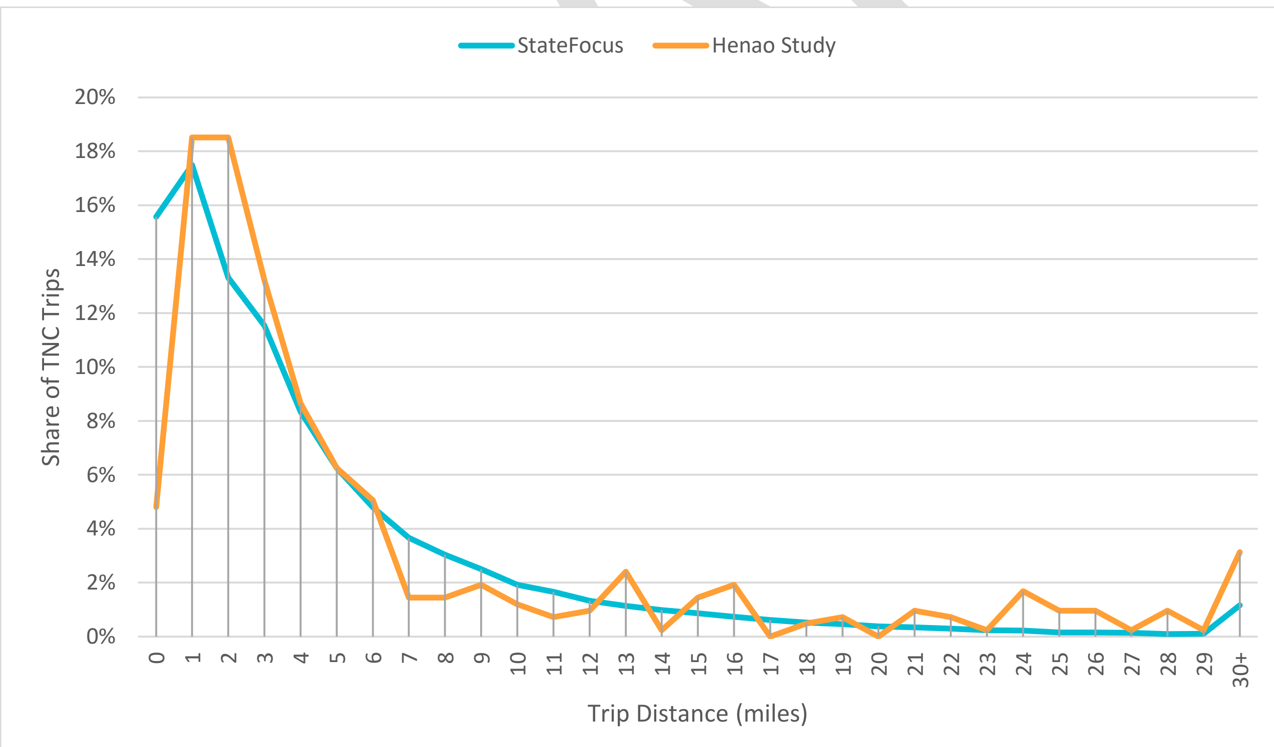
Notes: [1] TNC1 is a TNC trip with one passenger, TNC2 is a TNC trip with two passengers, and TNC3+ is a trip with 3 or more passengers. The model does not include pooled travel.

[2] Target shares of TNC trips by occupancy were assumed from Henao's data because it's locally-specific.

[3] Note that the number of zero-auto households in Colorado (5%) is lower than the nationwide average (9%), according to recent American Community Survey data. Therefore, the split of TNC users by auto availability was scaled down for zero-auto households from the 2017 NHTS data given the overall lower share of such households.

[4] Target shares of TNC trips by household income were assumed from the 2017 NHTS data.

Figure 3.3 Modeled TNC Trip Length Frequency Distribution (Base Year)



Source: Cambridge Systematics, Inc.

Disaggregate Data

Most existing studies that attempt to capture the mobility patterns of emerging mobility options are based survey data. TNCs were not required to publicly report their trip data until recently. This requirement is also limited to two cities at the time of documenting this report – Chicago and New York. Increasingly, more cities have released disaggregate TNC data for various reasons.

- City of Chicago released data in 2019.
- City of New York released data in 2018.
- The Massachusetts Department of Public Utilities released data in 2017.[29]
- At the time of writing this report (September 2019), the City of Seattle released TNC data following a public-records request, but the data not available in time to be analyzed for this study.

3.2 Existing Conditions (2018) Estimates

3.2.1 Service Coverage Areas

TNC providers in Colorado include Uber, Lyft, and HopSkipDrive, and their collective service areas are provided in **Figure 3.4**.

Figure 3.4 TNC Provider Coverage Areas

Maps of the coverage areas are included in the research paper titled "Transportation Provider Service Coverage in Disadvantaged Areas in Colorado" that is an appendix to the Emerging Mobilities Impacts Study report.

3.2.2 Methodologies for Estimates

Since there was no readily available data on TNC trips in Colorado at the time of this study, a combination of survey data, published research, and publicly-available TNC data applied to the context of Colorado allowed researchers to develop multiple estimates of TNC travel in Colorado. Since there was no data to validate these estimates, a variety of methodologies were utilized to estimate potential lower and upper bounds for the number of TNC trips and total TNC VMT in Colorado.

This section provides details on the development of those estimates and the recommended low, high, and best estimates of TNC travel in Colorado, and is organized based on the data underlying each methodology: i) the 2017 NHTS, ii) PSRC Household Travel Survey, iii) Chicago TNC data, and iv) the Fehr & Peers Study.

[29] https://tnc.sites.digital.mass.gov/2017/

National Household Travel Survey

As noted in **Section 3.1**, the NHTS asked respondents how often they use rideshare apps as well as travel diary responses that provide the number of times respondents actually used TNCs or taxis for travel on their travel day.

Reported ridesharing frequency was analyzed to obtain average number of daily rideshare trips per person. This data was summarized for both Colorado and, considering the relatively low sample size of records in Colorado, the entire national dataset to provide a range of estimates. Multiplying those TNC trip rates by the number of persons in Colorado results in a range of 59,500-87,800 TNC person trips, or 43,800-64,600 TNC vehicle trips, as shown in **Table 3.7.**

Table 3.7 NHTS Rideshare Frequency of Use to Estimate TNC Trips in Colorado

Metric	Colorado	Nationwide
Average number of uses, per day per person	0.01455	0.01126
Number of persons in Colorado in 2018 (ages 16+)	4,572,754	4,572,754
Estimated 2018 TNC person trips, per person per day	**66,547**	**51,419**
Estimated 2018 TNC vehicle Trips, per day	**48,932**	**37,861**

Source: Cambridge Systematics, Inc.

Notes: Person trips were converted to vehicle trips by applying an average TNC vehicle occupancy rate of 1.36 persons per vehicle, based on NHTS data and applied throughout this analysis to convert TNC person to vehicle trips and vice versa.

Frequency of rideshare use was based on weighted 2017 NHTS responses.

As shown in **Table 3.2**, an analysis of travel diary data from the NHTS revealed TNC mode shares for taxi and rideshare at 0.28% for Colorado and 0.47% Nationwide. Considering the low sample size in Colorado and potential bias of the nationwide dataset to be more likely to reflect areas of higher TNC activity (such as San Francisco or New York), it is reasonable to assume that the actual number of TNC trips might be in this range of 0.28%-0.47% of all person trips, which results in 35,600 – 63,500 TNC vehicle trips per day, as shown in **Table 3.8**.

Table 3.8 NHTS Mode Shares to Estimate TNC Trips in Colorado

Metric	Colorado	Nationwide
Taxi/TNC mode share	**0.28%**	**0.47%**
Total person trips in Colorado	20,065,224	20,065,224
Estimated 2018 taxi/TNC person trips per day	55,884	93,918
Estimated 2018 taxi/TNC vehicle trips per day	41,091	69,057
Estimated 2018 taxi vehicle trips per day	5,522	5,522
Estimated 2018 TNC vehicle trips per day	**35,569**	**63,535**

Source: Cambridge Systematics, Inc.

Note: The current number taxi trips can be found in **Table 4.1**.

A 1.36 vehicle occupancy factor was applied to the taxi/TNC person trips to obtain vehicle trips.

PSRC Household Travel Survey

PSRC Household Travel Survey data was used in two ways:

1. The responses to frequency of rideshare use was used to calculate an average number of rideshare trips per day and applied to the population of Colorado in areas where there is TNC service (under the assumption that the PSRC surveyed respondents all live in areas of TNC service, or, TNC service exists for the entire PSRC region surveyed). Estimates based on this methodology are summarized in **Table 3.9**.

2. A model (Dias et al., 2017) was estimated based on the 2015 data to predict frequency of rideshare. The proclivity towards using TNCs by Colorado residents was hence modeled by recreating this database of variables pertaining to the population of Colorado, using StateFocus's synthetic population. The model is estimated and applied at the person level, and not at the individual trip level. The model is therefore not akin to a traditional mode choice model that may include explanatory variables such as trip time or cost; rather, it is a person level model that purports to shed light on the potential adoption and intensity of use of TNCs while accounting for unobserved lifestyle preferences that may affect their use. Estimates based on this methodology are summarized in **Table 3.10**. The model specification can be found in **Appendix A.2**.

These estimates make use of both 2015 and 2017 survey data. Two estimates based on 2015 survey data result in low estimates – 22,500 or 29,000 TNC vehicle trips per day. The estimate based on 2017 survey data is considerably higher at 88,500 vehicle TNC trips per day.

Table 3.9 Frequency of Ridesharing based on 2015 and 2017 PSRC Household Survey Data

Frequency of ridesharing	PSRC Household Survey Results		Application of Model	Avg. Daily Rides per day
	2015	2017		
Never	87.1%	51.8%	90.0%	0
Less than 1 day per month	5.3%	19.0%	4.5%	6/365
1-3 days per month	4.8%	18.8%	4.6%	2/30
1 day per week	1.8%	5.2%	0.4%	1/7
2-4 days per week	0.7%	4.4%	0.6%	3/7
5 days per week	0.1%	0.6%		5/7
6-7 days per week	0.2%	0.2%		6.5/7
Sample Size	3,800	4,742		
Overall average number of rides per day	0.012	0.048		
Colorado population in TNC service areas	2,503,543	2,503,543		
Number of TNC person trips per day	**30,579**	**120,383**	**39,459**	
Average number of TNC vehicles per day	**22,484**	**88,517**	**29,014**	

Source: Cambridge Systematics, Inc.
Note: A 1.36 vehicle occupancy factor was applied to the TNC person trips to obtain vehicle trips.

Table 3.10 Estimate of TNC Trips based on 2015 PSRC Frequency of Use Model Application

MPO	Total TNC Trips	Share of Total Estimated TNC Trips by Region
DRCOG	32,908	83%
NFRMPO	2,187	6%
PPACOG	3,680	9%
PACOG	0	0%
GVMPO	518	1%
NonMPO	166	0%
Estimated 2018 TNC person trips per day	39,459	
Estimated 2018 TNC vehicle trips per day	**29,014**	

Source: Cambridge Systematics, Inc.
Note: A 1.36 vehicle occupancy factor was applied to the TNC person trips to obtain vehicle trips.

TNC Trip Generation Model for Chicago

In a recent investigative effort by Cambridge Systematics, publicly available 2018 rideshare data from Chicago and New York City were explored to investigate the potential use of these data for development of a predictive model, as described in a paper submitted to TRB for the 2020 annual meeting. Simple regression based trip generation models were estimated for both cities. The exogenous variables were used to predict the generated TNC trip at a Census Tract (for Chicago) or TAZ (for New York City) level. The model estimation results identified the statistically significant variables. These variables included population and employment density, access to major transit centers, median household income, and the presence of college campuses. The estimate results of the Chicago model is provided in **Appendix A.3**.

For this study, the Chicago model was applied to the state of Colorado to estimate the base year TNC trip generation at the Census tract level. The population, employment, and household income information are collected from the Census data for the year of 2015. The application of the model to the state of Colorado was applied only to the tracts that have TNC service. The results of this application are provided in **Table 3.11**.

Table 3.11 Application of Chicago TNC Trip Generation Model

MPO	TNC Vehicle Trips	Share of Total Estimated TNC Trips by Region
DRCOG	49,043	67%
NFRMPO	6,960	10%
PPACOG	11,383	16%
PACOG	53	0%
GVMPO	3,161	4%

MPO	TNC Vehicle Trips	Share of Total Estimated TNC Trips by Region
NonMPO	2,286	3%
Estimated 2018 TNC vehicle trips per day	72,885	

Source: Cambridge Systematics, Inc.

Chicago TNC and Taxi Data

Based on the rich data provided by Chicago, another tested approach was assuming that one might be able to estimate TNC use by how many taxi trips are taken in the region, as a proxy for visitor activity and other resident activities that are not completed by typical transportation modes, like transit or privately-owned vehicle trips. Using that approach, a factor of 7.38 was applied to the estimate of taxi trips in Colorado (provided in **Table 4.1**), resulting in 40,800 TNC vehicle trips in Colorado, as shown in **Table 3.12**.

Table 3.12 Application of Chicago TNC to Taxi Trip Ratio

Mode	Vehicle Trips	
	Chicago [1] (2018)	Colorado (2017)
Taxi	42,110	5,522
TNCs	310,943	**40,775**
Ratio of TNCs to Taxis	7.38	

Source: [1] Roy et al. (2019). Trips for the time period of data were averaged to daily trips.

Fehr & Peers Study

Using the reported TNC VMT as a share of total VMT for the core counties studied by Fehr & Peers, as summarized in **Table 3.13**, a linear regression was estimated to predict the TNC share of VMT based on the population and employment density and total VMT (which includes both personal travel and truck travel), as shown in **Figure 3.5**. Applying this equation to regions across Colorado yielded in an estimate of 1,400,000 TNC VMT for the state of Colorado, as shown in

Table 3.14.

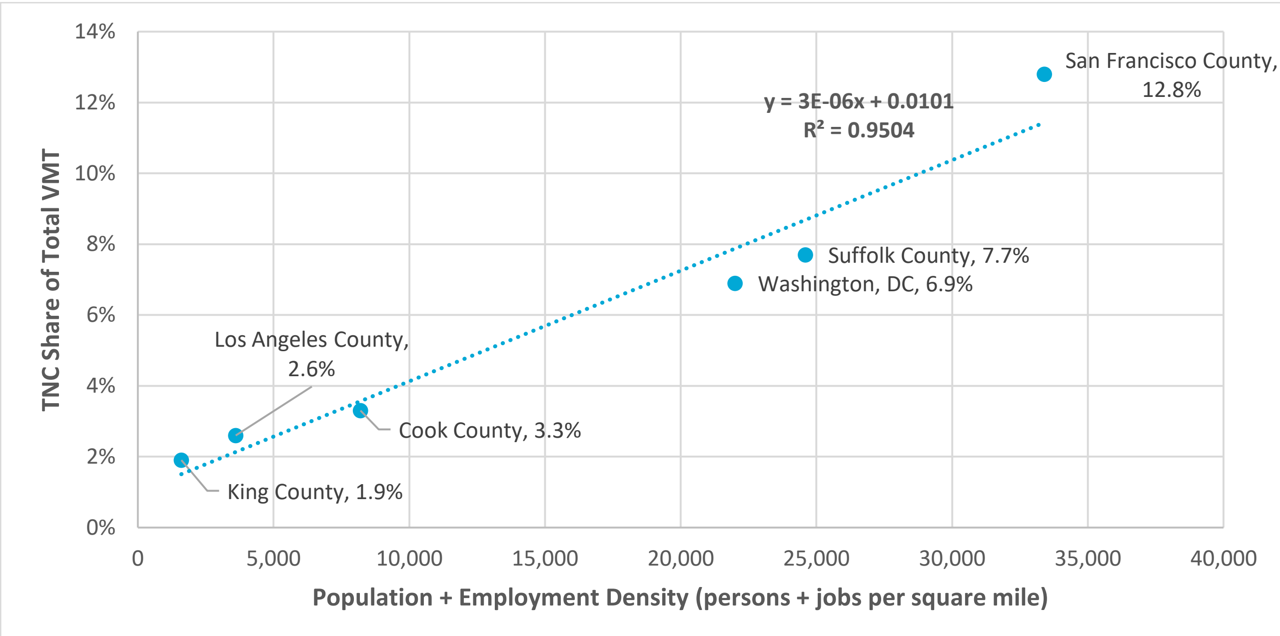
Table 3.13 Observed TNC VMT Shares of Total VMT

Core County	TNC VMT Share of Total VMT	Metro Region	TNC VMT Share of Total VMT
Suffolk County	7.7%	Boston	2.0%
Cook County	3.3%	Chicago	2.1%
Los Angeles County	2.6%	Los Angeles	1.4%
San Francisco County	12.8%	San Francisco	2.9%
King County	1.9%	Seattle	1.1%

Core County	TNC VMT Share of Total VMT	Metro Region	TNC VMT Share of Total VMT
Washington, DC	6.9%	Washington, DC	1.8%

Source: Fehr & Peers (2019)

Figure 3.5 TNC Share of Total VMT, by Population + Employment Density



Source: Cambridge Systematics, Inc., analysis of Fehr & Peers study

Table 3.14 Application of TNC VMT Estimates, based on 2018 Colorado Population and Employment Density

MPO	Population and Employment Density	Total VMT	Estimated TNC Share of Total VMT	Estimated TNC VMT	Estimated TNC Trips [3]
DRCOG	876	81,908,182	1.3%	1,048,285	89,551
NFRMPO	295	13,144,699	1.1%	144,380	12,334
PPACOG	420	14,942,300	1.1%	169,977	14,520
PACOG	101	3,399,865	0.0%[1]	0	0
GVMPO	71	2,886,925	1.0%	29,698	2,537
Non-MPO	13	24,695,782	0.0%[2]	4,101	350
Statewide	87	140,977,754		**1,396,441**	**119,292**

Source: Cambridge Systematics, Inc.

Notes: [1] The estimated TNC share of total VMT was postprocessed to 0% for the PACOG region because there is currently no TNC service in that region.

[2] The estimated TNC share of total VMT was postprocessed to a very small percentage (0.02%, based on analyses of other approaches for estimates) for the non-MPO regions because there is limited TNC service in that region.
[3] An assumed average TNC trip length of 11.7 miles (7 miles of passenger travel plus an average deadheading share of 41% of total TNC VMT) was applied to VMT to estimated number of trips.

3.2.3 Range of Estimates

The data collected and analyses performed resulted in ranges of observed metrics and estimates of TNC trips in Colorado, including the number of person and vehicle trips, average passenger trip length, deadheading, and total TNC VMT.

Number of Trips

Applying available TNC data to Colorado population and trip-making characteristics and utilizing a variety of approaches and methodologies yields an estimate of approximately 20,000-120,000 TNC vehicle trips in Colorado, as shown in **Table 3.15** and graphically in **Figure 3.6**. The lowest estimates are based on data from 2015 and higher estimates are based on the most recent data. Also shown in **Figure 3.6** are the vehicle trips for Seattle during this same time period[30]; both trends are similar. This suggests that the better estimates may be based on the most recent data, considering the rate at which TNC usage is increasing over time. Therefore, estimates based on 2015 data were excluded from

Considering this range of 36,000 to 119,000 vehicle trips, the best estimate for 2018 was determined to be approximately 63,400, an average of all estimates based on 2017 or later data. For context and a check for reasonableness, current TNC trips reported for other cities or regions can be found in **Table 3.16**.

Table 3.15 Colorado 2018 TNC Vehicle Trip Estimates

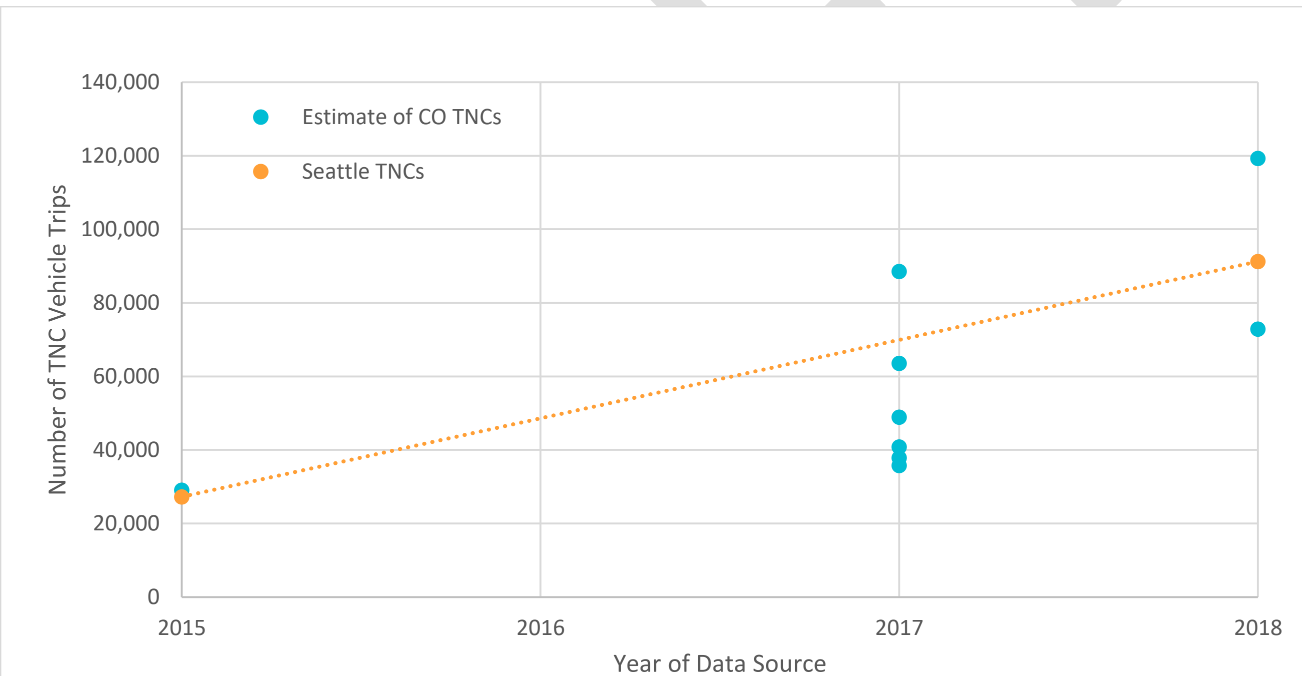
Primary Data Source	Year of Data	TNC Person Trips	TNC Vehicle Trips	Methodology
PSRC Survey	2015	30,600	22,500	Applied average frequency of rideshare use to CO population
Diaz et al (2015) model	2015	39,500	29,000	Applied model of TNC use in PSRC region to StateFocus zonal data
NHTS	2017	48,700	35,800	Applied Colorado mode shares (0.28%) to CO trips
NHTS	2017	86,400	63,500	Applied nationwide mode shares (0.47%) to CO trips
NHTS	2017	66,500	48,900	Applied Colorado average frequency of rideshare use to CO population
NHTS	2017	51,500	37,900	Applied Nationwide average frequency of rideshare use to CO population
PSRC Survey	2017	120,400	88,500	Applied average frequency of rideshare use to CO population

[30] Gutman, David. *How popular are Uber and Lyft in Seattle? Ridership numbers kept secret until recently give us a clue*. Seattle Times, November 5, 2018. https://www.seattletimes.com/seattle-news/transportation/how-popular-are-uber-and-lyft-in-seattle-ridership-numbers-kept-secret-until-recently-give-us-a-clue/

Primary Data Source	Year of Data	TNC Person Trips	TNC Vehicle Trips	Methodology
Chicago Taxis and TNCs	2018	55,500	40,800	Applied Chicago ratio of TNC trips to taxi trips
Chicago TNC Trip Generation Model	2018	99,100	72,900	Applied TNC trip generation model to CO Census Tracts
Fehr & Peers Study	2018	162,200	119,300	Estimated TNC share of total VMT divided by average total trip length
Best Estimate			**63,400**	An average of all results based on 2017 or later data
Low Estimate			**38,300**	An average of the lower end of results
High Estimate			**119,300**	Highest estimate of TNC vehicle trips

Source: Cambridge Systematics, Inc.

Figure 3.6 Colorado 2018 TNC Vehicle Trip Estimates by Year of Data Source



Source: Cambridge Systematics, Inc.

Table 3.16 Estimates of TNC Trips per Day for Other Cities or Regions

Geography	Year of Estimate	Population	Number of TNC Vehicle Trips per Day	Average TNC Trips per Person	Source
Seattle	2018, Quarter 2	3,940,000	91,200	0.02	How popular are Uber and Lyft in Seattle – David Gutman
San Francisco (Intra)	2016 (Weekday)	876,000	170,000	0.19	TNCs Today, TNCs and Congestion
Boston	2017	685,000	95,600	0.14	Gehrke et al. (2018)[31]
Massachusetts	2017	6,863,000	177,500	0.03	Gehrke et al. (2018)
Chicago	November 2018-March 2019	2,706,000	286,000	0.11	Roy et al. (2020)[32]
New York	2018	8,399,000	650,000	0.08	Momtaz et al. (2020)[33]

Notes: Where annual TNC trips were available, a factor of 1/365 was applied to estimate daily trips.

Passenger Trip Length

Review of recent TNC studies revealed that average TNC passenger trip length ranges from 2.60-8.27 miles, as shown in **Table 3.17**.

For the purpose of this study, **the average TNC passenger trip length is assumed to be 7 miles**. This value was chosen because it is locally-specific and reasonable compared to other estimates available. For example, San Francisco is geographically much smaller than the Denver metro area; shorter trip lengths would be expected in San Francisco compared to Denver.

Table 3.17 TNC Passenger Trip Length

Data Source	Year of Data	Geography	TNC Passenger Trip Length (miles)	Notes
2017 NHTS	2017	Nationwide	8.3	Includes both taxi and TNCs
Henao, A. (2017)	**2016**	**Denver**	**7.0**	
Roy, S. (2019)	2018	Chicago	5.8	
TNC's Today[34]		San Francisco	2.6	

[31] Gehrke, S., Felix, A., Reardon, T. "Fare Choices; A Survey of Ride-Hailing Passengers in Metro Boston" (Metropolitan Area Planning Council, 2018).

[32] Roy, S., Komanduri, A., Proussaloglou, K. (2020 – In publication) Evolution of ride-hailing and ridesharing in Chicago: 2013-2018, Transportation Research Record – 2020

[33] Momtaz, S., Lemp, J., Komanduri, A., Roy, S. (2020 – In Review) Quantifying the Impact of App-Based Ride Share Systems: Findings from NYC and Chicago, Transportation Research Board -2020

[34] Castiglione, Joe, Tilly Chang, Drew Cooper, Jeff Hobson, Warren Logan, Eric Young, Billy Charlton et al. "TNCs today: a profile of San Francisco transportation network company activity." San Francisco County Transportation Authority (June 2016) (2016).

Deadheading (non-passenger) Miles

Review of recent TNC studies revealed that deadheading (non-passenger) travel accounts for approximately 20%-50% of total TNC VMT, as shown in **Table 3.18**. For the purposes of this study, **the average deadheading (non-passenger) share of TNC is assumed to be 41%**. This value was chosen because it is locally-specific and reasonable compared to other estimates available.

Table 3.18 TNC Deadheading (non-passenger) Miles

Location of Study	Deadheading Share of Total TNC VMT	Data Source	Study
Denver	**41%**	**Driver data**	**Henao and Marshall (2018)**
Austin	37%	RideAustin TX	Komanduri et al (2018)[35]
New York	50%		Schaller (2018)[36]
San Francisco	20%	Uber and Lyft API data	SFCTA (2017)[37]
Boston	34%		
Chicago	35%		
Los Angeles	27%	Uber and Lyft Data	Fehr and Peers Study (2019)
Seattle	36%		
Washington DC	35%		

Total VMT

Applying an average passenger trip length of 7 miles with 41% of total TNC VMT as deadheading (a total of almost 12 miles per trip) to the range of TNC vehicle trip estimates results in a range of VMT estimates, as summarized in **Table 3.19**.

Table 3.19 Colorado 2018 TNC VMT Estimates

Year of Underlying Data	Number of TNC Vehicle Trips	Total TNC VMT	Methodology
2015	22,500	263,400	Applied average frequency of rideshare use to CO population
2015	29,014	339,600	Applied model of TNC use in PSRC region to StateFocus zonal data
2017	35,789	418,900	Applied Colorado mode shares (0.28%) to CO trips
2017	63,535	743,700	Applied nationwide mode shares (0.47%) to CO trips

[35] Komanduri, Anurag, Zeina Wafa, Kimon Proussaloglou, and Simon Jacobs. "Assessing the impact of app-based ride share systems in an urban context: Findings from Austin." *Transportation Research Record* 2672, no. 7 (2018): 34-46.

[36] Schaller, Bruce. "The new automobility: Lyft, Uber and the future of American cities." (2018).

[37] San Francisco County Transportation Authority. 2017. “TNCs Today: A Profile of San Francisco Transportation Network Company Activity.” https://www.sfcta.org/sites/default/files/content/Planning/TNCs/TNCs_Today_112917.pdf

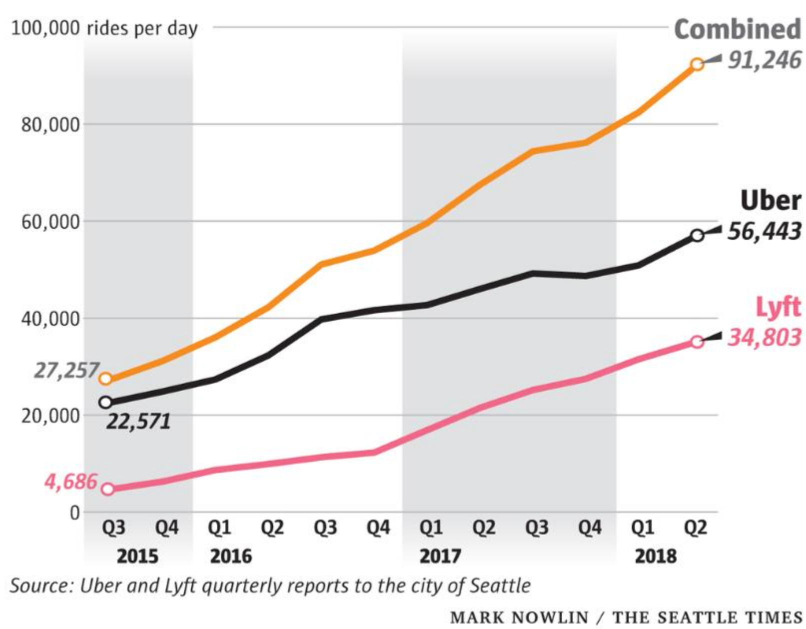
Year of Underlying Data	Number of TNC Vehicle Trips	Total TNC VMT	Methodology
2017	48,932	572,800	Applied Colorado average frequency of rideshare use to CO population
2017	37,861	443,200	Applied Nationwide average frequency of rideshare use to CO population
2017	88,529	1,036,300	Applied average frequency of rideshare use to CO population
2017	40,775	477,300	Applied Chicago ratio of TNC trips to taxi trips
2018	72,885	853,200	Applied TNC trip generation model to CO Census Tracts
2018	119,292	1,396,400	Estimated TNC share of total VMT divided by average total trip length
	63,450	**742,700**	**Best Estimate**
	38,300	**448,300**	**Low Estimate**
	119,292	**1,396,400**	**High Estimate**

Source: Cambridge Systematics, Inc.

3.3 Future Year (2030) Forecasts

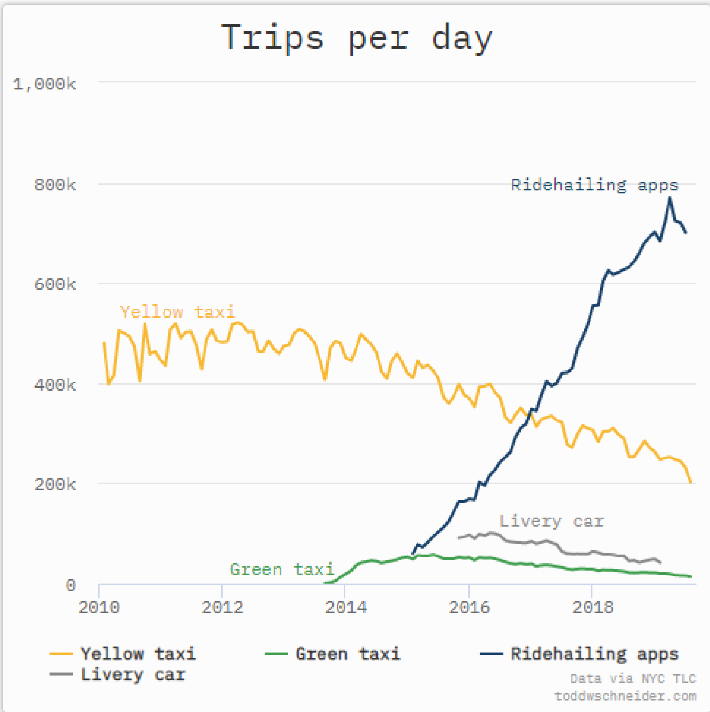
To forecast TNC travel in 2030, expected population and employment growth and the current trajectory of rapidly increasing TNC usage were two important considerations. Recently released TNC trip information from Seattle (**Figure 3.7**) and New York (**Figure 3.8**) reveal a rapidly increasing number of TNC trips over the past few years. It is probably safe to assume that TNC travel will continue increasing but likely not sustaining the current rate of growth (a 50% compound annual growth rate in Seattle) through 2030.

Figure 3.7 Seattle TNC Trip Trends (2015-2018)



Source: Gutman, David. *How popular are Uber and Lyft in Seattle? Ridership numbers kept secret until recently give us a clue*. Seattle Times, November 5, 2018. https://www.seattletimes.com/seattle-news/transportation/how-popular-are-uber-and-lyft-in-seattle-ridership-numbers-kept-secret-until-recently-give-us-a-clue/

Figure 3.8 New York City TNC Trip Trends (2010-2019)



Source: https://toddwschneider.com/dashboards/nyc-taxi-ridehailing-uber-lyft-data/

3.3.1 Methodologies for Estimates

Different approaches were implemented to estimate a range of TNC travel in 2030. The primary methodologies implemented included:

- Application of StateFocus, which resulted in the same mode shares (or propensities) as estimated today in Colorado;
- Assumption that an increase in TNC market will result in mode shares observed today in the Chicago region today, where the density today is similar to the forecasted density of Denver in 2030; and
- Assumption that an increase in TNC market will result in mode shares observed today in San Francisco, as an example of attainable TNC travel but much higher than experienced in Colorado and many other places in the county today.

StateFocus

The calibrated parameters, a result of the base year model calibration described in **Section 3.1**, were applied to the 2030 StateFocus scenario. The results of that model run are provided in **Table 3.20**, which show a 27% increase between the 2015 and 2030. Applying that 27% increase to the best estimate for 2018 results in **an estimated 80,686 TNC vehicle trips in 2030**.

Table 3.20 StateFocus Model Results for TNC Travel Estimates

Metric		2015	2030	Percent Change
Person Trips	TNC person trips	64,051	80,976	26%
	Total person trips	18,768,148	24,556,876	
	TNC mode share	0.34%	0.33%	
	Average TNC Trip Length	5.30	5.66	
Vehicle Trips	TNC person trips	53,306	67,786	**27%**
	Average TNC Trip Length	6.36	6.76	

Source: Cambridge Systematics, Inc.

Assuming Chicago Propensities

Using information from the Fehr & Peers study, today's population and employment density for the Chicago region is about 1,100 persons and jobs per square mile. Today, the DRCOG region has a population and employment density of about 880, but it is projected to rise to 1,050 in 2030. Given the relatively comparable densities of the Chicago region today and Denver region in 2030, it was assumed that one possible future would be TNC trip-making observed today in Chicago could be observed in Colorado in 2030. That propensity was measured as TNC VMT to be 2.1% of the total VMT (personal and truck travel combined). **Table 3.21** provides the results of that assumption.

Table 3.21 2030 TNC Trips and VMT, assuming Chicago-level Propensities

MPO	2030 Population + Employment Density	Total VMT	TNC VMT	TNC Vehicle Trips *
DRCOG	1,054	99,165,457	2,038,757	174,162
NFRMPO	380	18,437,149	379,052	32,381
PPACOG	516	19,395,045	398,746	34,063
PACOG	119	4,527,674	93,085	7,952
GVMPO	89	4,087,170	84,029	7,178
Non-MPO	16	33,549,231	689,744	58,922
Total	105	179,161,725	**3,683,412**	**314,658**

Source: Cambridge Systematics, Inc.
* An average trip length of 11.7 miles (passenger travel and deadheading) was assuming to convert VMT to vehicle trips.

Assuming San Francisco Propensities

Again using information from the Fehr & Peers study, the share of TNC travel is the highest for San Francisco, out of the core counties studied. This is an example of attainable TNC travel but much higher than what is observed in Colorado today. If we were to assume that TNCs continue to grow in popularity and TNC mode shares reach the level that San Francisco sees today, that would result in approximately 12.8% of total VMT (Fehr & Peers 2019). **Table 3.22** provides the results of that assumption, applied only to areas that currently have TNC service because it is assumed that TNCs would not reach that level of mode share in rural areas or areas unserved by TNCs today.

Table 3.22 2030 TNC Trips and VMT, assuming San Francisco-level Propensities

MPO	Total VMT	VMT in TNC Service Areas Only	TNC VMT	TNC Trips *
DRCOG	99,165,457	45,894,985	5,874,558	501,838
NFRMPO	18,437,149	9,919,197	1,269,657	108,461
PPACOG	19,395,045	16,381,111	2,096,782	179,119
PACOG	4,527,674	0	0	0
GVMPO	4,087,170	3,053,083	390,795	33,384
NONMPO	33,549,231	2,555,012	327,042	27,938
Total	179,161,725	77,803,388	**9,958,834**	**850,740**

Source: Cambridge Systematics, Inc.
* An average trip length of 11.7 miles (passenger travel and deadheading) was assuming to convert VMT to vehicle trips.

3.3.2 Range of Estimates

Several different approaches were implemented to estimate TNC travel in 2030, the primary estimates included:

- Application of StateFocus, which resulted in the same mode share (or propensities) estimated today in Colorado – an estimate of **81,000 vehicle trips**;
- Assuming an increase in TNC market will result in mode shares observed today in the Chicago region today, where the density today is similar to the forecasted density of Denver in 2030 – an estimate of **315,000 vehicle trips**; and
- Assuming an increase in TNC market in Colorado will result in mode shares observed today in San Francisco, as an example of attainable TNC travel but much higher than experienced in Colorado or many other places in the county – an estimate of **850,000 vehicle trips**.

These analyses led to an estimated 81,000 to 850,000 TNC vehicle trips per day in Colorado in 2030, with a best estimate of 315,000 vehicle trips. Assuming the same average trip length and deadheading, estimates for 2030 TNC VMT range from 950,000 to 10 million. This translates to approximately 0.5% to 5% of forecasted 2030 total VMT, as summarized in This wide range of impacts underscores the need for better data and a better understanding of who, where, when, and why people use TNCs.

4.0 Taxi

Various taxi data sources were used in order to estimate taxi trips and VMT and check for reasonableness. A couple of key studies on recent taxi travel are summarized here.

- **TNCs Today, a San Francisco based study** by The San Francisco County Transportation Authority, reported tracked TNC presence in the county compared to that of taxis in the region. Based on information from this database, the research team estimated that approximately 21,000 TNC drivers complied with the City's business registration requirements. In contrast, there were only approximately 1,800 San Francisco taxi vehicle medallions (SFMTA 2016). In terms of the total number of trips, taxis were estimated to be making 12 times fewer trips than TNCs in 2016, with about 40% of all taxi miles being deadheading miles. Taxis were estimated to be making 14,000 intra-SF vehicle trips on an average weekday, in contrast to similarly calculated TNC trips, which were estimated at about 170,000. Taxis were also found to have lesser coverage than TNCs within the region. Taxis are also subject to price controls, must provide access to all areas of the city, must provide service to people with disabilities, have greater insurance requirements, and are subject to driver background checks and vehicle inspections.

- **A Chicago-based before and after study** in review (Roy, S. et al, 2019) found a stronger concentration of taxi hails in 2018 were observed in the downtown core and the O'Hare airport regions than what existed in 2013. This analysis found that in census tracts associated with airports, the share of taxi trips increased by almost 17% between 2013 and 2018. The sharp increase in share of taxi travel was also observed to translate to an increase in their average trip lengths and durations. But overall, average weekday taxi trips reduced from about 13.8 million in a 6 month period in 2013-14 to about 6.3 million in the same 6 month period in 2018-19, while average weekend taxi trips reduced from 1.8 million in 2013-14 to about 0.6 million in 2018-19. This period saw a rapid rise in TNC use across this region.

Other studies reviewed for this study are included in **Appendix A.1**.

4.1 Data

The primary dataset on taxi travel in Colorado was provided by the Colorado Public Utilities Commission. Taxi travel information from Denver International Airport provided additional data for context and reasonableness checking.

Colorado Public Utilities Commission

Taxi trips (airport and non-airport) were obtained from the Colorado Public Utilities Commission and are reported in **Table 4.1**. This data revealed that taxi trips to airports had been steadily increasing from 2013 to 2015. After 2015, a constant and significant slump is observed through 2017, the latest data available. In addition to number of trips, the total passenger VMT and revenue was also provided. This information provides average number of trips, average passenger trip length, and average fare.

Table 4.1 Colorado Taxi Trips, Paid VMT, and Revenue

Metric		2013	2014	2015	2016	2017
Annual	Airport taxi trips	352,070	404,595	449,610	384,637	300,303
	Total taxi trips	4,251,193	4,532,745	3,963,105	2,830,280	2,015,557
	Paid VMT	22,508,143	22,851,467	21,393,451	13,861,433	9,715,864
	Total revenue (millions)	$ 80.4	$ 84.5	$ 82.8	$ 58.5	$ 40.0
Average Daily (annual / 365)	Airport taxi trips	965	1,108	1,232	1,054	823
	Total taxi trips	11,647	12,418	10,858	7,754	**5,522**
	Paid VMT	61,666	62,607	58,612	37,977	26,619
	Average passenger distance per trip (miles)	5.29	5.04	5.40	4.90	**4.82**
	Average fare per trip	$ 18.90	$ 18.64	$ 20.90	$ 20.67	**$ 19.85**

Source: Colorado Public Utilities Commission

Denver International Airport

Annual taxi trip data obtained from Denver International Airport (DEN) are reported in **Table 4.2**. TNC trips were also reported so that a comparison could be made between the two modes. In 2015, total taxi trips made to DEN were about two times the number of TNC trips. This trend flipped in the very next year where TNC trips overtook a significant share of taxi trips as inferred from the five-month periodic data for the year 2016.

Table 4.2 Taxi and TNC trips for Denver International Airport

Metric		2015	2016 (5 months)
Annual	Airport taxi trips	491,389	143,010
	Airport TNC trips	260,496	214,137
Average Daily (annual / 365 partial / 150)	Airport taxi trips	1,346	953
	Airport TNC trips	714	1,428

Source: Denver International Airport

4.2 Existing Conditions (2018) Estimates

Given the high confidence in local, recent taxi data provided by the Colorado Public Utilities Commission, the most recent estimate of 5,522 taxi trips was assumed as the best estimate for 2018. While researchers are confident that this is a reasonable estimate of taxis in Colorado, it should be noted that all taxi providers who reported to the PUC were in the Denver metro region. Taxis do exist outside of Denver, but the PUC suspected that they did not meet a threshold requiring reporting. Considering the population outside of the

Denver region, taxi trips were increased by 28%[38] to account for potential unreported taxi travel, a high estimate of taxi travel in Colorado.

The data provided revealed an average of 5,500 vehicle trips per day in 2017 and an average passenger trip length of 4.8 miles. The PUC advised researchers for this study to assume the total taxi miles traveled are double the paid miles, to account for non-passenger travel. This results in an estimate of 53,000 daily VMT by taxis today. Assuming approximately 5,500 to 7,000 vehicle trips and 10 miles a trip (including deadheading) results in approximately 55,000 VMT, with a high estimate of 70,000 VMT per day in 2018. These estimates are summarized in **Table 4.3**.

Table 4.3 Taxi Travel Estimates (2018)

Metric	2018	
	Best Estimate	High
Number of Daily Trips	5,522	7,068
Avg. Passenger Trip Length	4.82	4.82
Deadheading (% of total taxi VMT)	50%	50%
Total Daily VMT	53,238	68,144

Source: Cambridge Systematics, Inc.

4.3 Future Year (2030) Forecasts

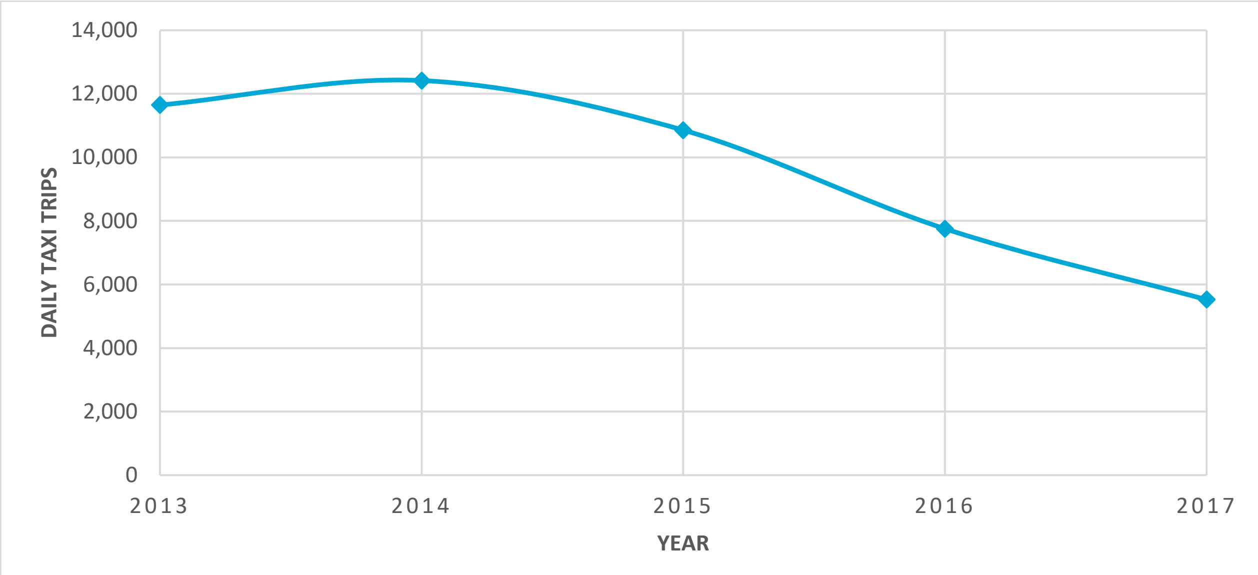
To forecast taxi travel in 2030, two approaches were utilized to estimate a range of possibilities:

- Taxi trips will continue to decline at its currently observed rate (shown in **Figure 4.1**), which would result in zero taxi trips before 2030; and
- Taxi travel will increase proportionally with expected growth in travel in Colorado (25% between 2018 and 2030), applied to the best and high estimates of taxi travel today.

The resulting estimates, based on these methodologies, are summarized in **Table 4.4**.

[38] A 28% increase represents the population in 2018 that's outside the DRCOG region but has taxi service (NFRMPO and PPACOG regions) divided by the total population in all regions with taxi service (DRCOG, NFRMPO, and PPACOG).

Figure 4.1 Taxi Trips (2013-2017)



Source: Colorado Public Utilities Commission

Table 4.4 Taxi Travel Estimates (2030)

Metric	2030		
	Best Estimate	Low	High
Number of Daily Trips	6,873	0	8,873
Avg. Passenger Trip Length	4.82		4.82
Deadheading (% of total taxi VMT)	50%		50%
Total Daily VMT	66,263	0	85,540

Source: Cambridge Systematics, Inc.

5.0 Carshare

Carshare is a popular emerging mode in the shared economy. Like traditional car rental, carsharing provides cars for rent for short periods of time. However, in carsharing, the vehicle is privately owned, and both the car owner and renter are verified individual members of the carsharing platform. The renter and owner of the car are the two end nodes of supply and demand of the network, and the carsharing company leverages this demand and supply using an app-based network. Unlike the traditional car rental services, some carsharing services are priced to include all the operational costs, such as, insurance and gas, etc. Carsharing can be classified in two groups based on the considering the characteristics of the car owners: **peer-to-peer** or peer carsharing, and **non-peer** carsharing.

Below is a brief summary of some key literature and information on various aspects of carsharing. Other literature reviewed for this study are listed in **Appendix A.1**.

- Martin and Shaheen (2016)[39] evaluated the impact of carsharing, specifically car2go services, in various cities in the US. In July 2015, for car2go, there were 39 roundtrip carsharing operators in North America with a total membership of 1,005,893 and a collective fleet of 18,582 vehicles. Between 2% to 5% of the car2go population sold a vehicle when they started using car2go, and 7% to 10% of respondents forewent acquiring a vehicle due to access to car2go vehicles. In terms of modal shift due to carshare, there was a mixed effect; both increases and decreases were found in different cities.

- Dias et al. (2017) examined data on carshare use from a household travel survey conducted by PSRC for the Seattle region. This study is discussed further in Section 5.1.

- Dill et al. (2017), in a study conducted in Portland, evaluated the impact of peer carsharing. Overall, car owners' VMT did not decrease, but the frequency of rental activity influenced owners' VMT. However, the rental activity observed was very low. Only 22% cars were rented more than once a month, while 55% of the cars were rented less than 5 times a year. For renters, one-third of carshare trips were reported to not take place if the carshare was not available, and 20% of trips were shifted from public transit.

- Stocker et al. (2016)[40] summarized findings from Zipcar's College Travel Study in 2015.

The estimates provided in this chapter are based from sources that in some cases focus on a single type of carsharing (peer or non-peer) and in other cases include all carsharing of both types (referred to hereafter as "total carsharing").

[39] Martin, E. W. and Shaheen, S. A. (2011) 'Greenhouse gas emission impacts of carsharing in North America', *IEEE Transactions on Intelligent Transportation Systems*, 12(4), pp. 1074–1086. doi: 10.1109/TITS.2011.2158539.

[40] Stocker, A. *et al.* (2016) *Effects on Vehicle Use and Ownership, Travel Behavior, Quality of Life, and Environmental Impacts*.

5.1 Data

5.1.1 Total Carsharing

National Household Travel Survey

As described in **Section 3.1**, the 2017 NHTS asked respondents about their trips. As shown in **Table 3.2**, mode shares of car rental/carshare trips for Colorado and nationwide are 0.45% and 0.20%, respectively. Similarly, as described in **Section 3.1** for TNCs, the NHTS asked respondents (those of at least 16 years of age) about frequency of carsharing use:

> *"In the past 30 days, how many times have you used a carsharing service where a car can be rented by the hour (e.g., Zipcar or car2go)?"*

Table 5.1 provides a summary of responses to that question. For Colorado and nationwide, over 99% of respondents had not used carsharing in the past 30 days.

Table 5.1 NHTS Carshare Use in Past 30 Days

Carshare Use (Times per Month)	Colorado		Nationwide	
	Unweighted	Weighted/Expanded	Unweighted	Weighted/Expanded
0	940	4,709,257	262,533	299,244,496
1	2	6,796	745	979,508
2	0	0	315	498,521
3	0	0	107	191,688
4	0	0	80	99,401
5	0	0	71	104,976
6	0	0	23	25,010
7+	0	0	140	203,537
Total	942	4,716,053	263,898	301,129,765

Source: 2017 National Household Travel Survey

2015 PSRC Household Travel Survey

Dias et al. (2017) examined data from the PSRC household travel survey. In 2015, the survey asked residents about their preferred and used travel modes, including emerging mobility modes such as peer-to-peer or non-peer carshare services, demographic characteristics such as income, education and household sizes, and cellphone use characteristics. Based on a sample size of over 2,700 people, carshare is used by less than 10% of the sample population. The frequencies of carsharing service usage from the survey responses are shown in the **Table 5.2**. Among people using carshare services, 16% used it more than three times a month.

Table 5.2 Frequency of Carsharing (2015 PSRC Survey Data)

Frequency of Carshare Use	Percentage
Never	90.7%
Less than 1 time per month	4.4%
1-3 times per month	3.5%
1 time per week	0.6%
2+ times per week	0.8%
Sample Size	2,789

Source: Dias et al. (2017) using data from the PSRC 2015 Household Travel Survey

5.1.2 Non-peer Carshare

Fleet Size Estimates

The fleet sizes of the carsharing companies by state were not readily available, and inquiries to local providers did not result in any fleet size information at the time of this report. Online news articles were sourced for any available information. Two sources were found which provided information on car2go fleet size in Colorado.

- *The Sentinel*. "Car2Go adds dedicated parking spaces to Anschutz campus in Aurora." *The Sentinel*, October 15, 2015, https://sentinelcolorado.com/news/car2go-adds-dedicated-parking-spaces-anschutz-campus-aurora/. Accessed October 23, 2019.
- Millman, E. "Go in style: Car2go adding Mercedes fleet to Denver car-share scene." *The Denver Post*, June 15, 2017, https://www.denverpost.com/2017/06/15/car2go-mercedes-denver/. Accessed October 23, 2019.

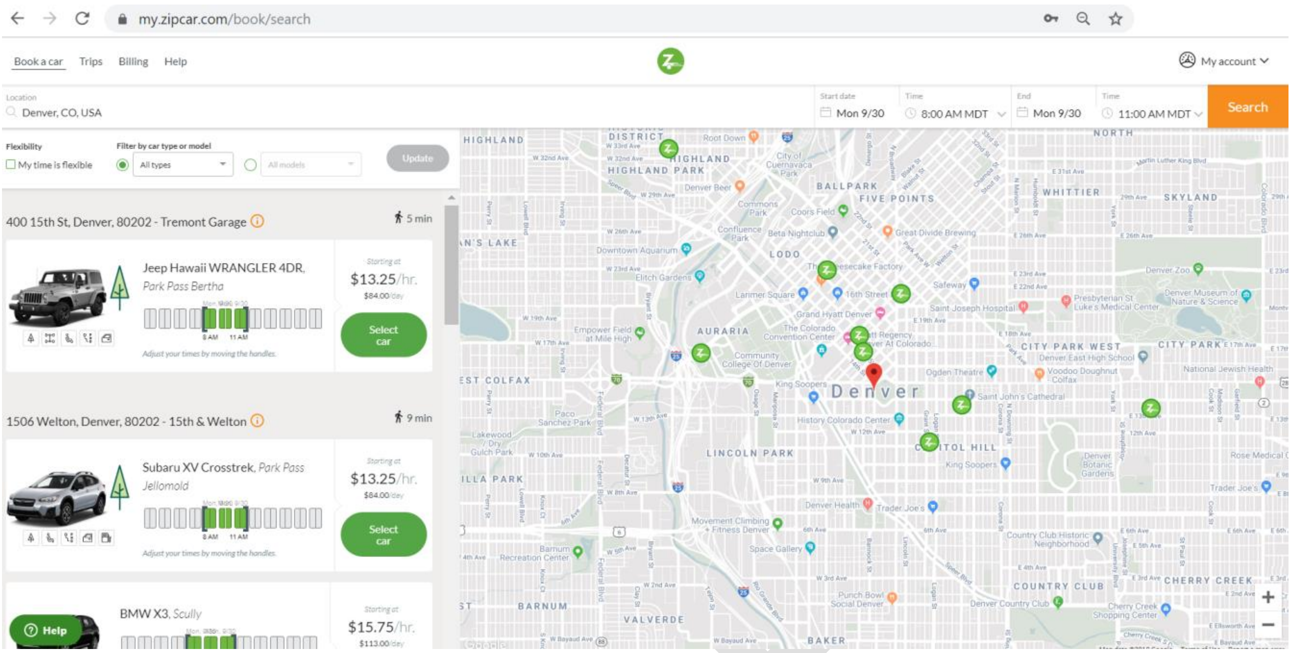
Table 5.3 provides car2go fleet size information in Colorado by year, based on information from these articles.

Table 5.3 Fleet Size for Car2Go

Year	Fleet Size	Source
2015	350	*The Sentinel*, October 15, 2015
2016	310	Millman, E. *The Denver Post*, June 15, 2017
2017	340	

To get an idea of fleet size for other carshare providers with any better information, the websites of providers were used to estimate available vehicles on a given day by searching for available vehicles for each location, city, or neighborhood in the state of Colorado on different days, multiple times per day, and for various rental durations. **Figure 5.1** shows an example list of available Zipcar vehicles at a given location and time at each parking station. It should be noted estimates based on the number of available vehicles do not include vehicles currently being used at the time of the collection of the information, and so the fleet sizes are probably a little larger.

Figure 5.1 Available Zipcar Vehicles



Source: Zipcar.com.

The maximum and minimum number of cars available for rent were summarized for weekdays and weekends separately. As shown in **Table 5.4,** the Zipcar available fleet size was estimated as 55 cars per day for the state of Colorado.

Table 5.4 Estimated Fleet Size for Zipcar

City	Fleet Size
Aurora	1
Boulder	12
Colorado Springs	1
Denver	25
Fort Collins	9
Golden	4
Greenwood Village	3
Total	55

Source: Cambridge Systematics, Inc. analysis of Zipcar.com.

5.1.3 Peer Carshare

Fleet Size Estimates

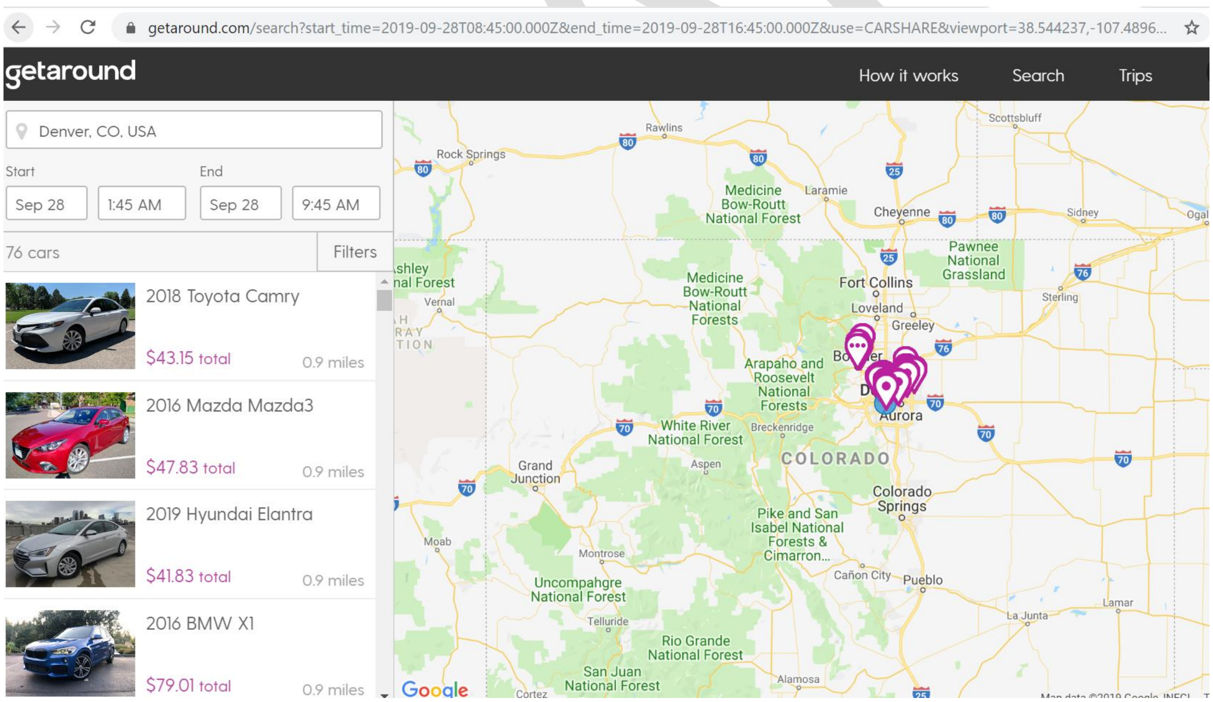
As described in the fleet estimates for Zipcar, the same process was utilized to estimate fleet size for peer carsharing providers Getaround and Turo. **Figure 5.2** and **Figure 5.3** show examples of lists of available cars for these providers. Due to lack of information to link any car across the platforms, it was unknown if or how many cars listed were available in multiple platforms, which could potentially over-estimate the actual fleet size. The estimated fleet size of Getaround and Turo are shown in **Table 5.5**. The list for available fleet size varies by weekdays and weekends. For Getaround, the fleet size ranged from 61 to 140. For Turo, the fleet size ranged from 200 to 210.

Table 5.5 Estimated Fleet Size for Getaround and Turo

Peer Carsharing Provider		Estimated Fleet	
		Min	Max
Getaround	Weekdays	61	124
	Weekend	129	140
	Overall	61	140
Turo	Weekdays	204	210
	Weekend	200	204
	Overall	200	210

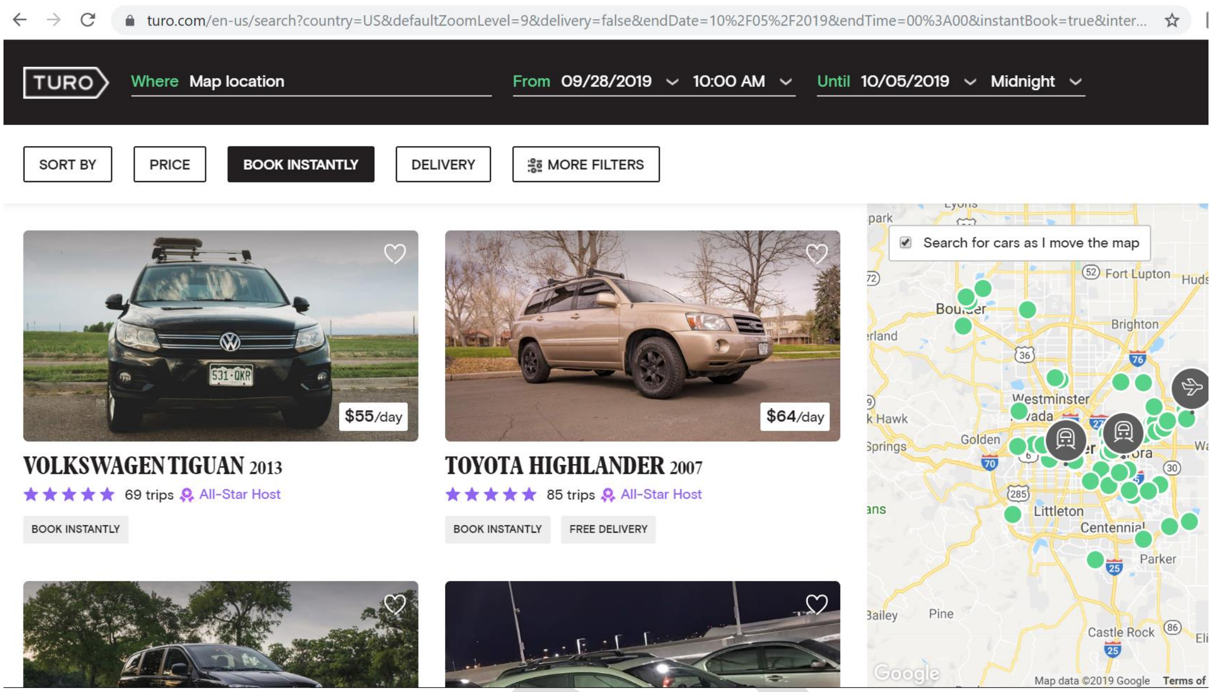
Source: Cambridge Systematics, Inc. analysis of Zipcar.com.

Figure 5.2 Available Getaround Vehicles



Source: getaround.com.

Figure 5.3 Available Turo Vehicles



Source: turo.com.

5.2 Existing Conditions (2018) Estimates

5.2.1 Service Coverage Areas

A list of the car sharing providers in Colorado is provided in **Table 5.6**.

Table 5.6 Carsharing Providers

Provider	Type of Carsharing
Getaround	Peer carshare
Turo	Peer carshare
Hyrecar	Peer carshare
Car2Go	Non-peer carshare
Zipcar	Non-peer carshare

Source: Cambridge Systematics, Inc.
Note: Hyrecar is understood to have very limited service and is not explicitly analyzed in this report.

Figure 5.4 Carsharing Provider Coverage

Maps of the coverage areas are included in the research paper titled “Transportation Provider Service Coverage in Disadvantaged Areas in Colorado” that is an appendix to the Emerging Mobilities Impacts Study report.

5.2.2 Methodologies for Estimates

Estimates for carsharing were provided for all carsharing providers (based on survey data where there was no distinction between non-peer and peer carsharing) and then estimated separately by carshare provider.

Total Carsharing

National Household Travel Survey

Reported carshare frequency (summarized in **Table 5.1**) was analyzed to obtain average number of daily carshare trips per person. This data was summarized for both Colorado and, considering the relatively low sample size of records in Colorado, the entire national dataset to provide a range of estimates. Multiplying those carshare trip rates by the number of persons in Colorado results in a range of 200-3,400 carshare person trips, or 100-1,700 vehicle trips, as shown in **Table 5.7.**

Table 5.7 NHTS Carshare Frequency of Use to Estimate Carshare Trips in Colorado (2018)

Metric	Colorado	Nationwide
Average number of uses, per day per person	0.000048	0.000754
Number of persons in Colorado in 2018 (ages 16+)	4,572,754	4,572,754
Estimated 2018 carshare person trips per day	**220**	**3,448**
Estimated 2018 carshare vehicle trips per day	**106**	**1,658**

Notes: Person trips were converted to vehicle trips by applying an average vehicle occupancy rate of 2.08 persons per vehicle, as determined from NHTS data for car rental/carsharing.
Frequency of carshare use was based on weighted 2017 NHTS responses.

Analysis of travel diary data from the NHTS revealed mode shares for car rentals and carshare at 0.45% for Colorado and 0.20% Nationwide. Using these mode shares and subtracting out the estimated car rentals leaves no carsharing trips, as shown in **Table 5.8**, leading researchers to believe this is not an a good methodology for estimating carsharing, likely due to the very small sample of NHTS respondents that used carsharing in 2017.

Table 5.8 NHTS Mode Shares to Estimate Carshare Trips in Colorado (2018)

Metric	Colorado	Nationwide
Taxi/TNC mode share	**0.45%**	**0.20%**
Total 2018 person trips in Colorado	20,065,224	20,065,224
Estimated 2018 car rental/carshare person trips per day	90,294	40,130
Estimated 2018 car rental/carshare vehicle trips per day	43,411	19,293
Estimated 2018 car rental vehicle trips per day	47,646	47,646
Estimated 2018 carshare vehicle trips per day	**-**	**-**

Note: The estimate 2018 car rental trips can be found in **Table 6.1**.
Person trips were converted to vehicle trips by applying an average vehicle occupancy rate of 2.08 persons

PSRC Household Travel Survey

Dias et al. (2017) estimated a model of the propensity to use carshare services using data from the 2015 PSRC household travel survey. This model was applied to using the 2015 synthetic population from StateFocus to obtain an estimate of carshare vehicle trips and person trips for regions in Colorado. Two variables in the model, smartphone ownership and licensed drivers, are not available in the synthetic population. Values (0 or 1) for these variables were assigned randomly to each person in the synthetic population to match overall smartphone ownership levels by age categories, as observed by Pew Research Center[41], and a driver's license share of 92% of the population (ages 16+) in Colorado, as reported by the Bureau of Transportation Statistics[42].

Results of the model application were post-processed for those residents in carshare service areas and shown in **Table 5.9**. Based on data from the Martin and Shaheen (2016) car2go impact study and other online data, a comparison between the number of customers and the utilization of available vehicles in summarized in **Table 5.10**. Based on these statistics, it was assumed that Denver residents are about half as likely to use carshare than Seattle for various reasons that might not be captured in the model. The application of this ratio adjustment results in **21,000 carshare person trips, or about 10,000 carshare vehicle trips**.

Table 5.9 Estimate of Carshare Trips based on 2015 PSRC Frequency of Use Model Application (2018)

MPO	Total Carshare Trips
DRCOG	31,861
NFRMPO	1,988
PPACOG	3,553
PACOG	0
GVMPO	490
Non-MPO	163
Estimated 2018 carshare person trips per day	38,055
Adjusted 2018 carshare person trips per day (applied factor of 0.54 as shown in Table 5.11)	21,051
Estimated 2018 carshare vehicle trips per day	10,128

Source: Cambridge Systematics, Inc.
Note: A 2.08 vehicle occupancy factor was applied to the carshare person trips to obtain vehicle trips.

[41] https://www.pewinternet.org/fact-sheet/mobile/

[42] https://www.bts.gov/content/licensed-drivers

Table 5.10 Comparison of Seattle and Denver Carsharing in 2015

	Seattle car2go (2015) [1]	Denver car2go (2015)	Ratio of Denver to Seattle carsharing
Customers	54,000	35,000 [2]	0.54
Customer trips per vehicle per day	6	5 [3]	

Source: [1] Martin and Shaheen (2016)
[2] https://www.denverpost.com/2015/08/26/car2go-eliminates-denver-metro-neighborhoods-from-service-area/
[3] Martin and Shaheen (2016) data averaged for all cities.

Non-peer Carshare

Car2go

Martin and Shaheen (2016) estimated the average number of car2go trips per vehicle as 5.0. Applying this rate to the car2go fleet size of 340 vehicles (**Table 5.3**) results in an average of 1,700 car2go trips per day. **Table 5.11** provides a range of estimates for average passenger trip length for car2go vehicles. The 6.8 miles per trip was applied to the 1,700 vehicle trips to obtain total passenger VMT for car2go. Assuming 3% of the total VMT for repositioning (Martin and Sheen, 2016) results in **approximately 12,000 VMT per day for car2go**.

Table 5.11 Passenger Trip Length: Non-peer Carshare

City	Average Miles per Trip	Notes	Source
San Diego	4.1		Martin & Shaheen (2016): Impacts of car2go
Washington DC	3.4		
Denver	3.9	Before replacing fleet with Mercedes	The Denver Channel, car2go in Denver: More users, longer trips, since switching to Mercedes-Benz [1]
Denver	**6.8**	After replacing fleet with Mercedes	

Source: Cambridge Systematics, Inc.

Zipcar

The estimated fleet size for Zipcar was assumed to be 55 (**Table 5.4**). It is unknown how often Zipcar vehicles are utilized. Considering that Zipcar vehicles may be used differently than car2go (car2go allows vehicles to be picked up and dropped off anywhere in their service boundary, therefore allowing shorter trips), the same assumptions applied for car2go were not applied for Zipcar. Instead, they were assumed to have longer trip lengths and durations than car2go (7 miles per trip) but less than car rentals (assumed to be 60 miles per day). Using professional judgment, a 15-mile trip was used as the best estimate. Considering the longer trip lengths, it was assumed that the number of times a vehicle is used per day would be less than car2go. For simplicity, it was assumed that each available vehicle is used for 15-miles per day, on average, resulting in **approximately 800 VMT per day for Zipcar**.

Peer Carshare

An estimated total of 300 peer carsharing vehicles are available on a given weekday in Colorado (**Table 5.5**). A study in Portland (Dill et al., 2017) estimated the number of trips per day for a vehicle before and after it became available for carsharing; the net difference was an increase of 0.4 trips per day. Applying this trip rate to the 300 vehicles results in approximately new trips per day for available carsharing vehicles. Assuming the same 15 miles per reservation that was applied to Zipcar rentals results in an estimated **1,800 VMT for peer carsharing.**

5.2.3 Range of Estimates

As described at the beginning of Section 5.2.2, estimates for total carsharing travel were based on the NHTS and PSRC data. The separate estimates for non-peer and peer carsharing, described later in Section 5.2.2 and Section 5.2.3, were based on a combination of limited available data from published studies and on professional judgment. **Table 5.12** summarizes the overall recommended best and high estimates for carsharing in Colorado. It is recognized that the range between the best estimates and the high estimates is very large in comparison to estimates for other modes; this is a result of very little local or recent data on carsharing and underscores the need for carsharing data in Colorado.

Table 5.12 Carshare Travel Estimates (2018)

Key Metric	Best Estimates			High Estimate for Total Carsharing
	Non-peer Carshare		Peer Carshare	
	car2go	Zipcar		
Number of trips per day	1,700	50	100	10,000
Avg. Passenger Trip Length (miles)	7	15	15	50
Repositioning	3%	0%	0%	0%
Total Daily VMT	12,000	1,000	2,000	500,000

Source: Cambridge Systematics, Inc.

5.3 Future Year (2030) Forecasts

5.3.1 Methodologies for Estimates

Similar to the estimates of current carsharing activity, future year forecasts were developed for total carsharing and then separately for non-peer and peer carsharing.

Total Carshare

PSRC Household Travel Survey

A similar methodology as described for the current year estimates was adopted for future year estimates, applying to the 2030 synthetic population. However, to more precisely estimate values for variables like smartphone penetration by age groups for the year 2030, the age groups were offset by a period of 15 years. This was done in order to ensure that smartphone ownership for younger people in the present time is not discounted as they age by 15 more years in 2030 and to avoid underestimating their cell phone usage in future years. The propensity to use carsharing in 2030 was applied in the same way as in the base year but with these added adjustments related to age. The result of that applied model is summarized in **Table 5.13**.

Table 5.13 Estimate of Carshare Trips based on 2015 PSRC Frequency of Use Model Application (2030)

MPO	Total Carshare Trips
DRCOG	92,653
NFRMPO	9,035
PPACOG	15,692
PACOG	0
GVMPO	0
Non-MPO	290
Estimated 2018 carshare person trips per day	117,670
Estimated 2018 carshare vehicle trips per day	**56,572**

Source: Cambridge Systematics, Inc.

Note: A 2.08 vehicle occupancy factor was applied to the carshare person trips to obtain vehicle trips.

Non-peer Car Share

Without historical trend data or better information about future use of non-peer carsharing, an assumed increase proportional to expected growth in travel in Colorado (25% between 2018 and 2030) results in an estimated **2,500 vehicles trips and 20,000 VMT for non-peer carsharing in Colorado in 2030.**

Peer Car Share

Without historical trend data or better information about future use of peer carsharing, an assumed increase proportional to expected growth in travel in Colorado (25% between 2018 and 2030) results in a best estimate of **200 vehicles trips and 3,600 VMT for non-peer carsharing in 2030 in Colorado.**

5.3.2 Range of Estimates

Total carshare travel in 2030 was estimated from application of a model based on PSRC data. Without historical trend data or better information about future use of non-peer and peer carsharing, development of best estimates were based on the assumption that carshare use will remain relatively similar to the best estimates of use today and were increased proportional to the increase in expected travel between 2018 and 2030. **Table 5.14** summarizes the overall recommended best and high estimates for carsharing in Colorado in 2030.

Table 5.14 Carshare Travel Estimates (2030)

Key Metric	Best Estimates			High Estimate for Total Carsharing
	Non-peer Carshare		Peer Carshare	
	car2go	Zipcar		
Number of trips per day	2,200	100	200	55k
Avg. Passenger Trip Length (miles)	7	15	15	50
Repositioning	3%	0%	0%	0%
Total Daily VMT	15k	1k	3k	2.8m

Source: Cambridge Systematics, Inc.

6.0 Car Rentals

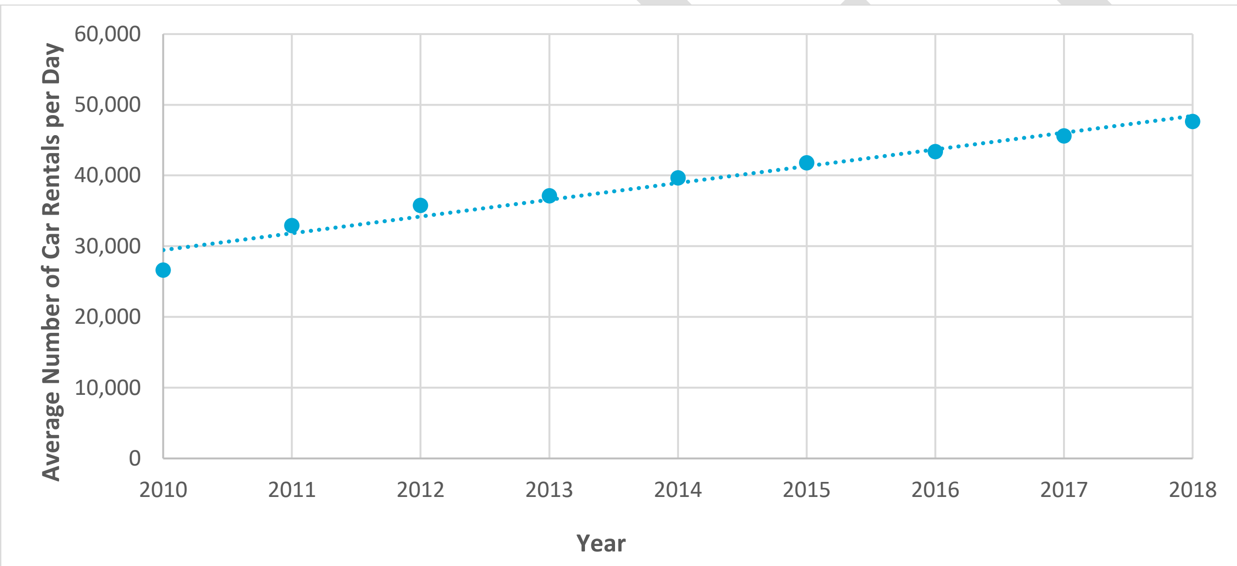
Like taxis, car rentals have been a long-standing option for travel, particularly for visitor travel. To understand the market, a body of literature on car rental travel characteristics was reviewed and are listed in **Appendix A.1**.

6.1 Data

Department of Revenue

Since 2010, every car rental has been charged a fee of $2 per day that is collected by the state and reported by the Department of Revenue. Subsequently, reliable data for car rentals is available online for years 2010-2018 and is summarized in **Figure 6.1**. The data provided reveals to an **average of 47,600 daily vehicle rentals per day in 2018**.

Figure 6.1 Average Number of Days of Car Rentals, per Day (2010-2018)

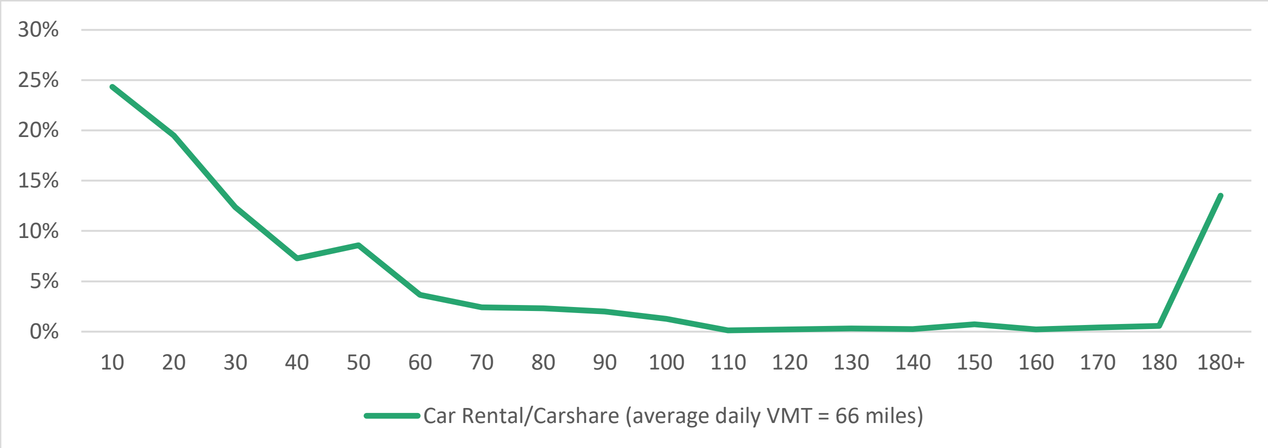


Source: Cambridge Systematics, Inc. analysis of Colorado Department of Revenue data.
Daily rental fee revenue is reported annually. Without better information, the annual daily rentals were divided by 365 for average car rentals per day.

National Household Travel Survey

It is unknown how much, on average, a rental car is driven per day. The only known data source available on car rental travel at the time of this research was the 2017 NHTS; an analysis of that data revealed an average trip length for car rental trips was approximately 25 miles and the total travel during a day was 66 miles. The distribution of total daily travel in a car rental or carshare travel is shown in **Figure 6.2**.

Figure 6.2 Frequency Distribution of Total Daily VMT for Car Rentals/Carshare



Source: Cambridge Systematics, Inc. analysis of 2017 NHTS data.

Local Data

A Colorado representative from Enterprise noted that their business model is different from other car rental companies in that 70% of their rentals are to local residents who need a temporary vehicle replacement. They reported that they do not track mileage per reservation so it is unknown how many miles their customers travel, on average, or how that compares to other car rental providers. Enterprise noted that those vehicle replacement rentals are not new miles; they are replacement miles of typical travel. Requests were made to Colorado car rental providers but no additional data or information was received.

6.2 Existing Conditions (2018) Estimates

As noted in **Section 6.1**, there was high confidence in the number of car rentals as provided by Department of Revenue data. Therefore, no additional estimates for number of existing car rentals were needed. It should be noted that there was little data available for car rental travel in a given day. A range of 25 miles (average car rental trip length from the 2017 NHTS) to 150 miles (the industry standard for maximum number of miles allowed on a vehicle per day) were assumed as the low and high estimates for travel. A 66-mile per day assumption (average car rental VMT per day from the 2017 NHTS) was assumed as a best estimate. **Table 6.1** summarizes the range of estimates for car rental travel today.

Table 6.1 Car Rental Travel Estimates (2018)

Key Metric	2018		
	Best Estimate	Low	High
Number of Daily Rentals	47,646	47,646	47,646
Avg. Passenger Travel per Day (miles)	66	25	150
Total Daily VMT	3,144,642	1,191,152	7,146,914

Source: Cambridge Systematics, Inc.

6.3 Future Year (2030) Forecasts

6.3.1 Methodologies for Estimates

While there was high confidence in the estimated number of car rentals per day provided by the Department of Revenue today, additional methodologies were explored to check for reasonableness of the data and provide various estimates for future car rental travel.

Future Airport Enplanements

Airport car rental trips for existing (2018) and future year (2030) conditions were estimated using observed and forecasted enplanement data for major passenger airports in Colorado in combination with information from an airport ground access study out of Minneapolis[43] that reported approximately 15,000 daily car rentals at the Minneapolis airport, out of 18 million enplanements, yielding an estimated average car rental trip rate per enplanement of 0.308.

The 2018 passenger enplanement data was obtained from the Federal Aviation Administration (FAA) Passenger Boarding (enplanement) data extracted from the Air Carrier Activity Information System (ACAIS) for Calendar Year 2018, while the 2030 passenger enplanement forecasts are from FAA's Terminal Area Forecast (TAF) for Fiscal Years 2018 – 2045[44]. **Table 6.2** below lists the airports for which enplanement data was obtained and used to estimate airport car rental trips.

Table 6.2 Observed and Forecasted Passenger Enplanements by Airport

Airport	CY 2018 Enplanements	FY 2030 Forecasted Enplanements	Percentage Growth
Denver	31,363,573	40,195,070	28%
Colorado Springs	846,075	919,985	9%
Aspen	287,904	298,546	4%
Durango	189,225	229,242	21%
Eagle	175,947	181,687	3%
Grand Junction	222,234	270,594	22%
Montrose	134,241	180,665	35%
Yampa Valley	100,548	124,309	24%
Total	*33,319,747*	*42,400,098*	*27%*

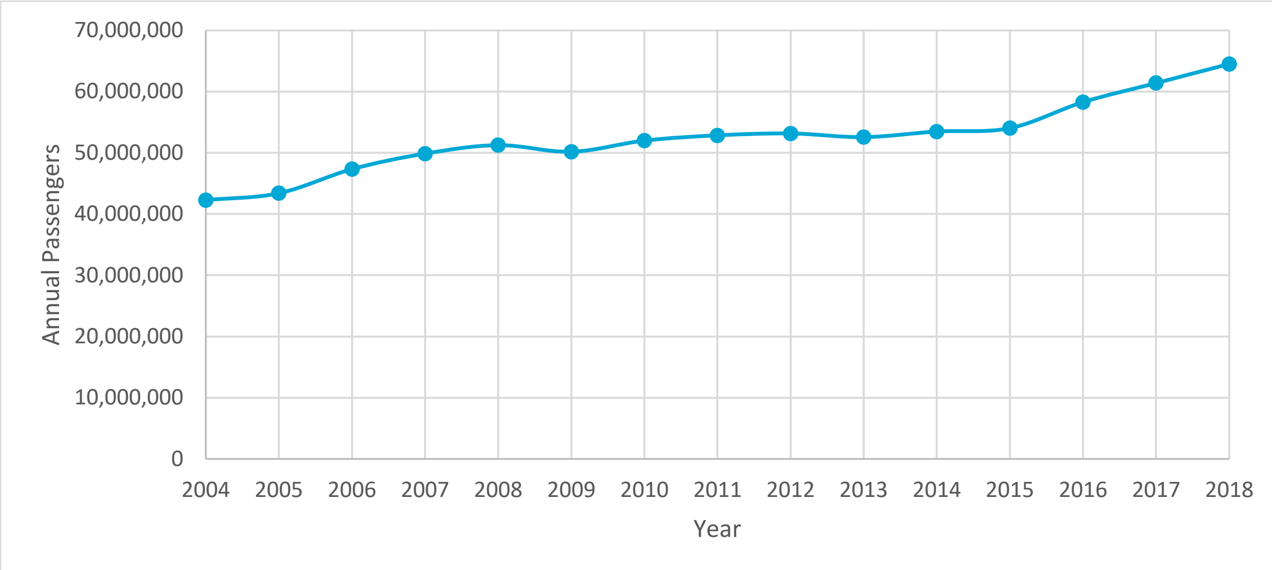
Source: Federal Aviation Administration

Additionally, historical enplanement data at DEN was analyzed to produce another set of 2030 enplanement forecasts based on a trend analysis of the data, as shown in **Figure 6.3**.

[43] Cambridge Systematics, Inc. 2012. *Minneapolis-St. Paul Airport Special Generator Survey*. https://metrocouncil.org/Transportation/Publications-And-Resources/TBI-Airport-Survey-Final-Report.aspx

[44] https://www.faa.gov/airports/planning_capacity/passenger_allcargo_stats/passenger/media/preliminary-cy18-commercial-service-enplanements.pdf

Figure 6.3 Annual Passengers at Denver International Airport (2004-2018)



Source: Denver International Airport

Without better information, annual enplanements were converted to daily enplanements by dividing by 365. Using 2018 enplanement data for Colorado and a 0.308 car rental rate, the estimated number of rentals was about 28,000. Comparing that to the 47,600 car rentals from the Department of Revenue data, it was estimated that 59% of total car rentals are to or from the airport (this seems reasonable compared to an IBIS World Report that noted 50% of car rental revenue came from airport rentals[45]). Applying that same factor to the estimated airport car rentals in 2030, an estimated total of **60,600 daily car rentals** could be assumed for 2030. Using a trend analysis to forecast enplanements, which is higher than the FAA forecasts, a total of **81,500 daily car rentals** could be assumed for 2030, as shown in **Table 6.3**.

Table 6.3 Estimated 2030 Car Rentals, based on Airport Enplanements

Airport	2018 Daily Enplanements	2030 Forecasted Daily Enplanements (FAA Forecasts)	2030 Forecasted Daily Enplanements (based on trend analysis)
Denver	85,928	110,123	145,739
COS	2,318	2,521	5,321
Aspen	789	818	1,338
Durango	518	628	879
Eagle	482	498	818
Grand Junction	609	741	1,033
Montrose	368	495	624
Yampa Valley	275	341	467

[45] Hayashi, Y. *et al.* (no date) ‘A model system for the assessment of the effects of car and fuel green taxes on CO2 emission’, *Elsevier*. Available at: https://www.sciencedirect.com/science/article/pii/S1361920900000213 (Accessed: 7 October 2019).IBISWorld US (2019) *Car Rental Industry Report*.

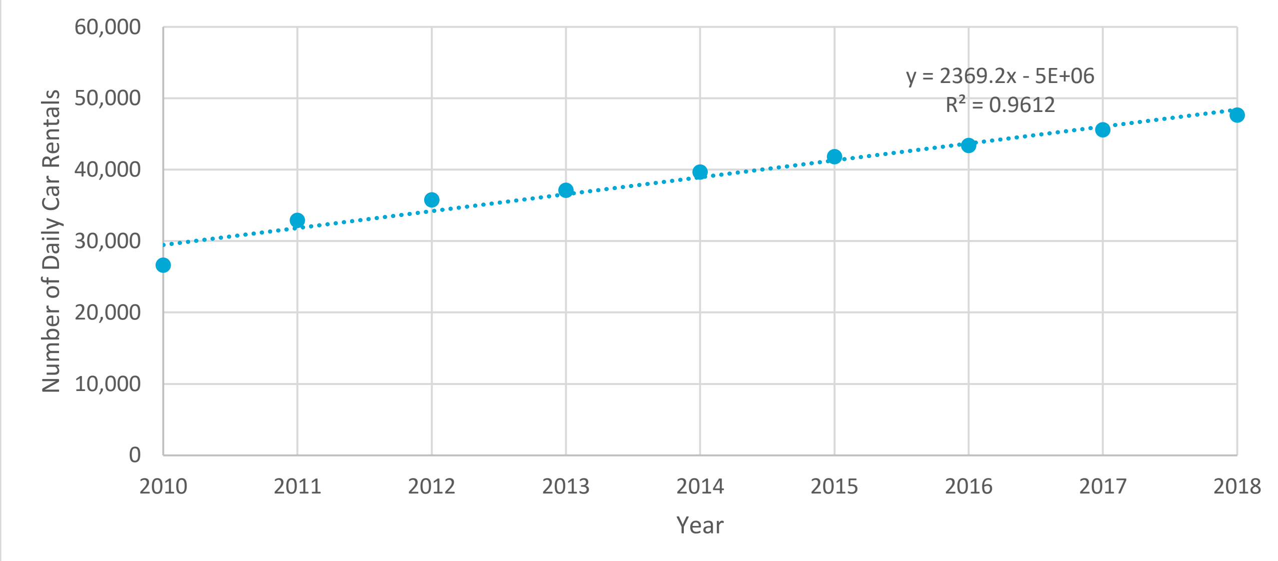
Airport	2018 Daily Enplanements	2030 Forecasted Daily Enplanements (FAA Forecasts)	2030 Forecasted Daily Enplanements (based on trend analysis)
All of Colorado	91,287	116,165	156,218
Daily Airport Car Rentals	28,098	35,756	48,084
Share of Airport Rentals	59%	59%	59%
Total Car Rentals	**47,646**	**60,631**	**81,536**

Source: Cambridge Systematics, Inc.
A car rental trip rate of 0.308 rentals per enplanement was assumed to convert enplanements to car rentals.

Linear Extrapolation

Historical car rental fee revenue data from 2010 to 2018, made available by the Department of Revenue, was used to estimate the linear relationship over time for car rentals. As shown in **Figure 6.4**, despite the emergence of new mobility options over recent years, car rentals have increased steadily and a linear regression reveals an excellent fit. Extrapolating that linear relationship to 2030 results in an estimated **76,400 car rentals per day in 2030**.

Figure 6.4 Linear Regression of Historical Data on Car Rentals



Source: Cambridge Systematics, Inc. analysis of Department of Revenue data

6.3.2 Range of Estimates

Given the uncertainty in average VMT per day, low and high estimates of car rental travel was bracketed by 25-mile and 150-mile per day assumptions, as assumed in 2018 estimates. These values were paired with the low and high assumptions for number of daily rentals, as estimated by applying different methodologies noted in **Section 6.3.1**. This results in ranges of 1.5 to 12 million VMT in 2030, as summarized in **Table 6.4**.

Table 6.4 Car Rental Travel Estimates (2030)

Key Metric	2030		
	Best	Low	High
Number of Daily Rentals	76,391	60,631	81,536
Avg. Passenger Travel per Day (miles)	65	25	150
Total Daily VMT	5,041,806	1,515,767	12,230,390

Source: Cambridge Systematics, Inc.

7.0 Residential Delivery

Residential deliveries for this analysis included third-party restaurant delivery, online grocery delivery, and parcel delivery of goods purchased online. Out of the six modes evaluated in the study, residential delivery was the most difficult to obtain reliable, quantifiable data that could be used for the analysis. Attempts were made to solicit information directly from the various market participants, but given the short notice, expedited project schedule, and corporate fears of divulging proprietary market data, no information was provided. Therefore, while every effort was made to make reasonable estimates for the number of residential deliveries, the lack of research and quantifiable data made it very difficult to bracket the estimates with lower and upper boundaries.

7.1 Data

Third Party Restaurant Delivery

An estimate of third-party restaurant delivery was developed using primarily anecdotal data. For the average number of orders per restaurant, anecdotal evidence gleaned from an interview with restaurant owner was used. The restaurant owner suggested he averaged about ten orders per day as a result of joining one of the third-party restaurant delivery platforms.[46] An average of eight orders per day was assumed for the analysis.

For the average trip length per delivery, the assumption was made that most firms use algorithms and machine learning to minimize the times and distances driven by the delivery drivers.[47] While the average trip length per delivery likely shows great variation depending on whether the customer is in an urban versus suburban location, the location of the driver when he/she accepts the order, and whether multiple orders are delivered in one delivery trip, a conservative estimate of five miles (includes deadhead) was assumed for each delivery.

The assumptions used for third-party restaurant delivery should be considered placeholders until better, observed data are available since there is considerable uncertainty with the number of restaurants that participate with third party delivery services, the average trip length of delivery drivers, and the average number of orders received by participating restaurants.

Parcel Delivery

The main data sources for estimating parcel delivery was the 2017 NHTS and Rodrigue's study on residential delivery in an apartment complex.

7.2 Existing Conditions (2018) Estimates

Third Party Restaurant Delivery

An estimate of the number of restaurants participating with the various firms was obtained via each firm's websites, inputting the major cities for Colorado, and reviewing the search results. A summary of the results is provided below. Each firm's website was accessed in September 2019.

[46] https://www.apnews.com/36be30dc1c944101a310bef3e79eca7a

[47] https://thenewstack.io/how-uber-eats-uses-machine-learning-to-estimate-delivery-times/

- DoorDash's - 2,700 restaurants;
- Uber Eats - 175 restaurants;
- Grubhub - 5,000 restaurants;
- OrderUp - 130 restaurants (reverse engineered from newspaper article suggesting 1,300 order per day in the Fort Collins/Greeley area); and
- Postmates – 140 restaurants in Denver and Colorado Springs.

Double counting is likely an issue with the since many restaurants participate on multiple platforms. Given the data limitations, only 50 percent of the total (8,000) was assumed for the total number of restaurants in Colorado since there is likely to be overlap with the two largest players in Colorado--Grubhub and DoorDash. Multiplying 4,190 restaurants by an average of 8 orders per day results in approximately 33,780 third-party restaurant deliveries. Assuming 5 miles per each delivery, total VMT would be 168,900.

Online Grocery Delivery

Online grocery delivery estimates were developed based on the assumption that typical household trip-making characteristics to the grocery store would also apply to online grocery purchases and deliveries. Using an assumption that households on average make 1.5 trips to the grocery per week,[48] the number of households (2,296,481) in Colorado for 2015 was multiplied by the average of 1.5 grocery trips. Based on these assumptions, there are 3,444,122 grocery trips made in the state during any given week. Dividing this value by 7 gives an estimate of 492,017 daily grocery trips. The United States currently lags other developed countries with online grocery purchases at 3 percent which suggests approximately 14,760 grocery deliveries, assuming they are all delivered and not picked up. The average trip length traveled by customers to a grocery store is 4 miles.[49] Assuming this distance would likely be the same distance as driven by an employee in delivering groceries, there would be approximately 118,804 VMT (including deadhead).

Parcel Delivery

Residential deliveries for online shopping were estimated using the 2017 NHTS and research conducted by Dr. John-Paul Rodrigue. The 2017 NHTS data for Colorado suggests 2.37 online purchases per month that were delivered. Converting this monthly figure to a daily value results in 0.095 average deliveries/person/day. For an estimate of 2017 daily residential deliveries, the average of 0.095 deliveries /person/day was multiplied by Colorado's 2015 population of 5,452,000, giving an estimate of **517,700 average daily residential deliveries.**

The major delivery/logistics firms like the United Parcel Service (UPS), Feder Express (FedEx), and Amazon process so many packages, they use algorithms to optimize their delivery routes, trying to make deliveries as efficient as possible. Detailed information for UPS was used to estimate UPS miles/package. This metric (UPS miles/package), served as guidance for the USPS, FedEx, and Amazon. On average, UPS drivers make 120 deliveries per day.[50] For an estimate of UPS miles per package, UPS' annual miles were divided

[48] https://www.creditdonkey.com/grocery-shopping-statistics.html

[49] http://couponsinthenews.com/2016/11/17/how-far-will-you-drive-to-get-your-groceries/

[50] https://www.wired.com/2013/06/ups-astronomical-math

by their annual number of UPS packages (3,000,000,000[51]/5,200,000,0000[52]) which results in 0.58 miles per package. Performing a similar calculation for the USPS, 2018 annual miles was 1,400,000,000[53] with a package volume of 6,200,000,000.[54] Dividing the annual miles by annual package volume is approximately 0.23 miles per package.

Rodrigue's research on parcel delivery in a residential apartment complex was used to estimate VMT by provider.[55] The VMT per package metric was used to scale the average number of deliveries. Table 7.1 provides the distribution of deliveries by firm and estimates for existing and 2030 VMT. Note the VMT estimates were increased by 25 percent to account for the VMT/parcel since they also include commercial deliveries which would be more concentrated than residential deliveries. Moreover, there was no direct data on the smaller delivery providers (e.g. FedEx, Amazon) which are likely to be less efficient than the larger providers.

Table 7.1 Parcel Delivery VMT Estimates

Delivery Firm	Percent of Parcel Delivery	VMT/Package	2018 VMT	2030 VMT
USPS	47%	0.23	68,679	139,049
UPS	28%	0.58	104,536	211,646
Federal Express	11%	0.58	41,068	83,147
Amazon	11%	0.58	41,068	83,147
Other	3%	1.15	22,400	45,353
Total			**277,500**	**562,342**

Source: Rodrigue (2017) and HDR calculations

Adding the residential deliveries from third-party restaurant delivery, on-line grocery delivery, and parcel delivery, the total estimate for residential deliveries in 2018 is 566,240. Total VMT for 2018 is 564,734. Table 7.2 provides a summary of the estimates.

51 https://pressroom.ups.com/pressroom/ContentDetailsViewer.page?ConceptType=PressReleases&id=1470099527110-745

52 https://pressroom.ups.com/pressroom/ContentDetailsViewer.page?ConceptType=FactSheets&id=1426321563187-193

5353 https://facts.usps.com/size-and-scope

54 https://facts.usps.com/table-facts/

55 Rodrigue, J.P., Residential Parcel Deliveries: Evidence from a Large Apartment Complex. Final Report, March 2017. Metro Freight Center of Excellence, Department of Global Studies & Geography, Hofstra University, Hempstead, New York, USA.

Table 7.2 Residential Delivery Estimates (2018)

Key Metric	2018			
	3rd Party Restaurant Delivery	Online Grocery Delivery	Parcel Delivery	Total
Number of Daily Deliveries	33,800	14,760	517,700	566,240
Average Delivery Trip Length (miles)	5	8	0.4	0.9
Deadhead	50%	50%	n/a	n/a
Daily VMT (miles)	168,900	118,800	277,750	564,734

Source: HDR

7.3 Future Year (2030) Forecasts

Third-Party Restaurant Delivery

For 2030, a compound annual growth rate (CAGR) of 20 percent was assumed based on market research conducted by UBS Bank.[56] While this growth assumption is very aggressive, some of the other assumptions used in the estimates may provide an offset to the conservative numbers used in the analysis such as the average trip length which implicitly seems short (5 miles including deadhead) or the average number of orders of eight.

Online Grocery Delivery

Online grocery purchase and deliveries are assumed to triple from 3 percent in 2018 to 9 percent in 2030 which would still put Colorado behind the United Kingdom and South Korea today where some estimate put online grocery purchases as high as 15 percent. Using the 2030 estimates for households in Colorado of 2,950,775 and a 9 percent share, there would be 56,908 residential grocery deliveries and 341,447 VMT in 2030.

Parcel Delivery

For 2030, an annual growth rate of 17 percent for three years[57] to 2020 was assumed, followed by a flat growth rate from 2020 to 2030. Therefore, any growth between 2020 and 2030 would be due to the growth in Colorado's population. Using the 2030 population of 6,892,000 with Rodrigue's growth rate assumptions, there would be 1,048,154 parcel deliveries.

Adding the residential deliveries from third-party restaurant delivery, on-line grocery delivery, and parcel delivery, the total estimate for residential delivery in 2030 is 1,406,187. Total VMT would be

[56] https://www.aol.com/article/finance/2018/07/02/ubs-online-food-delivery-could-be-a-dollar365-billion-industry-by-2030-here-are-the-winners-and-losers-from-that-mega-trend/23473052/

[57] Rodrigue, J.P., Residential Parcel Deliveries: Evidence from a Large Apartment Complex. Final Report, March 2017. Metro Freight Center of Excellence, Department of Global Studies & Geography, Hofstra University, Hempstead, New York, USA.

2,523,227. Table 7.3 provides a summary of the 2030 estimates.

Table 7.3 Residential Delivery Estimates (2030)

Key Metric	2030			
	3rd Party Restaurant Delivery	Online Grocery Delivery	Parcel Delivery	Total
Number of Daily Deliveries	301,186	56,907	1,048,154	1,406,247
Average Delivery Trip Length (miles)	5	8	0.53	1.8
Deadhead	50%	50%	n/a	n/a
Daily VMT (miles)	1,505,929	455,256	562,341	2,523,527

Source: HDR

8.0 Results

Any number of social, economic, or regulatory changes could substantially impact any or all of these modes of travel, but it is important to understand how they are operating today and what range of futures may lay ahead for these modes, Colorado's residents and visitors, the state's transportation infrastructure, and the environment.

The analyses presented in this report represents the average miles on the road today and their potential by 2030. These efforts have not accounted for a number of factors, including but not limited to the following:

- Any miles on the road by these modes that are substitutions for other vehicle travel;
- Any suppressed travel as a result of these options being available;
- Any induced travel as a result of these options being available; and
- Any impacts of one mode on another in the future.

Estimates for total vehicle trips and VMT per day by mode are provided in **Table 8.1** and **Table 8.2.**

Table 8.1 2018 Trip and VMT Estimates for Emerging Mobility Modes

Travel Metric	Emerging Mobility Mode	Today (~2018)			Share of Travel		
		Best Estimate	Low	High	Best Estimate	Low	High
Vehicle Trips	TNCs	63,000	38,000	120,000	0.7%	0.4%	1.3%
	Taxis	5,500	5,500	7,100	0.1%	0.1%	0.1%
	Non-peer Carshare	1,800	n/a	10,000	0.0%	n/a	0.1%
	Peer Carshare	100			0.0%		
	Car Rentals	47,600	47,600	47,600	0.5%	0.5%	0.5%
	Residential Deliveries	n/a	n/a	n/a			
	Total Vehicle Trips for Emerging Mobilities	**120,000**	**90,000**	**185,000**	**1.3%**	**1.0%**	**2.0%**
	Total Vehicle Trips in CO	9,071,000					
VMT	TNCs	748,000	448,000	1,440,000	0.5%	0.3%	1.0%
	Taxis	53,200	53,200	68,100	0.0%	0.0%	0.0%
	Non-peer Carshare	25,700	n/a	503,500	0.0%	n/a	0.4%
	Peer Carshare	58,000			0.0%		
	Car Rentals	3,153,000	1,190,000	7,140,000	2.2%	0.8%	5.1%
	Residential Deliveries	564,729	564,729	564,729	0.4%	0.4%	0.4%
	Total VMT for Emerging Mobilities	**4,602,629**	**2,257,929**	**9,716,329**	**3.2%**	**1.6%**	**6.9%**
	Total Statewide VMT	140,980,000					

Source: Cambridge Systematics, Inc.

Table 8.2 2030 Trip and VMT Estimates for Emerging Mobility Modes

Travel Metric	Emerging Mobility Mode	Today (~2018)			Share of Travel		
		Best Estimate	Low	High	Best Estimate	Low	High
Vehicle Trips	TNCs	315,000	81,000	850,000	1.9%	0.5%	5.0%
	Taxis	6,900	0	13,300	0.0%	0.0%	0.1%
	Non-peer Carshare	2,200	0	56,600	0.0%	0.0%	0.3%
	Peer Carshare	200	0		0.0%	0.0%	0.0%
	Car Rentals	76,400	60,600	81,500	0.5%	0.4%	0.5%
	Residential Deliveries	566,240					
	Total Vehicle Trips for Emerging Mobilities	400,000	140,000	1,000,000	2.4%	0.8%	5.9%
	Total Vehicle Trips in CO	16,969,000					
VMT	TNCs	3,700,000	950,000	10,000,000	2.1%	0.5%	5.6%
	Taxis	66,700	0	127,600	0.0%	0.0%	0.1%
	Non-peer Carshare	16,000	0	2,800,000	0.0%	0.0%	1.6%
	Peer Carshare	3,600	0		0.0%		
	Car Rentals	5,060,700	1,515,000	12,225,000	2.8%	0.8%	6.8%
	Residential Deliveries	2,523,227	2,523,227	2,523,227	1.4%	1.4%	1.4%
	Total VMT for Emerging Mobilities	11,000,000	5,000,000	28,000,000	6.3%	2.8%	15.4%
	Total Statewide VMT	179,162,000					

Source: Cambridge Systematics, Inc.

For context, **Table 8.3** provides the mode share in Colorado for 2010 (from the FRTC Survey). While it seems like this study is considering a small share of trips and VMT today – this is on par with transit travel, something transportation professionals been studying for many years. It is not insignificant, especially considering the trajectory of some of these modes over the past few years.

Table 8.3 Trip by Mode in Colorado (2010 Front Range Travel Counts Survey)

Mode	Number of Trips		Mode Share	
	Front Range*	DRCOG	Front Range*	DRCOG
Drive Alone	7,518,654	4,561,336	50.1%	46.9%
Shared Ride (2 persons)	3,387,673	2,315,258	22.6%	23.8%
Shared Ride (3+ persons)	2,674,926	1,777,129	17.8%	18.3%
Walk to Transit	186,998	165,416	1.2%	1.7%
Drive to Transit	94,349	93,276	0.6%	1.0%
Walk	701,123	519,081	4.7%	5.3%

Mode	Number of Trips		Mode Share	
	Front Range*	DRCOG	Front Range*	DRCOG
Bike	152,837	98,619	1.0%	1.0%
School Bus	296,289	187,504	2.0%	1.9%

* Front Range includes the DRCOG, NFRMPO, PPACOG, and PACOG regions of Colorado.

There is varying confidence in the estimates provided in this report due to data availability. Estimates with the lowest confidence are a result of very little or no available data; these low-confidence estimates include total number of TNC trips, car rental VMT per trip or reservation, and the number of trips and amount of VMT for any and all carsharing. Additionally, forecasts are based on a myriad of predictions regarding the future, including population, employment, the transportation system, travel costs, and travel behavior. There is potential for variation in any of those assumptions, making it difficult to forecast travel in the future. This report details the best estimates, accompanied by ranges of estimates, based on the data available to researchers at the time.

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A.2 Ridesharing and Carsharing Models using 2015 PSRC Survey Data

TABLE 2 Estimation Results for Bivariate Ordered Probit Model
(coefficients represent impact of variables on underlying propensities of ride-sourcing and car-sharing)

Variable	Ride-sourcing		Car-sharing	
	Coef	*t-stat*	*Coef*	*t-stat*
Education *(Base: Not achieved Bachelor's degree level)*				
Bachelor's degree or higher	0.326	3.554	0.380	3.474
Age *(Base: 18-34 years)*				
35-54 years	-0.419	-5.617	0.000	-
55 years and above	-1.113	-10.976	-0.408	-4.293
Employment *(Base: Unemployed)*				
Employed Part time	0.000	-	0.000	-
Employed (Full time)	0.199	2.348	0.242	2.5
Employed (Self-employed)	0.199	2.348	0.242	2.5
Has a valid driver's License *(Base: No)*				
Yes	0.000	-	1.551	6.066
Has a smartphone and single family *(Base: Doesn't have a Smartphone & Multi person HH)*				
No smartphone and a single person HH	0.000	-	-0.387	-1.577
Has a Smartphone x Non-single person HH	1.133	7.275	0.476	3.013
Has a Smartphone x Single person HH	1.133	7.275	0.476	3.013
Income *(Base: Above $100,000)*				
Below $49,999	-0.272	-3.144	-0.185	-1.735
Below $49,999 x Presence of children	-1.281	-3.566	-0.758	-3.260
$50,000-$99,999 x Presence of children	-0.680	-4.113	-0.943	-4.565
Vehicles in household *(Base: 0 vehicles)*				
1 vehicle	-0.673	-7.145	-1.292	-10.326
2 or more vehicles	-0.908	-11.357	-2.042	-14.609
1 vehicle x high density living	0.673	7.145	0.300	2.68
2+ vehicles x high density living	0.908	11.357	0.754	5.604
Threshold values				
δ_1 and ψ_1	0.172	1.379	-0.025	-0.142
δ_2 and ψ_2	0.623	4.978	0.415	2.350
δ_3 and ψ_3	1.455	11.117	1.097	5.993
δ_4 and ψ_4	1.826	13.827	1.379	7.203

Error correlation = 0.401 (t-stat: 8.725)
Log-likelihood (Null model): -3136.258
Log-likelihood (Full model): -2117.166
Pseudo-R^2 (McFadden) = 0.325

Notes: 1. The "Unemployed" category groups the following categories from Table 1: "Unpaid volunteer or intern", "Homemaker", "Retired" and "Not currently employed".
2. Null model is the model with only the thresholds in each of the ordered probits (sample shares model) with the constraint that the correlation term is zero.

A.3 TNC Trip Generation Model using Chicago TNC Data

Table 4. Trip Generation Model from Chicago and New York Data

Spatial Configuration		Chicago *Census Tract*		NYC *Taxi TAZ*	
Dependent Variables		**Trip Counts**		**Trip Counts**	
Model Type		**Linear**		**Linear**	
Independent Variables		**Estimates**	**t-stats**	**Estimates**	**t-stats**
Time of Day Constants	Monday – Friday: 6 am – 8 am	20.58	36.35	148.51	74.36
	Monday – Friday: 8 am – 11 am	41.58	43.36	202.22	66.05
	Saturday: 12 pm – 6 pm	34.43	38.69	148.50	55.62
	Monday – Friday: 3 pm – 5 pm	15.85	9.39	264.68	174.19
	Monday – Thursday: 5 pm – 12 am	21.31	32.82	288.87	130.69
	Friday – Saturday: 6 pm – 12 am	20.58	36.35	107.87	28.87
	Saturday – Sunday: 12 am – 2 am	41.58	43.36	148.51	74.36
Income	HH Med. Income ratio for County and Census Tract	5.24	5.43	-	-
	Ratio of HH Mean Income at Census Tract and HH Med. Income at County between 0.9 and 1.2	-3.82	-6.17	-	-
	Ratio of HH Mean Income at Census Tract and HH Med. Income at County between 1.2 and 1.5	2.61	2.81	-	-
	Ratio of HH Mean Income at Census Tract and HH Med. Income at County between 1.5 and 2.25	33.40	24.18	-	-
	Ratio of HH Mean Income at Census Tract and HH Med. Income at County More than 2.25	120.76	61.67	-	-
Existence of College	Large College	62.09	22.83	461.61	99.58
	Medium College	56.85	28.20	32.65	15.10
Population Density	Low-Density-Area	-	-	113.49	61.27
	Medium-Density-Area	18.40	12.37	52.79	20.18
	High-Density-Area	70.05	14.17	-137.76	-44.79
	Very High-Density-Area	-103.25	-15.86	49.34	13.70
Employment Density	Medium Job-Density Area	-	-	155.20	67.73
	High Job-Density Area	-10.33	-20.87	405.44	145.10
	Very High Job-Density Area	28.05	35.41	642.59	214.33
Transit Facility	Existence of major Train Stations	646.96	236.97	708.50	203.60
Time Of Day Specific Difference for a particular attribute	Monday – Friday (8 am – 11 am): Medium-Population-Density-Area	55.98	12.76	-	-
	Monday – Friday (8 am – 11 am): High-Population-Density-Area	98.42	6.10	-	-
	Monday – Thursday (3 pm – 5 pm): High Job-Density Area	10.34	7.23	-	-
	Monday – Thursday (5 pm – 12 am): Very High Job-Density Area	45.98	29.03	-	-
	Friday – Saturday (6 pm – 12 am): High Job-Density Area	46.77	29.94	-	-

Spatial Configuration		Chicago *Census Tract*		NYC *Taxi TAZ*	
Dependent Variables		**Trip Counts**		**Trip Counts**	
Model Type		**Linear**		**Linear**	
Independent Variables		**Estimates**	**t-stats**	**Estimates**	**t-stats**
	Friday – Saturday (6 pm – 12 am): Very High Job-Density Area	157.92	69.36	-	-
	Saturday – Sunday (12 am – 2 am): High-Population-Density-Area	224.41	7.39	-	-
	Saturday – Sunday (12 am – 2 am): High Job-Density Area	43.78	15.53	-	-
	Saturday – Sunday (12 am – 2 am): Very High Job-Density Area	76.32	19.24	-	-
Adj. R-Square		**0.312**		**0.617**	
Log-Likelihood		**- 314700**		**- 3775000**	

APPENDIX G

CHAPTER 4 SUPPORTING DOCUMENTATION—TRANSPORTATION IMPACT ANALYSIS

2017 and 2030 MOVES Summary

MOVES SUMMARY 2017

			MOVES Activity Level (VMT/day)		MOVES $CO2_e$ Emissions (Tons/Day)	
			2017		2017	
		Source Type	January	July	January	July
Vehicles	11	Motorcycle	266,868	1,357,550	125	584
	21	Passenger Car	55,602,400	70,239,600	22,225	27,640
	31	Passenger Truck	41,720,200	52,703,000	21,739	27,216
	32	Light Commercial Truck	10,627,800	13,425,500	5,609	7,005
	41	Intercity Bus	71,949	90,889	138	182
	42	Transit Bus	143,267	180,981	221	293
	43	School Bus	398,531	503,442	442	582
Trucks	51	Refuse Truck	202,729	256,096	382	504
	52	Single Unit Short-haul Truck	4,255,320	5,375,520	4,767	6,275
	53	Single Unit Long-haul Truck	239,002	301,918	248	329
	54	Motor Home	156,461	197,649	188	246
	61	Combination Short-haul Truck	1,741,770	2,200,280	3,281	4,339
	62	Combination Long-haul Truck	5,452,800	6,888,220	11,392	15,040
		Subtotal	120,879,097	153,720,645	70,756	90,234
		Average Weekday	137,299,871		80,495	

MOVES SUMMARY 2030

Month	Source Type	Source Type Decoder	Emissions	Activity (Daily VMT)	Emission Factor (Tons of CO2e/Mile)	Source Type % Activity	CDOT VMT	CDOT Category	Adjusted VMT	Adjusted Emissions (Tons CO2e/Day)
1 (January Weekday)	11	Motorcycle	140.873	301509	0.000467	0.25%	158,267,590	Vehicles (non-trucks)	387,869	181
	21	Passenger Car	16985.9	63596700	0.000267	51.69%			81,812,417	21851
	31	Passenger Truck	16738.8	46537200	0.000360	37.83%			59,866,641	21533
	32	Light Commercial Truck	4399.4	11837100	0.000372	9.62%			15,227,547	5660
	41	Intercity Bus	160.422	88490.9	0.001813	0.07%			113,837	206
	42	Transit Bus	266.227	181644	0.001466	0.15%			233,671	342
	43	School Bus	509.206	486315	0.001047	0.40%			625,608	655
	51	Refuse Truck	432.62	240986	0.001795	1.63%	20,894,135	Trucks	340,521	611
	52	Single Unit Short-haul Truck	5334.44	5132160	0.001039	34.71%			7,251,907	7538
	53	Single Unit Long-haul Truck	286.484	298204	0.000961	2.02%			421,372	405
	54	Motor Home	189.237	166658	0.001135	1.13%			235,493	267
	61	Combination Short-haul Truck	4143.25	2352700	0.001761	15.91%			3,324,441	5855
	62	Combination Long-haul Truck	12667.1	6596030	0.001920	44.61%			9,320,402	17899
7 (July Weekday)	11	Motorcycle	660.77	1533760	0.000431	0.98%	158,267,590	Vehicles (non-trucks)	1,550,402	668
	21	Passenger Car	20823.4	80338200	0.000259	51.31%			81,209,908	21049
	31	Passenger Truck	20697.5	58788000	0.000352	37.55%			59,425,878	20922
	32	Light Commercial Truck	5423.82	14953200	0.000363	9.55%			15,115,449	5483
	41	Intercity Bus	212.647	111786	0.001902	0.07%			112,999	215
	42	Transit Bus	352.718	229461	0.001537	0.15%			231,951	357
	43	School Bus	671.012	614337	0.001092	0.39%			621,003	678
	51	Refuse Truck	571.573	304424	0.001878	1.63%	20,894,135	Trucks	340,521	639
	52	Single Unit Short-haul Truck	7022.8	6483170	0.001083	34.71%			7,251,902	7856
	53	Single Unit Long-haul Truck	381.259	376706	0.001012	2.02%			421,373	426
	54	Motor Home	246.948	210530	0.001173	1.13%			235,493	276
	61	Combination Short-haul Truck	5483.73	2972040	0.001845	15.91%			3,324,445	6134
	62	Combination Long-haul Truck	16730.3	8332400	0.002008	44.61%			9,320,401	18714

APPENDIX G

CHAPTER 4 SUPPORTING DOCUMENTATION—TRANSPORTATION IMPACT ANALYSIS

2030 MOVES Input Specifications

2030 MOVES Input Specifications


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            <onroadvehicleselection fueltypeid="1"
fueltypedesc="Gasoline" sourcetypeid="21" sourcetypename="Passenger
Car"/>
            <onroadvehicleselection fueltypeid="1"
fueltypedesc="Gasoline" sourcetypeid="31" sourcetypename="Passenger
Truck"/>
            <onroadvehicleselection fueltypeid="1"
fueltypedesc="Gasoline" sourcetypeid="51" sourcetypename="Refuse Truck"/>
            <onroadvehicleselection fueltypeid="1"
fueltypedesc="Gasoline" sourcetypeid="43" sourcetypename="School Bus"/>
            <onroadvehicleselection fueltypeid="1"
fueltypedesc="Gasoline" sourcetypeid="53" sourcetypename="Single Unit
Long-haul Truck"/>
            <onroadvehicleselection fueltypeid="1"
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Short-haul Truck"/>
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fueltypedesc="Gasoline" sourcetypeid="42" sourcetypename="Transit Bus"/>
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Access" modelCombination="M1"/>
            <roadtype roadtypeid="3" roadtypename="Rural Unrestricted
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            <roadtype roadtypeid="4" roadtypename="Urban Restricted
Access" modelCombination="M1"/>
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      &lt;/roadtypes&gt;
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Exhaust"/>
            <pollutantprocessassociation pollutantkey="90"
pollutantname="Atmospheric CO2" processkey="90" processname="Extended
Idle Exhaust"/>
            <pollutantprocessassociation pollutantkey="90"
pollutantname="Atmospheric CO2" processkey="91" processname="Auxiliary
Power Exhaust"/>
            <pollutantprocessassociation pollutantkey="98"
pollutantname="CO2 Equivalent" processkey="1" processname="Running
Exhaust"/>
            <pollutantprocessassociation pollutantkey="98"
pollutantname="CO2 Equivalent" processkey="2" processname="Start
Exhaust"/>
            <pollutantprocessassociation pollutantkey="98"
pollutantname="CO2 Equivalent" processkey="90" processname="Extended Idle
Exhaust"/>
            <pollutantprocessassociation pollutantkey="98"
pollutantname="CO2 Equivalent" processkey="91" processname="Auxiliary
Power Exhaust"/>
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Exhaust"/>
            <pollutantprocessassociation pollutantkey="5"
pollutantname="Methane (CH4)" processkey="2" processname="Start
Exhaust"/>
            <pollutantprocessassociation pollutantkey="5"
pollutantname="Methane (CH4)" processkey="90" processname="Extended Idle
Exhaust"/>
            <pollutantprocessassociation pollutantkey="5"
pollutantname="Methane (CH4)" processkey="91" processname="Auxiliary
Power Exhaust"/>
            <pollutantprocessassociation pollutantkey="6"
pollutantname="Nitrous Oxide (N2O)" processkey="1" processname="Running
Exhaust"/>
            <pollutantprocessassociation pollutantkey="6"
pollutantname="Nitrous Oxide (N2O)" processkey="2" processname="Start
Exhaust"/>
            <pollutantprocessassociation pollutantkey="91"
pollutantname="Total Energy Consumption" processkey="1"
processname="Running Exhaust"/>
            <pollutantprocessassociation pollutantkey="91"
pollutantname="Total Energy Consumption" processkey="2"
processname="Start Exhaust"/>
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```
            <pollutantprocessassociation pollutantkey="91"
pollutantname="Total Energy Consumption" processkey="90"
processname="Extended Idle Exhaust"/>
            <pollutantprocessassociation pollutantkey="91"
pollutantname="Total Energy Consumption" processkey="91"
processname="Auxiliary Power Exhaust"/>
            <pollutantprocessassociation pollutantkey="1"
pollutantname="Total Gaseous Hydrocarbons" processkey="1"
processname="Running Exhaust"/>
            <pollutantprocessassociation pollutantkey="1"
pollutantname="Total Gaseous Hydrocarbons" processkey="2"
processname="Start Exhaust"/>
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pollutantname="Total Gaseous Hydrocarbons" processkey="90"
processname="Extended Idle Exhaust"/>
            <pollutantprocessassociation pollutantkey="1"
pollutantname="Total Gaseous Hydrocarbons" processkey="91"
processname="Auxiliary Power Exhaust"/>
      </pollutantprocessassociations>
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      </databaseselections>
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<internalcontrolstrategy
classname="gov.epa.otaq.moves.master.implementation.ghg.internalcontrolst
rategies.rateofprogress.RateOfProgressStrategy"><![CDATA[
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]]></internalcontrolstrategy>
      </internalcontrolstrategies>
      <inputdatabase servername="" databasename="" description=""/>
      <uncertaintyparameters uncertaintymodeenabled="false"
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      <geographicoutputdetail description="NATION"/>
      <outputemissionsbreakdownselection>
            <modelyear selected="false"/>
            <fueltype selected="false"/>
            <fuelsubtype selected="false"/>
            <emissionprocess selected="false"/>
            <onroadoffroad selected="true"/>
            <roadtype selected="false"/>
            <sourceusetype selected="true"/>
            <movesvehicletype selected="false"/>
            <onroadscc selected="false"/>
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keepSampledData="false" keepIterations="false"/>
            <sector selected="false"/>
            <engtechid selected="false"/>
            <hpclass selected="false"/>
            <regclassid selected="false"/>
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databasename="cms_baseline_2030_itr18_out" description=""/>
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      <outputvmtdata value="true"/>
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      <outputsho value="false"/>
      <outputsh value="false"/>
      <outputshp value="false"/>
      <outputshidling value="false"/>
      <outputstarts value="false"/>
      <outputpopulation value="false"/>
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      <pmsize value="0"/>
      <outputfactors>
            <timefactors selected="true" units="Days"/>
            <distancefactors selected="true" units="Miles"/>
            <massfactors selected="true" units="U.S. Ton"
energyunits="Million BTU"/>
      </outputfactors>
      <savedata>

      </savedata>

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      </donotexecute>

      <generatordatabase shouldsave="false" servername="" databasename=""
description=""/>
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truncateactivity="true" truncatebaserates="true"/>
</runspec>
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