MEMO

TO: SANDAG TDM and Modeling Staff

FROM: Rosella Picado, WSP

SUBJECT: Draft TDM Off-Model Methodology—March 2019 Revision

DATE: March 20, 2019

Introduction

SANDAG uses the Activity Based Model (ABM) to estimate performance measures and to evaluate the transportation network included in the Regional Plan (SANDAG's Regional Transportation Plan and Sustainable Communities Strategy (RTP/SCS). However, some strategies that contribute towards the reductions of greenhouse gas (GHG) emissions are not fully captured by the SANDAG ABM or the California Air Resources Board (ARB) Emissions Factor model.

The four largest MPOs in California (SANDAG, the Metropolitan Transportation Commission and Association of Bay Area Governments, the Sacramento Area Council of Governments, and the Southern California Association of Governments) have partnered to establish the Future Mobility Research Program. The purpose of the program is to jointly fund research on the potential impacts of transportation technologies, study key policy issues, and identify appropriate roles for the MPOs in relation to emerging transportation technologies. This cooperative effort ensures a consistent approach to evaluating the range of potential changes to travel behavior associated with emerging technologies and will provide recommendations on how to model travel behavior and incorporate technology into each MPO's RTP/SCS. The FMRP partnered in this effort to have a consistent approach in considering strategies whose GHG impacts are not captured through traditional modeling.

For SANDAG's Regional Plan, the off-model analysis included evaluating such strategies as carshare, electric vehicle charging stations, and carpool assumptions. The draft Transportation Demand Management (TDM) off-model strategies which are the focus of this memo, are as follows[1]:

- Vanpool
- Carshare
- Bikeshare
- Microtransit
- Pooled rides
- Community-based travel planning

[1] The Community-Based Travel Planning strategy was prepared by SANDAG staff. All other calculators referenced in this memo were developed in collaboration with WSP.

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Methodology

The inputs and assumptions listed within this methodology are draft and are subject to change, pending the selection of a preferred network scenario and the final regional growth forecast developed to inform the 2019 Regional Plan. Furthermore, the draft model data used in the draft calculators is subject to change, pending the selection of the preferred network scenario.

The draft off-model greenhouse gas emissions reduction strategies included in this off-model methodology memo are Transportation Demand Management (TDM) strategies which includes programs or services that encourage the use of transportation alternatives. Strategies proposed in this methodology includes programs facilitated and administered by SANDAG as well as services operated by third-parties. These programs and services include a vanpool subsidy program; transit solutions; regional support for shared mobility services, like bikeshare and carshare; incentives for pooled rides, and commuter outreach.

This memorandum documents the methodology for estimating vehicle miles traveled (VMT) and GHG emission reductions from vanpool, carshare, bikeshare, microtransit, pooled rides, and community-based travel planning. The methodology for estimating GHG emission reductions is a series of Excel spreadsheet calculators that estimate average VMT reductions for each program or shared mobility service type. The VMT reductions are based on historic data, applicable research, and case study findings, as documented in the "References" section within each strategy. Where possible and if available, local data was used to inform the assumptions used in the methodology. To minimize double counting, the methodology intentionally employs a conservative approach to estimate reasonable program impacts. While the off-model calculators utilize mode-based inputs from the ABM to estimate program impacts, calculator outputs remain off-model and do not interact or feed back into the ABM.

In general, the research is used to estimate the following methodology parameters:

a. Population that has access to the mobility service, or market. The market may be defined in terms of persons or households.

b. Level of supply/geographic extent. The level of supply may be defined as a function of cities or neighborhoods in which the program or service is available.

c. Regional infrastructure improvements. Regional investments in transportation infrastructure may help facilitate use of a mobility service and induce demand.

d. Baseline VMT. An estimate of the average VMT per person or per household, among persons/households that do not participate in the program or mobility service.

e. Project VMT. An estimate of the average VMT per person or per household expected among persons per households that participate in the program or mobility service. This could be estimated directly from average trip lengths, indirectly from mode shifts, changes in car occupancy, and/or reductions in average number of trips.

f. GHG emission factors. Based on total trip and Carbon Dioxide (CO_2) forecasts produced by the SANDAG ABM 14.0.1.

Summary

The six off-model greenhouse gas reduction strategies described in this memo will be considered during the transportation network development process of the 2019 Regional Plan. During the analysis, reductions in daily VMT and corresponding daily CO_2 emissions reductions will be reported using the draft companion calculators appended to this memo. Following this summary are the detailed methodologies of each of the six individual strategies.

VANPOOL PROGRAM

Program Description

Vanpooling is a flexible form of public transportation that provides groups of 5–15 people with a cost-effective and convenient rideshare option for commuting. SANDAG has been operating a regional vanpool program since 1995, and currently comprises of approximately 700 vans. The SANDAG Vanpool Program provides a subsidy of up to $400 per month for eligible vanpoolers to offset the cost of the lease of the vanpool vehicle and works with the vanpool vendors to conduct marketing and outreach through employers in the region to grow participation in the Program. All vanpools in the program are subsidized by SANDAG using Congestion Mitigation Air Quality (CMAQ) funds.

Per the Vanpool Program Guidelines, participating vanpools must have origins or destinations within San Diego County, operate at 80 percent occupancy, and travel a minimum of 20 one-way vehicle miles on San Diego County's highways. Vanpools may have an origin or destination outside of the San Diego County but must demonstrate that they meet the travel distance minimum on the region's highways. While the congestion and environmental benefits of vanpooling expand beyond San Diego County, the travel impacts and GHG emission reduction estimates accounted for in this methodology only account for vanpool travel that occurs within San Diego County. Based on historical program data, participants of the program are those that typically were driving alone to work and travel over 55 miles one-way to work[2].

The SANDAG TDM program, iCommute, has an Employer Services Program that works with major employers throughout the region to develop and implement commuter benefit programs. As part of their work plan, the Employer Services program conducts targeted outreach to host vanpool formation events at employer sites that are suitable candidates for vanpooling. Vanpools in the program represent commuters from diverse employer industries in the region including military, manufacturing, and technology or professional services. Currently one-half of all the vanpools comprise persons that work for the federal government. In addition to the subsidy provided by SANDAG, the federal government subsidizes their commute-related expenses through the federal Transportation Incentive Program (TIP), which is why a substantial number of vanpools in the San Diego region are federal employees. However, any employer contributions, TIP or other, are not tracked or administered by our program. All participants in the SANDAG Vanpool Program receive a monthly subsidy of up to $400 per vanpool and therefore all program impacts are entirely attributed to the SCS.

Assumptions

The following assumptions were incorporated into the off-model calculator for the Vanpool Program. The calculation of VMT reductions was based on the Regional Vanpool Program data specific to the vanpool fleet, as of June 30, 2018. This data included the total number of active vanpools, vehicle type, vanpooler industries, commute trip origin and destination, distance traveled within San Diego County, and vehicle occupancy. Future growth assumptions were based on two growth drivers:

a. Employment growth. Based on existing vanpool program trends, the proportion of vanpoolers relative to the total workers employed in San Diego County will remain approximately constant. Therefore, as the region adds jobs within industries that have historically had higher rates of vanpooling (i.e. military, biotech, federal employers, etc.), it is assumed that enrollment in the Vanpool Program will proportionally grow.

b. Travel time savings. Vanpools in the San Diego region can leverage the exclusive use of managed lanes (High Occupancy Vehicle (HOV), Interstate-15 (I-15) Express Lanes), to shorten their commute time during

[2] Based on FY 2018 Vanpool Program data, the average vanpooled travels a total roundtrip distance of 116 miles. Only vanpool travel that occurs in the San Diego region is accounted for in the off-model calculator. Miles traveled outside of the San Diego County are discounted from the final VMT estimates.

peak travel periods. Nearly half of the participants currently in the Vanpool Program travel in the I-15 Express Lanes. The reliability of the managed lanes makes vanpooling an attractive option. As the region's managed lane network expands, commuters who choose to vanpool, are likely to experience shorter travel times than commuters driving alone. This travel time savings will encourage a shift from driving alone to vanpooling.

Based on historical program participation data, three vanpool markets were defined based on the vanpoolers' employer industry: military vanpools, federal non-military vanpools, and non-federal vanpools. This segmentation was used to calculate employment growth factors that are specific to each of these industries. The travel time savings methodology also varies depending on industry type, since the destinations of the future military vanpools are defined. Other inputs, such as average distance traveled and average vehicle occupancy, also vary by type of industry.

The off-model employed for the Vanpool Program utilize mode-based inputs from the ABM to estimate program impacts, however the calculator outputs remain off-model and do not interact with the ABM. A summary of the principle assumptions underlying the CO2 emission reduction calculation for vanpools is shown in Table 1.

Table 1. Principle Approach to Vanpool CO2 Emissions Calculations

Quantity	Overall Approach	Inputs and Source

Market / Market Growth	• The primary market for vanpooling are commuters with home-to-work trips that are longer than 50 miles one way
	• Vanpool trip origins and destinations are expected to follow the existing trend
	• Vanpool program growth will occur proportionally with employment growth in the region
		• SANDAG Vanpool Program data, aggregated by origin/destination Metropolitan Statistical Area (MSA)
		  ○ Number of vans in program (FY 2018) by zip code of trip origin and trip destination, and type of employer (federal military, federal non-military, non-federal)
		• SANDAG growth forecast, aggregated by origin/destination MSA
		  ○ Population and employment by employer industry in each forecast year

Regional Infrastructure Improvements	• Proposed regional managed lane infrastructure investments (HOV lanes and Express Lanes) offer travel time savings to vanpools and are likely to increase demand for vanpooling
	• Change in demand calculated based on elasticity of demand with respect to travel time
		• SANDAG Vanpool Program data
		  ○ Estimated number of vanpool trips per month
		• SANDAG ABM data
		  ○ Average one-way weekday travel time (minutes), based on existing vanpool trip origins and destinations
		  ○ Average travel time savings by trip origin and destination in each forecast year future year, relative to 2016
		  ○ Marginal disutility of time, in-vehicle time coefficient

Baseline VMT	• Assume that vanpool participants would commute by car in single-occupant vehicles (SOVs), if vanpool is unavailable • Estimate average trip length based on existing program participation	• SANDAG Vanpool Program data ○ Average trip length
Program VMT	• Estimate Program VMT, based on estimated number of vanpools in forecast year and average vanpool occupancy	• SANDAG Vanpool Program data ○ Average vanpool occupancy

Quantity	Overall Approach	Inputs and Source
GHG Emission Factors		• SANDAG ABM 14.0.1

GHG Emission Calculator Methodology

CO2 reductions were calculated following the procedure described below; the principle parameters and data items underlying this method are listed in Table 2.

Vanpool demand due to regional employment growth:

1. To establish the current vanpool demand due to regional employment growth, data was obtained directly from SANDAG's Vanpool Program, reflecting active vanpools as of June 30, 2018. This demand was assumed to be representative of the vanpool fleet during the 2016 baseline year. Over the past five years, the number of active vanpools has fluctuated between 680 and 720 vehicles. The vanpool demand was then tabulated in a trip origin-destination matrix, where the trip origin represented the home location and the trip destination was the work location. Home and work locations were then identified at the level of Metropolitan Statistical Areas (MSA) if they fell within San Diego County, and County, if they fell outside San Diego County.
2. The total number of vanpools were multiplied within the destination MSA by the employment growth rate at the MSA, which was calculated as future year employment divided by 2016 employment. The new vanpools due to employment growth were then distributed to origin MSAs in the proportions observed in 2016.

Vanpool demand due to managed lane infrastructure investments:

3. Compute demand elasticity with respect to travel time. In lieu of observed demand elasticities, elasticity of demand was estimated using a logit mode choice model formulation (see below for details about this formulation).
4. Calculate average MSA to MSA travel time savings, defined as the difference between the travel time experienced when using all available highways, and the travel time experienced using general purpose lanes only (excluding HOV and Express Lanes). For trip origins outside of San Diego County, the travel time savings are computed only over the portion of the trip that occurs within San Diego County. Since the specific location of military bases is known, the travel time savings associated with military vanpools is computed specifically to the zones that comprise the military bases, rather than an average over all of the MSA destinations.
5. Compute the demand induced by travel time savings by applying the demand elasticity formula to the estimate number of vanpools for each scenario year, after accounting for employment growth.

Vanpool VMT and GHG reductions:

6. Calculate VMT reduction, which for each van is equal to the average roundtrip distance within San Diego County, multiplied by the number of passengers (excluding the driver).
7. Calculate the CO2 reduction corresponding to the VMT reduction and reduction in trip starts using the Emission Factors (EMFAC) 2014 CO2 emission rates.

Elasticity of Demand Methodology

Elasticity of demand with respect to travel time:

The elasticity of demand for vanpooling with respect to travel time was approximated using the formula for point elasticity derived from a logit model (Train, 1993):

*Elasticity = (coefficient of in-vehicle time) * average travel time * (1 – probability of vanpooling)*

The coefficient of in-vehicle time was obtained from the SANDAG ABM and reflects the value of the mode choice in-vehicle time coefficient for trips on work tours (-0.032 utils/minute).

The *probability of vanpooling* in the region represents the share of daily work trips that are suitable candidates for vanpooling. Based on historical program data and trends, the vanpool program is a suitable and convenient option for commuters that travel a one-way distance of 50 miles or more. Results from SANDAG's 2018 Commute Behavior Survey reveal commuters that exhibit these longer trip characteristics are representative of 2.7 percent of the San Diego employed population (SANDAG, 2018). Given a total employed population in 2016 of approximately 1.6 million workers (Census Bureau, 2016), this resulted in a total of 86,400 work trips that are suitable vanpool candidates. Based on program data, it is assumed that approximately 7,995 vanpool trips occur on an average weekday (699 vans x observed vanpool occupancy of 73% x two trips per day per vanpool participant). The *probability of vanpooling* is then reflected as a share of the actual vanpool trips divided by total work trips that are candidates for vanpooling, or 9.3% (7,995 vanpool trips / 86,400 work trips).

Table 2. Methodology Parameters, Vanpool CO2 Emissions Calculator

Parameter	Source	Details
Current vanpool inventory	Active vanpools as of June 30, 2018, SANDAG Vanpool Program	Inventory of vanpools in operation during base year (2018). Required data for each vanpool includes trip origin, trip destination, employment industry (federal military, federal non-military, non-federal), van capacity, roundtrip mileage. Trip origin and destination aggregated to MSAs if inside San Diego County, and to County if outside San Diego County
Coefficient of in-vehicle travel time	SANDAG ABM 14.0.1 Trip mode choice model, Work tours	SANDAG ABM value (-0.032 utils/minute) used to calculate elasticity of demand with respect to travel time and with respect to trip cost. Input to the demand elasticity formula
Total 2016 San Diego County workers	American Community Survey (2016, 1-Year Release)	Used to calculate vanpool mode market share, an input to the demand elasticity formula (estimated value of 1.6 million workers)
Probability of vanpooling	American Community Survey (2011-2016 5-Year Release); SANDAG Vanpool Program SANDAG 2018 Commute Behavior Survey	Used as an input to calculate elasticity of demand with respect to travel time. Estimated as the proportion total daily work trips that are suitable for vanpooling. Based on vanpool program market trends, it is assumed that daily work trips that are longer than 50 miles (one-way) are suitable for vanpooling .
Average work trips per month		Assumed at 44 work trips per month (22 work days, 2 trips per day). Used to calculate average lease cost per trip (input to demand elasticity calculation)
Average one-way vanpool mileage	SANDAG Vanpool Program Data. Active vanpools as of June 30, 2018. Salesforce report.	Based on SANDAG Vanpool Program data, *excluding distance traveled outside of San Diego County*
Average van capacity (seats)	SANDAG Vanpool Program Data. Active vanpools as of June 30, 2018. Salesforce report.	Based on SANDAG Vanpool Program data
Average van occupancy	SANDAG Vanpool Survey for National Transit Database Reporting, FY 2017/2018	Based on SANDAG Vanpool Program data
Postal zip code centroid coordinates	ESRI USPS zip code area boundary shapefile: https://www.arcgis.com/home/item.html?id=8d2012a2016e484dafaac0451f9aea24	Used to approximate the distance traveled by vanpools outside San Diego County

Parameter	Source	Details
County gateway centroids	US Census Bureau TIGER line file https://www.census.gov/geo/maps-data/data/tiger-line.html	Used to approximate the distance traveled by vanpools outside San Diego County. Gateways are assumed as follows, based on home county: • Los Angeles and Orange counties: Interstate 5 • Riverside and San Bernardino counties: Interstate 15 • Imperial county: Interstate 8

Calculator Inputs

Table 3 summarizes the calculator inputs for each future year scenario.

Table 3. Scenario Inputs, Vanpool CO2 Emissions Calculator

Data Item	Source	Required Input Data
Employment forecast	Draft Series 14: 2050 Regional Growth Forecast/San Diego Forward: The Regional Plan in ABM 14.0.1	For each scenario year and MSA: • Jobs by industry category
Regional Population Forecast	Draft Series 14: 2050 Regional Growth Forecast/San Diego Forward: The Regional Plan in ABM 14.0.1	For each scenario year: • Total employment
Travel times, non-military base destinations	SANDAG ABM 14.0.1	For each scenario year[3]: • TAZ-to-TAZ travel time, general purpose lane (AM_SOVGPM_TIME) • TAZ-to-TAZ travel time, managed lane (AM_HOV2TOLLM_TIME)
Travel times, military base destinations	SANDAG ABM 14.0.1	For each scenario year[4]: • TAZ-to-TAZ travel time, general purpose lanes (AM_SOVGPM_TIME) • TAZ-to-TAZ travel time, managed lanes (AM_HOV2TOLLM_TIME)
Emission factors	EMFAC 2014, SANDAG ABM 14.0.1	For each scenario year: • Trips (cold starts) regional emissions (ton) • Running CO2 regional emissions (ton) • Regional VMT • Regional trips

[3] Vanpool travel times were averaged to the MSA at both the trip origin and destination using an R Script, see traveltimesavings.R

[4] Since military base locations are known, the travel times of military vanpools were averaged to the MSA at the trip origin and base location TAZ(s) using an R Script, see traveltimesavings.R

Results

Table 4 summarizes the vehicle trip results, VMT and CO2 reductions attributed to the Regional Vanpool Program for each future year scenario.

Table 4: Regional Vanpool Program VMT and GHG Emission Reductions

Variable	2025	2035	2050
Total daily vehicle trip reductions	Final results pending selection of the preferred network scenario		
Total daily VMT reductions			
GHG reduction due to cold starts (short tons)			
GHG reduction due to VMT (short tons)			
Total daily GHG reduction (short tons)			
Total population			
Daily per capita GHG reduction (lbs/person)			
Daily per capita GHG reduction, change in percent			

References

SANDAG (2017). 2017 San Diego Regional Vanpool Participant Survey.

SANDAG (2018). 2018 Commute Behavior Survey.

Train, Kenneth (1993). Qualitative Choice Analysis. Theory, Econometrics, and an Application to Automobile Demand. The MIT Press: Cambridge, MA.

U.S. Census Bureau (2016). American Community Survey, 2016 1-Year Release.

CARSHARE

Program Description

Carshare is a shared mobility service highlighted in San Diego Forward: The 2019-2050 Regional Plan and an important component of the Regional Mobility Hub Strategy. Mobility hubs are places of connectivity where different modes of travel – walking, biking, transit, and shared mobility – converge and where there is a concentration of employment, housing, shopping, and/or recreation.

Carshare can provide connections to transit or fill gaps in a region's transit services, by providing an efficient transportation alternative that reduces reliance on the private automobile. By providing members with access to a vehicle for short-term use, a carshare service provides some of the benefits of a personal vehicle without the costs associated with owning one. As of January 2019, the San Diego region currently has two carshare service providers, Zipcar and Getaround. Zipcar provides roundtrip carshare service and Getaround operates a peer-peer carsharing service. Shared vehicles are distributed across a network of locations (or specified service area) within communities. Members can access the vehicles at any time with a reservation and are charged by time or by mile. In support of regional mobility hub planning efforts[5], the SANDAG TDM program seeks to promote and encourage the provision of carshare within the region's employment centers, colleges, and military bases.

Assumptions

The carsharing methodology described in this memo only accounts for VMT and GHG emission benefits associated with roundtrip carshare service. The peer-peer carshare service provider, Getaround, has only been operating in San Diego since November 2018 and observed impacts in the region are unknown. Car2go, a free-float carshare service provider in San Diego, ceased operations in the region in 2016 leaving Zipcar as the only carshare service provider in the region at the time. While the off-model calculator is able to account for the VMT reduction impacts of free-floating carshare service, it is assumed that this type of service will not return to the San Diego region due to the rise and popularity of on-demand ride-hailing service providers like Uber, Lyft, and Waze Carpool.

Research indicates that households that participate in carsharing tend to own fewer motor vehicles than non-member households (Martin et al, 2016). With fewer cars, carshare households shift some trips to transit and non-motorized modes, which helps to contribute to overall trip-making reductions. Estimates of the VMT reductions attributed to carshare participation have been reported to be seven fewer miles per day (Cervero, 2007) and up to 1,200 miles per year (Martin and Shaheen, 2010) for roundtrip carshare. A survey of car2go users in five North American cities, including San Diego[6], found that carshare households reported decreases in VMT ranging from 6 to 16 percent, with San Diego users reporting an average 10 percent VMT reduction, or approximately 1.4 miles per day (Martin and Shaheen, 2016). Similar behavior has been reported for participants in London's free-floating carshare service, with carshare members exhibiting a net decrease in VMT of approximately 1.5 miles per day (LeVine et al, 2014).

Based on market trends in the San Diego region, it is expected that carshare will remain a viable transportation option in neighborhoods that exhibit similar supporting land uses as those where carsharing is provided today. In support of regional mobility hub planning efforts, the SANDAG TDM program seeks to promote and encourage the provision of carshare within the region's employment centers, colleges, and military bases (Figure 1). Given the rapid trend towards automation, it is assumed that carsharing will be replaced by a fleet of shared and autonomous vehicles by the year 2050, therefore carshare coverage areas are only defined up until 2035. Within these defined carshare service areas, it is assumed that participation in the carshare program may vary depending on the supporting density characteristics (Transportation Sustainability Center, 2018). The population density thresholds that support carshare

[5] To learn more about SANDAG mobility hub efforts, visit www.sdforward.com/mobilityhubs
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participation in the region are based on the Car2Go service area prior to their exit from the San Diego market. Based on the 2016-2017 San Diego Regional Transportation Study (SANDAG, 2017) and available research on carshare participation rates, it is assumed that areas with a population greater than 17 people/acre will have a 2 percent participation rate. Areas with a population density lower than 17 people/acre will have a 0.5 percent participation rate. These density thresholds are specific to carshare trends exhibited in the San Diego region.

Carshare fleets are typically comprised of vehicles that are more fuel-efficient than the personally-owned vehicles. Some carshare providers offer a fleet at least partially comprised of zero-emission vehicles (ZEVs). The vehicle efficiency gains have been reported at 29 percent for roundtrip carshare (Martin and Shaheen, 2010) and 45 percent for one-way carshare (Martin and Shaheen, 2016). To avoid overestimation and to ensure that GHG emission reductions associated with fleet efficiencies are only captured in the SANDAG Electric Vehicle Programs off-model calculator, the carshare methodology does not account for fuel-efficiency of carshare vehicle fleets.

A summary of the principle assumptions underlying the CO2 emission reduction calculation for carshare is shown in Table 5.

Table 5: Principle Approach to Carshare CO2 Emissions Calculations

Quantity	Overall Approach	Inputs and Source

Market / Market Growth	• Estimate future carshare users based on population living in areas dense enough to support carsharing
	• Estimate carshare demand within three types of markets:
	  ○ Employment centers
	  ○ Colleges and universities
	  ○ Military bases
		• Define carshare coverage areas that are projected to offer carshare services
		  ○ Employment centers
		  ○ Colleges and universities
		  ○ Military bases
		• SANDAG ABM data
		  ○ Driving-age population in each future year by MSA
		• Share of the population that participates in carshare (2 percent in higher density areas and 0.5 percent in lower density areas based on data from the 2016-2017 San Diego Regional Transportation Study (SANDAG, 2017) and Puget Sound Region (Petersen et al, 2016)
		• A density threshold of 17 persons per acre is used to differentiate between participation in higher density and lower density areas based on the car2go service area prior to their exit from the San Diego market

Project VMT	• Estimate carshare VMT reduction based on roundtrip and one-way carshare case studies ○ It is assumed that free-float carshare service like Car2go will not return to the San Diego region due to the rise and popularity of on-demand ride-hailing service providers like Uber, Lyft, and Waze Carpool.	• 7 miles per day, traditional carshare (Cervero et al, 2007) • 1.1 miles per day, one-way (Martin and Shaheen, 2016)[7]
GHG Emission Factors	Note: No efficiency gains assumed relative to the region's carshare vehicle fleet. Emission reductions associated with vehicle fleet types are	SANDAG ABM 14.0.1

[7] Since there is currently no one-way carshare service provider in the region, the off-model calculator does not account for a VMT or GHG reduction from a one-way or free-floating service.

	captured in the Electric Vehicle Programs off-model calculator	

GHG Emission Calculator Methodology

The CO2 reduction attributed to the three carshare markets—general population, colleges, and military bases—is calculated following the procedures described below; the principle parameters and data items underlying these methods are listed in Table 6.

Carshare participation:

1. Identify the carshare service coverage areas. In support of regional mobility hub planning efforts, the SANDAG TDM program seeks to promote and encourage the provision of carshare within neighborhoods that exhibit similar supporting land uses as those where carsharing is provided today such as the region's employment centers, colleges, and military bases (Figure 1):
    a. General Population: These areas are defined as agglomerations of MGRAs and aggregated by MSA. The coverage areas could vary by scenario year, reflecting increasing land use density and a maturing carshare industry.
    b. College Staff and Students: Identify colleges and university areas where carshare services will operate in each scenario year. These areas are defined as agglomerations of MGRAs and aggregated by MSA.
    c. Military: Identify military bases where carshare services will operate in each scenario year. The military bases are defined as agglomerations of MGRAs and aggregated by MSA.
2. Calculate eligible population for carsharing:
    a. General Population: Estimate the eligible population for carsharing, which reside within the defined carshare coverage area boundaries and are persons older than 18 years old and younger than 65 years old.
    b. College Staff and Students: The eligible student population that are potential carshare participants corresponds to the total students enrolled (full-time and part-time) in each college/university campus and total staff employed at each campus.
    c. Military: Estimated carshare participants within the region's military bases corresponds to the employment at each base.
3. Calculate the carshare participation, defined as 2 percent of the eligible population in higher density areas and 0.5 percent of the eligible population in lower density areas. The population density thresholds that support carshare participation in the region are based on the Car2Go service area prior to their exit from the San Diego market.. Colleges and military bases, participation rates are assumed equal to higher density area carshare participation rates or 2 percent of the eligible population.

Carshare VMT and GHG reductions:

4. Calculate the VMT reduction from roundtrip carshare, assuming a daily average reduction of seven miles per day per roundtrip carshare member (Cervero et al, 2007).
5. Calculate the CO2 reduction corresponding to the VMT reduction, using the EMFAC 2014 CO2 emission rates.

Figure 1: Draft 2035 Carshare Coverage Areas

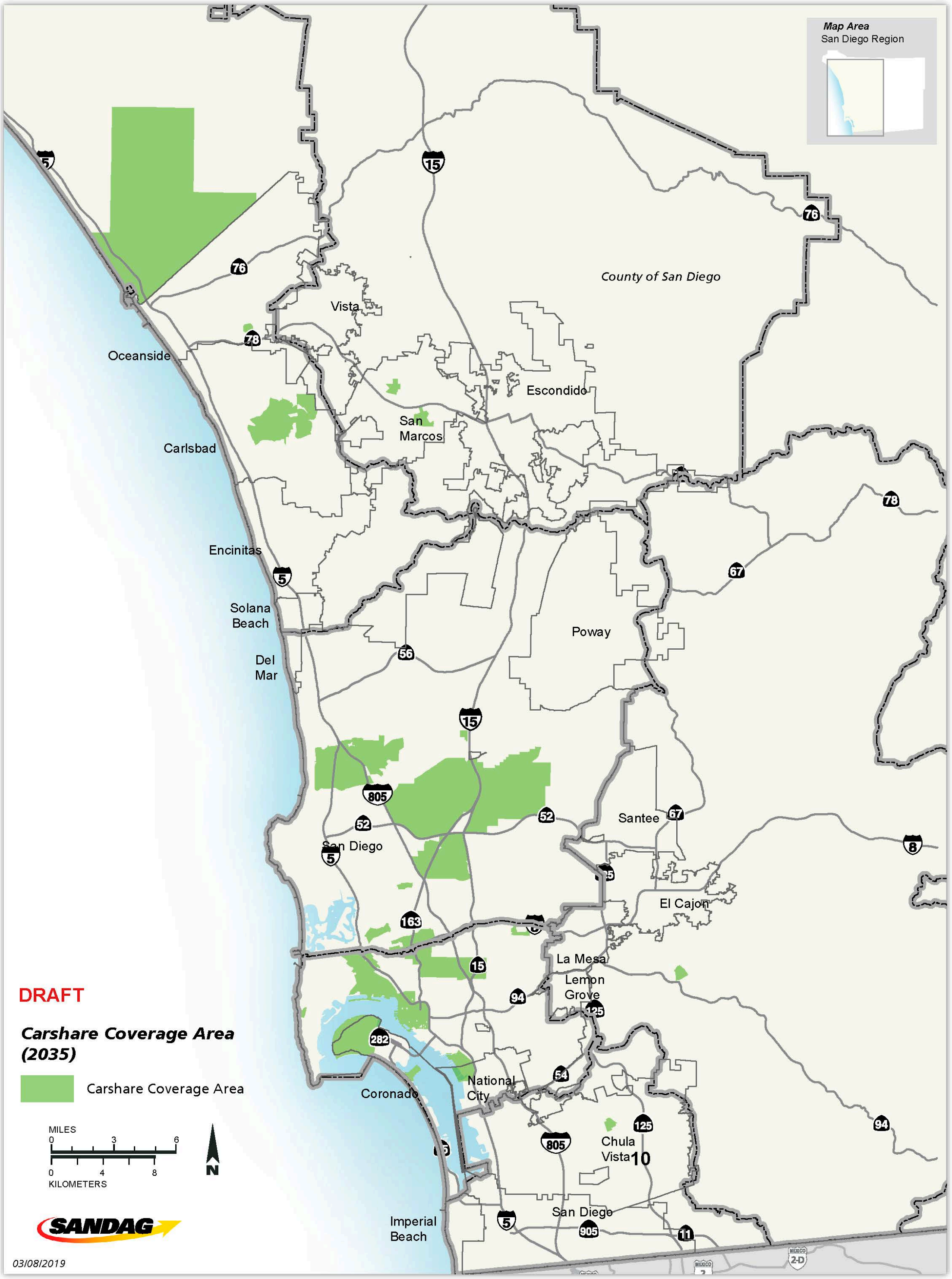

Table 6: Methodology Parameters, Carshare CO2 Emissions Calculator

Parameter	Source	Details
Carshare participation rate, higher density areas	2016-2017 San Diego Regional Transportation Study (SANDAG, 2017)	The 2016-2017 San Diego Regional Transportation Study reports that approximately 2 percent of the San Diego population are carshare participants. In the San Diego region, coverage areas with a population density greater than 17 persons per acre are assumed to reflect these participation rates.
Carshare participation rate, lower density areas	Petersen et al, 2016	Data for the Puget Sound region indicates that carshare participation in the Seattle-Bellevue-Redmond area is 2 percent in urban neighborhoods and 0.5 percent in suburban neighborhoods. In the San Diego region, coverage areas with a population density less than 17 persons per acre are assumed to reflect the participation rates of lower density neighborhoods in the Puget Sound region.
Carshare participation rates, college employees and students		Local data on the carshare participation at colleges is unavailable. Participation rates are assumed equal to higher density area carshare participation rates.
Carshare participation rates, military bases		Local data on the carshare participation at military bases is unavailable. Participation rates are assumed equal to higher density area carshare participation rates.
Daily VMT reduction, roundtrip carshare	Cervero et al, 2007	Estimated based on data for San Francisco's City CarShare service (7.0 miles per day)

Calculator Inputs

Table 7 summarizes the calculator inputs for each future year scenario.

Table 7: Scenario Inputs, Carshare CO2 Emissions Calculator

Data Item	Source	Required Input Data
Population and employment	Draft Series 14: 2050 Regional Growth Forecast/San Diego Forward: The Regional Plan in ABM 14.0.1	For each scenario year and MGRA: • Total population • Adult population (population 18-65 years old) • Total employment • Population density (total population / MGRA area in acres) • College student enrollment
Emission factors	EMFAC 2014, SANDAG ABM 14.0.1	For each scenario year: • Trips (cold starts) regional emissions (ton) • Running CO2 regional emissions (ton) • Regional VMT • Regional trips
Carshare coverage, General population	Draft San Diego Forward: The 2019-2050 Regional Plan	For each scenario year: o Carshare flag (1 if carshare operates in MGRA, 0 otherwise)
Carshare coverage, Colleges and universities	Draft San Diego Forward: The 2019-2050 Regional Plan	For each scenario year: o College/university flag (1 if carshare operates in college/university)
Carshare coverage, Military bases	Draft San Diego Forward: The 2019-2050 Regional Plan	For each scenario year: o Military base flag (1 if carshare operates on military base, 0 otherwise)

Results

Table 8 summarizes the vehicle trip, VMT and CO2 reductions attributed to carshare for each future year scenario.

Table 8: Carshare VMT and GHG Emission Reductions

Variable	2025	2035	2050
Total daily vehicle trip reductions	Final results pending selection of the preferred network scenario		
Total daily VMT reductions			
GHG reduction due to cold starts (short tons)			
GHG reduction due to VMT (short tons)			
Total daily GHG reduction (short tons)			
Total population			
Daily per capita GHG reduction (lbs/person)			
Daily per capita GHG reduction, change in percent			

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BIKESHARE

Program Description

Shared bicycle (bike) systems, also known as bikeshare, provide members of the public access to a fleet of bicycles for short trips in exchange for a fee. Bikeshare initially started out as station-based systems, in which the bicycles were borrowed from, and returned to designated docking stations. More recently, bikeshare providers have deployed bicycles and scooters equipped with payment technology and locks to allow users to pick them up, ride them, and drop them off anywhere within the service area. These systems are known as dockless bikeshare and scootershare systems.

The first bikeshare system in San Diego County, Discover®Bike, started operating in 2014, with plans to operate 1,800 bicycles and have 180 stations (City of San Diego, 2013). In 2017, Lime (formerly known as LimeBike), Mobike and ofo entered the San Diego market, offering traditional and pedal-assist dockless bikeshare and scootershare, expanding the bikeshare supply from a few hundred units to 3,000 to 5,000 units in less than one year of operations[8]. Additionally, several electric scootershare services (Razor, Bird, and others), established dockless operations within the City of San Diego in 2018. As of January 2019, Mobike and ofo ceased their dockless operations within San Diego. In March 2019, the City of San Diego announced that it had terminated its contract with station-based bikeshare provider, Discover®Bike, leaving only two dockless bikeshare providers, Lime and JUMP (Bowen, 2019). Lime offers traditional dockless bikes, electric scooters, and pedal-assist (electric) bikes; JUMP operates an all-electric bikeshare fleet.

SANDAG launched a Regional Micromobility Coordination effort among municipalities, transit agencies, universities, and military to establish best practices for effective micromobility operations. Micromobility refers to services like dockless bikeshare, e-scooters, and neighborhood electric vehicles (NEVs). At the March 7, 2019 Regional Micromobility Coordination meeting, local jurisdictions that partner with Lime announced that Lime is retiring traditional pedal bikes from its fleet and will be transitioning to an all-electric service.

Assumptions

The following assumptions informed the development of the bikeshare off-model calculator. It is assumed that bikeshare reduces GHG emissions by enabling users to take short-distance trips by bicycle instead of by automobile. In some cases, bikeshare can eliminate longer trips by enabling users to connect to transit. The shared service could also displace some walk trips, particularly when electric-assist options are available. The average trip distance of station-based bikeshare deployed for transit integration varies in the 1.3 to 2.4-mile range (Hernandez, 2018). In the 2017 Year End Report, ofo indicated that 80 – 90% of trips are less than 3 miles, which aligns with trip distances reported by bikeshare systems operating in other U.S. metropolitan areas in the 2.0 to 4.5-mile range. In San Diego County, anonymized and aggregated data from bikeshare operations indicated an average distance of 1.2 miles per pedal bike in 2018. Although other bikeshare operators within the U.S. reflect longer bikeshare trip distances, the data provided by local bikeshare operators was used to inform VMT & GHG reduction estimates to ensure bikeshare trip making assumptions conservatively reflect the San Diego market. An average car substitution rate of 20% for non-pedal assist bicycles is based on data from eight bikeshare systems operators in the U.S. (Table 10).

It is also assumed that the increasing availability of pedal-assist e-bikes and scooters will extend the range of bikeshare trip distances, facilitating travel by bike and scooters, opposed to driving alone in an automobile. Research conducted in North America and Europe that has tracked the utilization of pedal-assist bicycles owned or leased by their users, indicates that the average trip distance of e-bike trips is twice the distance traveled with regular bicycles (Cairns et al, 2017). In San Diego County, anonymized and aggregated data from bikeshare operators indicate an average distance

[8] Based on fleet estimates provided by Transit App in April 2018. Estimates were based on the number bikes that were available and not reserved at 5:00 AM P.T.

of 1.7 miles for e-bikes and e-scooters combined in 2018. Similarly, recent case study research on the JUMP bikeshare system in San Francisco, which also operates in the San Diego region, estimates that the average e-bike trip distance is 1.9 miles per trip. E-bike owners report car substitution rates of 37 percent for non-commute trips and 64 percent for commute trips (MacArthur et al, 2018), which are more than twice the average car substitution rates reported by various station-based traditional bikeshare systems. In its 2018 End of Year Report, Lime reports an average substitution rate of 37 – 40% based on operations in Los Angeles, Austin, Seattle, Atlanta, and Kansas City.

As part of the development of the Regional Plan and Sustainable Communities Strategy (SCS), SANDAG is planning for an expansion of the regional bikeway network. The attractiveness of biking in general, and bikeshare more specifically, will grow as cities build infrastructure that separates bicyclists from moving motor vehicles. The SANDAG ABM accounts for the impact of bikeway investments on personally-owned bike trip generation. However, this only accounts for the impact on personally-owned bike trips and not bikeshare trips resulting from these investments. Recently published research on New York's Citi Bikeshare system indicates that each new lane-mile of dedicated bike infrastructure results in an average of 102 additional bikeshare trips per day (Xu and Chow, 2018).

Based on the success of current bikeshare operations within San Diego County, coverage areas were defined to delineate where bikeshare operations are projected to be available (Figure 2). The bikeshare coverage areas are based on staff knowledge of interest or plans to pursue bikeshare operations within certain jurisdictions, in colleges and universities, military bases and SANDAG Smart Growth Opportunity Areas[9], which reflect a similar mix of land uses and density observed in current bikeshare operations. Staff is currently working with the cities in the North County Coastal region to deploy a bikeshare program and is actively involved in bikeshare deployment via SANDAG's Regional Micromobility Coordination Working Group. Through this working group, SANDAG is in the process of developing a micromobility data sharing clearinghouse to facilitate data collection and analysis of micromobility service operations in the region. This data will support regional planning activities and evaluation of micromobility travel patterns that may be used to augment this methodology in the future.

A summary of the principle assumptions underlying the CO2 emission reduction calculation for bikeshare is shown in Table 9.

Table 9: Principle Approach to Bikeshare CO2 Emissions Calculations

Quantity	Overall Approach	Inputs and Source
Market / Market Growth	• Estimate utilization from experience of bikeshare systems in operation in U.S. cities	• Define coverage areas that are projected to offer bikeshare services • SANDAG ABM data ○ Population in coverage area for each forecast year by MSA
Supply	• Number of bikes per 1,000 persons in bikeshare coverage area	• Average bike supply for U.S. bikeshare systems (The Bikeshare Planning Guide and other sources) • Higher bike supply density assumed in parts of the county by MSA to reflect providers responding to more demand (The Bikeshare Planning Guide)
Regional Infrastructure Improvements	• Estimate increase in bikeshare trips due to regional bicycle infrastructure investments (new bike lane miles)	• An additional 102 bikeshare trips induced for each additional bike lane mile (Xu and Chow, 2018) • SANDAG ABM data ○ Miles of bike lanes for each forecast year based on 2016 Active Transportation Networks

9 SANDAG Smart Growth Opportunity Areas. https://www.sandag.org/uploads/projectid/projectid_296_13994.pdf

Quantity	Overall Approach	Inputs and Source
Program VMT	• VMT reduction estimated based on substitution rate of auto trips, and average bikeshare trip length	• Inputs obtained from reported data for various U.S. bikeshare systems: o Average bikeshare trips per bike (pedal and e-bike) o Percent of trips that would have used a car o Average trip length • Differentiate utilization of traditional bikes and e-bikes, given research that indicates the latter are used for longer trips (Cairns et al, 2017)
GHG Emission Factors		• SANDAG ABM 14.0.1

GHG Emission Calculator Methodology

The CO2 reduction attributed to bikeshare and scootershare was calculated following the procedures described below.

Bikeshare membership within the region:

1. Identify the bikeshare service coverage areas. The bikeshare coverage areas reflect a similar mix of land uses observed in current bikeshare operations including SANDAG Smart Growth Opportunity Areas, colleges and universities, military bases, and ongoing local agency initiatives to deploy bikeshare operations. These areas are defined as agglomerations of MGRAs and aggregated by MSA. The coverage areas could vary by scenario year, reflecting increasing land use density and a maturing bikeshare industry (Figure 2*)*.

2. Calculate the total population in the bikeshare coverage area, including persons living in non-institutional group quarters (e.g., college dormitories).

3. Estimate the projected bicycle supply, given the size of the population in the bikeshare area. The recommended minimum supply of bicycles, based on station-based system data, is 10-30 bicycles per 1,000 persons (ITDP, 2014). A supply of ten bicycles per person was assumed for the most urbanized and well-visited areas of San Diego County (Central and North City MSAs), while a supply of five bicycles per person was assumed for the other less-dense areas.

4. Estimate the total number of daily bikeshare trips. Based on data reported by various U.S. bikeshare systems, the bikeshare daily trip rates for the San Diego region are estimated to be within 1.2 – 2.3 daily trips per bike. The derivation of these trip rates is described below in the *Bikeshare System Trip Rates* section. Recent research conducted on San Francisco's bikeshare services, revealed that the JUMP bikeshare system observed an average of 2.8 average daily trips per bike (Lazarus, J. et al, 2019). Although higher than the trip rates input used in this off-model methodology, this research helps to further validate the conservative approach and inputs employed in this methodology.

Bikeshare demand due to bikeway infrastructure and fleet types:

5. Estimate the induced demand for biking resulting from investments in bicycling infrastructure. An induced demand of 102 daily bikeshare trips per new bike lane-mile was estimated based on data from Citi Bikeshare (Xu and Chow, 2018).

6. Estimate the number of bikeshare trips that are taken in pedal-assist bicycles. Based on e-bike data provided by local operators and shared mobility industry trends that favor more electric-assisted devices in the future, SANDAG staff estimates that 100 percent of all bikeshare trips will be made via an e-bike or e-scooter by 2020. As of March 2019, the San Diego region will have two primary bikeshare operators, Lime and JUMP. As of early in 2019, Lime is transitioning its fleet to all-electric (pedal-assist and e-scooters) while JUMP

operates an all-electric fleet (pedal-assist and e-scooters) in the region. Given the industry trend towards fleet electrification since bikeshare operations initiated in 2014 in the region, staff estimates that 100 percent of the fleet will be electric in 2020.

Bikeshare VMT and GHG reductions:

7. Calculate the proportion of bikeshare trips that replace a car trip. Car substitution rates are assumed to be 20 percent for traditional bikeshare and 37 percent for pedal-assist bikes, following the rates reported in the research cited above.

8. Calculate the VMT reduction resulting from the car trips replaced by bikeshare trips. Based on anonymized and aggregated data from 2018 bikeshare operations in the region, the average trip length for traditional pedal bikes is 1.2 miles and 1.7 miles for pedal-assist bikes and scooters, combined.

9. Calculate the corresponding CO2 reduction corresponding to the VMT reduction, using the EMFAC 2014 CO2 emission rates.

Bikeshare System Trip Rates

Since bikeshare trip generation rates for the San Diego region are unavailable, trip rate estimates are based on information from other U.S. bikeshare systems. Bikeshare operators in the San Diego region did not provide bikeshare trip generation estimates. Table 10 presents the relevant data gathered from multiple sources and is documented in the References section. A regression model was estimated using the following form:

$$\frac{Trips}{bicycle} = \beta \times \frac{Bikes}{1{,}000\ Persons}$$

Bikeshare trip information from operations in the U.S. resulted in a trip rate multiplier (β) of 0.23 applied to the bike supply density (bicycles per 1,000 persons in the coverage area).

The principle parameters and data items underlying the bikeshare CO2 emission calculations are listed in Table 11.

Table 10: Bikeshare System Utilization Data

City	Bikeshare System	Population in bikeshare coverage area	Annual members	Number of bicycles	Average daily bikeshare trips	Bikes per 1000 persons in coverage area	Average daily rides per bicycle
Washington DC	Capital Bikeshare	225,000	18,000	1,800	5,502	8.0	3.1
Minneapolis	Nice Ride Minnesota	190,000	3,500	1,325	735	7.0	0.6
Seattle	Seattle DOT	600,000	n/a	1,200	1,929	2.0	1.6
Portland	Portland BOT	210,000	3,519	464	858	2.2	1.9
New York	Citi Bike	814,000	19,692	9,242	57,897	11.4	6.3
Boston	Blue Bikes	179,904	14,577	1,800	3,600	10.0	2.0
Denver	Denver Bikeshare	190,242	2,111	800	972	4.2	1.2
San Antonio	San Antonio Bikeshare	33,281	11,488	500	179	15.0	0.4

Figure 2: Draft 2035 Bikeshare Coverage Areas

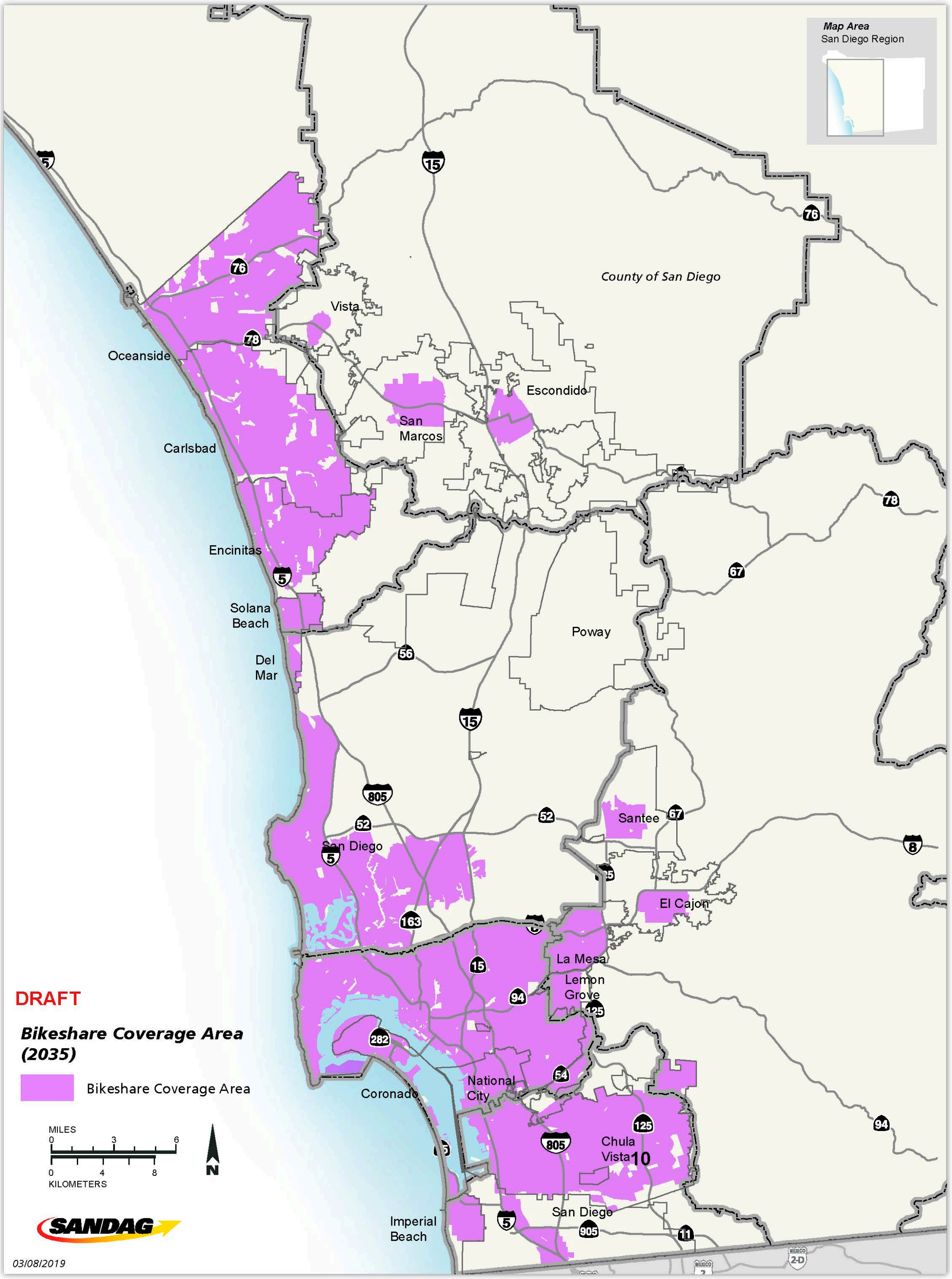

Table 11: Methodology Parameters, Bikeshare CO2 Emissions Calculator

Parameter	Source	Details
Bikeshare trip rate	Capital Bikeshare, 2012 Nice Ride Minnesota, 2010 Seattle DOT, 2018 Portland BOT, 2017 NYC Citi Bike, 2017 Blue Bikes Boston, 2017 Denver Bikeshare, 2016 San Antonio Bikeshare, 2017	Based on the estimated bikeshare fleet size within the respective MSA, the bikeshare trip rate is estimated at 2.3 daily trips per bike for Central and North City MSA, 1.2 daily trips per bike for the rest of MSAs.
Bikeshare bike supply	Bikeshare Planning Guide (ITDP, 2014)	Assumed at 10 bicycles per 1,000 persons in the Central and North City areas, and at 5 bicycles per 1,000 persons elsewhere in San Diego County.
Induced demand due to bike-lane infrastructure	Xu and Chow, 2018	Estimated at 102 additional daily bikeshare trips per bike lane-mile.
Percent of electric-assisted bikes and scooters	Draft San Diego Forward: The 2019-2050 Regional Plan	Based on the market trend towards more electric assisted devices in the future and local operator shift towards operating primarily all-electric bike fleets.
Car substitution rate, traditional bicycles	Capital Bikeshare, 2012 Nice Ride Minnesota, 2010 Seattle DOT, 2018 Portland BOT, 2017 NYC Citi Bike, 2017 Blue Bikes Boston, 2017 Denver Bikeshare, 2016 San Antonio Bikeshare, 2017	Estimated as the average car substitution rate of U.S. bikeshare systems, or 20 percent.
Car substitution rate, pedal-assist bicycles	MacArthur et al, 2018 Lime Year-End Report 2018.	Estimated at 37 percent, based on reported utilization of shared e-bikes across multiple pilot studies. In the 2018 End of Year Report, Lime reports an average substitution rate of 37 – 40% based on its operations in Los Angeles, Austin, Seattle, Atlanta, and Kansas City.
Average trip distance, traditional bicycles	Based on anonymized and aggregated data provided by bikeshare operators in the region	Based on anonymized and aggregated data from 2018 bikeshare operations in the region, the average trip length for traditional pedal bikes is 1.2 miles. Similarly, TCRP 2018 research on average trip distance for station-based bikeshare ranges from 1.3 to 2.4 miles per trip (Hernandez et al, 2018).
Average trip distance, pedal-assist bicycles	Based on anonymized and aggregated data provided by bikeshare operators in the region	Based on anonymized and aggregated data from 2018 bikeshare operations in the region, the average trip length for pedal-assist bikes and scooters 1.7 miles. Similarly, e-bike trip characteristics from JUMP bikeshare in San Francisco, California indicate that the average e-bike trip distance is 1.9 miles per trip (Lazarus, J. et al, 2019).

Calculator Inputs

Table 12 summarizes the calculator inputs for each future year scenario.

Table 12: Scenario Inputs, Bikeshare CO2 Emissions Calculator

Data Item	Source	Required Input Data
Population and employment	Draft Series 14: 2050 Regional Growth Forecast/San Diego Forward: The Regional Plan in ABM 14.0.1	For each scenario year and MGRA: • Total population
Bikeway lane miles	Draft San Diego Forward: The 2019-2050 Regional Plan	For each scenario year and MSA: • Total bikeway lane miles in each MSA (Class I, Class II, and Class III bikeway segments)
Bikeshare coverage	Draft San Diego Forward: The 2019-2050 Regional Plan	For each scenario year: • Bikeshare flag (1 if bikeshare operates in MGRA, 0 otherwise)
Emission factors	EMFAC 2014, SANDAG ABM 14.0.1	For each scenario year: • Trips (cold starts) regional emissions (ton) • Running CO2 regional emissions (ton) • Regional VMT • Regional trips

Results

Table 13 summarizes the vehicle trip, VMT and CO2 reductions attributed to bikeshare.

Table 13: Bikeshare VMT and GHG Emission Reductions

Variable	2025	2035	2050
Total daily vehicle trip reductions	Final results pending selection of the preferred network scenario		
Total daily VMT reductions			
GHG reduction due to cold starts (short tons)			
GHG reduction due to VMT (short tons)			
Total daily GHG reduction (short tons)			
Total population			
Daily per capita GHG reduction (lbs/person)			
Daily per capita GHG reduction, change in percent			

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POOLED RIDES

Program Description

The pooled rides strategy utilizes application (app)-enabled services to facilitate carpooling in the region by matching drivers with passenger who are traveling in the same direction. These app-enabled services have the potential to fill empty seats, increase average vehicle occupancies, and reduce traffic congestion. GHG reductions would be realized whenever travelers shift from driving alone to app-enabled carpooling; without adequate policies in place, pooled ride users may also shift from other modes, like transit, bike, or walking.

There are a few common examples of app-enabled pooling services to date. Transportation Network Companies (TNC) offer the option of pooling rides from independent travel parties that share a similar trip origin and destination. The “pooled” ride options offered by Uber and Lyft (Uber Pool and Lyft Line, respectively) incentivize carpooling by offering a discount on the price of individual rides. Similarly, Waze Carpool provides dynamic ridesharing services by matching drivers with potential carpool partners on a per-ride basis. Passengers reimburse the driver based on the miles traveled and the IRS mileage reimbursement rate.

SANDAG recently launched a carpool incentive program with technology partner, Waze. The carpool incentive program provides a trip subsidy to eligible employees to help encourage carpooling. The SANDAG ABM model accounts for some carpool travel within the model’s shared ride mode categories. However, due to insufficient and limited data, the model is unable to explicitly account for the impact of carpool incentive programs or carpooling activity associated with new app-enabled services. SANDAG plans for the continued implementation of a carpool incentive program based on the Waze Carpool model that will provide a small trip subsidy to passengers, further incentivizing the use of carpooling. It is assumed that participation in the program will be administered by the iCommute Employer Services team, which will determine program eligibility for the carpool trip subsidy. The program will subsidize eligible employees that currently drive alone to work and are not suitable candidates for commuting by vanpool, microtransit, or transit.

Assumptions

The following assumptions were incorporated into the pooled rides off-model calculator. To date, there is very little research information on pooled rides. TNCs that offer pooled services do not share adequate trip data on pooling activity. Uber reports that 20 percent of their rides globally, and 30 percent of the rides in New York and Los Angeles, are on Uber Pool (Tech Crunch, 2016), however, it is not necessarily the case that a ride on Uber Pool is, in fact, a pooled ride. Moreover, the total number of rides served by Uber and Lyft in San Diego is unknown. Therefore, the off-model methodology for pooled rides only accounts for pooled services following the Waze carpool model. To estimate the impacts of app-enabled pooled rides throughout the region, regional survey data of app-enabled ridesharing activity was used as a proxy to estimate pooled ride use. The survey data collected did not differentiate between the different app-enabled rideshare models that were used for travel; such as dynamic carpooling like Waze Carpool or on-demand ride-hailing services like Uber or Lyft.

SANDAG used app-enabled pooled ride utilization data that was gathered through the 2016-2017 San Diego Regional Transportation Study and 2018 Commute Behavior Survey. As shown in Table 14, the app-enabled rideshare mode share decreases with increasing auto ownership. Self-administered internet-based surveys conducted in several U.S. metropolitan areas reported that on-demand ride-hailing use was predominantly for discretionary travel, with few users indicating it was their primary mode for work trips (Clewlow and Mishra, 2017). Contrary to this expectation, the 2016-2017 San Diego Regional Transportation Study reports that app-enabled ride-hailing utilization is higher for work than for non-work trips. A second difference relates to how utilization is reported; the nationwide study reports the frequency of ride-hailing, while the limited availability of San Diego data was used to estimate app-enabled ride-hailing mode shares. Since work trips account for roughly only 20 percent of all person trips, in terms of trip frequency, there are more discretionary trips than work trips, even if the relative mode share of ride-hailing for discretionary trips is lower than for work trips.

The 2016-2017 San Diego Regional Transportation Study did not ask respondents to indicate whether they hailed a shared or pooled app-enabled trip. However, limited information on app-enabled ride-hailing use was available from the 2018 Commute Behavior Survey. As shown in Table 14, the proportion of all app-enabled ride-share trips that were pooled is highest for workers from 0-car households and decreases rapidly with increasing auto ownership. The total number of pooled rides taking place in the San Diego region was calculated by applying the mode shares in Table 14 to estimates of total person trips predicted by the SANDAG ABM.

Table 14: Pooled Ride Mode Shares, San Diego Region

	2018 Commute Behavior Survey	2016-2017 San Diego Regional Transportation Study	
Ride-hailing mode	Work trips	Work trips	Non-work trips
All app-enabled ride-hailing trips			
0-car household	5.97%	19.28%	8.10%
1-car household	1.87%	0.87%	0.32%
2+ car household	0.20%	0.36%	0.11%
Proportion of ***pooled*** app-enabled ride-hailing trips			
0-car household	50%		
1-car household	43%	n/a	n/a
2+ car household	14%		

Based on ABM data, a two-step process was applied to predict the number of app-enabled pooled ride trips in future years. First, a simple mode choice model was developed to predict the likelihood of using an app-enabled pooled ride service as opposed to driving alone, assuming no difference in travel times between driving alone and pooling. No difference in travel time is based on the assumption that a pooled trip would occur similar to pooling via the Waze Carpool app, in which the driver & passenger(s) are matched based on their similar origin and destination and meet at a common pick-up location, thereby mitigating route deviations or additional trip links. In this first step, the likelihood of pooling is solely a function of the difference in trip cost between driving alone and pooling and a pooled-ride mode-specific constant that captures the overall preference expressed by the observed pooled-ride mode shares. The second step applied a demand elasticity formula to predict the increase in pooling that would result from investments in managed lanes. As the region's managed lane network expands, commuters who choose to pool will experience shorter travel times than commuters driving alone. This travel time savings will further encourage a shift from driving alone to pooling.

The assumptions underlying the level of service calculations for each modal option are shown in Table 15. Based on the SANDAG ABM, the cost of driving alone is 16.30 cents per mile in 2016 (in 2010 $) and is projected to increase to 26 cents per mile by 2035. Since the cost of a pooled ride is not known with certainty, it is assumed that the cost of pooling will utilize the reimbursement model currently used by Waze Carpool. Waze Carpool reimburses drivers based on the Internal Revenue Service (IRS) standard mileage reimbursement rate for travel in personally-owned automobiles, which was 54 cents per mile in 2016 or 49 cents in 2010 $. The auto operating costs used in the model only account for variable costs (gas, tire, maintenance); whereas the IRS mileage reimbursement rate accounts for both variable and fixed costs (insurance, license, registration, taxes, depreciation). Based on historical data from the

Bureau of Transportation Statistics (BTS), variable costs account for approximately 28% of the total cost per mile. Based on this assumption, variable costs associated with the IRS mileage reimbursement rates in 2016 are estimated to be 15 cents per mile in 2010 $ (49 cents x .28 = 13.72 cents). It is assumed that the cost of pooling in future years will remain the same as the cost ratio of pooling to driving alone in 2016 (16.3 cents/13.7 cents = 1.188). This pooled ride index factor of 1.188 is applied to model-based auto operating costs to estimate the cost of pooling in future years for consistency with ABM auto operating costs assumptions. The SANDAG carpool incentive program will provide a minor trip subsidy that will lower the cost of pooling per trip. Non-work trips will not be subsidized by SANDAG. To calculate travel time savings, the calculator uses the travel times predicted by the SANDAG ABM for each scenario year, for drive-alone and carpool vehicles, respectively.

Table 15: Pooled Ride Level of Service Assumptions

Level of service attribute	Drive alone, 2016—2050	Pooled ride, 2016—2050
Travel time	General purpose lane travel times	HOV and Managed lane travel times
Trip cost (cents/mile)		
Work trips	16.3 – 18.70 [1]	9.72 cents – 11.74 [2]
Non-work trips		13.0 cents – 15.74

[1] Auto operating cost assumed in the SANDAG ABM; varies based on scenario year
[2] Pooled ride costs based on estimated pooled ride costs; indexed with auto operating costs to account for variable costs only (gas, tire, maintenance) in future years. Cost for pooled work trips includes minor trip subsidy from SANDAG.

A summary of the principle assumptions underlying the CO2 emission reduction calculation for pooled rides is shown in Table 16.

Table 16: Principle Approach to Pooled Rides CO2 Emissions Calculations

Quantity	Overall Approach	Inputs and Source
Market / Market Growth	• Estimate total number of pooled app-enabled ride-hailing trips as a share of drive alone trips and segmented by household auto ownership	• SANDAG ABM data, for each scenario year o Drive alone trips predicted in each future year auto ownership category o Auto operating cost • 2016-2017 San Diego Regional Transportation Study o Utilization frequency--percentage of users that use a ride-hail service, work and non-work trips • 2018 Commute Behavior Survey o Proportion of ride-hail trips that are pooled
Regional Infrastructure Improvements	• Proposed regional managed lane infrastructure investments (HOV lanes and Express Lanes) offer travel time savings for carpooling and will increase demand for app-enabled pooling • Change in demand calculated based on elasticity of demand with respect to travel time	• SANDAG ABM data, for each scenario year o Average drive alone and carpool travel times o Average value of time o Marginal disutility of time, in-vehicle time coefficient • Internal Revenue Service (IRS) o 2016 mileage reimbursement rate
Program VMT	• Estimate program VMT based on estimated number of pooled rides in	• SANDAG ABM data, for each scenario year o Average drive-alone trip distance, work and non-work trips • Average vehicle occupancy

	forecast year and average vehicle occupancy	
GHG Emission Factors		• SANDAG ABM 14.0.1

GHG Emission Calculator Methodology

The CO2 reduction attributed to pooled rides was calculated following the procedures described below. The principle parameters and data items underlying the pooled rides CO2 emission calculations are listed in Table 17.

Pooled (app-enabled) trips within the region:

1. Based on the SANDAG ABM predictions for each scenario year, sum the number of drive-alone person trips by origin MSA, destination MSA, purpose (work/other), time period, and household auto ownership category
2. Lookup the average travel time for each MSA-to-MSA origin/destination market, based on the travel time skims produced by the SANDAG ABM for drive-alone trips and carpool trips, respectively
3. Lookup the average trip distance for each MSA-to-MSA origin/destination market, based on the distance skims produced by the SANDAG ABM for drive alone trips.
4. Estimate the cost of driving alone by applying the auto operating cost to the average trip distance
5. Estimate the cost of pool-riding by applying the indexed mileage reimbursement rate to the average trip distance and any trip subsidies as proposed in the Regional Plan.
6. Estimate the proportion of pooled rides in each trip market listed above, using the binomial mode choice model described below
7. Estimate the additional pooled ride trips that will be incentivized by managed lane investments, applying the demand elasticity formula

Pooled rides VMT and GHG reductions:

8. Calculate pooled ride VMT based on the average MSA-to-MSA trip distance and pooled ride prediction, assuming an average pool ride auto occupancy of 3 persons per car. The pooled ride occupancy corresponds with the minimum HOV requirements being recommended as part of the Regional Plan’s managed lane investments.
9. Calculate the pooled ride VMT reduction. Since the shift is from drive alone to pooled ride, the difference between the total person trips and the vehicle trips used for pooled-riding is equal to the vehicles removed from highways by the availability of ride-pooling.
10. Calculate the corresponding CO2 reduction corresponding to the VMT reduction, using the EMFAC 2014 CO2 emission rates.

Pooled ride mode shifting model

Both the 2016-2017 San Diego Regional Transportation Study and 2018 Commute Behavior Survey provide some information about the current utilization of app-enabled pooled rides. To predict how utilization might change in response to a cost subsidy, a mode choice model was specified and calibrated to the current observed utilization. The model takes the form of a binomial logit mode choice model, with two choices—drive alone and pooled riding. The utility of each mode is a function of trip cost and a mode-specific constant that captures un-included attributes or preferences:

$$Utility = \alpha + \beta \times trip\ cost$$

Given this utility specification and the assumption of logit error terms, the probability of pooled-riding is then given by:

$$Probability\ (pooled\ ride) = \frac{1}{1 + e^{U(drive\ alone) - U(pooled\ ride)}}$$

By convention, the mode-specific constant (α) for the drive alone mode was set as zero. The trip cost coefficient (β) was computed from the definition of value of time, derived from regional median household income, and the in-vehicle time coefficient used in the SANDAG ABM for trips on work tours. The mode-specific constant for the pooled-ride mode was calibrated so that when the model is applied in 2016, assuming no subsidies, it predicts the mode shares observed in the 2016-2017 San Diego Regional Transportation Study and 2018 Commute Behavior Survey. The calibrated constants are shown in Table 17.

Elasticity of demand with respect to travel time savings:

The elasticity of demand for pooled rides with respect to travel time was approximated using the formula for point elasticity derived from a logit model (Train, 1993):

*Elasticity w.r.t. travel time= (coefficient of in-vehicle time) * average travel time * (1 – probability of app-enabled pooling)*

The coefficient of in-vehicle time was obtained from the SANDAG ABM and reflects the value of the mode choice in-vehicle time coefficient for trips on work tours (-0.032 utils/minute). The probability of pooled rides was calculated for each scenario year, using the pooled ride mode choice model while the average travel time was based on the single-occupant vehicle travel time.

The change in demand resulting from travel time savings is then equal to:

*Percent change in app-enabled pooled ride trips = elasticity w.r.t travel time * percent change in travel time*

The percent change in travel time was calculated based on the average weekday travel time savings associated with the use of managed lanes from the ABM.

Table 17: Methodology Parameters, Pooled Ride CO2 Emissions Calculator

Parameter	Source	Details
Observed pooled ride mode shares	SANDAG (2017). 2016-2017 San Diego Regional Transportation Study. SANDAG (2018). 2018 Commute Behavior Survey.	The observed ride-hailing mode share and the share of ride-hail pooled options, were used to estimate the total number of pooled app-enabled trips in the San Diego region for the base year (2016). This trip estimate serves as the calibration target for the pooled ride mode shifting model
Pooled ride average vehicle occupancy		In lieu of observed data, the calculator conservatively assumes the minimum occupancy to qualify as a pooled ride trip (3 persons per car). The pooled ride occupancy corresponds with the minimum HOV requirements being recommended as part of the Regional Plan's managed lane investments.
Coefficient of in-vehicle travel time (utils/minute)	SANDAG ABM 14.0.1 Trip mode choice model, work tours	SANDAG ABM value (-0.032 utils/minute). Used to calculate elasticity of demand with respect to travel time. Input to the demand elasticity formula and mode choice model
Average value of time	Preliminary Series 14 Forecast	Derived value ($9.80/hour), estimated as one-third median household income for San Diego region ($61,400), expressed as an hourly wage rate ($29.52/hour). The value of time is used to calculate an average coefficient of cost, for the pooled ride mode choice model
Pooled ride mode-specific constant		Mode choice model pooled ride constants were calibrated by trip purpose and auto ownership category: • Work trips

Parameter	Source	Details
		○ 0-car household: -2.60 ○ 1-car household: -5.90 ○ 2+ car household: -7.90 • Non-work trips ○ 0-car household: -2.90 ○ 1-car household: -6.30 ○ 2+ car household: -8.40

Calculator Inputs

Table 18 summarizes the calculator inputs for pooled rides for each future year scenario.

Table 18: Scenario Inputs, Pooled Rides CO2 Emissions Calculator

Data Item	Source	Required Input Data
Drive alone person trips	SANDAG ABM 14.0.1	For each scenario year, origin MSA and destination MSA: • Strategy year • Origin MSA • Destination MSA • Time period (AM, Midday, PM) • Trip mode (Drive Alone) • Trip purpose (Work, School, Other) • Household auto ownership (0, 1, 2+) • Person trips
Auto operating cost (cents/mile)	SANDAG ABM 14.0.1	Used to calculate the cost of driving-alone; accounts for fuel and vehicle maintenance. Auto operating cost varies from 16.3 cents/mile (2010 $) in 2016 to 18.7 cents/mile (2010 $) in 2050.
Pooled ride mileage cost (cents/mile)	Internal Revenue Service, 2016 standard mileage reimbursement rate for travel in personally-owned automobile.	IRS mileage reimbursement rate used to calculate the cost of a pooled ride trip based on the Waze Carpool model; equal to 13.72 cents/mile in 2016 (2010 $). The cost of pooling is estimated using the pooled rides index factor in future years.
Pooled rides index factor		Used to estimate the cost of pooling in future years based on ABM auto operating costs, which account for variable costs (gas, tire, maintenance) only. It is assumed that the cost of pooling in future years will remain the same as the rate of pooling to driving alone in 2016 (16.3/13.7 = 1.188)
Travel times and trip distance	SANDAG ABM 14.0.1	For each scenario year, origin MSA and destination MSA: • Strategy year • Origin MSA • Destination MSA • Time period (AM, Midday, PM) • Average one-way weekday travel time, drive-alone, general purpose lanes, (minutes) • Average one-way weekday travel time, drive-alone, managed lanes, (minutes) • Average one-way weekday trip distance, drive alone, general purpose lanes (miles)
Emission factors	EMFAC 2014, SANDAG ABM 14.0.1	For each scenario year: • Trips (cold starts) regional emissions (ton) • Running CO2 regional emissions (ton) • Regional VMT • Regional trips

Results

Table 19 summarizes the vehicle trip, VMT and CO2 reductions attributed to app-based pooled rides.

Table 19: Pooled Ride VMT and GHG Emission Reductions

Variable	2025	2035	2050
Total daily vehicle trip reductions	Final results pending selection of the preferred network scenario		
Total daily VMT reductions			
GHG reduction due to cold starts (short tons)			
GHG reduction due to VMT (short tons)			
Total daily GHG reduction (short tons)			
Total population			
Daily per capita GHG reduction (lbs/person)			
Daily per capita GHG reduction, change in percent			

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MICROTRANSIT

Program Description

Microtransit services utilize real-time ride-hailing, mobile tracking and app-based payment (Faigon et al., 2018) to provide demand-based service to users. Microtransit services are flexible and can operate vehicles that range from small sport utility vehicles (SUV) to large shuttle buses to provide transit-like services. In San Diego County, a type of microtransit service called the Free Ride Everywhere Downtown (FRED) has been operating in downtown San Diego since 2016. The FRED service is managed by Civic San Diego, the City of San Diego's non-profit entity that oversees downtown development. FRED operates a fleet of neighborhood electric vehicles (NEVs) within a defined service area that can be hailed in real-time or via an app-based reservation system and fulfills rides that are typically less than two miles long (Steele, 2017). The service is free to users and is paid for by advertisers, parking meter revenues, and grants. Through conversations with the FRED service provider, it is anticipated that FRED will expand its service to other parts of the region that have similar land uses and visitor destinations as Downtown San Diego. In support of regional mobility hub planning efforts[10], the SANDAG TDM program seeks to promote and encourage the provision of NEV microtransit to provide critical connections to and from mobility hubs.

In addition to the NEV shuttle service, other types of microtransit services operate as a crowd-sourced, route-deviation, demand responsive form of transit, such as Bridj, and Via that operate international microtransit services. These services help to reduce GHG emissions by providing an alternative to automobile travel in areas where traditional fixed-route transit does not operate, where service is relatively infrequent, or where demand for transit exceeds the capacity provided by public transit agencies. SANDAG is proposing to incentivize the deployment of a commuter-oriented microtransit service in areas not currently well-served by fixed-route transit. The provision of an operational subsidy that reduces the cost of a trip would make this a cost-effective alternative for commuters. As with the vanpool program, the SANDAG Employer Services Program will conduct targeted outreach with major employers throughout the region to identify employees that may be suitable candidates for the commuter shuttle service as proposed in this methodology.

With the exception of FRED and a few privately sponsored employer shuttles, the emergence of microtransit is a new concept in the San Diego region. Without sufficient empirical data on microtransit use the SANDAG ABM is unable to consider microtransit as a transportation mode, therefore the GHG emission reductions of NEV and commuter shuttle trips are unaccounted for by the model.

The methodology presented in this memo accounts for two microtransit services:

- Neighborhood electric vehicles (NEVs) that operate within a defined service area and can be hailed in real-time to fulfill rides that are less than two miles long; and
- Commuter shuttle services that provide a feasible alternative to automobile travel in areas where traditional fixed-route transit is poor or does not operate.

This calculator does not address microtransit services that could be designed to interface with other transit services (trunk line or local).

Assumptions

To estimate impacts resulting from the deployment of NEV shuttle service, it is assumed that these shuttle services will operate very similarly to the FRED service in downtown San Diego. The NEV shuttle would be deployed within

[10] To learn more about SANDAG mobility hub efforts, visit www.sdforward.com/mobilityhubs

designated areas to provide critical connections to high-frequency transit stations, corresponding to the regional mobility hub network[11] (Figure 3), and will fulfill short trips that are less than two miles in length. The off-model calculator assumes that the NEV shuttle mode shares will be similar to the FRED mode share observed today, or 0.41 percent. This mode share is estimated based on the number of rides reported by FRED (Van Grove, 2019) and the total person trips in the current FRED service area, as predicted by the SANDAG ABM. It's assumed that NEV microtransit services, like FRED, reduce GHG emissions by offering an emissions-free alternative for short trips that could otherwise be completed by car, bicycle, transit, or walking. As such, it is assumed that one-third of the NEV shuttle trips would have otherwise been automobile trips, should this service not exist. The auto substitution rate is consistent with auto substitution rates reported for e-bike users (37%), a motorized service that also primarily fulfills short trips (less than 2 miles) and deemed comparable to NEVs. Staff is working to establish a micromobility data clearinghouse and hopes to partner with FRED to collect and evaluate trip data that may be used to inform this methodology in the future.

The other type of microtransit service accounted for in this off-model methodology will provide commuters with a viable transportation option to the region's major employment centers (Figure 4) from areas where there is currently no or poorly fixed-route transit available, where traditional transit service is very infrequent, and/or there are long walk-access distances. The commuter shuttle service will use 15-passenger vehicles to fulfill trips that are less than thirty miles one-way to the region's top employment centers and military bases. Commuters with trips that are over thirty miles one-way are not considered microtransit candidates and filtered out of the trip estimates as these types of trips are assumed to be more viable for the SANDAG Vanpool Program[12]. Unlike vanpools, which are typically comprised of employees from the same company, the commuter shuttles will group commuters with similar travel patterns independently of their employer. Additionally, participation in the Vanpool Program is not restricted by a geographical boundary, meaning that a vanpooler's employers could be located anywhere throughout the region. Participation in the commuter shuttle service, however, is constrained by the employer's location, which must be located within the pre-defined coverage areas (see Table 23) including Downtown San Diego, Sorrento Valley, East Carlsbad, Kearny Mesa, Camp Pendleton, and more.

The commuter shuttles will pick up commuters, based on their trip origin and destination, at a common pick up location. It is assumed that shuttle users will travel a maximum of 5-minutes to-and-from the origin and destination either via biking or walking, consistent with SANDAG mobility hub planning efforts. A minimum level of demand is required for the shuttles to operate and was assumed to be 80 percent, consistent with the occupancy threshold for the SANDAG Regional Vanpool Program, or 12 passengers per vehicle per hour, corresponding to 36 trips over the 3-hour AM peak period.

A summary of the principle assumptions underlying the CO2 emission reduction calculation for microtransit is shown in Table 20.

Table 20: Principle Approach to Microtransit CO2 Emissions Reduction Calculations

Quantity	Overall Approach	Inputs and Source
Market / Market Growth	• Estimate potential microtransit users for two microtransit service types within the region: (1) NEV shuttle service that fulfills short trips (~two miles max) within mobility hubs	• Define NEV shuttle coverage areas (based on regional mobility hub network) • Define commuter shuttle coverage areas (dense employment centers) • SANDAG ABM data

[11] More information on the regional mobility hub network methodology is available in Attachment A

[12] Based on FY 2018 Vanpool Program data, the average vanpooled travels a roundtrip distance of 116 miles or 58 miles one-way.

	(2) commuter shuttle service to high density employment centers for commuters with no or poor fixed-route transit available and where trips are less than 30 miles to the employment centers • Estimate microtransit trips within the NEV shuttle and commuter shuttle coverage areas	○ Person and daily auto trips less than two miles long that start and end within the NEV shuttle coverage areas ○ Home to work drive alone person trips to commuter shuttle coverage areas with no or poor fixed-guideway transit service and less than 30 miles • NEV shuttle mode share • Commuter shuttle mode share dependent on time and cost, as compared to driving alone
Supply; Regional Infrastructure Improvements	• Refine microtransit trip estimates based on projected commuter shuttle travel time and fares. Assumes commuter shuttle service can leverage managed lane infrastructure for travel	• Commuter shuttles priced comparatively to the cost of single ride transit fare in the region. • Commuter shuttles travel at prevailing highway speeds
Program VMT	• Program VMT based on predicted microtransit trip and trip lengths in forecast year • Assumes that only some of the demand is shifting from driving alone	• SANDAG ABM data ○ Average trip length of trips that switch to microtransit • Auto substitution rate
GHG Emission Factors		• SANDAG ABM 14.0.1

GHG Emission Calculator Methodology

The CO2 reduction attributed to microtransit was calculated following the procedures described below.

NEV shuttle service:

1. Identify the areas where the NEV shuttles will operate by scenario year (Figure 3) These areas are defined as agglomerations of MGRAs and aggregated by MSA. The coverage areas could vary by scenario year, reflecting increasing land use density that could support NEV shuttle service.
2. Based on the SANDAG ABM, compute the total number of daily person and daily auto trips that start and end within the NEV shuttle coverage areas and are two miles long or shorter. Aggregate totals by MSA and scenario year.
3. Compute the number of NEV shuttle person trips by applying the observed mode share of 0.41 percent to the person trip totals.
4. Compute the proportion of NEV shuttle trips that switched from driving alone by applying the car substitution rate to the total NEV shuttle trips. It is assumed that one-third of the NEV shuttle trips would have been auto trips, should this service not exist. The auto substitution rate is consistent with auto substitution rates reported for e-bike users (37%), a motorized service that also primarily fulfills short trips (less than 2 miles) deemed comparable to NEVs.
5. Based on trip estimates provided by FRED, average trip distances vary between 1 - 1.7 miles per ride. To not overestimate trip distances, an average trip distance of 1 mile per trip is used. It is assumed that trip distances in future years will reflect existing trip trends given that NEV services would be deployed within defined areas and primarily continue to fulfill trips less than 2 miles.

6. Based on the SANDAG ABM, compute the average trip distance of auto trips less than two miles long within the specified coverage areas for each scenario year.

NEV shuttle VMT and GHG reductions:

7. Compute the NEV shuttle VMT by applying the average trip distance to the estimated NEV shuttle trips (trips that replaced autos only).
8. Calculate the corresponding CO2 reduction corresponding to the VMT and trip reduction reductions, using the EMFAC 2014 CO2 emission rates.

Commuter shuttle microtransit:

9. Identify the employment centers that will be served by the commuter shuttle service (Figure 4).
10. Based on the SANDAG ABM predictions for each scenario year, sum the number of drive-alone home-to-work person trips by origin MGRA and destination MGRA.
11. Find the best transit path from each origin MGRA to each destination MGRA in the trip universe.
12. Lookup the in-vehicle and out-of-vehicle transit travel time (including walk access and egress time) for each MGRA-to-MGRA origin/destination trip market, based on the transit skims produced by the SANDAG ABM for premium transit trips.
13. Lookup the average trip distance for each MGRA-to-MGRA origin/destination market, based on the distance skims produced by the SANDAG ABM for drive alone trips.
14. Filter out trips in MGRA-to-MGRA markets with high fixed-route transit productivity. The remaining trips are the market for microtransit trips.
15. Apply the microtransit mode choice model to the pool of trips that makeup the microtransit market. This mode choice model is described below.
16. Summarize the predicted microtransit demand by origin MSA and destination employment center.
17. Refine microtransit estimates, based on minimum demand threshold. Filter out trips in (origin MSA, destination employment center) pairs with fewer than 36 trips, corresponding to 12 one-way passenger trips per hour over the 3-hour AM peak period.

Commuter shuttle VMT and GHG reductions:

18. Estimate microtransit VMT based on the average MSA-to-employment center trip distance and microtransit demand. Since the microtransit mode choice model is applied to drive alone trips only, each microtransit trip represents one less vehicle on the road.
19. Estimate the total microtransit VMT reduction as twice the reduction computed for home-to-work trips, to account for the return trip from work to home.
20. Calculate the corresponding CO2 reduction corresponding to the VMT and trip reduction, using the EMFAC 2014 CO2 emission rates.

Commuter shuttle mode choice model

The commuter shuttle market consists of home to work drive-alone person trips with a destination in one of the identified employment centers. This pool of drive alone trips was obtained from the SANDAG ABM predictions for each scenario year. Since the commuter shuttles will be deployed to augment where transit service is nonexistent or poor, it is necessary to filter out from the pool of drive alone trips those that already have a good fixed-route transit path. Since the SANDAG ABM model does not report the alternative transit option of trips for which the chosen mode is auto, a likely transit path was reconstructed for each drive alone trip. Using a somewhat simplified level of service criteria, yet consistent with the stop-to-stop transit skims and MGRA-to-stop walk paths produced by the SANDAG ABM, the best transit path for each origin/destination MGRA pair was found and associated with each drive alone trip in the microtransit market. The current average speed for fixed-route transit is 9 mph, including stop wait time and walk access/egress time or 0.15 miles per minute. The estimated microtransit trips which held a low average speed, meaning for which the fixed-route transit speed was higher, were filtered out from the microtransit market to account for microtransit trips that may directly compete with transit and may actually be more suitable transit trips.

To predict the commuter shuttle utilization, a simple drive alone versus transit mode choice model was specified and applied to the drive alone trips in the microtransit service markets. The model takes the form of a binomial logit mode choice model, with two choices—drive alone and microtransit. The utility of each mode is a function of trip cost, travel time (including in-vehicle and out-of-vehicle time) and a mode-specific constant that captures un-included attributes or preferences.

$$Utility = \alpha + \beta_c \times trip\ cost + \beta_{ivt} \times in\ vehicle\ time + \beta_{ovt} \times out\ of\ vehicle\ time$$

Given this utility specification and the assumption of logit error terms, the probability of choosing transit is then given by:

$$Probability\ (transit) = \frac{1}{1 + e^{U(drive\ alone) - U(transit)}}$$

By convention, the mode-specific constant (α) for the drive alone mode was set at zero. The value of the SANDAG ABM in-vehicle time coefficient for trips on work tours was used for β_{ivt}, while β_{ovt} was set at 2.5 times the value of β_{ivt}. The trip cost coefficient (β_c) was computed from the definition of value of time ($VOT = \beta_{ivt}/\beta_c$), with value of time estimated from median wage data for the San Diego region. The microtransit alternative specific constant was asserted at a value equivalent to 20 minutes of in-vehicle time (-0.64). For reference, when this model is applied to predict the fixed-route transit mode share, it results in a calibrated transit constant equivalent to 12 minutes of in-vehicle time (-0.40). The more negative constant value asserted for microtransit correlates to a more conservative assumption, essentially indicating that the model assumes that microtransit is perceived less favorably than fixed-route transit, all else equal. The level of service attributes for driving alone and commuter shuttle are shown in Table 21, and the calibrated constants and other calculator parameters are shown in Table 22.

Table 21: Commuter Shuttle Level of Service Attributes

Level of service attribute	Driving alone	CB shuttle
Trip cost	Based on trip distance and auto operating cost for the scenario year (16.3 - 26.0 cents per mile) from SANDAG ABM model	\$3.37 per trip, or 50 percent premium over the San Diego Metropolitan Transit System (MTS) fixed-route bus and light rail full boarding fare of \$2.25 A fare analysis of areas where microtransit service providers Chariot & Bridj operate revealed that the cost per trip for microtransit is on average 50 percent higher than single bus fare within that service area

In-vehicle time	Based on trip distance and average speed of 30 mph	Based on trip distance and average speed of 30 mph, based on the average speed of select MTS *Rapid* bus service routes. *Rapid* provides high-frequency, limited-stop bus service throughout the San Diego region. Routes 235, 280, and 290 leverage managed lane infrastructure to fulfill trips, similar to the proposed commuter shuttle service
Out-of-vehicle time	n/a	7.5 minutes of average wait time and 10 minutes of walk access and egress time (5 minutes at the origin and 5 minutes at the destination)

Figure 3: Draft 2035 NEV Microtransit Coverage Areas

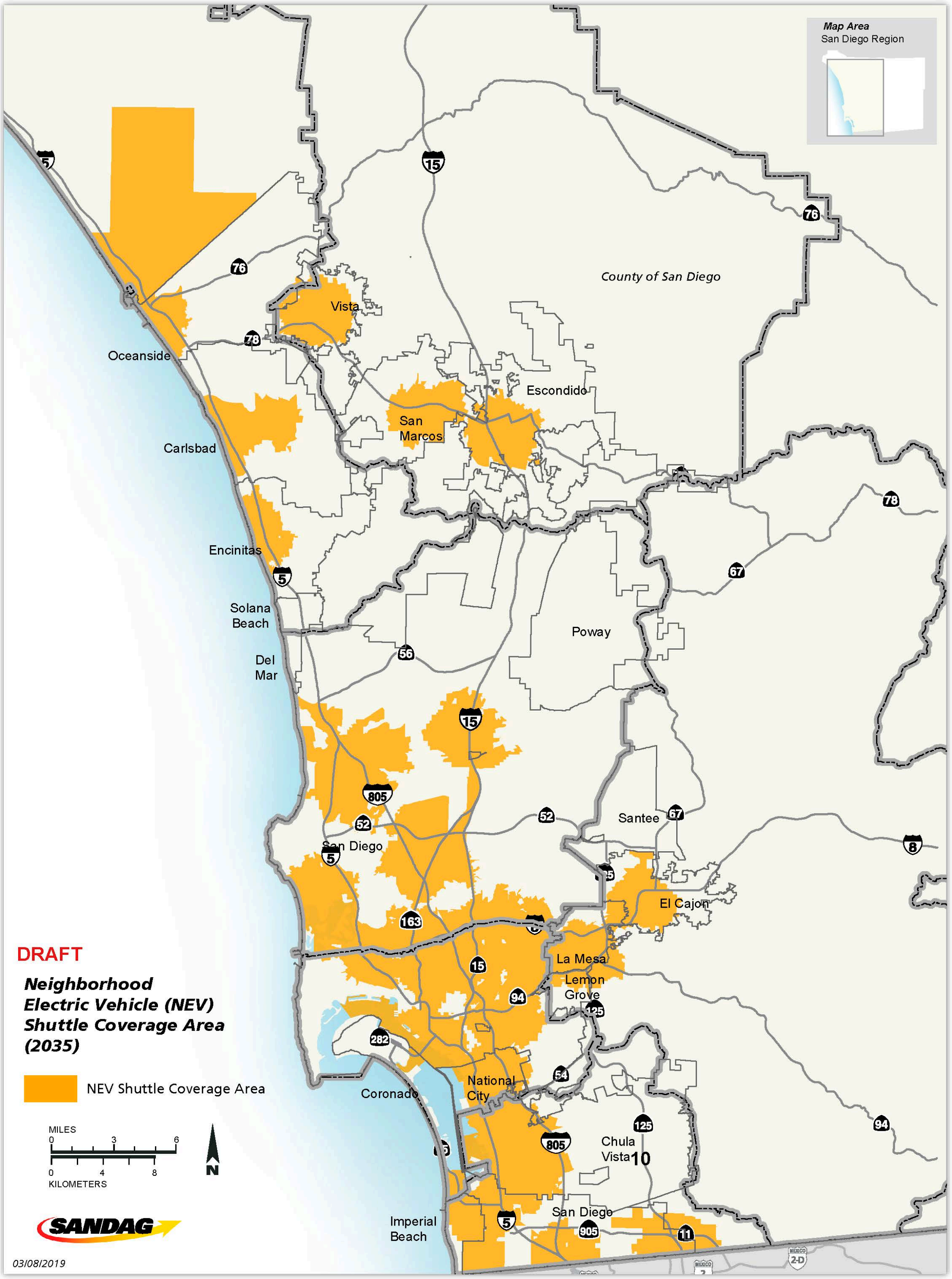

Figure 4: Draft 2035 Commuter Shuttle Microtransit Coverage Area

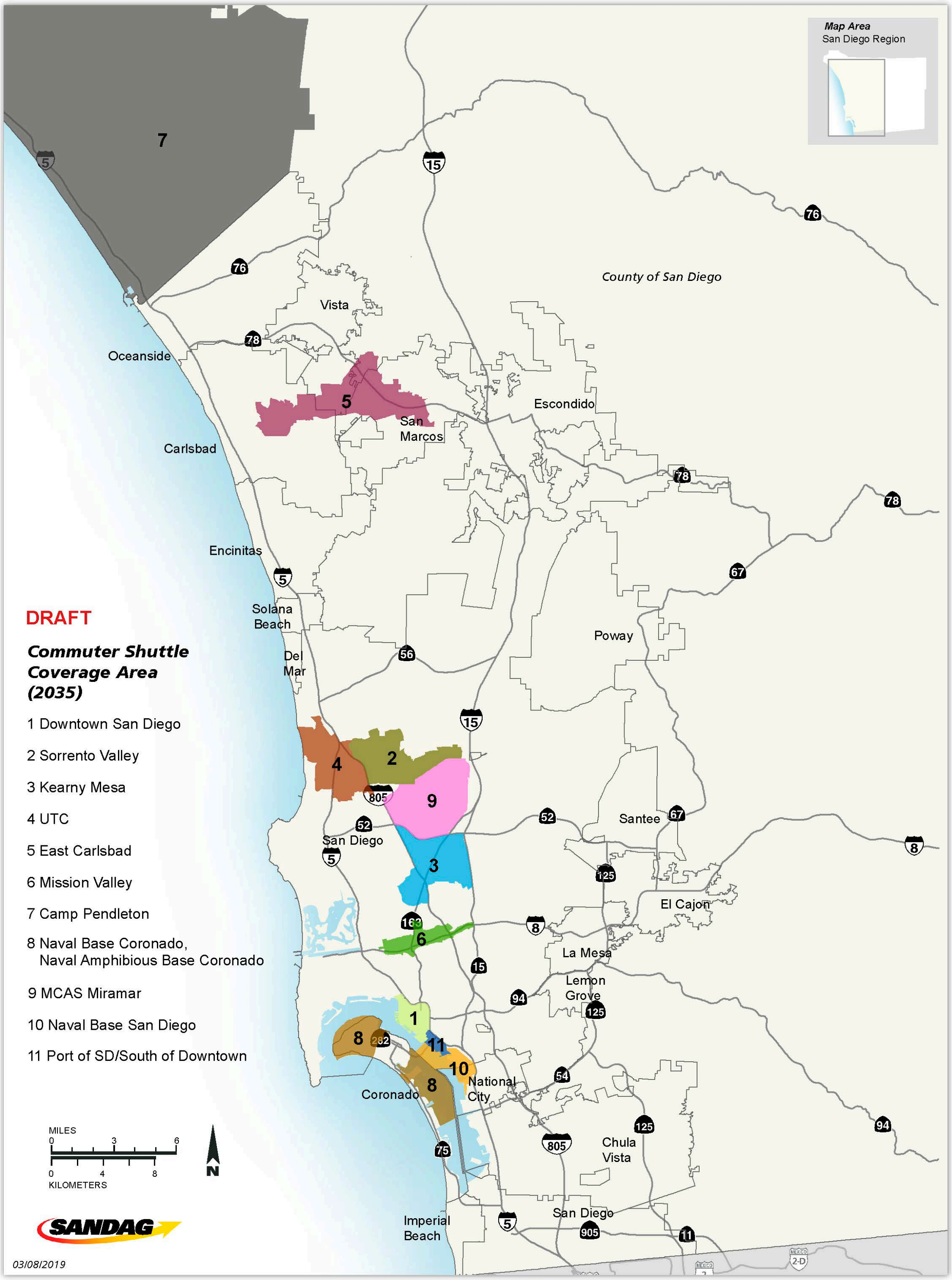

Table 22: Microtransit Commuter Shuttle Mode Choice Parameters, Microtransit CO2 Emissions Calculator

Parameter	Source	Details
Average NEV trip distance		Based on trip estimates provided by FRED, 2/11/19, average trip distances vary between 1 - 1.7 miles per ride. It is assumed that trip distances would reflect current trends given that NEV services would be deployed within defined areas and primarily fulfill trips less than 2 miles
NEV shuttle mode share	Van Grove, 2019 SANDAG ABM 14.0.1	Estimated based on FRED reported utilization of approximately 17,500 monthly rides in 2018 (Van Grove, 2019), person trips that are 2-miles or shorter in the existing NEV shuttle service area, and an average of 30 service days per month
Coefficient of in-vehicle travel time (civt) (utils/minute)	SANDAG ABM 14.0.1 Trip mode choice model, work tours	SANDAG ABM value (-0.032 utils/minute). Used to calculate elasticity of demand with respect to travel time. Input to the demand elasticity formula and mode choice model
Ratio of out of vehicle to in vehicle time coefficient		Ratio (2.5) reflects best practices for travel demand models
Average value of time	Preliminary Series 14 Forecast	Derived value ($9.80/hour), estimated as one-third median household income for San Diego region ($61,400), expressed as an hourly wage rate ($29.52/hour). The value of time is used to calculate an average coefficient of cost, for the commuter shuttle mode choice model
Cost coefficient		Derived value (-0.0020) from the definition of value of time (marginal disutility of time / marginal disutility of cost); 0.6 is a unit conversion factor required because VOT is in $/hour, civt is in minutes, and cost should be expressed in cents
Microtransit mode-specific constant		The commuter shuttle microtransit alternative specific constant was asserted at a value equivalent to 20 minutes of in-vehicle time (-0.64)

Calculator Inputs

Table 23 summarizes the calculator inputs for each future year scenario.

Table 23: Scenario Inputs, Microtransit CO2 Emissions Calculator

<table>
<tr><th>Data Item</th><th>Source</th><th>Required Input Data</th></tr>
<tr><td>Microtransit coverage area (NEV and Commuter Shuttle services)</td><td>Draft San Diego Forward: The 2019-2050 Regional Plan</td><td>For each scenario year and Master Geographic Reference Area (MGRA):
• MSA Id
• TAZ Id
• Area (acres)
• NEVSHUTTLE_FLAG -- NEV shuttle service flag (1 if service operates in MGRA, 0 otherwise)
• CBSHUTTLE_FLAG – Commuter shuttle service flag:
o 1 if Downtown San Diego
o 2 if Sorrento Valley
o 3 if Kearny Mesa
o 4 if UTC
o 5 if East Carlsbad
o 6 if Mission Valley
o 7 if Camp Pendleton
o 8 if Naval Base Coronado, Naval Amphibious Base Coronado
o 9 if MCAS Miramar
o 10 if Naval Base San Diego
o 11 if Port of San Diego/South of Downtown
o 0 otherwise
• OP_YEAR_NEVSHUTTLE -- Year that NEV shuttle service becomes operational in this MGRA
• OP_YEAR_CBSHUTTLE -- Year that commuter shuttle service becomes operational in this MGRA</td></tr>
<tr><td>Population and employment</td><td>Draft Series 14: 2050 Regional Growth Forecast/San Diego Forward: The Regional Plan in ABM 14.0.1</td><td>For each scenario year and Master Geography Reference Area (MGRA):
• Strategy year
• NEVSHUTTLE_FLAG -- NEV shuttle service flag (1 if service operates in MGRA, 0 otherwise)
• CBSHUTTLE_FLAG -- Commuter shuttle service flag (see Microtransit Coverage input item above)
• Total employment
• Total population</td></tr>
<tr><td>Regional trips, NEV shuttle</td><td>SANDAG ABM 14.0.1</td><td>For each scenario year:
• indivTripData_3.csv (SANDAG ABM 14.0.1 output)
• TAZ-to-TAZ drive alone distance, general purpose lanes, median VOT, AM Peak (SANDAG ABM 14.0.1 output)
• Process trip data file with SANDAG_microtransitCalculatorTables.R to produce this summary of trips less than 2 miles long
o Origin MSA
o Origin MSA NEV shuttle service flag
o Destination MSA
o Destination MSA NEV shuttle service flag
o Sum of person trips less than 2 miles long
o Sum of auto trips less than 2 miles long</td></tr>
<tr><td></td><td>SANDAG ABM 14.0.1</td><td>For each scenario year:</td></tr>
</table>

Data Item	Source	Required Input Data
Regional trips, Commuter shuttle		• indivTripData_3.csv (SANDAG ABM 14.0.1 output) • TAZ-to-TAZ drive alone distance, general purpose lanes, AM Peak (SANDAG ABM 14.0.1 AMF output) • TAP-to-TAP commuter rail walk to transit skim, AM Peak (SANDAG ABM) • walkMGRATAPEquivMinutes.csv • SANDAG_TAP_TAP_to_MAZ_MAZ_IVT_OVT.R generates home to work trips • Process trip data file with [SANDAG ABM Transit Mode Share.xlsx] to produce these summary matrices of home to work trips: o Home MSA to employment center destination, total home-to-work drive alone trips o Home MSA to employment center destination, total home-to-work drive alone trips with origins with no or poor transit service o Home MSA to employment center destination, total home-to-work microtransit trips, full fare o Home MSA to employment center destination, total home-to-work average microtransit trip distance, full fare o Home MSA to employment center destination, total home-to-work microtransit trips, subsidized fare o Home MSA to employment center destination, total home-to-work average microtransit trip distance, subsidized fare
Emission factors	EMFAC 2014, SANDAG ABM 14.0.1	For each scenario year: • Running CO_2 regional emissions (short tons) • Regional vehicle-miles traveled (VMT) • Regional vehicle trip starts • Trip start CO_2 regional emissions (short tons)
Commuter shuttle service operations	Draft San Diego Forward: The 2019-2050 Regional Plan	These assumptions define the level of service for commuter shuttle service. • Commuter shuttle fare (cents) • Average vehicle travel speed (mph) • Average time waiting for a ride (min) • Average access/egress time, total (min) • Maximum trip distance (miles) • Minimum demand per origin MSA (trips)

Results

Table 24 summarizes the vehicle trip, VMT and CO2 reductions attributed to microtransit.

Table 24: Microtransit VMT and GHG Emission Reductions

Variable	2025	2035	2050
Total daily vehicle trip reductions	Final results pending selection of the preferred network scenario		
Total daily VMT reductions			
GHG reduction due to cold starts (short tons)			
GHG reduction due to VMT (short tons)			
Total daily GHG reduction (short tons)			
Total population			
Daily per capita GHG reduction (lbs/person)			
Daily per capita GHG reduction, change in percent			

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COMMUNITY BASED TDM OUTREACH

The Community-Based Travel Planning strategy was prepared by SANDAG staff.

Program Description

Community-based travel planning (CBTP) is a residential-based approach to TDM outreach and a proven method for encouraging sustained travel behavior change. CBTP provides households with customized information, incentives and support to encourage the use of transportation alternatives. The approach involves a team of trained 'Travel Advisors' engaging residents at-home or in their communities to offer information, incentives, and advice about how members of households can travel in alternative ways that meet their needs. Teams of trained Travel Advisors visit all households within a targeted geographic area, have tailored conversations about residents' travel needs, and educate residents about the various transportation options available to them. Travel Advisors are trained in motivational interviewing techniques that helps to facilitate intrinsic motivation to inspire changed behaviors.

Following the one-on-one conversation with a Travel Advisor, residents receive resources and incentives that are relevant to their transportation needs that can reduce the barriers to trying transportation alternatives. Examples of incentivized packets include:

- A trial transit pass, assistance with transit trip planning and a free bikeshare membership to provide a first and last mile solution to transit
- Regional vanpool program information and ride-matching assistance coupled with a "first month free" vanpool promotion.

Travel Advisors not only provide information, but they also play a key role in educating residents on how to use transportation services by providing step-by-step support with planning a transit trip, accessing and using shared mobility programs, using online trip planning tools, enrolling in the vanpool or carpool program, etc. Within twelve weeks of the initial doorstep conversation and incentive distribution, Travel Advisors follow-up with all participating households with a survey to see how travel behavior has changed, what their experience has been, and if any additional support is needed.

SANDAG partnered with a consulting firm to conduct a small CBTP pilot project in Encinitas, California in March 2014. The project was branded as "Travel Encinitas" and targeted nearly 400 households to encourage residents to try transportation alternatives for commuting purposes or for local trips. The "Travel Encinitas" pilot demonstrated that CBTP has good potential for the San Diego region, with participants indicating that they drove less and walked, biked, and carpooled more frequently as a result of the pilot. Based on the success of the "Travel Encinitas" CBTP pilot, SANDAG is proposing to expand community based TDM outreach to target households that are typically within a 5-minute bike shed around select high-frequency transit stations or major regional bikeway investments within the region in 2025 and 2035 (Figure 5). In a few instances, the CBTP boundary was expanded beyond a 5-minute bike shed due to the transit-oriented nature of the community, which may be more conducive to driving to and parking at a local transit station. Households targeted for CBTP outreach include households near the Mid-Coast Trolley, Barrio Logan Transit Station, City Heights Mid-City Centerline Station, Iris Trolley Station, South Bay Rapid stations, Grantville Trolley Station, 8th Street Station, Costal Rail Trail, and Inland Rail Trail. Surveys before and after CBTP participation will be implemented to track program performance.

The coverage areas listed within this document are subject to change, pending the selection of a preferred network scenario.

Assumptions

In addition to the San Diego data from the "Travel Encinitas" pilot project, data from CBTP initiatives in Portland, Oregon, Pleasanton, California, Mill Creek, Washington, and King County, Washington was used to estimate VMT and GHG reductions associated with a regional Community-based TDM Outreach program. Based on data from nine CBTP cases studies, between 10 and 30 percent of households typically agree to participate and actively engage with a Travel Advisor, which results in an average 12 percent reduction in SOV trips. These program assumptions were applied to model-based outputs of households within the defined CBTP areas (number of daily driving trips and driving trip distance for participating households) to estimate VMT impacts. Evaluations of CBTP programs typically focus on impacts during the year after programs are implemented via short surveys; long-term evaluations that provide information on how long behavior change persists due to PTP programs is limited.

The principle parameters and data items underlying the CBTP CO2 emission calculations are listed in Table 25.

Table 25: Methodology Parameters, CBTP CO2 Emissions Calculator

Quantity	Overall Approach	Inputs and Source
Market / Market Growth	• Target households typically within a 5-minute bike shed around select high-frequency transit stations or regional bikeway investments	• SANDAG ABM data, for each scenario year o Households typically within 5-minute bike shed including Mid-Coast Trolley, Barrio Logan Transit Station, City Heights Mid-City Centerline Station, Iris Trolley Station, South Bay *Rapid* stations, Grantville Trolley Station, 8th Street Station, Costal Rail Trail, and Inland Rail Trail.
Supply	• Based on national CBTP case studies, estimates participation rate, cost, and impact of households that participate in CBTP	• CBTP Case Studies o Decrease in SOV trips for households participating in CBTP o CBTP participation rate o Cost per households targeted for CBTP
Program VMT	• Estimate VMT reduction based on average household trips and trip length	• SANDAG ABM data, for each scenario year o Average daily one-way driving trips per household o Average one-way trip length for driving trips (miles)
GHG Emission Factors		• SANDAG ABM 14.0.1

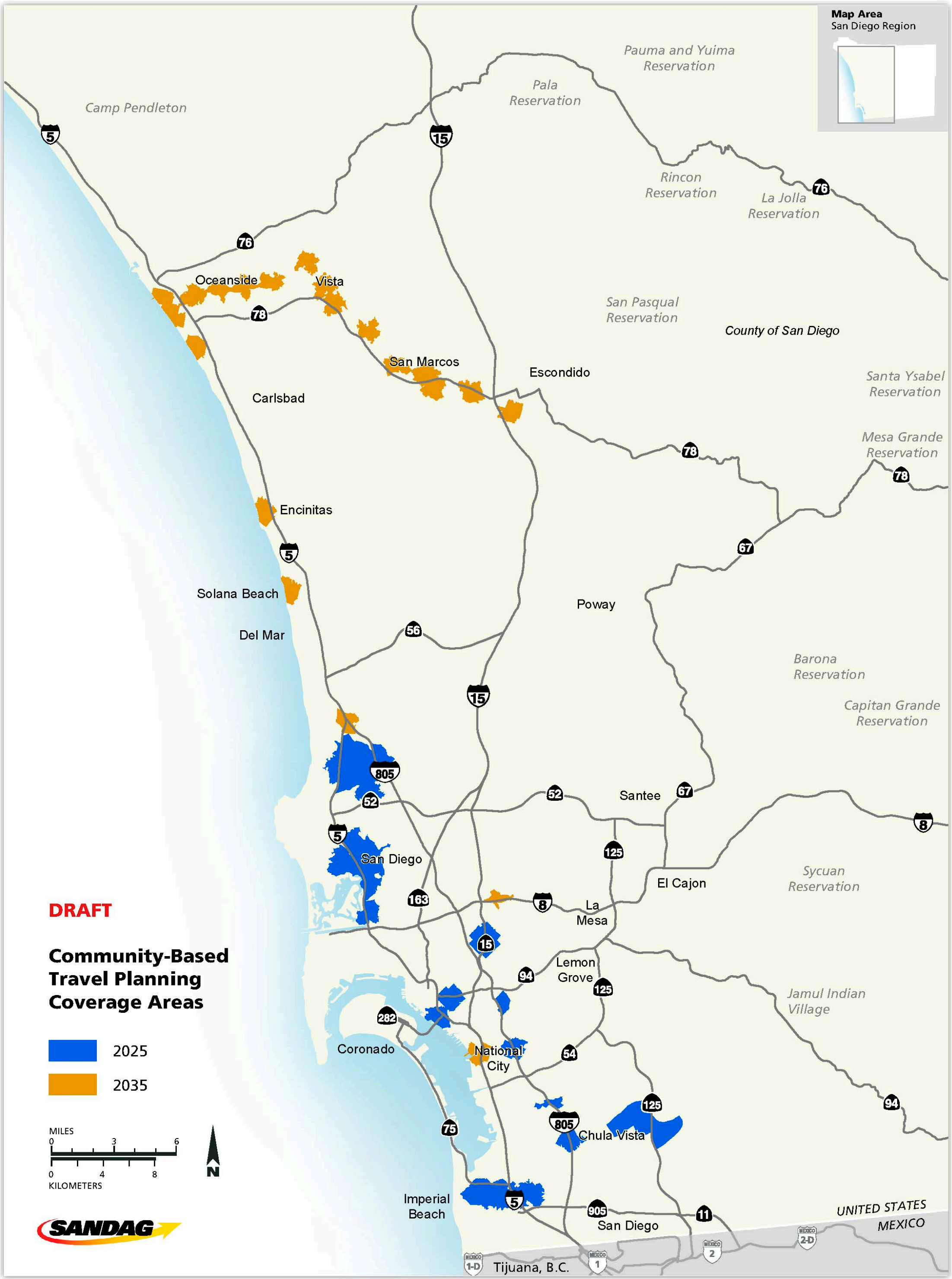
GHG Emission Calculator Methodology

The CO2 reduction attributed to CBTP was calculated following the procedures described below.

1. The number of households was identified within the designated target areas for CBTP to determine the number of households participating in CBTP. Based on nine CBTP case studies, it was assumed that an average 17 percent of targeted households would participate.
2. The total number of participating households was multiplied by the average reduction in SOV trips among participants. The average daily one-way driving trips affected was used to calculate the average daily number of vehicle trips reduced by participants.
3. The daily vehicle trips reduced was multiplied by the average one-way trip length for driving to calculate average daily VMT reductions.

4. The corresponding CO_2 reduction factor was calculated corresponding to the VMT and trip reduction, using the EMFAC 2014 CO_2 emission rates.

Figure 5: Draft 2035 – 2050 CBTP Coverage Areas



Calculator Inputs

Table 26 summarizes the Carbon Dioxide emissions calculator inputs for each future year scenario. Table 26 summarizes the Carbon Dioxide emissions calculator inputs for each future year scenario.

Table 26: Scenario Inputs, CBTP CO2 Emissions Calculator

Parameter	Source	Details
Average cost per household targeted for CBTP	Portland SmartTrips; Salmon Friendly Trips, 2017; Smart Trips Pleasanton, 2016; Green Lake in Motion, 2015; Renton in Motion, 2014; Burien in Motion, 2014; Curb @ Home, 2017; Travel Encinitas, 2014	The cost per household targeted for CBTP can vary depending on households and level of investment. On average, the cost per household targeted for CBTP costs $20.56. This is used to estimate annual program costs in 2025 and 2035.
Number of households targeted for CBTP	Draft Series 14: 2050 Regional Growth Forecast/San Diego Forward: The Regional Plan in ABM 14.0.1	The total number of households within the defined CBTP coverage areas.
Average participation rate	Portland SmartTrips; Salmon Friendly Trips, 2017; Smart Trips Pleasanton, 2016; Green Lake in Motion, 2015; Renton in Motion, 2014; Burien in Motion, 2014; Curb @ Home, 2017; Travel Encinitas, 2014	On average, 17 percent on households targeted for CBTP participate
Average reduction in SOV trips for participating households	Portland SmartTrips; Salmon Friendly Trips, 2017; Smart Trips Pleasanton, 2016; Green Lake in Motion, 2015; Renton in Motion, 2014; Burien in Motion, 2014; Curb @ Home, 2017; Travel Encinitas, 2014	On average, households that participate in CBTP decrease their SOV trips by 12 percent
Average daily one-way driving trips per household	SANDAG ABM 14.0.1	The average daily one-way trips vary by scenario year: 2016, 2020, and 2025 data is from no-build scenario and 2035 is from Scenario E from ABM 14.0.1
Average one-way trip length for driving trips (miles)	SANDAG ABM 14.0.1	The average one-way trip length for driving trips varies by scenario year: 2016, 2020, and 2025 data is from no-build scenario and 2035 is from Scenario E from ABM 14.0.1
Emission factors	EMFAC 2014, SANDAG ABM 14.0.1	For each scenario year: • Running CO2 regional emissions (short tons) • Regional vehicle-miles traveled (VMT) • Regional vehicle trip starts • Trip start CO2 regional emissions (short tons)

Results

Table 27 summarizes the vehicle trip, VMT and CO2 reductions attributed to CBTP.

Table 27: CBTP VMT and GHG Emission Reductions

Variable	2025	2035	2050
Total daily vehicle trip reductions	Final results pending selection of the preferred network scenario		
Total daily VMT reductions			
GHG reduction due to cold starts (short tons)			
GHG reduction due to VMT (short tons)			
Total daily GHG reduction (short tons)			
Total population			
Daily per capita GHG reduction (lbs/person)			
Daily per capita GHG reduction, change in percent			