Appendix D:

Sustainable Communities Strategy Documentation and Related Information

Table of Contents

Table of Tables

Table of Figures

Appendix D: Sustainable Communities Strategy Documentation and Related Information

This appendix includes documentation in support of the Sustainable Communities Strategy (SCS) pursuant to California Senate Bill 375 (Steinberg, 2008) (SB 375) and describes how San Diego Forward: The 2021 Regional Plan (2021 Regional Plan) fulfills requirements of the SCS as described in SB 375,[1] including:

- Submittal of the Technical Methodology to Estimate Greenhouse Gas (GHG) Emissions for the 2021 Regional Plan and SCS from the San Diego Association of Governments (SANDAG) to the California Air Resources Board (CARB) and letter from CARB accepting this Technical Methodology
- SB 375 GHG Targets set by CARB and Results of GHG Emissions Reductions
- Matrix that outlines the requirements of the SCS as described in SB 375 and California Assembly Bill 805 (Gonzalez Fletcher, 2017) (AB 805) and where the 2021 Regional Plan addresses the requirements—either in specific chapters of the 2021 Regional Plan or in specified appendices
- Resource areas and farmland in the region
- SB 375 Areas for Transit Priority Projects and California Senate Bill 743 (Steinberg, 2013) (SB 743) Transit Priority Areas

Technical Methodology to Estimate Greenhouse Gas Emissions

Pursuant to SB 375, CARB is required to review each metropolitan planning organization's (MPO's) proposed Technical Methodology for quantifying GHG emissions reductions from the SCS as well as the final quantification. The Technical Methodology to Estimate GHG Emissions for the 2021 Regional Plan and SCS was first submitted to CARB on September 25, 2020. SANDAG coordinated with CARB staff on review and edits to the Technical Methodology prior to submitting a Final Technical Methodology to CARB on February 26, 2021. Attachment 1 includes:

- April 20, 2021, correspondence from CARB to SANDAG regarding Technical Methodology to Estimate GHG Emissions
- February 26, 2021, correspondence from SANDAG to CARB regarding Technical Methodology to Estimate GHG Emissions for the 2021 Regional Plan and SCS

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1 Pursuant to Government Code Section 65080(d)(2), SANDAG is required to adopt and submit its update to San Diego Forward: The 2015 Regional Plan by December 31, 2021.

Senate Bill 375 Greenhouse Gas–Reduction Targets Set by California Air Resources Board and Results of Greenhouse Gas Emissions Reductions

In 2010, CARB established the original SB 375 regional GHG-reduction targets for each MPO for years 2020 and 2035. For the San Diego region, the carbon dioxide (CO_2) reductions were set at 7% and 13% per capita for cars and light trucks from 2005, respectively. In 2018, CARB approved updated targets that reflect more aggressive per capita CO_2 reductions of 15% for 2020 and 19% for 2035 compared to 2005.

2020 Greenhouse Gas–Reduction Target

SANDAG has prepared an estimate for CO_2 reductions in 2020 using a fusion of existing data and estimated regional travel. Because there are no direct methods for measuring either vehicle miles traveled (VMT) or GHG emissions, SANDAG must deploy estimation techniques to determine whether the 2020 GHG-reduction target was met. In line with CARB SCS evaluation guidelines, SANDAG adjusted the regional VMT estimate for 2020 from the activity-based model system (ABM2+) based on observed freeway counts, speeds, and VMT estimates from the Caltrans Performance Measurement System (PeMS). The adjusted VMT data tables are then used within EMFAC 2014 for CO_2 emissions modeling. Based on this methodology, the San Diego region reduced per capita CO_2 emissions by 17.9% in 2020 compared to 2005 baseline, which exceeds the 2020 target set for SANDAG of 15% reduction. Attachment 2 contains the methodology for calculating the estimate for CO_2 reductions in 2020.

PeMS measured data for 2020 was significantly impacted by COVID-19 due to intermittent stay-home orders; changes in employment, employee work location, and telework; tourism travel; package and food delivery; crossborder travel restrictions; declines in public transit ridership; and price of gasoline, among many other impacts.

2035 Greenhouse Gas–Reduction Target

Implementation of the SCS is estimated to result in a 20% CO_2 emissions reduction for cars and light-duty trucks by 2035. The GHG reductions for the 2021 Regional Plan were calculated using the CARB model EMFAC 2014 and adjustment factors provided by CARB to account for differences in emissions rates between EMFAC 2007 (used to set the original targets in 2010) and EMFAC 2014. Off-model calculators were used to calculate emissions reductions associated with strategies that are not accounted for in SANDAG travel demand modeling tools (see Table D.4). Table D.1 summarizes the CO_2 per capita reductions from on-model and off-model strategies after accounting for the EMFAC adjustment factor and induced demand adjustment factor. Attachment 3 contains the methodology for calculating the induced demand adjustment factor.

Table D.1: Summary of CO_2 Per Capita Reductions as Compared to 2005: On- and Off-Model Results and Adjustment Factors

Summary of CO_2 Per Capita Reductions as Compared to 2005: On- and Off-Model Results and Adjustment Factors	
	2035
Per Capita Reduction (On-Model Results Only)	−19.3%
Per Capita Reduction (Off-Model Results Only)	−3.01%
CARB Adjustment Factor for EMFAC 2007–2014	1.7%
Induced Demand Adjustment Factor	0.20%
Per Capita Reductions	**−20.4%**

2050 Estimated Greenhouse Gas Reduction

While the state does not set a 2050 target for GHG emissions reduction, similar methods were used to estimate per capita CO_2 emissions reductions from cars and light-duty trucks as a percent reduction compared to 2005 levels. It is important to note that after 2035, SANDAG is not proposing to continue the Regional Electric Vehicle (EV) Incentive Program due to Executive Order N-79-20 requiring all new cars and passenger trucks sold in California to be zero-emission vehicles. After 2035, SANDAG also assumes that free-floating carsharing programs may sunset due to the rise and popularity of on-demand ridehailing services. These assumptions result in lower "off-model" reductions in 2050 (see Table D.4). For 2050, on-model CO_2 reduction is −20.3% and off-model CO_2 reduction is −2.61%. After applying the CARB adjustment factor of 1.6% and an induced demand adjustment factor of 0.27%, estimated CO_2 reductions for 2050 are −21%.

2021 Regional Plan Strategy Quantification

The strategies in the 2021 Regional Plan that contribute to GHG reductions toward the region's target span a wide range of scenarios employing methods to influence the performance of the region's transportation system. The elements of these strategies can be broken down into Transportation System Infrastructure and Operations, Demand Management, Land Use, and Zero-Emission Vehicles. As described in Table D.2, some strategies included in the 2021 Regional Plan are a continuation or expansion of strategies from the 2015 Regional Plan, while some strategies are new for the 2021 Regional Plan. The quantification approach for each strategy is indicated in Table D.2. Chapter 3 and Appendix B: Implementation Actions describe the commitments or key actions that implement the 2021 Regional Plan strategies.

The two main quantification approaches are the SANDAG regional travel demand model ABM2+ and a set of off-model calculators developed to handle elements that cannot be treated by ABM2+. Appendix S: Travel Demand Modeling Tools includes documentation of the travel demand model and off-model calculators. The selected approach for each strategy element is based first upon a determination of whether that element can be represented in the ABM2+ travel demand model. This determination has been made based upon the ABM2+ technical documentation, the ABM2+ sensitivity analysis report, and the findings of the ABM2+ technical advisory committee. As described in the Technical Methodology submitted to CARB (Attachment 1), those elements that cannot be represented in ABM2+ were then considered for off-model quantification based upon the expected impact of that element on the overall performance of the transportation system as well as an identification of a feasible off-model methodology and associated recommendations from CARB and prior off-model developments (at SANDAG and other MPOs). SANDAG contracted with the University of California Institute of Transportation Studies (UCITS) through the UC Irvine campus to validate the overall quantification approaches along with the development and updating of the off-model quantification approach. The UCITS assessment is also included in Appendix S.

Table D.2: Quantification Approach for 2021 Regional Plan Strategies

Quantification Approach for 2021 Regional Plan Strategies		
Strategy	**Inclusion in Prior SCS?**	**Quantification Approach**
Transportation System Infrastructure and Operations		
Complete Corridors and Transit Leap: • Managed Lanes • High-Occupancy Vehicle (HOV)/ High-Occupancy Toll (HOT) policies • Regional Bike Network • Commuter Rail • Light Rail • Next Generation *Rapid* • Local Bus	Yes. 2021 SCS expands on these strategies.	Coded as transportation network improvements in ABM2+.
Mobility Hubs and Flexible Fleets: • Local Complete Streets • Parking management • Microtransit • Micromobility • Pooled Transportation Network Companies (TNCs) • E-bikes	Mobility Hubs were introduced in the prior SCS, but investment and specific geographic information was limited, as were associated strategies and fleet assumptions.	Mobility Hubs are used as a geographic area for applying Complete Streets, parking, microtransit, and micromobility strategies in ABM2+. Pooled TNCs and e-bikes are reflected in mode choices in ABM2+.
Next Operating System (Next OS): • Active Transportation Demand Management (ATDM) • Smart Signals	Yes. 2021 SCS expands on these strategies.	ATDM reflected as improved travel reliability in ABM2+. Smart Signals reflected as reduced intersection delays in ABM2+.
Demand Management		
Telework	Yes. Ability to capture primarily and occasional telework is new.	Primarily and occasional teleworker assumptions applied in ABM2+.
Pooled rides (private)	Yes, off-model in prior SCS.	Off-Model
Vanpool	Yes, off-model in prior SCS.	Off-Model
Carshare	Yes, off-model in prior SCS.	Off-Model
Regional Transportation Demand Management (TDM) Ordinance	No, new off-model calculator.	Off-Model

Quantification Approach for 2021 Regional Plan Strategies

Strategy	Inclusion in Prior SCS?	Quantification Approach
Pricing strategies: • Road usage charge • Transit Fare Subsidies • Congestion pricing/toll rates • Parking • TNC fees	Carryover pricing strategies include congestion pricing/toll rates, parking pricing. New pricing strategies include road usage charge, transit fare subsidies, and TNC fees.	Pricing strategies reflected in ABM2+ as follows: • Road usage charge: per-mile charge added to the auto operating cost. • Transit Fare Subsidies: one-way and daily transit fares defined for each service type • Congestion pricing/tolled rates: per-mile tolls defined by time of day for each Managed Lane corridor and fixed-fee tolls for the SR 125 toll road. • Parking: hourly, daily, and monthly rates applied to certain Mobility Hub areas and charged to auto trips destined for those specified areas. • TNC fees: applied as fixed fee per trip.
Land Use		
SCS Land Use Pattern that considers: • Job–Housing Balance • Mixing of uses • Transit-Oriented Development • Regional Housing Needs Assessment	Yes. The 2021 SCS includes expanded land use policies reflected in the SCS land use pattern.	Mobility Hub areas used as a framework for the allocation of housing and jobs in the land use pattern developed in Integrated Land Use, Demographic, and Economic Model (I-LUDEM) and impact modeled in ABM2+.
Zero-Emission Vehicles		
Regional EV Charger Program	Yes, off-model in prior SCS. The 2021 SCS includes an expanded EV Charger Program.	Off-Model
Regional EV Incentive Program	No. The EV Incentive Program is a new SCS strategy.	Off-Model

Strategies Applied in ABM2+

Strategies applied in ABM2+ have underlying parameters used to represent the modes and policies described in Table D.2. Table D.3 defines the assumptions used to apply various strategies to ABM2+ for the year 2035.

Table D.3: Strategies Applied in ABM2+ for the Year 2035

Strategies Applied in ABM2+ for the Year 2035		
Category	**Input Description**	**2035**
Managed Lanes	HOV and toll assumptions	ML3+ (all ML facilities are priced) – Vehicles carrying three or more persons are allowed and pay no toll for use. Single-occupancy vehicles and two-person vehicles that pay a toll are permitted to use the facility.
Pricing ($2020)	Managed Lane/HOT rates	$0.30/mile a.m. and p.m. peak $0.30/mile off-peak
	Regional road usage charge	$0.03/mile
Parking Cost ($2020)	Urban shed, major employment centers, U.S.–Mexico border	Hourly: $3.25 Daily: $25 Monthly: $350
	Central Mobility Hub	Hourly: $5 Daily: $39 Monthly: $450
	Coastal Communities	Hourly: $2.25 Daily: $16 Monthly: $250 (Add in Imperial Beach, Coronado, and La Jolla)
	Suburban Communities	Hourly: $1.50 Daily: $12 Monthly: $150
Telework	Rates for primary and occasional teleworkers	Primarily telework: 10.9% Occasional telework: 11.8%
TNCs ($2020)	TNC fee (single)	Fixed: $1.25/trip
	TNC fee (shared)	Fixed: $0.65/trip
Micromobility	Speed	15 mph average
	Cost ($2020)	Micromobility cost: $1 fixed + $0.20/min $0 for access/egress to transit
	Wait time	3 minutes in urban, 5 minutes suburban
	Constant	60 minutes
	Value of time ($2020)	$15
E-Bikes	Personally owned e-bike	36% of privately owned bikes are e-bikes

Strategies Applied in ABM2+ for the Year 2035

Category	Input Description	2035
Microtransit	Speed	17 mph
	Flat fare ($2020)	$1.25 one way/$3 day
	Wait time	4 minutes
	Access time	0 minutes
	Constant	120 minutes
	Maximum distance	3 miles
Transit Fares ($2020)	Local bus, arterial *Rapid*, some non-Express Freeway *Rapid*s, Express Bus, Trolley, and SPRINTER	$1.25 one way/$3 day
	Express Freeway *Rapid*	$2.50 one way/$6 day
	Commuter Rail	$3 one way/$6 day
	COASTER Connection, Automated People Mover	Free
ATDM	Capacity increase from Integrated and Cooperative Management of roadway system yielding increase in travel reliability	7% unreliability reduction
Smart Signals	Benefits from reduced intersection delays	Delay at signalized intersections decreased by 20% (arterials)

Off-Model Strategies

SANDAG has included five off-model strategies to estimate GHG emissions reductions from programs that cannot be applied in ABM2+. These include vanpool, carshare, pooled rides, Regional TDM Ordinance, and EV programs. The EV programs consist of both a Vehicle Incentive Program and an EV Charging Incentive Program. Both EV programs are modeled in a single calculator to capture the interactions between the two programs and avoid double counting of emissions reductions. Details on the methods and assumptions of the off-model calculators are included in Appendix S. Table D.4 summarizes the CO_2 reductions associated with each off-model strategy.

Table D.4: Summary of Off-Model Strategies: Percent Per Capita CO_2 Reduction as Compared to 2005

Summary of Off-Model Strategies: Percent Per Capita CO_2 Reduction as Compared to 2005		
Off-Model Strategy	**2035**	**2050**
Vanpool	0.31%	0.32%
Carshare	0.17%	—
Pooled Rides	0.01%	0.01%
Regional TDM Ordinance	0.37%	0.56%
EV Programs (Vehicle Incentive and Charger Program)	2.15%	1.72%
Total	**3.01%**	**2.61%**

Sustainable Communities Strategy and Regional Comprehensive Plan Regulation Information

Table D.5 summarizes where the 2021 Regional Plan addresses SCS and Regional Comprehensive Plan regulations.

Table D.5: Sustainable Communities Strategy and Regional Comprehensive Plan Regulation Information

Sustainable Communities Strategy and Regional Comprehensive Plan Regulation Information		
	Regulatory Text	**Addressed**
SCS Requirement	**California Government Code (CGC) Section 65080(b)(2)(B)** Each metropolitan planning organization shall prepare a sustainable communities strategy subject to the requirements of Part 450 of Title 23 of and Part 93 of Title 40 of the Code of Federal Regulations, including the requirement to utilize the most recent planning assumptions considering local general plans and other factors. The sustainable communities strategy shall:	The focus of Chapter 2 is the Sustainable Communities Strategy (SCS); however, components of the SCS are integrated throughout the 2021 Regional Plan chapters and appendices.
Land Use	CGC Section 65080(b)(2)(B)(i) Identify the general location of uses, residential densities, and building intensities within the region.	See Regional Plan Chapter 2 and Appendices D (Sustainable Communities Strategy Documentation and Related Information) and F (Regional Growth Forecast and Sustainable Communities Strategy Land Use Pattern).
Housing Goals	CGC Section 65080(b)(2)(B)(vi) Consider the state housing goals specified in Sections 65580 and 65581.	See Regional Plan Chapter 2 and Appendix K (Regional Housing Needs Assessment Plan).
	CGC Section 65080(b)(2)(B)(ii) Identify areas within the region sufficient to house all the population of the region, including all economic segments of the population, over the course of the planning period of the regional transportation plan taking into account net migration into the region, population growth, household formation and employment growth.	See Regional Plan Chapter 2 and Appendices F (Regional Growth Forecast and Sustainable Communities Strategy Land Use Pattern) and K (Regional Housing Needs Assessment Plan).
	CGC Section 65080(b)(2)(B)(iii) Identify areas within the region sufficient to house an eight-year projection of the regional housing need for the region pursuant to Section 65584.	See Regional Plan Chapter 2 and Appendices F (Regional Growth Forecast and Sustainable Communities Strategy Land Use Pattern), and K (Regional Housing Needs Assessment Plan).
Natural Resources	CGC Section 65080(b)(2)(B)(v) Gather and consider the best practically available scientific information regarding resource areas and farmland in the region as defined in subdivisions (a) and (b) of Section 65080.01.	See Regional Plan Chapter 2 and Appendices D (Sustainable Communities Strategy Documentation and Related Information) and AA (Regional Habitat Conservation Vision).
Transportation Network	CGC Section 65080(b)(2)(B)(iv) Identify a transportation network to service the transportation needs of the region.	See Regional Plan Chapters 1 and 2. Also see Appendices A (Transportation Projects, Programs, and Phasing) and T (Network Development and Performance).

Sustainable Communities Strategy and Regional Comprehensive Plan Regulation Information

	Regulatory Text	Addressed
Meeting GHG Reduction Targets	CGC Section 65080(b)(2)(B)(vii) Set forth a forecasted development pattern for the region, which, when integrated with the transportation network and other transportation measures and policies, will reduce the greenhouse gas emissions from automobiles and light trucks to achieve, if there is a feasible way to do so, the greenhouse gas emission reduction targets approved by the state board.	See Regional Plan Chapters 2 and 3. Also see Appendices B (Implementation Actions), D (Sustainable Communities Strategy Documentation and Related Information), and F (Regional Growth Forecast and Sustainable Communities Strategy Land Use Pattern).
Meeting Federal Air Quality Requirements	CGC Section 65080(b)(2)(B)(viii) Allow the regional transportation plan to comply with Section 176 of the federal Clean Air Act (42 U.S.C. §7506).	See Regional Plan Chapter 2 and Appendix C (Air Quality Planning and Transportation Conformity).
Informational Meetings	**CGC Section 65080(b)(2)(E)** The metropolitan planning organization shall conduct at least two informational meetings in each county within the region for members of the board of supervisors and city councils on the sustainable communities strategy and alternative planning strategy, if any. The metropolitan planning organization may conduct only one informational meeting if it is attended by representatives of the county board of supervisors and city council members representing a majority of the population in the incorporated areas of that county.	See Appendix G (Public Involvement Program).
Public Participation Plan	**CGC Section 65080(b)(2)(F)** Each metropolitan planning organization shall adopt a public participation plan, for development of the sustainable communities strategy and an alternative planning strategy, if any, that includes all of the following:	See Appendix G (Public Involvement Program).
Public Participation Plan – Outreach	CGC Section 65080(b)(2)(F)(i) Outreach efforts to encourage the active participation of a broad range of stakeholder groups in the planning process, consistent with the agency's adopted Federal Public Participation Plan, including, but not limited to, affordable housing advocates, transportation advocates, neighborhood and community groups, environmental advocates, home builder representatives, broad-based business organizations, landowners, commercial property interests, and homeowner associations.	See Appendix G (Public Involvement Program).

Sustainable Communities Strategy and Regional Comprehensive Plan Regulation Information

	Regulatory Text	Addressed
Public Participation Plan – Consultation	CGC Section 65080(b)(2)(F)(ii) Consultation with congestion management agencies, transportation agencies, and transportation commissions.	See Appendix G (Public Involvement Program).
Public Participation – Workshops	CGC Section 65080(b)(2)(F)(iii) Three workshops throughout the region to provide the public with the information and tools necessary to provide a clear understanding of the issues and policy choices. Each workshop, to the extent practicable, shall include urban simulation computer modeling to create visual representations of the SCS and the alternative planning strategy.	See Appendix G (Public Involvement Program).
Public Participation Plan – SCS Public Review	CGC Section 65080(b)(2)(F)(iv) Preparation and circulation of a draft SCS and an alternative planning strategy, if one is prepared, not less than 55 days before adoption of a final regional transportation plan.	See Appendix G (Public Involvement Program).
Public Participation Plan – Public Hearings	CGC Section 65080(b)(2)(F)(v) At least three public hearings on the draft sustainable communities strategy in the regional transportation plan and alternative planning strategy, if one is prepared. If the metropolitan transportation organization consists of a single county, at least two public hearings shall be held. To the maximum extent feasible, the hearings shall be in different parts of the region to maximize the opportunity for participation by members of the public throughout the region.	See Appendix G (Public Involvement Program).
Public Participation Plan – Public Notice	CGC Section 65080(b)(2)(F)(vi) A process for enabling members of the public to provide a single request to receive notices, information, and updates.	See Appendix G (Public Involvement Program).
Consideration of Spheres of Influence Adopted by Local Agency Formation Committee	**CGC Section 65080(b)(2)(G)** In preparing a sustainable communities strategy, the metropolitan planning organization shall consider spheres of influence that have been adopted by the local agency formation commissions within its region.	See Appendix F (Regional Growth Forecast and Sustainable Communities Strategy Land Use Pattern).

Sustainable Communities Strategy and Regional Comprehensive Plan Regulation Information

	Regulatory Text	Addressed
CARB GHG Reduction Targets for San Diego Region	**CGC Section 65080(b)(2)(H)** Prior to adopting a sustainable communities strategy, the metropolitan planning organization shall quantify the reduction in greenhouse gas emissions projected to be achieved by the sustainable communities strategy and set forth the difference, if any, between the amount of that reduction and the target for the region established by the state board.	See Regional Plan Chapter 2. Also see Appendices D (Sustainable Communities Strategy Documentation and Related Information) and S (Travel Demand Modeling Tools).
Consideration of Financial Incentives for Cities and Counties with Resource Areas or Farmlands	**CGC Section 65080(b)(4)(C)** The metropolitan planning organization or county transportation agency, whichever entity is appropriate, shall consider financial incentives for cities and counties that have resource areas or farmland, as defined in Section 65080.01, for the purposes of, for example, transportation investments for the preservation and safety of the city street or county road system and farm-to-market and interconnectivity transportation needs. The metropolitan planning organization or county transportation agency, whichever entity is appropriate, shall also consider financial assistance for counties to address countywide service responsibilities in counties that contribute towards the greenhouse gas emission reduction targets by implementing policies for growth to occur within their cities.	See Regional Plan Chapter 3 and Appendix B (Implementation Actions).
Regional Comprehensive Plan Requirements from AB 805	**Public Utilities Code (PUC) 132360.1(b)** The regional comprehensive plan shall address the greenhouse gas emissions reduction targets set by the State Air Resources Board as required by Section 65080 of the Government Code and include strategies that provide for mode shift to public transportation.	See Regional Plan Chapter 2. Also see Appendices A (Transportation Projects, Programs, and Phasing), B (Implementation Actions), and T (Network Development and Performance).
	PUC 132360.1(c) The regional comprehensive plan shall identify disadvantaged communities as designated pursuant to Section 39711 of the Health and Safety Code and include transportation strategies to reduce pollution exposure in these communities.	See Regional Plan Chapter 2. Also see Appendix H (Social Equity: Engagement and Analysis).

Resource Areas and Farmland in the San Diego Region

The following maps show projected land use and natural resource areas for 2035 and 2050. The land use maps in Figures D.1 (2035 Land Use) and D.2 (2050 Land Use) were generated using the Series 14 Regional Growth Forecast and SCS Land Use Pattern where future development and growth is concentrated in urbanized areas near existing and future transportation networks (detailed information can be found in Appendix F: Regional Growth Forecast and Sustainable Communities Strategy Land Use Pattern). San Diego's vast amounts of natural land and resources are valuable for conservation and recreation. Figures D.3 through D.7 show where vegetation, existing and proposed habitat conservation lands, wetlands, important agricultural lands, and other natural resources are located within the San Diego region. One of the strategies of the 2021 Regional Plan is to preserve natural resources and farmland to the extent feasible for current and future residents and visitors to the region.

Figure D.1: 2035 Sustainable Communities Strategy Land Use Pattern

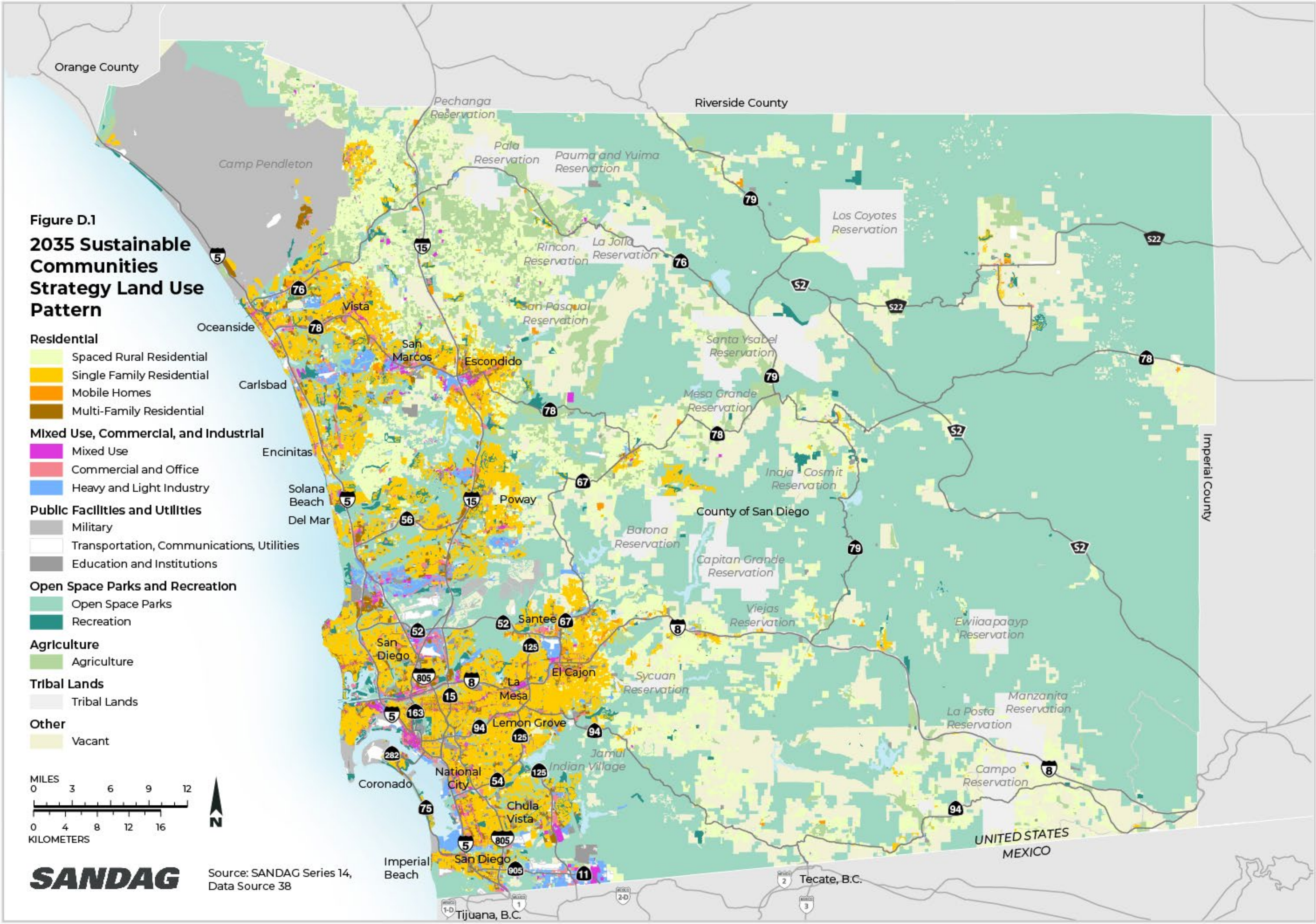


Figure D.2: 2050 Sustainable Communities Strategy Land Use Pattern

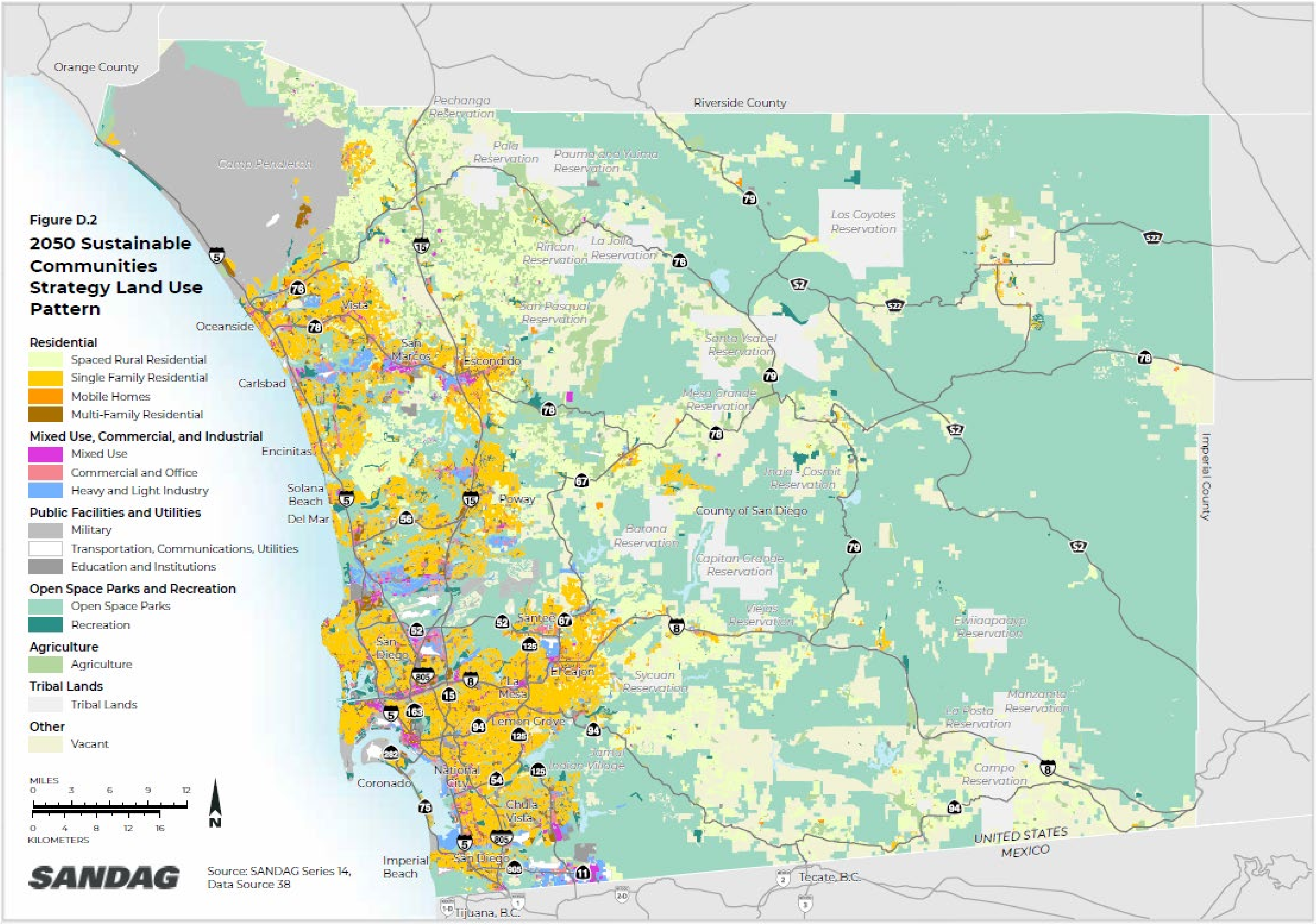


Figure D.3: Existing San Diego Region Wetlands

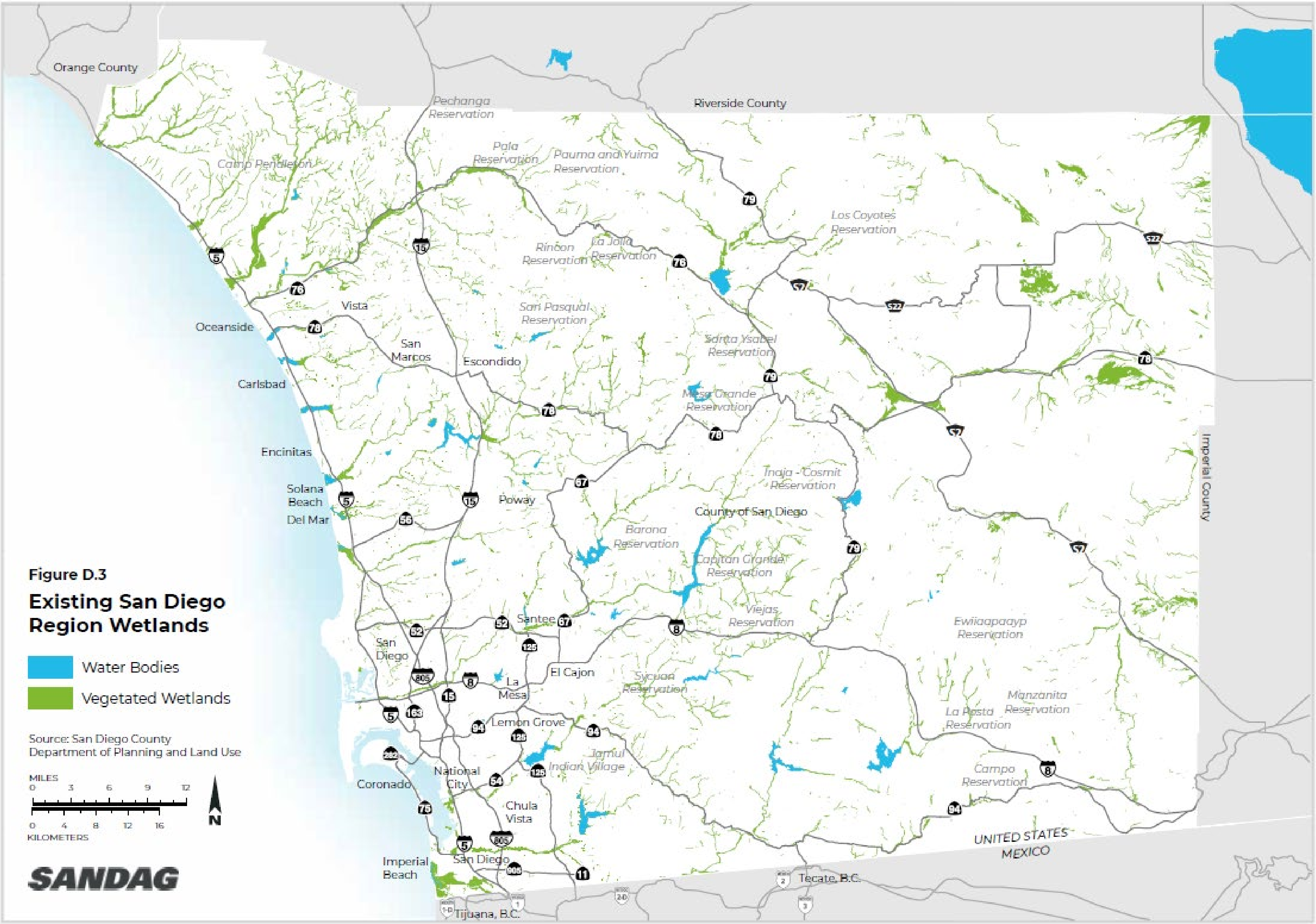


Figure D.4: Existing San Diego Region Important Agricultural Lands

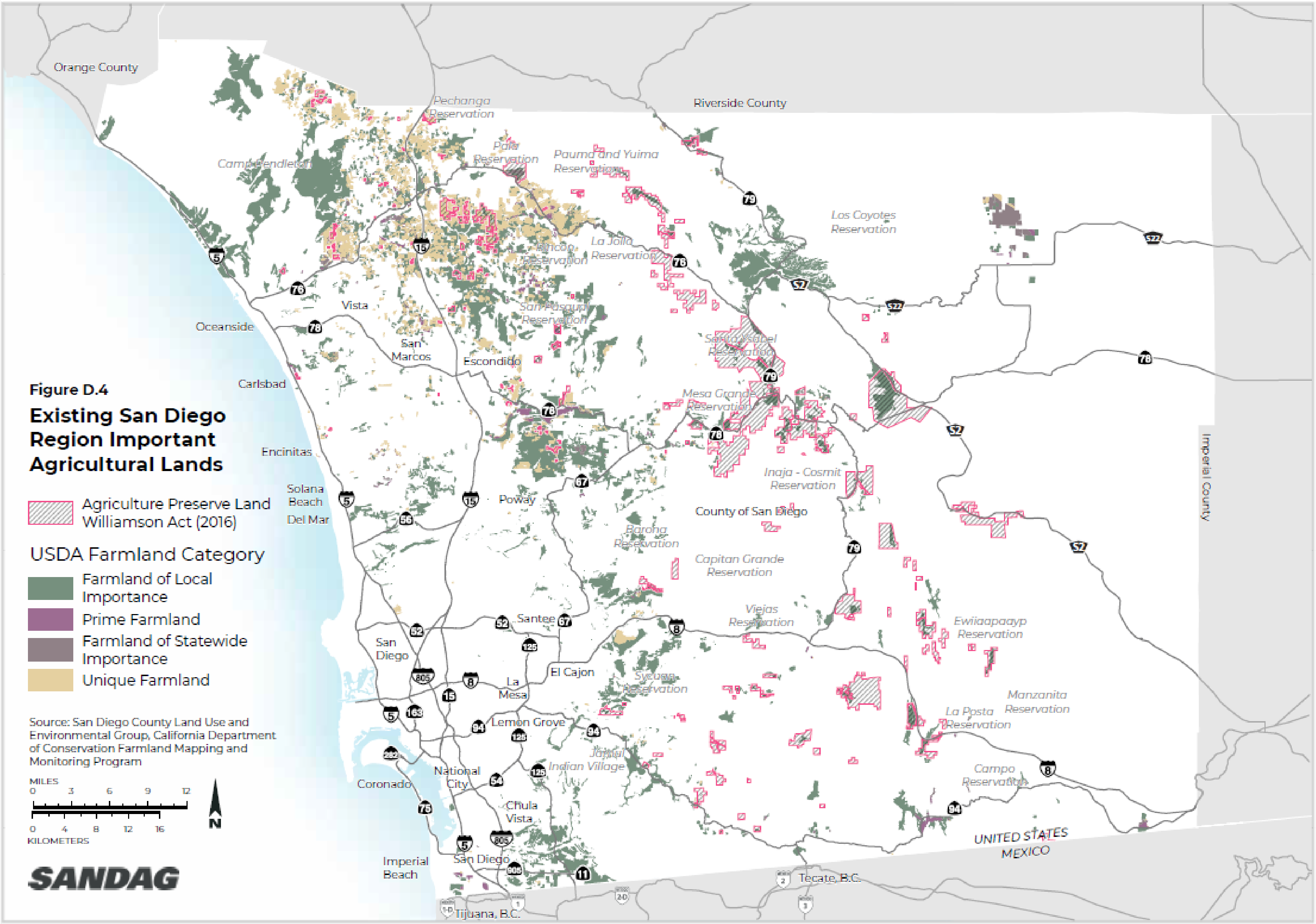


Figure D.5: Existing and Proposed San Diego Region Habitat Conservation Lands

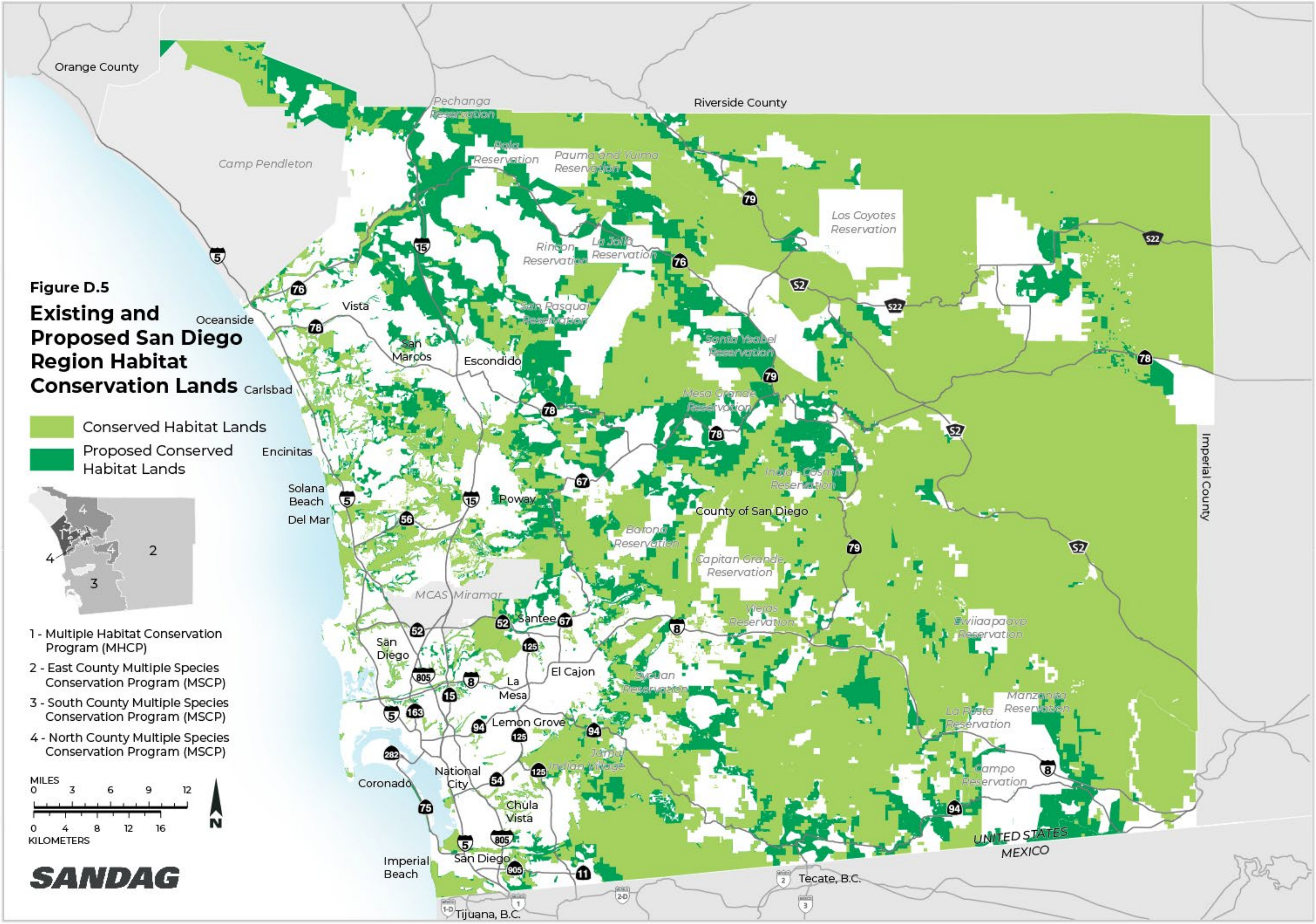


Figure D.6: Existing San Diego Region Generalized Vegetation

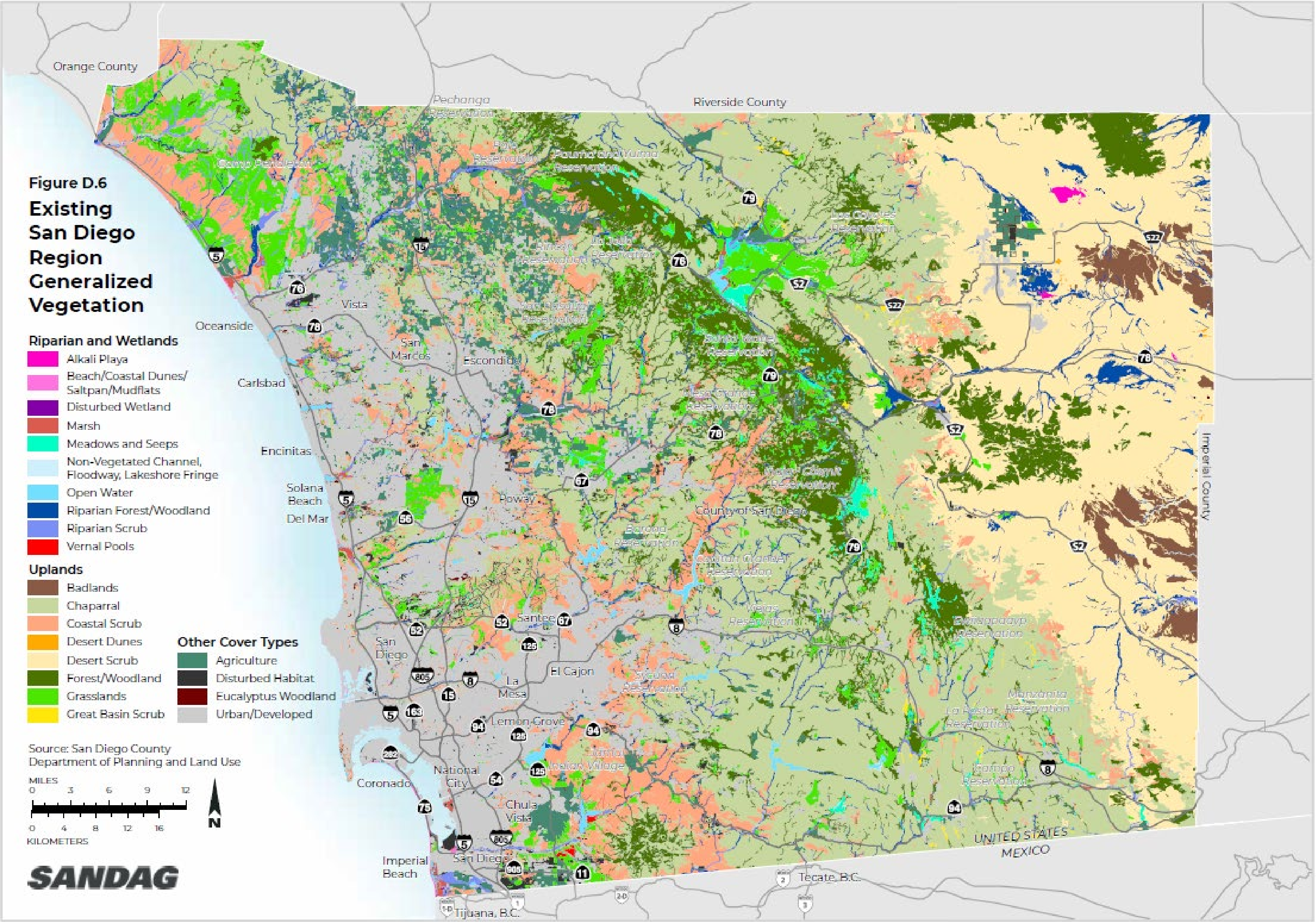
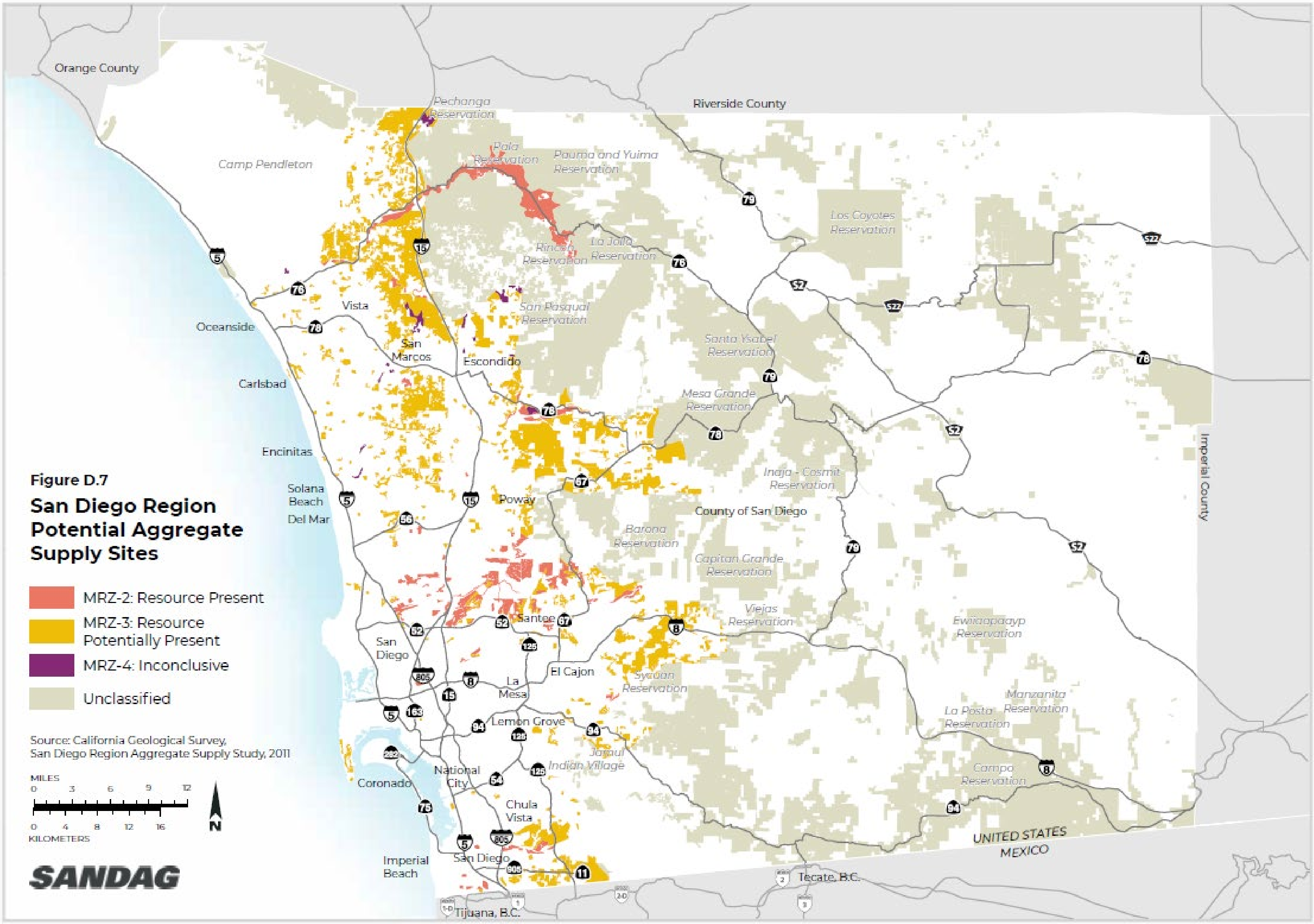


Figure D.7: San Diego Region Potential Aggregate Supply Sites



Transit Priority Projects Under Senate Bill 375

SB 375 provides a streamlined environmental review for Transit Priority Projects[2] that, among other things, are located within a half mile of a "major transit stop," defined in Public Resources Code Section 21064.3,[3] or "high-quality transit corridor," defined as a corridor with fixed-route bus service with service intervals no longer than 15 minutes during peak commute hours. Figures D.8 and D.9 depict potential areas for Transit Priority Projects based on the 2035 and 2050 transit systems, respectively.

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2 "Transit Priority Project" is defined in Public Resources Code Section 21155.1.

3 "Major transit stop" means a site containing any of the following:

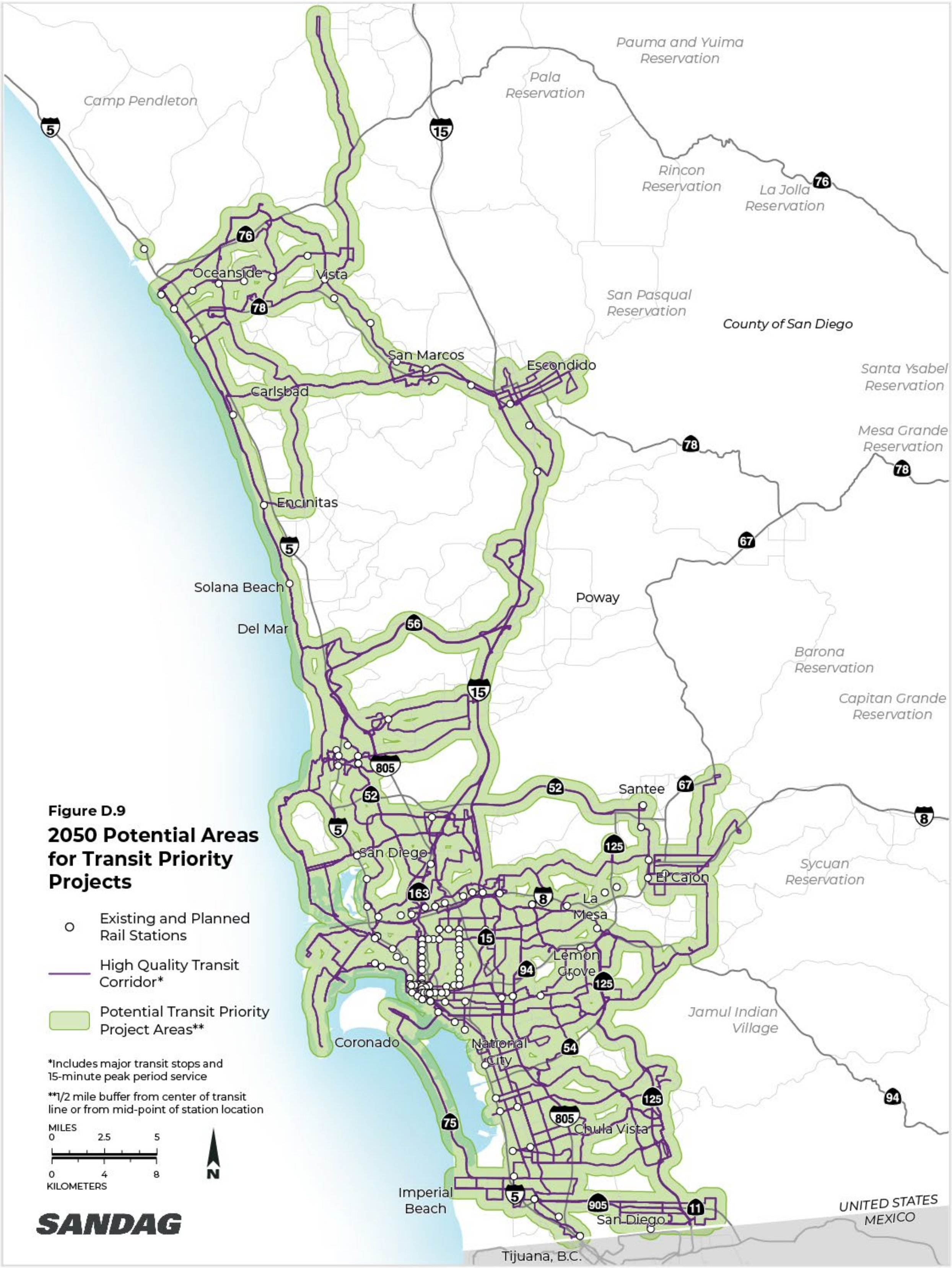
a. An existing rail or Bus *Rapid* Transit station.

b. A ferry terminal served by either a bus or rail transit service.

c. The intersection of two or more major bus routes with a frequency of service interval of 15 minutes or less during the morning and afternoon peak commute periods.

Figure D.8: 2035 Potential Areas for Transit Priority Projects

Figure D.9: 2050 Potential Areas for Transit Priority Projects



Transit Priority Areas Under Senate Bill 743

SB 743 provides for streamlined environmental review for projects within Transit Priority Areas, which is an area within a half mile of a "major transit stop," defined in Public Resources Code 21064.3.[4] Figures D.10 and D.11 depict Transit Priority Areas as defined by SB 743 based on the 2035 and 2050 transit systems, respectively.

[4] "Major transit stop" means a site containing any of the following:

a. An existing rail or Bus *Rapid* Transit station.
b. A ferry terminal served by either a bus or rail transit service.
c. The intersection of two or more major bus routes with a frequency of service interval of 15 minutes or less during the morning and afternoon peak commute periods.

Figure D.10: 2035 Transit Priority Areas

Figure D.11: 2050 Transit Priority Areas

Attachments

Attachment 1A: Correspondence from California Air Resources Board to SANDAG regarding Technical Methodology to Estimate Greenhouse Gas Emissions

Attachment 1B: Correspondence from SANDAG to California Air Resources Board regarding Technical Methodology to Estimate Greenhouse Gas Emissions for San Diego Forward: The 2021 Regional Plan and SCS

Attachment 2: Senate Bill 375 2020 Greenhouse Gas Reduction Estimate

Attachment 3: Senate Bill 375 Greenhouse Gas Adjustment Due to Induced Demand

Appendix D Attachment 1A:

Correspondence from California Air Resources Board to SANDAG regarding Technical Methodology to Estimate Greenhouse Gas Emissions

April 20, 2021

Mr. Hasan Ikhrata
Executive Director
San Diego Association of Governments
401 B Street, Suite 800, San Diego, CA 92101
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RE: CARB Review of San Diego Association of Governments' 2021 RTP/SCS Senate Bill 375 Greenhouse Gas Emissions Technical Quantification Methodology

Dear Mr. Ikhrata:

California Air Resources Board (CARB) staff appreciates San Diego Association of Governments' (SANDAG) Senate Bill 375 (SB 375) technical quantification methodology submittal on September 28, 2020, pursuant to requirements under California Government Code section 65080 (b) (2) (J) (i), as well as additional information SANDAG has provided in response to CARB staff's concerns transmitted on November 23, 2020 and February 26, 2021. CARB staff has reviewed all materials that SANDAG has provided on its proposed technical methods and planning analysis tools for assessing SB 375 transportation-related greenhouse gas emissions from its 2021 SCS. Based on our review, staff believes there are no aspects of the submitted technical methodology that would yield inaccurate estimates of greenhouse gas emissions and does not have further changes to suggest.

However, CARB is requesting SANDAG document, at the time of submittal, details on how various strategies in the SCS interact. Specifically, CARB staff requests that SANDAG document and demonstrate how it has avoided double-counting of GHG emission reductions across multiple off-model strategies in their SCS submittal as described below. We appreciate SANDAG staff's expressed willingness to continue to work with CARB staff on its quantification methods.

Off Model Strategy Calculation Methods

For strategies that will be quantified off-model, CARB staff requests SANDAG include a discussion of how it intends to address potential double counting among any strategies overlap off-model and travel demand model quantification. In addition, SANDAG should provide details on the quantification for each off-model strategy in accordance with CARB's *Final Sustainable Communities Strategy Program and Evaluation Guidelines* (SCS Evaluation Guidelines). This should include information on the current and future level of deployment, target population, funding sources, key assumptions, data sources, and step-by-step emission calculations.

CARB staff will conduct its final evaluation, as outlined in the SCS Evaluation Guidelines, once SANDAG submits the final SCS to CARB. The SCS Evaluation Guidelines are intended to clarify the scope of CARB's updated evaluation process, and will focus on changes to land use and transportation strategies and investments that MPOs are making from one SCS to the next. As part of the final review process, CARB staff may request additional information to conduct and support our final evaluation pursuant to SB 375.

We look forward to continuing our collaboration with SANDAG as it finalizes and adopts its 2021 SCS. If you have any questions, please contact me at *nicole.dolney@arb.ca.gov*.

Sincerely,

Nicole Dolney Bourne

Nicole Dolney Bourne
Chief, Transportation Planning Branch
Sustainable Transportation and Communities Division

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Appendix D Attachment 1B:

Correspondence from SANDAG to California Air Resources Board regarding Technical Methodology to Estimate Greenhouse Gas Emissions for San Diego Forward: The 2021 Regional Plan and SCS

Technical Methodology to Estimate Greenhouse Gas Emissions for San Diego Forward: The 2021 Regional Plan and Sustainable Communities Strategy from the San Diego Association of Governments

Introduction

California Senate Bill 375 (Steinberg, 2008) (SB 375) requires that metropolitan planning organizations (MPOs) submit a description of the technical methodology they intend to use to estimate the greenhouse gas (GHG) emissions from their Sustainable Communities Strategy (SCS) to the California Air Resources Board (CARB). This technical methodology is submitted in compliance with Government Code § 65080(b)(2)(J)(i) and reflects the best available information as of February 2021.

San Diego Forward: The 2021 Regional Plan (2021 Regional Plan) serves as the long-range planning document for the San Diego region, and it also functions as the Regional Transportation Plan (RTP) and SCS, which will comply with state and federal regulations including SB 375 and federal air quality conformity.

This report describes the proposed technical methodology to estimate GHG emissions for the 2021 Regional Plan. Components currently under development are noted in this report. San Diego Association of Governments (SANDAG) staff will provide information to CARB on those components as they are finalized.

SANDAG has completed two Regional Plan/SCS cycles to date, adopting the latest SCS (San Diego Forward: The 2015 Regional Plan) in October 2015. CARB accepted that SANDAG's first SCS (2050 Regional Transportation Plan) and second SCS (San Diego Forward: The 2015 Regional Plan) if implemented, would meet or exceed the applicable targets of 7% reduction for 2020 and 13% reduction for 2035 relative to 2005. The target achievement for the 2050 Regional Transportation Plan was estimated at 14% for 2020 and 13% for 2035. The target achievement for the 2015 Regional Plan was estimated at 15% for 2020 and 21% for 2035.

For the 2021 Regional Plan, slated for adoption in late 2021, the 2035 per capita GHG target has been updated through a CARB action in March 2018. For the San Diego Region, the updated target is now 19% per capita reduction by 2035 relative to 2005. The 2021 Regional Plan also will include the new 15% per capita reduction target for 2020, although that date will have passed when SANDAG releases the Draft 2021 Regional Plan in 2021.

The 2021 Regional Plan will include strategies and investments that influence travel decisions and land use patterns between 2021 and 2050, a 30-year time horizon. Table 1 displays the proposed analysis years to be used in forecasting GHG emissions for the 2021 Regional Plan. The year 2035 target for the 2021 Regional Plan will be at the midpoint between adoption (2021) and the Regional Plan's horizon year (2050). An additional 2025 phasing year has been selected. Additional interim years will be modeled for the purposes of meeting federal air quality conformity requirements.

Table 1. Analysis Years for the 2021 Regional Plan

Year	Purpose
2005	Base Year for SB 375 GHG emission-reduction Target Setting
2016	Base Year for 2021 Regional Plan/SCS
2020	SB 375 GHG Emission Reduction Target
2025	Interim Phase Year
2035	SB 375 GHG Emission Reduction Target
2050	Horizon Year

Progress Made to Date

The development of the 2021 Regional Plan was initiated with a rethinking of the vision for the San Diego region including a reimagining of mobility solutions to be included in the Regional Plan. The vision that was subsequently developed was shaped by five interrelated strategies for mobility, collectively known as the 5 Big Moves. The strategies that comprise the 5 Big Moves are Complete Corridors, Transit Leap, Mobility Hubs, Flexible Fleets, and a next-generation transportation operating system known as the Next OS. In short, these investments are being planned to achieve vastly more efficient and accessible major corridors of travel, a completely new high-speed and high-capacity public transit network, a new network of Mobility Hubs where people and multiple mobility options come together, Flexible Fleets of vehicles that offer people quick mobility options when and where they need them, and a regionwide digital platform that unifies the 5 Big Moves.

The development of the new vision for the San Diego Region was created in three phases:

Phase 1: Concept Development

The general concept for the Vision was informed significantly by early work on the 2019 Regional Plan, which led to the 2019 Federal Regional Transportation Plan (2019 Federal RTP). This work included reviewing case studies and best practices, consulting with transportation operators in the region, interviewing private-sector providers, and gathering other perspectives, including significant community input gained through two outreach programs in 2018. Insights gained from these previous efforts—in conjunction with more recent work—have served as the foundation for the 2021 Regional Plan.

SANDAG also conducted a series of focus groups, each with a diverse cross-section of the region's residents, to gather feedback on how each of the 5 Big Moves could improve participants' lives. In this sense, the Vision reflects the views and opinions of real people from communities throughout the region. SANDAG designed the Vision based on both data analysis and what people told the agency in these focus groups. This process is known as Human-Centered Design. For example, individuals in focus groups were asked what they thought about SANDAG's ideas for Flexible Fleets and then what they thought would make Flexible Fleets a viable alternative to driving alone. Many residents said they would view a Flexible Fleet service as a real alternative to driving if it could get them from their home to a public transit station within ten minutes. SANDAG also went on a roadshow throughout the region and hosted visiting hours at SANDAG in the Vision Lab that allowed staff to engage with community organizations, individuals, and groups to communicate and gather feedback on the 5 Big Moves. SANDAG professionals relied on all of this feedback as they built the Vision.

Meanwhile, a Vision Advisory Panel was convened to gain insights from private industry leaders about how emerging technology might enhance personal mobility and how public–private partnerships might accelerate their adoption in the region. The Panel consisted of executives and thought leaders in the fields of wireless communications, intelligent transportation systems, original equipment manufacturing (auto, bus, truck), data analytics, artificial intelligence and automation, fleet-management systems, and venture funding based in Southern California.

Phase 2: Network Development

Once SANDAG developed a conceptual idea for what a future regional transportation network might look like, it was time to actually build the network. This required a series of iterative analyses in which data related to population, employment, and demographics were repeatedly analyzed in order to reach the best answer to a given question—where a new commuter rail line might be needed most, or where to situate a Mobility Hub, for example. Decisions about how to build each network were based on data analysis as well as feedback from residents, professional judgment, and SANDAG's deep knowledge of the region's diverse communities.

SANDAG gathered data from numerous sources, including surveys by the federal government on the location of employees and employers, the U.S. Census Bureau, land use information from local jurisdictions, individual traveler data from cellular devices, goods-movement data from trucking and other commercial transport operations, and citizen feedback. Data was primarily analyzed using the geographic information system (GIS) tool, ArcGIS, and geospatial statistical methods. GIS in transportation planning can take numerous sources of data and visualize them on maps to model traffic patterns, plan new routes and services, and assess the environmental impacts of new transportation infrastructure. ArcGIS is a GIS tool maintained by the Environmental Systems Research Institute (ESRI), and all SANDAG's geospatial analyses use the ArcGIS platform.

Phase 3: Network Refinement

The final steps in the development of the Vision for the 2021 Regional Plan were to refine critical elements of the network and to verify that the Vision network would meet future mobility needs. With the Transit Leap and Mobility Hubs networks developed, a process known as a propensity analysis was conducted to ensure that each service would be located where it would be needed most based on the area's demographics and how people in that particular area travel. Transit Leap and Complete Corridors networks were evaluated to ensure that sufficient freeway and transit capacity would be available to meet future travel demands on every major corridor in the region.[1]

Schedule

Working toward a late 2021 adoption date, the 2021 Regional Plan has achieved the following interim milestones. Future work will be developed based on the activities surrounding the development of the transportation vision (noted as "anticipated").

- On February 22, 2019, the Board of Directors unanimously approved an action plan to develop a bold new vision for San Diego Forward: The 2021 Regional Plan.
- On April 26, 2019, staff introduced the 5 Big Moves as key strategies for developing a transportation system that provides safe, convenient, equitable, and attractive travel choices

[1] More information about the development of the Regional Transportation Vision, including the Summary Report and timeline, can be found at sandag.org/uploads/meetingid/meetingid_5317_27885.pdf

that will meet state and federal requirements, including a Sustainable Communities Strategy that achieves the greenhouse gas emission reduction targets set by CARB. This phase included the start of the public process for scenario development.

- On July 12, 2019, staff presented more detail on the 5 Big Moves to the Board for discussion. The presentation showed how key employment and commute data was being used to develop new solutions to longstanding commute challenges. The Board directed staff to continue development of the 2021 Regional Plan, focusing on the 5 Big Moves and conforming to all state and federal requirements, while also prioritizing specific corridors using the Complete Corridors model.
- On September 27, 2019, the Board allocated $593.4 million over the next five fiscal years to advance planning for 12 Complete Corridors and a Central Mobility Hub with transit connectivity to the airport. The Board action also included funding for regional programs related to the 5 Big Moves (Regional Electric Vehicle Charger Incentive Program, Flexible Fleets Pilot, and Smart Center Concept of Operations).
- On October 8, 2019, Governor Gavin Newsom signed Assembly Bill 1730 (Gonzalez) into law. This law, in effect, keeps the region in compliance with state laws to ensure important state funds continue to flow to the region while the 2021 Regional Plan is being developed. Also in October, the Board approved the 2019 Federal RTP to keep important transportation funding coming to the region while the vision is being developed. In November, the U.S. Department of Transportation issued the 2019 Federal RTP air quality conformity finding.
- From January through August 2020, staff delivered a series of presentations to the Policy Advisory Committees and Board on topics related to the Regional Plan in preparation for the presentation of the vision. Presentation topics included our regional economy, data-driven planning, big data, regulatory requirements, environmental impact reports, transportation modeling, lessons learned from COVID-19, and the Regional Vision.
- In February 2021,staff conducted the SCS Information Session.
- Spring/Summer 2021 (anticipated): Staff will release the Draft 2021 Regional Plan and Draft EIR for public comments and conduct outreach and workshops.
- Summer 2021 (anticipated): Staff will address public comments and finalize the Plan and EIR.
- Late 2021 (anticipated): Staff will seek Board adoption of the 2021 Regional Plan. The adopted 2021 Regional Plan will be submitted to CARB requesting acceptance of the SCS. It will also be submitted to the California Transportation Commission and Caltrans to comply with state requirements, and to the U.S. Federal Highway Administration, the U.S. Federal Transit Administration, and the U.S. Environmental Protection Agency to seek the air quality conformity finding.

2015 Regional Plan CARB SCS Evaluation Recommendations

During CARB's review of the 2015 Regional Plan and SCS, two recommendations were provided to SANDAG regarding the modeling methodology. These recommendations are as follows:

- CARB staff recommends that SANDAG should consider using the latest version of the California Household Travel Survey. They should revisit and recalibrate the mode choice model using the latest household travel survey data.

- CARB staff recommends that SANDAG should consider conducting stated preference surveys of households and firms to improve the location choice model of their ABM. Further, SANDAG should collect floor space rent data to improve the economic characteristics of land use model.

As stated in this technical methodology, SANDAG conducted a 2016–2017 Household Travel Survey for the purposes of the updated SCS as discussed in the Travel Demand Modeling section of this document. The recent travel survey was used to update the mode choice model used in the preparation of the 2021 Regional Plan SCS.

SANDAG implemented a population synthesizer that handles the evolution of households using historical data to determine if a household is created, dissolved, or has members added or subtracted. This is similar to a household location choice model but retains greater consistency between forecast years due to the evolutionary aspects.

Floor space rent is not a specific variable in the land use model used in the 2021 Regional Plan and SCS, but the model used does consider patterns of past development, of which cost of floor space is an attribute. The land use system being developed for the 2025 Regional Plan does take cost of floor space into account for both residential and non-residential land uses by type (office, industrial, retail).

Overview of Existing Conditions

Since the adoption of the current Sustainable Communities Strategy in 2015, several notable changes have occurred in the region that are likely to influence the development of the 2021 Regional Plan. These changes include completion of key transportation projects, updated plans and policies from local jurisdictions, new outlooks on regional growth and funding availability, and emergence of new mobility services. In recognition of these changes, SANDAG pursued an extension in the adoption schedule for its third SCS to allow for time to develop and evaluate a Regional Vision to inform the 2021 Regional Plan. This Vision provides the framework for the 2021 Regional Plan centered around the 5 Big Moves.

Key transportation projects completed since 2015:

- South Bay *Rapid*
- State Route 15 Transit Only Lanes
- Interstate 805 High-Occupancy Vehicle lanes (State Route 52 to Carroll Canyon Road)
- Significant progress on Mid-Coast Trolley
- Sweetwater Bikeway – Plaza Bonita Segment
- Bayshore Bikeway – 32nd Street to Vesta Street
- Inland Rail Trail (Phase 1)
- State Route 15 Commuter Bikeway
- Bayshore Bikeway – National City Segment
- Coastal Rail Trail – Encinitas (Chesterfield Drive to Santa Fe Drive)

Updated plans and policies from local jurisdictions:

- Climate Action Plans: 17 of the region’s 19 jurisdictions have an adopted CAP (up from 9 in 2015)

- Updated Community Plans/Specific Plans
- Jurisdictions are currently updating housing elements to reflect Cycle 6 RHNA and incorporate many new housing laws

New outlook on regional growth and funding availability:

- Updated population forecast for San Diego region is 6.5% lower in 2050 compared to prior plan
- In 2016, SANDAG sales tax initiative failed at the ballot
- In 2020, Metropolitan Transit System decides to withhold additional transit specific sales tax initiative due to challenges of bringing such a measure forward during the current pandemic

Emergence of new mobility services:

- Since 2015, bikeshare and scootershare services launched in several jurisdictions, military bases, and college campuses
- In 2017, SANDAG partnered with Waze Carpool to encourage dynamic ridesharing with major employers including military bases
- The neighborhood electric vehicle (NEV) service also known as Free Ride Everywhere Downtown (FRED), operated by Circuit, operates in Downtown San Diego and continues to grow. FRED transported 194,600 riders in 2018 compared to 132,000 riders in 2017
- In 2018, ridehailing companies Uber and Lyft started providing shared rides, otherwise known as "pooled ridehailing," which matches passengers with similar origin and destination with the same driver
- In 2019, SANDAG received a Caltrans planning grant to conduct a statewide ridehailing survey in partnership with SCAG and MTC. The 2019 Transportation Study, which will be completed in Spring 2021, will help the agencies gain insight on the relative travel behaviors of people across California and how new services such as Uber, Lyft, and electric scooters are changing travel choices statewide
- In 2019, SANDAG, North County Transit District, and the City of Carlsbad partnered to deploy a microtransit pilot to serve commuters traveling to the Carlsbad employment center
- In 2019, the City of Oceanside partnered with FordX to launch Hoot Rides, a neighborhood electric vehicle rideshare pilot. The all-electric shuttles served the Downtown Oceanside area, providing residents and visitors with an affordable and convenient connection to the nearby Oceanside Transit Center and community events

The Importance of Data

Data analysis combined with stakeholder input will continue to guide the development of a comprehensive vision for a transportation ecosystem that leverages technology to create a safe, adaptable, and equitable transportation network with fast, fair, and clean choices to move around the region seamlessly.

Thoughts on the Pandemic

Since March 2020, economic conditions have changed dramatically due to the COVID-19 pandemic. It is anticipated that these declining conditions will influence short-term growth forecasts, transit, shared mobility ridership, and the certainty of near-term revenue sources, particularly those tied to economic activity. SANDAG will continue to evaluate both economic and social conditions related to the pandemic and if/how these will impact the development of the 2021 Regional Plan.

SANDAG conducts ongoing research and data collection, and surveyed thousands of residents and businesses across the region, to truly understand the impacts of COVID-19 on socioeconomic and travel patterns. During the early stay-at-home orders, freeway traffic levels sharply declined along with vehicle emissions, but traffic and air quality are now returning to pre-COVID conditions. Although many reported driving less during the health crisis, survey results showed that 78% of respondents reported using online shopping and deliveries more than usual. Border crossings for both pedestrians and privately owned vehicles were down substantially. Transit ridership plummeted, reaching its lowest level in April 2020 with a 70% reduction compared to the same period in 2019, but data shows that ridership is recovering, and many essential workers continue to rely on public transit. Survey results suggest that the fear of riding public transit may not be as profound as expected. Three in every five residents recently surveyed said they would use public transit at least occasionally once a vaccine for COVID-19 was available. Many businesses transitioned to telework and will consider offering telework options in the future, but according to a survey of some of the largest employers in the region, most employers will continue to offer telework on a part-time basis for a portion of their workforce. Like telework, we also saw more people biking and walking to get around. Overall, COVID-19 revealed immense disparities across the region and inequities in access to opportunities, jobs, education, healthcare, and other community resources.

Population and Employment Growth Forecasts

SANDAG will create a population, housing, and jobs forecast for the 2021 Regional Plan in two steps: first, by developing a regionwide forecast of population, jobs, and housing units, and second, by allocating this regionwide total to the subregional level.

At the region level, the 2021 Regional Plan will use population projections developed by the California Department of Finance (DOF) in January 2020. These publicly available projections include detailed data by age, race, ethnicity, and sex for single-year increments out to 2050. SANDAG is involved in review of the projections from DOF and was able to provide input and feedback in the development of the 2020 projections series before finalization.

SANDAG decided to use these projections as the regionwide population controls because recent state-level changes narrowed the threshold for alignment between DOF population projections and an agency-developed population projection. With the passage of California Assembly Bill 1086 (Daly, 2017), councils of governments would be required to confer with the state to use an agency-developed population projection that fell outside a 1.5% threshold below or above the DOF population projection. This margin of variance from the state numbers is much smaller than in previous years, leaving less room for a council of governments to vary from state-level inputs or methodology when developing its own population projection. Due to this recent change, SANDAG elected to use the DOF population projection.

Rates of household formation, unemployment, and labor force participation are then applied to this cohort-specific regionwide population total to arrive at the number of households and jobs in the region. Goals were set for the housing unit forecast to achieve a healthy vacancy rate of 4% in the region and household headship rates from the 2010 decennial census were used as targets for 2050. These controls are used to arrive at the forecast of housing units at the region level.

The combination of a vacancy rate of 4% and a smaller household size derived from the application of household headship rates applied to an aging population results in a relative increase in housing units in this forecast even though population increases are lower than in previous forecast versions.

The higher employment numbers in this forecast as compared to previous forecasts can also be attributed to differences in the characteristics of the population. Future employment is estimated based on historic labor force participation rates with assumptions about how they will change in the future. When these rates are applied to the age, race, ethnicity, and sex structure of the population in the latest DOF projections, the result is higher employment counts than in previous forecast versions. The future assumptions about labor force participation were included in future assumptions covered in the Peer Review Panels held about the Series 14 forecast.

An economic forecast will also be developed based on the cohort-specific regionwide forecast. Specifically, income growth is calculated based on historically observed rates and forecasted to arrive at median household income and household income by five income categories. All demographic and economic rates are based on observed data and rely on historical trends to forecast future conditions.

SANDAG vetted the use of the DOF projections along with the socioeconomic and demographic rates used in the regionwide forecast with the Board of Directors as well as with three expert panels comprising industry professionals and regional stakeholders.

This methodology differs from the regional growth forecast methodology used in the 2015 Regional Plan. For the 2015 Regional Plan/SCS, the regionwide data was developed using a model called the Demographic and Economic Forecasting Model (DEFM). The use of the DOF population projections in conjunction with the socioeconomic and demographic rates described above is a replacement of the DEFM methodology. The allocation of the regional population, housing units, and jobs to subregional areas is performed using the Integrated Land Use, Demographic, and Economic Model (I-LUDEM), described in the Land Use Modeling section below.

The draft regionwide population total in 2050 for the 2021 Regional Plan/SCS is 3.7 million persons, which is lower than the previous regionwide population of 4.1 million persons from the 2015 Regional Plan/SCS. This lower projected growth can be attributed to falling fertility rates and lower rates of domestic and international migration to the region. Jobs in the region are projected to rise by almost 460,000 jobs between 2016 and 2050. The increase in jobs between 2012 and 2050 in the 2015 Regional Plan and 2021 Regional Plan was similar at about 460,000 more jobs.

Regional Growth	2015 Regional Plan/SCS	2021 (Draft) Regional Plan/SCS
Population		
Base year (2012/2016)	3,143,429	3,309,510
2020	3,435,713	3,383,954
2035	3,853,698	3,620,348
Housing		
Base year (2012/2016)	1,165,818	1,190,555
2020	1,249,684	1,226,461
2035	1,394,783	1,409,866
Employment		
Base year (2012/2016)	1,450,913	1,646,419
2020	1,624,124	1,704,071
2035	1,769,938	1,921,475

Quantification Approaches

2021 Regional Plan Strategy Quantification

The strategies under consideration in the 2021 Regional Plan span a wide range of scenarios employing methods to influence the performance of the region's transportation system. The elements of these strategies can be broken down into Transportation System Infrastructure and Operations, Demand Management, Land Use, and Zero Emission Vehicles. The two main quantification approaches are SANDAG's regional travel demand model ABM2+ and a set of off-model calculators developed to handle elements that cannot be treated by ABM2+. The selected approach for each strategy element is based first upon a determination of whether that element can be represented in the ABM2+ travel demand model. This determination has been made based upon the ABM2+ technical documentation, the ABM2+ sensitivity analysis report, and the findings of the ABM2+ technical advisory committee. Those elements that cannot be represented in ABM2+ were then considered for off-model quantification based upon the expected impact of that element on the overall performance of the transportation system and its associated externalities as well as an identification of a feasible off-model methodology and associated recommendations from CARB and prior off-model developments (at SANDAG and other MPOs). SANDAG contracted with the University of California, Institute of Transportation Studies through the U.C. Irvine campus to validate the overall quantification approaches along with the development and updating of the off-model quantification approach.

Regional Plan/SCS Strategy	Inclusion in Prior SCS?	Quantification Approach
Transportation System Infrastructure and Operations Description of the 5 Big Moves available in the Vision for the 2021 Regional Plan Network Development Summary Report: sdforward.com/summary		
Complete Corridors and Transit Leap: • Managed Lanes • HOV/HOT policies • Regional Bike Network • Commuter rail • Light Rail • Next Generation Rapid • Local Bus	Yes. 2021 SCS is likely to expand on these strategies	Coded as transportation network improvements in ABM2+
Mobility Hubs and Flexible Fleets: • Local complete streets • Parking management • Microtransit • Micromobility • Pooled TNCs • E-bikes	Mobility Hubs were introduced in the prior SCS, but investment and specific geographic information was limited, as were associated strategies and fleet assumptions	Mobility Hubs are used as a geographic area for applying complete streets, parking, microtransit, and micromobility strategies in ABM2+ Pooled TNCs and E-bikes are reflected in mode choices in ABM2+
Next OS: • Active Transportation Demand Management (ATDM) • Smart Signals	Yes. 2021 SCS is likely to expand on these strategies	ATDM reflected as improved travel reliability in ABM2+ Smart signals reflected as reduced intersection delays in ABM2+
Demand Management		
Telework	Yes. Ability to capture primarily and occasional telework is new	Primarily and occasional teleworker assumptions applied in ABM2+
Pooled rides (private)	Yes, off-model in prior SCS	Off-Model
Vanpool	Yes, off-model in prior SCS	Off-Model
Carshare	Yes, off-model in prior SCS	Off-Model
Regional TDM Ordinance	No, new off-model calculator	Off-Model

Regional Plan/SCS Strategy	Inclusion in Prior SCS?	Quantification Approach
Pricing Strategies: • Road user charge • Transit Fare Subsidies • Congestion Pricing/Toll Rates • Parking • TNC Fees	Carryover pricing strategies include congestion pricing/toll rates, parking pricing New pricing strategies include road user charge, transit fare subsidies, and TNC fees	Pricing strategies reflected in ABM2+ as follows: • Road user charge: per-mile charge added to the auto operating cost • Transit Fare Subsidies: one-way and daily transit fares defined for each service type • Congestion Pricing/Tolled Rates: per-mile tolls defined by time of day for each managed lane corridor and fixed-fee tolls for the State Route 125 toll road • Parking: hourly, daily, and monthly rates applied to certain Mobility Hub areas and charged to auto trips destined for those specified areas • TNC Fees: applied as fixed fee per trip
Land Use		
SCS Land Use Pattern that considers: • Job–Housing Balance • Mixing of uses • Transit-oriented development • Housing needs	Yes. The 2021 SCS will likely include expanded land use policies reflected in the SCS land use pattern	Mobility Hub areas used as a framework for the allocation of housing and jobs in the land use pattern developed in Integrated Land Use, Demographic, and Economic Model (I-LUDEM) and impact modeled in ABM2+
Zero Emission Vehicles		
Regional EV Charger Program	Yes, off-model in prior SCS. The 2021 SCS will likely include an expanded EV charger program	Off-Model
Regional EV Incentive Program	No. The EV incentive program would be a new SCS strategy	Off-Model

Interregional Travel

The external travel models predict characteristics of all vehicle trips and selected transit trips crossing the San Diego County border. This includes both trips that travel through the region without stopping and trips that are destined for locations within the region. The external–external, external–internal, and internal–external trips in San Diego County were segmented into these trip types: U.S.–U.S., U.S.–Mexico, Mexico–San Diego County, San Diego County–Mexico, U.S.–San Diego County, and San Diego County–U.S.

Here, "U.S." represents locations in the United States outside of San Diego County. The total count of trips by production and attraction location was estimated in a series of steps:

1. The number of trips made by Mexican residents to attractions in San Diego was based on 2010–2011 Cross Border Survey data.
2. The trips in the 2016–2017 Household Travel Survey were expanded to estimate the total number of trips made by San Diego residents to attractions in Mexico.
3. The number of Mexico–San Diego County (1) and San Diego County–Mexico (2) trips was subtracted from the total number of border crossings to derive an estimate of the number of U.S.–Mexico trips. The distribution of U.S.–Mexico trips among external stations on the U.S. side of San Diego County is assumed to be proportional to the total volume at each external station, regardless of the port of entry at the Mexican border.
4. The number of U.S.–Mexico trips was then subtracted from the total number of trips in the SCAG cordon survey to arrive at an estimate of the combined total of U.S.–U.S., U.S.–SD, and SD–U.S. trips with routes through San Diego County.
5. Finally, the actual amounts of U.S.–U.S., U.S.–SD, and SD–U.S. trips at each external station were estimated from the remaining trips (4) according to their proportions in the successfully geocoded responses in the SCAG cordon survey.

Details of the interregional travel survey can be found in the SANDAG ABM2 Model Update (2018) report from the ABM2+ wiki reports and documents list at github.com/SANDAG/ABM/wiki/Reports-and-Documents.

EMFAC Version

For the 2021 Regional Plan, SANDAG will use EMFAC 2014 for CO_2 emissions modeling for SB 375 purposes. SANDAG will use EMFAC 2014 based on the 2019 SCS Guidelines, which state that MPOs should use the same version of EMFAC as they used for the second SCS (i.e., 2015 Regional Plan). In addition, SANDAG will use the EMFAC adjustment to the percent reduction in CO_2 per capita methodology developed by CARB for the second SCS. The adjustment for SANDAG is +1.8% per capita reduction for 2020 and +1.7% per capita reduction for 2035; that is, the 2021 Regional Plan SCS has to reduce the estimated change in CO_2 by nearly two additional percentage points. The applied methodology can be found in Appendix A.

2020 GHG Quantification

SANDAG's 2020 GHG target will be evaluated using a fusion of existing data and estimated regional travel. 2020 will be a historic year when the SCS is submitted, but because there are no direct methods for measuring either VMT or GHG, SANDAG will need to deploy estimation techniques to determine whether the 2020 GHG target was met. Sources of VMT estimates are available from Caltrans Highway Performance Monitoring System (PeMS) for freeway VMT and regional estimates from Caltrans Highway Performance Monitoring System (HPMS). HPMS data will not be available for 2020 until after the adoption of the SCS, but historical data may be used to assist with estimation techniques. PeMS freeway VMT and speed data for weekday traffic can be used to scale ABM weekday regional VMT estimates. The adjusted VMT data tables can then be used within EMFAC 2014 for CO_2 emissions modeling. PeMS measured data for 2020 will be significantly impacted by COVID-19 due to changes in employment, employee work location and telecommuting, tourism travel, package and food delivery, crossborder restrictions, virus transmission fear on transit vehicles, and transportation costs for gasoline, among many other impacts.

Land Use/Travel Demand Modeling

Land Use Modeling

As a part of a regular data-collection process, SANDAG updates the land use datasets that are used as the base year of the forecast. This process includes updating housing units, employment, and school inventories at the parcel level. This is done with a variety of external data sources such as census data, assessor data, aerial imagery, employment datasets, and other San Diego–specific sources. For the 2021 Regional Plan/SCS this process was completed in order to create the base year file for 2016.

Once the regional growth forecast data are created, SANDAG staff uses parcel-level data on future residential and non-residential capacity to allocate the population, housing units, and jobs to the subregional areas. For the 2021 Regional Plan/SCS, this parcel-level capacity was developed based on input from local jurisdiction staff on in-process projects and updated planning assumptions.

After this capacity is developed, staff programmatically allocates the housing units and jobs that were forecasted at the region level to specific parcels using a subregional allocation model called the Integrated Land Use, Demographic, and Economic Model (I-LUDEM). This is done in part by using controls developed at subregional levels that ensure targets of vacancy rates and household headship rates are met. Housing growth is prioritized or constrained in the region based on measures such as areas within the County Water Authority, areas outside of the CalFire "Very High" hazard areas, areas relatively close to transit, and areas with higher density capacity, which are weighted more heavily than areas with less dense capacity.

After housing units are assigned to the subregional areas, households that represent an occupied housing unit are developed to accommodate the forecasted population in the region. These households are developed based on the application of cohort-specific household headship rates and sociodemographic characteristics to the projected population. These demographic rates are assigned to members of each household based on data from the American Community Survey (ACS) or the 2010 decennial census.

As an SCS strategy, SANDAG may intensify or prioritize residential and non-residential development within certain areas to align the land use pattern with anticipated transportation investments. In some cases, this housing unit or job capacity is higher than the capacity that was developed in conjunction with local jurisdictions for the 2015 Regional Plan/SCS. Additionally, for the 2021 Regional Plan/SCS, the 6th Cycle Regional Housing Needs Assessment (RHNA) Plan is used as a control to ensure that each jurisdiction reaches the total number of housing units that has been allocated by the analysis year 2035. As a result, SANDAG will have a policy-driven SCS Land Use Pattern for use in the 2021 Regional Plan/SCS. This is in addition to a baseline regional growth forecast with a subregional allocation that is consistent with adopted plans.

This subregional allocation method used in the 2021 Regional Plan/SCS is different in some respects from the method used in the 2015 Regional Plan/SCS. First, the subregional model used a tool called the PECAS in the 2015 plan that is not used in the 2021 RP/SCS. Second, the integration of the yearly population estimates as the base year of the forecast in the I-LUDEM model is new to the 2021 Regional Plan/SCS; in the 2015 Regional Plan/SCS the yearly estimates and the subregional forecast were created from two separate processes.

Travel Demand Modeling

SANDAG will use an update of its second-generation Activity Based Model (ABM2+) for the analysis of the 2021 Regional Plan. ABM2+ provides a systematic analytical platform and is intensively data-driven so that different alternatives and inputs can be evaluated in an iterative and controlled environment.

SANDAG first used an ABM for the 2015 Regional Plan/SCS, the second SCS for the San Diego Region. SANDAG has since completed the development of ABM2 and applied it in the 2019 Federal RTP. The major enhancements to ABM2+ from ABM[2] include the following items:

- Implementation of emerging technologies such as micromobility (e-scooter), transportation network company (TNC), microtransit, and autonomous vehicle
- Incorporation of Strategic Highway Research Program recommendations regarding improving the sensitivity of travel models to pricing and reliability
- Implementation of an airport ground access model for the Cross Border Xpress (CBX) facility that serves the Tijuana International Airport
- Replacement of an asserted, aggregate commercial vehicle model with a disaggregate commercial vehicle model
- Update of volume-delay function parameters based upon an analysis of INRIX travel time data
- Calibration and validation using the 2016–2017 SANDAG Household Travel Survey, 2015 Transit On-Board Survey, 2018 Commute Behavior Survey, and 2019 SB1 TNC Survey and reflection of telecommute travel patterns observed from the surveys and Census American Community Survey (ACS) data
- Update of the algorithm used to find transit paths
- Update of the heavy truck model, which models external–internal truck flows, to incorporate the latest Freight Analysis Framework (FAF4) data and projections

To guide ABM2+ development, SANDAG formed an ABM Technical Advisory Committee (TAC). The 11-member TAC is comprised of nationally recognized leaders in the travel demand modeling field who come from a vast array of organizations, such as Federal Highway Administration, CARB, major MPOs, academia, and independent consultancies.

SANDAG hosted two rounds of TAC review and evaluation. The first TAC meeting was held in May 2019 to evaluate modeling strategies to address emerging technologies, such as Transportation Network Companies (TNCs), connected and autonomous vehicles (CAV), transformative modes (e.g., high-speed rail), micromobility (e.g., e-scooters, dockless bicycles), and pricing options. The second TAC meeting was held in March 2020 to follow up on implementing TAC's short-term model recommendations from the first meeting and to evaluate ABM2+ and its usage for the 2021 Regional

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[2] See reports "SANDAG ABM2+ Enhancements to support 2021 RTP (2020)" and "SANDAG ABM2 Model Update (2018)" from the SANDAG ABM2+ reports and documents wiki: github.com/SANDAG/ABM/wiki/Reports-and-Documents

Plan. The TAC gave very high remarks on ABM2+, concluding that it not only remained well above the state of the practice, but that some components were state-of-the-art for travel demand models. The new mobility features in ABM2+ go beyond the state of the practice, especially for transportation network company (TNC) and autonomous vehicle (AV) components.

Due to the future uncertainty in autonomous vehicle (penetration rates, level of AV, public policies and regulations), SANDAG will turn off AV components when developing the 2021 SCS based upon the recommendation from the TAC.

Draft ABM2+ Sensitivity Tests

As part of model evaluation for TAC and for addressing CARB's Final Sustainable Communities Strategy Program and Evaluation Guidelines, sensitivity tests were conducted to examine the responsiveness of ABM2+ to potential SANDAG 2021 Regional Plan strategies in February 2020. The extent of sensitivity analysis significantly exceeded the typical validation level for MPOs according to the TAC members. The sensitivity tests include land use, transit infrastructure and active transportation, local/regional pricing, new mobility, and exogenous variables. Tests in new mobility category, including autonomous vehicles (AV), transportation network companies (TNC), and micromobility (e-scooter, e-bike, etc.), were part of validation of the newly implemented features. Most sensitivity tests were conducted using forecast year 2035 and revenue-constrained networks from the 2019 Federal RTP, with 2035 revenue-constrained scenario as the baseline scenario to derive elasticity. To account for the full potential impact of population growth on VMT and mode shares, staff used two 2050 land use scenarios: job housing balance and mix of land use to lower VMT prepared in August 2019. After the TAC meeting, SANDAG conducted additional sensitivity tests on teleworking. The original TAC meeting sensitivity testing report is included as Appendix B.

Induced Travel Analysis

Induced travel refers to the phenomenon that occurs after improvements are made to some aspect of the transportation system in which users of the transportation system engage in more travel.

Induced travel could be reflected in two categories: short-term and long-term. Both short-term and long-term induced travel are attributed to increased vehicle travel due to added capacity to the roadway system (either a new roadway or an existing roadway expansion).

Short-term induced travel could come from individual and household travel response to added capacity, such as:

- choosing to travel at a different time of day (e.g., shifting from before the peak hour to peak hour)
- choosing to travel on a different route (e.g., using the now-faster roadway rather than a slower, alternative route)
- choosing to travel more frequently and to add more stops on a tour (or fewer stops but more tours)
- choosing to travel by car rather than by walking, biking, or public transportation
- choosing to travel to a different place, such as a more distant but newer grocery store or destination

SANDAG ABM2+ explicitly captures all the above short-term induced travel behaviors through simulating changes in time of day, route assignment, frequency, mode, and location choice in response to the improved accessibility brought about by a roadway widening in a congested corridor. Depending on the scale of the response, the outcome may be only a very minor reduction in congestion in the corridor. The table below matches the above behaviors to the SANDAG model components that represent the behavior in question. The table also includes the broad time frame in which the response is expected.

Response to Increase in Supply	Timeframe of Change	ABM2+ Component(s)
Travel at a different time of day or on a different day	Short (within weeks of the improvement)	Scheduling, Daily Activity Pattern
Travel on a different route	Short	Assignment
Travel more frequently	Short	Daily Activity Pattern, Tour Generation, Stop Frequency
Travel by a different travel mode	Short	Mode Choice
Travel to a different place (e.g., grocery store)	Short	Activity Location Choice
Choose to work or go to school in a different place	Medium (within months of the improvement)	Work or School Location Choice

SANDAG's past efforts of sensitivity testing using a draft version of ABM2 for a 2016 forecast year and network with 50% freeway capacity increase result in a 1.4% VMT increase compared to the base year 2016 scenario, an elasticity of 0.2, which is within the range from SB 375 Research on Impacts of Transportation and Land Use-Related Policies.[3] SANDAG will evaluate the VMT elasticity due to a change of capacity in ABM2+. Capacity changes will be evaluated for facilities that may be included in the Regional Plan, including general purpose lanes, managed lanes, HOV lanes, operational improvements on general purpose facilities, and freeway connectors. Repurposed general-purpose lanes will assume no added or reduced induced demand VMT. Where the ABM2+ elasticity is less than documented research, where available, SANDAG plans to use the difference as a VMT adjustment factor to the induced travel VMT calculated from the National Center for Sustainable Transportations (NCST) Induced Travel Calculator (annual VMT factored to an average weekday). If the facility type is not included in the available research from CARB, SANDAG will further adjust the induced travel VMT using an adjustment factor based on a method such as the ratio of vehicle capacity between the facilities.

Elasticity research = freeway elasticity X (facility capacity / freeway general purpose lane capacity)

Induced Travel VMT = (NCST Induced Travel VMT) x (annual VMT to average weekday VMT adjustment factor) x (1 – (elasticity ABM2+ / elasticity research))

If additional research or methodology recommendations are brought forward by peer reviews of the analysis and evaluation performed, SANDAG will modify, adapt, document, and communicate the new methodology. For example, if new research is identified that articulates an acceptable induced demand VMT elasticity range for HOV lanes, SANDAG will work to incorporate the new information.

[3] Senate Bill 375 – Research on Impacts of Transportation and Land Use–Related Policies. arb.ca.gov/our-work/programs/sustainable-communities-program/research-effects-transportation-and-land-use

Long-term induced travel effects include potential household relocation to outer suburbs due to increased access provided by new or expanded roadways and potential land use development in areas with higher-than-average VMT without policies intervention. The relationship between land use and transportation accessibility is complicated and not explicitly represented in ABM2+. However, the SANDAG planning process does consider the land-development plans of local jurisdictions, and the 2021 Regional Plan will consider an SCS land use pattern that complements the proposed transportation system.

Project Selection

Compared to prior plans, SANDAG took a different approach in identifying roadway projects and considers them one part of our system of complete corridors. Because growth in the San Diego region is expected to occur primarily in the western third of the region, travel demand is anticipated to occur primarily on existing major corridors. In identifying projects for the Vision network, SANDAG staff proposed a Managed Lane network to support maximizing the use of existing facilities and creating a seamless systemwide Managed Lanes network that will provide more transportation choices traveling from one end of the region to another. Managed lanes will offer priority and access to transit and high occupancy vehicles which creates higher person capacity on those lanes than general purpose lanes. Developing the Vision network included assessing and estimating increased person capacity opportunity of Managed Lanes as well as transit services that will be available to meet future travel corridor demands.

The next step in the project selection process was to evaluate the projects as corridor “bundles” to determine which corridors had both the most need and opportunity to provide multi-modal alternatives. This was a departure from past Regional Transportation Plans (RTP), where SANDAG utilized transportation project evaluation criteria to prioritize projects by mode specific categories (e.g., highways individually, transit service individually, active transportation individually, etc.).

While the previous mode specific analysis was effective in targeting key issues (such as congestion) it did not speak to the full suite of impacts of those corresponding potential “solutions” such as inducing additional VMT. In contrast, the multimodal bundles evaluated for the 2021 Regional Plan were created to better reflect choices travelers face when traveling to and from regional destinations. Additionally, the bundle analysis allowed the projects to recognize demand inducing characteristics (i.e., congestion) but to leverage this characteristic to reward projects that provide *alternatives* to solving congestion by traditional means (i.e., roadway capacity). For example, previous congestion only scoring on corridors would have emphasized capacity increasing projects that alleviated congestion. The more congestion, the more need to quickly act to provide additional capacity, etc. Alternatively, a multimodal perspective was seen as a way to provide congestion relief alternatives and score those multimodal projects accordingly, thereby rewarding alternative modes and corridors which are multimodal. The following “Mobility and Safety” criteria subset of the project bundle evaluation criteria showcase the dynamic nature of the analysis which speaks to congestion (10 max points) but also speaks to availability of transit capacity to serve those congested corridors (3 max points), combined person peak throughput capacity (5 max points), and transit reliability (5 max points).

Mobility and Safety		30
MS1 Person Peak Throughput Capacity (PTC)	Transit PTC (MS2) + Vehicle PTC(MS3) times vehicle occupancy	5
MS2 Transit PTC	Peak transit capacity (transit rider capacity per number of vehicles/headways per hour)	3
MS3 Vehicle PTC	Peak vehicle capacity (vehicles per lane per hour)	2
MS4 Congestion	Travel time reliability and average peak hour of excessive delay per lane (NPMRDS data)	10
MS5 Safety	Safety incidents (fatalities, serious injuries, and visible injuries)	5
MS6 Transit Reliability	Transit reliability measured by miles of dedicated guideway and transit priority investments.	5

Additionally, multimodal projects (on congested corridors) were awarded points under the "Environment and Quality of Life" evaluation category with access to transit (10 max points), mode availability (2 max points), bike and pedestrian access (2 max points), communities of concern transit access (10 max points), and number of transit stations within mobility hubs (max 5 points)

Environment and Quality of Life		35
EQL1 Access to Transit	People and jobs within ½ mile of a transit station or within a mobility hub[4]	10
EQL2 Activity Centers	Activity Centers within ¼ mile of a transit station	3
EQL3 Network Connectivity	Number of direct connectors and direct access ramps	2
EQL4 Mode Availability	Measure of mode availability (in miles) for transit, managed lanes, and general-purpose lanes.	2
EQL5 Bike and Pedestrian Access	Portion of projects that are located within a mobility hub[5]	3
EQL6 Communities of Concern	Communities of concern (seniors, minorities, low-income residents) within ½ mile of a transit station or within a mobility hub.	10
EQL7 Transit access to future density	Number of transit stations located within mobility hubs[6]	5

The multimodal scoring examples highlight how traditional capacity enhancing projects would score well under the congested corridors criteria (max 10 points) but would score poorly under virtually all of the other categories.

Auto Operating Cost

Common travel-modeling practice assumes that as a person considers whether to drive or take another mode of transportation, two driving cost components are considered: 1) fuel cost per mile of

[4] Mobility hubs offer increased services and infrastructure improvements to access transit
[5] Captures concentration of bicycle and pedestrian improvements focused in mobility hub areas
[6] Mobility hub areas are used as a proxy for future density.

travel and 2) non-fuel operating costs. Fuel cost per mile is calculated based on forecasts for how much gas will cost, as well as the fuel efficiency of a vehicle. Non-fuel operating costs comprise vehicle maintenance, repair, and tires. Auto operating cost (AOC) does not typically include the costs associated with the purchase of a vehicle (purchase/lease costs, insurance, depreciation, registration and license fees) as these are part of a long-term auto ownership decision-making process.

For the 2015 SCS and SB 375 GHG target-setting, SANDAG and the other large MPOs in the state developed a consistent approach to define, estimate, and forecast AOC. After the 2nd SCS cycle, CARB produced an AOC draft calculator that provides a framework for producing an average AOC for all fuel types.

In addition to the CARB AOC draft calculator, SANDAG uses the Oil Price Information Service (OPIS) by IHS Markit for current and historical gasoline prices and the U.S. Energy Information Administration (EIA) for future gasoline prices. The OPIS data was purchased for San Diego County specifically.

The EIA publishes an Annual Energy Outlook forecast with several variations of forecasts for economic growth, oil prices, and resources and technology based on different assumptions (which effectively results in a range of forecasts). The Big 4 MPO group for the 2nd SCS used the U.S. EIA AEO (Annual Energy Outlook) low forecast plus 75% of the difference between the high and low oil price forecast with an adjustment from U.S. costs to California costs. U.S. to San Diego cost differences have been escalating in recent years with the 2019 San Diego average costs reaching $1 per gallon higher than the U.S. average.

For the 2021 Regional Plan and third SCS, SANDAG plans to use the CARB draft AOC calculator assumptions for alternative fuel prices, maintenance, fuel consumed, and fuel efficiency. The only exception to the CARB draft AOC calculator is for gasoline fuel costs. Gasoline fuel costs will be based on the 2020 US EIA AEO low forecast plus 75% of the difference between the high and low oil price forecast with adjustment from U.S. costs to San Diego costs. The gasoline fuel cost calculation is consistent with the methodology applied in the second SCS and 2018 target setting. Additionally, the US EIA fuel forecasts are historically volatile with forecasts being heavily factored based on the current year starting price. Using a forecast that is higher than reference case brings the fuel costs somewhat closer to the assumptions used over the past decade and more in line with historic average fuel costs. SANDAG will hold the 2019 U.S. to San Diego cost difference of $1 constant through the forecasted years. Maintenance costs are under review by SANDAG as the values in the CARB draft AOC calculator use the AAA costs which are based on national current-year costs of automobiles. SANDAG is reviewing the cost differences from national to California and whether the fleet age may impact maintenance costs through the forecast.

The table below compares the 2035 AOC used in the 2015 SCS with draft values for use in the 2021 SCS. Note that 2035 draft AOC for use in the 2021 Regional Plan SCS is lower by almost 35% from 2015 Regional Plan SCS. The more detailed AOC calculations for 2020, 2025, 2035, and 2050 are located in Appendix C.

2035 Forecasts of Auto Operating Costs (Prices in Year 2010 Dollars)

Factor	2015 SCS	2021 SCS (draft)
Pass. Veh. Fleet MPG	27.2	36.8 (gas)
Gasoline Prices ($/gallon)	$4.87	$4.04 (gas)
Non-Fuel Costs ($/mile)	$0.088	$0.069 (gas)
AOC ($/mile)	$0.267	$0.174 (all fuels)

Approach to Incremental Progress Reporting

As part of the modeling effort to provide the Incremental Progress reporting, SANDAG plans to analyze the 2015 Regional Plan SCS2 networks and policies within the ABM2+ model system, including updated exogenous variables. The tables below demonstrate the proposed approach for normalizing key factors and input assumptions. SANDAG will compare this analysis to the 2015 SCS2 results for key regional transportation metrics such as VMT, trip mode share, and SB 375 passenger vehicle GHG per capita.

All GHG results will be analyzed using EMFAC 2014.

Several categories of factors are identified below with description as to what SCS, ABM, or Growth Forecast are used to define them. The categories include, but are not limited to, the following items:

- **Networks and Policies** – would include items such as highway, transit, and active transportation projects; on-model strategies such as HOV policies, toll rates for managed lanes and toll roads, parking, local mileage-based user fees, traffic signal improvements, ATDM, and transit fares.
- **ABM Version** – would include changes to travel behavior collected from recent household, transit, and other travel surveys; improvements to methodologies such as new model components or modified procedures.
- **Interregional Travel** – changes to airport demand forecasts, international crossborder demand, and interregional domestic travel such as trips from Orange County, Los Angeles County, Riverside County, and Imperial County.
- **Demographics and Land Use** – Regional growth forecasts for housing and employment land use, population (households, group quarters, military) by age, race, and ethnicity, households by income, and employment by category.
- **Telework** – telecommuting patterns are updated with each ABM version based on new surveys, census data, and projections, but can also be modified based on regional policies.

The three model runs that will be used are:

1. SCS2 2035 Scenario (as submitted)
2. SCS2 2035 Network and Policy Scenario with Updated Exogenous Variables
3. SCS3 2035 Scenario

Incremental Progress Land Use and Demographics

Incremental progress model runs will perform a stepwise advancement to the land use and demographic data. SCS2 used SANDAG's Series 13 Growth Forecast. For the 2021 Regional Plan and SCS3, SANDAG updated the zoning and land use information from the local jurisdictions and updated the economic growth forecast detailed in the earlier Land Use Modeling section. SANDAG has produced two versions of the Series 14 forecast, one based on baseline estimates of growth and growth patterns from local jurisdictions (Baseline) and another with focused growth patterns for population and employment within our Mobility Hubs and Smart Growth Opportunity Areas (SCS3 Land Use). The incremental step (Model Run 2) between SCS2 and SCS3, where SANDAG will allow exogenous variables and land use to update, will use the Baseline forecast which would occur in the region without larger policy influence from the regional plan implementation. The 3rd model run will use the SCS3 Land Use which includes policy changes being facilitated by the 2021 Regional Plan.

In the 2015 Regional Plan (SCS2), SANDAG had one land use scenario that was also referred to as the Series 13 Regional Growth Forecast. In the 2021 Regional Plan (SCS3), SANDAG has prepared the Series 14 Regional Growth Forecast and will have both a "baseline land use scenario" and an "SCS land use scenario" with differing assumptions about the distribution of housing and jobs in the region.

Incremental Progress Off-Model Adjustments

Off-model calculators are developed using inputs from the specific ABM version the calculator was designed for. Applying SCS2 off-model assumptions within the SCS3 calculator framework is not currently possible. Instead, SANDAG will add the SCS2 off-model adjustments to Model Run 2 GHG results.

Incremental Progress Model Run Details

Model Run 1: SCS2 2035 Scenario (as submitted)

Factor or Assumption	Details
SCS Networks and Policies	SCS2 2035 regional networks and policies
Version of SANDAG ABM	ABM1
Auto Operating Cost; Vehicle Fleet Efficiency	SCS2 AOC assumptions
Interregional Travel	SCS2 assumptions
Demographics; Household Income; Household Demographics	2015 Series 13 growth forecast and regional median income
Telework	SCS2 assumptions
Off-Model Adjustments	SCS2 ABM1 off-model adjustment calculators

Model Run 2: SCS2 2035 Network and Policy Scenario with Updated Exogenous Variables

Factor or Assumption	Details
SCS Networks and Policies	SCS2 2035 regional networks and policies
Version of SANDAG ABM	ABM2+
Auto Operating Cost; Vehicle Fleet Efficiency	SCS3 AOC assumptions
Interregional Travel	SCS3 assumptions
Demographics; Household Income; Household Demographics	2021 Series 14 baseline growth forecast (based on existing general plans, community plans, and planned development) and regional median income
Telework	SCS3 baseline assumptions
Off-Model Adjustments	SCS2 ABM1 off-model adjustments applied as is (no modification due to changed ABM 2+ model run outputs values)

Model Run 3: SCS 3 2035 Scenario

Factor or Assumption	Details
SCS Networks and Policies	SCS3 2035 regional networks and policies
Version of SANDAG ABM	ABM2+
Auto Operating Cost; Vehicle Fleet Efficiency	SCS3 AOC assumptions
Interregional Travel	SCS3 assumptions
Demographics; Household Income; Household Demographics	2021 Series 14 SCS3 land use scenario (applied policy land use changes to the baseline land use to coordinate with proposed mobility hub mobility options) and regional median income
Telework	SCS3 policy assumptions
Off-Model Adjustments	SCS3 ABM2+ off-model adjustment calculators

Off-Model Strategies

In instances where the impacts of certain 2021 Regional Plan/SCS policies under consideration cannot be measured in ABM2+, SANDAG will rely on off-model techniques based on academic literature reviews, collaboration with other MPOs and research institutions, and consultation with CARB's Policies and Practices Guidelines.

For the 2021 Regional Plan, the off-model analysis will include an evaluation of a suite of current and prospective shared mobility strategies including vanpool, carshare, carpool, the implementation of a regional transportation demand management ordinance (TDMO), and electric vehicle strategies, including an EV charger program and EV incentive program. Strategies proposed in this methodology include programs facilitated and administered by SANDAG as well as services operated by third parties. To support this evaluation, SANDAG is partnering with the University of California, Institute of Transportation Studies to review and validate SANDAG's travel behavior modeling and off-model methodologies. Additionally, SANDAG, as one of the four largest MPOs in California, has partnered with the Metropolitan Transportation Commission, the Sacramento Area Council of Governments, and the Southern California Association of Governments to establish the Future Mobility Research Program and jointly fund research on the potential impacts of transportation technologies. This cooperative effort developed a consistent approach to evaluating the range of potential changes to travel behavior associated with emerging technologies and provided recommendations on how to model travel behavior and incorporate technology into each MPO's RTP/SCS.

The methods employed for the off-model calculators are based on the Travel Demand Management (TDM) Calculators developed by WSP USA and the EV Calculators developed by Ascent Environmental. ITS Irvine was contracted in March 2020 to conduct a methodological review of these calculators, which is reflected herein and in Appendices D and E. The methodological review generally affirmed the approaches adopted by WSP USA and Ascent Environmental, with some suggestions adopted to improve the methodological validity of the calculators. WSP USA developed calculators to evaluate the benefits of carshare, bikeshare, vanpool, microtransit, pooled rides, and community-based travel planning. The bikeshare, microtransit, and community-based travel planning calculators were originally developed for use in the deferred 2019 SCS but are not being used for the 2021 Regional Plan. In the case of bikeshare and microtransit, the behavior represented by the calculator is now captured by ABM2+. The programs represented in the community-based travel planning calculator are now captured in the more broad-based TDMO off-model calculator developed by ITS Irvine. For the calculators developed by WSP and Ascent Environmental that are being used in the 2021 Regional Plan (carshare, vanpool, pooled rides, EV programs), ITS Irvine will be updating parameters based upon new or updated data sources and more recent findings in the literature.

TDM off-model calculators

The methodology for off-model estimation of VMT and GHG emission reductions from the TDM strategies share a common overall methodology that is implemented in a series of Excel spreadsheet calculators for strategies involving vanpool, carshare, bikeshare (captured in ABM2+), pooled rides, and a regional travel demand management ordinance. These strategies are part of SANDAG's regional TDM Program, also known as iCommute. iCommute works with employers throughout the region to design and implement commuter benefit programs and provides residents with information about vanpool and carpool services, shared mobility, support for biking, information about teleworking, and transit solutions.

The VMT reductions are based on historical data, applicable research, and case study findings for each strategy. Where possible and if available, local data were 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 ABM2+ to estimate program impacts, calculator outputs remain off-model and do not interact or feed back into ABM2+.

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

1. **Population that has access to the mobility service, or market**. The market may be defined in terms of persons or households.
2. **Level of supply/geographic extent**. The level of supply may be defined as a function of cities, neighborhoods, or employers in which the program or service is available.
3. **Regional infrastructure improvements**. Regional investments in transportation infrastructure (such as managed lanes) may help facilitate use of a mobility service and induce mode shift away from driving alone.
4. **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.
5. **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 is estimated directly from average trip lengths and indirectly from mode shifts, changes in car occupancy, and/or reductions in average number of trips.
6. **GHG emission factors**. Based on total trip forecasts produced by the SANDAG ABM and Carbon Dioxide (CO2) estimates developed with EMFAC 2014.

Common Scenario Inputs to TDM off-model calculators

Though the methodologies of the individual TDM calculators differ, they operate on similar sets of input data, which are summarized in Table OM.1. Generally, these data are drawn from the regional growth and travel demand forecasts produced by I-LUDEM and ABM2+ and include population and employment forecasts, travel demand and travel time forecasts, and regional running and cold start emissions totals for the determination of regional emissions factors that are applied to compute emissions savings by program.

Table OM.1. Common scenario inputs to TDM off-model calculators

Data	Source(s)	Details
Employment forecast	I-LUDEM	For each scenario year and Master Geography Reference Area (MGRA): • jobs by industry category (SANDAG ABM classification)
Regional Population Forecast	I-LUDEM	For each scenario year and MGRA: • total households • adult population • MGRA residential area • household density • population density • college student enrollment
Travel times between San Diego MSAs	SANDAG ABM	For each scenario year & MSA pair: • AM travel time, general purpose lanes • AM travel time, managed lanes
Regional Trip Data	SANDAG ABM	Regional trips for each scenario year & MSA pair: • Time period (EA, AM, MD, PM, NT) • Trip mode (drive alone, carpool, non-motorized, and transit) • Trip purpose (Work, School, Other) • Household auto ownership (0, 1, and 2+)
Emission factors	SANDAG ABM + EMFAC 2014	For each scenario year: • Trips (cold starts) regional emissions (ton) • Running CO_2 regional emissions (ton) • Regional VMT • Regional trips

In addition to the scenario inputs, certain model parameters are used across the TDM calculators, as shown in Table OM.2. These parameters capture common behavioral characteristics that are consistent across all models (on- and off-model).

Table OM.2. Common parameters for TDM off-model calculators

Parameters	Source(s)	Notes
Marginal disutility of travel time	SANDAG ABM	Used in the calculation of demand elasticity
Median value of time	SANDAG ABM	Used to calculate an average coefficient of cost, for the demand elasticity formulas
Auto operating cost	SANDAG ABM	Used to calculate the cost of driving alone and accounts for fuel and vehicle maintenance. Expressed in cents per mile in (2010 $)
Coefficient of in-vehicle travel time	SANDAG ABM Trip mode choice model, Work tours	Used to calculate elasticity of demand with respect to travel time and with respect to trip cost. Input to the demand elasticity formula

The following sections detail specific program characteristics along with the methodologies and assumptions for each TDM off-model calculator.

Vanpool

Program Overview, Rationale, and Performance to Date

The SANDAG Vanpool program is offered by iCommute. This program provides a subsidy of up to $400 per month for eligible vanpool groups. The program requires that vanpools have either an origin or destination in San Diego County, maintain 80% vehicle occupancy, and travel at least 20 miles within the County. Vanpools have been shown to reduce greenhouse gas emissions since only one (albeit larger) vehicle is required to transport the same number of people that would normally take 7 to 15 single-occupant vehicles to transport. In FY 2019, the vehicle miles traveled reduction attributed to the vanpool program was approximately 93 million miles.

Based on historic trends, the 2015 Regional Plan envisioned the Vanpool Program to grow 13% by 2020 (approximately 811 vanpools), 62% by 2035 (approximately 1,163 vanpools), and 110% by 2050 (approximately 1,512 vanpools). Since the adoption of the 2015 Regional Plan, the program has implemented improved program administration and policies to facilitate monthly surveying to track program performance. The iCommute team works closely with major employers and conducts targeted marketing campaigns to encourage the formation of vanpools in the region. In 2019, the program even grew to offer more diverse and affordable vehicles from three vanpool vendors, including an all-electric vanpool service. Despite these improvements, as of May 2020, the Vanpool Program has 590 registered vanpools with an average daily round trip of 103 miles (or 51.5 miles one way). Reductions in vanpool participation vary but are largely attributed to major employers who have withdrawn support and contributions for employees that vanpool. In recent months, due to COVID-19, the program has seen many employers withdraw financial support for vanpooling and shift employees to teleworking where possible, leading to a further decrease in vanpools.

More than 85% of vanpools in the SANDAG program use vehicles with a maximum occupancy of seven to eight passengers, and almost half of vanpools originate from Riverside County. The influx of vanpools traveling into the region from Riverside County can leverage managed lanes on the Interstate 15 that allow vanpoolers to use the high-occupancy vehicle lanes free of charge and offer travel time reliability.

More than half of the vanpools are military or federal employees who also benefit from the Transportation Incentive Program (TIP) stipend, making vanpooling a cost-effective alternative to driving alone. Participation in the Vanpool Program is expected to grow through iCommute outreach and incentives. Vanpools can also leverage managed lanes and high-occupancy vehicles for travel and can take advantage of priority parking for rideshare at employment sites and within mobility hubs.

Off-model Calculator Assumptions and Methodology

The following assumptions are incorporated into the off-model calculator for the Vanpool Program. The calculation of VMT reductions is based on the Regional Vanpool Program data including vanpool fleet and trip information. This data includes the total number of active vanpools, vehicle type, vanpooler industries, commute trip origin and destination, distance traveled within San Diego County, and vehicle occupancy. Historical program data indicates that the Vanpool program caters to a workforce that commutes long distances to work (50 miles one way on average) and that work for large employers that have fixed schedules.

Based on existing vanpool program trends, the vanpool off-model calculator estimates that vanpooling in the region will continue to grow relative to the total workers employed in San Diego County. Therefore, as the region adds jobs within industries that have historically had higher rates of vanpooling (i.e., military, biotech, federal employers), it is assumed that enrollment in the Vanpool Program will also grow. While employers in the region are currently implementing telework policies due to COVID-19, the industries in which vanpooling thrives are those that in large part are considered "non-teleworkable," such as manufacturing and military, which require employees to perform their job duties on site. As such, the employment-based vanpool growth projections are only based on those jobs sectors where vanpooling is suitable.

Vanpools in the San Diego region can also leverage the exclusive use of managed lanes (High-Occupancy Vehicle and Interstate-15 Express Lanes) to shorten their commute time during peak travel periods. The reliability of the managed lanes makes vanpooling an attractive option. Consistent with this assumption, the vanpool off-model calculator assumes that 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 used to derive the impact of vanpooling on GHG and VMT, such as average distance traveled and average vehicle occupancy, also vary by type of industry and are based on historical Vanpool Program data.

The vanpool program off-model GHG-reduction methodology is as follows:

1. Segment active vanpools in program and summarize their associated travel characteristics (average round-trip mileage, occupancy) into three targeted markets: federal, military, non-federal
2. Estimate vanpool growth due to employment for each vanpool market
    - Vanpool growth due to employment for each MSA = Base year vanpools * percent change in employment markets (federal, military, non-federal) using SANDAG employment forecasts
    - 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.

3. Estimate vanpool growth due to managed lane investments for each vanpool market using SANDAG model travel times
   - 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.
   - Uses a logit discrete choice model to model vanpool mode shifts. Formula for logit elasticity with respect to travel time:
     elasticity = (marginal disutility wrt travel time) * (travel time) / (1 – probability of vanpooling)
   - Compute the demand induced by travel time savings by applying the demand elasticity formula to the estimated number of vanpools for each scenario year, after accounting for employment growth.
     elasticity wrt travel time * % change in travel time
4. Estimate VMT reduction for each vanpool market
   - VMT Reduction = total vanpools [2 + 3] * average occupancy (exc. driver) * round-trip mileage within San Diego County only

The detailed Vanpool off-model calculator information is included as Appendix F.

Carshare

Program Overview, Rationale, and Performance to Date

Carshare services offer access to vehicles as short-term rentals 24 hours a day, seven days a week. Carshare can provide first-mile/last-mile connections to transit or fill gaps in the region's transit services by providing an efficient transportation alternative for commute and non-commute trips. As part of the 2015 Regional Plan, SANDAG sought to incentivize and expand the reach of carshare to employment centers and urban communities that are not currently served by this mobility option (and that the private market may be hesitant to enter) in order to complement and improve access to regional transit services. Since the adoption of the 2015 Regional Plan, the carshare market in the region has changed with the exit of one-way carshare service provider, car2go, from the region. To date, only round-trip and peer-to-peer services exist in the San Diego region. These services include ZipCar, Turo, and Getaround.

As part of the Regional Vision of the 2021 Regional Plan, Flexible Fleets are envisioned to operate throughout the region. Flexible Fleets are shared, on-demand vehicles like micromobility, carshare, rideshare, microtransit, and last-mile delivery. Fleets could provide more travel options that reduce the reliance on owning a personal vehicle and offer reliable connections to and from transit. To help encourage deployment of Flexible Fleets like carshare in the region, SANDAG is currently developing a Flexible Fleet Implementation Strategic Plan that will outline opportunities for Flexible Fleets in the region and will provide a roadmap for deployment in the next ten years. To complement the Strategic Plan, SANDAG is planning to procure a bench of Flexible Fleet providers including microtransit, carshare, on-demand rideshare, and micromobility. The bench will be available for SANDAG and its partners like transit agencies, cities, and non-profit organizations to implement services that meet community needs.

The expansion of carshare services is envisioned as part of the Regional Mobility Hub network to support connections to transit and reduce the reliance on driving. SANDAG will support carsharing through iCommute outreach and incentives as well as the provision of infrastructure (e.g., electric vehicle chargers, designated/priority parking, or curb space) needed to support carsharing in mobility hubs.

Research indicates that households that participate in carsharing tend to own fewer motor vehicles than non-member households.[7] 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 miles per day[8] and up to 1,200 miles per year[9] for round-trip carshare. A survey of car2go users in five North American cities, including San Diego, found that carshare households reported decreases in VMT ranging from 6% to 16%, with San Diego users reporting an average 10% VMT reduction, or approximately 1.4 miles per day.[10] 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.[11]

Off-model Calculator Assumptions and Methodology

The carsharing methodology only accounts for VMT and GHG emission benefits associated with round-trip carshare service. 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 ridehailing service providers like Uber, Lyft, and Waze Carpool.

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, military bases, and within the proposed mobility hub network. Given the future trend toward mobility-as-a-service, it is assumed that carsharing will evolve to be part of a fleet of shared, electric, and on-demand 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.[12] 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. Based on the 2016–2017 San Diego Regional Transportation Study and available research on carshare participation rates, it is assumed that areas with a population greater than 17 people/acre will have a 2% participation rate. Areas with a population density lower than 17 people/acre will have a 0.5% participation rate. These density thresholds are specific to carshare trends exhibited in the San Diego region. VMT reduction impacts from round-trip carshare also assume a daily

[7] Martin, E. and S. Shaheen (2016). Impacts of car2go on Vehicle Ownership, Modal Shift, Vehicle Miles Traveled, and Greenhouse Gas Emissions. An Analysis of Five North American Cities.

[8] Cervero, R. A. Golub, and Nee (2007) "City CarShare: Longer-Term Travel-Demand and Car Ownership Impacts", Presented at the 87th Transportation Research Board Annual Meeting, Washington, D.C.

[9] Martin, E., and S. Shaheen (2010), "Greenhouse Gas Emission Impacts of Carsharing in North America," Mineta Transportation Institute. MTI Report 09-11.

[10] Martin, E. and S. Shaheen (2016). Impacts of car2go on Vehicle Ownership, Modal Shift, Vehicle Miles Traveled, and Greenhouse Gas Emissions. An Analysis of Five North American Cities.

[11] Le Vine, S., M. Lee-Gosselin, A. Sivakumar, J. Polak. (2014). "A new approach to predict the market and impacts of round-trip and point-to-point carsharing systems: Case study of London." Transportation Research Part D: Transport and Environment, Vol. 32, pp. 218–229.

[12] Transportation Sustainability Center (2018), Carshare Market Outlook. its.berkeley.edu/node/13158

average reduction of seven miles per day per round-trip carshare member based on the latest available research.[13]

The carshare program off-model GHG reduction methodology is as follows:

1. Defines geographic areas (MGRAs) and target markets deemed suitable for carsharing
   - Mobility hubs – general population
   - Colleges/universities – college staff and students
   - Military – military personnel on base
2. Estimate "eligible adult population" within carshare coverage areas through 2035 using SANDAG population forecast
   - Segment population within coverage area into higher-density areas (>17 persons/acre) or lower-density areas (<=17 persons/acre) as participation varies by density
3. Estimate carshare participation by applying the participation rate to eligible populations
   - Carshare participation rates = 2% in high-density areas or 0.5% in low-density areas
4. Estimate VMT reduction = total carshare membership [3] * round-trip carshare VMT reduction

The detailed Carshare off-model calculator information is included as Appendix G.

Pooled Rides

Program Overview, Rationale, and Performance to Date

As part of the 2015 Regional Plan, SANDAG planned to launch a formal carpool incentive program in the summer of 2016. The program would provide incentives for carpoolers and drivers for a set period of time to encourage and facilitate carpool creation. This carpool incentive program was formally launched in 2017 as part of the iCommute Program and in partnership with Waze Carpool. The program provides incentives to employees for forming new carpoolers (passengers and drivers) through the Waze carpool app, which links drivers with passengers headed in the same direction. To date, more than 200 employees have participated in the Carpool Incentive Program and about 130 rides have been completed through the incentive program. Outside of the carpool incentive program, iCommute and Waze have also implemented other promotions as part of Rideshare Week or with specific employers like the military to encourage pooling to work. SANDAG envisions encouraging pooling though continued incentives and outreach with iCommute. Participants in the Program can also leverage managed lanes and high-occupancy vehicles for travel and can take advantage of priority parking for rideshare at employment sites and within mobility hubs.

Off-model Calculator Assumptions and Methodology

The pooled rides off-model calculator accounts for the VMT and GHG benefits of SANDAG's carpool incentive program. Uber reports that 20% of their rides globally, and 30% of the rides in New York and Los Angeles, are on Uber Pool;[14] 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. While there is a limited, but growing, body of research on pooled rides, data on pooled TNC trips is limited due to lack of data sharing from app-enabled companies that offer pooled services. To help remedy this,

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[13] Cervero, R. A. Golub, and Nee (2007) "City CarShare: Longer-Term Travel-Demand and Car Ownership Impacts", Presented at the 87th Transportation Research Board Annual Meeting, Washington, D.C.

[14] TechCrunch (2016). Interview with David Plouffe, Chief Advisor for Uber. techcrunch.com/2016/05/10/uber-says-that-20-of-its-rides-globally-are-now-on-uber-pool/?ncid=rss

SANDAG, in partnership with MTC and SCAG, received a Caltrans planning grant to conduct a statewide ridehailing survey. The survey, known as the 2019 Transportation Study, evaluates the impact of ridehailing activity, including pooled ridehailing trips, throughout the state. Data from the 2019 Transportation Study are being used to inform the development of the pooled rides off-model calculator.

The structure of the off-model methodology for pooled rides is structured around the Waze carpool model, which is the current carpool incentive program partner, in which the driver and 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. Building on the success of the existing carpool incentive program, the pooled rides off-model calculator assumes that the SANDAG carpool incentive program will continue to provide a minor trip subsidy that will lower the cost of pooling per trip. Non-work trips will not be subsidized by SANDAG. The calculator employs a reimbursement model based on the Waze Carpool service to compute a pooled ride index factor representing the cost ratio of pooling to driving alone.

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. Data on app-enabled pooled ride utilization data was gathered through the 2016–2017 San Diego Regional Transportation Study, 2018 Commute Behavior Survey, and the 2019 Transportation Study. Generally, these studies show that 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 ridehailing use is higher for work than for non-work trips.

Similar to the vanpool off-model calculator, the pooled rides off-model calculator also assumes that commuters that pool in the San Diego region can leverage the exclusive use of managed lanes (High-Occupancy Vehicle and Interstate 15 Express Lanes) to shorten their commute time during peak travel periods. The reliability of the managed lanes makes pooling an attractive option. As the region's managed lane network expands, commuters who choose to pool to work are likely to experience shorter travel times than commuters driving alone, which will encourage a shift from driving alone to vanpooling. While both the vanpool and pooled rides calculator focus on the commuting population, the target market within the pooled rides off-model calculator focuses on the workforces that commute short distances to work (ten miles one way on average) rather than the longer-distance commuters captured within the vanpool off-model calculator.

The pooled rides program off-model GHG-reduction methodology is as follows:

1. Estimate baseline pooling target market
    - Pooling market = drive-alone trips from SANDAG ABM2+ * pooled ride mode share based on 2019 Transportation Study
2. Estimate increase in pooled rides due to managed lane investments
    - New pooled trips due to managed lanes = elasticity with respect to travel time * % change in travel time
    - Uses a logit discrete choice model to model pooled ride mode shifts. Formula for logit elasticity with respect to travel time:
    - elasticity = (marginal disutility with respect to travel time) * (travel time) / (1 – probability of app-enabled pooling)

3. Total pooled ride trips = baseline pooling market [1] + pooled trips induced by managed lane time savings [2]
4. Estimate vehicle trips required to serve the person trips = total pooled ride trips [3] / minimum vehicle occupancy required per Carpool Incentive Program
5. Estimate vehicles replaced by pooling = total pooled ride trips [3] – vehicle trips required to serve pooled trip demand [4]
6. Estimate person miles traveled reduced by pooled trips = total pooled ride trips [3] * average trip distance based on SANDAG ABM2+
7. Estimated VMT reduction = total person miles [6] * proportion of vehicles eliminated by pooled riding [5/3]

The detailed Pooled Rides off-model calculator information is included as Appendix H.

Regional TDM Ordinance

Program Overview, Rationale, and Performance to Date

The SANDAG iCommute Program works with more than 200 employers on a voluntary basis to implement commuter benefit programs. Since the adoption of the 2015 Regional Plan, the iCommute program has expanded to a team of seven Account Executives that work with employers of all sizes throughout the region. Employers survey their employees to track their mode share over time. Employers are rewarded and recognized through the iCommute Diamond Awards for measurably reducing single-occupant vehicle trips by employees. On average, the employers that work with iCommute have reduced their drive-alone mode share by 10%. As part of the 2021 Regional Plan, SANDAG is exploring a regional TDM ordinance that would require employers with more than 250 employees to implement and monitor a commuter program that would require them to demonstrate reductions in their drive-alone rate by encouraging employees reduce solo commute trips. Employers must demonstrate the achievement of this drive-alone reduction targets through application of one or more Travel Demand Management (TDM) strategies, including, but not limited to:

- **Commuter services**. Offering programs like secured bike lockers and free rides home in case of an emergency can make it easier for commuters to use transit and other alternatives to driving alone.
- **Financial Subsidies and Incentives**. Financial incentives and pre-tax commuter benefits for commuters can lower the out-of-pocket cost for commuters who choose alternatives to driving alone.
- **Marketing, Education, and Outreach**. Outreach events, educational campaigns, and marketing strategies help raise awareness of alternative commute options.
- **Parking Management**. Employers can offer cash incentives, transit passes in lieu of a parking space, and preferred parking for high-occupancy vehicles as incentives to choosing an alternative commute option. Charging for parking at the workplace can act as a disincentive to drive alone.
- **Telework and Flexible Work Schedules**. Employers can develop workplace policies that promote telework, flexible schedules, and/or compressed work schedules to reduce peak commute trips.
- **On-Site Amenities**. Secured bike lockers and showers can offer convenience for commuters who choose to bike to work.
- **Employer-Provided Transit**. Employer-provided transit can help to serve the first-mile/last-mile connection to transit and/or provide direct pooling options for employees traveling from the same direction.

In the near term, SANDAG will conduct necessary research and outreach to develop a policy and legislative framework for implementation. Next, SANDAG will phase in a pilot program with employers, after which the program will be evaluated and refined for full implementation in the region. Since the impact of this type of regulation cannot be modeled in SANDAG's ABM2+ model, capturing the impacts of a TDMO program requires the development of an off-model calculator.

Off-Model Calculator Assumptions and Methodology

The TDMO will be employer-based, meaning that the regulations will require that employers demonstrate that their employees (as a group) are meeting their proposed drive-alone reduction targets. SANDAG intends to expand existing iCommute Employer Program offerings to assist employers with implementing and monitoring their TDM programs. Further, it is assumed that the ordinance will only apply to specific employers, namely larger employers with at least 250 employees. These employers will be provided with options from a set of TDM strategies to achieve the target. It is assumed that the suite of strategies available to employers will be flexible and build upon other SANDAG commuter programs like the Vanpool Program, Carpool Incentive Program, Try Transit Program, and more.

The TDMO off-model calculator computes the impact of large employers implementing a commuter program that would achieve the desired drive-alone reduction targets. Given the success of the voluntary iCommute Employer Program, with which employers have reduced their drive-alone rate by 10%, SANDAG anticipates that the TDMO program will achieve an average drive-alone reduction target of 15% by 2035. The off-model calculator computes the target reductions in drive-alone commute trips in each MSA. Since the options in the TDMO program includes employer-sponsored vanpool and pooled-ride programs, the calculator allows for the trip reductions computed by the vanpool and pooled-ride calculators for large employers to be subtracted from the computed excess to avoid double-counting.

The TDMO off-model GHG reduction methodology is as follows:

1. Estimate fraction of a.m. and p.m. trips associated with large employers (LEs).
   - The fraction of employees impacted for each MSA is the number of employees working for firms with > 250 employees divided by the number of employees working for all firms.
   - The fraction of a.m. and p.m. trips impacted for each MSA pair is assumed to be the same as the fraction of employees associated with LEs at the employment end of the trip. The employment end of trips in a period (the fraction of trips for which work is the origin and the fraction for which work is the destination) is determined from work trip-directionality analysis of the OD and period obtained from the ABM2+ forecast. The origin-to-work fraction is combined with the work-to-destination fraction to produce a total fraction for each MSA OD pair.
2. Forecast the number of drive-alone a.m./p.m. trips associated with LEs for each MSA OD pair, computed as the period-specific fraction of LE OD trips times the forecast number of drive-alone OD trips during that period.
3. Compute target drive-alone trip splits for LE work trips in the a.m. and p.m. periods between each MSA origin and destination
   - Target is a 15% in 2035 and 25% in 2050 reduction in ABM 2+ forecast drive-alone shares
4. Establish LE drive-alone trips allowance for each MSA OD pair by applying drive-alone-reduction targets to drive-alone trips associated with large employers
   - Computed as target drive-alone LE work trip splits [3] times the forecast total work trips (from ABM2+) times the large employer fraction [1]
5. Estimate TDMO trip reductions
   - Assumes that ABM2+ forecast trips exceeding the established drive-alone allowance in the target year are reduced by the TDMO. TDMO-required reductions in a.m./p.m. drive-alone work

trips for each MSA OD pair computed as the difference between the forecast [2] and the allowance [4]. If this value is less than zero, the ABM2+ forecast exceeds the TDMO target, so the TDMO will not reduce additional trips and the reductions are set to zero for this period.

- Upon implementation and monitoring of TDMO, SANDAG program data will inform these assumptions.

6. Estimate baseline VMT reduction = TDMO trip reductions [5] * average trip distance based on SANDAG ABM2+
7. Deduct other calculator drive-alone work trip and VMT reductions (vanpool and pooled rides) between TDMO phasing and target year to avoid double counting

The detailed Regional TDM Ordinance off-model calculator information is included as Appendix I.

Electric Vehicle Programs Calculator

Program Overview, Rationale, and Performance to Date

In the 2021 Regional Plan/SCS, SANDAG will consider two types of electric vehicle (EV) programs: EV Charger Program and Vehicle Incentive Program. The EV Charger Program, which was included in the 2015 Regional Plan, would incentivize the installation of public and workplace Level 2 charging. The 2015 Regional Plan assumed that the EV Charger Program would incentivize Level 1 and Level 2 charging. Based on market changes since 2015, the EV Charger Program is now focused only on Level 2 charging. The investment in charging infrastructure would extend the electric range for plug-in hybrid electric vehicles and lead to a reduction in GHG emissions beyond what is estimated in EMFAC. The Vehicle Incentive Program would offer rebates for the purchase of EVs. The vehicle rebates would be in addition to the state's investment in the Clean Vehicle Rebate Project and GHG emission reductions would be proportional to regional and state rebate amounts.

The 2015 Regional Plan called for SANDAG to establish an incentive program in 2020 for public EV chargers as a GHG-reduction measure for the SCS and as a GHG-mitigation measure in the EIR. SANDAG also committed $30 million from 2020–2050 for the program to achieve the GHG reductions. Since the Plan was adopted, SANDAG received a Caltrans Sustainable Communities Planning Grant in 2018 (that ended in June 2020) to research and develop the charger incentive program. This project helped SANDAG establish partnerships with the San Diego County Air Pollution Control District (APCD) and California Energy Commission's (CEC's) California Electric Vehicle Infrastructure Project (CALeVIP) to offer a more comprehensive rebate program as the San Diego County Incentive Project (SDCIP).

In September 2019, the Board approved the establishment of OWP 3502000 for the regional EV charger program (SDCIP) with a budget of $9 million for FYs 2020–2025. SDCIP partners have committed budgets for three years to start, and SANDAG will seek to continue partnerships with state and local co-funders for future program years and will coordinate with the local utility San Diego Gas & Electric (SDG&E). SDCIP opened on October 27, 2020, to great demand. A project requirements webinar was held August 27, 2020; a pre-launch webinar for participants was held October 6, 2020; and a workforce training webinar for electricians and a permit streamlining webinar for local governments were held October 22, 2020, and October 20, 2020, respectively. News about these and future SDCIP events will be available at the SDCIP website. Eligible rebate applicants will be able to apply for up to $80,000 per DC fast charger and up to $6,000 per Level 2 charger. With a three-year combined incentive budget of about $21.7 million, SDCIP is expected to help fund approximately 1,100 Level 2 chargers and 250 DC fast chargers in the San Diego region. On opening day, SDCIP's three-year budget was fully reserved, with wait-list applications exceeding $50 million in projects.

Since the 2015 Regional Plan, SANDAG ran the Plug-in San Diego project through two consecutive CEC grants. Plug-in SD implemented recommendations from the Regional EV Readiness Plan through a combination of resource development, training, and technical assistance through an EV Expert. SANDAG is continuing some of this technical assistance in SDCIP to ensure a successful infrastructure incentive program. Since 2016, SDG&E's Power Your Drive (PYD) Program has also added about 3,000 EV chargers at workplaces, fleets, and multifamily residences in the region. SANDAG serves on the Program Advisory Council for SDG&E's PYD and other EV infrastructure programs. SDG&E and SANDAG are coordinating on future EV infrastructure planning and investments.

Off-model Calculator Methodology and Assumptions

The EV off-model calculator estimates the CO_2 reductions and costs associated with implementation of both a Regional Electric Vehicle Charger Program (RECP) and Vehicle Incentive Program (VIP). Both programs are included in a single calculator to account for the interactions between the two programs. The calculator expands upon MTC's EV off-model methodology and applies a similar methodology to calculate emission reductions from SANDAG's proposed version of the RECP and VIP. Recent policies, research, studies, and models used to develop the 2021 Regional Plan EV off-model calculator include:

- EO B-16-12 and EO B-48-18, which set a target of 1.5 million ZEVs and 5 million ZEVs in the State by 2025 and 2030, respectively
- California Plug-In Electric Vehicle Infrastructure Projections: 2017–2025, published by the California Energy Commission (CEC) in March 2018, including projections of the PEV vehicle fleet mix, charger inventory, and charging demand by county that would achieve the 1.5 million ZEV statewide target by 2025 established in EO B-16-12 and 250,000 EV chargers statewide, including 10,000 DC Fast Chargers, by 2025 established in EO B-48-18 (CEC 2018)
- Electric Vehicle Infrastructure Projection Tool (EVI-Pro), released in early 2018 by the National Renewable Energy Laboratory's (NREL) and CEC, which estimates the public charging infrastructure needed to support a targeted PEV mix by 2025 for various regions across the state by county. Although this tool is not publicly available at this time, NREL and CEC released a web-based data viewer that summarizes the results of the tool for California, including anticipated charger counts and charger loads. The results of EVI-Pro were used to develop projections in CEC's California Plug-In Electric Vehicle Infrastructure Projections: 2017–2025 report. (NREL 2018a, NREL 2018b)
- EMFAC2017, released in late 2017 by CARB, which updates the statewide vehicle population, emissions, and VMT forecasts by fuel type, vehicle class, and other factors, accounting for adjusted ZEV forecasts that are generally more conservative than previously assumed in EMFAC 2014 (CARB 2017b). EMFAC2017 also accounts for a minimum regulatory compliance scenario under the ZEV mandate in the State's Advanced Clean Cars Program. This mandate requires vehicle manufacturers to produce an increasing number of ZEVs for model years 2018 through 2025.

EV Off-Model calculator includes the following key methods and assumptions used in the model's calculations. The differences from MTC's approach resulted in a more complex calculator, but also one that accounts for San Diego–specific factors.

- CO_2 reductions from the RECP and VIP were calculated in two key steps. First, the difference was taken between the total eVMT supported by each respective program and the eVMT anticipated in a business-as-usual (BAU) forecast for a given milestone year. In cases where the program's eVMT would result in more eVMT than the BAU forecast, the additional eVMT was attributed to the displacement of the same VMT from equivalent gasoline light-duty vehicles (LDV), which was then translated to CO_2 reductions associated with the reduced gasoline LDV VMT. Second, the resulting CO_2 reductions were scaled to SANDAG-related efforts by applying the ratio of SANDAG incentives to non-SANDAG incentives on a dollar-per-dollar basis. To avoid double-counting reductions between the RECP and VIP, the calculator assumes that the reductions from additional PHEVs under VIP would be a subset of any additional PHEV eVMT supported by RECP because the RECP is assumed to extend the electric range of any PHEVs purchased under the VIP.

- The BAU forecast was based on a combination of 2018 vehicle populations from DMV registration data, EMFAC2017 ZEV growth rates, and adjustment of EMFAC's daily VMT per vehicle forecasts to SANDAG travel demand modeling.
- CO_2 reductions from the RECP were based on the difference between the total eVMT supported by a targeted number of all non-residential chargers, including existing and new chargers, in the SANDAG region and the eVMT anticipated in the BAU forecast for the SANDAG region for a given milestone year. The targeted total number of chargers in the SANDAG region was calculated using local PEV-to-charger ratios estimated by CEC's EVI-Pro analysis. EVI-Pro estimates that these ratios would change over time and vary by PEV type. The targeted total number of chargers would be equal to the sum of all existing chargers as of 2018 and any new chargers added starting from 2018. To estimate the number of chargers needed to be incentivized by SANDAG, the number of existing non-residential chargers was subtracted from the targeted number of all non-residential chargers in the region.
- EV chargers were assumed to charge both BEVs and PHEVs. The eVMT provided to each type of vehicle per charger by non-residential charger type (e.g., public versus workplace) reflect the findings and assumptions in CEC's 2018 study and EVI-Pro runs.
- CO_2 reductions from the VIP were based the difference between the targeted EV population for a given milestone year and the EV population anticipated in the BAU forecast. Average VMT and eVMT per vehicle per day were based on EMFAC2017 defaults, which vary by calendar year and vehicle type.
- As SB 375 only requires MPOs to address tailpipe emissions; upstream emissions from additional electricity demand from EVs are ignored.

The detailed Electric Vehicles Programs off-model calculator information is included as Appendix J.

Other Data-Collection Efforts

SANDAG regularly collects data to support monitoring of the Regional Plan/SCS, updating of modeling/forecasting tools, developing strategies for the Regional Plan/SCS, and informing local jurisdiction planning and monitoring efforts. Data also are compiled to support calibration and validation of the activity-based model (ABM) where modeled results are compared against base year observed data as follows:

- Compiled transportation project information from local jurisdictions
- Census data
- Traffic counts
  - Passenger and commercial vehicle counts
  - Bike counts
  - Transit ridership
  - Observed travel time and speeds
  - Traffic volumes
- Parking inventory and cost information
- Day/overnight visitors
- Commuters into San Diego County

Additional Data-Collection Efforts

Some data-collection efforts at SANDAG are focused on supporting local jurisdictions' planning and monitoring activities. To support monitoring of Climate Action Plans, SANDAG developed a Regional Climate Action Planning (ReCAP) Framework and prepares customized reports, called ReCAP Snapshots, for each jurisdiction on their GHG emissions inventory and activity data related to CAP measures.[15] The Snapshots compile data across several sectors, including clean energy, energy-efficiency, active transportation, transit ridership, and water use. In support of California Senate Bill 743 (Steinberg, 2013) implementation, SANDAG developed a web-based map application for local jurisdictions to access VMT data derived from the ABM.[16]

Additionally, a variety of data are collected for performance-monitoring efforts for the 2021 Regional Plan. Per federal requirements, performance-monitoring data will be included in the Federal System Performance Report and Federal Congestion Management Process Appendix as part of the 2021 Regional Plan.

[15] SANDAG Climate Action Programs:
sandag.org/index.asp?classid=17&subclassid=46&projectid=565&fuseaction=projects.detail
[16] SANDAG SB 743 VMT Maps:
arcgis.com/apps/webappviewer/index.html?id=5b4af92bc0dd4b7babbce21a7423402a

Appendices

Appendix A: EMFAC GHG Version Adjustment

1. Jon Taylor Email
2. CARB Methodology to Calculate CO2 Adjustments to EMFAC Output for SB 375 Target Demonstrations
3. Applied SB 375 CO2 Adjustments

Appendix B: SANDAG ABM2+ Sensitivity Testing Report

Appendix C: SANDAG Auto Operating Cost Calculations

Appendix D: Ascent Environmental Electric Vehicle Calculations Memo

Appendix E: WP TDM Off-Model Memo

Appendix F: SANDAG Vanpool Calculator Review and Comparison

Appendix G: SANDAG Carshare Calculator Review and Comparison

Appendix H: SANDAG Pooled Rides Calculator Review and Comparison

Appendix I: SANDAG Regional TDM Ordinance Calculator Review and Comparison

Appendix J: SANDAG Electric Vehicle Programs Calculator Review and Comparison

Appendix A
EMFAC GHG Version Adjustment

From: Taylor, Jonathan@ARB [mailto:jonathan.taylor@arb.ca.gov]
Sent: Tuesday, June 30, 2015 5:24 PM
To: Daniels, Clint; 'Guoxiong Huang'; Bruce Griesenbeck (BGriesenbeck@sacog.org); David Ory; Tanisha Taylor (Taylor@sjcog.org); ehahn@Stancog.org; Matt Fell (matt.fell@mcagov.org); terri.king@co.kings.ca.us; jeff@maderactc.org; Kai Han (KHan@fresnocog.org); RBrady@tularecog.org; Vincent Liu (vliu@kerncog.org); Bhupendra Patel (BPatel@ambag.org); JWorthley@slocog.org; blasagna@bcag.org; 'Andrew Orfila'; Sean Tiedgen (stiedgen@srta.ca.gov); Norberg, Keith@TRPA
Cc: Ken Kirkey; ggarry@sacog.org; Stoll, Muggs; Huasha Liu (LIU@scag.ca.gov) (LIU@scag.ca.gov); Mike Bitner (mbitner@fresnocog.org); rball@kerncog.org; terri.king@co.kings.ca.us; patricia@maderactc.org; Marjie.Kirn@mcagov.org; nguyen@sjcog.org; Park, Rosa@DOT; BKimball@tularecog.org; cdevine@bcag.org; hadamson@ambag.org; SDevencenzi@slocog.org; pimhof@sbcag.org; dlittle@srta.ca.gov; Haven, Nick@TRPA; Kalandiyur, Nesamani@ARB; Roberts, Terry@ARB
Subject: Methodology to Adjust EMFAC Output for SB 375 Target Demonstrations

To All MPO Technical Staff,

Now that many of the MPOs are working on their second round of SCSs, and with ARB recently releasing a new version of EMFAC, we want to provide guidance on how to deal with changes arising from different EMFAC versions as you do your GHG quantification determinations for the second round of SCSs.

We request that you use the attached methodology if you will be using a different version of EMFAC for quantifying reductions from your second SCS than the EMFAC version you used for your first SCS. Our intent with this methodology is to maintain the same level of stringency for meeting the current targets even though there are emission rate changes when switching EMFAC versions. When targets are updated next year, they will probably be based on EMFAC 2014, therefore, this methodology would not be required with the new targets until a new version of EMFAC was released to supersede EMFAC 2014. Our plan is to update the methodology at that time.

Please look over this methodology and let us know if you have any questions or concerns. For general questions, please contact me by email at jonathan.taylor@arb.ca.gov or by phone at 916-445-8699. For specific technical questions on the adjustment calculations, please contact Nesamani Kalandiyur at nesamani.kalandiyur@arb.ca.gov or 916-324-0466.

I'd like to take this opportunity to thank all of you for your generous assistance and patience as ARB staff have evaluated your SCSs. I am sure you are all proud of your accomplishments in meeting the goals of SB 375, and we ARB staff look forward to continuing to work with all of you.

Best,

Jon

Jonathan Taylor, P.E.
Assistant Chief,
Air Quality Planning and Science Division
California Air Resources Board
jonathan.taylor@arb.ca.gov
Ph. 916-445-8699
FAX: 916-322-3646

Methodology to Calculate CO2 Adjustment to EMFAC Output for SB 375 Target Demonstrations

Background:

In 2010, ARB established regional SB 375 greenhouse gas (GHG) targets in the form of a percent reduction per capita from 2005 for passenger vehicles using the ARB Emission Factor model, EMFAC 2007. EMFAC is a California-specific computer model that calculates weekday emissions of air pollutants from all on-road motor vehicles including passenger cars, trucks, and buses. ARB updates the EMFAC model periodically to reflect the latest planning assumptions (such as vehicle fleet mix) and emissions estimation data and methods. Since the time when targets were set using EMFAC2007, ARB has released two subsequent versions, EMFAC2011[1] and EMFAC2014[2].

ARB has improved the carbon dioxide (CO2) emission rates in EMFAC2011 and EMFAC2014, based on recent emission testing data and updated energy consumption for air conditioning. In addition, vehicle fleet mix has been updated in EMFAC2011 and again in EMFAC2014 based on the latest available Department of Motor Vehicle data at the time of model development. These changes have lowered the overall CO2 emission rates in EMFAC2011 and EMFAC2014 compared to EMFAC2007.

Purpose:

Some metropolitan planning organizations (MPOs) used EMFAC 2007 to quantify GHG emissions reductions from their first Regional Transportation Plan/Sustainable Communities Strategy (RTP/SCS); others used EMFAC 2011. As MPOs estimate GHG emissions reductions from subsequent RTP/SCSs, they will use the latest approved version of EMFAC, but using a different model will influence their estimates and their ability to achieve SB 375 targets. The goal of this methodology is to hold each MPO to the same level of stringency in achieving their SB 375 targets regardless of the version of EMFAC used for its second RTP/SCS.

ARB staff has developed this methodology to allow MPOs to adjust the calculation of percent reduction in per capita CO2 emissions used to meet the established targets when using either EMFAC2011 or EMFAC2014 for their second RTP/SCS. This method will neutralize the changes in fleet average emission rates between the version used for the first RTP/SCS and the version used for the second RTP/SCS. The methodology adjusts for the small benefit or disbenefits resulting from the use of a different version of EMFAC by accounting for changes in emission rates, and applies an

[1] EMFAC2011 was approved by USEPA in March 2013.
[2] EMFAC2014 is under review for USEPA approval.

adjustment when quantifying the percent reduction in per capita CO_2 emissions using EMFAC2011 or EMFAC2014.

Applicability:

The adjustment is applicable when the first RTP/SCS was developed using either EMFAC2007 or EMFAC2011 and the second RTP/SCS will be developed using a different version of the model (EMFAC2011 or EMFAC2014).

- Hold the 2005 baseline CO_2 per capita estimated in the first RTP/SCS constant. Use both the human population and transportation activity data (VMT and speed distribution) from the first RTP/SCS to calculate the adjustment.
- Add the adjustment to the percent reduction in CO_2 per capita calculated with EMFAC2011 or EMFAC2014 for the second RTP/SCS. This will allow equivalent comparison to the first RTP/SCS where emissions were established with EMFAC 2007 or EMFAC2011.

Example Adjustment Calculation (hypothetical for illustration purposes):

In this example, the first RTP/SCS was developed using EMFAC2007 and the second RTP/SCS using EMFAC2011 to calculate the CO_2 per capita.

Step1: Compile the CO_2 per capita numbers from the MPO's first adopted RTP/SCS using EMFAC 2007 without any off-model adjustments for calendar years (CY) 2005, 2020, and 2035 for passenger vehicles.

Calendar Year	**EMFAC2007 CO2 Per capita (lbs/day)**
2005	30.0
2020	28.8
2035	27.6

Step 2: Calculate the percent reductions in CO_2 per capita from the 2005 base year for CY 2020 and 2035 from Step 1.

Calendar Year	**EMFAC2007 Percent Reductions (%)**
2020	4.0%
2035	8.0%

Step 3: Develop the input files for the EMFAC2011 model using the same activity data for CY 2020 and 2035 from the first adopted RTP/SCS (same activity data used in Step 1) and execute the model.

Step 4: Calculate the CO_2 per capita for CY 2020 and 2035 using the EMFAC2011 output from Step 3; do not include Pavley I, LCFS, and ACC benefits for passenger vehicles.

Calendar Year	EMFAC2011 CO2 Per capita (lbs/day)
2020	28.2
2035	27.9

Step 5: Calculate the percent reductions in CO_2 per capita for CY 2020 and 2035 calculated in Step 4 from base year 2005 established in Step 1.

Calendar Year	EMFAC2011 Percent Reductions (%)
2020	6.0%
2035	7.0%

Step 6: Calculate the difference in percent reductions between Step 5 and Step 2 (subtract Step 5 results from Step 2 results) for CY 2020 and 2035; this yields the adjustment for the respective CY.

Calendar Year	EMFAC2011 Adjustment (%)
2020	-2.0%
2035	+1.0%

Step 7: Develop the input files for the EMFAC2011 model using the activity data from the new/second RTP/SCS for CY 2020 and 2035 without any off-model adjustments and execute the model.

Step 8: Calculate the CO_2 per capita for CY 2020 and 2035 using the EMFAC2011 output from Step 7; do not include Pavley I, LCFS, and ACC benefits for passenger vehicles.

Calendar Year	EMFAC2011 CO2 Per capita (lbs/day)
2020	26.4
2035	26.1

Step 9: Calculate the percent reductions in CO_2 per capita for CY 2020 and 2035 calculated in Step 8 from base year 2005 established in Step 1.

Calendar Year	EMFAC2011 Percent Reductions (%)
2020	12.0%
2035	13.0%

Step 10: Add the adjustment factors from Step 6 to the percent reductions calculated for the new/second RTP/SCS (Step 9) using EMFAC 2011 for CY 2020 and 2035.

Calendar Year	Adjusted Percent Reductions (%)
2020	10.0%
2035	14.0%

Follow the same steps to adjust for use of EMFAC2007 or EMFAC2011 to EMFAC2014. Do not include any off-model adjustments during application of the EMFAC adjustment factor.

Appendix A3 – Applied SB 375 CO2 Adjustments

SB375 CO2 Adjustment for Differences between EMFAC2007 and EMFAC2014

Step 1	CO2 per Capita from 1st adopted RTP/SCS using EMFAC2007 without any off-model adjustments for passenger vehicles			
	Calendar Year	EMFAC2007 CO2	EMFAC2007 CO2/Capita	Notes
	2005	*39,511*	26.0	2005 Pop = 3,034,388
	2020	41,111	23.3	Series 12 Activity & Pop
	2035	48,297	24.0	Series 12 Activity & Pop

Step 2	Calculate percent reductions in CO2 per capita from the 2005 base year from Step 1			
	Calendar Year		EMFAC2007 CO2/Capita Percent Reduction	Notes
	2020		-10.5%	
	2035		-7.7%	

Step 3	Develop Input Files for EMFAC2014 from 1st SCS activity data

Step 4	Calculate CO2 using EMFAC2014 using output from Step 3 (for certain versions of EMFAC you would need to exclude Pavley I, LCFS, and ACC benefits for PVs)			
	Calendar Year	EMFAC2014 CO2 (tons)	EMFAC2014 CO2 (lbs)/Capita	Notes
	2020	40,288	22.79	Series 12 Activity & Pop
	2035	47,424	23.56	Series 12 Activity & Pop

Step 5	Calculate the percent reductions in CO2 per capita calculated in Step 4 from base year 2005 established in Step 1			
	Calendar Year		EMFAC2014 CO2/Capita % Reduction	Notes
	2020		-12.3%	
	2035		-9.4%	

Step 6	Calculate the difference in percent reductions between Step 5 and Step 2 (subtract Step 5 results from Step 2 results)			
	Calendar Year		EMFAC2014 Adjustment %	Notes
	2020		-1.8%	
	2035		-1.7%	

Appendix B
SANDAG ABM2+ Sensitivity Testing Report

SANDAG ABM2+
Sensitivity Testing Report

September 2020

Table of Contents

Objectives

San Diego Association of Governments (SANDAG) modeling staff conducted a series of sensitivity tests to demonstrate the effects of various inputs on vehicle miles traveled (VMT), mode share, trip length, and transit boardings using Activity Based Model (ABM2+). This work was performed in response to the Final Sustainable Communities Strategy Program and Evaluation Guidelines issued by the California Air Resources Board (CARB) and to examine the responsiveness of ABM2+ to potential SANDAG 2021 Regional Plan strategies. Since draft ABM2+ software versions were used in this study, the performance metrics varied slightly. These metrics are for sensitivity testing analysis only and should not be interpreted as final ABM2+ performance metrics.

Description of Sensitivity Tests

In February 2020, to prepare for the ABM2+ technical advisory committee (TAC) peer review held in March 2020, the modeling staff conducted a series of sensitivity tests. Following CARB's sensitivity test guidelines, staff conducted land use, transit infrastructure and active transportation, local/regional pricing, new mobility, and exogenous variable sensitivity tests as described in Table 1. Some tests were adjusted either to conform to the ABM2+ structure or to set with testing values that are more in line with Regional Plan (RTP) strategies. Tests in the new mobility category, including autonomous vehicles (AV), transportation network companies (TNC), and micromobility (E-Scooter, E-Bike, etc.), were beyond CARB's recommendations. Most sensitivity tests were based on 2035 model runs using 2035 revenue constrained networks from the 2019 Federal RTP. The Population forecast was prepared by SANDAG Economic and Demographic Analysis (EDAM) staff in August 2019. The 2035 revenue constrained scenario was used as the baseline scenario to derive elasticity. Land use–related tests used the 2050 forecast to account for the full potential impact of population growth on VMT and mode share.

Table 1. Descriptions of ABM2+ Sensitivity Tests

CARB Category	Description	Test ID	Scenario	Year
Land Use	baseline	1	baseline	2050
	job/housing balance	2	new downtown	2050

	mix of land use	3	low VMT	2050
	street pattern via intersection density	4	10%	2050
		5	–10%	2050
	residential density	6	50%	2050
		7	–50%	2050
Transit and Active Transportation	2035 baseline without AV	8	2035 baseline without AV	2035
	transit headways (frequencies)	9	50%	2035
		10	–50%	2035
	self-owned E-Bike	11	12 mph	2035
		12	15 mph	2035
Local/Regional Pricing	mileage-based fee via AOC	13	50%	2035
		14	–50%	2035
	transit fare	15	50%	2035
		16	free	2035
		17	–50%	2035
	managed lane/toll price	18	50%	2035
		19	–50%	2035
	parking costs	20	high	2035
		21	very high	2035
Exogenous Variables	free flow speed	22	reduce 5 mph on freeways	2035
		23	reduce 5 mph on all roads	2035
	household income	24	–1/3	2035
		25	1/3	2035
	regional employment	26	10%	2035
		27	–10%	2035
New Mobilities	2035 baseline with AV	28	2035 baseline with AV	2035
	TNC cost (all)	29	50%	2035
		30	–50%	2035
	pooled TNC cost	31	–50%	2035
		32	–75%	2035
	TNC wait time	33	–50%	2035
		34	50%	2035
	micromobility speed	35	30mph	2035
	micromobility focus	36	micromobility speed 20 mph, constant 0, cost and access time halved	2035
	access to micromobility	37	good	2035
		38	very good	2035
	micromobility cost	39	-50%	2035

		40	50%	2035
	AV household penetration rate	41	50%	2035
		42	0%	2035
	AV in-vehicle time coefficient	43	Reduce from 0.75 to 0.6	2035
		44	Increase from 0.75 to 0.9	2035
	AV operating cost scaler	45	Reduce from 0.7 to 0.5	2035
		46	Increase from 0.7 to 0.9	2035
	AV terminal time scaler	47	Reduce from 0.65 to 0.5	2035
		48	Increase from 0.65 to 0.8	2035
	TNC optimization	49	TNC optimization	2035
		50	TNC transit optimization	2035
	AV and TNC combos	51	20% household AV penetration rate and 30 min TNC benefits	2035
		52	20% household AV penetration rate and 7.5 min TNC benefits	2035
		53	50% household AV penetration rate and 15 min TNC benefits	2035
Telework	existing pattern	54	Existing telework rates	2035
	moderate growth pattern	55	Moderate telework rate growth	2035
	maximum growth pattern	56	Maximum telework rate growth	2035

Baseline Scenarios

Staff created three baseline scenarios to ensure consistency when comparing results from multiple scenarios in the same test group, including:

- 2050 baseline without AV
- 2035 baseline without AV
- 2035 baseline with AV (20% household AV penetration rate)

The 2050 baseline without AV was used for comparing scenarios in the land use test category. The 2035 baseline without AV, a business as usual scenario, was used for comparing 'conventional' tests, such as transit fare, transit service, and AOC tests. The 2035 baseline with AV was used for comparing all new mobility tests that assume a 20% household AV penetration rate. During the three-month testing period, there were a few minor software changes, which resulted in slightly different software versions. All comparisons in this report were checked to ensure the same software version was used for baseline and build tests in each test group.

Description of Test Input Changes

Land Use

Staff tested three 2050 population growth alternatives: business as usual – baseline, jobs close to housing, and low VMT.

- *Test 1 2050 Baseline without AV:* 2050 baseline using revenue constrained networks (Figures 10, 11, and 12 in Appendix B) and land use (Figures 3 and 6 in Appendix B) from the 2019 Federal RTP. The impact of AVs was not included.
- *Test 2 2050 Jobs close to housing:* This alternative represents a job/housing balance scenario with population growth concentrated in one of San Diego's job centers, Sorrento Valley.
- *Test 3 2050 Low VMT:* This alternative represents a scenario with population growth concentrated in urban cores with good transit, walk, and bike accessibilities. The construction of this Low VMT land use alternative is described in Figures 13, 14, and 15 in Appendix B.
- *Test 4 and 5 Intersection density:* In the MGRA input file, intersection densities were set to be 10 percent less or 10 percent more than the corresponding values in the 2050 baseline scenario. It should be noted that road networks were not changed, only the intersection density variable was modified. These tests fall into the controlled-variable test category per CARB's guidelines which define the controlled-variable land use tests as: these *are simply hypothesis testing which holds all other variables constant, neglecting the supply-demand interaction between inter-dependent variables in reality, to determine the change in model outputs (e.g., VMT, VHT, vehicle trips, mode share) with respect to the change in a single land use related variable (e.g., residential density, employment density, compact housing development).*
- *Tests 6 and 7 Residential density:* In the MGRA[1] input file, residential densities were set to be 50 percent less or 50 percent more than the corresponding values in the 2050 baseline scenario. It should be noted that households were not re-distributed, only the residential density variable was modified. These tests fall into CARB's controlled-variable test category.

Transit and Active Transportation

These tests evaluated transit and active transportation-related strategies through a more frequent transit service and the expansion of self-owned E-Bikes that operate at faster speeds than regular bikes.

- *Test 8 2035 Baseline without AVs:* This is a 2035 baseline scenario with revenue constrained networks (Figures 7, 8, and 9 in Appendix B) and land use (Figures 2 and 5 in Appendix B) from the 2019 Federal RTP. The impact of AVs was not included.
- *Tests 9 and 10 Transit Frequency:* For each scenario's transit route attribute table, the frequencies by route were set to be 50 percent less or 50 percent more than the corresponding values in the 2035 baseline.
- *Tests 11 and 12 Self-Owned E-Bike:* In the two test scenarios, bike speed was increased from 10mph to 12mph and 15mph, respectively, to represent the impact of self-owned E-Bikes. Maximum bike distance thresholds were scaled up. Additionally, distance coefficients used to calculate bike logsums were scaled to reflect bike speed changes.

Local/Regional Pricing

These tests evaluated local/regional pricing-related strategies through mileage-based pricing (auto operating cost), reduction in transit fare cost, tolled roadways, and parking pricing.

[1] MGRA – Master Geographic Reference Areas are approximately 23,000 geographic areas in San Diego County created by overlaying unique combinations of jurisdictional, census and other geographies to create the basic building blocks for spatial analysis by SANDAG.

- *Test 13 and 14 Mileage-base fees:* Fuel and maintenance costs were set to be 50 percent less or 50 percent more than the corresponding values in the 2035 baseline.
- *Tests 15, 16 and 17 Transit Fare:* For each scenario's transit route attribute table, the fares by route were set to be 50 percent less, free, or 50 percent more than the corresponding values in the 2035 baseline. The zone-based fare for commuter rail was updated in the same manner as the route-based fare assumption.
- *Test 18 and 19 Managed lane/Toll price:* The toll price of managed lanes/toll roads were set to be 50 percent less or 50 percent more than the corresponding values in the 2035 baseline.

Test 20 and 21 Parking cost scenarios: Staff constructed two test scenarios using the 2035 parking fee schedule provided by SANDAG planning staff. Each of the 6,556 MGRAs in mobility hubs is given hourly, daily, and monthly parking fees by mobility hub type as described in Table 2.

Table 2. Descriptions of ABM2+ Sensitivity Tests

Mobility Hub Type	# of MGRAs	Hourly	Daily	Monthly
1 – Urban Shed High	855	$6.5	$39	$571
2 – Tier 1 Employment Centers	391	$4.9	$29	$408
3 – Other Urban Shed Tracts	908	$4.9	$29	$408
4 – Costal	1,780	$3.3	$20	$245
5 – Child Shed	2,622	$1.6	$10	$131

Note: 2010 $ value

SANDAG Data Solutions (DS) staff provided 2035 parking space data for MGRAs in mobility hubs (5,689 out of 6,556 mobility hub MGRAs). Since the 2035 baseline parking data was prepared at an earlier time using slightly different data sources and methodologies, a small portion of the estimated MGRA parking spaces were lower than those in the 2035 baseline scenario. For any given MGRA, if parking space data was not provided or was lower than 2035 baseline parking spaces, then staff used the 2035 baseline parking space data.

There are four parking area types ("parkarea") in ABM:

1. Designates a parking constrained MGRA. Parking charges apply and are calculated as a weighted average of parking costs in MGRAs in parkarea 1 or 2 within walking distance (3/4 mile). The parking costs are weighted inversely by distance and by the number of spaces. Trips with destinations in a MGRA in parkarea 1 may choose to park in a different MGRA. A parking location choice model is applied to auto trips with destinations in parkarea 1.
2. This is a reserve area of parking for parkarea 1, e.g. a residential or commercial area immediately around downtown. Trips with destinations in parkarea 1 may choose to park in a MGRA in parkarea 2, and parking charges may apply. In the base year, parkarea 2 MGRAs were constrained to be a quarter-mile buffer around downtown.
3. Only trips with destinations in the same MGRA may park here. Parking charges apply but are not calculated as a weighted average of walkable MGRAs.
4. Only trips with destinations in the same MGRA may park here. Parking charges do not apply (free parking)

High parking cost scenario: First, staff set parkarea to 1 for all 6,556 MGRAs in mobility hubs. Staff then updated the 2035 baseline parking costs using data from Table 2. All the updated costs were decreased by 50 percent. The parking cost in this scenario is higher than the 2035 baseline.

Very high parking cost scenario: First, staff set parkarea to 1 for all 6,556 MGRAs in mobility hubs. Staff then updated the 2035 baseline parking cost using data from Table 2. All the updated costs were increased by 50 percent over the values in Table 2. The parking cost in this scenario is much higher than the 2035 baseline.

Exogenous Variables

These tests evaluated exogenous factors through free flow speeds, household income, regional employment, and telework rates. CARB recommended that MPOs should conduct sensitivity tests on some of the most common exogenous variables in the travel demand model such as income distribution and auto operating cost. Auto operating cost tests are included in the pricing section.

- *Tests 22 and 23 Free flow speed:* Staff wrote Python scripts to create two modified networks with free flow speed reduced by 5mph on freeways and all roads, respectively.
- *Tests 24 and 25 Household income:* Household income was set to be one-third less or one-third more than the corresponding values in the 2035 baseline.
- *Tests 26 and 27 Regional total employment:* In the persons file, the number of full-time workers was set to be 10 percent less or 10 percent more than the corresponding values in the 2035 baseline. In the MGRA input file, employment at each MGRA was set to be 10 percent less or 10 percent more than the corresponding values in the 2035 baseline.
- *Test 54 Existing pattern:* Represents a business as usual scenario with permanent and occasional telework rates at 7% and 8%, respectively (same as the 2016/2017 household survey).
- *Test 55 Moderate growth pattern:* Represents a moderate telework growth scenario with permanent and occasional telework rates at 9% and 12%, respectively.
- *Test 56 Maximum growth pattern:* Represents a maximum telework growth scenario with permanent and occasional telework rates at 25% and 13%, respectively (same as the 2016/2017 household survey).

New mobility

These tests evaluated new mobility-related strategies through autonomous vehicles (AV), transportation network companies (TNC), and micromobility modes such as E-Scooters and shared E-Bikes. Since there are limited studies evaluating the impact of new mobility-related strategies, CARB's guidelines indicated that the current practice of the quantification of the GHG benefit is generally conducted through off-model analysis. ABM2+ was enhanced with explicit modeling of AV, TNC, and micromobilities. Staff were able to test new mobility scenarios beyond CARB's recommendations. Since some new mobility modes are included in multiple model components (e.g. resident model, airport model, visitor model, and cross border model), staff made changes to all model components whereas the new mobility modes apply.

- *Test 28 2035 baseline with AV:* 2035 baseline with AV using revenue constrained networks and land use from the 2019 Federal RTP. The impact of AV was included (the default AV penetration rate is 20 percent).

- *Tests 29 and 30 TNC cost:* Costs for single and pooled TNC modes was set to be 50 percent less or 50 percent more than the default values in the 2035 baseline.
- *Tests 31 and 32 Pooled TNC cost:* Costs for only the pooled TNC mode was set to be 50 or 75 percent less than the default values in the 2035 baseline.
- *Tests 33 and 34 TNC wait time:* Wait times for single and pooled TNC modes was set to be 50 percent less or 50 percent more than the corresponding default values in the 2035 baseline.
- *Test 35 Micromobility speed:* The micromobility mode speed was increased from 12 to 30 mph.
- *Test 36 Micromobility focus:* The micromobility mode speed was increased from 12 to 20 mph. The micromobility variable cost and fixed cost were set to $0.1/minute and $0.5, respectively (reduced by 50 percent compared with the default in the 2035 baseline). The micromobility constant was set to 0 (default is 60 in the 2035 baseline). Lastly, the micromobility access time was reduced by half in the MGRA-based input file from 5, 10, and 120 minutes to 2.5, 5, and 60 minutes for urban, suburban, rural MGRAs.
- *Test 37 and 38 Access to micromobility:* Access time to micromobility was specified in number of minutes by MGRA, to represent spatial differences in the availability of micromobility options such as E-Scooters. The baseline micromobility accessibility was estimated by SANDAG planning staff to be 5 minutes in the urban cores, 15 minutes in suburban areas within the City of San Diego, and unavailable elsewhere. For these sensitivity tests, the micromobility access time was set to 3, 5, and 15 minutes and 1, 3, and 5 minutes for urban, suburban, and rural MGRAs respectively.
- *Tests 39 and 40 Micromobility cost:* Costs for micromobility mode was set to be 50 percent less or 50 percent more than the default values in the 2035 baseline
- *Tests 41 and 42 Household AV penetration rate:* AV penetration rates were set to 50 percent and 100 percent (default is 20 percent in the 2035 baseline).
- *Test 43 and 44 AV in-vehicle time coefficient:* AV in-vehicle time coefficients were set to 0.6 and 0.9 (default is 0.75 in the 2035 baseline).
- *Tests 45 and 46 AV operating cost:* AV operating cost scalers were set to 0.5 and 0.9 (the default is 0.7 in the 2035 baseline).
- *Tests 47 and 48 AV terminal time:* AV terminal time scalers were set to 0.5 and 0.8 (the default is 0.65 in the 2035 baseline).
- *Test 49 TNC optimization:* The assumption was made that the TNC fleet is autonomous and much more widely available than current. The AV penetration rate was set to 0 percent. TNC wait time was set to be 50 percent less than the default values in the 2035 baseline. In mode choice UEC files, the alternative-specific constants (ASCs) of all TNC modes (TNC-Transit, single, and pooled-TNC) were increased by 30 minutes of equivalent in-vehicle time benefit, and Taxi alternative was turn off.
- *Test 50 TNC Transit optimization:* The AV penetration rate was set to 0 percent. The ASCs for TNC-Transit mode were increased by 30 minutes of equivalent in-vehicle time benefit.
- *Test 51 TNC benefits and 20 percent AV penetration rate:* The AV penetration rate was set to 20 percent. TNC wait time was set to be 50 percent less than the default values in the 2035 baseline. The ASCs for all TNC modes (TNC-Transit, single, and pooled) were increased by 30 minutes of equivalent in-vehicle time benefit, and the Taxi alternative was turned off.

- *Test 52 TNC benefits and 20 percent AV penetration:* The AV penetration rate was set to 20 percent. TNC wait time was set to be 50 percent less than the default values in the 2035 baseline. The ASCs for all TNC modes (TNC-Transit, single, and pooled) were increased by 7.5 minutes of equivalent in-vehicle time benefit, and the Taxi alternative was turned off.
- *Test 53 TNC benefits and 50 percent AV penetration:* The AV penetration rate was set to 50 percent. TNC wait time was set to be 50 percent less than the default values in the 2035 baseline. The ASCs for all TNC modes (TNC-Transit, single, and pooled) were increased by 15 minutes of equivalent in-vehicle time benefit, and the Taxi alternative was turned off.

Results and Findings

This section describes the sensitivity testing results and key findings. While some tests were simply hypothetical and were designed to mechanically examine the model's responsiveness to key variables, some other tests shed some insights of whether and how much the model responds to potential policy dials. The performance metrics analyzed include VMT, mode share, transit boardings, trip distance by mode, total trips, and in some cases test specific outputs such as toll road volumes. The analysis varied slightly, depending on the travel markets affected by the change of tested variables. While some analyses were based on metrics of all models including special market models like visitor, cross border, and truck models, some other analyses were for San Diego county resident models only.

Land Use

Land Use Tests (Tests 2 & 3)

Compared with the 2050 baseline, the low VMT land use alternative test had the following results:

- Total personal trips made by San Diego residents decreased by 1.2% (Figure 4)
- Average auto ownership decreased from 1.69 to 1.64 (Figure 2). Households without cars increased from 10.6% to 12.2% (Figure 3).
- VMT decreased by 3.7% (Figure 1)
- San Diego resident mode shares (Figure 5):
    - Drive alone (DA) decreased from 45.4% to 44.6%
    - Shared ride 2 (SR2) decreased from 23.6% to 23.3%
    - Shared ride 3 (SR3) decreased from 16.0% to 15.4%
    - Transit increased from 2.9% to 3.1%
    - Active modes (walk, bike, and micromobility) increased from 10.7% to 12.0%
- Transit boarding increased by nearly 5% (Figure 6)
- Average San Diego resident trip distance decreased from 6.1 miles to 5.9 miles; Trip distance of non-mandatory trips such as recreational, eating out, maintenance, shopping, and visiting all decreased. Work trip distance change was insignificant (Table 3).

Compared with the 2050 baseline, the jobs close to housing alternative test had the following results:

- VMT decreased by 2.0% (Figure 1)

- Average auto ownership decreased from 1.69 to 1.66 (Figure 2). Households without cars increased from 10.6% to 11.1% (Figure 3).
- Total personal trips made by San Diego residents decreased by 0.4% (Figure 4)
- San Diego resident mode shares (Figure 5):
    - DA decreased from 45.4% to 45.2%
    - SR2 decreased from 23.6% to 23.4%
    - SR3 decreased from 16.0% to 15.9%
    - Transit increased from 2.9% to 3.0%
    - Active modes (walk, bike, and micromobility) increased from 10.7% to 10.9%
- Transit boarding increased by 2.7% (Figure 6)
- Average San Diego resident trip distance decreased from 6.1 miles to 6.0 miles. Work trip distance decreased. Trip distance of non-mandatory trips such as recreational, eating out, maintenance, and shopping also decreased (Table 3).

These results confirm that ABM2+ is sensitive to land use alternatives. When households and population growth are concentrated in urban core areas, the model indicated lower VMT, lower auto mode shares, higher walk, bike, and transit mode shares, and shorter trip distances. Another interesting finding was that total person trips decreased, which may be caused by reduced auto ownership. It should be noted that the tested alternatives did not include employment growth.

Figure 1. VMT Change: Land Use Alternatives vs 2050 Baseline (tests 2 and 3)

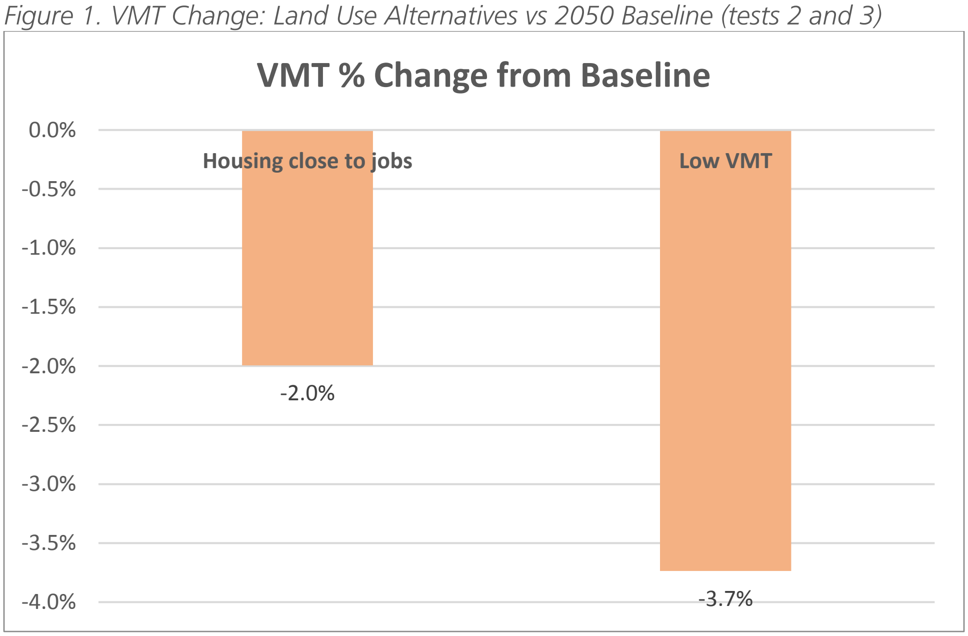


Figure 2. Average Auto Ownership: Land Use Alternatives vs 2050 Baseline (tests 2 and 3)

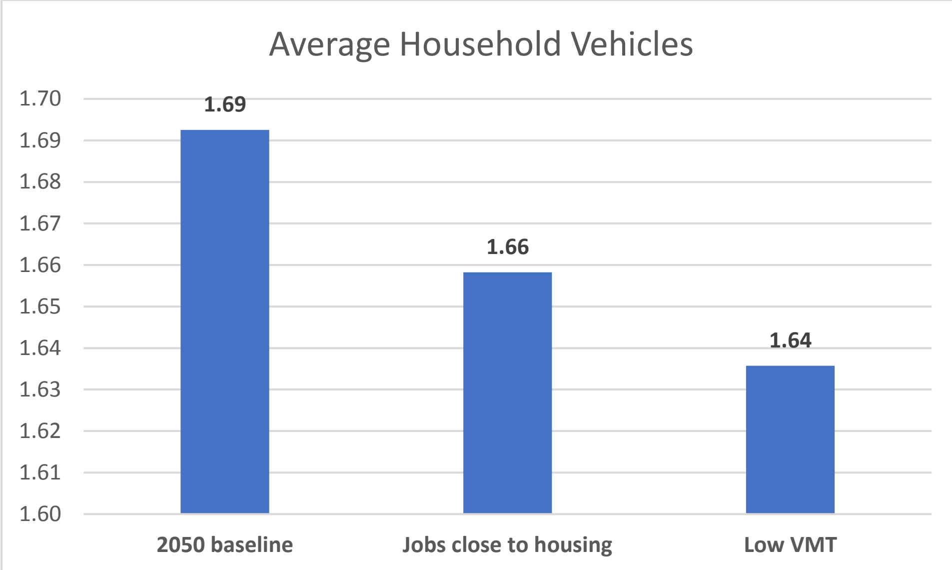


Figure 3. Average Auto Ownership by Number of Vehs: Land Use Alternatives vs 2050 Baseline (tests 2 and 3)

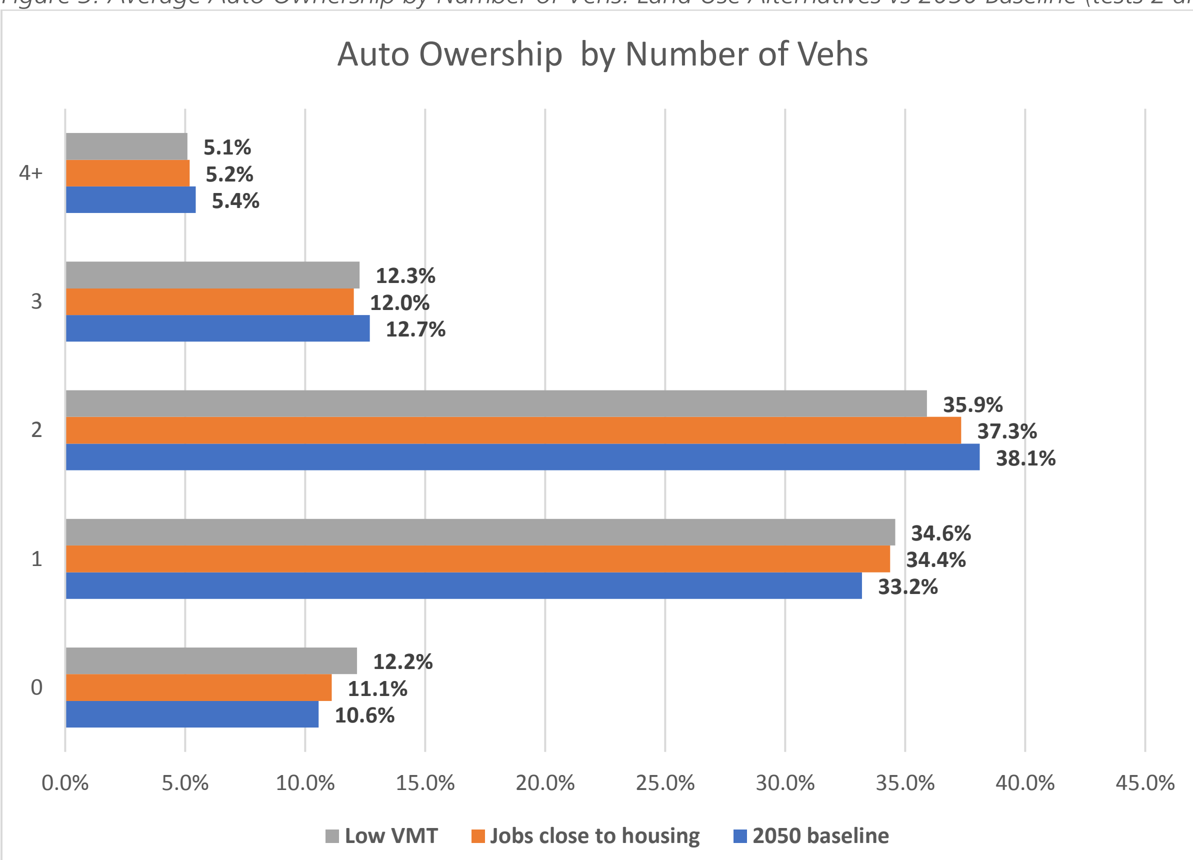


Figure 4. Total Person Trips: Land Use Alternatives vs 2050 Baseline (tests 2 and 3)

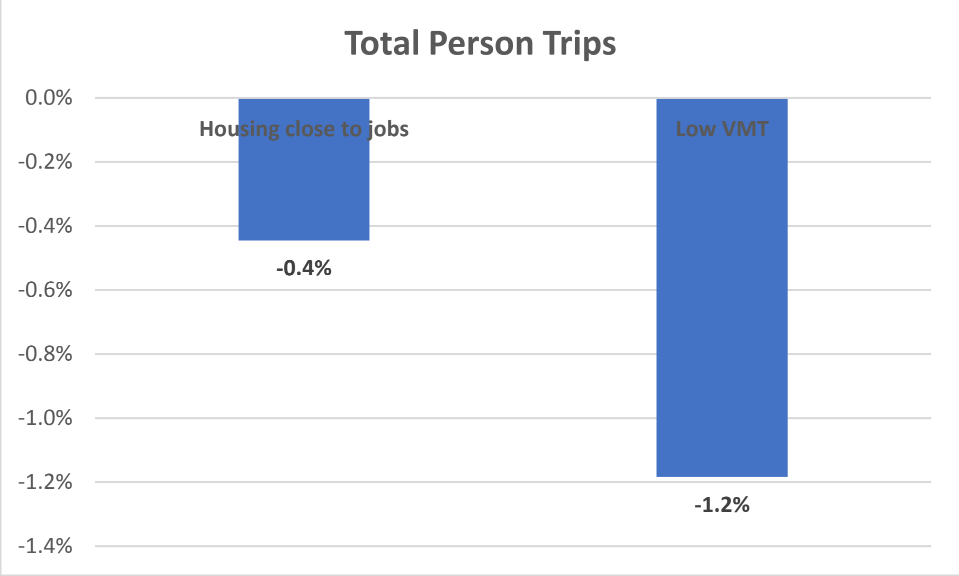


Figure 5. Mode Share of Person Trips: Land Use Alternatives vs 2050 Baseline (tests 2 and 3)

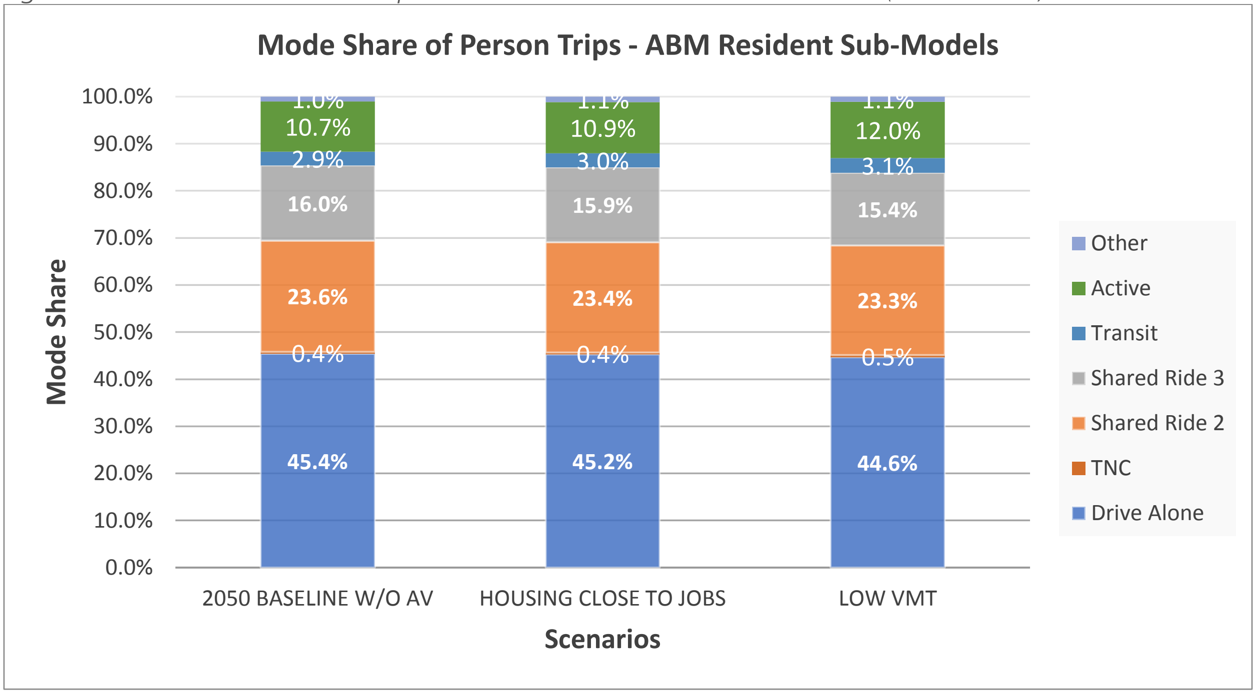


Figure 6. Transit Boarding Change from Baseline: Land Use Alternatives vs 2050 Baseline (tests 2 and 3)

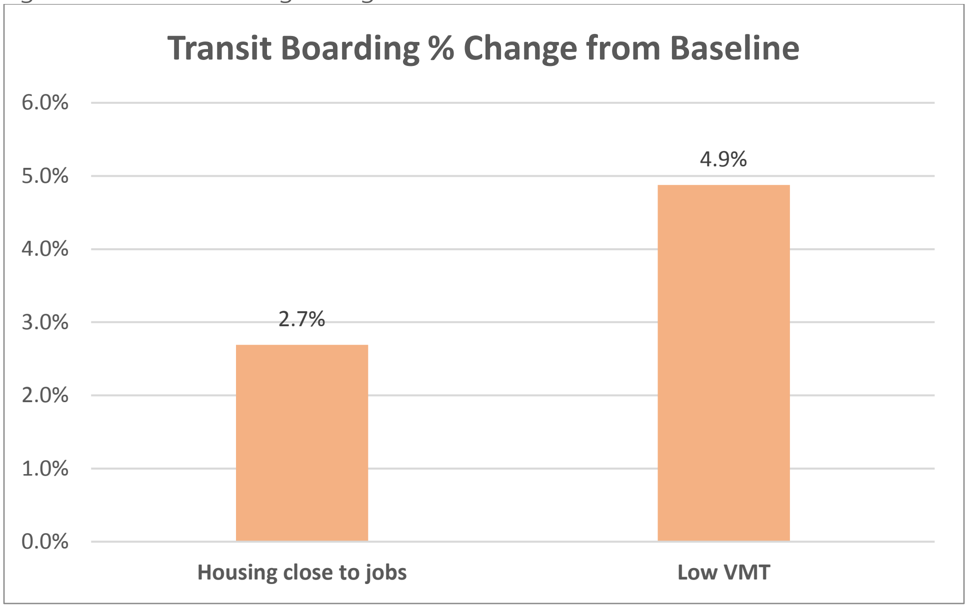


Table 3. Person Trip Distance by Purpose: Land Use Alternatives vs 2050 Baseline (tests 2 and 3)

Alternative	Rec.	Dining	Escort	Home	Maint.	School	Shop	Univ	Visit	Work	Total
2050 baseline w/o AV	4.9	5.3	5.2	6.0	5.1	4.6	4.2	8.2	5.8	10.3	6.1
Housing close to jobs	4.7	5.2	5.1	5.9	4.9	4.6	4.2	8.1	5.8	10.2	6.0
Low VMT	4.6	5.1	4.9	5.7	4.9	4.3	4.0	8.2	5.6	10.3	5.9

Residential Density & Intersection Density Tests (Tests 4-7)

Compared with the 2050 baseline, the 50% higher residential density test had the following results:

- VMT decreased by 1.1% (Figure 7)
- San Diego resident mode shares (Figure 8):
  - DA decreased from 45.4% to 44.8%
  - SR3 decreased from 16.0% to 15.7%
  - Transit increased from 2.9% to 3.3%
  - Active modes (walk, bike, and micromobility) increased from 10.7% to 11.1%
- Transit boarding increased by over 10% (Figure 9)

Compared with the 2050 baseline, the 50% lower residential density test had the following results:

- VMT increased by 0.9 % (Figure 7)
- San Diego resident mode shares (Figure 8):
  - DA increased from 45.4% to 46.0%
  - Transit decreased from 2.9% to 2.6%
  - Active mode (walk, bike, and micromobility) decreased from 10.7% to 10.2%

- Transit boarding decreased by nearly 10% (Figure 9)

These results confirm that the ABM2+ is sensitive to residential density. When residential density increased, the model indicated lower VMT, lower auto mode shares, and higher walk, bike, and transit mode shares. When residential density decreased, the opposite effects were observed. It should be noted that these are simply hypothesis tests which hold all other variables constant, neglecting the supply-demand interaction between inter-dependent variables. In the SANDAG model, residential densities are calculated from the synthetic population and MGRA acreage. Since the synthetic population was not altered, the test results should not be interpreted as the effects of +-50% population changes.

Compared with the 2050 baseline, the 10% higher intersection density test had the following results:

- Insignificant VMT change (Figure 7)
- Active mode (walk, bike, and micromobility) increased slightly from 10.7% to 10.8% (Figure 8)
- Transit boarding increased slightly by 1.0% (Figure 9)

Compared with the 2050 baseline, the 10% lower intersection density test had the following results:

- Insignificant VMT change (Figure 7)
- Active mode (walk, bike, and micromobility) decreased slightly from 10.7% to 10.4% (Figure 8)
- Insignificant Transit boarding change (Figure 9)

Although ABM2+ responds to intersection density changes in the expected direction, the impact of +-10% intersection density changes were limited. When intersection density increased, the model indicated slightly higher walk, bike, and transit mode shares. When intersection density decreased, the opposite effects were observed. It should be noted that these are simply hypothesis tests which holds all other variables constant, neglecting the supply-demand interaction between inter-dependent variables. In the SANDAG model, walk and bike times are calculated between each MGRA using an all-streets network. In this test, only the intersection density variable at the MGRA level was changed; the actual network was not altered from the baseline scenario. Therefore, the non-motorized times and distances in the model were unchanged from the baseline scenario; the test results should not be interpreted as the effects of +-10% road network build in the region.

Figure 7. VMT Change: Residential Density & Intersection Density Tests (Tests 4-7)

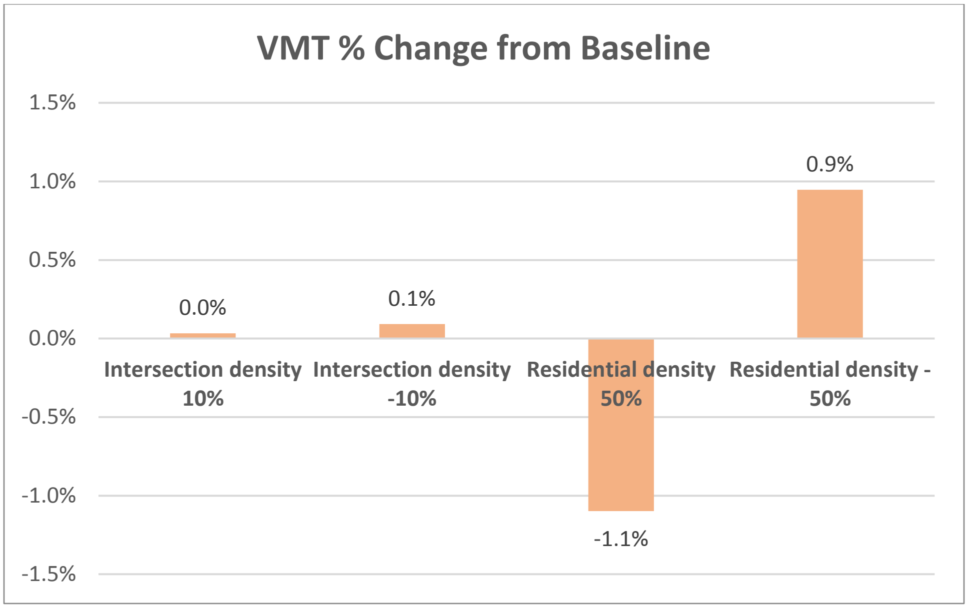

VMT % Change from Baseline
1.5%
1.0%
0.5%
0.0%
-0.5%
-1.0%
-1.5%
0.0%
0.1%
-1.1%
0.9%
Intersection density 10%
Intersection density -10%
Residential density 50%
Residential density -50%

Figure 8. Mode Share of Person Trips: Residential Density & Intersection Density Tests (Tests 4-7)

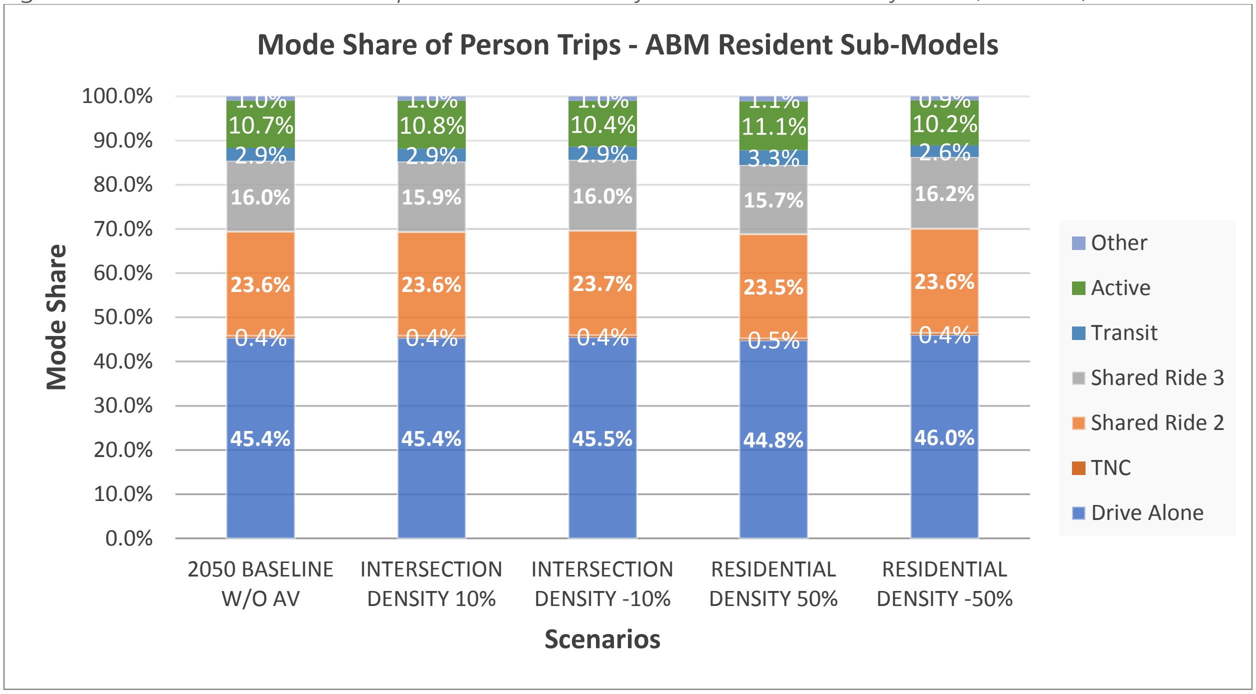
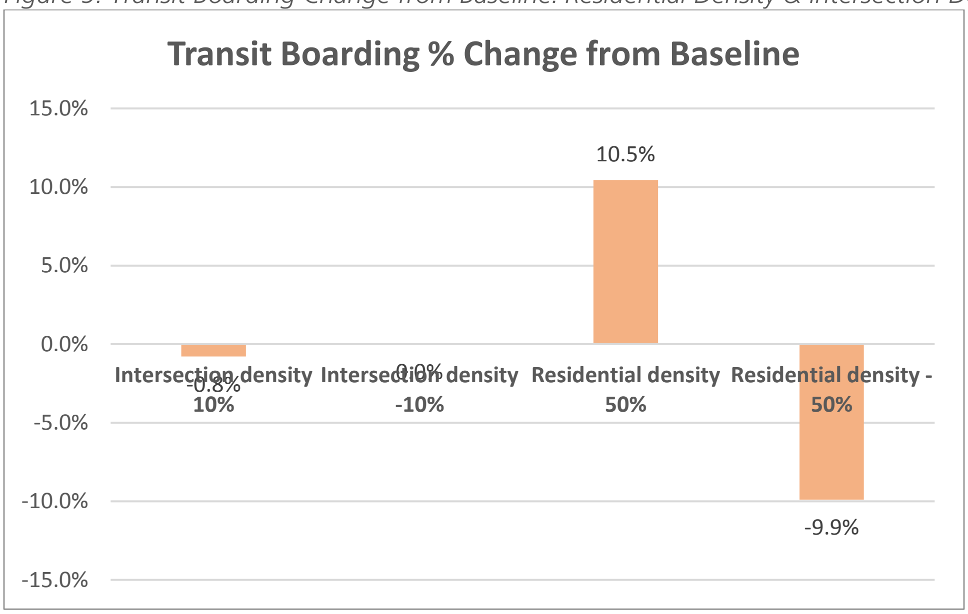


Figure 9. Transit Boarding Change from Baseline: Residential Density & Intersection Density Tests (Tests 4-7)



Transit and Active Transportation

Transit Headway Tests (Tests 9 & 10)

Compared with the 2035 baseline, the 50% more frequent transit services test had the following results:

- VMT increased by 0.3% (Figure 10)

- Mode share for all models (Figure 11):
    - DA decreased from 45.3% to 45.1%
    - Transit increased from 2.7% to 3.1%
- Transit boarding increased by over 16% (Figure 12), suggesting that a 1 percent increase in transit frequency will lead to a ridership increase of 0.32% (elasticity of 0.32).

Compared with the 2035 baseline, the 50% less frequent transit services test had the following results:

- Insignificant VMT change (Figure 13)
- Mode share changes of all models (Figure 11):
    - DA increased from 45.3% to 45.5%
    - Transit decreased from 2.7% to 2.5%
- Transit boarding decreased by over 11% (Figure 12), suggesting that a 1 percent decrease in transit frequency will lead to a ridership decrease of 0.22% (elasticity of 0.22).

The results confirm that ABM2+ is sensitive to transit frequency. When transit services frequency improved, the model indicated higher transit mode share, lower drive alone mode share, and higher transit boardings. When transit services frequency was decreased, the opposite effects were observed. It should be noted that transit boardings changed the most on routes whose headways were changed the most; in other words, reducing headway from 60 minutes to 30 minutes has a much larger effect than changing the headway from 10 minutes to 5 minutes. Another interesting finding was that VMT increased slightly when transit services improved. This may be caused by the additional bus VMT generated by the more frequent services (Table 4).

Figure 10. VMT Change: Transit Headway Tests (Tests 9 & 10)

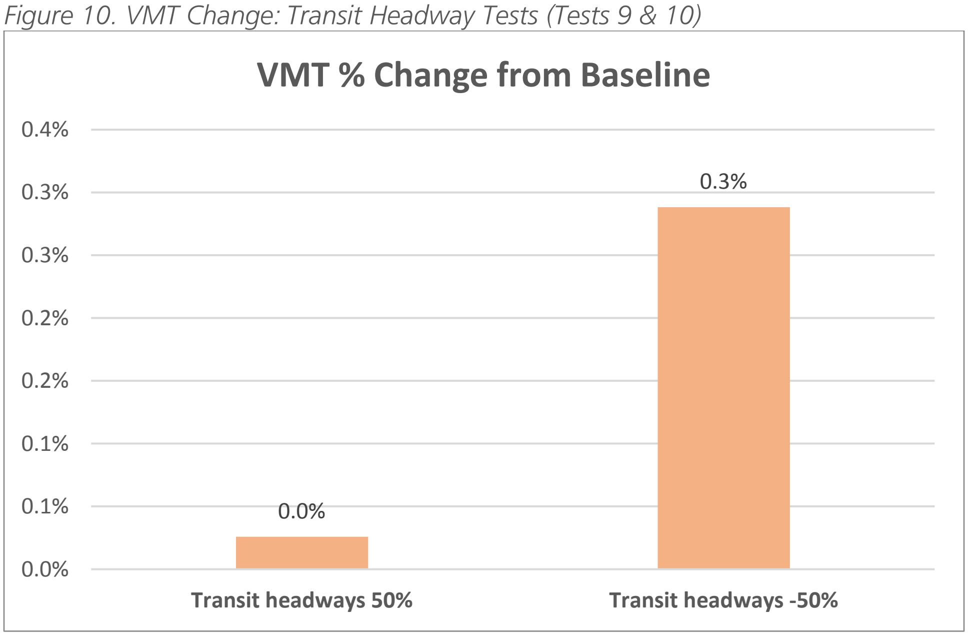


Figure 11. Mode Share of Person Trips: Transit Headway Tests (Tests 9 & 10)

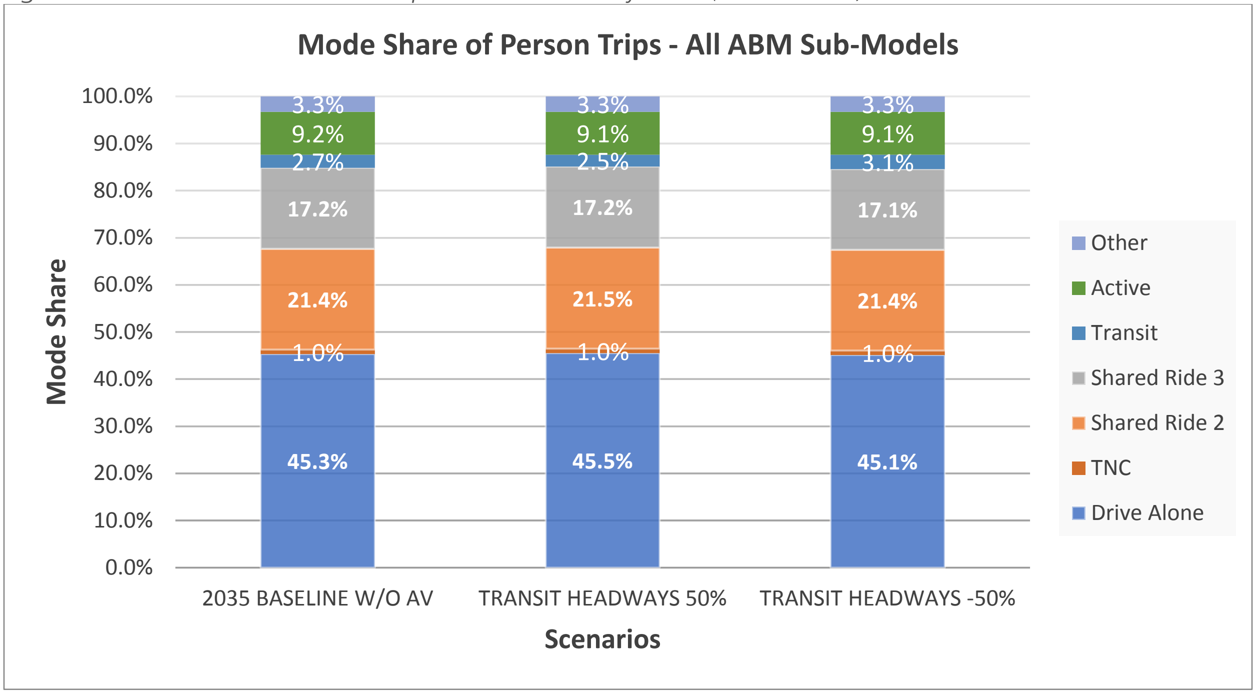


Figure 12. Transit Boarding Change from Baseline: Transit Headway Tests (Tests 9 & 10)

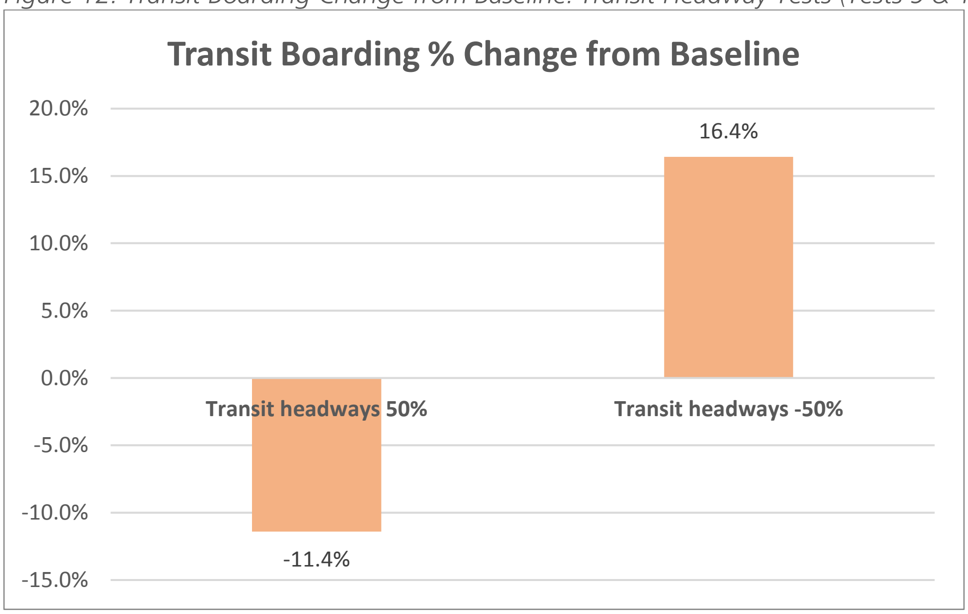


Figure 13. VMT Change from Baseline (Bus Excluded): Transit Headway Tests (Tests 9 & 10)

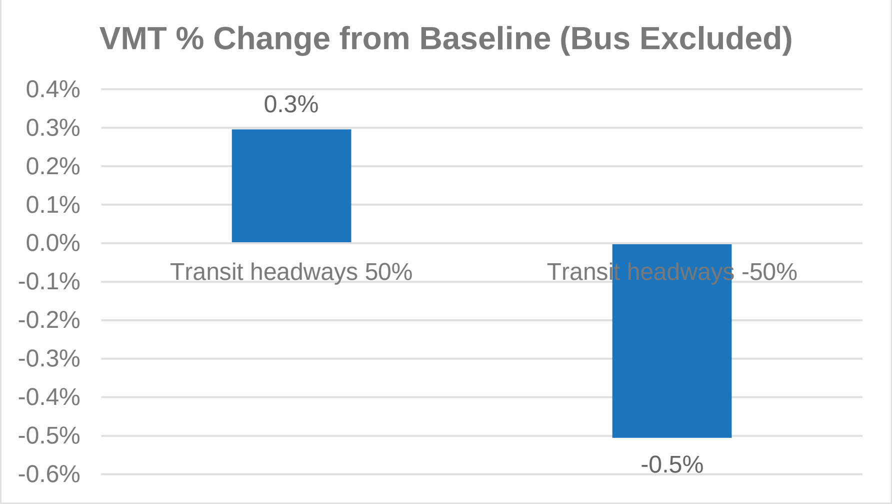


Table 4. VMT by Mode: Transit Headway Tests (Tests 9 & 10)

description	Auto	Truck	Bus	Total	VMT % Change	Total (Bus Excluded)	VMT % Change
2035 baseline w/o AV	90,028,010	4,911,338	762,403	95,701,751	-	94,939,348	
Transit headways 50%	90,306,080	4,914,248	506,083	95,726,411	0.0%	95,220,328	0.3%
Transit headways -50%	89,563,664	4,895,720	1,518,248	95,977,632	0.3%	94,459,384	-0.5%

Self-Owned E-Bike Tests (Tests 11&12)

The average regular bike speed is 10mph. To test the impact of faster self-owned E-Bikes, staff created two scenarios by increasing the average bike speed to 12mph and 15mph. If the E-Bike speed is 15mph, the average 12mph bike speed scenario represents that 40% of all bikes are E-Bike. The average 15mph bike speed scenario represents that 100% of all bikes are E-Bikes.

Compared with the 2035 baseline, the test which increased bike speed from 10 mph to 12 mph had the following results:

- VMT decreased slightly by 0.1% (Figure 14)
- Mode shares of all models (Figure 16):
    - DA decreased from 45.8% to 45.7%
    - Active mode (walk, bike, and micromobility) increased from 10.0% to 10.1%
- Average bike distance increased from 3.3 miles to 3.6 miles (Table 5)

Compared with the 2035 baseline (with AV), the test which increased bike speed from 10 mph to 15 mph had the following results:

- VMT decreased by 0.3% (Figure 14)
- Mode share changes (Figure 16):
    - DA decreased from 45.8% to 45.6%

  - Active mode (walk, bike, and micromobility) increased from 10.0% to 10.3%
- Average bike distance increased from 3.3 miles to 4.1 miles; Transit, regular TNC, and pool TNC distances all increased slightly (Table 5).

The results confirm that ABM2+ is sensitive to bike speed. When bike speed increased, the model indicated lower VMT, lower drive alone mode share, and higher active mode (walk, bike, and micromobility) mode share. The slightly lowered transit mode share suggests that there is competition between transit mode and bike mode (Figure 15). As bike speed increased, the average bike distance also increased.

Figure 14. VMT Change: Self-Owned E-Bike Tests (Tests 11&12)

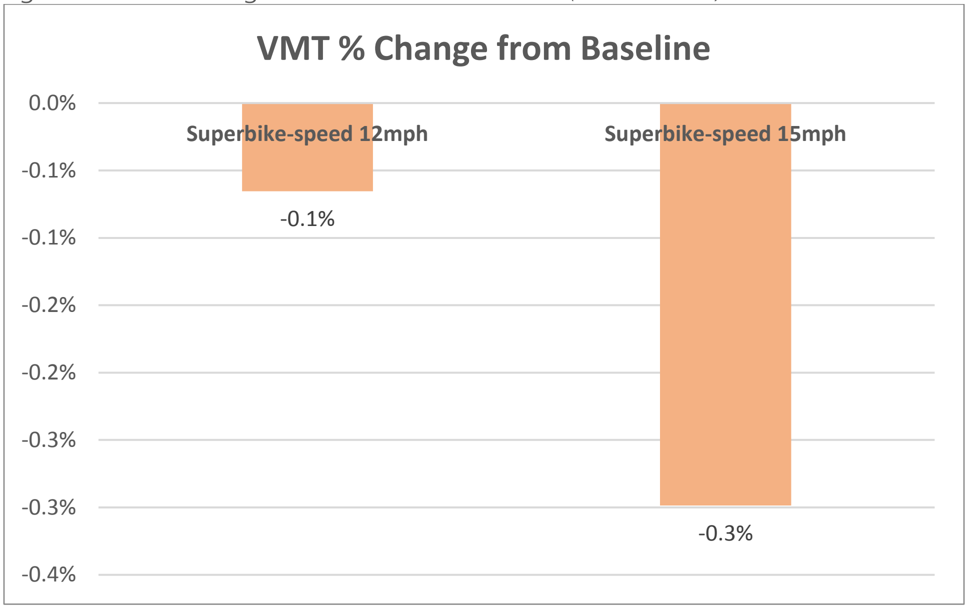


Figure 15. Transit Boarding Change: Self-Owned E-Bike Tests (Tests 11&12)

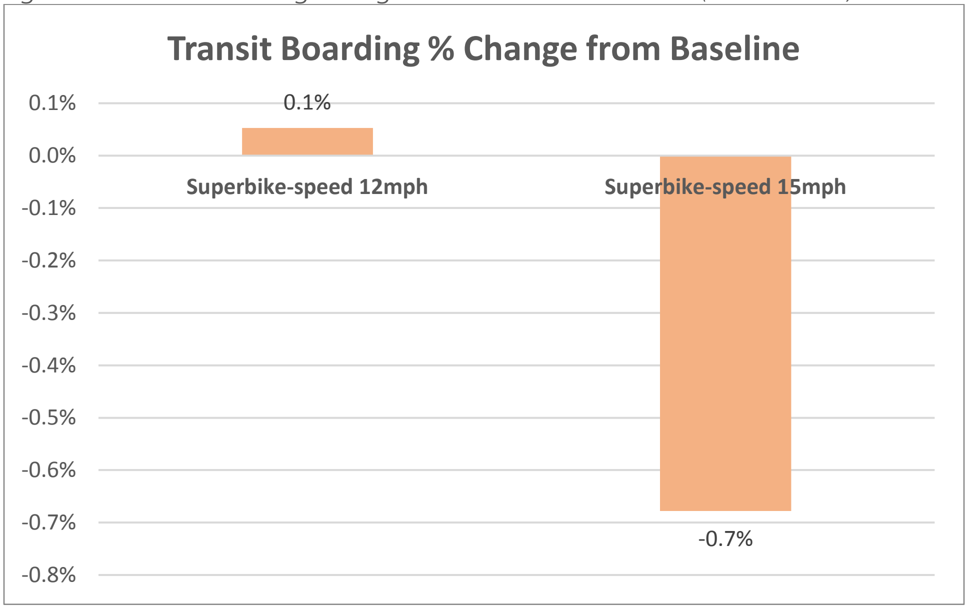


Figure 16. Mode Share of Person Trips: Self-Owned E-Bike Tests (Tests 11&12)

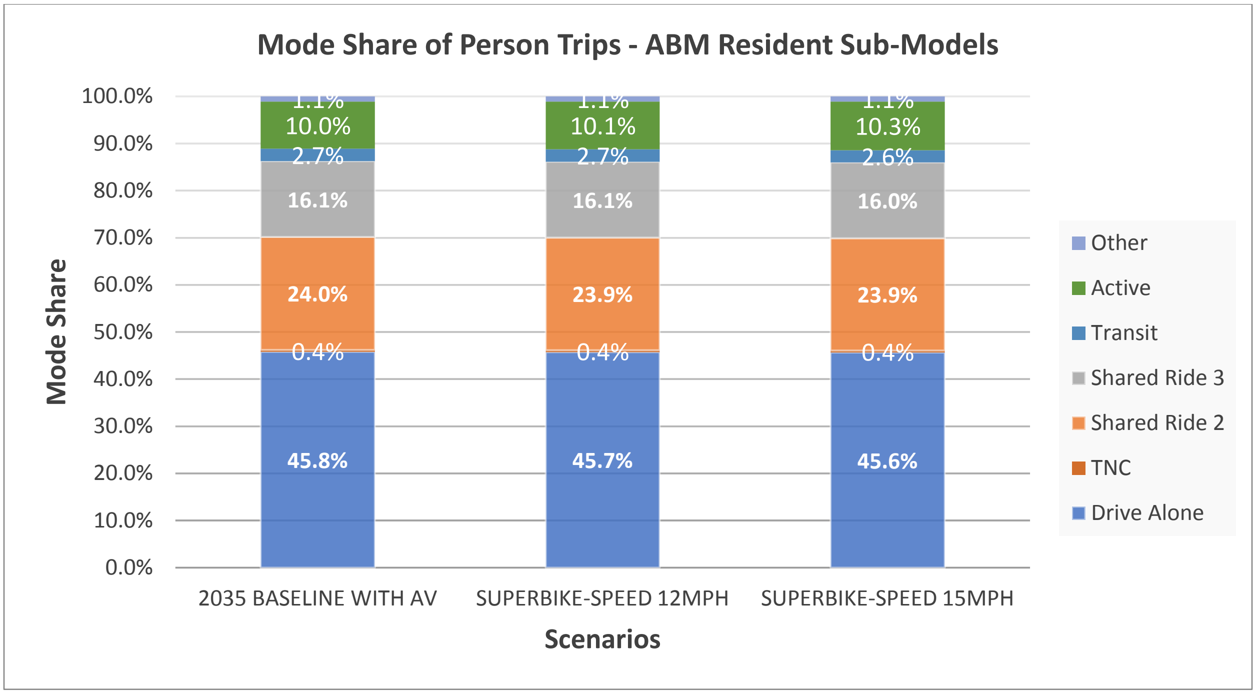


Table 5. Trip Length by Mode: Self-Owned E-Bike Tests (Tests 11&12)

description	DA	SR2	SR3	TNC	Pooled TNC	Walk	Bike	Transit	Total
2035 baseline with AV	8.0	7.2	8.3	7.7	6.0	0.8	3.3	9.1	7.3
Superbike-speed 12mph	7.9	7.2	8.3	7.8	6.1	0.8	3.0	9.2	7.3
Superbike-speed 15mph	8.0	7.2	8.3	7.7	6.1	0.8	2.7	9.2	7.3

Local/Regional Pricing

Auto Operating Cost (AOC) Tests (Tests 13 & 14)

Compared with the 2035 baseline, the 50% AOC increase test had the following results:

- VMT decreased by 5% (Figure 17), suggesting that a 1 percent increase in AOC will lead to a VMT decrease of 0.1% (elasticity of -0.1).
- Mode shares for all models (Figure 18):
  - DA decreased from 45.3% to 44.9%
  - SR2 decreased from 21.4% to 21.3%
  - SR3 decreased from 17.2% to 16.8%
  - Transit mode share increased from 2.7% to 3.1%
  - Active modes (walk, bike, and micromobility) increased from 9.2% to 9.5%
- Transit boarding increased by nearly 14% (Figure 19)
- Average trip distance decreased from 7.2 miles to 7.0 miles; DA, SR2, and SR3 trip distances all decreased; Transit trip distance increased (Table 6).

- Total person trips for San Diego residents and all travelers decreased by 1.5% and 1.7%, respectively (Figure 20).

Compared with the 2035 baseline, the 50% AOC decrease test had the following results:

- VMT increased by 3.8% (Figure 17), suggesting that a 1 percent decrease in AOC will lead to a VMT increase of 0.08% (elasticity of -0.08).
- Mode share changes for all models (Figure 18):
    - DA increased from 45.3% to 45.7%
    - SR2 increased from 21.4% to 21.6%
    - SR3 increased from 17.2% to 17.6%
    - Transit mode share decreased from 2.6% to 2.3%
    - Active mode (walk, bike, and micromobility) decreased from 9.2% to 8.8%
- Transit boarding decreased by nearly 14% (Figure 19).
- Average trip distance increased from 7.2 miles to 7.5 miles; DA, SR2, and SR3 trip distances all increased; Transit trip distance decreased (Table 6).
- Total personal trips for San Diego residents and all travelers increased by 1.8% and 2.0% respectively (Figure 20).

The results confirm that auto operating cost is a key variable that affects VMT and mode share. When AOC increased, the model indicated lower auto mode share, higher transit, walk, bike, and micromobility mode shares, and shorter trip distance. The AOC increase, essentially making driving less affordable, lowered overall travel demand by 1.7%. The combined effect of mode share shifts toward non-auto modes, reduced travel demand, and shorter trip distance resulted in significant VMT decrease. When AOC decreased, the opposite effects were observed.

Figure 17. VMT Change from Baseline: Auto Operating Cost (AOC) Tests (Tests 13 & 14)

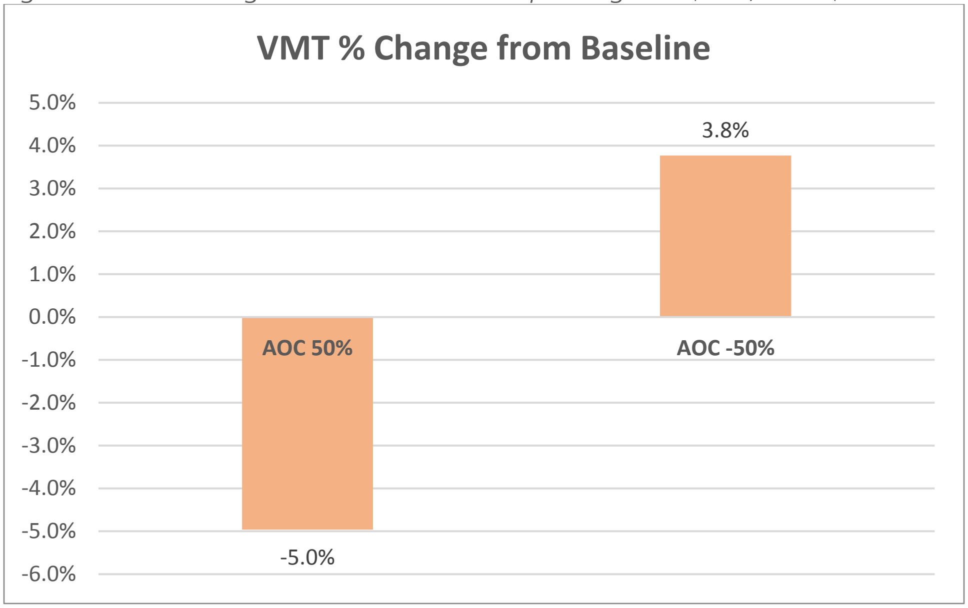


Figure 18. Mode Share of Person Trips: Auto Operating Cost (AOC) Tests (Tests 13 & 14)

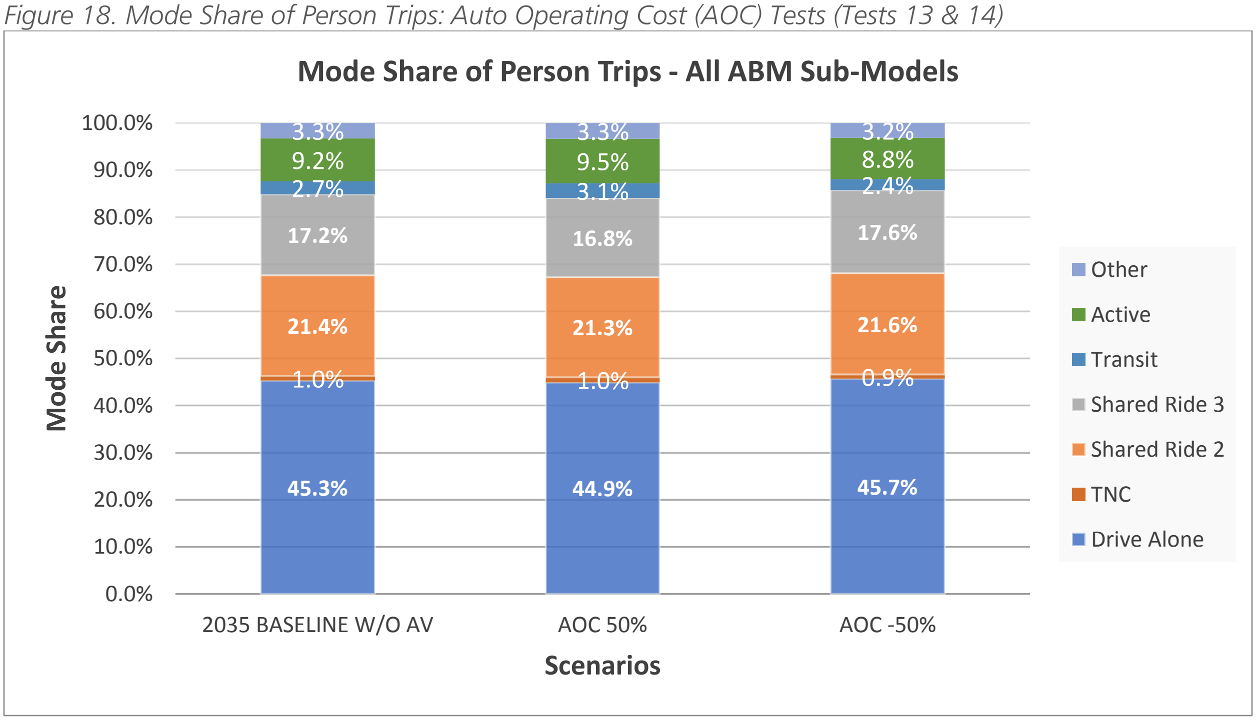


Figure 19. Transit Boarding Change from Baseline: Auto Operating Cost (AOC) Tests (Tests 13 & 14)

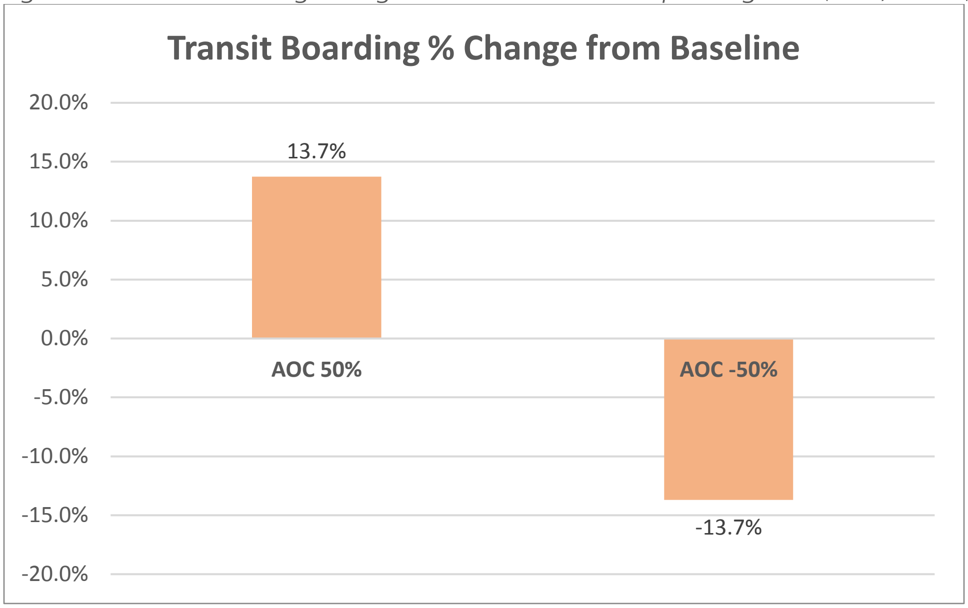


Figure 20. Total Person Trips Change from Baseline: *Auto Operating Cost (AOC) Tests (Tests 13 & 14)*

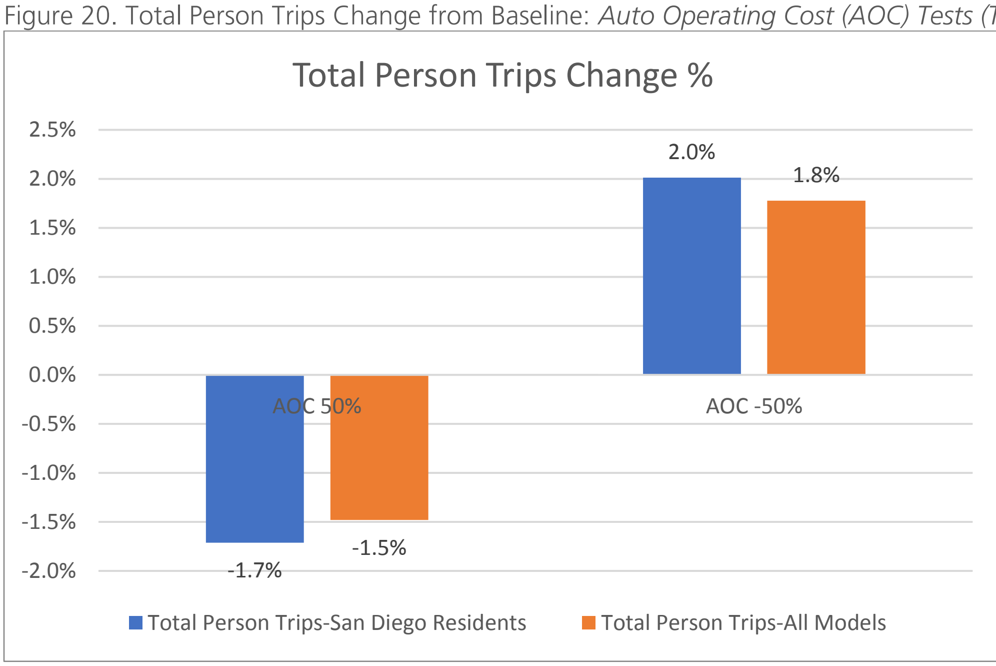


Table 6. Person Trip Distance by Mode: Auto Operating Cost (AOC) Tests (Tests 13 & 14)

description	DA	SR2	SR3	TNC	Pooled TNC	Walk	Bike	Transit	Total
2035 baseline w/o AV	7.9	7.2	7.8	7.6	4.8	0.8	3.2	9.2	7.2
AOC 50%	7.7	7.0	7.4	7.8	5.0	0.8	3.3	9.7	7.0
AOC -50%	8.2	7.5	8.4	7.5	4.6	0.8	3.0	8.8	7.5

Transit Fare Tests (Tests 15-17)

Compared with the 2035 baseline, the free transit fare test had the following results:

- VMT decreased by 1.1% (Figure 21)
- Mode shares for all models (Figure 22):
    - DA decreased from 45.3% to 44.6%
    - SR3 decreased from 17.2% to 16.9%
    - Transit increased from 2.7% to 4.0%
    - Active modes (walk, bike, and micromobility) decreased slightly from 9.2% to 9.0%
- Transit boarding increased by nearly 50% (Figure 23), suggesting that a 1 percent decrease in transit fare will lead to a transit ridership increase of 0.5% (elasticity of -0.5).

Compared with the 2035 baseline, the 50% fare decrease test had the following results:

- VMT decreased by 0.5% (Figure 21)
- Mode shares of all models (Figure 22):
    - DA decreased from 45.3% to 45.0%
    - Transit increased from 2.7% to 3.3%
    - Active modes (walk, bike, and micromobility) decreased slightly from 9.2% to 9.1%
- Transit boarding increased by over 20% (Figure 23), suggesting that a 1 percent decrease in transit fare will lead to transit ridership increase of 0.4% (elasticity of -0.4).

Compared with the 2035 baseline, the 50% fare increase test had the following results:

- VMT increased by 0.4% (Figure 21)
- Mode share changes (Figure 22):
    - DA increased from 45.3% to 45.6%
    - Transit decreased from 2.7% to 2.3%
- Transit boarding decreased by 17% (Figure 23), suggesting that a 1 percent increase in transit fare will lead to a transit ridership decrease of 0.38% (elasticity of -0.38).

The results confirm that ABM2+ is sensitive to transit fares. When transit fares decreased, the model indicated lower VMT, higher transit mode share, and lower drive alone mode share. The slightly lower walk, bike, and micromobility mode shares suggest that there is competition between transit mode and walk, bike, and micromobility modes. When transit fares increased, the opposite effects were observed.

Figure 21. Total Person Trips Change from Baseline: *Transit Fare Tests (Tests 15-17)*

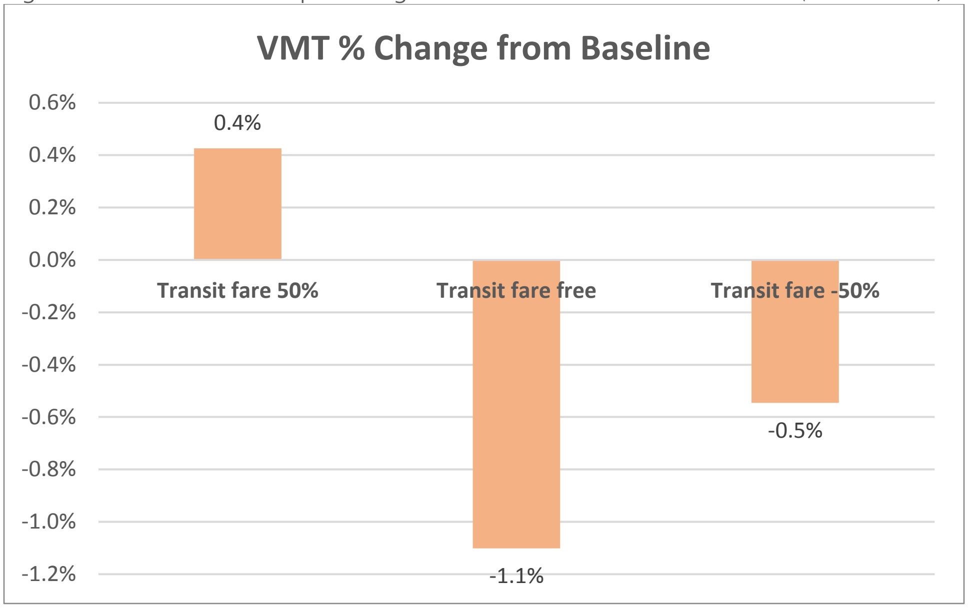


Figure 22. Mode Share of Person Trips: *Transit Fare Tests (Tests 15-17)*

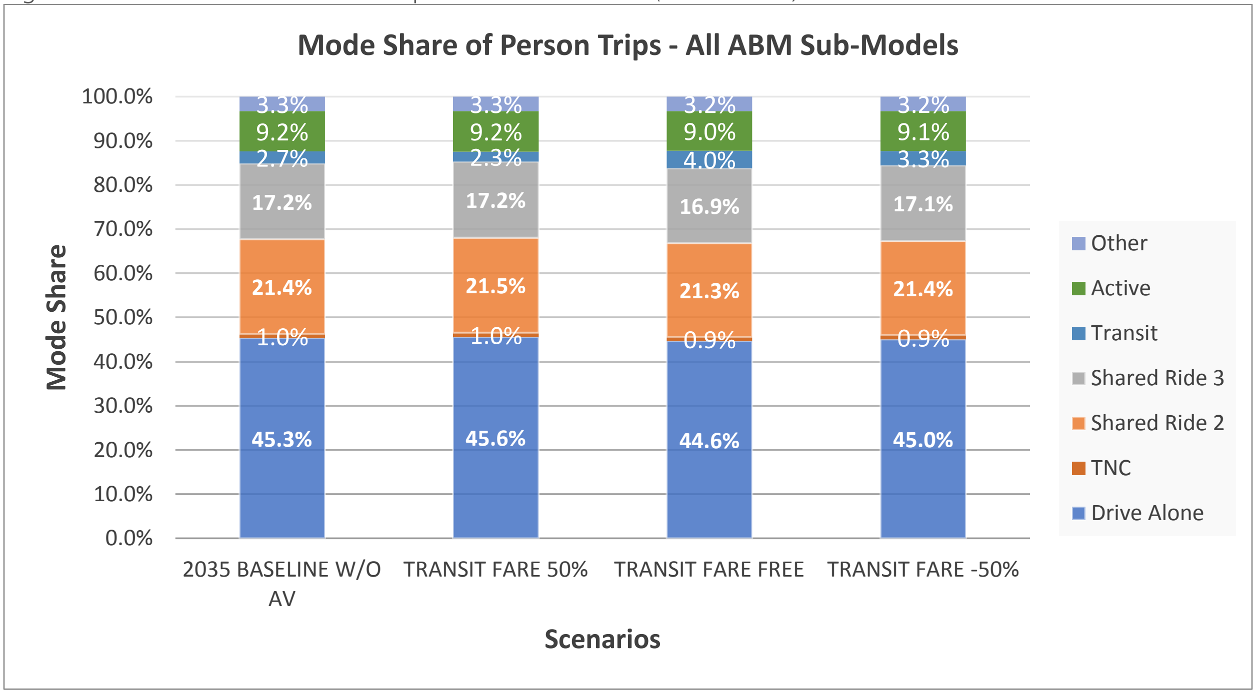
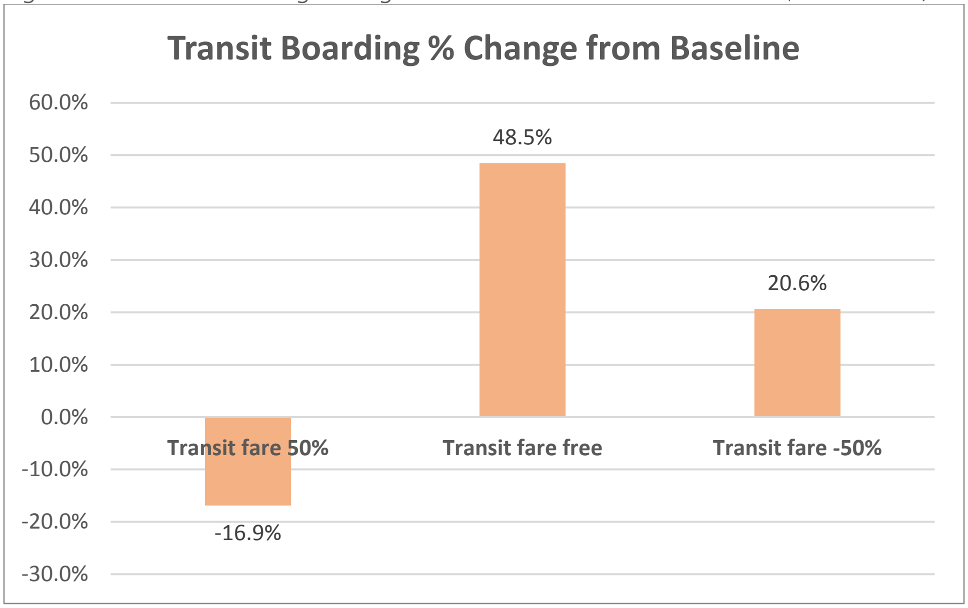


Figure 23. Transit Boarding Change from Baseline: *Transit Fare Tests (Tests 15-17)*



Managed Lane/Toll Price Tests (Tests 18 & 19)

Compared with the 2035 baseline, the 50% toll increase test had the following results:

- VMT decreased slightly by 0.1% (Figure 24)
- Percent of VMT on toll roads decreased from 3.2% to 2.6% (Figure 27)
- Insignificant mode share changes (Figure 25)
- Toll road volumes decreased significantly by 20% (Figure 26).

Compared with the 2035 baseline, the 50% toll decrease test had the following results:

- VMT increased by 0.2% (Figure 24)
- Percent of VMT on toll roads increased from 3.2% to 4.1% (Figure 27)
- Insignificant mode share changes (Figure 25)
- Toll road volumes increased by 33% (Table 26)

The results confirm that ABM2+ is sensitive to managed lane/toll pricing. When toll price increased, both traffic volumes and VMT on toll roads decreased significantly. However, the model only indicated slightly lower VMT primarily because toll roads are only a very small portion of San Diego's transportation system. Also note that on I-15, only single-occupant vehicles are tolled; therefore changing the toll cost only affects the price for SOV usage of the facility, and when SOV usage decreases, there is additional capacity for high-occupancy vehicles which may take advantage of the increased available capacity. When managed lane/toll price decreased, the opposite effects were observed.

Figure 24. VMT Change from Baseline: Managed Lane/Toll Price Tests (Tests 18 & 19)

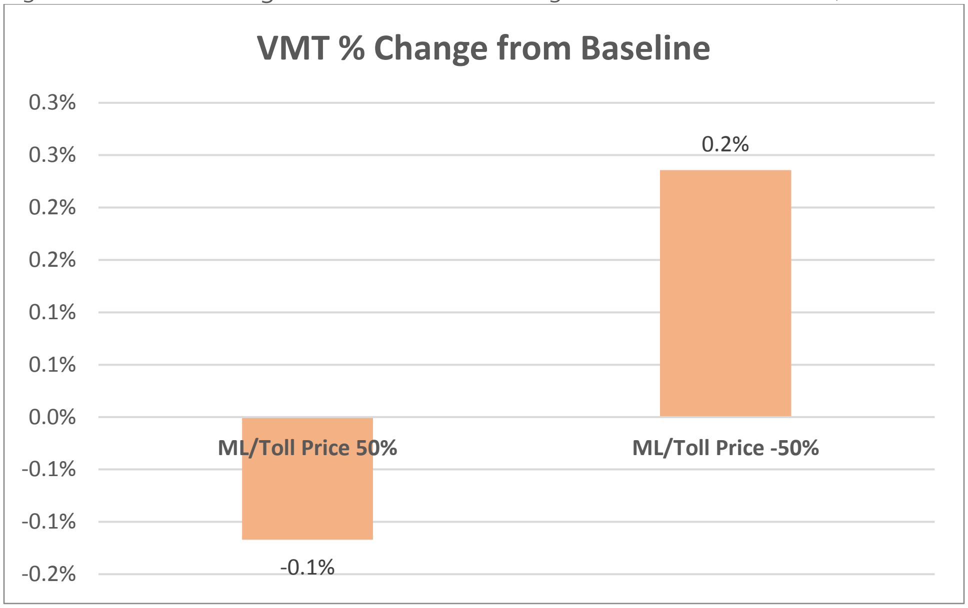


Figure 25. Mode Share of Person Trips: Managed Lane/Toll Price Tests (Tests 18 & 19)

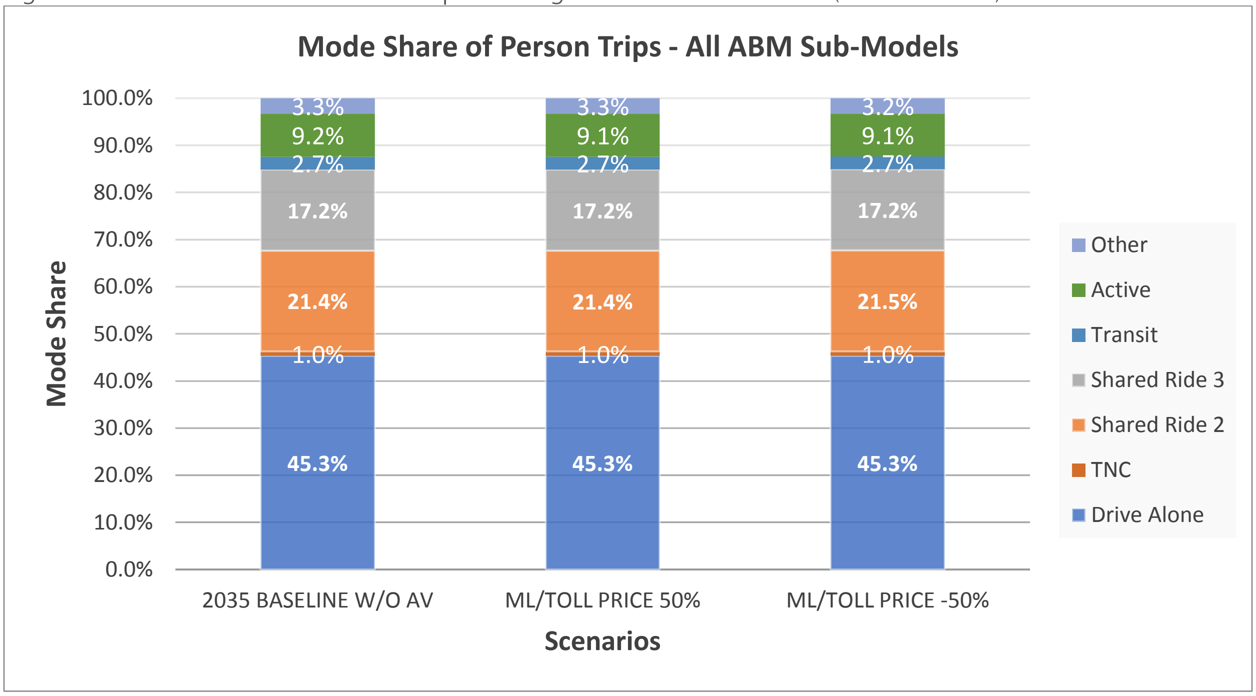


Figure 26. Toll Road Volumes Change from Baseline: Managed Lane/Toll Price Tests (Tests 18 & 19)

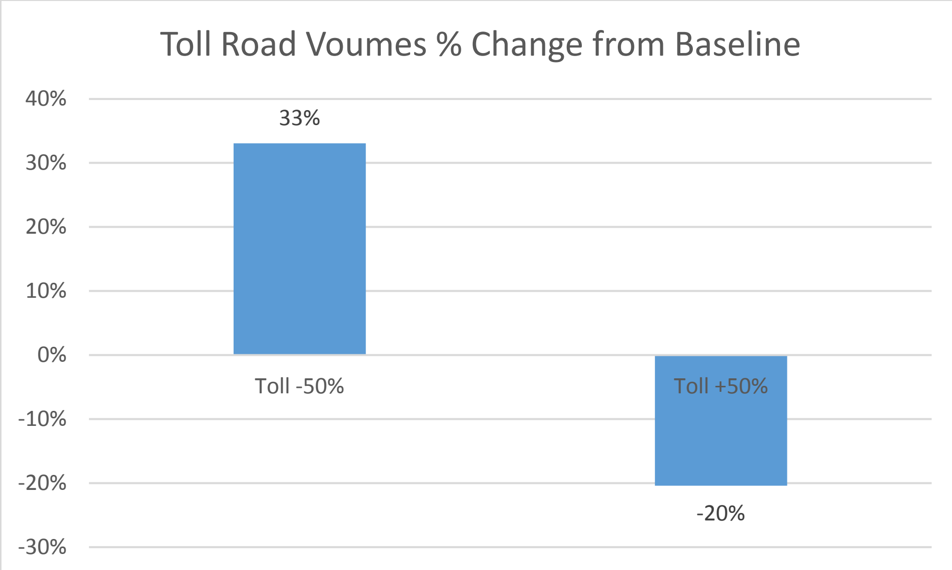
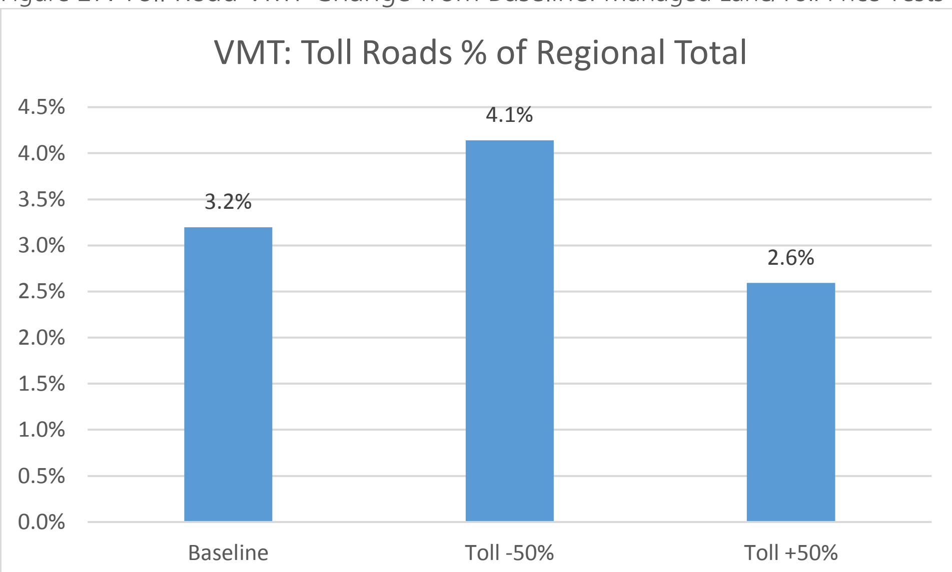


Figure 27. Toll Road VMT Change from Baseline: Managed Lane/Toll Price Tests (Tests 18 & 19)



Parking Cost Tests (Tests 20 & 21)

In comparison with the baseline, the high parking cost test had the following results:

- VMT decreased by 1.4% (Figure 28)
- Mode shares for all models (Figure 29):
  - DA decreased from 45.3% to 44.1%
  - SR3 increased from 17.2% to 17.4%

    - Transit increased from 2.7% to 3.2%
    - Active modes (walk, bike, and micromobility) increased from 9.2% to 9.5%
- Transit boarding increased by over 17% (Figure 30)
- Although the overall trip distance change was insignificant, DA trip distance increased slightly from 7.9 miles to 8.0 miles (Table 7).
- Total person and vehicle trips decreased by 0.2% and 0.4%, respectively (Figure 31).

In comparison with the baseline, a very high parking cost had the following results:

- VMT decreased by 2.8% (Figure 28);
- Mode share changes (Figure 29):
    - DA decreased from 45.3% to 42.7%
    - SR3 increased from 17.2% to 17.8%
    - Transit mode share increased from 2.7% to 3.6%
    - Active modes (walk, bike, and micromobility) increased from 9.2% to 10.1%
- Transit boarding increased by nearly 30% (Figure 30)
- Although the overall trip distance change was insignificant, DA trip distance increased from 7.9 miles to 8.1 miles (Table 7).
- Total person and vehicle trips decreased by 0.5% and 1.2%, respectively (Figure 31).

The results confirm that parking cost is a key variable that affects VMT and mode shares. When parking price increased, the model indicated lower VMT, lower DA mode share, higher transit mode share, and higher walk, bike, and micromobility mode shares. The slightly increased drive alone distance indicated that drivers park further away from destinations to avoid high parking fees.

Figure 28. VMT Change from Baseline: Parking Cost Tests (Tests 20 & 21)

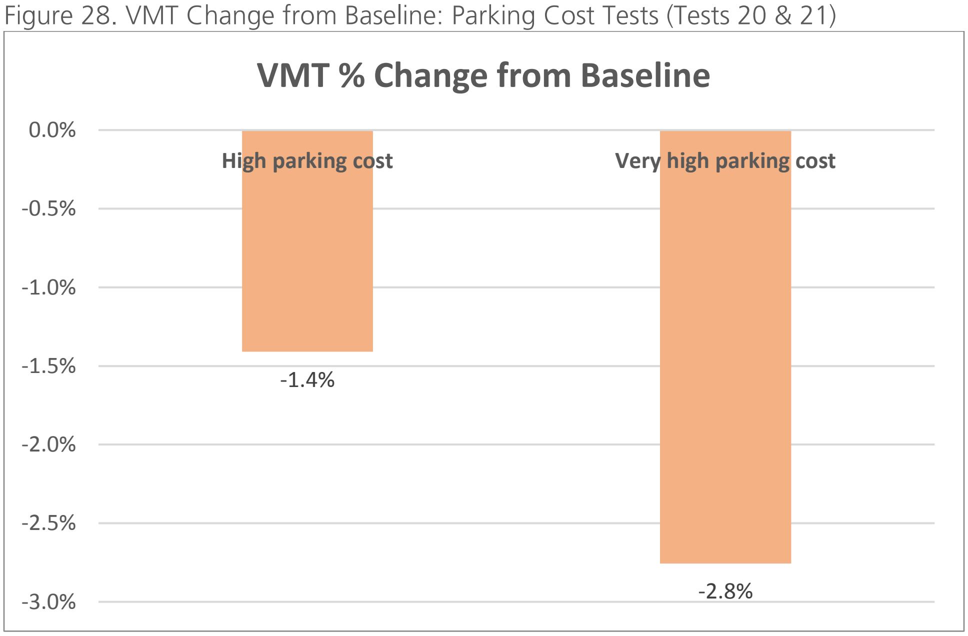


Figure 29. Mode Share of Person Trips: Parking Cost Tests (Tests 20 & 21)

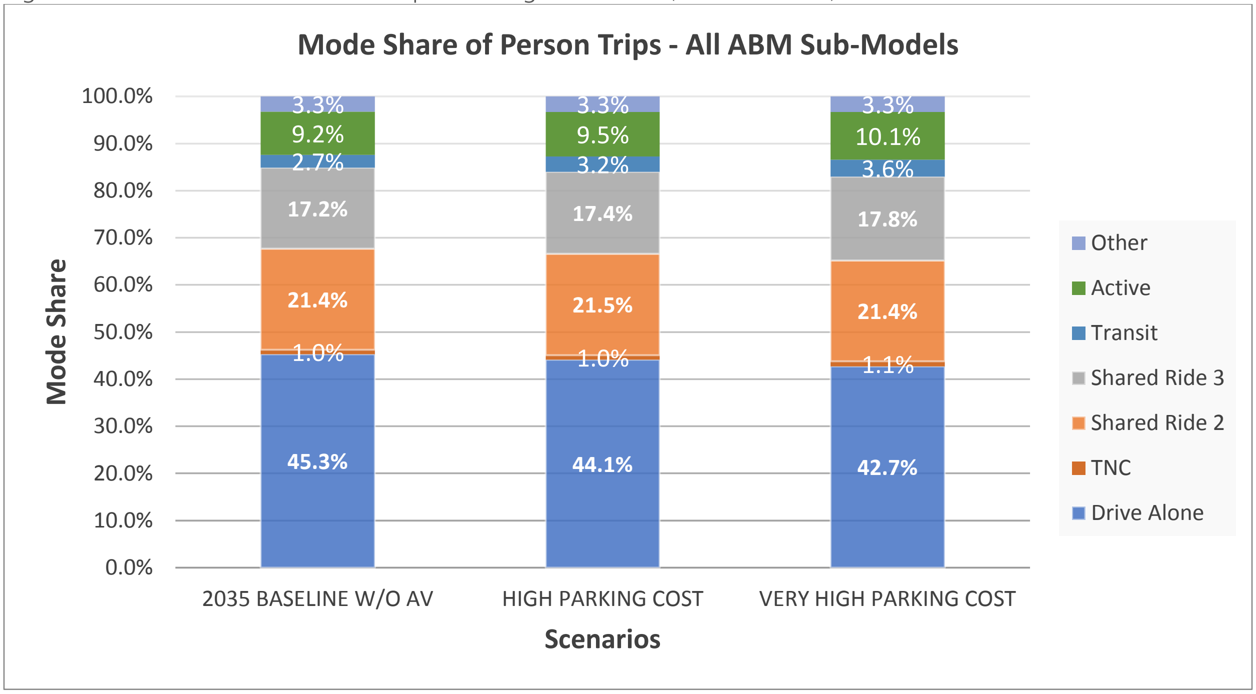


Figure 30. Transit Boarding Change from Baseline: Parking Cost Tests (Tests 20 & 21)

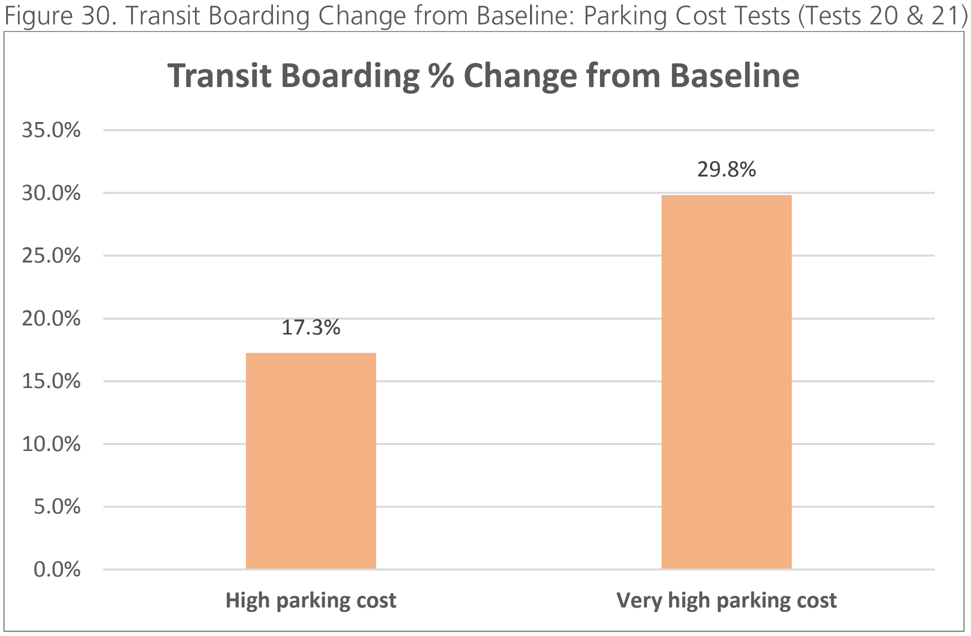


Figure 31. Total Person Trips and Trips Change from Baseline: Parking Cost Tests (Tests 20 & 21)

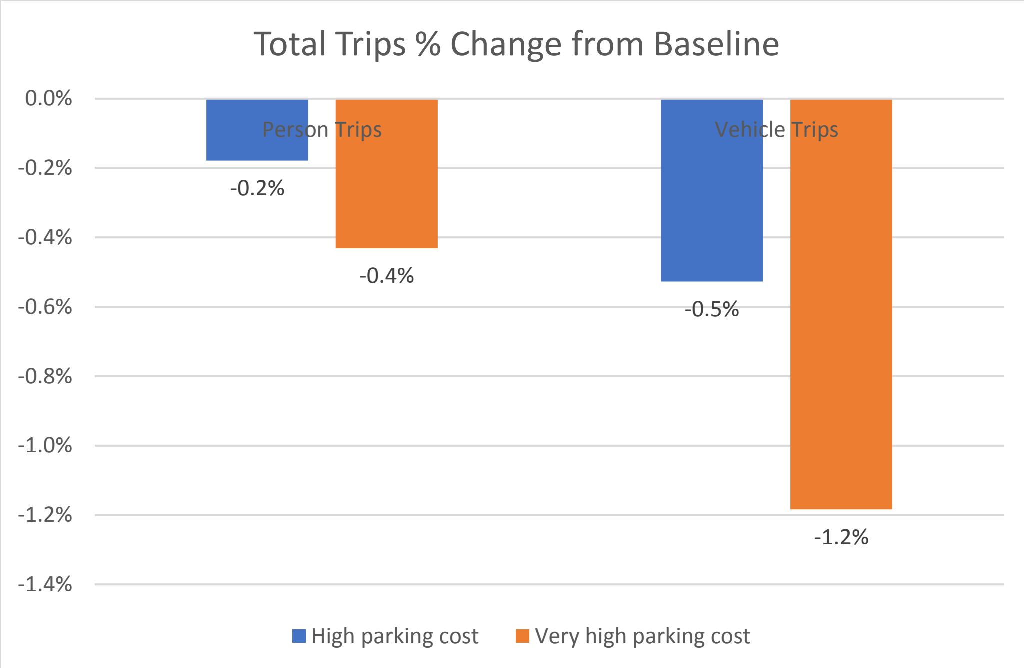


Table 7. Person Trip Distance by Mode: Parking Cost Tests (Tests 20 & 21)

description	DA	SR2	SR3	TNC	Pooled TNC	Walk	Bike	Transit	Total
2035 baseline w/o AV	7.9	7.2	7.8	7.6	4.8	0.8	3.2	9.2	7.2
High parking cost	8.0	7.2	7.8	7.5	4.7	0.8	3.2	9.2	7.2
Very high parking cost	8.1	7.3	7.8	7.3	4.7	0.8	3.2	9.2	7.2

Exogenous Variables

Free Flow Speed Tests (Tests 22 & 23)

Compared with the 2035 baseline, the 5mph free flow speed decrease on freeways test had the following results:

- VMT decreased by nearly 0.5% (Figure 32)
- Insignificant mode share changes (Figure 33)
- Average trip distance decreased slightly from 7.3 miles to 7.2 miles. DA, SR3, and truck trip distances all decreased (Table 8).

Compared with the 2035 baseline, the 5mph free flow speed decrease on all roadways test had the following results:

- VMT decreased by 1.3% (Figure 32)
- Insignificant mode share changes (Figure 33)
- Average trip distance decreased slightly from 7.3 miles to 7.2 miles. DA, SR3, and truck trip distances all decreased (Table 8).

The results lead to the conclusion that reducing free flow speed results in lower VMT. Although mode share changes were insignificant, average trip distance decreased, indicating that the lowered free flow speed discouraged longer trips.

Figure 32. VMT Change from Baseline: Free Flow Speed Tests (Tests 22 & 23)

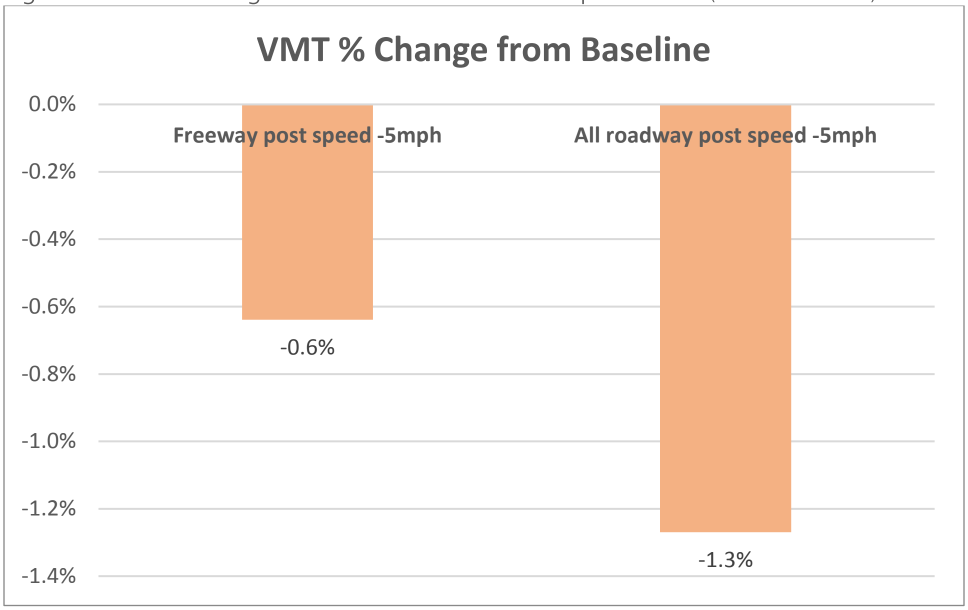


Figure 33. Mode Share of Person Trips: Free Flow Speed Tests (Tests 22 & 23)

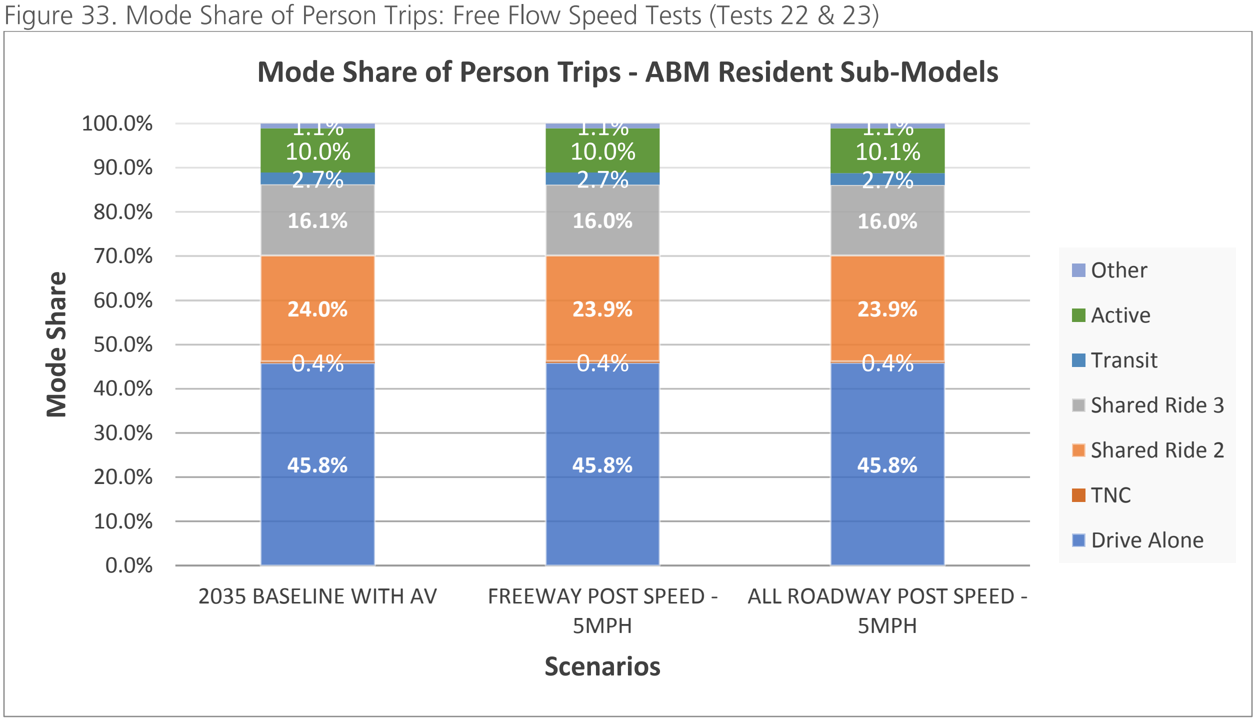


Figure 34. Transit Boarding Change from Baseline: Free Flow Speed Tests (Tests 22 & 23)

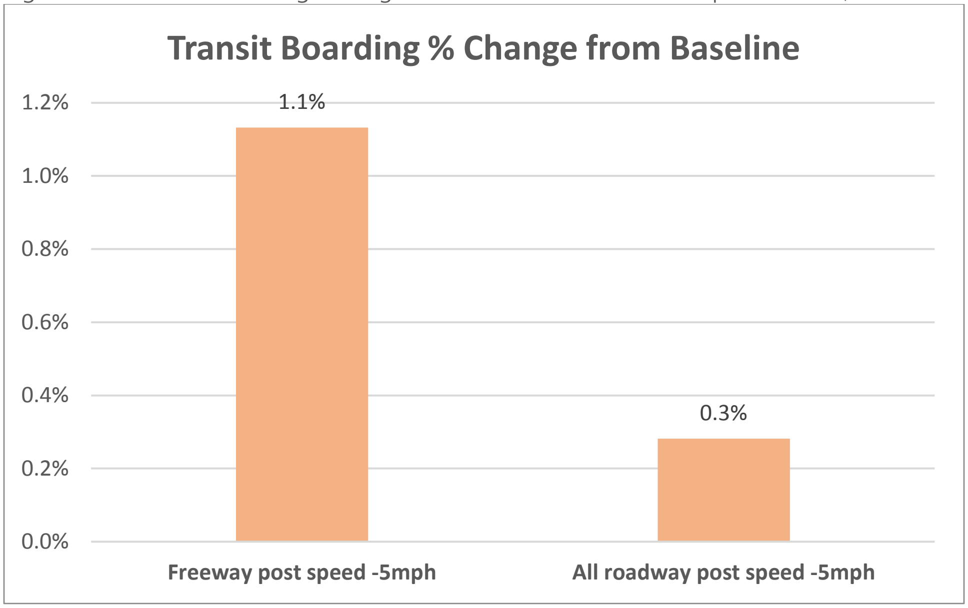


Table 8. Person Trip Distance by Mode: Free Flow Speed Tests (Tests 22 & 23)

description	DA	SR2	SR3	TNC	Pooled TNC	Walk	Bike	Transit	Total
2035 baseline with AV	8.0	7.2	8.3	7.7	6.0	0.8	3.3	9.1	7.3
Freeway post speed -5mph	7.9	7.2	8.2	7.7	6.1	0.8	3.3	9.2	7.2
All roadway post speed -5mph	7.9	7.2	8.2	7.7	6.1	0.8	3.4	9.2	7.2

Household Income Tests (Tests 24 & 25)

In comparison with the 2035 baseline, a test with household income lowered by a third had the following results:

- VMT decreased by 3.3% (Figure 35)
- San Diego resident mode shares (Figure 36):
  - DA decreased from 45.8% to 45.5%
  - SR3 decreased from 16.6% to 16.4%
  - Transit increased from 2.6% to 2.8%
  - Active mode (walk, bike, and micromobility) increased from 9.9% to 10.2%
- Transit boarding increased by 5.5% (Figure 37)
- Trip distance of DA, SR2, and SR3 all decreased; TNC and Taxi trip distance also decreased (Table 9).
- Total person trips of San Diego residents decreased by 2.6% (Figure 38)

In comparison with the 2035 baseline, a test with household income increased by a third had the following results:

- VMT increased by 2% (Figure 35)
- Mode share changes (Figure 36):
    - DA increased from 45.8% to 45.9%
    - SR3 increased from 16.6% to 16.8%
    - Transit decreased from 2.6% to 2.4%
    - Active mode (walk, bike, and micromobility) decreased slightly from 9.9% to 9.8%
- Transit boarding decreased by 3.5% (Figure 37)
- Trip distance of DA, SR2, and SR3 all increased; TNC and Taxi trip distance also increased (Table 9).
- Total person trips of San Diego residents increased by 1.6% (Figure 38)

The results suggest that ABM2+ is sensitive to household income. When household income increased, the model indicated higher VMT, higher auto mode share, lower transit, walk, bike, and micromobility mode shares. The results confirm that a population with higher income would generate more travel demand. With higher income, the distance of auto modes, TNC, and taxi all increased, indicating a higher income encouraged driving or using mobility as a service. When household income decreased, the opposite effects were observed. It should be noted that these are simply hypothesis tests which hold all other variables constant, neglecting the supply-demand interaction between inter-dependent variables. The test results should not be interpreted as the effects of +-1/3 household income changes in San Diego.

Figure 35. VMT Change from Baseline: Household Income Tests (Tests 24 & 25)

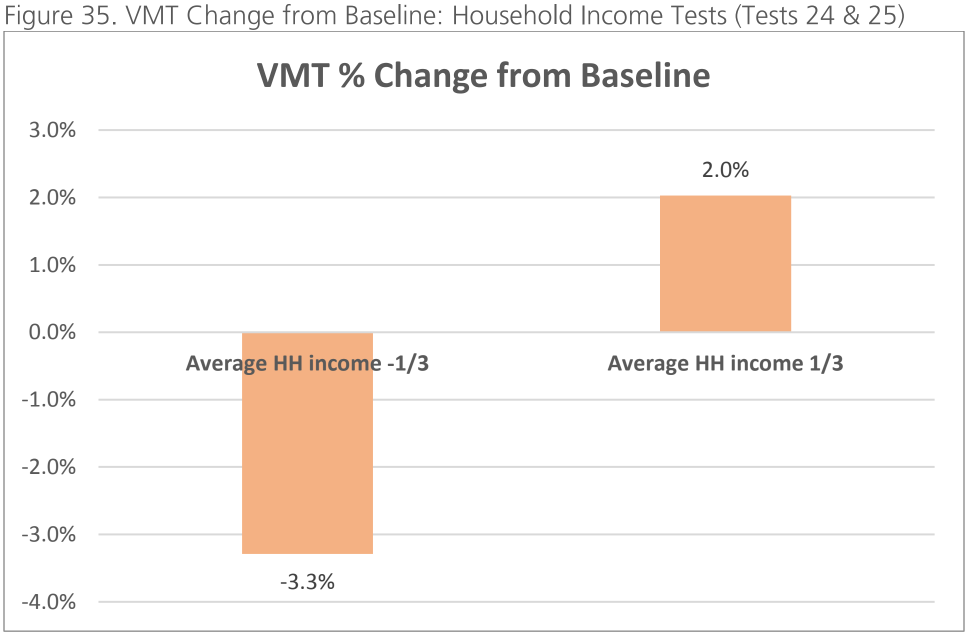


Figure 36. Mode Share of Person Trips: Household Income Tests (Tests 24 & 25)

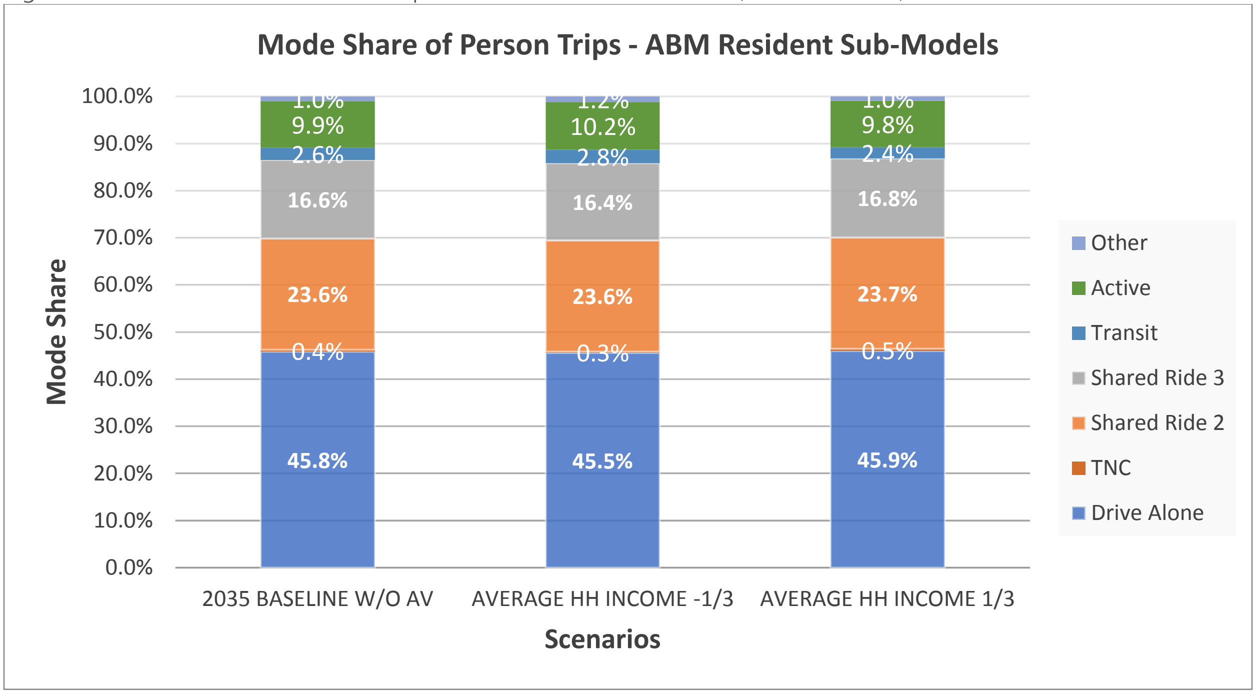


Figure 37. Transit Boarding Change from Baseline: Household Income Tests (Tests 24 & 25)

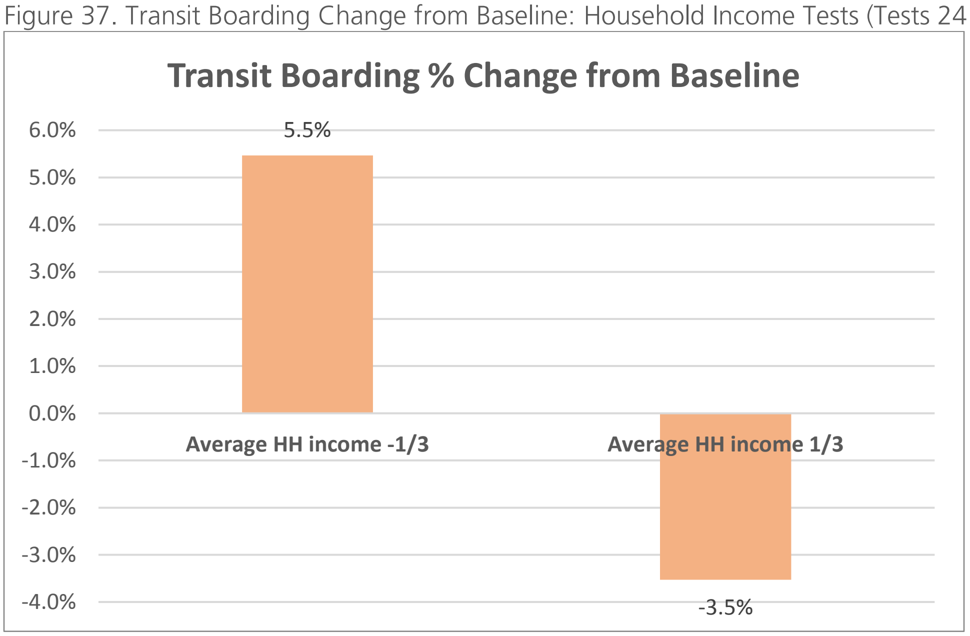


Figure 38. Total Person Trips Change from Baseline: Household Income Tests (Tests 24 & 25)

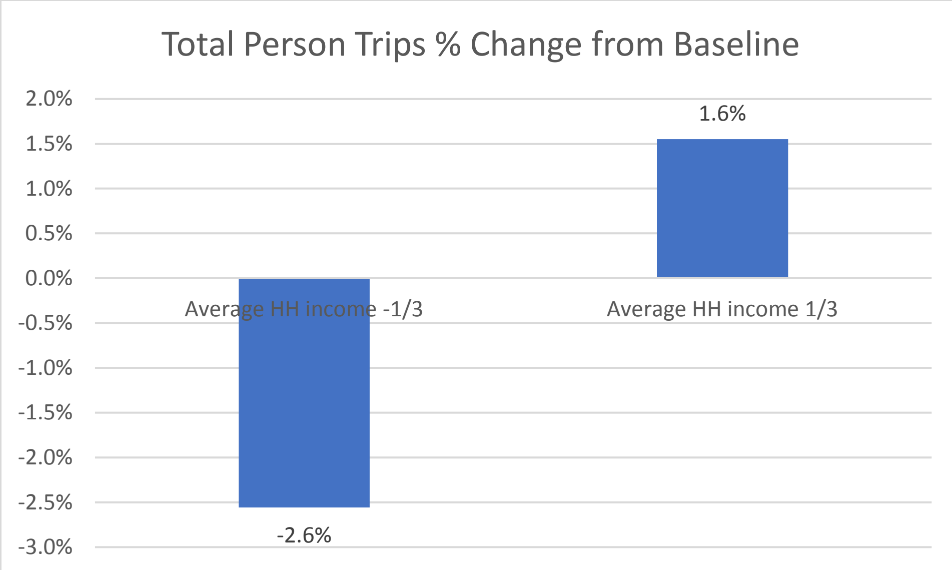


Table 9. Person Trip Distance by Mode: Household Income Tests (Tests 24 & 25)

description	DA	SR2	SR3	TNC	Pooled TNC	Walk	Bike	Transit	Taxi	Total
2035 baseline w/o AV	7.5	5.7	5.9	3.3	3.6	0.8	3.2	8.9	0.9	6.1
Average HH income -1/3	7.4	5.6	5.8	3.1	3.4	0.8	3.3	9.0	0.8	6.1
Average HH income 1/3	7.6	5.8	6.0	3.5	3.7	0.8	3.1	8.9	1.0	6.2

Regional Employment Tests (Tests 26 & 27)

In comparison with the 2035 baseline, a test with 10% larger regional employment had the following results:

- VMT increased by over 4% (Figure 39)
- San Diego resident mode shares (Figure 41):
  - DA increased from 45.8% to 47.9%
  - SR2 decreased from 23.6% to 22.5%
  - SR3 decreased from 16.6% to 15.7%
  - Transit increased from 2.6% to 2.7%
  - Active mode (walk, bike, and micromobility) decreased slightly from 9.9% to 9.8%
- Transit boarding increased by over 5% (Figure 40)

- Average trip distance of San Diego residents increased from 6.1 miles to 6.3 miles; While work trip length decreased from 10.3 miles to 10.1 miles, non-mandatory trip distance in general increased (Table 10).
- Total person trips of San Diego residents increased by 1.6% (Figure 42).

In comparison with the 2035 baseline, a test with 10% smaller reginal employment had the following results:

- VMT decreased by over 6% (Figure 39)
- Mode share changes (Figure 41):
    - DA decreased from 45.8% to 42.7%
    - SR2 increased from 23.6% to 25.0%
    - SR3 increased from 16.6% to 18.4%
    - Active mode (walk, bike, and micromobility) decreased slightly from 9.9% to 9.8%
- Transit boarding decreased by nearly 2% (Figure 40).
- Average trip distance of San Diego residents decreased from 6.1 miles to 5.9 miles; While work trip length increased from 10.3 miles to 10.5 miles, non-mandatory trip distance in general decreased (Table 10).
- Total person trips of San Diego residents decreased by 0.5% (Figure 42).

The experiments suggest that ABM2+ is sensitive to regional employment. When regional employment increased, the model indicated higher VMT, high travel demand, higher DA mode share, lower shared ride auto mode shares, and lower walk, bike, and micromobility mode shares. Although overall trip distance increased, work trip distance decreased, indicating the abundance of jobs allow workers to choose jobs closer to home. When regional employment decreased, the opposite effects were observed. It should be noted that these are simply hypothesis tests which hold all other variables constant, neglecting the supply-demand interaction between inter-dependent variables. The test results should not be interpreted as the effects of +-10% regional employment changes in San Diego.

Figure 39. VMT Change from Baseline: Regional Employment Tests (Tests 26 & 27)

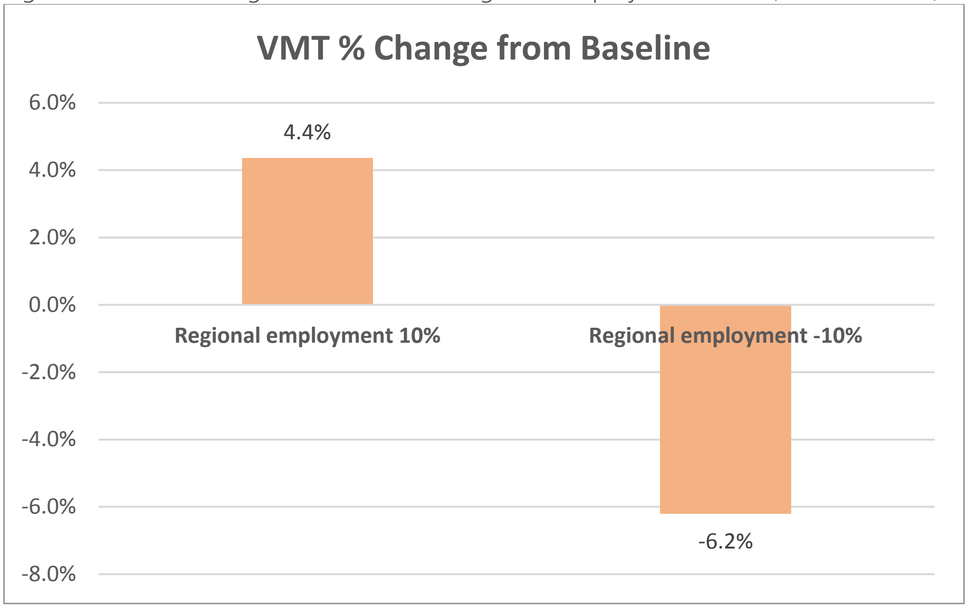


Figure 40. Transit Boarding Change from Baseline: Regional Employment Tests (Tests 26 & 27)

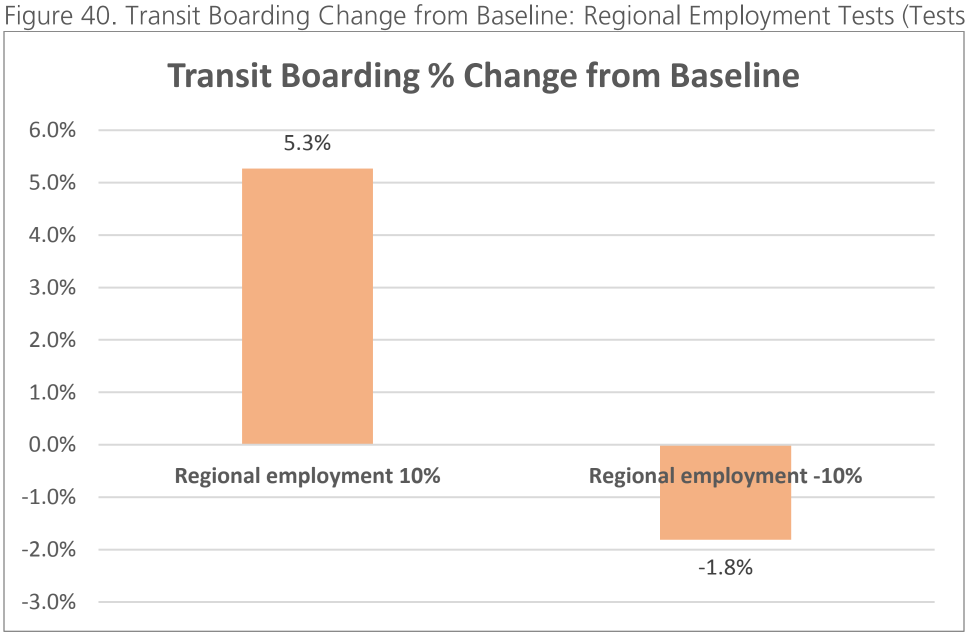


Figure 41. Mode Share of Person Trips: Regional Employment Tests (Tests 26 & 27)

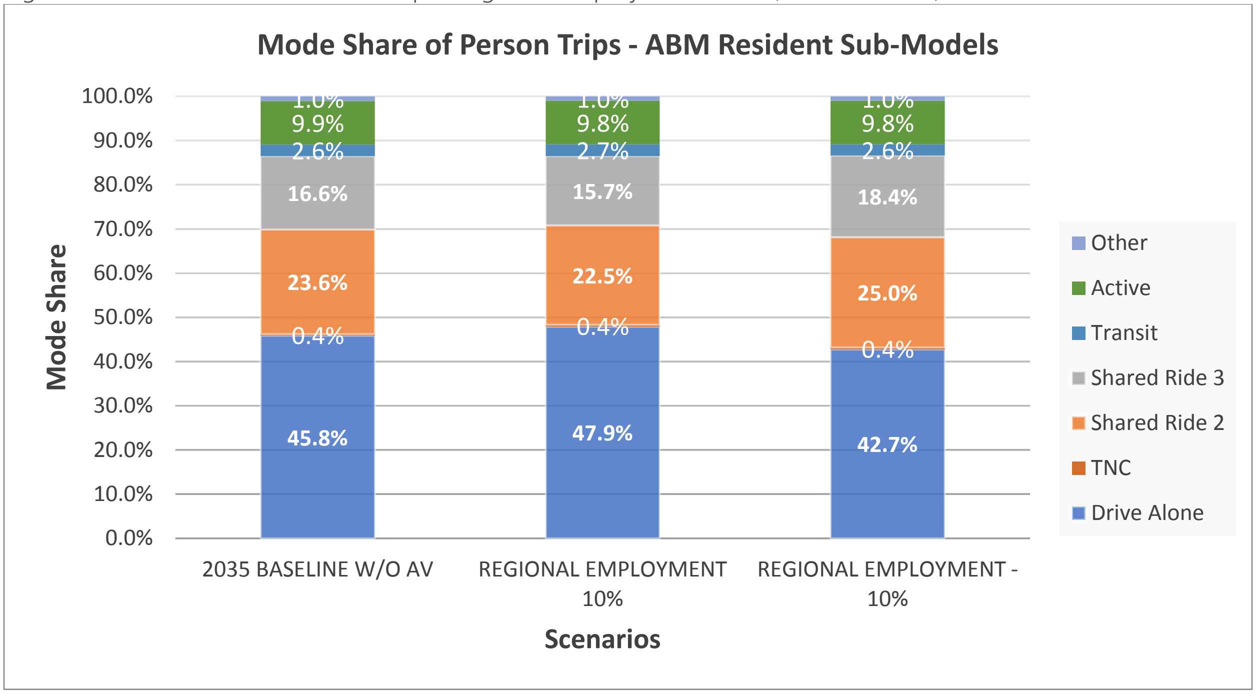


Figure 42. Total Person Trips Change from Baseline: Regional Employment Tests (Tests 26 & 27)

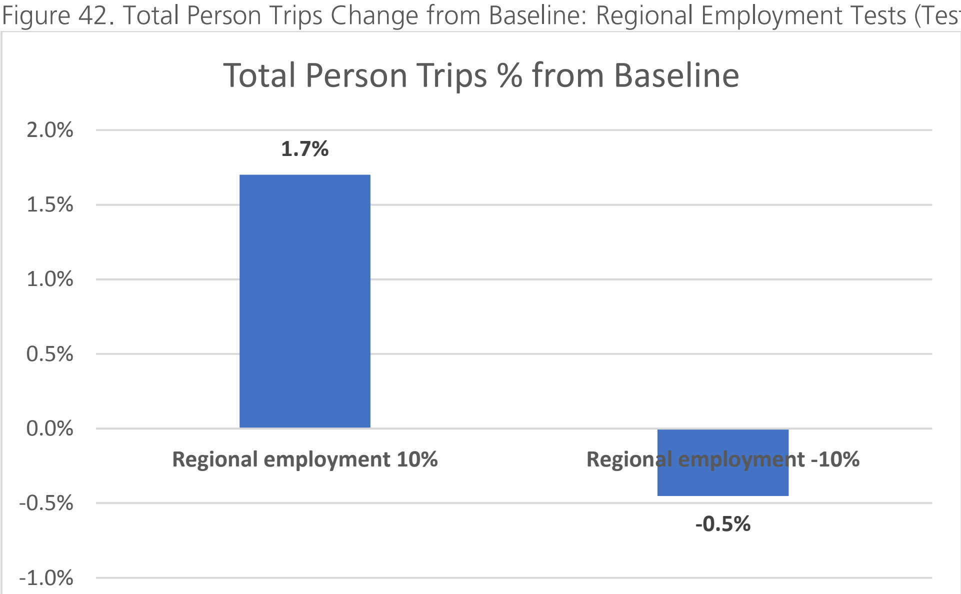


Table 10. Person Trip Distance by Purpose: Household Income Tests (Tests 24 & 25)

description	Rec.	Dining	Escort	Maint.	School	Shop	Univ.	Visit	Work	Total
2035 baseline w/o AV	5.0	5.3	5.2	5.2	4.6	4.3	8.2	6.0	10.3	6.1
Regional employment 10%	5.0	5.4	5.3	5.2	4.6	4.3	8.3	6.0	10.1	6.3
Regional employment -10%	4.9	5.2	5.0	5.2	4.6	4.2	8.3	5.8	10.5	5.9

New mobility

TNC Cost Tests (Tests 29 & 30)

In comparison with the 2035 baseline, a test with 50% higher TNC cost had the following results:

- Insignificant VMT change (Figure 43)
- Mode shares for all models (Figure 44):
    - DA increased from 45.3% to 45.4%
    - TNC decreased significantly from 0.8% to 0.4%
    - Insignificant transit mode share change.
- Transit boarding increased by over 1% (Figure 46)
- Total TNC trips decreased by 35%, suggesting that a 1 percent increase in TNC cost will lead to a TNC trip decrease of 0.7% (elasticity of -0.7) (Figure 47).
- Deadhead TNC VMT (no passengers) increased slightly from 41.9% to 42.3% and pooled TNC VMT decreased from 11.6% to 11.0% (Figure 46).
- Although average trip distance change was insignificant, regular TNC trip distance increased from 7.7 miles to 9.1 miles, pooled TNC trip distance increased from 6.0 miles to 6.2 miles (Table 11).

In comparison with the 2035 baseline, a test with 50% lower TNC cost had the following results:

- VMT increased by 0.4% (Figure 43)
- Mode shares for all models (Figure 44):
    - DA decreased from 45.3% to 45.2%
    - SR3 decreased from 16.7% to 16.1%
    - Transit decreased from 2.7% to 2.6%
    - TNC increased from 0.8% to 1.8%
- Transit boarding decreased by 2% (Figure 46)
- Total TNC trips increased by 97%, suggesting that a 1 percent decrease in TNC cost will lead to a TNC trip increase of 2.0% (elasticity of -2.0) (Figure 47).
- Deadhead TNC trips (no passenger) decreased from 41.9% to 41% and pooled TNC increased from 11.6% to 13.1% (Figure 46).
- Although average trip distance change was insignificant, regular TNC trip distance decreased from 7.7 miles to 7.6 miles, pooled TNC trip distance increased from 6.0 miles to 6.6 miles (Table 11).

The results suggest that the TNC cost increase did not have a significant impact on VMT and mode shares, except for the significant TNC mode share decrease. The TNC cost increase caused a significant TNC trip distance increase from 7.7 miles to 9.1 miles. Deadhead TNC VMT did not change much, but pooled TNC VMT decreased.

When TNC cost decreased, VMT increased, TNC mode share increased significantly, and transit mode share decreased. This suggests a competition between TNC and transit. As TNC became more affordable, mode shares shifted from transit to TNC and caused more VMT. As TNC cost decreased, among the three auto modes (DA, SR2, and SR3), only SR3 mode share increased significantly, which needs more investigation. Deadhead TNC VMT decreased slightly, but pooled TNC VMT increased.

Figure 43. VMT Change from Baseline: TNC Cost Tests (Tests 29 & 30)

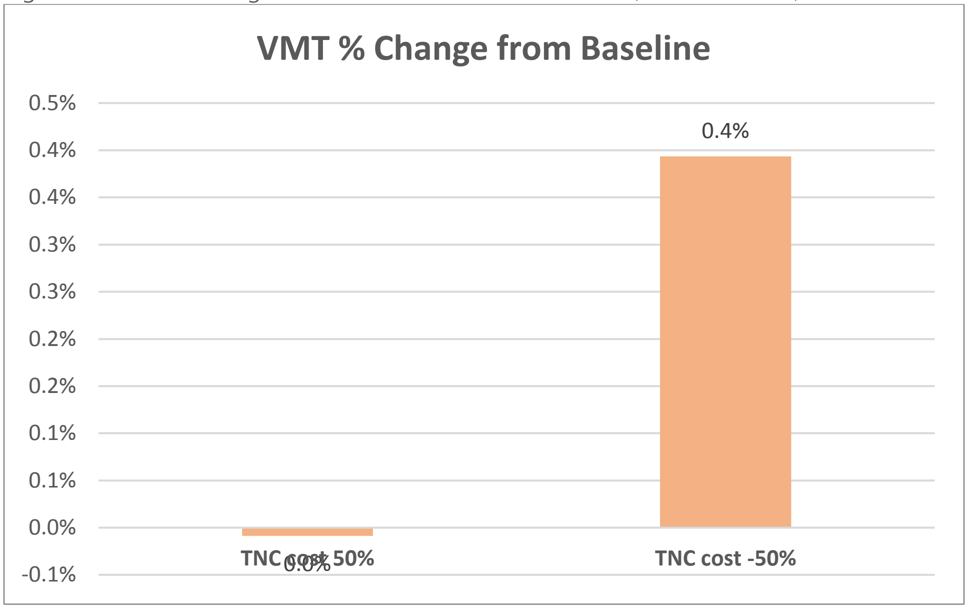


Figure 44. Mode Share of Person Trips: TNC Cost Tests (Tests 29 & 30)

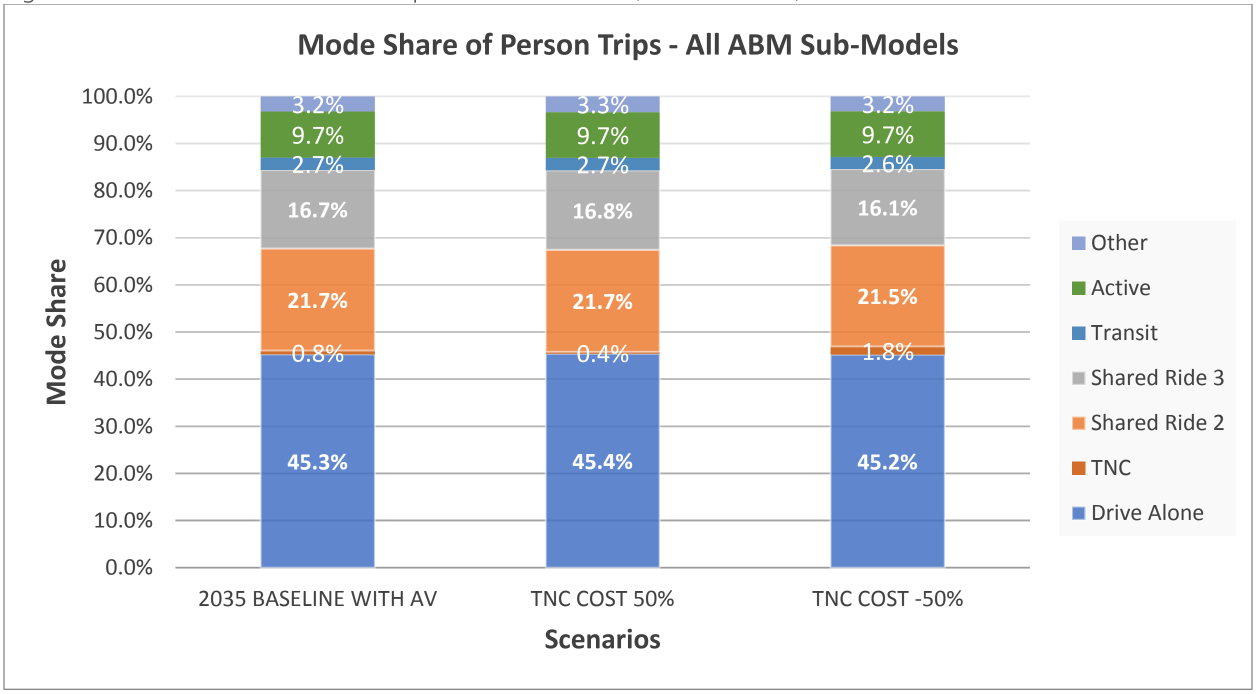


Figure 45. Transit Boarding Change from Baseline: TNC Cost Tests (Tests 29 & 30)

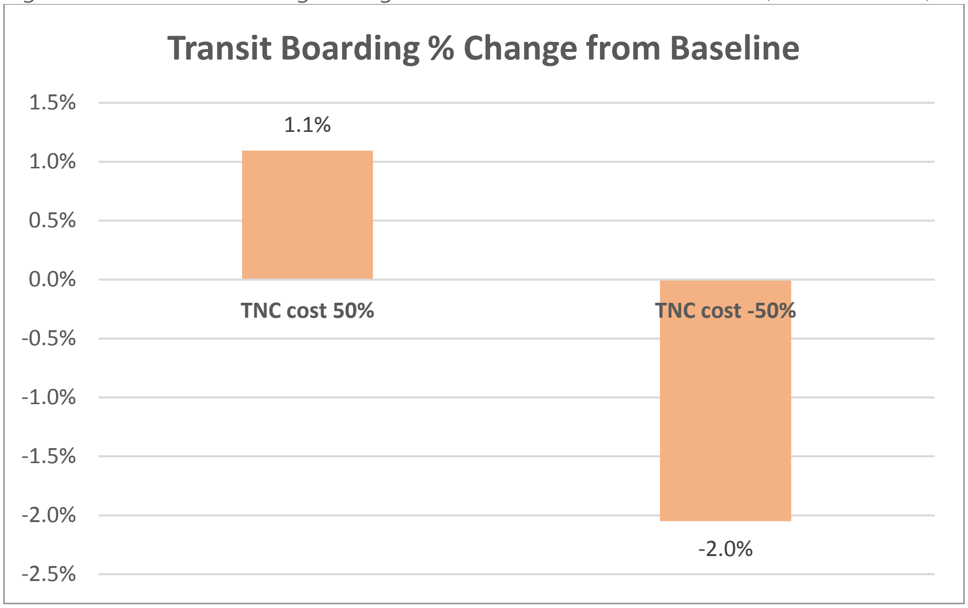


Figure 46. Share of TNC Trips by Number of Passengers: TNC Cost Tests (Tests 29 & 30)

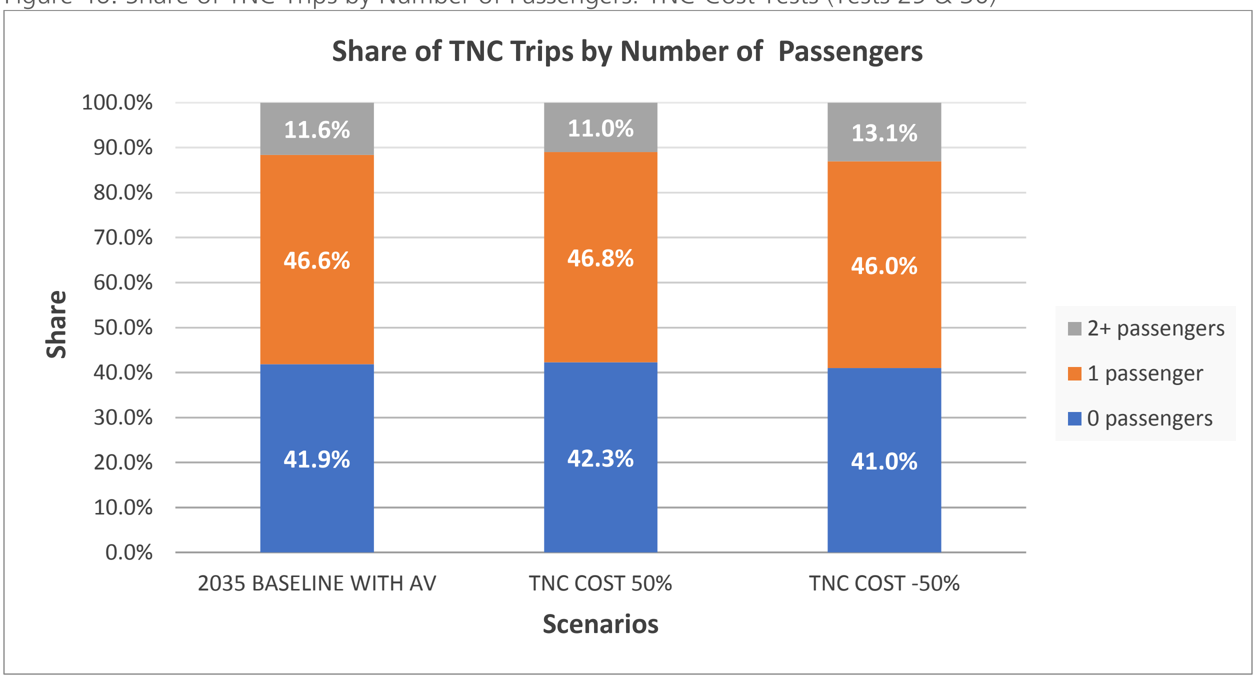


Figure 47. TNC Trips Change from Baseline: TNC Cost Tests (Tests 29 & 30)

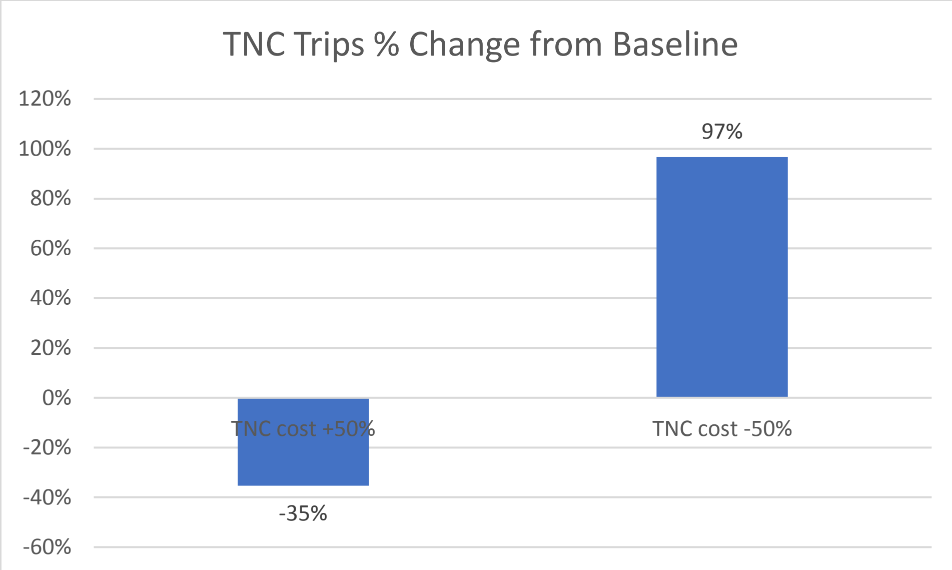


Table 11. Person Trip Distance by Mode: Household Income Tests (Tests 24 & 25)

description	DA	SR2	SR3	TNC	Pooled TNC	Walk	Bike	Transit	Total
2035 baseline with AV	8.0	7.2	8.3	7.7	6.0	0.8	3.3	9.1	7.3
TNC cost 50%	7.9	7.2	8.3	9.1	6.2	0.8	3.3	9.1	7.3
TNC cost -50%	8.0	7.2	8.2	7.6	6.6	0.8	3.3	9.2	7.3

Pooled TNC Cost Tests (Tests 31 & 32)

In comparison with the 2035 baseline, a test with 50% lower pooled TNC cost had the following results:

- Insignificant VMT change (Figure 48)
- VMT generated by TNC increased by 1.0% (Figure 49)
- Among all TNC VMT, pooled TNC VMT decreased from 9.6% to 9.3% and deadhead TNC VMT decreased from 31.7% to 31.1% (Figure 51).
- Mode shares for all models (Figure 50):
    - DA decreased from 45.4% to 45.3%
    - Transit decreased from 2.7% to 2.6%.
    - Pooled TNC increased from 0.1% to 0.2%, a 100% increase, suggesting that a 1 percent decrease in pooled TNC cost will lead to a pooled TNC trip increase of 2% (elasticity of -2.0).
- Transit boarding decreased by nearly 1% (Figure 52)
- Although average trip distance change was insignificant, pooled TNC trip distance increased from 8.7 miles to 9.4 miles (Table 12).

In comparison with the 2035 baseline, a test with 75% lower pooled TNC cost had the following results:

- VMT increased by 0.1% (Figure 46)
- TNC VMT increased by 2.6% (Figure 49)
- Among all TNC VMT, pooled TNC VMT increased from 9.6% to 12.8% and deadhead TNC VMT decreased from 31.7% to 29.1% (Figure51).
- Mode share changes (Figure 50):
    - DA decreased from 45.4% to 45.1%
    - Transit decreased from 2.7% to 2.6%.
    - Pooled TNC increased from 0.1% to 0.4%, a 300% increase, suggesting that a 1 percent decrease in pooled TNC cost will lead to pooled TNC trip increase of 4% (elasticity of -4.0).
- Transit boarding decreased by nearly 2% (Figure 52)
- Although the average trip distance change was insignificant, pooled TNC trip distance increased from 8.7 miles to 10.7 miles (Table 12).

The results suggest pooled TNC cost reductions had significant impact on pooled TNC trips, but limited impact on overall VMT. When pooled TNC costs decreased, pooled TNC mode share was higher, and both drive alone and transit mode shares were lower, indicating that TNC competes with both drive alone and transit modes. Pooled TNC trip distance increased and regular TNC trip distance decreased. This suggests two findings. First, travelers tend to take longer pooled TNC trips as the cost becomes more affordable. Second, more affordable pooled TNC shifted longer regular TNC trips to pooled TNC trips. In the 50% cost reduction test, pooled TNC VMT was slighter lower than baseline, which is counter intuitive and needs further investigation.

Figure 48. VMT Change from Baseline: Pooled TNC Cost Tests (Tests 31 & 32)

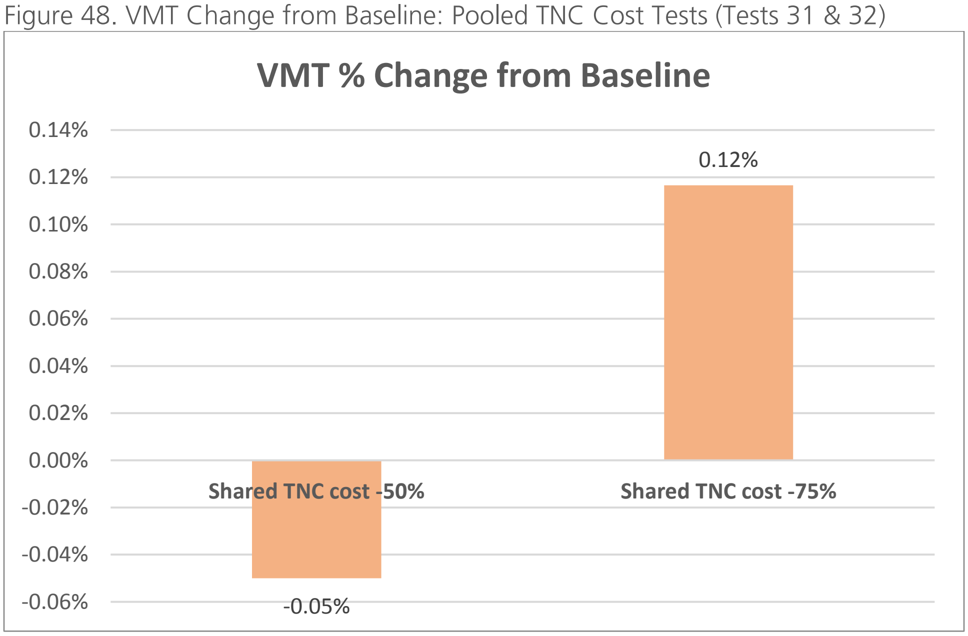


Figure 49. TNC VMT Change from Baseline: Pooled TNC Cost Tests (Tests 31 & 32)

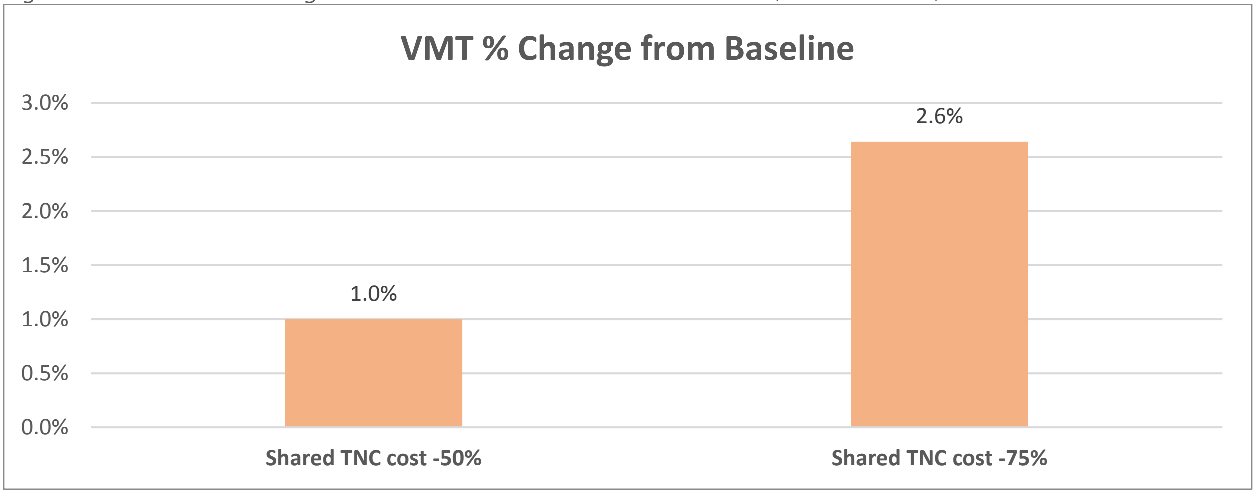


Figure 50. Mode Share of Person Trips: Pooled TNC Cost Tests (Tests 31 & 32)

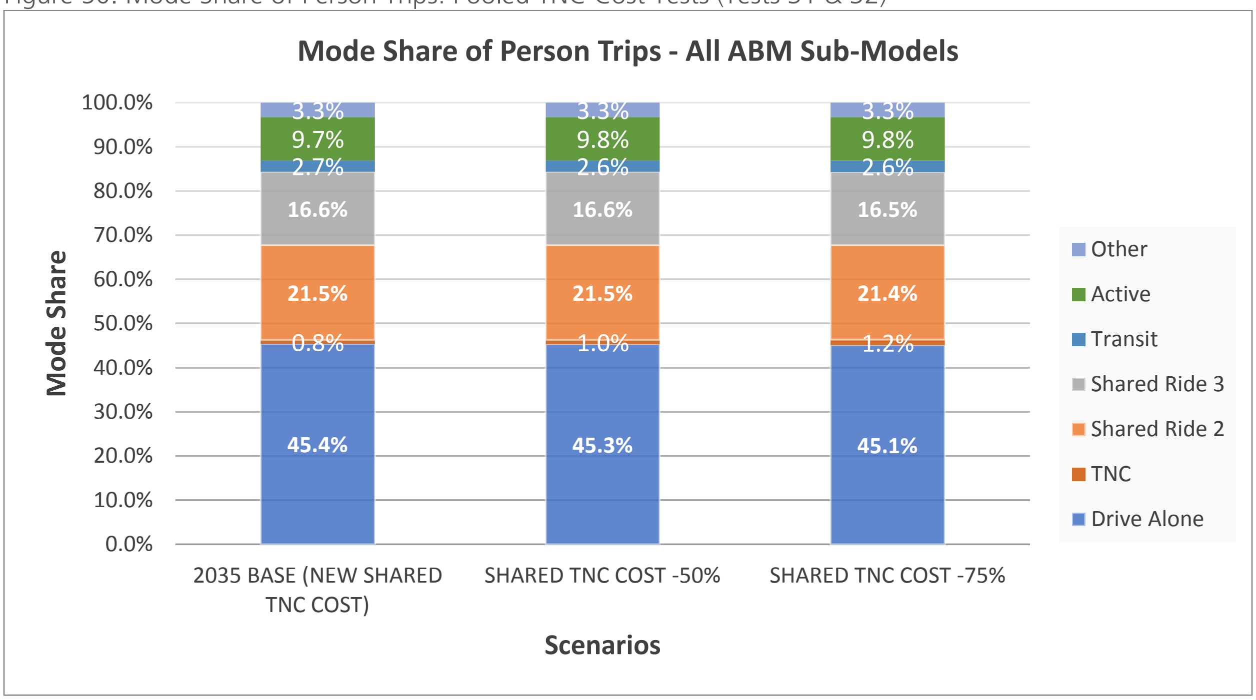


Figure 51. Share of TNC VMT by Occupancy: Pooled TNC Cost Tests (Tests 31 & 32)

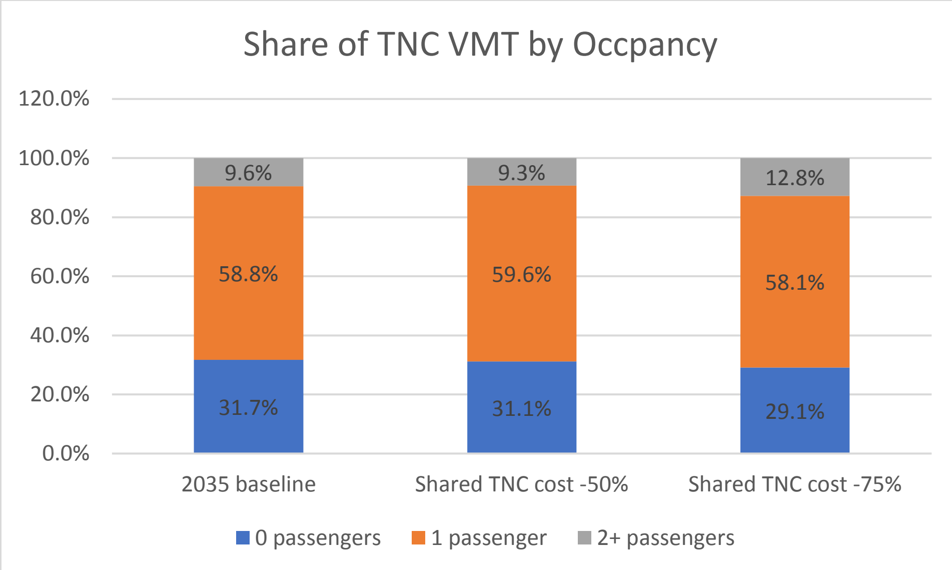


Figure 52. Transit Boarding Change from Baseline: Pooled TNC Cost Tests (Tests 31 & 32)

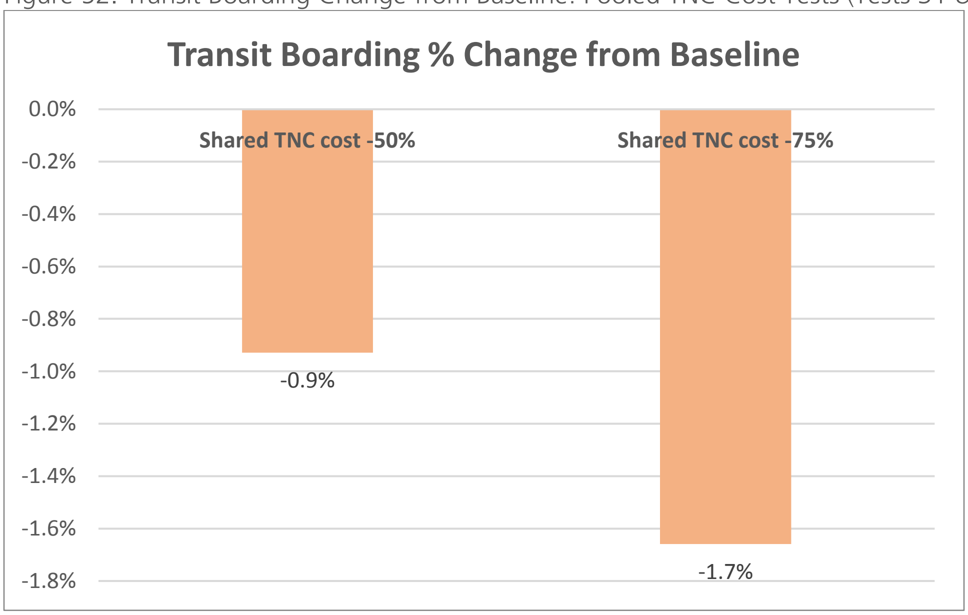


Table 12. Person Trip Distance by Mode: Pooled TNC Cost Tests (Tests 31 & 32)

description	DA	SR2	SR3	TNC	Pooled TNC	Walk	Bike	Transit	Total
2035 base (new Shared TNC cost)	7.9	7.2	8.3	7.7	8.7	0.8	3.3	9.1	7.2
Shared TNC cost - 50%	7.9	7.2	8.3	7.4	9.4	0.8	3.3	9.1	7.2
Shared TNC cost - 75%	7.9	7.2	8.3	7.1	10.7	0.8	3.3	9.1	7.2

TNC Wait Time Tests (Tests 33 & 34)

Compared with the 2035 baseline, a 50% TNC wait time decrease test had the following results:

- Mode share changes were insignificant, except TNC mode share which increased from 0.8% to 0.9% (Figure 53).
- Total TNC trips increased by 13%, suggesting that a 1 percent decrease in TNC wait time will lead to a TNC trip increase of 0.26% (elasticity of -0.26) (Figure 54).
- Share of TNC VMT increased from 0.85% to 0.95% (Figure 55)

Compared with the 2035 baseline, a 50% TNC wait time increase test had the following results:

- Mode share changes were insignificant except TNC mode share which decreased from 0.8% to 0.7% (Figure 53).
- Total TNC trips decreased by 9%, suggesting that a 1 percent increase in TNC wait time will lead to a TNC trip decrease of 0.18% (elasticity of -0.18) (Figure 54).
- Share of TNC VMT decreased from 0.85% to 0.79% (Figure 55)

The results suggest TNC wait time had significant impact on TNC trips but limited impact on regional VMT because of the very small TNC mode share. When TNC wait time decreased, both TNC trips and TNC VMT increased. When TNC wait time increased, the opposite effects were observed.

Figure 53. Transit Boarding Change from Baseline: TNC Wait Time Tests (Tests 33 & 34)

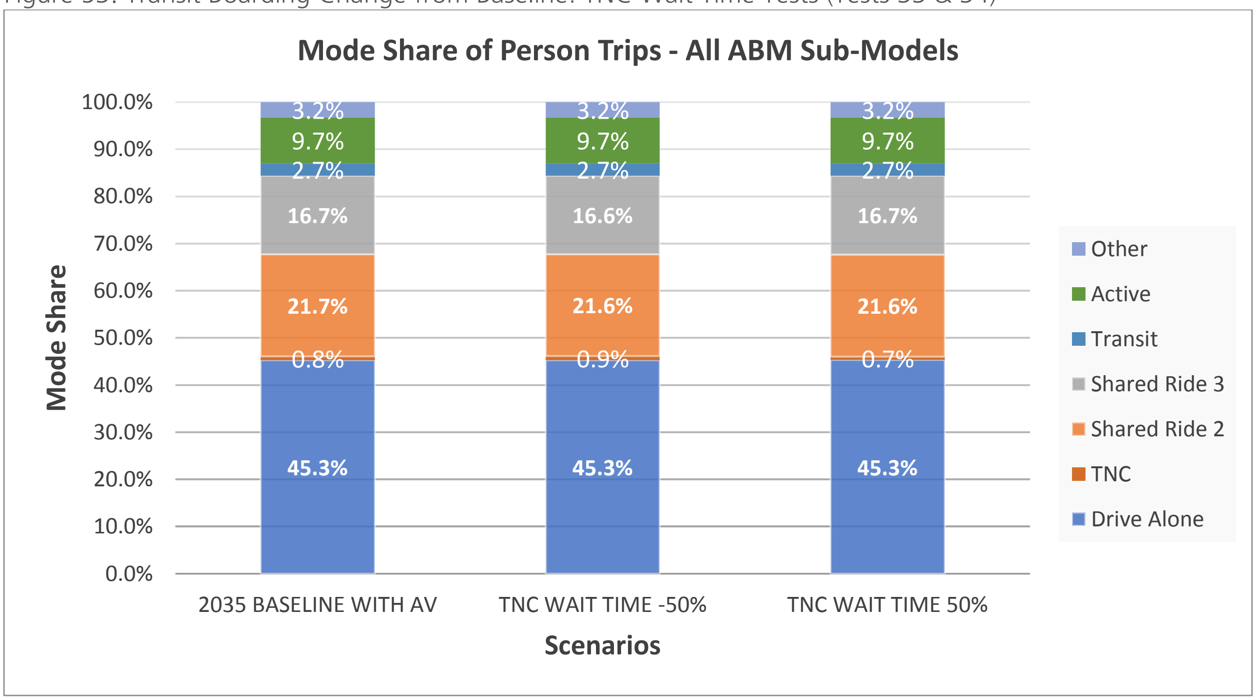


Figure 54. TNC Trips Change from Baseline: TNC Wait Time Tests (Tests 33 & 34)

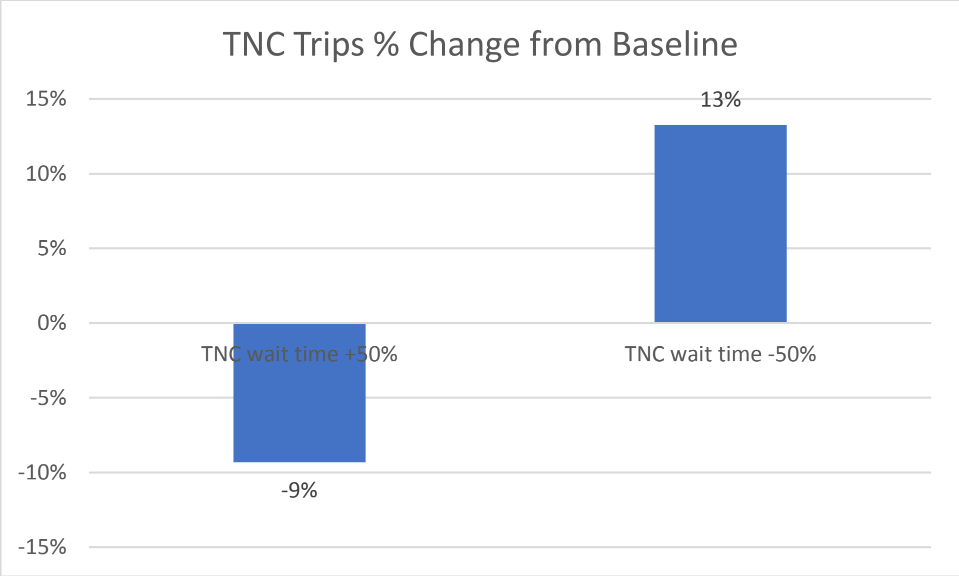
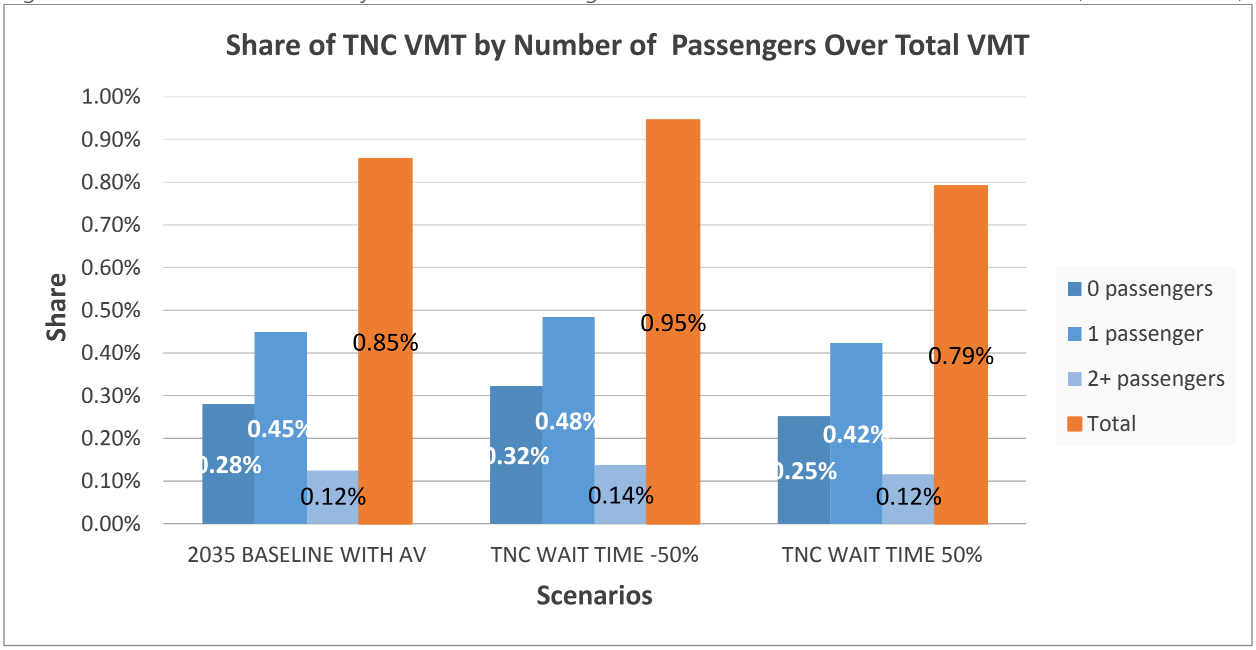


Figure 55. Share of TNC VMT by Number of Passengers Over Total VMT: TNC Wait Time Tests (Tests 33 & 34)



Micromobility Speed Tests (Tests 35 & 36)

In comparison with the 2035 baseline, a test increasing micromobility speed from 12mph to 30 mph had the following results:

- VMT decreased slightly by 0.1% (Figure 56)
- Insignificant mode share changes (Figure 57)

- Transit boarding decreased by nearly 1% (Figure 58)
- Total micromobility trips increased by 33% (Figure 59)
- Although average trip distance change was insignificant, micromobility trip distance increased from 0.9 miles to 1.0 mile (Table 13).

In comparison with the 2035 baseline, a micromobility focus test with micromobility speed set to 20mph, 0 constant, and halved wait time and costs had the following results:

- VMT decreased by 0.8% (Figure 56)
- Mode share changes of all models (Figure 57):
    - DA decreased from 45.3% to 44.6%
    - SR2 decreased from 21.7% to 21.3%
    - SR3 decreased from 16.7% to 16.3%
    - Transit decreased from 2.7% to 2.5%
    - Active modes (walk, bike, and micromobility) increased from 9.7% to 11.4%, with the micromobility mode increasing significantly from 0.1% to 1.7%.
- Transit boarding decreased by nearly 5% (Figure 58)
- Total micromobility trips increased significantly by over 15 times (Figure 59)
- Although average trip distance change was insignificant, micromobility trip distance decreased from 0.9 miles to 0.6 mile (Table 13).

The results suggest micromobility speed alone had limited impact on VMT and mode shares, primarily because speed is one of many variables in the micromobility choice structure. When micromobility speed increased, the model indicated higher micromobility trips, but the overall mode share impact was insignificant. The test of giving significant benefit to micromobility by reducing cost, wait time, penalty constant, and increasing speed suggested that the model is sensitive to micromobility if enough benefit is given to micromobility.

Figure 56. TNC Trips Change from Baseline: Micromobility Speed Tests (Tests 35 & 36)

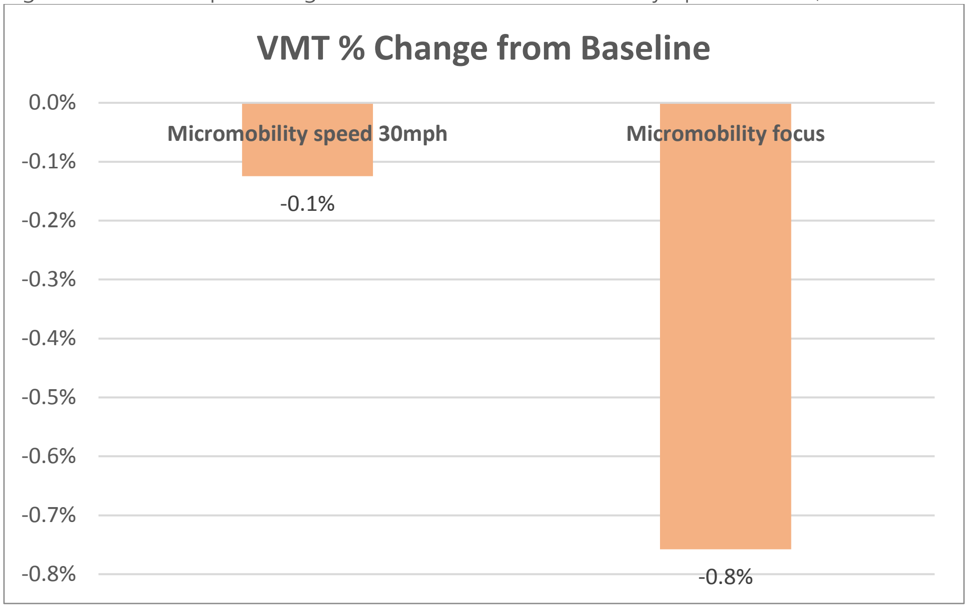


Figure 57. Mode Share of Person Trips: Micromobility Speed Tests (Tests 35 & 36)

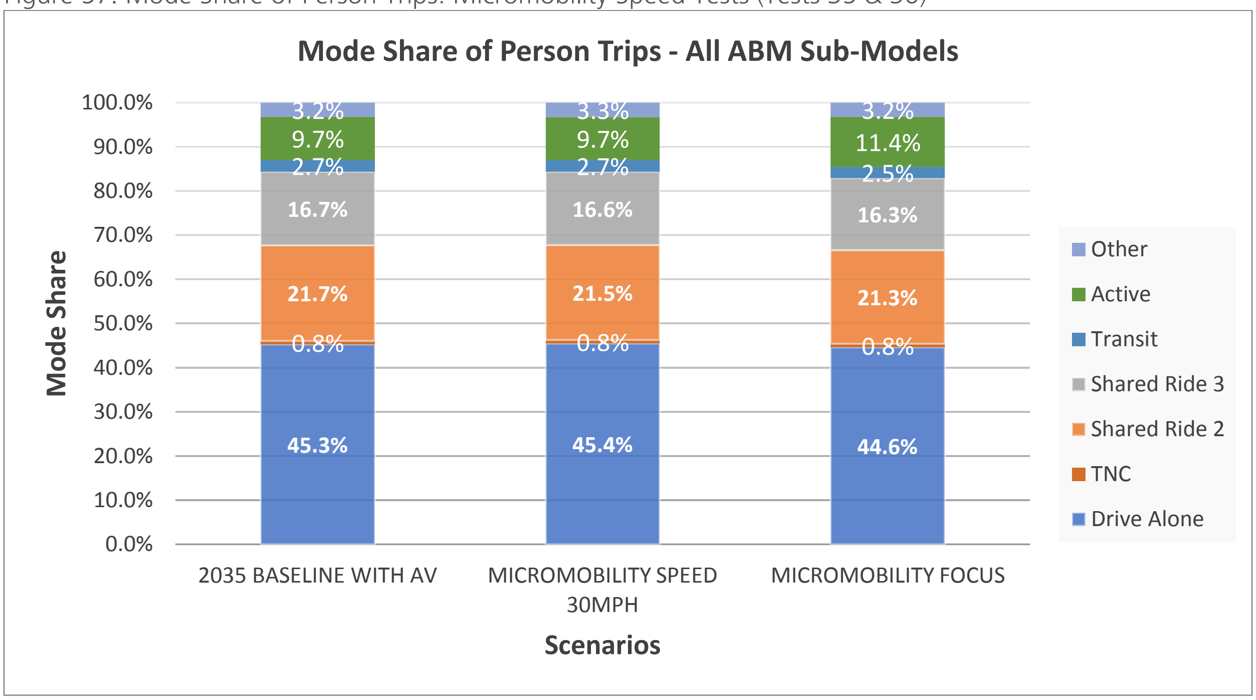


Figure 58. Transit Boarding Change from Baseline: Micromobility Speed Tests (Tests 35 & 36)

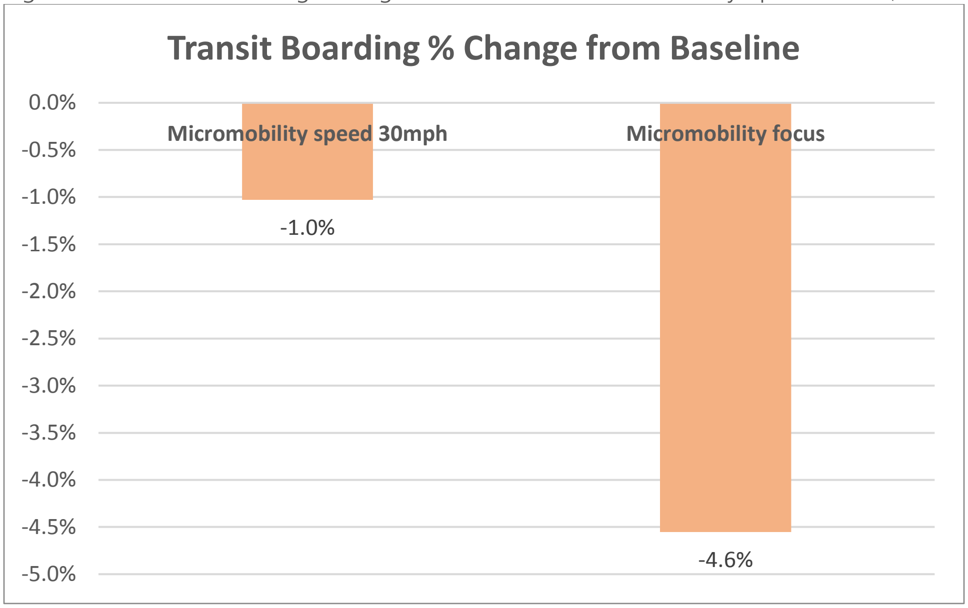


Figure 59. Micromobility Trips Change from Baseline: Micromobility Speed Tests (Tests 35 & 36)

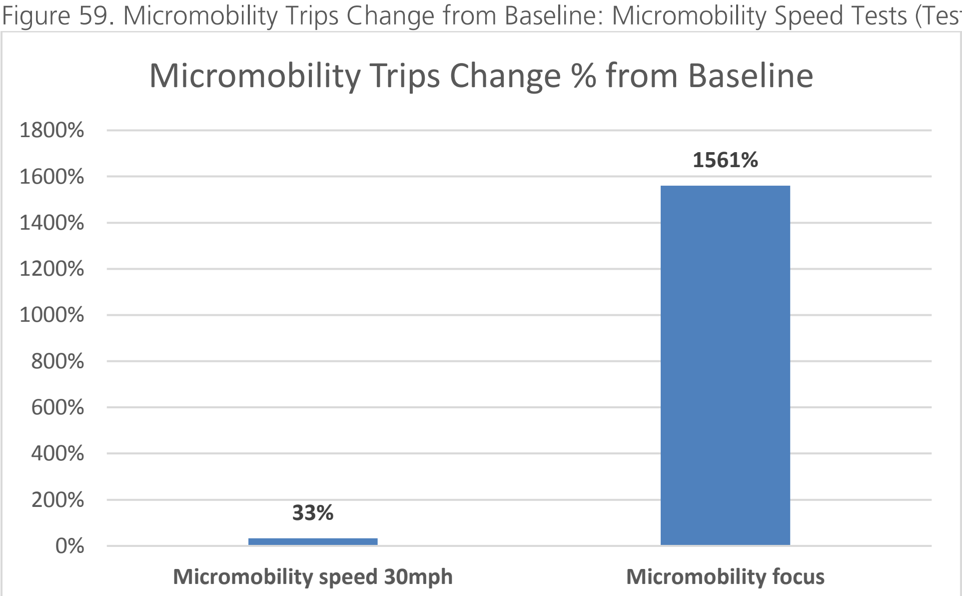


Table 13. Person Trip Distance by Mode: Micromobility Speed Tests (Tests 35 & 36)

description	DA	SR2	SR3	TNC	Pooled TNC	Walk	MM	Bike	Transit	Total
2035 baseline with AV	8.0	7.2	8.3	7.7	6.0	0.8	0.9	3.3	9.1	7.3
Micromobility speed 30mph	7.9	7.2	8.3	7.7	8.7	0.8	1.0	3.3	9.1	7.2
Micromobility focus	8.0	7.3	8.4	7.9	6.2	0.7	0.6	3.5	9.4	7.2

Micromobility Access Time Tests (Tests 37 & 38)

In comparison with the 2035 baseline, a test improving micromobility access time (see description of test 37 in the previous chapter) had the following results:

- Insignificant VMT change
- Insignificant mode share changes
- Total MM trips increased by over 120% (Figure 60).
- The share of micromobility trips for the total walk and micromobility trips increased from 2.0% to 4.0% (Figure 62).

In comparison with the 2035 baseline, a test significantly improving micromobility access time (see description of test 38 in the previous chapter) had the following results:

- Insignificant VMT change
- Insignificant mode share changes
- Total MM trips increased by 375% (Figure 60)
- The share of micromobility trips for the total walk and micromobility trips increased from 2.0% to 9.0% (Figure 62).

The results suggest micromobility access time had significant impact on micromobility trips and the share of micromobility trips, but limited impact on VMT and mode shares. When access time was improved, the total micromobility trips and share of micromobility increased significantly, but the effect on VMT was insignificant. This is likely due to the low share of micromobility and the relatively short trip length of micromobility trips. In the 'Good MM Access' scenario, the change in total walk and micromobility trips was negative but very small - possibly insignificant when compared to Monte Carlo simulation error.

Figure 60. Micromobility Trips Change from Baseline: Micromobility Access Time Tests (Tests 37 & 38)

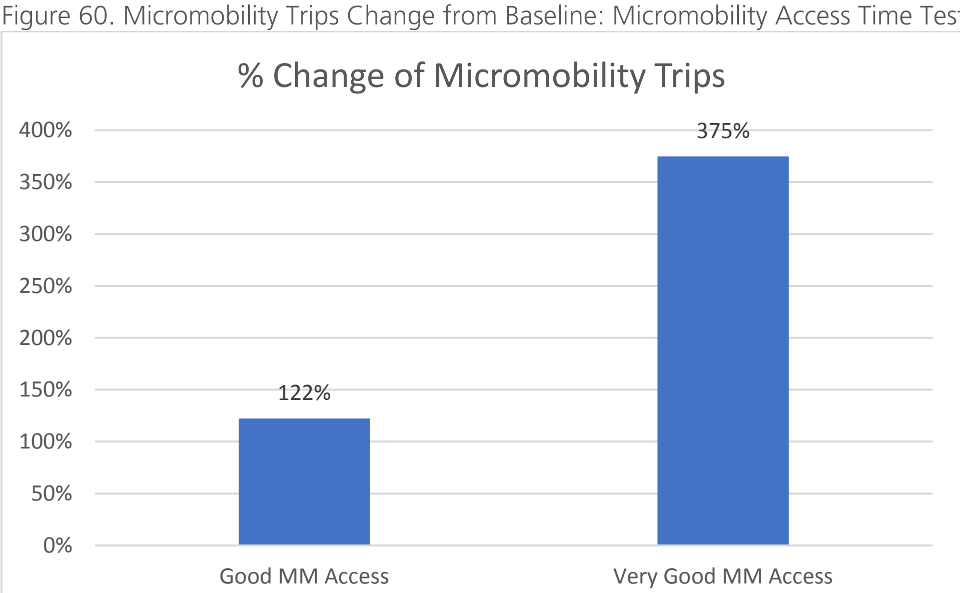


Figure 61. Walk & Micromobility Trips Change from Baseline: Micromobility Access Time Tests (Tests 37 & 38)

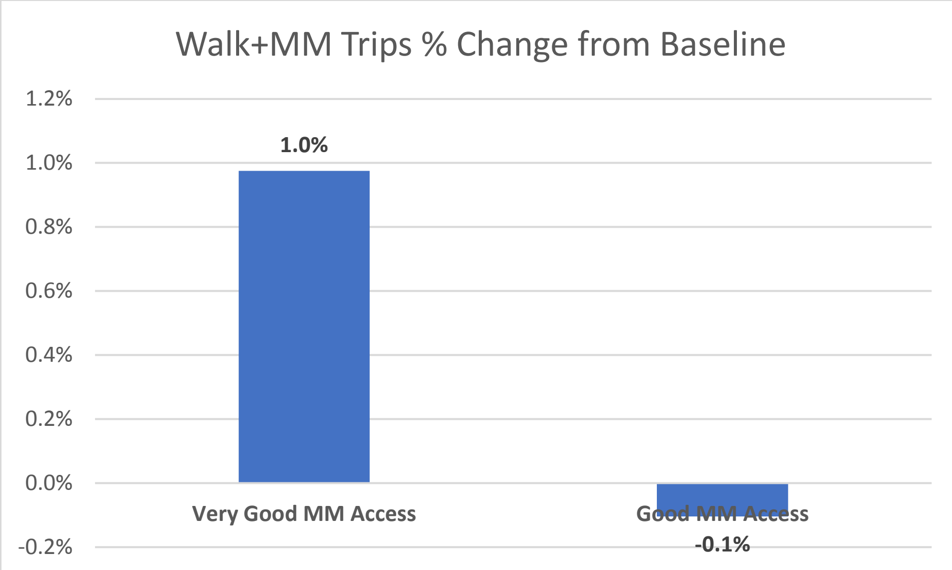
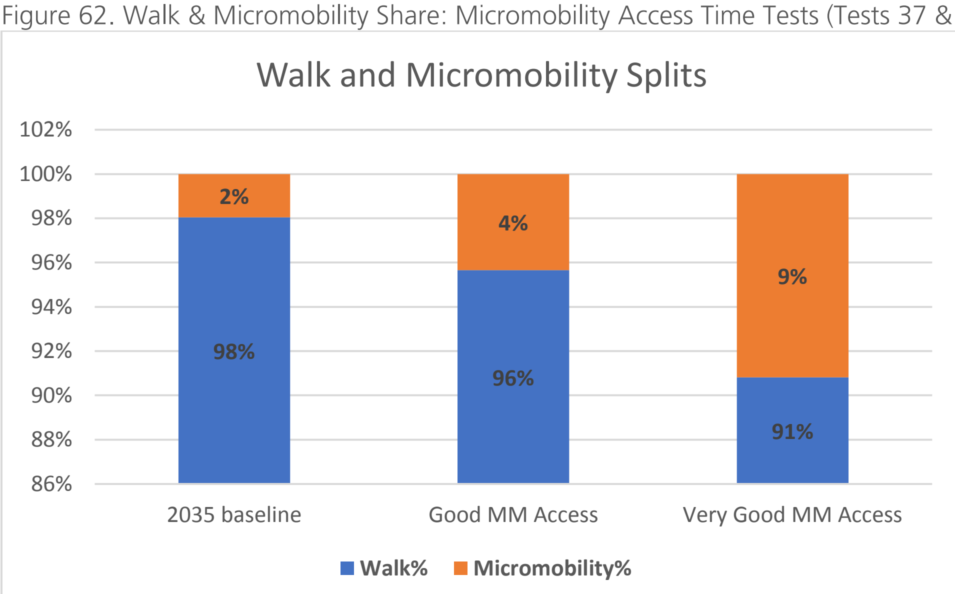


Figure 62. Walk & Micromobility Share: Micromobility Access Time Tests (Tests 37 & 38)



Micromobility Cost Tests (Tests 39 & 40)

In comparison with the 2035 baseline, a test increasing micromobility cost by 50% had the following results:

- Insignificant VMT change
- Insignificant mode share changes

- Total micromobility trips decreased by 40%, suggesting that a 1 percent increase in micromobility cost will lead to a micromobility trip decrease of 0.8% (elasticity of -0.8) (Figure 63).
- The share of micromobility trips for the total walk and micromobility trips decreased from 2.0% to 1.2% (Figure 65).

In comparison with the 2035 baseline, a test decreasing micromobility cost by 50% had the following results:

- Insignificant VMT change
- Insignificant mode share changes
- Total micromobility trips increased by 19%, suggesting that a 1 percent decrease in micromobility cost will lead to a micromobility trip increase of -0.38% (elasticity of -0.38) (Figure 63).
- The share of micromobility trips for the total walk and micromobility trips increased from 2.0% to 2.3% (Figure 65).

The results suggest micromobility cost had significant impact on micromobility trips and the share of micromobility trips, but limited impact on VMT or total walk and micromobility trip share. The number of micromobility trips responded reasonably to changes in cost, with derived elasticity of -0.4 to -0.8. However, the total share of walk and micromobility trips predicted by the model was not sensitive to these cost changes. This is in part due to the way that the model is formulated, where most of the model competition is between the micromobility and walk mode. Simply increasing or decreasing the cost of the mode was not enough to change the generalized walk time and subsequently impact the competition between walk\micromobility and other modes in the model.

Figure 63. Micromobility Trips Change from Baseline: Micromobility Cost Tests (Tests 39 & 40)

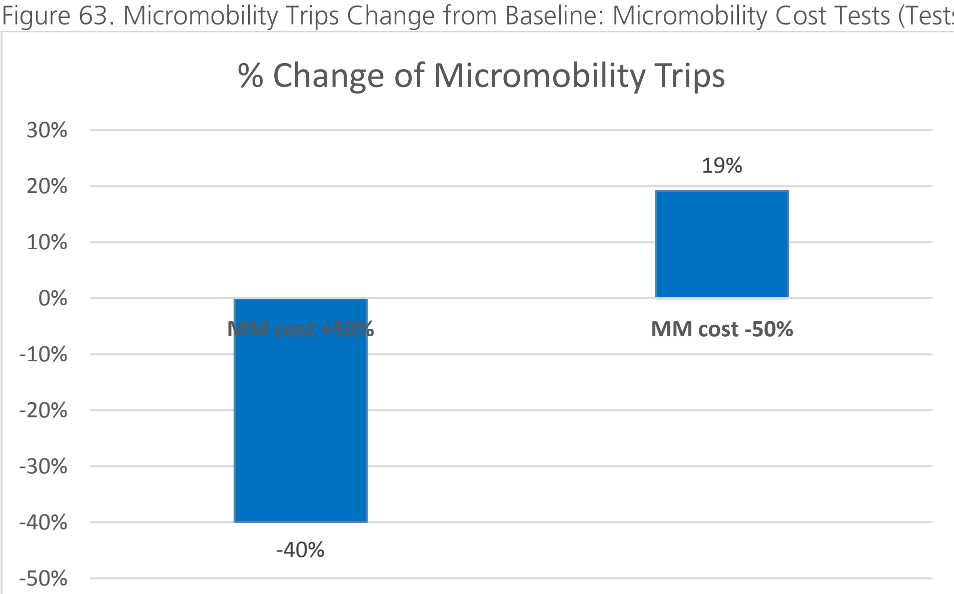


Figure 64. Walk & Micromobility Trips Change from Baseline: Micromobility Cost Tests (Tests 39 & 40)

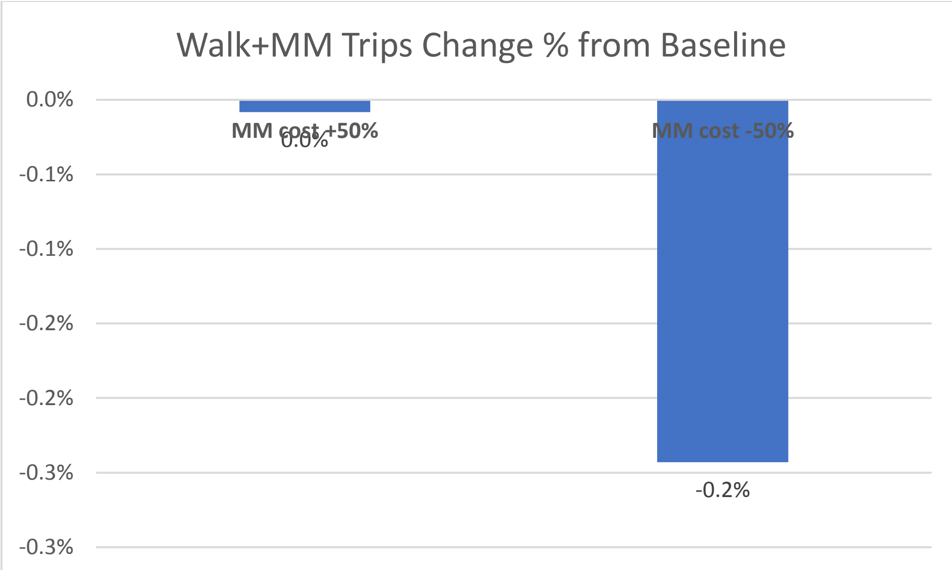
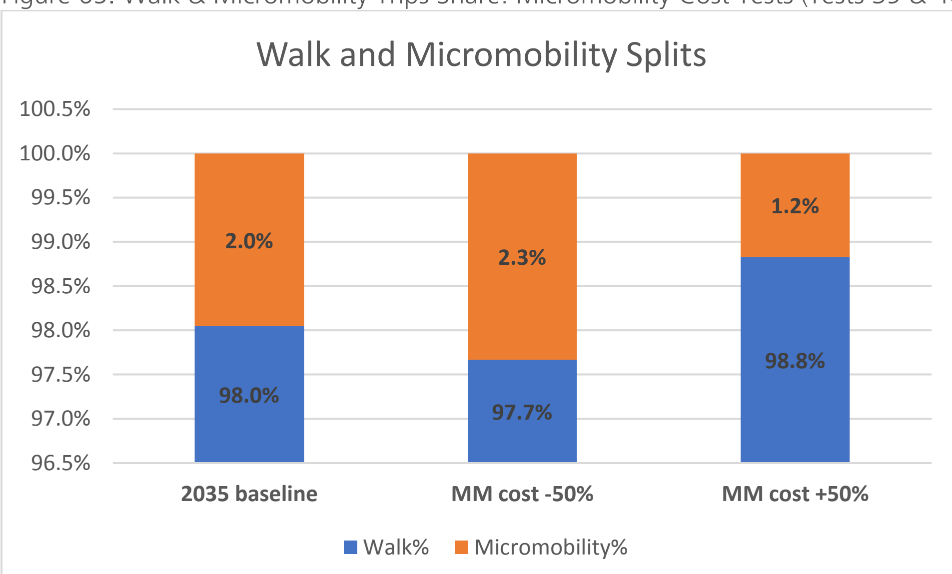


Figure 65. Walk & Micromobility Trips Share: Micromobility Cost Tests (Tests 39 & 40)



AV Penetration Rate Tests (Tests 41 & 42)

Compared with the 2035 baseline without AV, the 20% AV penetration test had the following results:

- VMT increased by 12%, suggesting that a 1 percent increase in AV penetration rate will lead to a VMT increase of 0.6% (elasticity of 0.6) (Figure 66).

- AV trips account for 19% of regional total vehicle trips, suggesting that a 1 percent increase in AV penetration rate will lead to an AV trip increase of 0.95% (elasticity of 0.95) (Figure 67).
- About 40% of AV VMT was generated by 'zombie' AV trips with no passengers; only 2% of AV VMT was generated by trips with 2 or more passengers (Figure 68).
- Total trips decreased slightly by 0.3% (Figure 69)
- Mode share changes for San Diego resident models (Figure 70):
    - SR2 increased from 23.6% to 24.0%
    - SR3 decreased from 16.6% to 16.1%
    - Transit increased from 2.6% to 2.7%
- Transit boarding increased by nearly 3% (Figure 71)
- Average trip distance increased from 6.1 miles to 6.2 miles (Table 14).

Compared with the 2035 baseline without AV, the 50% AV penetration test had the following results:

- VMT increased by 21%, suggesting that a 1 percent increase in AV penetration rate will lead to a VMT increase of 0.4% (elasticity of 0.4) (Figure 66).
- AV trips account for 33% of regional total vehicle trips, suggesting that a 1 percent increase in AV penetration rate will lead to an AV trip increase of 0.66% (elasticity of 0.66) (Figure 67).
- Total trips decreased slightly by 2.1% (Figure 69)
- About 40% of AV VMT was generated by 'zombie' AV trips with no passengers; only 2% with 2 or more passengers (Figure 68).
- Mode share changes for San Diego resident models (Figure 69):
    - DA decreased from 45.8% to 45.0%
    - SR2 increased from 23.6% to 24.4%
    - SR3 decreased from 16.6% to 14.8%
    - Transit increased from 2.6% to 3.2%
    - Active modes increased from 9.9% to 10.8%
- Transit boarding increased by over 20% (Figure 71)
- Average trip distance increased from 6.1 miles to 6.2 miles; trip distance of all auto modes increased (Table 14).

The results of the experiment indicated a significant VMT increase as the household AV penetration rate increased. Nearly 40% of AV VMT was from 'zombie' AV trips. Zombie AV VMT accounted for 10% and 18% of regional VMT and were the majority of the regional VMT increases in the two tested scenarios (Figure 72). Total trips decreased as AV penetration rate increased, probably because the model was calibrated to factor in 10% and 25% reductions in auto ownership for 20% and 50% AV penetration rates, respectively (Figure 69). Average trip distance increased slightly, indicating AV trips tend to be longer. Drive alone mode share decreased while transit and active (walk, bike, and micromobility) mode shares increased, probably because the reduced auto ownership (Figure 73) shifted some auto trips to transit and non-motorized trips.

Figure 66. VMT Change from Baseline: AV Penetration Rate Tests (Tests 41 & 42)

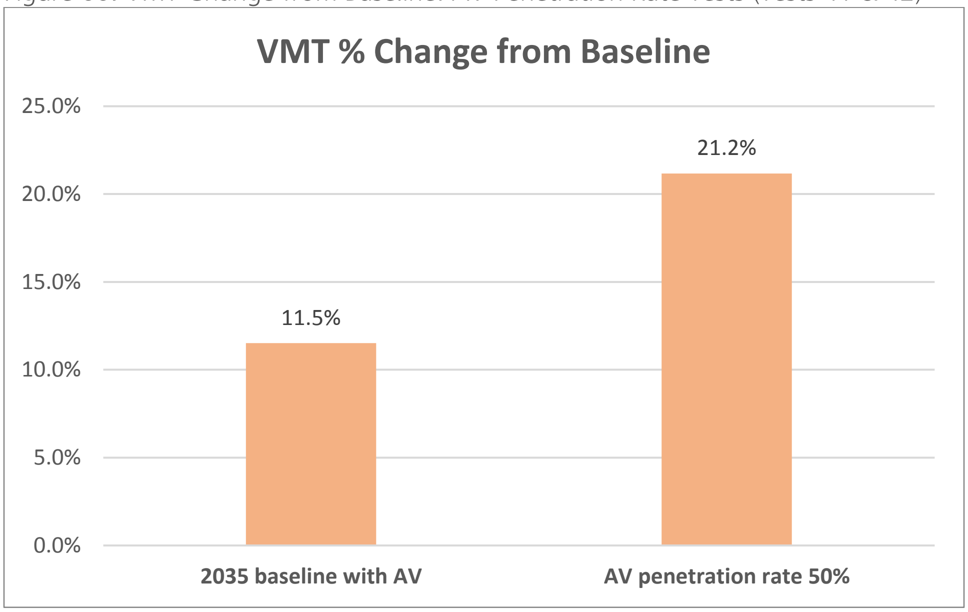


Figure 67. Share of AV Trips and AV VMT of Reginal Total: AV Penetration Rate Tests (Tests 41 & 42)

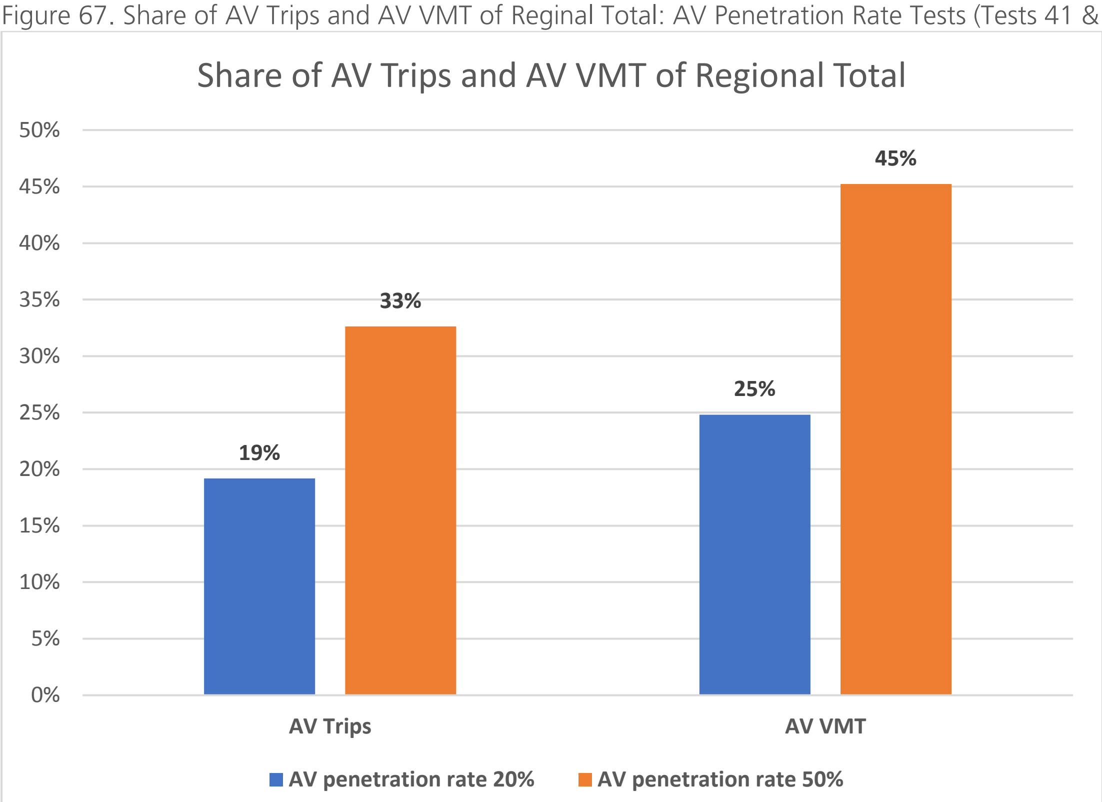


Figure 68. AV VMT by Occupancy: AV Penetration Rate Tests (Tests 41 & 42)

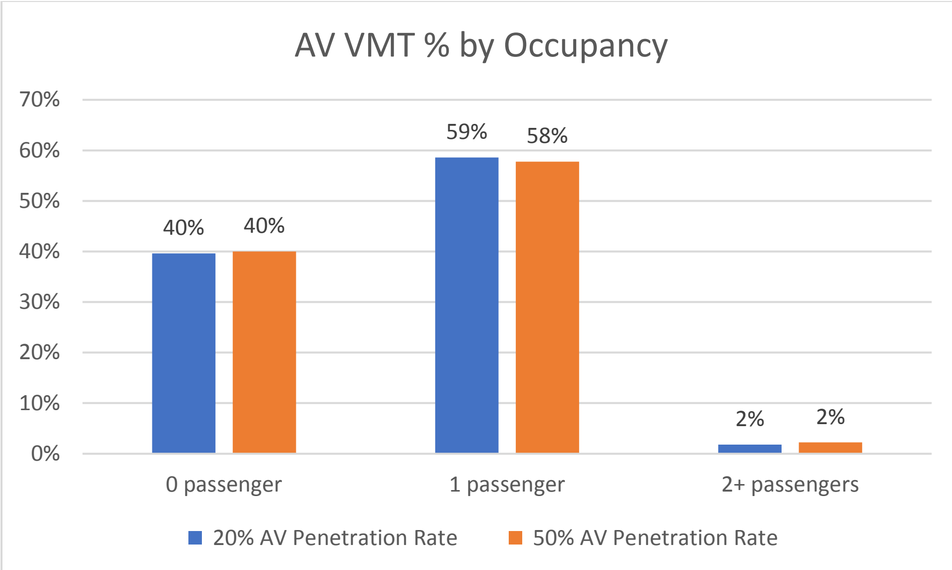


Figure 69. Total Trips Change from Baseline: AV Penetration Rate Tests (Tests 41 & 42)

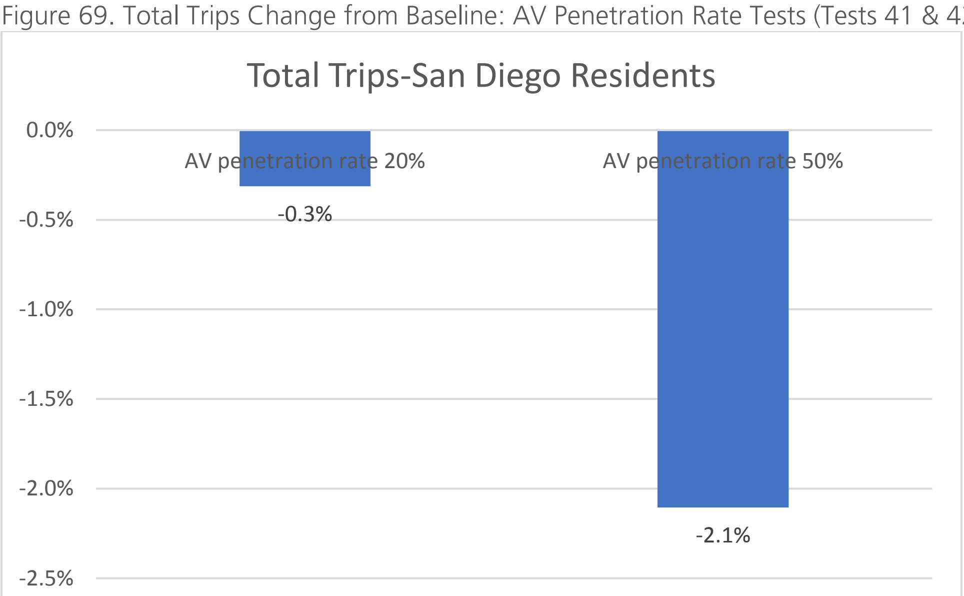


Figure 70. Mode Share of Person Trips: AV Penetration Rate Tests (Tests 41 & 42)

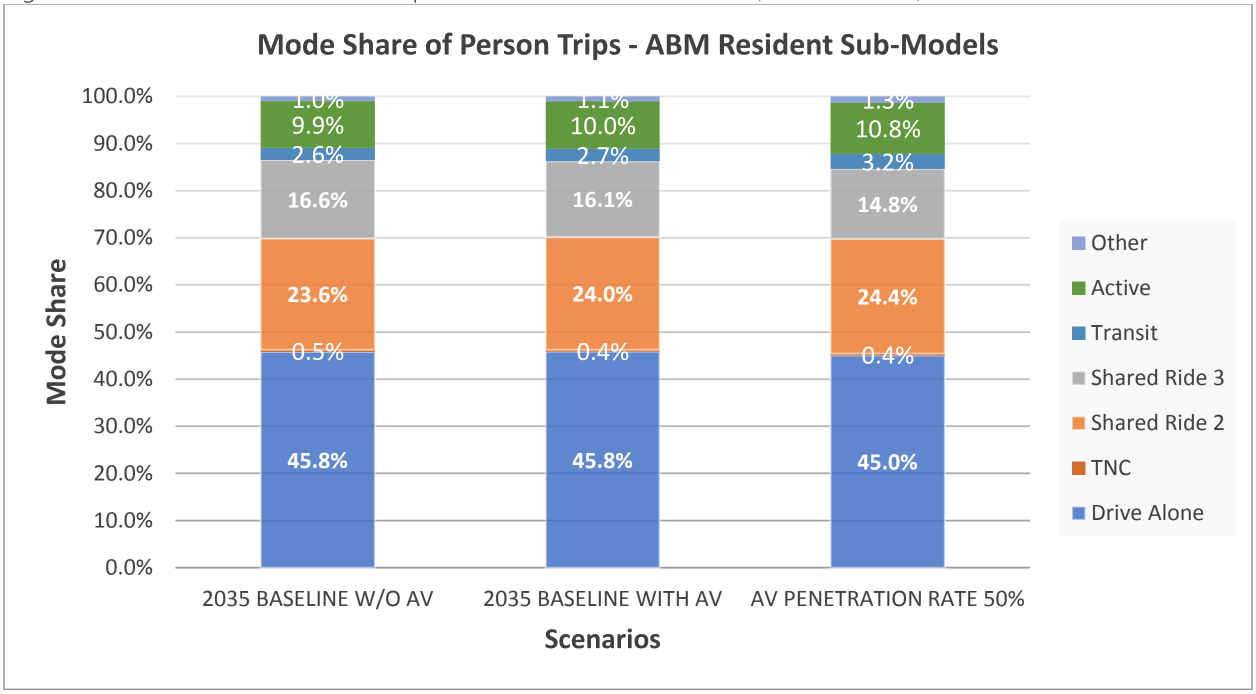


Figure 71. Transit Boarding Change from Baseline: AV Penetration Rate Tests (Tests 41 & 42)

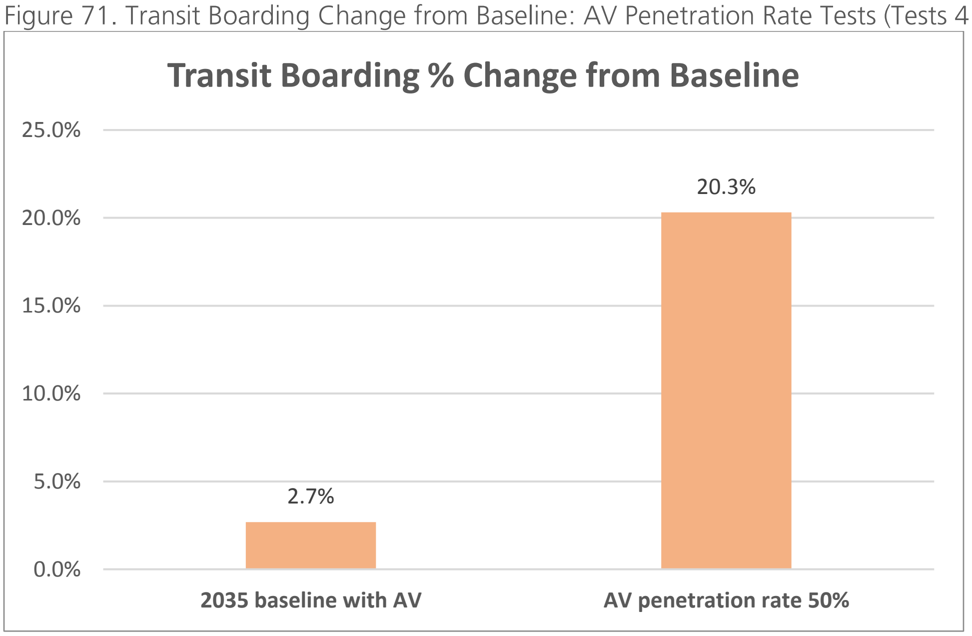


Figure 72. Zombie AV VMT & Regional VMT Increase: AV Penetration Rate Tests (Tests 41 & 42)

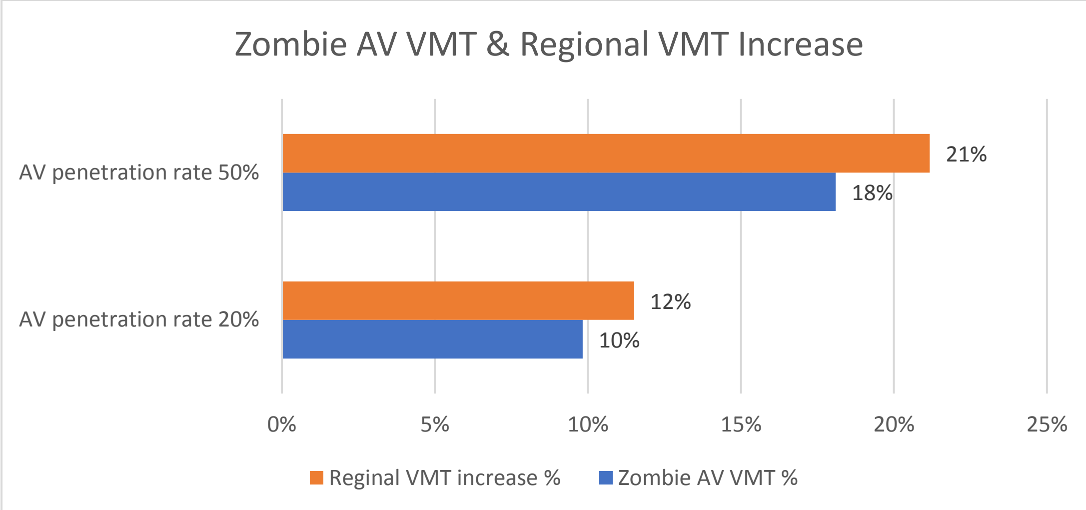


Figure 73. Auto Ownership by Vehicle Type: AV Penetration Rate Tests (Tests 41 & 42)

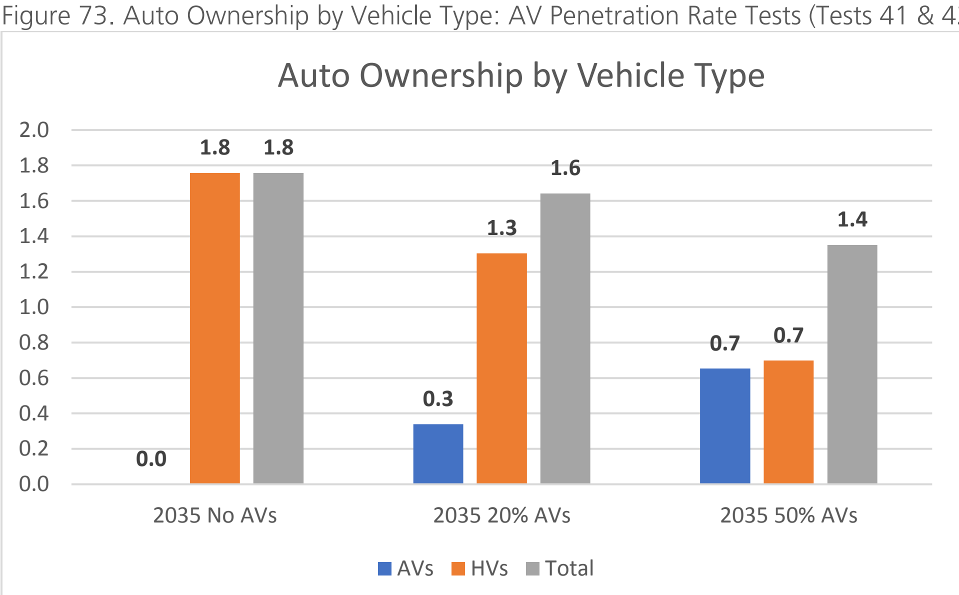


Table 14. Person Trip Distance by Mode: AV Penetration Rate Tests (Tests 41 & 42)

description	DA	SR2	SR3	TNC	Pooled TNC	Walk	Bike	Transit	Total
2035 baseline w/o AV	7.5	5.7	5.9	3.3	3.4	0.8	3.2	8.9	6.1
2035 baseline with AV	7.5	5.7	5.9	3.3	3.2	0.8	3.3	8.7	6.2
AV penetration rate 50%	7.6	5.8	6.1	3.3	3.3	0.8	3.4	8.5	6.2

AV In-Vehicle Time (IVT) Coefficient Tests (Tests 43 & 44)

Compared with the 2035 baseline with a 0.75 AV IVT coefficient, the 0.6 AV IVT coefficient test had the following results:

- Regional VMT increased by 0.5% (Figure 74)
- Insignificant mode share changes (Figure 75)
- Share of AV VMT in regional total increased from 24.8% to 25.1% (Figure 76)

Compared with the 2035 baseline with a 0.75 AV IVT coefficient, 0.9 AV IVT coefficient test had the following results:

- VMT decreased by 0.4% (Figure 74)
- Insignificant mode share changes (Figure 75)
- Share of AV VMT in regional total decreased from 24.8% to 24.6% (Figure 76).

The results suggest that the ABM2+ is sensitive to the AV in-vehicle time coefficient. As AV IVT coefficient decreased, both regional VMT and AV VMT increased slightly. However, the AV IVT coefficient had limited impact on mode shares. When AV IVT coefficient increased, the opposite patterns was observed.

Figure 74. VMT Change from Baseline: AV In-Vehicle Time (IVT) Coefficient Tests (Tests 43 & 44)

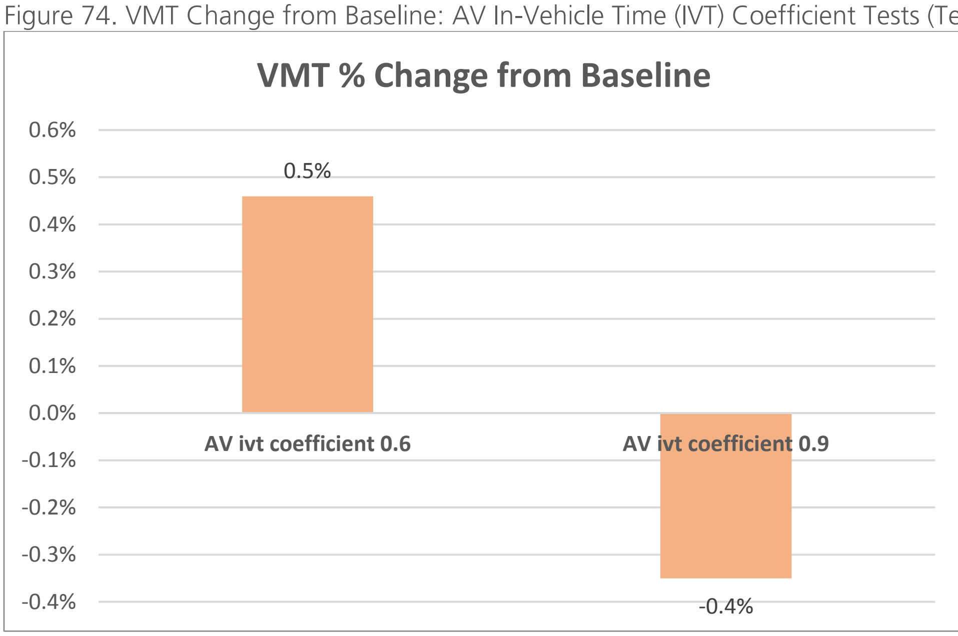


Figure 75. Mode Share of Person Trips: AV In-Vehicle Time (IVT) Coefficient Tests (Tests 43 & 44)

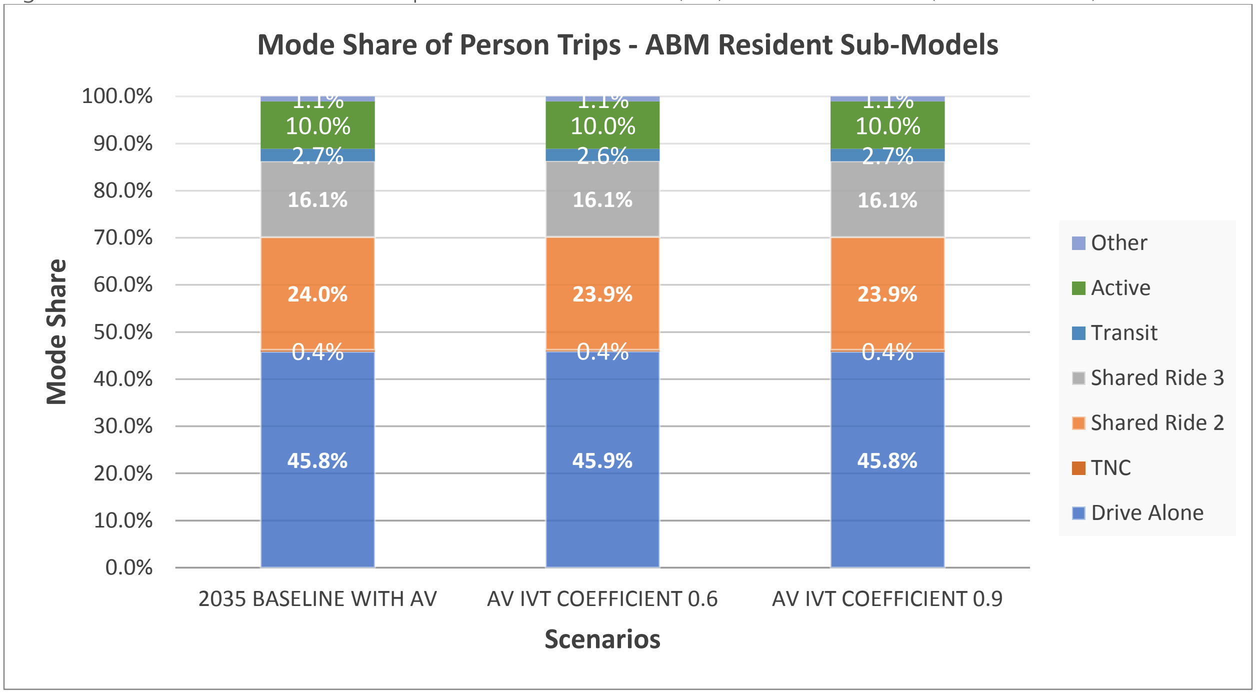
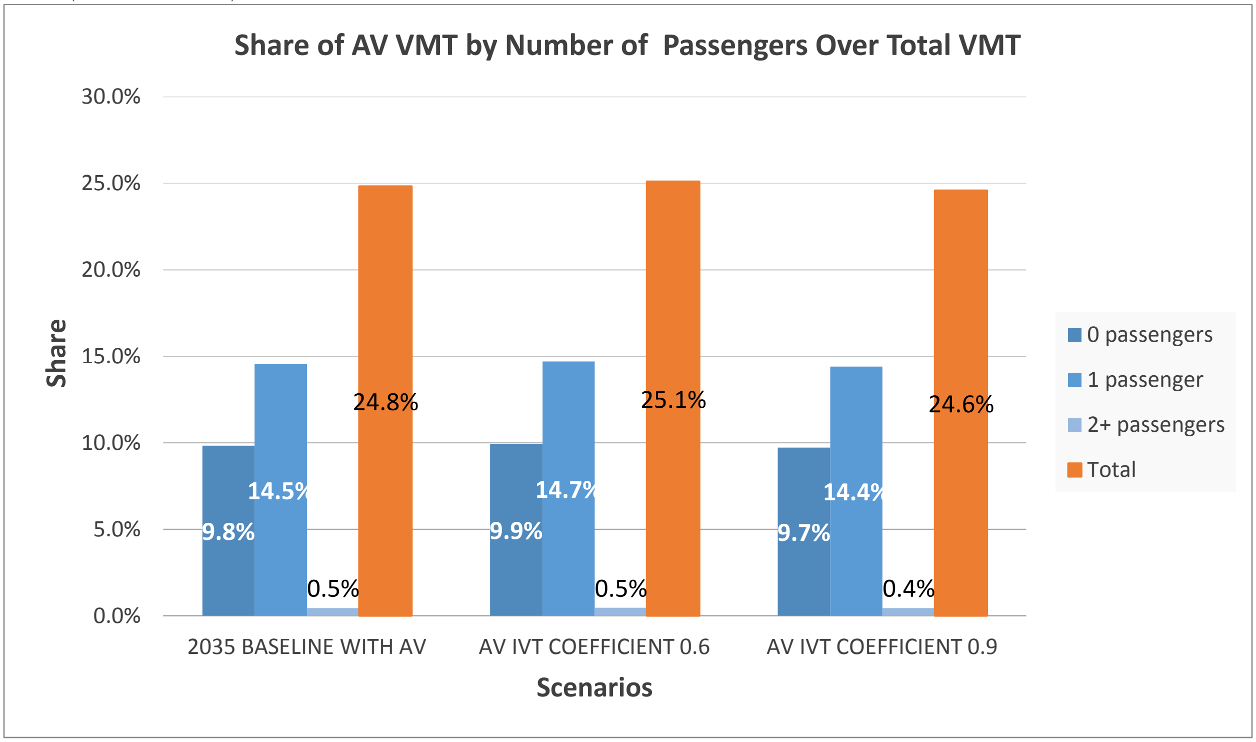


Figure 76. Share of AV VMT by Number of Passengers Over Total VMT: AV In-Vehicle Time (IVT) Coefficient Tests (Tests 43 & 44)



AV Auto Operating Cost Scaler Tests (Tests 45 & 46)

Compared with the 2035 baseline with a 0.7 AV AOC scaler, 0.5 AV AOC scaler test had the following results:

- Regional VMT increased by 0.7% (Figure 77)
- Insignificant mode share changes (Figure 78)
- Share of AV VMT in regional total increased from 24.8% to 25.0% (Figure 79).

Compared with the 2035 baseline with 0.7 AV AOC scaler, 0.9 AV AOC scaler test had the following results:

- VMT decreased by 0.4% (Figure 77)
- Insignificant mode share changes (Figure 78)
- Share of AV VMT in regional total increased from 24.8% to 24.6% (Figure 79).

The results suggest that ABM2+ is sensitive to AV AOC. As the AV AOC scaler decreased, both regional VMT and AV VMT increased slightly. However, the AV AOC scaler had limited impact on mode shares. When the AV AOC scaler increased, the opposite patterns were observed.

Figure 77. VMT Change from Baseline: AV Auto Operating Cost Scaler Tests (Tests 45 & 46)

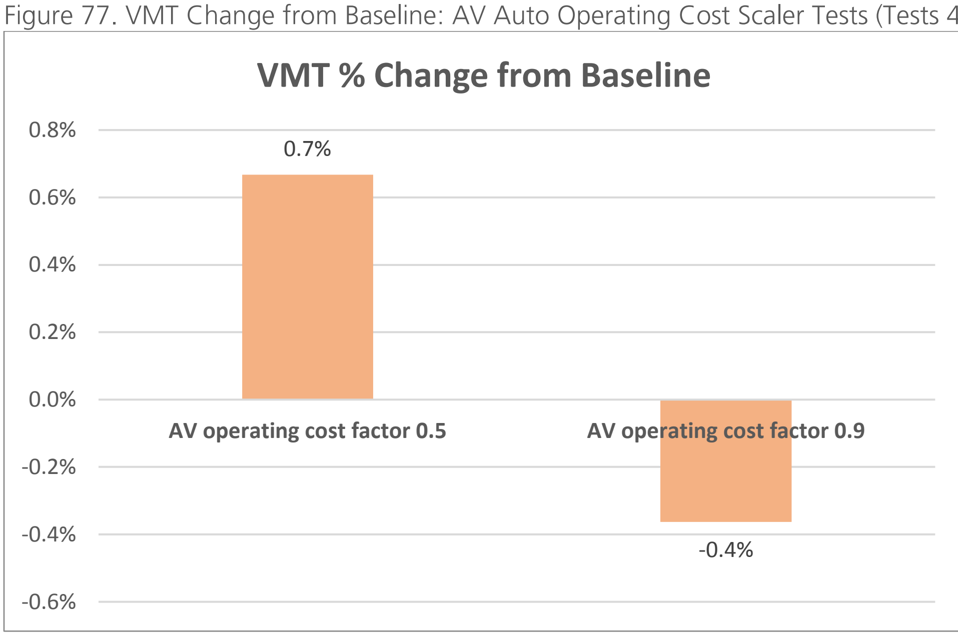


Figure 78. Mode Share of Person Trips: AV Auto Operating Cost Scaler Tests (Tests 45 & 46)

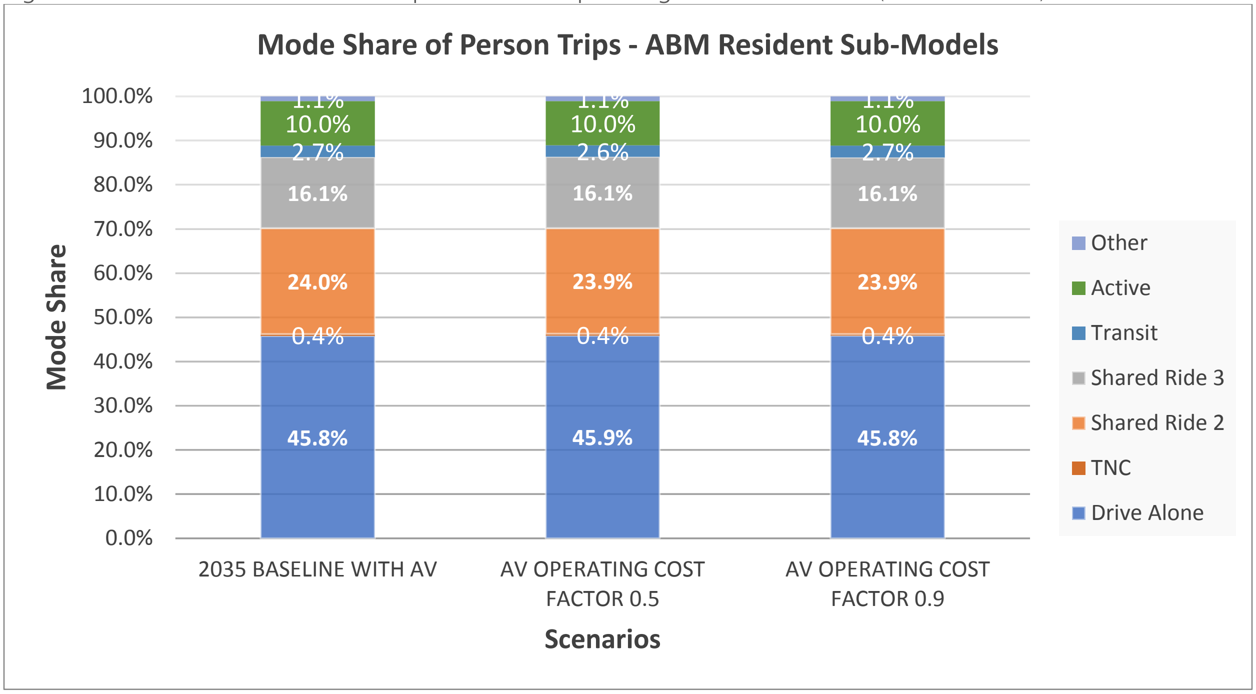
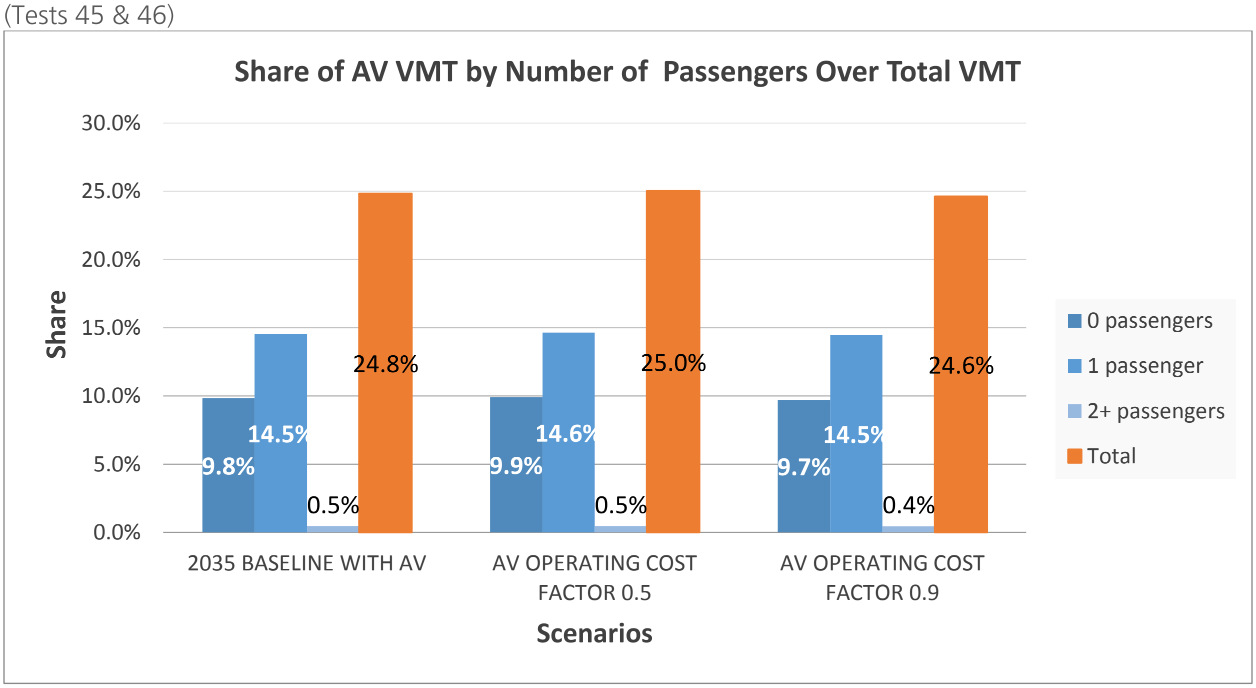


Figure 79. Share of AV VMT by Number of Passengers Over Total VMT: AV Auto Operating Cost Scaler Tests (Tests 45 & 46)



AV Terminal Time Tests (Tests 47 & 48)

In comparison with the 2035 baseline with a default AV terminal time factor of 0.65, a 0.5 AV terminal time factor test had the following results:

- Overall regional VMT increased slightly by 0.1% (Figure 80)
- Insignificant mode share changes (Figure 81)

In comparison with the 2035 baseline with a default AV terminal time factor of 0.65, a larger 0.8 AV terminal time factor test had the following results:

- Insignificant VMT change (Figure 80)
- Insignificant mode share changes (Figure 81)

The results suggest that the model had limited sensitivity to the AV terminal time scaler. When the AV terminal time changed in either direction, VMT and mode share changes were insignificant.

Figure 80. VMT Change from Baseline: AV Terminal Time Tests (Tests 47 & 48)

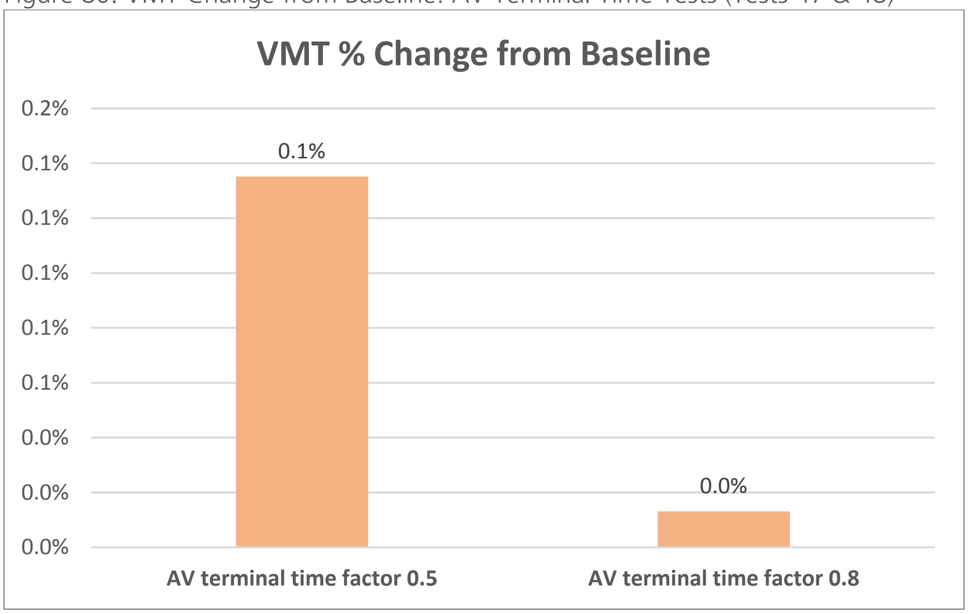
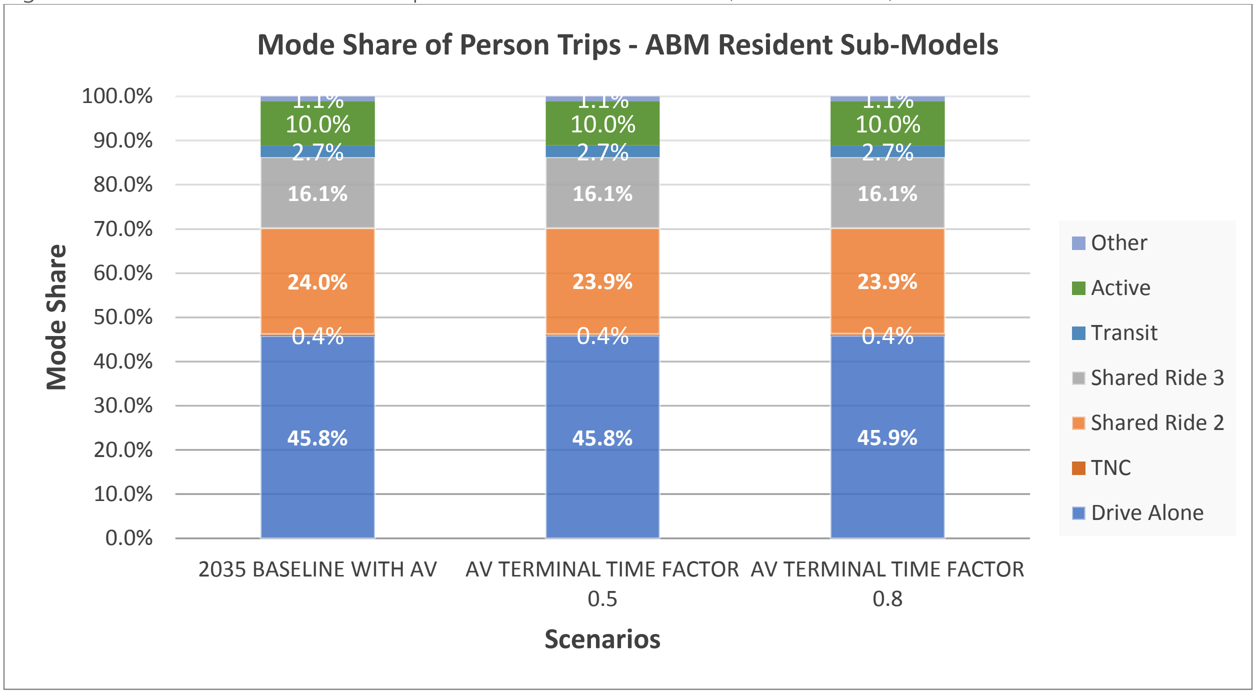


Figure 81. Mode Share of Person Trips: AV Terminal Time Tests (Tests 47 & 48)



TNC Optimization Tests (Tests 49 & 50)

In comparison with the 2035 baseline without AVs, the TNC optimization scenario had the following results:

- VMT increased slightly by 0.3% (Figure 82)
- Mode share for all models (Figure 84):
  - Drive alone decreased from 45.3% to 45.0%.
  - TNC increased from 0.9% to 1.9%.
  - Transit decreased from 2.6% to 2.5%.
  - Active modes (walk, bike, and micromobility) decreased from 9.7% to 9.6%.
- Transit boarding decreased by 2.2% (Figure 83)
- Share of TNC VMT in regional total increased from 1.1% to 1.9% (Figure 85).

In comparison with the 2035 baseline without AVs, the transit TNC optimization scenario had the following results:

- Insignificant VMT change (Figure 82).
- Insignificant mode share changes (Figure 84).
- Transit boarding increased slightly by 0.2% (Figure 83).

The results suggest that the model was sensitive to the TNC optimization scenario when all TNC were given 30-minute benefits. While TNC mode share increased significantly, auto, transit and active mode shares all decreased, indicating competition between TNC and all other modes.

On the other hand, the results suggest that the model had limited sensitivity to the TNC transit optimization scenario when only TNC transit were given 30-minute benefits. The lack of sensitivity could be explained by the very small TNC transit mode share (roughly 0.01%). Regardless of how much benefit was given to TNC transit, with such a small mode share, the impact of TNC transit on model results was insignificant.

Figure 82. VMT Change from Baseline: TNC Optimization Tests (Tests 49 & 50)

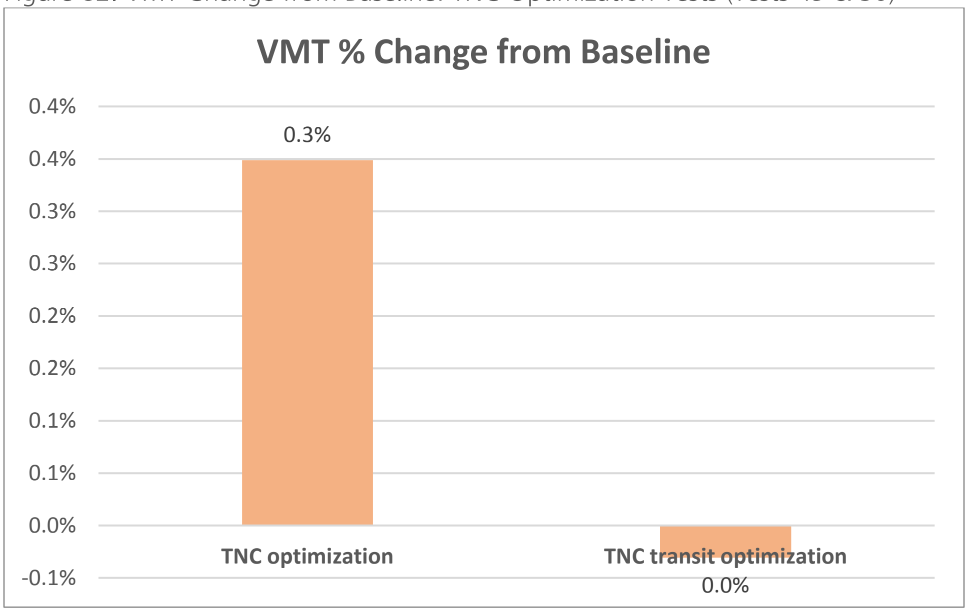


Figure 83. Transit Boarding Change from Baseline: TNC Optimization Tests (Tests 49 & 50)

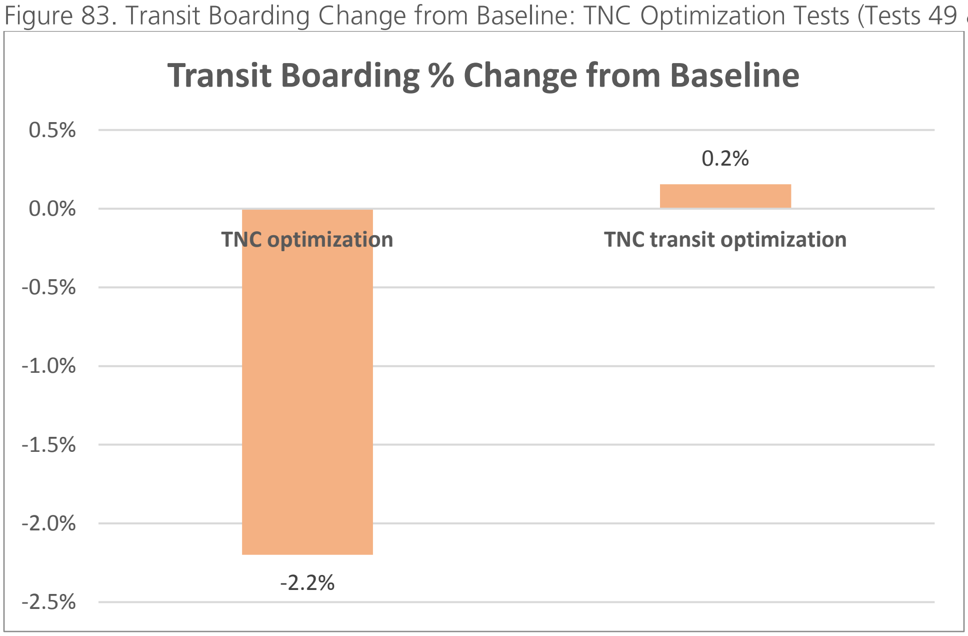


Figure 84. Mode Share of Person Trips: TNC Optimization Tests (Tests 49 & 50)

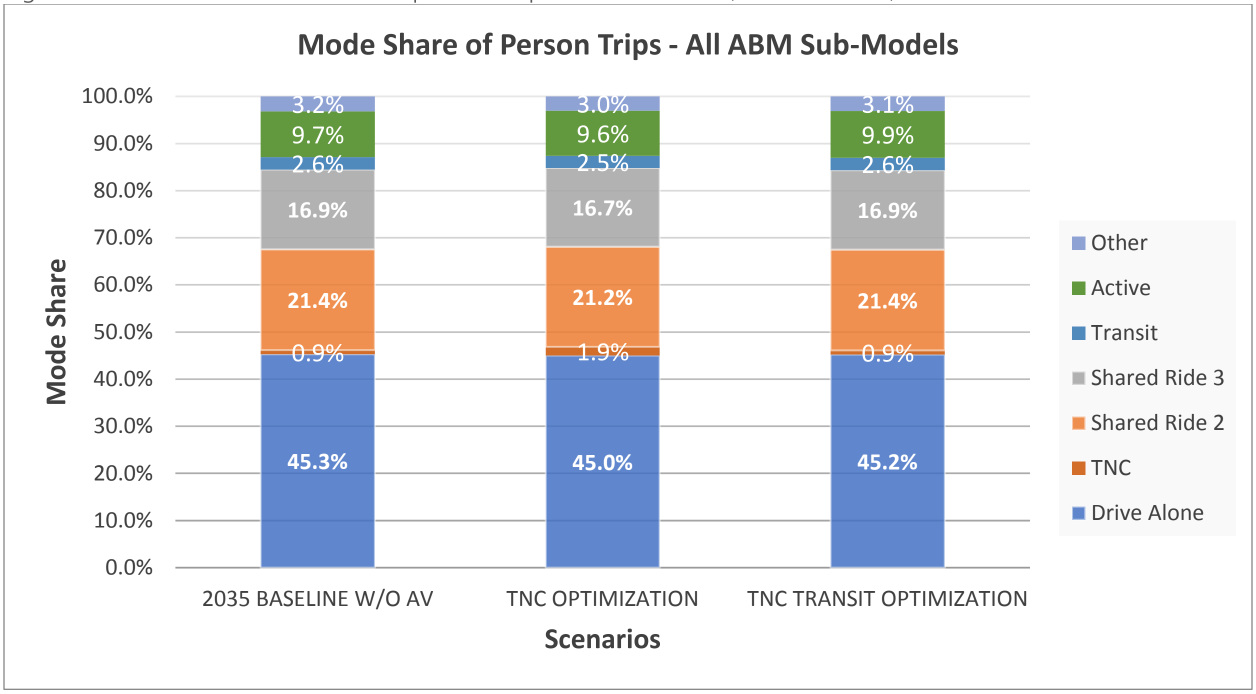
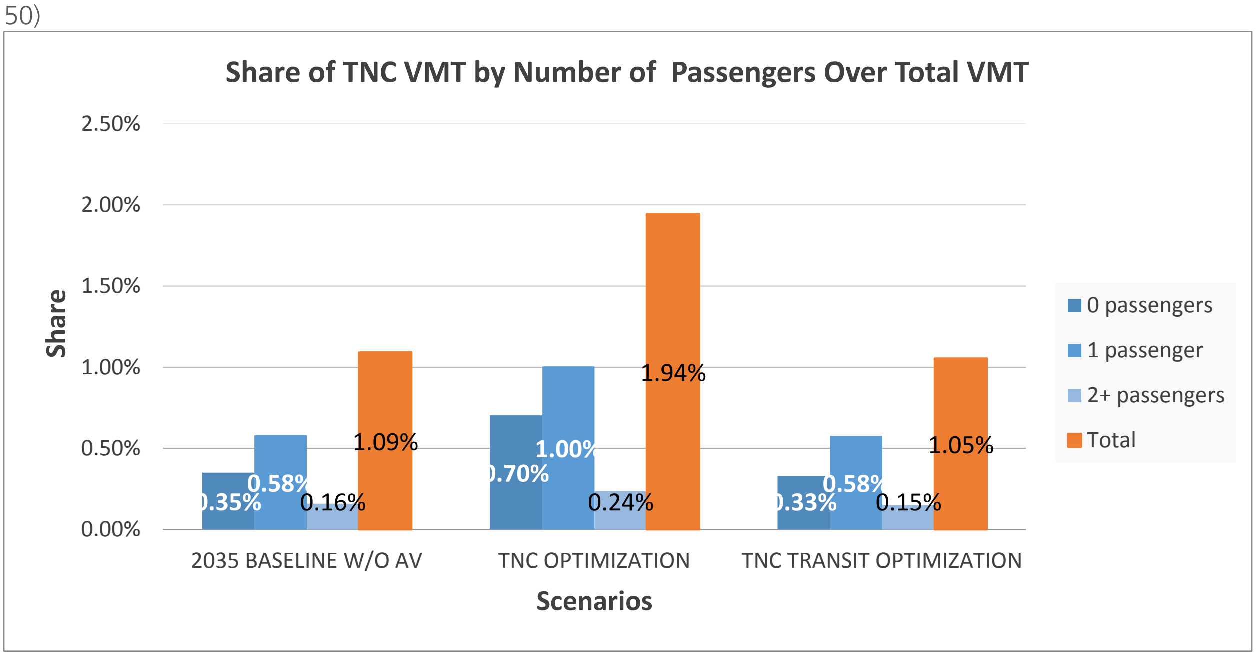


Figure 85. Share of TNC VMT by Number of Passengers Over Total VMT: TNC Optimization Tests (Tests 49 & 50)



AV and TNC Combo Tests (Tests 51-53)

In comparison with the 2035 baseline with 20% AV, the 20% AV with 30 minutes TNC benefit test had the following results:

- VMT increased slightly by 0.1% (Figure 86)
- Mode share of all models (Figure 87):
    - Drive alone decreased from 45.3% to 45.1%.
    - SR3 decreased from 16.7% to 16.4%.
    - TNC increased from 0.8% to 1.7%.
    - Active modes (walk, bike, and micromobility) decreased from 9.7% to 9.6%.
- Share of TNC VMT in regional total increased from 0.9% to 1.6% (Figure 89).
- Overall trip distance change was insignificant; Regular TNC trip distance decreased from 7.7 miles to 6.3 miles; Pooled TNC trips decreased from 6.0 miles to 5.4 miles (Table 15).

In comparison with the 2035 baseline with 20% AV, the 20% AV with 7.5 minutes TNC benefit test had the following results:

- VMT change was insignificant (Figure 86)
- Mode share changes were insignificant, except TNC mode share increased from 0.8% to 1.0% (Figure 87).
- Share of TNC VMT in regional total change was insignificant (Figure 89).
- Overall trip distance change was insignificant; Regular TNC trip distance decreased from 7.7 miles to 7.5 miles; Pooled TNC trips decreased from 6.0 miles to 5.8 miles (Table 15).

In comparison with the 2035 baseline with 20% AV, the 50% AV with 15 minutes TNC benefit test had the following results:

- VMT increased by nearly 9% (Figure 86)
- Mode share of all models (Figure 87):
    - Drive alone decreased from 45.3% to 44.6%.
    - SR2 increased from 21.7% to 21.9%.
    - SR3 decreased from 16.7% to 15.5%.
    - Transit increased from 2.7% to 3.2%.
    - TNC increased from 0.8% to 1.1%.
    - Active modes (walk, bike, and micromobility) increased from 9.7% to 10.3%.
- Transit boarding increased by 17% (Figure 88)
- Share of TNC VMT in regional total increased from 0.9% to 1.0% (Figure 89).
- Overall trip distance change was insignificant; Regular TNC trip distance decreased from 7.7 miles to 7.0 miles; Pooled TNC trips decreased from 6.0 miles to 4.7 miles (Table 15).

The results suggest that the model is sensitive to the combined AV penetration rate and TNC benefit changes. Regional VMT increased significantly in the 50% AV scenario but not in the 7.5

minutes and 30 minutes TNC benefit scenarios (both with 20% AV), indicating that the key driver of VMT is AV penetration rate not TNC benefit. The results also indicate ABM2+ is sensitive to TNC benefits; with 30 minutes TNC benefits, the TNC mode share increased significantly from 0.8% to 1.7%.

Figure 86. VMT Change from Baseline: AV and TNC Combo Tests (Tests 51-53)

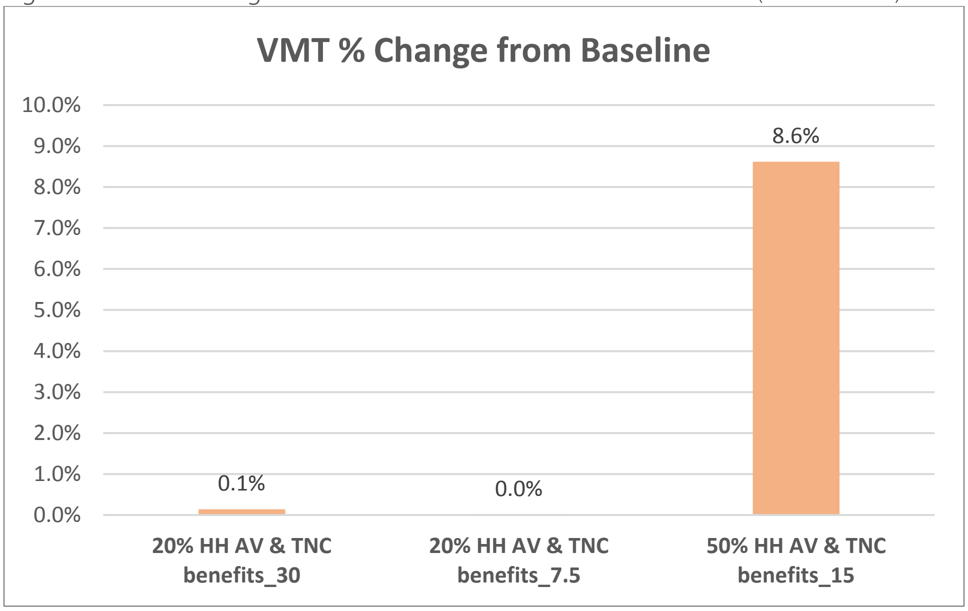


Figure 87. Mode Share of Person Trips: AV and TNC Combo Tests (Tests 51-53)

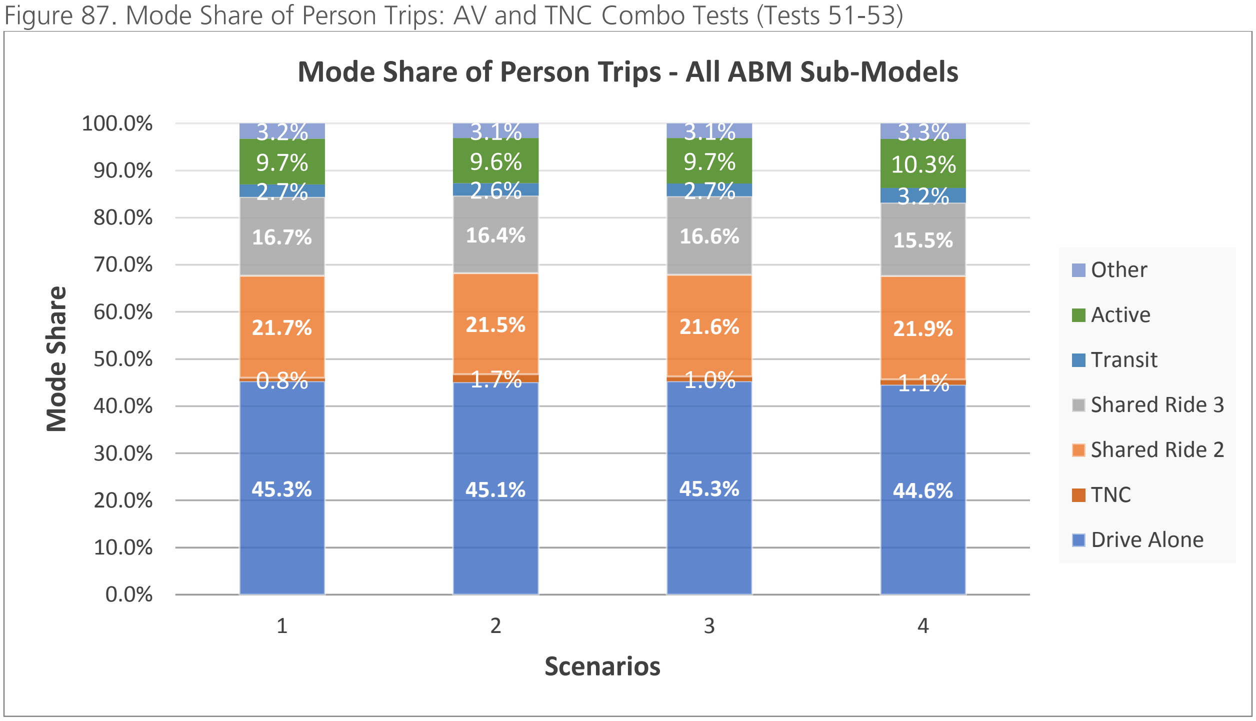


Figure 88. Transit Boarding Change from Baseline: AV and TNC Combo Tests (Tests 51-53)

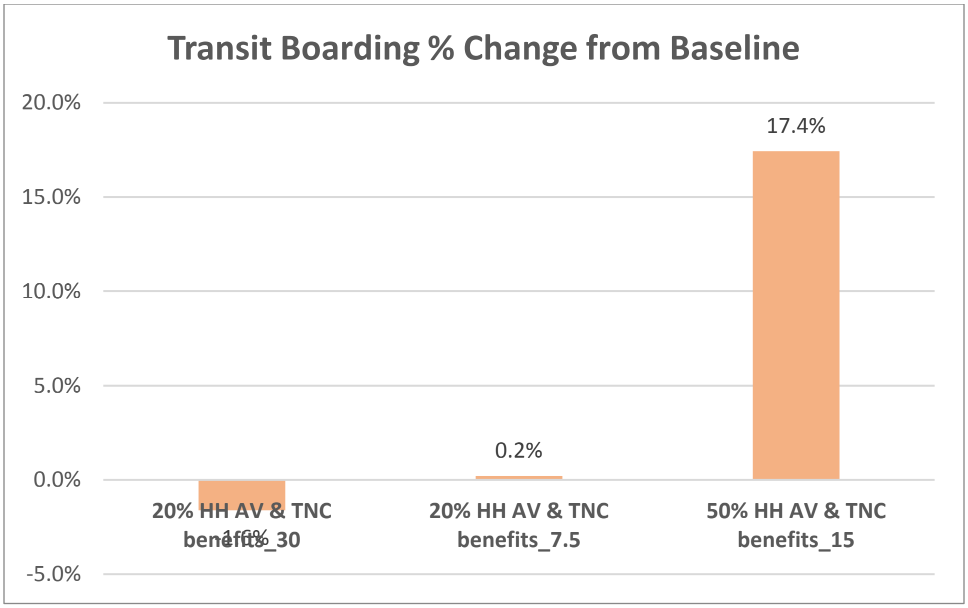


Figure 89. Share of TNC VMT by Number of Passengers Over: AV and TNC Combo Tests (Tests 51-53)

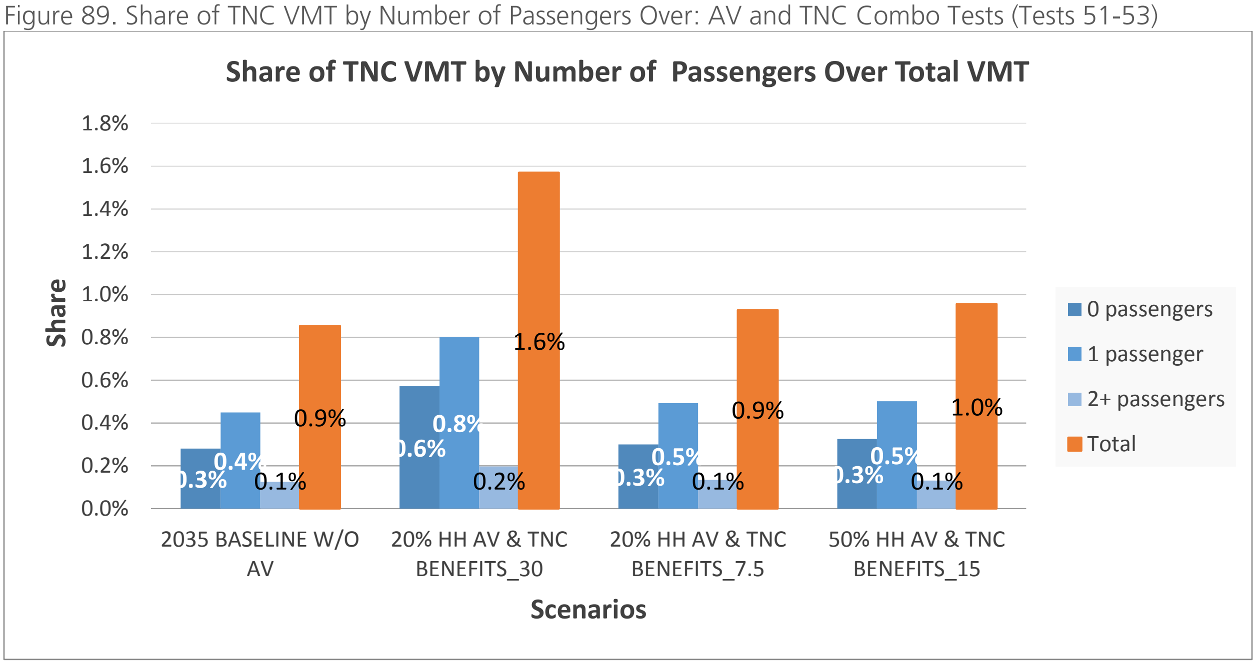


Table 15. Person Trip Distance by Mode: AV Penetration Rate Tests (Tests 41 & 42)

description	DA	SR2	SR3	TNC	Pooled TNC	Walk	Bike	Transit	Total
2035 baseline with AV	8.0	7.2	8.3	7.7	6.0	0.8	3.3	9.1	7.3
20% HH AV & TNC benefits_30	8.0	7.2	8.3	6.3	5.4	0.8	3.3	9.2	7.3
20% HH AV & TNC benefits_7.5	8.0	7.2	8.3	7.5	5.8	0.8	3.3	9.1	7.3
50% HH AV & TNC benefits_15	8.0	7.3	8.6	7.0	4.7	0.8	3.4	8.9	7.3

Telework

Telework Rate (Tests 54, 55 & 56)

In May 2020, amid the COVID19 pandemic, staff conducted telework sensitivity tests to evaluate the responsiveness of ABM2+ to various telework scenarios. In ABM2+, there are two types of telework, permanent and occasional telework. Permanent telework is modeled in the work from home model, while the impact of occasional telework is reflected in daily activity pattern, telework frequency, non-mandatory tour frequency, and non-mandatory tour stop frequency models. Since telework modeling in ABM2+ is based on the 2016/2017 household travel behavior survey, ABM2+ telework results represent the pre-COVID19 'normal' condition. Neither temporary COVID19 shelter in place nor post-COVID19 new 'normal' conditions are reflected in ABM2+ telework modeling.

Staff tested three 2035 telework alternatives (Table 16): existing pattern (business as usual) scenario, moderate growth scenario, and maximum growth scenario.

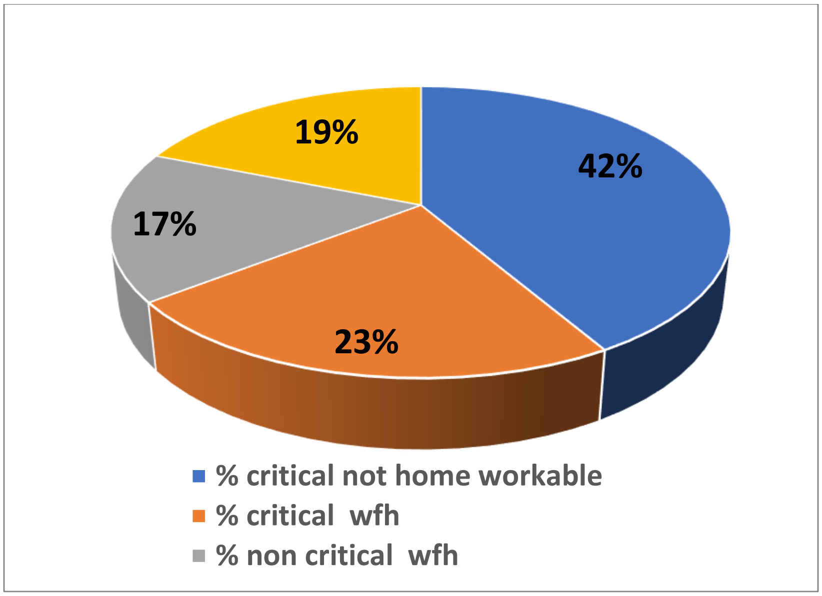
Table 16. 2035 telework alternatives

CARB Category	Description	Test ID	Scenario	Year
Telework	Existing pattern	54	Existing telework rates	2035
	Moderate growth pattern	55	Moderate telework rate growth	2035
	Maximum growth pattern	56	Maximum telework rate growth	2035

In each of the three scenarios, occasional telework is further broken down to 1 day a week, 2-3 days a week, and 4+ days a week categories using the observed proportions from the 2016/2017 household survey.

The maximum telework scenario is constructed using data from an analysis by a SANDAG economist. In the analysis, workers in San Diego are categorized into four categories (below). Combining both critical and non-critical workers who can work from home, roughly 40% of San Diego's workforce are telework-able, while the other 60% are not. In test 56, the combined permanent and occasional telework rate is 38%, roughly representing a maximum possible telework scenario.

- Critical workers but not home workable (42%)
- Critical workers who can work from home (23%)
- Non-critical workers but not home workable (19%)
- Non-critical workers who can work from home (17%)



Telework Sensitivity Testing Results

In comparison with the existing telework pattern, the moderate telework growth scenario had the following results:

- Overall trip rate decreased from 4.51 to 4.49 (Figure 90). All categories except teleworking 2-3 days/week decreased (Figure 91).
- Mode shares (Figures 92 & 93):
  - Drive alone decreased from 45.9% to 45.5%.
  - SR2 increased from 23.5% to 23.6%
  - SR3 increased from 16.6% to 16.7%.
  - Walk mode increased from 8.8% to 9.0%
  - Transit decreased from 2.6% to 2.5%
- Auto trip length decreased from 6.1 to 6.0 (Figure 94). Walk trip length decreased from 3.2 to 3.1 (Figure 95).
- Transit boardings decreased by 1.7% (Figure 96)
- VMT decreased by 1.5% (Figure 97). VMT per capita decreased from 24.3 to 23.9 (Figure 98). All Worker VMT telework types decreased (Figure 99).

In comparison with the existing telework pattern, the maximum telework scenario had the following results:

- Trip rate decreased from 4.51 to 4.47 (Figure 90). All telework categories decreased (Figure 91).
- Mode shares (Figures 92 & 93):
  - Drive alone decreased from 45.9% to 43.6%.

- SR2 increased from 23.5% to 24.7%
- SR3 increased from 16.6% to 17.5%.
- Walk mode increased from 8.8% to 9.2%
- Transit decreased from 2.6% to 2.4%

- Auto trip length decreased from 6.1 to 5.8 (Figure 94). Walk trip length decreased from 3.2 to 2.9 (Figure 95).
- Transit boardings decreased by 5.4% (Figure 96)
- VMT decreased by 4.7% (Figure 97). VMT per capita decreased from 24.3 to 23.1 (Figure 98). All Worker VMT telework types decreased (Figure 99).

The results suggest that the model is sensitive to permanent and occasional telework rate changes. When compared with non-teleworkers, teleworkers generally generate fewer and shorter trips, drive alone less while shareriding and walking more, avoid peak-time travel, and have a smaller VMT per capita. Additionally, those who primarily work from home tend to have a higher trip rate, shorter trip distances, and smaller drive alone mode share, rates of peak-time travel, and VMT per capita when compared to occasional teleworkers. In general, as telework rate increases, the regional VMT, transit ridership, and peak-hour congestion all decrease.

Figure 90. Worker Trip Rate: Telework Rate Tests (Tests 54-56)

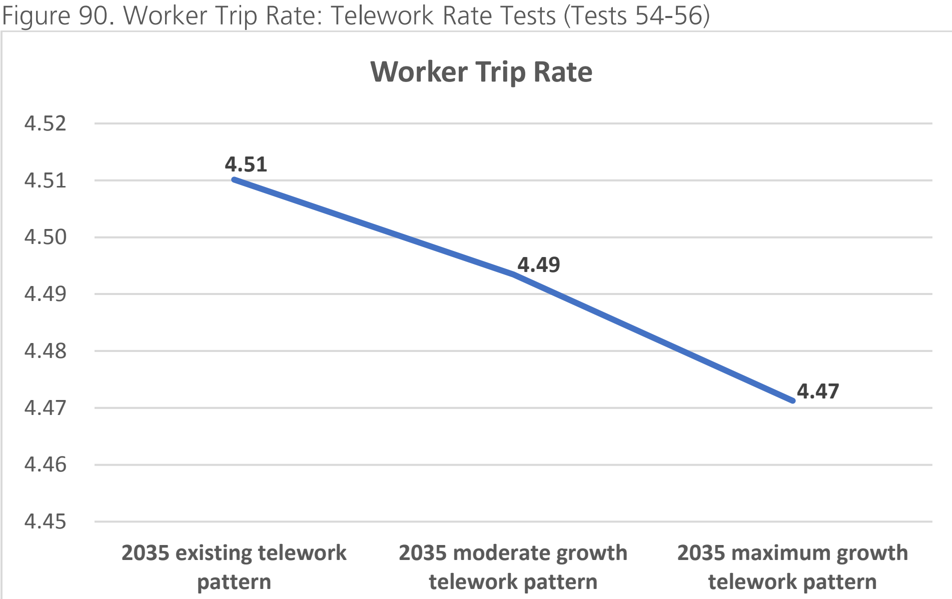


Figure 91. Worker Trip Rate by Telework Type: Telework Rate Tests (Tests 54-56)

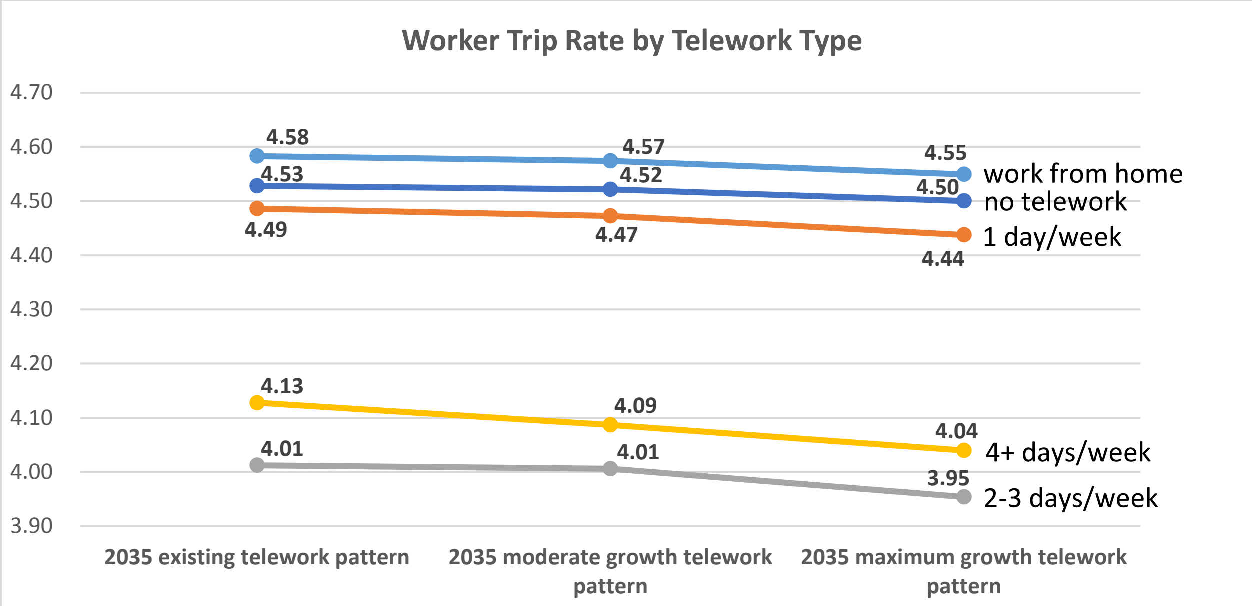


Figure 92. Auto Mode Shares: Telework Rate Tests (Tests 54-56)

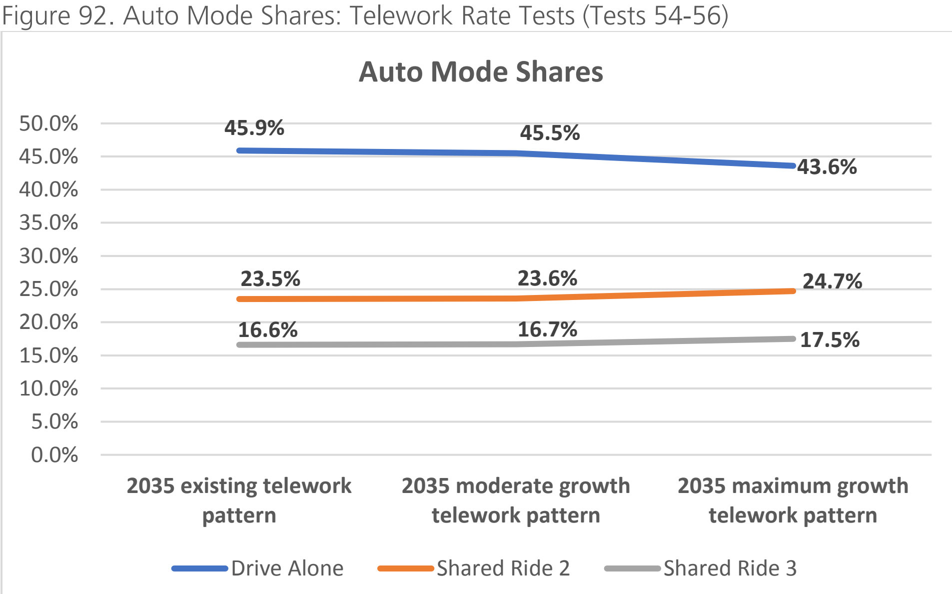


Figure 93. Non-Auto Mode Shares: Telework Rate Tests (Tests 54-56)

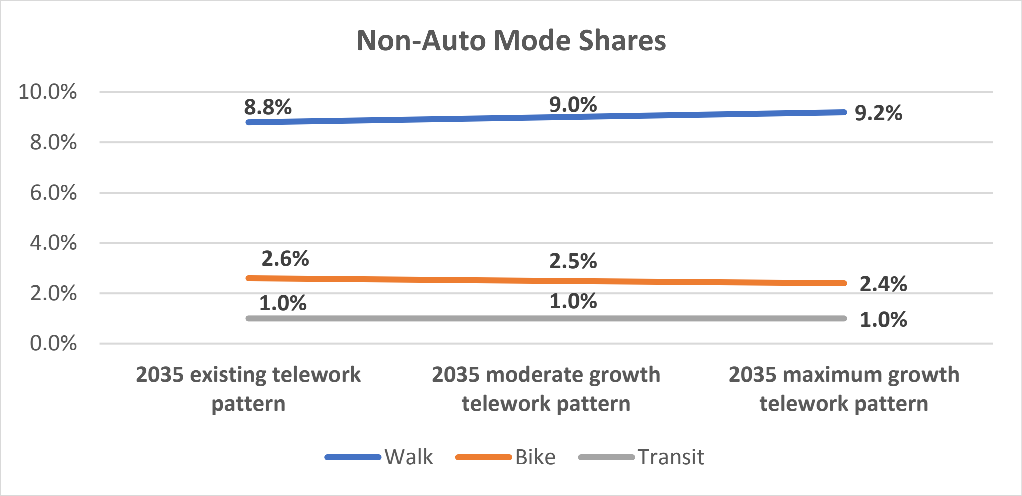


Figure 94. Auto Trip Length: Telework Rate Tests (Tests 54-56)

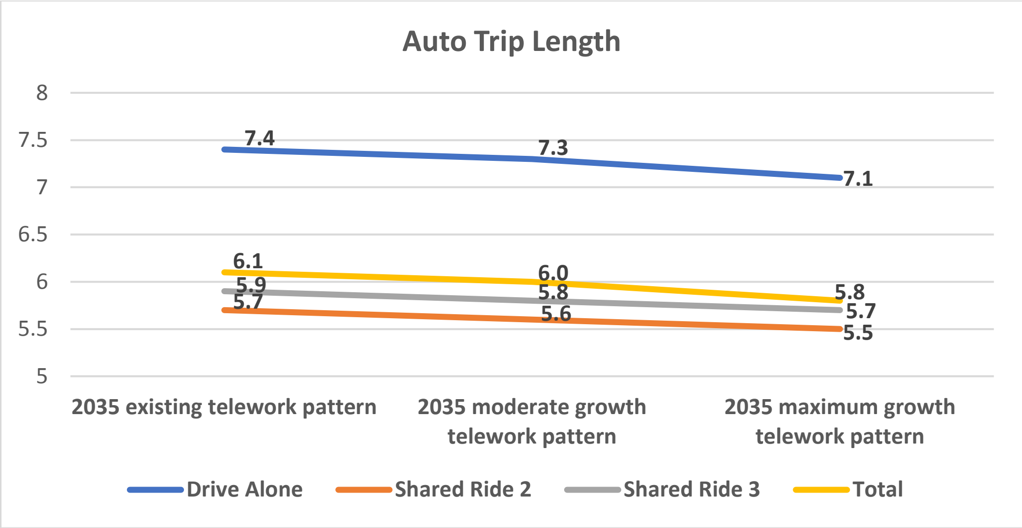


Figure 95. Auto Trip Length: Telework Rate Tests (Tests 54-56)

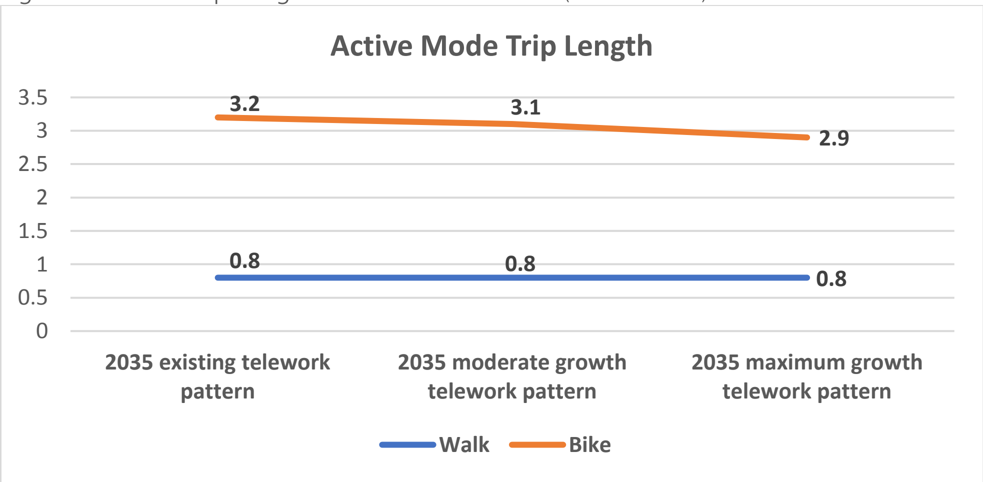


Figure 96. Transit Boarding Change from Baseline: Telework Rate Tests (Tests 54-56)

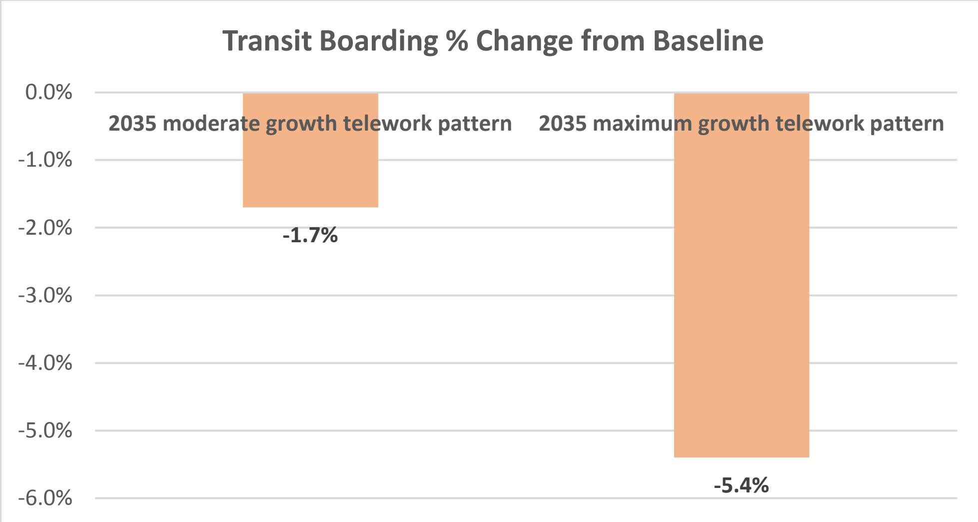


Figure 97. Telework Rate & VMT Reduction: Telework Rate Tests (Tests 54-56)

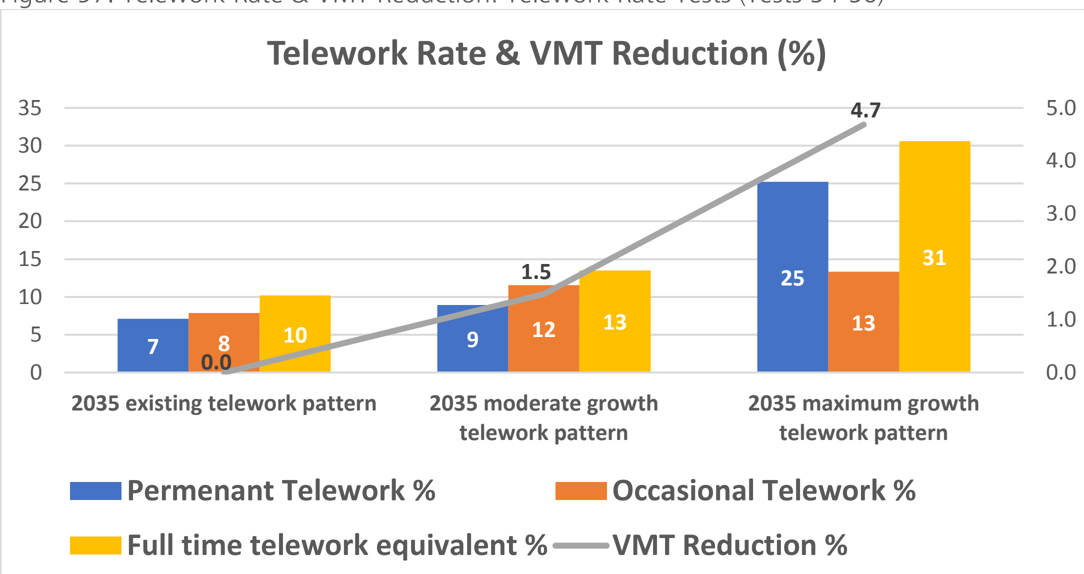


Figure 98. VMT Per Capita: Telework Rate Tests (Tests 54-56)

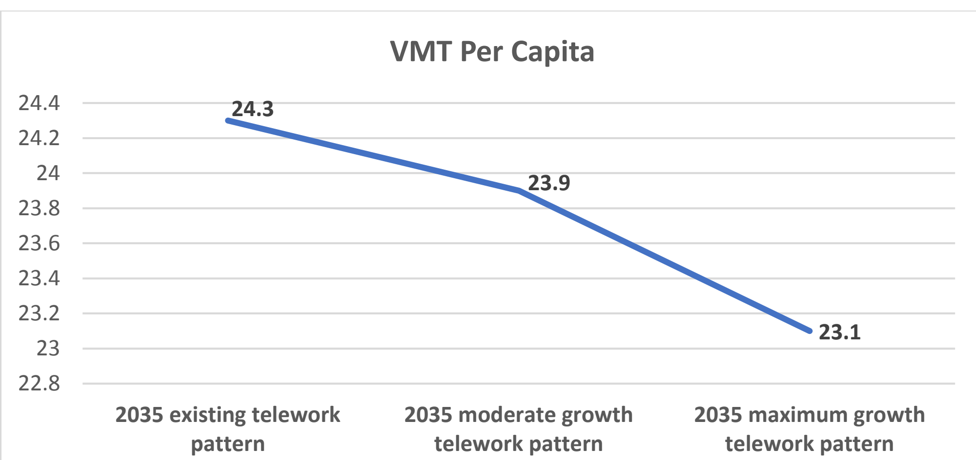
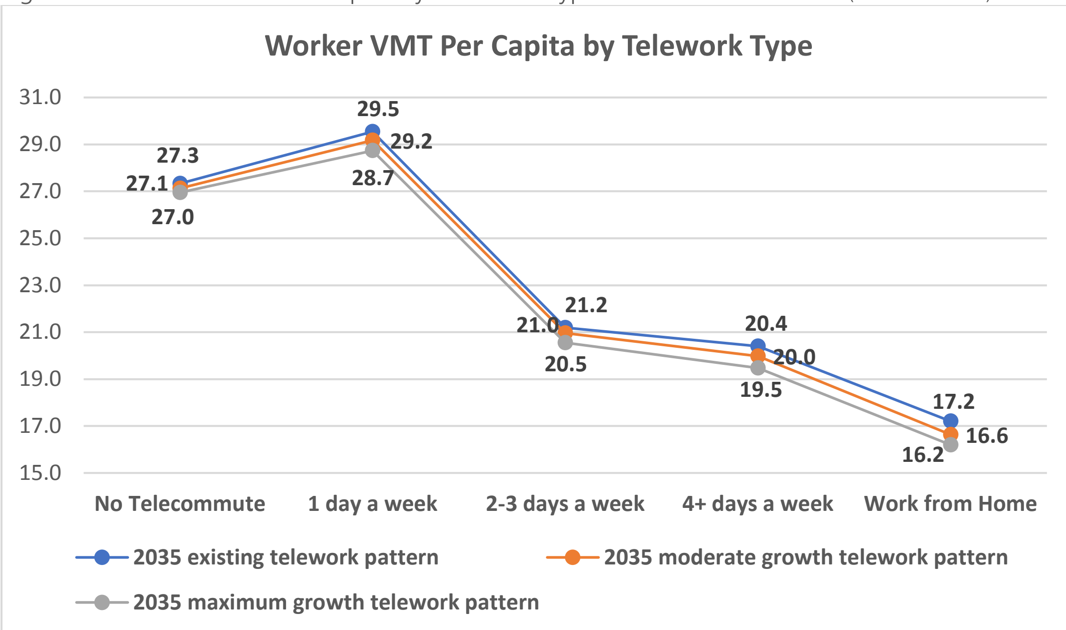


Figure 99. Worker VMT Per Capita by Telework Type: Telework Rate Tests (Tests 54-56)



Appendix C
SANDAG Auto Operating Cost Calculations

Auto Operation Cost Calculator (Draft For Comments Only)

Select MPO	SANDAG
Select Calendar Year	2020

	GASOLINE			DIESEL			ELECTRIC			HYDROGEN			PHEV		
	Data Source	Value		Data Source	Value		Data Source	Value		Data Source	Value		Data Source	Value	
		Default	Custom		Default	Custom		Default	Custom		Default	Custom		Default	Custom
Fuel Cost (dollar/gasoline gallon equivalent)[1]	Custom		3.74	Default	3.34		Default	6.45		Default	14.80			4.95	4.95
Non-fuel Cost (cents per mile) [2]	Custom		7.91	Default	7.91		Default	6.55		Default	7.91			6.99	6.99
VMT	Default	88,715,887		Default	1,020,620		Default	496,651		Default	60,891		Default	913,087	
Fuel Efficiency (mile/gasoline gallon equivlent)	Gasoline	25.79		Diesel	35.71		Electric	113.93		Hydrogen	74.19		PHEV	56.25	
Auto Operating Cost by Fuel Type (Cents/Mile)	Gasoline	22.43		Diesel	17.27		Electric	12.22		Hydrogen	27.86		PHEV	14.68	

Calendar Year	2020
Auto Operating Cost (Cents/Mile)	22.24

CARB Calculator is using 2017 dollars
SANDAG ABM2+ uses 2010 dollars

CPI Adjusted value → ¢19.3 per mile

Steps:
1. Select MPO and Calender Year from the drop-down list.
2. Select "Default" or "Custom" mode for each parameter from the drop-down list
3. Enter custom value(s) after selecting "Custom" mode for fuel cost, non-fuel cost and VMT

Note:
1- Input as 2017 dollars/cents
2- Include maintenace, repair and tire cost

Auto Operation Cost Calculator (Draft For Comments Only)

Select MPO	SANDAG
Select Calendar Year	2025

	GASOLINE			DIESEL			ELECTRIC			HYDROGEN			PHEV		
	Data Source	Value		Data Source	Value		Data Source	Value		Data Source	Value		Data Source	Value	
		Default	Custom		Default	Custom		Default	Custom		Default	Custom		Default	Custom
Fuel Cost (dollar/gasoline gallon equivalent)[1]	Custom		4.17	Default	3.78		Default	6.57		Default	12.56			5.40	5.40
Non-fuel Cost (cents per mile) [2]	Custom		7.91	Default	7.91		Default	6.55		Default	7.91			6.99	6.99
VMT	Default	90,162,637		Default	1,183,323		Default	1,051,622		Default	381,376		Default	2,187,369	
Fuel Efficiency (mile/gasoline gallon equivlent)	Gasoline	29.97		Diesel	40.65		Electric	121.06		Hydrogen	79.32		PHEV	65.44	
Auto Operating Cost by Fuel Type (Cents/Mile)	Gasoline	21.81		Diesel	17.20		Electric	11.98		Hydrogen	23.75		PHEV	14.36	

Calendar Year	2025
Auto Operating Cost (Cents/Mile)	21.48

CARB Calculator is using 2017 dollars
SANDAG ABM2+ uses 2010 dollars

CPI Adjusted value → ¢18.6 per mile

Steps:
1. Select MPO and Calender Year from the drop-down list.
2. Select "Default" or "Custom" mode for each parameter from the drop-down list
3. Enter custom value(s) after selecting "Custom" mode for fuel cost, non-fuel cost and VMT

Note:
1- Input as 2017 dollars/cents
2- Include maintenace, repair and tire cost

Auto Operation Cost Calculator (Draft For Comments Only)

Select MPO	SANDAG
Select Calendar Year	2035

	GASOLINE			DIESEL			ELECTRIC			HYDROGEN			PHEV		
	Data Source	Value		Data Source	Value		Data Source	Value		Data Source	Value		Data Source	Value	
		Default	Custom		Default	Custom		Default	Custom		Default	Custom		Default	Custom
Fuel Cost (dollar/gasoline gallon equivalent)[1]	Custom		4.65	Default	4.16		Default	6.61		Default	10.32			5.75	5.75
Non-fuel Cost (cents per mile) [2]	Custom		7.90	Default	7.91		Default	6.55		Default	7.91			6.99	6.99
VMT	Default	93,031,627		Default	1,312,533		Default	1,788,700		Default	945,473		Default	3,685,158	
Fuel Efficiency (mile/gasoline gallon equivlent)	Gasoline	36.82		Diesel	48.32		Electric	135.64		Hydrogen	88.65		PHEV	76.28	
Auto Operating Cost by Fuel Type (Cents/Mile)	Gasoline	20.53		Diesel	16.51		Electric	11.42		Hydrogen	19.55		PHEV	13.89	

Calendar Year	2035
Auto Operating Cost (Cents/Mile)	20.06

CARB Calculator is using 2017 dollars
SANDAG ABM2+ uses 2010 dollars

CPI Adjusted value → ¢17.4 per mile

Steps:
1. Select MPO and Calender Year from the drop-down list.
2. Select "Default" or "Custom" mode for each parameter from the drop-down list
3. Enter custom value(s) after selecting "Custom" mode for fuel cost, non-fuel cost and VMT

Note:
1- Input as 2017 dollars/cents
2- Include maintenace, repair and tire cost

Auto Operation Cost Calculator (Draft For Comments Only)

Select MPO	SANDAG
Select Calendar Year	2050

	GASOLINE			DIESEL			ELECTRIC			HYDROGEN			PHEV		
	Data Source	Value		Data Source	Value		Data Source	Value		Data Source	Value		Data Source	Value	
		Default	Custom		Default	Custom		Default	Custom		Default	Custom		Default	Custom
Fuel Cost (dollar/gasoline gallon equivalent)[1]	Custom		5.01	Default	4.16		Default	6.61		Default	10.32			5.92	5.92
Non-fuel Cost (cents per mile) [2]	Custom		7.91	Default	7.91		Default	6.55		Default	7.91			6.99	6.99
VMT	Default	98,827,162		Default	1,416,540		Default	2,107,994		Default	1,166,734		Default	4,290,741	
Fuel Efficiency (mile/gasoline gallon equivlent)	Gasoline	39.25		Diesel	50.98		Electric	161.18		Hydrogen	107.94		PHEV	82.50	
Auto Operating Cost by Fuel Type (Cents/Mile)	Gasoline	20.67		Diesel	16.06		Electric	10.65		Hydrogen	17.47		PHEV	13.62	

Calendar Year	2050
Auto Operating Cost (Cents/Mile)	20.10

CARB Calculator is using 2017 dollars
SANDAG ABM2+ uses 2010 dollars

CPI Adjusted value → ¢17.4 per mile

Steps:
1. Select MPO and Calender Year from the drop-down list.
2. Select "Default" or "Custom" mode for each parameter from the drop-down list
3. Enter custom value(s) after selecting "Custom" mode for fuel cost, non-fuel cost and VMT

Note:
1- Input as 2017 dollars/cents
2- Include maintenace, repair and tire cost

CPI Usage in ABM2+

CPI values are used to adjust costs from recent years to a 2010-equivalent year cost as based on the ABM2+ model. BLS CPI is used for San Diego based on the items specified below.

Source:
https://data.bls.gov/pdq/SurveyOutputServlet?data_tool=dropmap&series_id=CUURS49ESA0,CUUSS49ESA0

CPI for All Urban Consumers (CPI-U)
Series Id: CUURS49ESA0,CUUSS49ESA0
Not Seasonally Adjusted
Series Title: All items in San Diego-Carlsbad, CA, all urban consumers, not seasonally adjusted
Area: San Diego-Carlsbad, CA
Item: All items
Base Period: 1982-84=100

CPI Data:

Year	**CPI**	**Factor**
2010	245.464	1.00000
2011	252.91	1.03033
2012	256.961	1.04684
2013	260.317	1.06051
2014	265.145	1.08018
2015	269.436	1.09766
2016	274.732	1.11924
2017	283.012	1.15297
2018	292.547	1.19181
2019	299.433	1.21987
2020*	302.589	1.23272

**March 2020*
Data extracted on: June 3, 2020 (1:16:34 PM ET)

How to use:
If you have a 2018-based cost, for example a $2.50 transit fare, divide the $2.50 by the 2018 CPI factor 1.19181 to get a 2010-equivalent year cost of $2.10.

Appendix D
Ascent Environmental
Electric Vehicle Calculations

Memo

600 B Street, Suite 300
San Diego, CA 92101
916.444.7301

Date: February 7, 2019

To: Susan Freedman and Allison Wood, San Diego Association of Governments

From: Brenda Hom and Honey Walters

Subject: **SANDAG Electric Vehicle Off-Model Calculator Methodology for SCS Compliance – 2019 San Diego Forward: The Regional Plan – February 2019 Revision**

The San Diego Association of Governments (SANDAG) tasked Ascent with preparing a carbon dioxide (CO_2) emissions calculator for regional electric vehicle (EV) programs that would be considered "off-model" greenhouse gas (GHG) reduction strategies in San Diego Forward: The 2019-2050 Regional Plan (2019 Regional Plan). The 2019 Regional Plan is SANDAG's third Regional Transportation Plan and Sustainable Communities Strategy (RTP/SCS) pursuant to Senate Bill (SB) 375.

SB 375, signed into law in 2008, aligns regional transportation planning efforts and land use and housing allocation with overall State GHG reduction goals. Assembly Bill (AB) 32 (2006) and Executive Order (EO) S-3-05 (2005) established targets for the State to reduce its GHG emissions to 1990 levels by 2020 and 80 percent below 1990 levels by 2050. SB 32, signed in 2016, set an intermediate target of reducing statewide emissions to 40 percent below 1990 levels by 2030. Given that transportation accounts for nearly 40 percent of the state's emissions, the efforts in SB 375 to reduce regional transportation-related emissions are key to supporting the State's GHG reductions goals. (California Air Resources Board [CARB] 2017, 2018a).

SB 375 requires metropolitan planning organizations (MPOs), such as SANDAG, to adopt an SCS or Alternative Planning Strategy, showing land use allocation in each MPO's Regional Transportation Plan. The California Air Resources Board (CARB), in consultation with the MPOs, provides each affected region with per capita reduction targets for GHGs emitted by passenger cars and light trucks in their respective regions for 2020 and 2035. SANDAG serves as the MPO for San Diego county and adopted San Diego Forward: The 2015 Regional Plan in October 2015. In March 2018, CARB adopted the Target Update for the SB 375 targets tasking SANDAG to achieve a 15 percent and a 19 percent per capita reduction in CO_2 emissions from 2005 levels by 2020 and 2035, respectively (CARB 2018a).

In order to ensure that the emissions reductions are solely attributed to MPO actions, CARB sets a number of stipulations in its recommended SB 375 SCS GHG reduction methodology (CARB 2011). CARB recommends that MPOs use a post-processed set of vehicle emissions factors in CARB's EMissions FACtor (EMFAC) model that prevent MPOs from taking credit from improving State and federal vehicle efficiency standards to achieve the assigned targets. This stipulation generally leads MPOs to reduce emissions by reducing vehicle miles traveled (VMT) through land use and transportation planning strategies. Although planning efforts may account for the majority of CO_2 emission reductions under SB 375, CARB allows for the inclusion of "off-model" strategies where MPOs can take emissions reductions credit for transportation programs and other activities that are not fully captured in the regional transportation model, such as SANDAG's Activity Based Model (CARB 2011). The "off-model" strategy programs may include transportation demand management (TDM) and EV incentive programs, which are not generally correlated with land use planning. The "off-model" quantification of the emissions reductions from SANDAG's EV incentive programs under the 2019 Regional Plan is the subject of this memorandum.

2019 REGIONAL PLAN EV OFF-MODEL APPROACH

Background and Purpose

EVs will play a significant role in meeting California's climate goals to reduce GHG emissions from transportation, which accounted for 41 percent of the state's emissions in 2016 (CARB 2018b). The Midterm Review of Advanced Clean Cars Program report confirmed that existing vehicle programs and vehicle emission standards will add at least 1 million zero emission vehicles (ZEVs) on the state's roads and highways by 2025. In the report, CARB also recommended that California make a major push to develop new post-2025 standards while working with automakers, federal regulators and partner states to further develop the market for electric cars. CARB projects that the ZEV market will see more than 20 new electric and plug-in model introductions with greater driving range at mass-market prices and more choices of body styles, brands, and consumer utility in the next few years (CARB 2017a).

In planning for a cleaner statewide vehicle fleet after 2025, EO B-48-18, signed by Governor Brown in January 2018, directs all State entities to work with the private sector to have at least 5 million ZEVs on the road by 2030, as well as install 200 hydrogen fueling stations and 250,000 electric vehicle charging stations by 2025. It specifies that 10,000 of the electric vehicle charging stations should be direct current (DC) fast chargers. Therefore, the population of ZEVs will likely grow at a faster pace than current adoption rates based on CARB's analysis and the direction in EOs. The state and individual regions within the state can significantly exceed the projected number of ZEVs in EMFAC with the successful blend and implementation of regulations, incentives, infrastructure, public-private partnerships, and education and outreach campaigns (International Council on Clean Transportation 2016). The analysis presented in this memorandum provides the GHG emission reductions from the increased displacement of conventional gasoline vehicles with EVs in the SANDAG region, based on proposed EV incentive programs under the 2019 Regional Plan.

In preparation for development of the EV off-model calculator, Ascent reviewed methods used by other MPOs in California, including the Association of Bay Area Governments (ABAG) and Metropolitan Transportation Commission (MTC), Southern California Association of Governments (SCAG), and Sacramento Area Council of Governments (SACOG). In 2013, MTC was one of the first MPOs to develop an EV off-model methodology that accounted for specific EV incentive programs (CARB 2014). MTC used the same approach again in 2017 for Plan Bay Area 2040 (MTC 2017). SCAG's 2016 RTP/SCS adopted MTC's EV methodology to develop their off-model calculations (SCAG 2015). SACOG used the difference in EV market penetration forecasts between two versions of EMFAC (EMFAC2011 and EMFAC2014) to calculate EV off-model reductions relative to EMFAC2011 (SACOG 2015).

The EV programs considered by SANDAG for the 2019 Regional Plan would be most similar to MTC's approach, which quantified CO_2 reductions from a regional EV charger program and a vehicle incentive program. The regional charger program would increase the percentage of electric vehicle miles travelled (eVMT) in the region by increasing the use of battery electric vehicles (BEV) and extending the electric range of plug-in hybrid electric vehicles (PHEV) through the addition of public, workplace, and Direct Current (DC) Fast chargers. The vehicle incentive program would encourage faster turnover of gasoline passenger vehicles to BEVs and PHEVs through rebates relative to default vehicle populations based on EMFAC PEV growth rates and existing vehicle populations. Similar to MTC, SANDAG is considering a Regional EV Charger Program (RECP) and Vehicle Incentive Program (VIP) as part of 2019 Regional Plan to increase the share of eVMT and plug-in electric vehicle (PEV) population in the region.

In reviewing MTC's approach and recent EV studies released by governmental and non-governmental research groups, Ascent found that a number of assumptions used in prior calculators could be expanded upon and better substantiated. Recent EV research includes new charging infrastructure studies specific to California and the SANDAG region, as listed in the bulleted section below. Thus, Ascent updated MTC's approach to include these studies to allow for further variability and substantiation of the assumptions and data used in the calculations. The resulting calculator replaces the EV off-model methodology used in San Diego Forward: The 2015 Regional Plan.

It should be noted that PHEVs and BEVs are herein referred together as PEVs. PEVs and hydrogen fuel cell electric vehicles are together referred to as ZEVs.

The purpose of this EV off-model calculator is to estimate the CO_2 reductions and costs associated with implementation of SANDAG's proposed RECP and VIP. The estimated reductions would contribute towards meeting SB 375 regional CO_2 reduction targets for 2020 and 2035, updated by CARB in March 2018 (CARB 2018a). This calculator expands upon MTC's EV off-model methodology and applies a similar methodology to calculate emission reductions from SANDAG's proposed version of the RECP and VIP. MTC's approach was first developed as part of Plan Bay Area, MTC's 2013 Metropolitan Transportation Plan and Sustainable Communities Strategy (MTP/SCS). At the time MTC's MTP/SCS was being developed, data and studies related to EV charging, travel, and market behavior were limited because PEVs had only been mass produced for about three years in the U.S., starting with the 2010 Nissan Leaf. SANDAG's EV off-model calculator for 2019 Regional Plan takes advantage of more recent and locally-specific research on the EV market and EV travel and charging behavior. Recent policies, research, studies, and models used to develop the 2019 Regional Plan EV off-model calculator include:

- EO B-16-12 and EO B-48-18, which set a target of 1.5 million ZEVs and 5 million ZEVs in the State by 2025 and 2030, respectively.
- *California Plug-In Electric Vehicle Infrastructure Projections: 2017-2025*, published by the California Energy Commission (CEC) in March 2018, which includes projections of the PEV vehicle fleet mix, charger inventory, and charging demand by county that would achieve the 1.5 million ZEV statewide

target by 2025 established in EO B-16-12 and 250,000 EV chargers statewide, including 10,000 DC Fast Chargers, by 2025 established in EO B-48-18 (CEC 2018);

- *Plug-in Electric Vehicle Market Growth Analysis*, prepared by the Center for Sustainable Energy (CSE) for SANDAG in March 2018, which forecasts PEV sales in the San Diego region based on historical PEV sales trends in the area (CSE 2018);

- Electric Vehicle Infrastructure Projection Tool (EVI-Pro), released in early 2018 by the National Renewable Energy Laboratory's (NREL) and CEC, which estimates the public charging infrastructure needed to support a targeted PEV mix by 2025 for various regions across the state by county. Although this tool is not publicly available at this time, NREL and CEC released a web-based data viewer that summarizes the results of the tool for California, including anticipated charger counts and charger loads. The results of EVI-Pro were used to develop projections in CEC's *California Plug-In Electric Vehicle Infrastructure Projections: 2017-2025* report. (NREL 2018a, NREL 2018b);

- EMFAC2017, released in late 2017 by CARB, which updates the statewide vehicle population, emissions, and VMT forecasts by fuel type, vehicle class, and other factors, accounting for adjusted ZEV forecasts that are generally more conservative than previously assumed in EMFAC 2014 (CARB 2017b). EMFAC2017 also accounts for a minimum regulatory compliance scenario under the ZEV mandate in the State's Advanced Clean Cars Program. This mandate requires vehicle manufacturers to produce an increasing number of ZEVs for model years 2018 through 2025.

With respect to the RECP, SANDAG's EV off-model approach is the first among the MPOs to use CEC's EVI-Pro's region-specific results to account for how changes to the targeted PEV population would affect the recommended number of chargers needed. The EVI-Pro tool, mentioned above, uses real-world travel data from mass market consumers to determine the charging infrastructure needed for residential, workplace, and public areas under a variety of scenarios (Alternative Fuels Data Center [AFDC] 2018). CEC's EVI-Pro runs also accounted for county-level PEV distributions and forecast, charger densities, travel behavior, and land use profiles. Additional higher-level factors included fuel sensitivities and range anxiety. Ascent used EVI-Pro results for San Diego County. EVI-Pro's results are limited to forecast years through 2025, which anticipate a maximum PEV share of 4.3 percent of the light-duty fleet in the SANDAG region. In comparison, under EO B-16-12 and EO B-48-18, the targeted statewide EV population mix is approximately five percent by 2025 and 16 percent by 2030. For modeling purposes, Ascent assumed that the trend in charger-to-PEV ratios and other charging behavior anticipated by EVI-Pro through 2025 for San Diego County would continue through 2050.

Key Methods and Assumptions

SANDAG's EV Off-Model includes the following key methods and assumptions used in the model's calculations. The differences from MTC's approach resulted in a more complex calculator, but also one that accounts for San Diego-specific factors.

- CO_2 reductions from the RECP and VIP were calculated in two key steps. First, the difference was taken between the total eVMT supported by each respective program and the eVMT anticipated in a business-as-usual (BAU) forecast for a given milestone year. In cases where the program's eVMT would result in more eVMT than the BAU forecast, the additional eVMT was attributed to the displacement of the same VMT from equivalent gasoline light-duty vehicles (LDV), which was then translated to CO_2 reductions associated with the reduced gasoline LDV VMT. Second, the resulting CO_2 reductions were scaled to SANDAG-related efforts by applying the ratio of SANDAG incentives to non-SANDAG incentives, on dollar-per-dollar basis. To avoid double counting reductions between the RECP and VIP, Ascent assumed that the reductions from additional PHEVs under VIP would be a subset of any additional PHEV eVMT supported by RECP because the RECP is assumed to extend the electric range of any PHEVs purchased under the VIP.

- The BAU forecast was based on a combination of 2018 vehicle populations from DMV registration data, EMFAC2017 ZEV growth rates, and adjustment of EMFAC's daily VMT per vehicle forecasts to SANDAG travel demand modeling.

- CO_2 reductions from the RECP were based on the difference between the total eVMT supported by a targeted number of all non-residential chargers, including existing and new chargers, in the SANDAG region and the eVMT anticipated in the BAU forecast for the SANDAG region for a given milestone year. The targeted total number of chargers in the SANDAG region was calculated using local PEV-to-charger ratios estimated by CEC's EVI-Pro analysis. EVI-Pro estimates that these ratios would change over time and also vary by PEV type. The targeted total number of chargers would be equal to the sum of all existing chargers as of 2018 and any new chargers added starting from 2018. To estimate the number of chargers needed to be incentivized by SANDAG, the number of existing non-residential chargers was subtracted from the targeted number of all non-residential chargers in the region.

- EV chargers were assumed to charge both BEVs and PHEVs. The eVMT provided to each type of vehicle per charger by non-residential charger type (e.g., public vs. workplace) reflect the findings and assumptions in CEC's 2018 study and EVI-Pro runs.

- CO_2 reductions from the VIP were based the difference between the targeted EV population for a given milestone year and the EV population anticipated in the BAU forecast. Average VMT and eVMT per vehicle per day were based on EMFAC2017 defaults, which varies by calendar year and vehicle type.

- As SB 375 only requires MPOs to address tailpipe emissions, upstream emissions from additional electricity demand from EVs are ignored.

Other assumptions include:

- Chargers have a 90 percent charging efficiency;

- Level 2 and DC Fast Chargers would be rated at 6.6 kilowatt (kW) and 105 kW, respectively, starting in 2025;

- PHEVs would not have the ability to use DC Fast Charging; and

- CEC's EVI-Pro analysis defines a charger as "a connector that can serve a vehicle at the full rated power capacity without any operational limitations" (CEC 2018:4). SANDAG's EV off-model tool adopts this definition.

Regardless, the calculator allows the user to adjust these inputs and assumptions in light of evolving research. Other specific assumptions used in the calculator are detailed in the rest of this memorandum.

Model Inputs

The calculator is set up such that the user can input basic program assumptions for the regional charger and vehicle incentive programs (RECP and VIP) for each milestone year (2020, 2025, 2030, 2035, and 2050). Default assumptions included in the background calculations for RECP and VIP can also be changed by the user, if necessary. For each program, the user can choose a target scenario based on preprogrammed inputs or choose a custom target scenario. SANDAG's chosen scenario should reflect the desired exceedance above BAU EV forecasts in order to appropriately assign GHG reduction credits and incentive costs to SANDAG efforts. All scenarios should be based on daily VMT forecasts from the version of SANDAG's regional transportation model that aligns with the applicable Regional Plan.

Scenarios

The tool allows the user to select a different forecast scenario for either the RECP or VIP to determine the total charger or PEV population that SANDAG hopes to achieve under those programs. The preprogrammed inputs include full and partial iterations of three preset scenarios based on State EV targets under EO B-16-12 (State Targets), CEC's EV forecast in EVI-Pro (CEC forecasts), and EV forecasts anticipated in CSE's market study (CSE forecasts). For example, the user can select the full CEC forecast scenario or a 70 percent CEC forecast scenario, which scales down the PEV and charger targets that would have occurred under the CEC forecast scenario by 70 percent. The following describe the three preprogrammed scenarios and the custom scenario option in the tool.

- **State Targets:** The State Targets under EO B-16-12 and EO B-48-18 to achieve 1.5 million EVs by 2025 and 5 million EVs by 2030 were apportioned to the SANDAG region based on the ratios between the EV population in SANDAG and the state as a whole, as modeled by EMFAC2017.

- **CEC Forecast**: The CEC's forecast scenario is based on what the CEC anticipates the PEV population will be like for the SANDAG region in order to meet State Targets for 2025, including the statewide target of having 250,000 EV chargers statewide by 2025. The CEC forecast scenario also accounts for a variety of economic and organizational factors that influence PEV usage. The model assumes that the CEC forecast trends would continue past 2025.

- **CSE Forecast:** The CSE Forecast scenario is based on either a linear or second-order polynomial trend of the PEV population in SANDAG based on historical sales. The second-order polynomial forecast is currently the preferred CSE Forecast scenario per SANDAG staff, though the user has the option to change the trend assumption in the background calculations.

- **Custom Inputs:** The model also allows the user to input custom charger or PEV population targets or custom scenarios based on a chosen fraction of either the State Targets or the CEC forecasts.

Regional Electric Vehicle Charger Program

The RECP CO_2 calculations require the user to select a target scenario of the number of PEVs to be supported by the charger program. This calculator utilizes CEC's results from EVI-Pro (average charger counts based on the default scenario) to calculate a PEV-to-charger ratio for each charger destination type (e.g., workplace, public) that is characteristic of the SANDAG region's EV charging behavior. This provides a recommended number of chargers needed to support the targeted PEV population. Alternatively, the model allows the user to decide on the specific number of chargers to be installed under the program based on fiscal or administrative limitations. The number of average active hours of charging per charger specific to each PEV type and charger type was calculated from CEC's EVI-Pro model results.

With respect to program costs, the user can input the average capital and administrative costs associated with each new charger funded or incentivized by the program. The average costs can be varied or remain constant over time depending on how SANDAG designs the program.

Vehicle Incentive Program

Similar to the RECP calculations, the VIP calculations require the user to either select a target PEV scenario or choose a custom targeted number of vehicles that would be incentivized under the program. If a custom target is chosen, the user can input the number of BEVs or PHEVs that would be incentivized by each milestone year starting with 2020. Once the number of PEVs is selected, the calculator utilizes the average VMT per PEV per day and the default PHEV utility factor (UF) used in EMFAC2017 to estimate the total eVMT associated with VIP. The PHEV utility factor (UF) is defined as the percent of PHEV VMT that is electric. To estimate the CO_2 reductions, the total eVMT from the population of EVs under the VIP is subtracted by the eVMT from population of EVs in the BAU forecast. The additional eVMT under the VIP is assumed to offset emissions from equivalent gasoline LDVs.

With respect to program costs, the user can input the average capital and administrative costs associated with each vehicle incentive. The average costs can be varied or remain constant over time depending on how SANDAG designs the program.

Comparison to State Targets

The calculator allows for the user to evaluate how SANDAG's EV program contributes to the region's overall per-capita CO_2 reduction targets under SB 375 and how the resulting PEV populations compares to the San Diego region's share of the State's EV targets under EO B-16-12 and B-48-18. Once finalized, the forecasted population and daily VMT for the San Diego region can be input into the calculator for each milestone year. To calculate the per-capita CO_2 reductions associated with the EV off-model calculations, total daily reductions from both programs are divided by SANDAG's forecasted population. To evaluate how SANDAG's EV programs would help achieve the State's EV targets, SANDAG's total EV population and eVMT under both EV programs are compared to SANDAG's LDV population and VMT, respectively, for each milestone year.

SANDAG EV OFF-MODEL METHODOLOGY

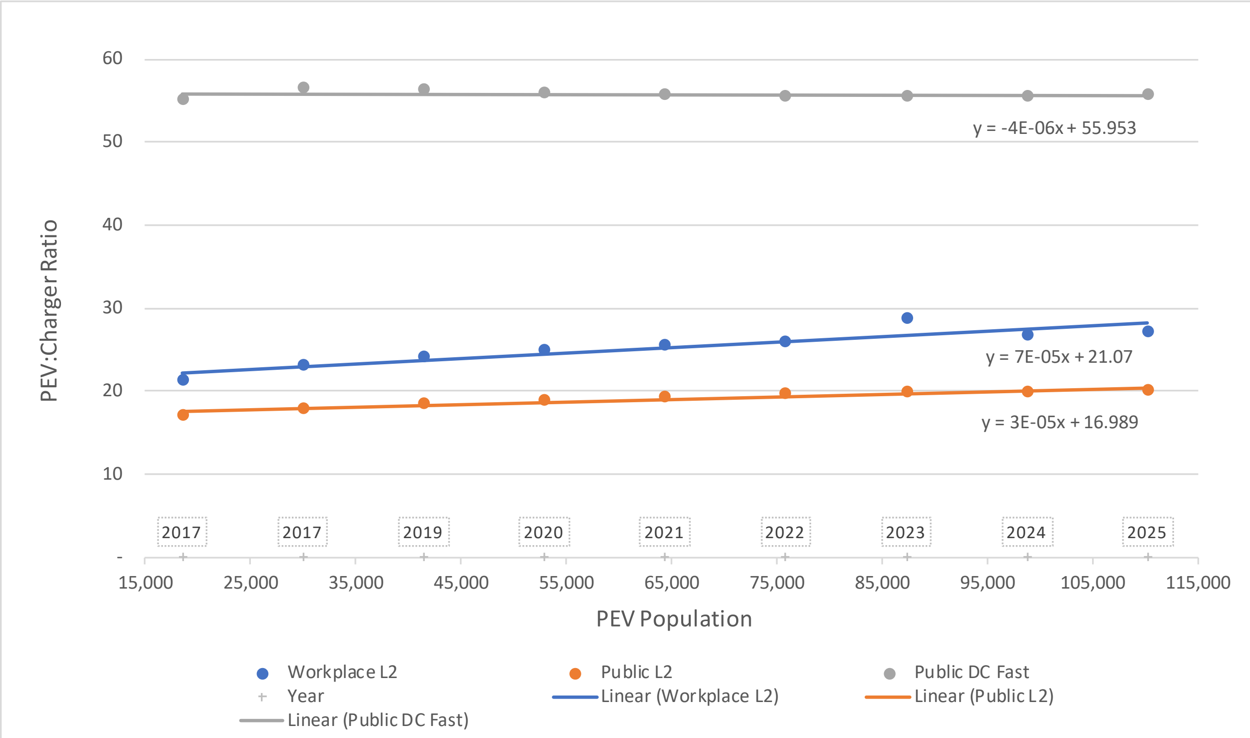
SANDAG's EV off-model calculator quantifies the CO_2 reductions attributable to SANDAG's EV programs that go beyond the reductions that would occur under current State legislation. The calculator quantifies CO_2 reductions associated with implementation of the RECP and VIP for the milestone years 2020, 2025, 2030, 2035, and 2050. These years have been selected primarily to be consistent with the milestone years set in AB 32, SB 32, and SB 375. The tool allows the user to adjust program targets (e.g., number of chargers or vehicles incentivized) and other assumptions to calculate the CO_2 reductions relative to a BAU forecast. The BAU forecast of PEV and eVMT growth is based on historical vehicle sales data and assumed regulatory compliance with the State's ZEV mandate, as modeled in EMFAC2017. Descriptions of how the BAU forecast was calculated for BEVs and PHEVs are shown on pages 11 and 16, respectively. This approach allows CO_2 reductions to be separated out for only SANDAG's programs rather than both State and SANDAG actions.

Both the RECP and VIP calculators use the same assumptions for vehicle emission factors of offset gasoline LDVs and average miles travelled per day per vehicle by vehicle type. For offset gasoline LDVs, emission factors were modeled in EMFAC2017 for the SANDAG region for each milestone year. The EMFAC2017 web database was used to obtain the emission factors, in contrast with the desktop version of EMFAC that includes the post-processed SB 375 analysis option. The SB 375 analysis option in EMFAC is typically used to determine the emissions reductions associated with VMT reductions in future years under a given transportation plan, so that MPOs do not rely on increasing vehicle efficiencies to meet the regional SB 375 CO_2 reduction targets. However, for the purposes of assigning CO_2 reductions to the proposed EV programs, it is more conservative to compare to more efficient gasoline vehicles that have lower emission factors than to compare to gasoline vehicles that have higher emission factors that would have been assumed under the SB 375 analysis option.

Regional Electric Vehicle Charger Program

Under the RECP, SANDAG would continue to expand the public EV charging infrastructure in the San Diego region to support and incentivize the growing PEV population in the region. Chargers alone do not reduce CO_2 emissions. However, the public EV charging infrastructure allows for the PEV population to grow by making it easier and more convenient for PEV drivers to charge their vehicles. The relationship between the charging infrastructure and the PEV population and travel behavior has been a primary study focus for several research groups, including various universities, national laboratories, and state agencies. However, until recently, this research has been limited to the behavior of early PEV adopters.

As the State prepares for greater adoption of PEVs to fulfill its climate goals, SANDAG's RECP calculator utilizes CEC's recent EVI-Pro modeling to account for travel and charging behavior that is more representative of mainstream drivers in the San Diego region (CEC 2018:1). The PEV-to-charger ratios from CEC's EVI-Pro modeling was used to estimate the number of chargers needed to support a given PEV population, accounting for San Diego-specific estimates of the PEV fleet mix, access to home charging, and other factors. The resulting PEV-to-charger ratios characterize the demand for various charger types for a given PEV population and is the basis for both the CO_2 reduction and cost estimates related to the RECP. Based on CEC's results, Ascent calculated a ratio of one charger for approximately every 17 to 56 PEVs, depending on the targeted PEV population and type of charger. Charger types include workplace Level 2, public Level 2, and public DC Fast Chargers. The relationship between PEV population and charger demand by charger type for the San Diego region is shown in Figure 1.



Note: Adapted from CEC's results from EVI-Pro for the San Diego Region, consistent with results in "California Plug-In Electric Vehicle Infrastructure Projections: 2017-2025 Future Infrastructure Needs for Reaching the State's Zero Emission-Vehicle Deployment Goals." (CEC 2018). [1]

Figure 1 PEV-to-Charger Ratio vs. PEV Population for the San Diego Region (2017-2025)

Figure 1 shows the PEV-to-charger ratios between the 2017 and 2025 PEV population in the San Diego region, as assumed in CEC's EVI-Pro modeling. These ratios vary depending on the type of charger and are primarily used to calculate the number of chargers by type needed in the region under the RECP (see Equation 3). This figure also shows that, for 2025, CEC estimates that SANDAG's fair share of PEVs to meet the 2025 goals under EO B-16-12 is 110,227 PEVs. In contrast, EMFAC2017 forecasts that the SANDAG region would have 61,378 PEVs by 2025, almost half of the State's 2025 target. Ascent assumes that the linear trend between 2017 and 2025 would continue past 2025. As such, the equations shown in Figure 1 are used to calculate the number of workplace and public Level 2 and public DC Fast Chargers needed to support a given PEV population, as used in Equation 3. SANDAG's goal under the RECP is to meet the charger demand under a selected PEV population scenario.

CO_2 reductions from implementation of the RECP are based on the effect of the additional chargers on BEV and PHEV travel activity, assumed to offset equivalent gasoline LDV VMT. The RECP affects BEV and PHEV activity differently because charging behavior differs between BEV and PHEV drivers. While BEV drivers may experience range anxiety due to a limited presence of chargers, all miles associated with BEV driving are electric and BEVs are assumed to primarily charge at home (See Figure 2). On the other hand,

[1] EVI-Pro should not be confused with EVI-Pro Lite, a simplified version of EVI-Pro, was not used in this analysis (AFDC 2018). Although EVI-Pro Lite is a publicly available version of EVI-Pro, it does not include many of the assumptions embedded in CEC's California-specific runs. In comparisons between EVI-Pro and EVI-Pro Lite, the latter substantially underestimates the number of DC Fast Chargers in the San Diego region. EVI-Pro Lite also requires the user to input the PEV fleet mix and level of access to home charging, whereas CEC already uses data specific to the San Diego region to support those assumptions.

PHEV drivers have the option of travelling further using gasoline after their electric-only range has been exhausted and a nearby charger is unavailable (It should be noted that no diesel PHEVs are currently on the market). However, the increased availability of chargers could allow PHEV drivers to extend their electric-only range, resulting in a greater percentage of eVMT across all miles driven in a PHEV.

Equations 1 through 3 are used to calculate the CO_2 reductions from BEVs and PHEVs under the RECP for a given milestone year. (Note that SANDAG's EV off-model calculator allows users to adjust all variables, though defaults are provided and explained herein.)

$$E_{RECP} = \left(E_{BEV_{RECP}} + E_{PHEV_{RECP}}\right) * \frac{I_{SANDAG\_RECP}}{I_{SANDAG\_RECP} + I_{Non-SANDAG\_Chargers}} \qquad (Equation\ 1)$$

Where:

E_{RECP} = Emissions reductions associated with implementation of RECP (MT CO_2)

E_{BEV_RECP} = Emissions reductions associated with BEVs under the RECP (MT CO_2)

E_{PHEV_RECP} = Emissions reductions associated with PHEVs under the RECP (MT CO_2)

I_{SANDAG} = Average incentive per chargers under the RECP offered by SANDAG (Dollars)

$I_{Non-SANDAG\_Chargers}$ = Average incentives per charger totaled across all non-SANDAG programs in the SANDAG region (Dollars)

To attribute the reductions to the RECP, specifically, an additional adjustment is made based on the proportion of the RECP incentives to all incentives offered on a per-charger basis.

BEV CO_2 Reductions

CO_2 reductions from BEVs are based on the difference between emissions from charging associated with the eVMT provided to BEVs under the RECP compared to the eVMT from BEVs anticipated by EMFAC. Any additional eVMT from the RECP is assumed to offset equivalent gasoline LDV VMT. Thus, for a given milestone year, BEV emission reductions from the RECP are based on Equation 2.

$$E_{BEV_{RECP}} = \frac{\left(VMT_{BEV_{RECP}} - VMT_{BEV_{BAU}}\right) * (EF_{Gas})}{10^6 \frac{g}{MT}} \qquad (Equation\ 2)$$

Where:

E_{BEV_RECP} = Emissions reductions from additional BEV eVMT from chargers operating under the RECP scenario compared to the BAU forecasts (MT CO_2)

VMT_{BEV_RECP} = eVMT associated with the electricity provided by chargers to BEVs under the RECP (mi/day)

VMT_{BEV_BAU} = eVMT associated with all BEV VMT under the BAU forecast (mi/day)

EF_{Gas} = Emissions factor per mile associated with gasoline LDVs in the SANDAG region, as modeled in EMFAC2017 (g CO_2/mi). Based on the four EMFAC vehicle categories included in the model's SB 375 analysis option (passenger cars [LDA], light duty trucks with an estimated total weight less than 3,750 pounds [LDT1], light duty trucks with an estimated total weight less between 3,751 and 5,750 pounds [LDT2], and medium duty trucks [MDV]).

VMT_{BEV_RECP} is the eVMT provided to BEVs by all chargers in the SANDAG region including those associated with RECP that would have been installed after 2019. VMT_{BEV_BAU} is the product of the BEV population and the average daily VMT per EV, based on EMFAC2017 results that were adjusted by the difference between SANDAG VMT forecasts and EMFAC VMT forecasts. These and other adjustments were made to EMFAC results because EMFAC2017 does not output EV populations by PEV type and because EMFAC VMT forecasts were not developed based on locally-specific data, as SANDAG VMT forecasts are. The following adjustments were made to EMFAC results to estimate the BAU BEV forecasts:

1. Based forecasts on 2018 BEV populations for San Diego County taken from DMV vehicle registration data,

2. Forecasted the 2018 BEV population into the future years by using EMFAC's assumed growth in LDVs and the assumed proportion of new vehicles that must be ZEVs under the state's ZEV mandate, and

3. Applied an adjustment factor based on the ratio between the SANDAG regional VMT forecast with EMFAC2017's VMT forecast to population and daily VMT per vehicle (CARB 2015, Department of Motor Vehicles [DMV] 2018).

These adjustments were made because EMFAC2017 uses historical vehicle populations through calendar year 2016 and regulation-based EV projections for years after 2016. Thus, projections were calibrated based on actual 2018 vehicle populations. The SANDAG regional VMT forecasts are considered a variable in this off-model calculator and are not shown here due to the current development of SANDAG's travel demand model as part of the 2019 RTP/SCS. The assumptions behind EMFAC's growth forecasts for ZEVs are shown in Table 1 for each ZEV type.

VMT_{BEV_RECP} is calculated from the total number of chargers, active charging time for BEVs per charger, and EV fuel economy as shown in Equation 3.

$$VMT_{BEV_{RECP}} = \sum_{i=Charger\ Type}^{n} \frac{C_i * H_{i_{BEV}} * P_i * \eta_{charger}}{FE_{EV}} \qquad (Equation\ 3)$$

Where:

VMT_{BEV_RECP} = eVMT associated with the electricity provided by chargers to BEVs under the RECP

i = charger type (e.g., Level 2 or DC Fast Charger)

C_i = Cumulative number of chargers by type installed under RECP (chargers).

H_{i_BEV} = Active hours charged by charger type, per charger, per day associated with BEVs (hours/charger)

P_i = Power rating of charger type (e.g., 6.6 kW for Level 2 chargers or between 55 and 105 kW for DC Fast Chargers)

$\eta_{charger}$ = Charger efficiency (i.e., electricity delivered by the charger divided by the electricity drawn from the electricity grid by the charger)

FE_{EV} = Fuel economy of electric vehicles (kWh/mi) (e.g., 0.225 kWh/mi)

Table 1 Zero Emission Vehicle Forecast Assumptions

	PHEV	BEV	FCEV
DMV 2018 Population in San Diego County[1]	11,216	14,960	135
Sectors	Required Percent of New LDV Sales that Must be ZEVs in EMFAC2017[2]		
Model Year	PHEV	BEV	FCEV
2019	1.86%	0.54%	5.44%
2020	3.26%	0.98%	8.59%
2021	4.82%	1.52%	11.34%
2022	5.25%	2.54%	11.93%
2023	6.01%	3.05%	13.00%
2024	6.70%	3.56%	13.98%
2025 through 2050	7.32%	4.06%	14.89%
Sectors	Calculated Year-over-Year Percent Growth in ZEV Population in San Diego County assumed in EMFAC2017		
Model Year	PHEV	BEV	FCEV
2019	20%	6%	167%
2020	28%	11%	141%
2021	30%	15%	104%
2022	26%	14%	69%
2023	23%	14%	50%
2024	20%	13%	40%
2025	18%	12%	36%
2026	16%	10%	27%
2027	13%	9%	21%
2028	12%	9%	17%
2029	10%	8%	15%
2030 through 2050	3-9%	2-7%	3-12%

Notes: EMFAC2017 uses the same future ZEV sales requirements as assumed in EMFAC 2014.

EMFAC = EMission FACtor model; ZEV = zero emission vehicle; SANDAG = San Diego Association of Governments; PHEV = plug-in hybrid electric vehicle; BEV = battery electric vehicle; FCEV = fuel cell electric vehicle.

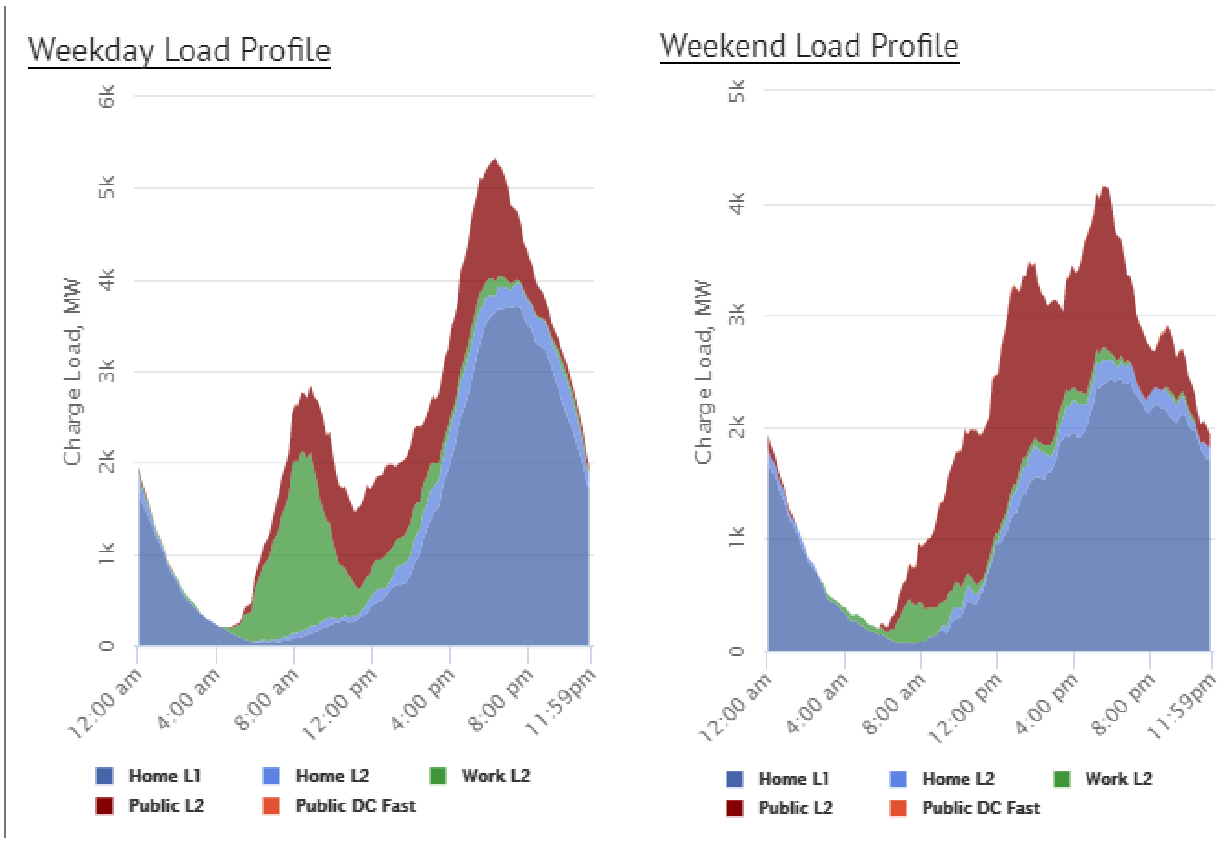
[1] DMV 2018

[2] CARB 2015: Table 3.3-7

Source: CARB 2015: Table 3.3-7, DMV 2018

C_i is calculated from the charger-to-PEV ratio from EVI-Pro (See Figure 1). The active charging referred to in H_i is distinct from charging time, because a car may still be plugged in but not actively charging as the attached car may have completed or stopped charging. For H_i, the default charging activity is shown in at the bottom of Table 3 where workplace chargers are estimated to actively charge BEVs for 0.6 hours and PHEVs for 2.2 hours per charger, across multiple vehicles over the course of an average day. Values in Table 3 were calculated from load profiles by charger type, as shown in Figure 2. These charging times are consistent with the understanding that PHEVs would need to charge more frequently due to their smaller range compared to BEVs. P_i, $\eta_{charger}$, and FE_{EV} assumptions are consistent with those used in CEC's EVI-Pro runs statewide. CEC assumed a charger efficiency of 90 percent in its analysis for all charger types (CEC 2018:25). Charger efficiency is understood here as the electricity delivered by the charger divided by the electricity drawn from the electricity grid by the charger.

The default H_i values given above are calculated from charger load results from CEC's EVI-Pro runs for the SANDAG region (NREL 2018b). The charger load results show how much power, in MW, is drawn from each charger destination type (e.g., public level 2, workplace level 2, and public DC fast charger) over a 24-hour period, as shown in Figure 2. These results varied by the day of the week. Weekday and weekend loads were combined to provide average daily loads.



Source: NREL 2018a. Note that Public DC Fast charger loads are imperceptible in this figure due to very small loads in comparison to other charger types.

Figure 2 Weekend and Weekday Power Load by Charger Destination Type over a 24-hour Period for SANDAG in 2025

The area under the curve by each charger type is equal to the daily electricity demand for all chargers in the SANDAG region in 2025, under CEC's target scenario in their 2018 infrastructure report (CEC 2018). Dividing the total energy delivered (in MWh) by the average charger power rating (in kW) gives the average hours charged by charger type. Ascent further disaggregated the charging hours by PEV type using the charger demand profile by PEV type assumed in CEC's modeling (CEC 2018: Figure 4.5). This methodology to calculate the charging hours was recommended by CEC (Bedir, Pers. Comm., 2018). See Table 3 for the resulting calculated active daily charging hours by PEV type and charger type based on the data shown in Figure 2. It was assumed that the 2025 charging behavior by charger type would stay constant from 2020 through 2050. CEC's EVI-Pro analysis did not have similar data available for years other than 2025.

PHEV CO_2 Reductions

For CO_2 reductions from PHEVs, the approach differs from the BEV calculations because the chargers affect the overall electric UF of PHEVs. Depending on the charger assumptions, the chargers would increase the amount of eVMT provided to PHEVs. Dividing the eVMT provided by the chargers by the PHEV VMT assumed in EMFAC would result in a higher UF relative to EMFAC defaults, potentially beyond the maximum UF for PHEVS. The maximum UF for PHEVs, assuming access to charging is widely available, is 80 percent according to a 2017 NREL study and the San Diego 2025 PEV fleet mix [NREL 2017: Figure 26]. MTC used this approach of comparing UFs to assign CO_2 reductions to the MTC's RECP and estimated a UF of 80 percent with additional chargers.

However, PHEV UF assumed under the RECP is inextricably connected with the assumptions used to estimate reductions from the VIP. This is because the VIP has the potential to increase overall PHEV VMT by increasing the number of PHEVs in the region. This affects the calculation of the PHEV UF under the RECP because the UF is calculated by dividing PHEV eVMT provided under the RECP by the total PHEV VMT. Thus, the calculations are set up to avoid double counting reductions from PHEVs from the two programs. This approach is detailed in Equations 4 through 7.

$$E_{PHEV_{RECP}} = E_{PHEV_{BAU}} - E_{PHEV_{SANDAG}} - E_{PHEV_{VIP}} \qquad (Equation\ 4)$$

Where:

E_{PHEV_RECP} = Emissions reductions associated with PHEVs under the RECP (MT CO_2)

E_{PHEV_BAU} = Emissions from PHEVs and Gasoline LDVs in the BAU forecast (MT CO_2)

E_{PHEV_SANDAG} = Emissions from PHEVs that would occur under the RECP and VIP (MT CO_2)

E_{PHEV_VIP} = Emissions reductions from PHEVs that would occur under the VIP only (MT CO_2)

The overall PHEV daily VMT, regardless of fuel types, is assumed to be equal for both E_{PHEV_BAU} and E_{PHEV_SANDAG}. E_{PHEV_VIP} is calculated in Equation 10. The PHEV-related VMT (VMT_{PHEV_SANDAG}) under both programs is assumed to be equal to the product of 1) the total number of PHEVs anticipated under the VIP (incentivized and existing) and 2) average daily VMT per gasoline LDV assumed in the BAU forecast. The PHEV population target under the VIP needs to be greater than or equal to the BAU forecasts to achieve applicable reductions. The VIP CO_2 reductions from PHEVs are subtracted from the total in Equation 4 to avoid double counting.

Equation 5 describes how E_{PHEV_BAU} is calculated.

$$E_{PHEV_{BAU}} = \frac{\left(VMT_{PHEV_{VIP}} - \left[VMT_{PHEV_{BAU}} * UF_{EMFAC}\right]\right) * EF_{Gas}}{10^6 \frac{g}{MT}} \qquad (Equation\ 5)$$

Where:

E_{PHEV_BAU} = BAU-forecasted emissions from PHEVs and Gasoline LDVs (MT CO_2)

VMT_{PHEV_VIP} = Daily VMT associated with entire PHEVs population under the VIP (mi/day)

VMT_{PHEV_BAU} = BAU-forecasted daily VMT associated with all PHEVs (mi/day)

UF_{EMFAC} = Default PHEV Utility Factor assumed in EMFAC2017 (%).

EF_{Gas} = Emissions factor per mile associated with gasoline LDVs in the SANDAG region, as modeled in EMFAC2017 (g CO_2/mi). Based on EMFAC vehicle categories LDA, LDT1, LDT2, and MDV.

VMT_{PHEV_VIP} is the product of the total PHEV population under VIP and the average daily miles per gasoline LDV, as modeled in EMFAC2017. VMT_{PHEV_BAU} is calculated by multiplying the PHEV population and the average daily gasoline VMT per LDV, based on EMFAC2017 results that were adjusted by the difference between SANDAG VMT forecasts and EMFAC VMT forecasts. As with the approach for BEVs, these and other adjustments were made to EMFAC results because EMFAC2017 does not output EV populations by PEV type and because EMFAC VMT forecasts were not developed based on locally-specific data, as SANDAG VMT forecasts are. The following adjustments were made to EMFAC results to estimate the business-as-usual PHEV forecasts:

1. Based forecasts on 2018 PHEV populations for San Diego County taken from DMV vehicle registration data,

2. Forecasted the 2018 PHEV population into the future years by using EMFAC's assumed growth in LDVs and the assumed proportion of new vehicles that must be ZEVs under the state's ZEV mandate, and

3. Applied an adjustment factor based on the ratio between the SANDAG regional VMT forecast with EMFAC2017's VMT forecast to both the PHEV population and daily VMT per vehicle (CARB 2015, DMV 2018).

As with the approach for BEVs, these adjustments were made because EMFAC2017 uses historical vehicle populations through calendar year 2016 and regulation-based EV projections for years after 2016. Thus, projections were calibrated based on actual 2018 vehicle populations. The SANDAG regional VMT forecasts are considered a variable in this off-model calculator and are not shown here due to the current development of SANDAG's travel demand model as part of the 2019 RTP/SCS. EMFAC's ZEV forecast assumptions are shown in Table 1.

UF_{EMFAC} was based on data obtained directed from CARB. CARB provided PHEV UF assumptions for each model year (MY) starting with MY 2018. Prior to MY 2018, EMFAC assumes all PHEVs have a UF of 40 percent, which was the assumption used in MTC's EV off-model calculator. For EMFAC2017, however, CARB increased the UF assumptions for future model years to account for increasing electric range of available PHEVs (Long, pers. comm., 2018b). EMFAC2017 UF assumptions by model year are summarized in Table 2. These assumptions were applied to the PHEV population mix in EMFAC to calculate a weighted average UF_{EMFAC} that accounts for the different UFs across model years for a given calendar year.

Table 2 EMFAC2017 PHEV Utility Factor Assumptions

Model Year	PHEV UF
Pre-2018	40%
2018	46%
2019	47%
2020	48%
2021	50%
2022	55%
2023	56%
2024	58%
2025 though 2050	59%

Notes: UF assumptions apply statewide. EMFAC = EMission FACtor model; PHEV = plug-in hybrid electric vehicle; UF = utility factor.

Source: Long, pers. comm., 2018b

Equation 6 describes how E_{PHEV_RECP} is calculated.

$$E_{PHEV_{SANDAG}} = \frac{\left(VMT_{PHEV_{VIP}} - [1 - UF_{RECP}]\right) * EF_{Gas} + VMT_{PHEV_{VIP}} * UF_{RECP} * EF_{EV}}{10^6 \frac{g}{MT}} \qquad (Equation\ 6)$$

Where:

E_{PHEV_SANDAG} = Emissions from PHEVs as anticipated under 2019 Regional Plan scenarios with the implementation of the off-model programs (MT CO_2)

VMT_{PHEV_VIP} = Daily VMT associated with PHEVs under the VIP (mi/day)

UF_{RECP} = PHEV utility factor associated with charger scenario under the RECP. Limited to be between UF_{EMFAC} and a maximum of 80 percent. (%)

EF_{Gas} = Emissions factor per mile associated with gasoline LDVs in the SANDAG region, as modeled in EMFAC2017 (g CO_2/mi). Based on EMFAC vehicle categories LDA, LDT1, LDT2, and MDV.

EF_{EV} = FE_{EV} * EF_E (g CO_2/mi) (See Equation 2)

UF_{RECP} is the calculated PHEV UF associated with the charging scenario under the RECP, as shown in Equation 7.

$$UF_{RECP} = \frac{eVMT_{PHEV_{RECP}}}{VMT_{PHEV_{VIP}}} \qquad (Equation\ 7)$$

Where,

$eVMT_{PHEV\_RECP}$ = eVMT associated with the electricity provided by chargers to PHEVs under the RECP

VMT_{PHEV_VIP} = Daily VMT associated with PHEVs under the VIP (mi/day)

$eVMT_{PHEV\_RECP}$ is the eVMT provided to PHEVs by all chargers in the SANDAG region including those associated with RECP. $eVMT_{PHEV\_RECP}$ is calculated identically to Equation 3, with the exception of H_i. In the case of PHEVs, H_{i_PHEV} refers to the active hours charged by charger type per charger per day associated with PHEVs. To simplify model assumptions, the H_i for both BEVs and PHEVs were assumed to be constant for all milestone years based on charger load assumptions used in CEC's EVI-Pro analysis for 2025 for the San Diego region.

Tables 3 and 4 show the assumptions and calculation of the active charging hours (H_i) for BEVs and PHEVs by non-residential charger type based on the CEC's EVI-Pro charger load profile, which is based on data behind Figure 2. Table 3 shows the charger load profile that CEC's EVI-Pro model quantified for the San Diego region in 2025 broken out by PEV and charger type. Table 4 shows the estimated charging behavior (i.e., hours of charge per day per PEV by charger type and day of the week) based on the data in Table 3. The average daily charging patterns by PEV are used as the active charging hours (H_i) applied in Equation 3 to calculate the VMT anticipated from each PEV type under the RECP.

Note that fuel cell electric vehicles (FCEV) were not included in the RECP calculations because FCEVs are assumed to only be fueled via hydrogen fueling stations and are not assumed to have on-board batteries that can be charged separately from the hydrogen fuel cell.

Table 3 CEC EVI-Pro Charging Behavior Results for 2025 in the San Diego Region

Metric	Unit	Workplace L2	Public L2	Public DC Fast	Total
EVI-Pro Charger Load Results[4]	Number of Chargers[1]	4,051	5,485	1,981	11,517
	MWh/weekday[2]	86	79	53	218
	MWh/weekend[2]	21	106	125	252
	BEV kW[3]	6.6	6.6	105	N/A
	PHEV kW[3]	4.9	4.9	-	N/A
Percent of Demand Associated with BEVs by Charger Type	%[5]	27	6	100	N/A
Percent of Demand Associated with PHEVs by Charger Type	%[5]	73	94	0	N/A
BEVs per charger by type	Vehicles[6]	11	8	22	4
PHEVs per charger by type	Vehicles[6]	16	12	33	6

Notes: Values may not sum due to rounding. DC = direct current; CEC = California Energy Commission; MWh = megawatt-hours; BEV = battery electric vehicle; PHEV = plug-in hybrid electric vehicle; L2 = Level 2 charger, kW = kilowatt; PEV = plug-in electric vehicle

[1] NREL 2018b

[2] Bedir, Pers. Comm., 2018

[3] CEC 2018: Table 4.1

[4] CEC assumed a charger efficiency of 90% across all chargers and PEV combinations (CEC 2018: 25)

[5] CEC 2018: Figure 4.5

[6] Calculated by dividing the number of chargers by the 2025 BEV or PHEV population based on a total population of 110,227 and apportioned based on the calibrated EMFAC population forecast for BEVs and PHEVs in 2025.

Table 4 Calculated Active Charger Load and Hours per Charger by PEV in 2025 in the San Diego Region[1]

Metric	Day	Workplace L2	Public L2	Public DC Fast	Total
kWh delivered to ALL BEVs per day per charger	Weekday	5	1	24	30
	Weekend	0	0	6	6
	Average	4	1	19	23
kWh delivered to ALL PHEVs per day per charger	Weekday	14	12	0	26
	Weekend	3	16	0	20
	Average	11	13	0	24
Active Charging Hours for ALL BEVs per day per charger (H_{i_BEV})[2]	Weekday	0.8	0.1	0.2	1
	Weekend	0.0	0.0	0.1	0.1
	Average	0.6	0.1	0.2	1
Active Charging Hours for ALL PHEVs per day per charger (H_{i_PHEV})[3]	Weekday	2.9	2.5	0	5
	Weekend	0.7	3.3	0	4
	Average	2.2	2.7	0	5

Notes: Values may not sum due to rounding. DC = direct current; MWh = megawatt-hours; BEV = battery electric vehicle; PHEV = plug-in hybrid electric vehicle; L2 = Level 2 charger, kWh = kilowatt-hours; PEV = plug-in electric vehicle

[1] For each charger type, active charging hours by PEV equals the product of daily MWh, efficiency, and percent demand by PEV type divided by the number of chargers based on data shown in Table 3.

[2] The average daily results should be used to represent the H_{i_BEV} variable shown in Equation 3.

[3] The average daily results should be used to represent the H_{i_PHEV} variable based on Equation 3.

Vehicle Incentive Program

Under the VIP, SANDAG would offer incentives for drivers to replace older gasoline passenger vehicles with equivalent PEVs. While SANDAG could consider incentivizing fuel-cell electric vehicles (FCEVs) in addition to PEVs, this calculator only accounts for reductions associated with incentives for PEVs due to the relatively small FCEV population forecast and limited amount of existing infrastructure (see Table 1). The VIP would increase the share of PEVs among the LDA fleet in the San Diego region. It is assumed that the VIP would not increase or decrease overall VMT in the San Diego region anticipated under 2019 Regional Plan.

The CO_2 reductions associated with the VIP are essentially a comparison of the new eVMT that would occur from the additional BEVs and PHEVs incentivized under the program beyond the BAU forecast. To account for reductions attributed to non-SANDAG incentives, an additional adjustment is made based on the proportion of the VIP incentives to all incentives offered on a per-vehicle basis. The calculation of CO_2 reductions from VIP are reflected in Equations 8 through 10. Similar to Equation 1, the emissions reductions from VIP are the sum of the emissions reductions from BEVs and PHEVs under the program.

$$E_{VIP} = \left(E_{BEV_{VIP}} + E_{PHEV_{VIP}}\right) * \frac{I_{SANDAG\_VIP}}{I_{SANDAG\_VIP} + I_{Non-SANDAG\_ZEV}} \qquad (Equation\ 8)$$

Where:

E_{VIP} = Emissions reductions associated with implementation of VIP (MT CO_2)

E_{BEV_VIP} = Emissions reductions associated with BEVs under the VIP (MT CO_2)

E_{PHEV_VIP} = Emissions reductions associated with PHEVs under the VIP (MT CO_2)

I_{SANDAG} = Average incentive per ZEV under the VIP offered by SANDAG (Dollars)

$I_{Non\text{-}SANDAG\_Chargers}$ = Average incentive per ZEV totaled across all non-SANDAG programs in the SANDAG region (Dollars)

<u>BEV CO_2 Reductions</u>

CO_2 reductions from BEVs are based on the difference between emissions from charging associated with the eVMT of the BEVs incentivized under the VIP compared to the eVMT from BEV anticipated by EMFAC. Any additional eVMT from the VIP is assumed to offset equivalent gasoline LDV VMT. Similar to Equation 2, BEV emission reductions from the VIP are based on the following equation.

$$E_{BEV_{VBIP}} = \frac{\left(VMT_{BEV_{VIP}} - VMT_{BEV_{BAU}}\right) * EF_{Gas}}{10^6 \frac{g}{MT}} \qquad (Equation\ 9)$$

Where:

E_{BEV_VIP} = Emissions reductions from the BEV population under VIP compared to the BAU forecast (MT CO_2)

VMT_{BEV_VIP} = eVMT associated with all BEVs including those incentivized under the VIP (mi/day)

VMT_{BEV_BAU} = eVMT associated will all BEV VMT under the BAU forecast (mi/day)

EF_{Gas} = Emissions factor per mile associated with gasoline LDVs in the SANDAG region, as modeled in EMFAC2017 (g CO_2/mi). Based on EMFAC vehicle categories LDA, LDT1, LDT2, and MDV.

Because both Equations 2 and 9 calculate reductions relative to EMFAC-forecasted VMT, BEV emissions reductions from VIP (E_{BEV_VIP}) are assumed to be independent of the BEV reductions from RECP (E_{BEV_RECP}). VMT_{BEV_VIP} is the product of the targeted BEV population under VIP and the average daily miles per vehicle for EVs as modeled in EMFAC2017 and adjusted based on the difference between SANDAG and EMFAC VMT forecasts. VMT_{BEV_BAU} and EF_{Gas} are the same values used in Equation 2.

<u>PHEV CO_2 Reductions</u>

For emission reductions from PHEVs, the approach is similar to Equation 6 with an added complication behind the UF assumption.

$$E_{PHEV_{VIP}} = \frac{\left(VMT_{PHEV_{VIP}} * [1 - UF_{VIP}]\right) * EF_{Gas}}{10^6 \frac{g}{MT}} \qquad (Equation\ 10)$$

Where:

E_{PHEV_VIP} = Emissions from PHEVs as anticipated under the VIP (MT CO_2)

VMT_{PHEV_VIP} = Daily VMT associated with PHEVs under the VIP (mi/day)

UF_{VIP} = PHEV utility factor assumed for VIP (%)

EF_{Gas} = Emissions factor per mile associated with gasoline LDVs in the SANDAG region, as modeled in EMFAC2017 (g CO_2/mi). Based on EMFAC vehicle categories LDA, LDT1, LDT2, and MDV.

VMT_{PHEV_VIP} is the product of the targeted PHEV population under VIP and the average daily miles per vehicle for gasoline LDVs as modeled in EMFAC2017 and adjusted based on the difference between SANDAG and EMFAC VMT forecasts. To be conservative and to avoid circular arguments, UF_{VIP} is assumed to be equal to the UF assumed under EMFAC2017 (UF_{EMFAC}).

Incentive Costs

To estimate the cumulative incentive program costs to SANDAG, the user can input SANDAG's incentive costs per charger or vehicle and percent-based administrative costs (e.g., five percent of all vehicle incentives) for each milestone year. For the RECP, the user can choose SANDAG's average incentive cost per workplace charger, public L2 charger, and public DC Fast Charger. For the VIP, the user can choose SANDAG's average incentive cost per BEV and PHEV. The total cost of each program would be based on the per-unit incentives multiplied by the associated new chargers or PEV populations as of 2018, as calculated from the EV off-model calculator for each milestone year. The calculated costs are cumulative, because the tool calculates the cumulative number of new chargers and PEVs as of 2018 associated with the RECP and VIP. Thus, the input costs per unit should reflect the average cost across all new chargers or vehicle incentivized since 2018.

Results

[TO BE ADDED ONCE SANDAG SELECTS SCENARIO]

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Long, Jeffrey. Staff Air Pollution Specialist. Mobile Source Analysis Branch, Air Quality Planning and Science Division, California Air Resources Board, El Monte, CA. June 25, 2018a – email to Brenda Hom of Ascent Environmental with a breakdown of the ZEV population by ZEV type and model year through 2017 for the month of October 2016 in the SANDAG region, as modeled in EMFAC2017;

June 8, 2018b – email to Brenda Hom of Ascent Environmental with the assumed utility factor for PHEVs in EMFAC2017 by model year.

Appendix E
WP TDM Off-Model Memo

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

CO_2 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 CO_2 reduction corresponding to the VMT reduction and reduction in trip starts using the Emission Factors (EMFAC) 2014 CO_2 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

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SANDAG (2018). 2018 Commute Behavior Survey.

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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

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[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

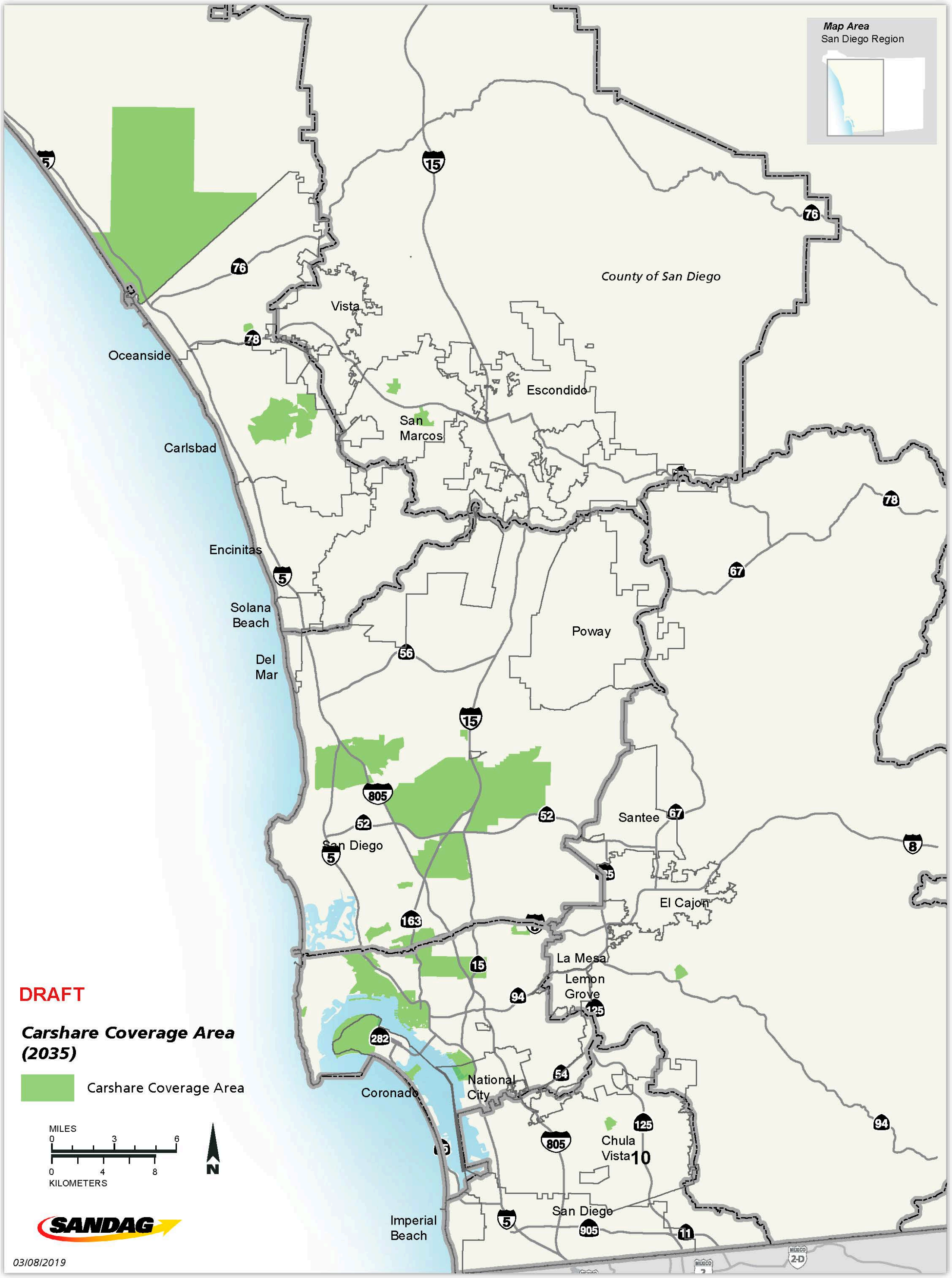

Table 6: Methodology Parameters, Carshare CO2 Emissions Calculator

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: ○ 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: ○ 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: ○ Military base flag (1 if carshare operates on military base, 0 otherwise)

Results

Table 8 summarizes the vehicle trip, VMT and CO_2 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: ○ Average bikeshare trips per bike (pedal and e-bike) ○ Percent of trips that would have used a car ○ 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

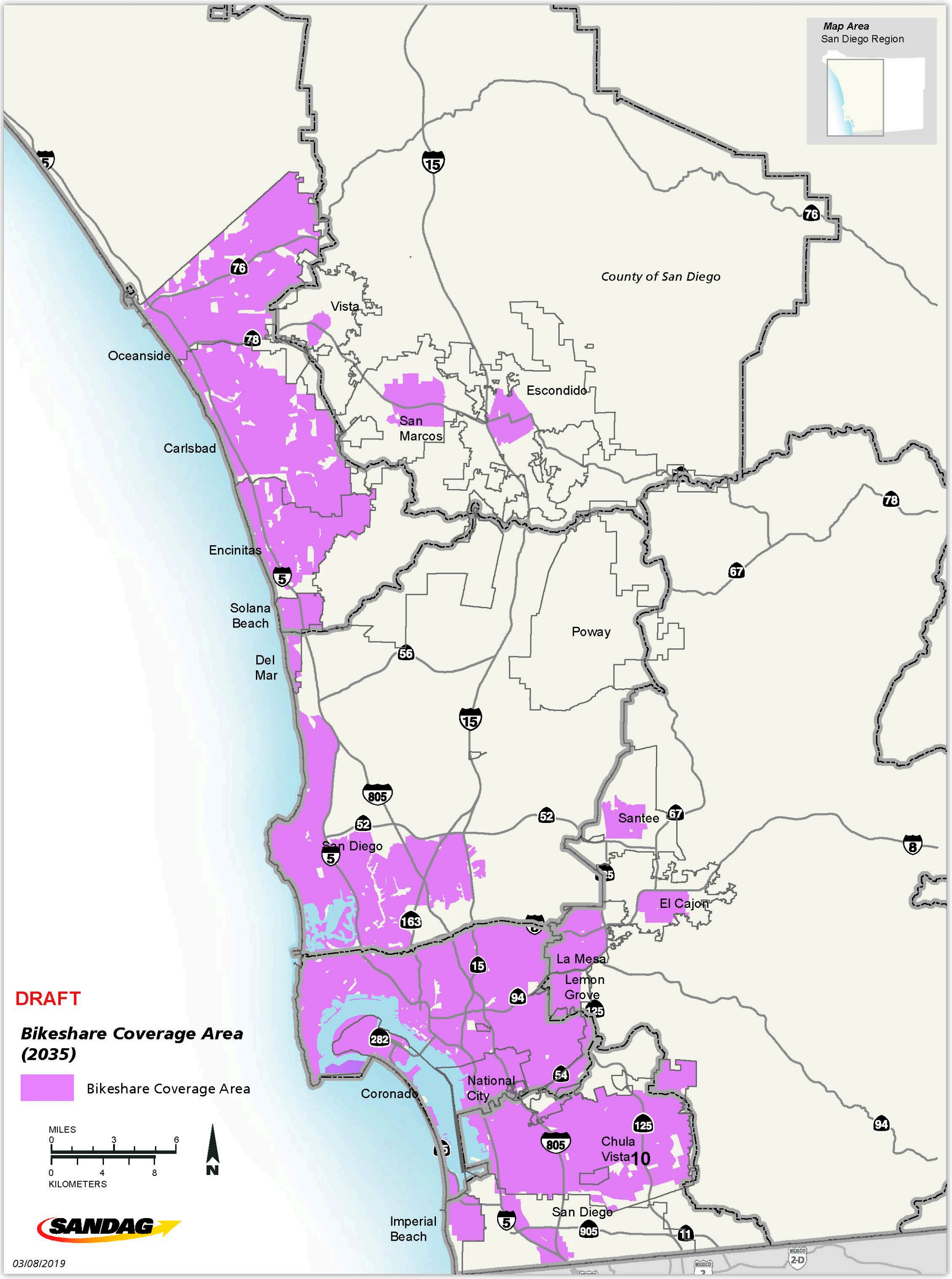

Table 11: Methodology Parameters, Bikeshare CO2 Emissions Calculator

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 ○ Drive alone trips predicted in each future year auto ownership category ○ Auto operating cost • 2016-2017 San Diego Regional Transportation Study ○ Utilization frequency--percentage of users that use a ride-hail service, work and non-work trips • 2018 Commute Behavior Survey ○ 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 ○ Average drive alone and carpool travel times ○ Average value of time ○ Marginal disutility of time, in-vehicle time coefficient • Internal Revenue Service (IRS) ○ 2016 mileage reimbursement rate
Program VMT	• Estimate program VMT based on estimated number of pooled rides in	• SANDAG ABM data, for each scenario year ○ 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

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[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

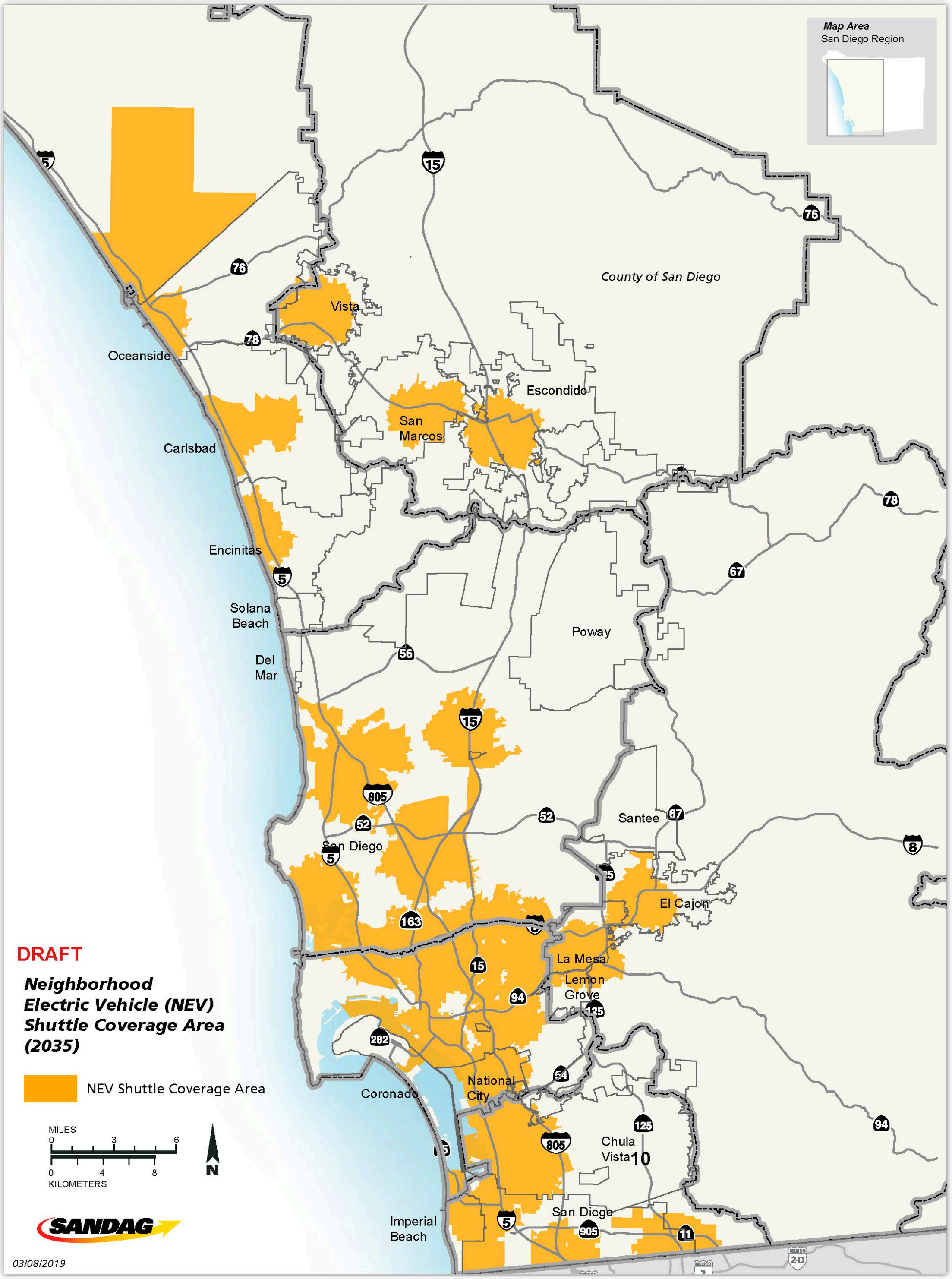

Figure 4: Draft 2035 Commuter Shuttle Microtransit Coverage Area

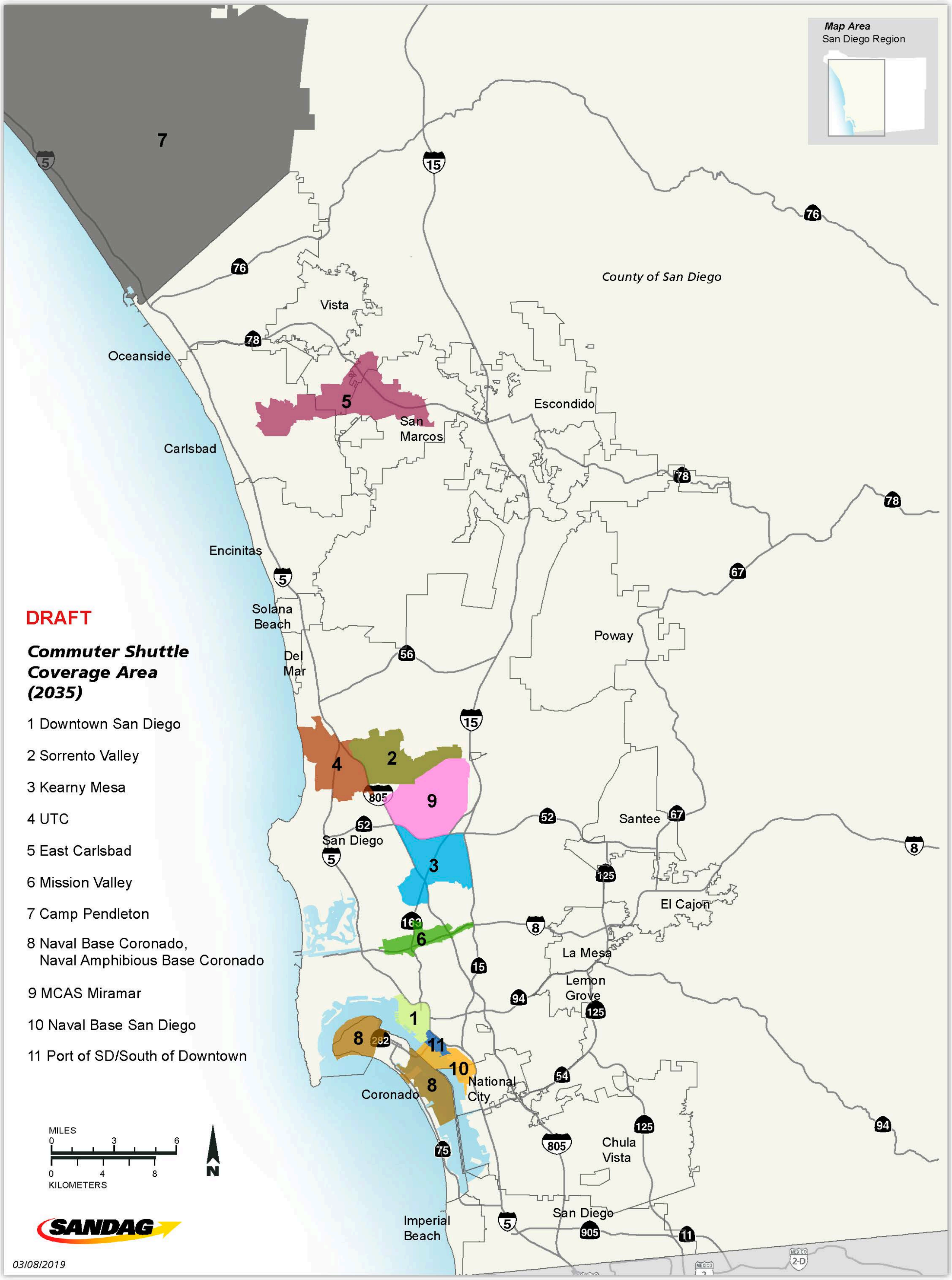

Table 22: Microtransit Commuter Shuttle Mode Choice Parameters, Microtransit CO_2 Emissions Calculator

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

Data Item	Source	Required Input Data

Microtransit coverage area (NEV and Commuter Shuttle services)	Draft San Diego Forward: The 2019-2050 Regional Plan	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:
		  ○ 1 if Downtown San Diego
		  ○ 2 if Sorrento Valley
		  ○ 3 if Kearny Mesa
		  ○ 4 if UTC
		  ○ 5 if East Carlsbad
		  ○ 6 if Mission Valley
		  ○ 7 if Camp Pendleton
		  ○ 8 if Naval Base Coronado, Naval Amphibious Base Coronado
		  ○ 9 if MCAS Miramar
		  ○ 10 if Naval Base San Diego
		  ○ 11 if Port of San Diego/South of Downtown
		  ○ 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

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 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

Regional trips, NEV shuttle	SANDAG ABM 14.0.1	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
		  ○ Origin MSA
		  ○ Origin MSA NEV shuttle service flag
		  ○ Destination MSA
		  ○ Destination MSA NEV shuttle service flag
		  ○ Sum of person trips less than 2 miles long
		  ○ Sum of auto trips less than 2 miles long

	SANDAG ABM 14.0.1	For each scenario year:

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.

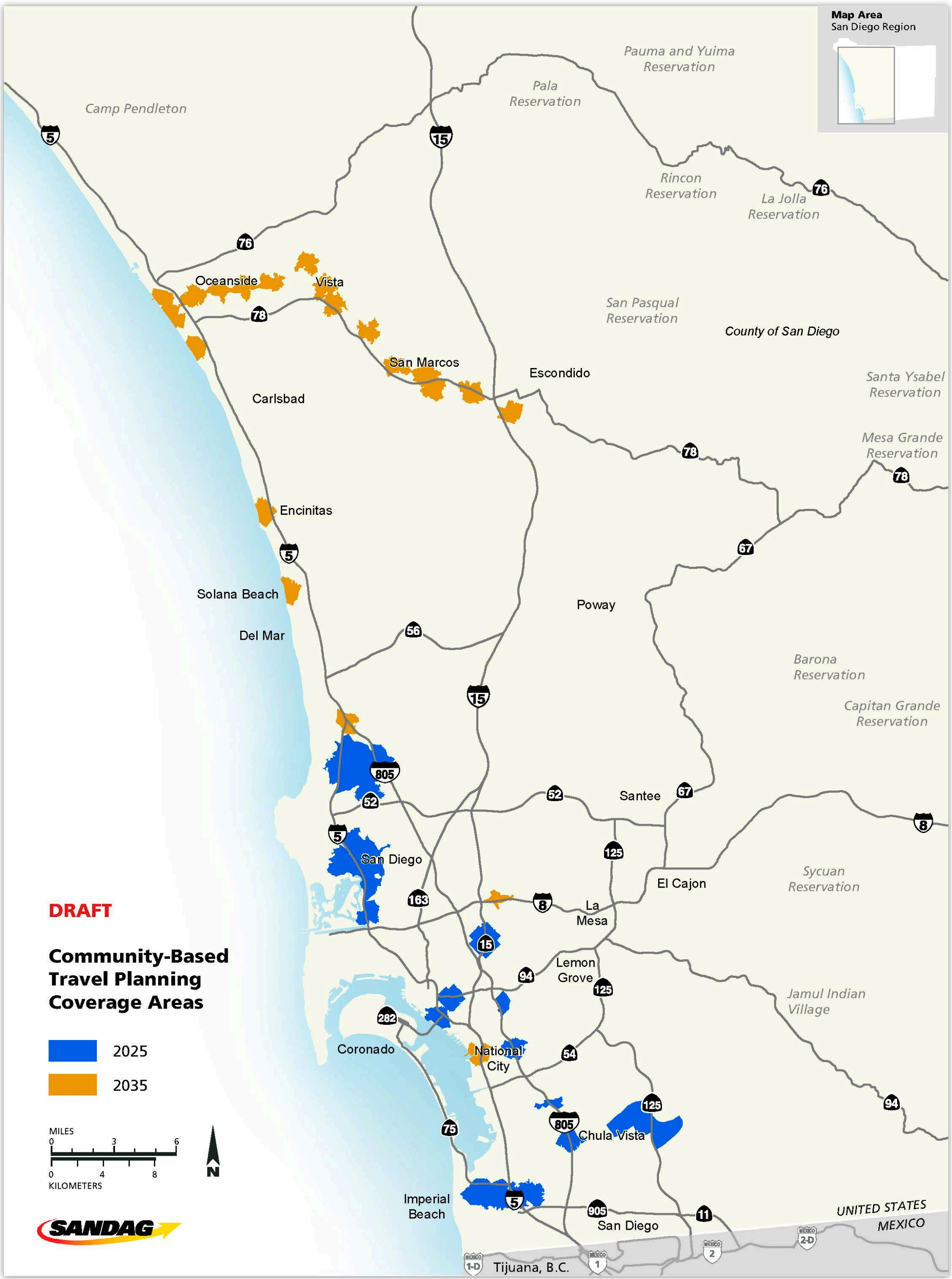
1. The number of households was identified within the designated target areas for CBTP to determine the number of households participating in CBTP. Based on nine CBTP case studies, it was assumed that an average 17 percent of targeted households would participate.

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			

Appendix F
SANDAG Vanpool Calculator
Review and Comparison

Vanpool Off-Model Methodologies Review

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11/13/2020

Summary

This document provides a review of SANDAG's Vanpool off-model calculator (OMC) that was originally developed by WSP Inc. (WSP, 2019) as compared to CARB's recommended methodology (CARB 2019a, 2019b). The methods were found to be consistent with best practices. In addition to the review the vanpool OMC was updated to reflect the most recent SANDAG Vanpool Program Data (from May 2020) and the most recent ABM 2+ forecasts. There were 590 registered vanpools in May 2020, which reflects decreases in program participation due to both major employers who have withdrawn support and to COVID-19 impacts at the time. Over the past five years, the number of active vanpools has fluctuated between 680 and 720 vehicles. The recent active Vanpool demand dropped to 590 van pools, which is likely to be affected by COVID-19. Current vanpool program requires at least 80% of occupancy for the benefit and at least 20 miles of travel distances within the County. The recent growth of teleworking is likely to affect the decrease in vanpools, though any easing of the COVID-19 pandemic may have the opposite effect in terms of an increased demand for mobility. Since is it too early to know how these potential changes will interact in terms of a trend going forward, it is reasonable to use the May 2020 results as an intermediate point of reference. The results of the updates produce a somewhat lower per capita reduction (0.35% reduction vs the original 0.46% reduction), which is to be expected given the lower vanpool participation rates found in May of 2020. Though this performance is diminished, the calculator's GHG reduction estimates are still significant and may evolve over time.

Please note that the inputs, assumptions, and emission reduction estimates listed within this methodology are draft and are subject to change pending the development of a final network and land use scenario to inform the 2021 Regional Plan.

Review of the SANDAG Vanpool Calculator

ITS-Irvine reviewed models, assumptions, and modeling inputs. Overall, the vanpool OMC follows CARB's (2019b) recommendations from its Final Sustainable Communities Strategy Program and Evaluation Guidelines-Appendices. This includes specific methodological recommendations such as accounting properly for interregional travel and double counting with other calculators. For instance, the vanpool OMC excludes the portion of SCAG's VMT in Internal-External trip (IX) and External-Internal trip (XI), depending on the origin, destination coordinates and gateways for origins and destinations. Furthermore, the vanpool calculator resolves a double-counting issue by considering average occupancy excluding drivers, thus emissions from vans are counted.

The core modeling inputs to the vanpool calculator include:

- EMFAC 2014 emission factors
- EMFAC 2014 VMT
- SANDAG population forecasts
- SANDAG employment forecasts by industry category per SANDAG ABM classification
- SCAG employment forecasts by county
- SANDAG travel time skim data (military/non-military base destinations)
- Average vanpool mileage (as of May 20, 2020, SANDAG Vanpool Program)
- Average van capacity (as of May 20, 2020, SANDAG Vanpool Program)
- Average van occupancy (as of May 20, 2020, SANDAG Vanpool Program)
- Postal zip code centroid coordinates (used to approximate the distance traveled by vanpools outside San Diego County)
- County gateway centroids (Used to approximate the distance traveled by vanpools outside San Diego County)

No methodological changes to these inputs were deemed necessary by our review other than updating the population and travel forecasts (trips, skims, and VMT) from SANDAG's ABM2+ model and the vanpool statistics from the recent program data.

Table 1 shows the additional parameters and assumptions used in the calculator. ITS-Irvine's review of the SANDAG Vanpool calculator assessed whether parameter changes were appropriate based upon any changes to the literature since the calculators were developed by WSP (2019). We found that the assumptions (i.e., the marginal disutility of travel time and the person trips suitable for vanpooling assumptions) are up to date and are consistent with the ABM 2+, though parameter updates to the vanpool inventory using the most recent data available from SANDAG was warranted.

Table 1. Parameters and assumptions of SANDAG Vanpool calculator

Parameter	Source	Details
Current vanpool inventory	Active vanpools as of May 20, 2020, SANDAG Vanpool Program)	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.
Marginal disutility of travel time	SANDAG ABM 2+ Trip mode choice model, Work tours	In-vehicle time coefficient of the work trip mode choice model, SANDAG ABM 2+ (the same as ABM14.0.1)

Total person trips that are suitable for vanpooling	U.S. Census Bureau (2016). American Community Survey, 2016 1-Year Release.	Used to calculate vanpool mode market share, an input to the demand elasticity formula (value rounded to 1.6 million workers).

GHG Emission Calculator Methodology

ITS-Irvine also reviewed the core methodology employed by the calculator and found it to be consistent with CARB's (2019) Final Sustainable Communities Strategy Program and Evaluation Guidelines. The calculator computes CO2 reductions following the procedure described below.

Establish the current vanpool demand:

1. 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, or at the county level if they fell outside San Diego County.

The main assumptions underlying the number of vanpool program participants are based on two factors:

1. Employment growth: it is assumed that the participant rates over employment remain the same in the future, thus the number of vanpoolers is a function of the number of employees.
2. Mode shift from travel time savings. Vanpool incentives include the exclusive use of managed lanes including High Occupancy Vehicle and the Interstate-15 Express Lanes). The shifted demand is measured from the elasticity approach, which is derived from a logit model. Travel time savings from managed lanes attract more vanpoolers, which could reduce VMT by mode shift from drive alone.

Vanpool demand due to regional employment growth:

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.

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 estimated number of vanpools for each scenario year, after accounting for employment growth.

Table 2 shows a summary of the calculated vanpool demand both due to regional employment growth and the impact of managed lane investments.

Table 2. Estimated vanpool demand

6.

Vanpool Program Growth Estimates

1. Vanpool demand due to regional employment growth	2020	2035	2050	Notes
	Total vanpools due to regional employment growth			
Vanpool Industry				
Military	228	244	248	Assumes that the number of vanpools changes proportionally with employment at the destination MSA (County if vanpool destination is outside San Diego County).
Federal Non-Military	115	126	135	
Non-Federal	247	281	302	
TOTAL	590	651	685	
2. Vanpool demand due to managed lane investments	**2020**	**2035**	**2050**	**Notes**
	Total vanpools due to managed lane infrastructure			
Vanpool Industry				
Military	-	9	14	Induced demand for vanpools as the region builds managed lanes which result in travel time savings relative to traveling on general purpose lanes. Travel time savings vary by trip origin and destination, and by scenario year.
Federal Non-Military	-	8	11	
Non-Federal	-	15	21	
TOTAL	-	32	45	
TOTAL VANPOOLS	**2020**	**2035**	**2050**	**Notes**
Vanpool Industry				
Military	228	253	262	
Federal Non-Military	115	134	146	
Non-Federal	247	296	323	
TOTAL	**590**	**683**	**730**	

Vanpool VMT and GHG reductions:

7. Calculate VMT reduction, which for each van is equal to the average round trip distance within San Diego County, multiplied by the number of passengers (excluding the driver). It is noteworthy that the calculator only accounts for vanpool travel within San Diego County only. Out-of-county distance approximated based on home zip code coordinates.

8. Calculate the CO_2 reduction corresponding to the VMT reduction and reduction in trip starts using the Emission Factors (EMFAC) 2014 CO_2 emission rates.

Table 3 shows the estimated VMT and GHG reduction results of the updated vanpool OMC. Compared with the estimated results of the original OMC, shown in Table 4, the changes in input data had a notable impact on daily per capita GHG reduction because both active vanpools and the VMT forecasts have decreased since the updates to the regional model. Although the travel time saving of the simulation run from ABM2+ is higher than that of the original OMC, the reduction in vanpool participants of the active vanpool program in 2020 have significantly affected the results, leading to a smaller per capita GHG reduction in all target years versus the original calculator.

Table 3. Estimated VMT and GHG Reduction Results of the updated Vanpool OMC

VMT and GHG Reduction Results

Variable	2020	2035	2050
Plan CO2 Emissions			
Regional population	3,383,955	3,620,349	3,746,077
Daily CO2 emissions (short tons)	38,881	38,199	38,777
Daily emissions per capita (lbs)	22.98	21.10	20.70
Total daily vehicle trip reduction	6,012	6,967	7,452
Total daily VMT reduction	307,133	355,422	379,780
VMT reduced in San Diego County	259,598	300,336	320,910
GHG reduction due to cold starts (short tons)	0.6	0.6	0.7
GHG reduction due to VMT (short tons)	121.9	137.3	145.5
Daily Total GHG reduction (short tons)	122.5	137.9	146.2
Daily Per capita GHG reduction (lbs/person)	-0.072	-0.076	-0.078
Daily Per capita GHG reduction	-0.31%	-0.36%	-0.38%

Table 4. Estimated VMT and GHG Reduction Results of the original Vanpool OMC

VMT and GHG Reduction Results

Variable	2020	2035	2050
Plan CO2 Emissions			
Regional population	3,374,125	3,709,575	3,967,090
Daily CO2 emissions (short tons)	38,652	42,139	43,371
Daily emissions per capita (lbs)	22.91	22.72	21.87
Total daily vehicle trip reduction	6,669	8,106	8,547
Total daily VMT reduction	386,286	469,271	493,683
VMT reduced in San Diego County	334,101	405,763	426,853
GHG reduction due to cold starts (short tons)	0.6	0.8	0.8
GHG reduction due to VMT (short tons)	160.8	189.1	194.3
Daily Total GHG reduction (short tons)	161.4	189.8	195.1
Daily Per capita GHG reduction (lbs/person)	-0.096	-0.102	-0.098
Daily Per capita GHG reduction	-0.42%	-0.45%	-0.45%

References

1. WSP (2019). Draft TDM Off-Model Methodology—March 2019 Revision. WSP Inc.

2. CARB (2019a) Final Sustainable Communities Strategy Program and Evaluation Guidelines, available at https://ww2.arb.ca.gov/resources/documents/scs-evaluation-resources

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

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Appendix G
SANDAG Carshare Calculator Review and Comparison

Carsharing Off-Model Methodologies Review

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11/13/2020

Summary

This document provides a review of SANDAG's Carsharing off-model calculator (OMC), originally developed by WSP, Inc. (WSP, 2019), compared to CARB's recommended methodology (CARB 2019a, 2019b). Generally, the calculator follows the quantification methodology steps of CARB's guidelines and is based upon valid assumptions and up-to-date parameters from the literature. The calculator was updated using the most recent ABM 2+ forecasts and reflect significant changes to coverage areas in 2035. The combined impacts of these updates lead to approximately double (0.20% reduction vs 0.10% reduction) the estimates per capita GHG in the updated calculator versus the original calculator.

Please note that the inputs, assumptions, and emission reduction estimates listed within this methodology are draft and are subject to change pending the development of a final network and land use scenario to inform the 2021 Regional Plan.

Review of the SANDAG Carsharing Calculator

Upon initial review, we realized it was important to note that there are several types of carsharing services, including roundtrip, one-way (either a free-float carshare service or station-based model), and peer-to-peer, that are relevant for quantification methodologies in CARB's SCS Evaluation Guidelines. SANDAG's carsharing calculator only considers roundtrip carsharing since other types of carsharing services do not exist in San Diego. Car2go, a free-float carshare service that was previously operating in San Diego, ceased operation in the region in 2016 and left all North American markets in 2020.

Once establishing the submarket that the calculator is targeting, we reviewed the general methodology, which is described in more detail below, and found it consistent with CARB guidelines. We also reviewed the core modeling inputs to the carshare calculator, which include:

- EMFAC 2014 Emission factors
- EMFAC 2014 VMT
- SANDAG employment forecasts
- SANDAG population forecasts
- SANDAG MGRA residential area (acres)
- SANDAG MGRA college student enrollment and employment

- Carshare Mobility Hub coverage (1 if carshare operates in MGRA, 0 otherwise)
- Carshare College/university coverage (1 if carshare operates in college)
- Carshare Military base coverage (1 if carshare operates on base, 0 otherwise)

No methodological changes to these inputs were deemed necessary by our review other than updating the population and travel forecasts (trips, skims, and VMT) from SANDAG's ABM2+ model and reviewing the carshare coverage indicators to confirm their correctness.

Our review also included assessing what parameter changes were appropriate based upon any changes to the literature since the calculators were developed by WSP Inc. (2019). Table 1 indicates the parameters and assumptions of the calculator. Our review found that the assumptions summarized in the table are based upon valid research and data sources that have not been superseded by any literature we could identify.

Table 1. Parameters and assumptions of SANDAG carsharing calculator

Parameter	**Source**	**Details**
Carshare participation rate in higher density areas	SANDAG (2017). 2016-2017 San Diego Regional Transportation Study.	For each scenario year:proportion of urban population that will become carshare members
Carshare participation rate in lower density areas	Petersen, E., Y. Zhang, and A. Darwiche (2016).	For each scenario year: proportion of suburban population that will become carshare members
Membership rate,	Assumed equal to higher density area carshare participation rates or 2 percent of the eligible population	For each scenario year: proportion of college employees that will become carshare members
Daily VMT reduction, roundtrip carshare	Cervero, R. A. Golub, and Nee (2007)	For each scenario year: VMT reduction per roundtrip carshare member

We reviewed models, assumptions, and modeling inputs and found that the carsharing OMC follows CARB's Final Sustainable Communities Strategy Program and Evaluation Guidelines and Appendices in terms of data sources, supporting literature for assumptions, and efforts avoiding double counting. For instance, 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. Furthermore, the carsharing OMC drops the impact of carsharing service in 2050 by assuming that a carsharing service will no longer be available in 2050 as shared, on-demand services (e.g., ridehailing, microtransit) continue to grow in popularity.

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 for each of the markets;

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:

    a. Mobility hubs (General Population): Define agglomerations of MGRAs and aggregated by MSA. The coverage areas vary by scenario year, reflecting increasing land use density and a maturing carshare industry.

    b. College/Universities (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 (Military personnel on base): 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 the 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 is 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 correspond 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 CO_2 reduction corresponding to the VMT reduction, using the EMFAC 2014 CO_2 emission rates.

The main assumptions regarding carsharing membership are based on the population density and the carshare service coverage area. Table 2 and Table 3 show the eligible employment and estimated carshare participation in 2020 and 2035, respectively. The enlarged coverage of carshare services in 2035 increases the estimated Carshare participation. The carshare service coverage substantially increases to 6,743 MGRAs (Master Geographic Reference Areas) from 31 MGRA in 2020. As such, it is expected that in 2035 employment centers will have 15,026 participants. College staff and student participation will increase to 1,735 and 6,607 respectively. Military bases will include 2,256 participants while there are no participants in 2020 given the current carshare market in the San Diego region.

Table 2. Eligible employments and estimated carshare participation in 2020

	Strategy Inputs -- Year 2020																		
	Employment Centers							Colleges - Staff				Colleges - Students				Military Bases			
MSA	MGRAs in employment center coverage area	Eligible adult population within the coverage area (thousands)	Eligible adult population in higher density areas within the coverage area (thousands)	Eligible adult population in lower density areas within the coverage area (thousands)	Carshare participation rate, higher density areas [4]	Carshare participation rate, lower density areas [5]	Estimated carshare participation	MGRAs in college coverage area	College / University employment	Carshare participation rates, college staff [4]	Estimated carshare participation	MGRAs in college coverage area	College / University enrollment	Carshare participation rates, college students [4]	Estimated carshare participation	MGRAs in military base coverage area	Military base employment	Carshare participation rates, military bases [4]	Estimated carshare participation
Central	26	4	3	0	2.0%	0.50%	68	10	13,027	2.0%	261	10	42,732	2.0%	855	-	-	2.0%	-
North City	5	0	0	0	2.0%	0.50%	2	17	30,822	2.0%	616	17	44,222	2.0%	884	-	-	2.0%	-
South Suburban	-	-	-	-	2.0%	0.50%	-	-	-	2.0%	-	-	-	2.0%	-	-	-	2.0%	-
East Suburban	-	-	-	-	2.0%	0.50%	-	-	-	2.0%	-	-	-	2.0%	-	-	-	2.0%	-
North County West	-	-	-	-	2.0%	0.50%	-	-	-	2.0%	-	-	-	2.0%	-	-	-	2.0%	-
North County East	-	-	-	-	2.0%	0.50%	-	3	4,534	2.0%	91	3	16,627	2.0%	333	-	-	2.0%	-
East County	-	-	-	-	2.0%	0.50%	-	-	-	2.0%	-	-	-	2.0%	-	-	-	2.0%	-
Total	31	4	3	0			70	30	48,383		968	30	103,581		2,072	-	-		-

Table 3. Eligible employments and estimated carshare participation in 2035

	Strategy Inputs -- Year 2035																		
	Employment Centers							Colleges - Staff				Colleges - Students				Military Bases			
MSA	MGRAs in employment center coverage area	Eligible adult population within the coverage area (thousands)	Eligible adult population in higher density areas within the coverage area (thousands)	Eligible adult population in lower density areas within the coverage area (thousands)	Carshare participation rate, higher density areas [4]	Carshare participation rate, lower density areas [5]	Estimated carshare participation	MGRAs in college coverage area	College / University employment	Carshare participation rates, college staff [4]	Estimated carshare participation	MGRAs in college coverage area	College / University enrollment	Carshare participation rates, college students [4]	Estimated carshare participation	MGRAs in military base coverage area	Military base employment	Carshare participation rates, military bases [4]	Estimated carshare participation
Central	2,671	336	288	48	2.0%	0.50%	6,004	14	15,709	2.0%	314	14	71,360	2.0%	1,427	9	59,189	2.0%	1,184
North City	1,167	217	179	39	2.0%	0.50%	3,771	21	53,260	2.0%	1,065	21	111,642	2.0%	2,233	11	9,808	2.0%	196
South Suburban	352	72	51	21	2.0%	0.50%	1,132	1	464	2.0%	9	1	24,768	2.0%	495	-	-	2.0%	-
East Suburban	959	108	72	35	2.0%	0.50%	1,623	2	2,507	2.0%	50	2	38,770	2.0%	775	-	-	2.0%	-
North County West	635	45	27	18	2.0%	0.50%	623	2	1,158	2.0%	23	2	21,745	2.0%	435	6	43,788	2.0%	876
North County East	959	127	83	44	2.0%	0.50%	1,873	4	12,665	2.0%	253	4	62,067	2.0%	1,241	-	-	2.0%	-
East County	-	-	-	-	2.0%	0.50%	-	-	-	2.0%	-	-	-	2.0%	-	-	-	2.0%	-
Total	6,743	905	700	205			15,026	44	85,763		1,715	44	330,352		6,607	26	112,785		2,256

Table 4 shows the estimated VMT and GHG reduction results of the updated carshare OMC. We also compared it with the results of the original calculator developed by WSP (2019) that are shown in Table 5. This comparison indicates that the changes in input data had a notable impact on daily per capita GHG reduction. This is because of changes to the carshare service area defined as part of the Regional Mobility Hub network. The number of MGRAs covered by the carshare service in 2035 is 6,743 MGRAs and its estimated carshare participation is 25,604 members. However, the original OMCs estimated 12,068 members from 1,192 MGRAs in the same year.

Table 4. Estimated VMT and GHG Reduction Results of the updated Carshare OMC

VMT and GHG Reduction Results			
Variable	**2020**	**2035**	**2050**
Plan CO2 Emissions			
Daily CO2 emissions (short tons)	38,881	38,199	Given the rapid trend towards automation, it is assumed that a carsharing service will no longer be available in 2050 and will instead be replaced by a fleet of shared and autonomous vehicles by the year 2050.
Daily emissions per capita (lbs)	22.98	21.10	
Daily VMT reduction			
Roundtrip carshare	21,764	179,225	
Total VMT reduction	21,764	179,225	
Total daily GHG reductions (short tons)	10.2	81.9	
Daily per capita GHG reduction (lbs/person)	0.0060	0.0453	
Daily per capita GHG reduction	-0.03%	-0.21%	

Table 5. Estimated VMT and GHG Reduction Results of the original Carshare OMC

VMT and GHG Reduction Results			
Variable	**2020**	**2035**	**2050**
Plan CO2 Emissions			
Daily CO2 emissions (short tons)	38,663	42,139	Given the rapid trend towards automation, it is assumed that a carsharing service will no longer be available in 2050 and will instead be replaced by a fleet of shared and autonomous vehicles by the year 2050.
Daily emissions per capita (lbs)	22.92	22.72	
Daily VMT reduction			
Roundtrip carshare	78,331	88,395	
Total VMT reduction	78,331	88,395	
Total daily GHG reductions (short tons)	37.7	41.2	
Daily per capita GHG reduction (lbs/person)	0.0223	0.0222	
Daily per capita GHG reduction	-0.10%	-0.10%	

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Appendix H
SANDAG Pooled Rides Calculator Review and Comparison

Pooled Rides Off-Model Methodologies Review

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Summary

This document provides a review of SANDAG's Pooled rides off-model calculator that was originally developed by WSP Inc. (WSP, 2019). The pooled program subsidizes eligible employees that currently drive alone to work and are not suitable candidates for commuting by vanpool, microtransit, or transit. In addition to subsidy, as the region's managed lane network expands, commuters/non-work related travelers 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. We compare the calculator to CARB's recommended methodology (CARB 2019a, 2019b) and use the 2019 Transportation Study commissioned by SANDAG (SANDAG, 2019) for calibrating the off-model calculator. We find that the calculator is methodology consistent with best practices and, with the parameter updates, uses the most recent data available to estimate the anticipated behavior of the population with respect to the pooled ride mode in the presence of incentives and managed lane investments. Updates to the calculator using the 2019 TNC Survey lead to smaller estimated GHG reductions than WSP's (2019) original calculator. Though the results produce nominal reductions to the ABM2+ forecasts, we recommend maintaining the calculator for the 2021 Sustainable Communities Strategy and reassessing the performance of pooled rides during the next cycle as this is still an evolving mode that may gain future acceptance with changes in population attitudes.

Please note that the inputs, assumptions, and emission reduction estimates listed within this methodology are draft and are subject to change pending the development of a final network and land use scenario to inform the 2021 Regional Plan.

Review of the SANDAG Pooled Rides Calculator

ITS-Irvine's review of the SANDAG pooled ride calculator included assessing what parameter changes were appropriate based upon any changes to the literature since the calculators were developed by WSP (2019).

The core modeling inputs to the pooled rides calculator include:

- EMFAC 2014 Emission factors
- EMFAC 2014 VMT

- SANDAG population forecasts
- SANDAG regional trips
- SANDAG travel time skim data

No methodological changes to these inputs were deemed necessary in our review other than updating the population and travel forecasts (trips, skims, and VMT) from SANDAG's ABM2+ model.

Table 1 summarizes the parameters and assumptions used by the calculator. ITS-Irvine's review assessed whether parameter changes were appropriate based upon any changes to the literature since the calculators were developed by WSP (2019). We found that the assumptions and parameters are up to date and defensible based upon the current state of the practice, with the following notes:

- Newer San Diego-specific data on revealed pooled ride mode shares is available from the 2019 Transportation Study (vs the 2018 survey used by WSP), which is reflected in this table and was used to update the calculator as described in following sections.
- The marginal disutility of travel time was updated to be consistent with the most recent ABM 2+ forecasts.
- The remaining assumptions and parameters remaining justifiable either via policy or by being based upon the most recent appropriate data sources.

Table 1. Parameters and assumptions of SANDAG pooled rides calculator

Parameter	**Source**	**Details**
Pooled ride mode shares	2019 Transportation Study	The mode-specific constant is calibrated based on the observed proportions of pooled ride use reported in the 2019 Transportation Study.
Pooled ride average vehicle occupancy		In lieu of observed data, the calculator assumes the minimum occupancy to qualify as a pooled ride trip (3 persons per car)
Marginal disutility of travel time	SANDAG ABM 2+	Used in the calculation of demand elasticity
Median value of time	Preliminary Series 14 Forecast	Derived value ($9.80/hr.), estimated as one-third median household income for San Diego region ($61,400), expressed as an hourly wage rate ($29.52/hr.). The value of time is used to calculate an average coefficient of cost, for the demand elasticity formula.
Pooled ride mode-specific constant	Calibrated from the Transportation Study	Mode-specific constants asserted to reflect the county-wide pooled app-enabled rideshare utilization (mode share) reported by the 2019 Transportation Study

Auto operating cost	SANDAG ABM 2+	Used to calculate the cost of driving-alone; accounts for fuel and vehicle maintenance. Expressed in cents per mile in (2010 $).
Pooled rides cost per mile	Internal Revenue Service, 2016 standard mileage reimbursement rate for travel in personally-owned automobile.	Expected pooled ride service fare, in cents per mile, including subsidies. Separate values for work and non-work trips, to reflect work-trip subsidies.

GHG Emission Calculator Methodology

ITS-Irvine also reviewed the core methodology employed by the calculator and found that it follows CARB's (2019a, 2019b) Final Sustainable Communities Strategy Program and Evaluation Guidelines. The inputs include detailed strategies associated with pooled rides, such land use and transportation (managed lanes, ridematching programs), location (origin and destination and travel times), and subsidy for pooled rides (new mobility). In addition, the calculator avoids double-counting by taking vehicle trips required to serve the trips, which implies that the shift from drive-alone trips to pooled rides is the amount of the total estimated trips excluding the number of pooled ride drivers.

The calculator computes the CO2 reduction attributed to pooled rides using the following procedures.

Computing pooled (app-enabled) trips within the region:

1. Based on the SANDAG ABM2+ predictions for each scenario year, sum the number of drive-alone person trips by origin MSA, destination MSA, purpose (work/other), time period(AM/PM peak, non-peak), 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 ABM2+ 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 ABM2+ 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 pooling 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 (a binomial logit model). This model 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.

7. Estimate the additional pooled ride trips that will be incentivized by managed lane investments (travel time savings), applying the demand elasticity formula (Train 1993).

Computing 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.

The behavior of travelers in pooled ride calculator is based on two assumptions:

1. Drive-alone trips will shift to pooled rides if a subsidy is provided. A binary logit model is used to model this behavior. The explanatory variables of this logit model are travel distance, auto operation cost, pooled ride cost that is subsidized, and mode specific constants.

2. Travel time savings of pooled rides from the usage of managed lanes will better attract pooled rides from drive-alone trips. This behavior is modeled by elasticity, originated from a binary logit model.

For the calibration of logit models, SANDAG requested that we utilize data from the recent Transportation Study (2019), which focused on respondents from San Diego County. Table 1 shows the weighted mode share of pooled rides recorded by the survey. It is noteworthy that we also include all types of app-enabled pooled rides such as Uber Pool, Lyft Shared, and Waze Carpool. Although ABM 2+ includes pooled TNCs, the purpose of the off-model calculator is to capture the impacts of the carpool incentive program and managed lane investments in the region where it leads to increasing inter-household pooling. Furthermore, subsidies currently provided in partnership with Waze Carpool may also be extended to on-demand ridehailing solutions such as Uber or Lyft, which ABM2+ does not consider.

Table 2. 2019 Transportation Study pooled modeshare, weighted

Total Pooled	Work-related	Nonwork	total

0	0.076%	0.275%	**0.261%**
1	0.043%	0.198%	**0.164%**
2+	0.010%	0.048%	**0.040%**
Total	**0.019%**	**0.091%**	**0.076%**

The survey results indicate that the mode share of carpool matches is only 0.076% (10,366 trips over a total of 13,614,928 trips). However, the original version of the pooled-ride calculator estimates 8,536 pooled ride trips versus a total of 4,859,394 drive-alone trips (0.176%) in 2020.

ITS-Irvine re-calibrated the mode-specific constants of a binary logit model in the pooled rides calculator using the weighted trip frequencies from the 2019 Transportation Study that show the aggregated mode share for pooled ride matches. To do this, ITS-Irvine developed a mode-specific constant calibrator as an excel spreadsheet that estimates target mode share by scaling down the OMC's mode share from the ratio of the difference between calculator's predicted mode share for 2020 (which acts as a calibration base year) and the 2019 Transportation Study mode share for pooled rides. The implied assumption is that the 2019 Transportation Study data aligns with behavior that would be expected in the 2020 base year. The current version uses the excel solver with ordinary least squares for the calibrations. The constants are calibrated to match shares for household size and vehicle ownership groups from the 2019 TNC survey data.

The constants found from the calibrator, shown in Table 3 in comparison to the constants from the 2018 survey, were then used to update those in the pooled ride calculator. The mode specific constants are lower than the original calculator. Specifically, the constants for zero car households for both work trips and non-work trips are much lower than the original value, which leads to the expectation that the mode share of both categories will be significantly lower than in the original calculator.

Table 3. Updated mode specific constants

Pooled rides alternative-specific		**Original (2018 San Diego Commute Behavior Survey)**	**Updated (2019 TNC-User Travel Survey-San Diego)**
work trips	Zero cars	-2.60	-7.29
	One car	-5.90	-7.86
	Two or more cars	-7.90	-9.34

non-work trips	Zero cars	-2.90	-5.93
	One car	-6.30	-6.25
	Two or more cars	-8.40	-7.68

Table 4 shows a summary of pooled ride demand as computed by the calculator. ITS-Irvine also compared the estimated pooled ride demand with the original calculator, as shown in Table 5. Because of decreased mode specific constants, the updated calculator estimates lower pooled ride ridership except for non-work trips associated with households having more than one car. The updated calculator estimates that travel time savings from managed lane investments have insignificant impacts on pooled ride ridership, in part because the travel time savings of managed lanes in ABM 2+ is lower than the previous data, as shown in Table 6.

Table 4. Estimated Pooled ride demand of the updated calculator

Variable	2020	2035	2050	Notes
Pooled ride person trips, base demand				
Work trips (AM and PM Periods), zero car households	19	13	11	The demand for pooled rides is estimated by applying a mode shift model to the base drive alone trips. The mode shift model was calibrated to observed mode shares [1,6]. This model is segmented by household auto ownership, consistent with the differences in aggregate mode shares in the observed data.
Work trips (AM and PM Periods), one car households	158	129	114	
Work trips (AM and PM Periods), two+ car households	132	110	101	
Non-work trips (all time periods), zero car households	165	195	198	
Non-work trips (all time periods), one car households	1,228	1,327	1,293	
Non-work trips (all time periods), two+ car households	1,173	1,267	1,294	
Pooled ride person trips, demand due to managed lane investments				
Work trips (AM and PM Periods), zero car households	0	0	0	Investments in managed lanes that reduce travel time for carpoolers can further incentivize pooled ride transpiration options. The percent change in demand as a function of travel time savings is estimated based on the elasticity of demand for pooled rides with respect to travel time. The elasticity of demand varies by origin-destination market and by time period.
Work trips (AM and PM Periods), one car households	0	0	0	
Work trips (AM and PM Periods), two+ car households	0	0	0	
Non-work trips (all time periods), zero car households	0	0	0	
Non-work trips (all time periods), one car households	0	0	0	
Non-work trips (all time periods), two+ car households	0	0	0	
Pooled ride person trips, base and induced				
Work trips (AM and PM Periods), zero car households	19	13	11	Total pooled ride trips = base trips + trips induced by managed lane time savings
Work trips (AM and PM Periods), one car households	159	129	114	
Work trips (AM and PM Periods), two+ car households	132	110	102	
Non-work trips (all time periods), zero car households	165	195	198	
Non-work trips (all time periods), one car households	1,229	1,327	1,293	
Non-work trips (all time periods), two+ car households	1,174	1,267	1,294	
Total pooled ride trips				
Total person trips	2,877	3,041	3,013	*= sum of all pooled ride trips*
Vehicle trips required to serve the person trips	959	1,014	1,004	*= pooled ride trips / average vehicle occupancy*
Vehicles replaced by pooled ride service	1,918	2,027	2,008	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.

Table 5. Estimated Pooled ride demand of the original calculator

Variable	2020	2035	2050	Notes
Pooled ride person trips, base demand				
Work trips (AM and PM Periods), zero car households		1,036	1,351	The demand for pooled rides is estimated by applying a mode shift model to the base drive alone trips. The mode shift model was calibrated to observed mode shares [1,6]. This model is segmented by household auto ownership, consistent with the differences in aggregate mode shares in the observed data.
Work trips (AM and PM Periods), one car households		1,062	1,200	
Work trips (AM and PM Periods), two+ car households		320	323	
Non-work trips (all time periods), zero car households		2,545	3,564	
Non-work trips (all time periods), one car households		1,544	1,771	
Non-work trips (all time periods), two+ car households		454	483	
Pooled ride person trips, demand due to managed lane investments				
Work trips (AM and PM Periods), zero car households		20	23	Investments in managed lanes that reduce travel time for carpoolers can further incentivize pooled ride transpiration options. The percent change in demand as a function of travel time savings is estimated based on the elasticity of demand for pooled rides with respect to travel time. The elasticity of demand varies by origin-destination market and by time period.
Work trips (AM and PM Periods), one car households		16	18	
Work trips (AM and PM Periods), two+ car households		6	6	
Non-work trips (all time periods), zero car households		10	11	
Non-work trips (all time periods), one car households		5	5	
Non-work trips (all time periods), two+ car households		2	1	
Pooled ride person trips, base and induced				
Work trips (AM and PM Periods), zero car households		1,056	1,374	Total pooled ride trips = base trips + trips induced by managed lane time savings
Work trips (AM and PM Periods), one car households		1,078	1,218	
Work trips (AM and PM Periods), two+ car households		326	329	
Non-work trips (all time periods), zero car households		2,555	3,575	
Non-work trips (all time periods), one car households		1,550	1,776	
Non-work trips (all time periods), two+ car households		456	485	
Total pooled ride trips				
Total person trips		7,020	8,756	*= sum of all pooled ride trips*
Vehicle trips required to serve the person trips		2,340	2,919	*= pooled ride trips / average vehicle occupancy*
Vehicles replaced by pooled ride service		4,680	5,837	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.

Table 6.Comparisons of travel times between ABM2+ and ABM14.0 (original calculator)

		Average one-way weekday travel time					
		AM peak		PM peak		Midday peak	
Data	Year	mixed flow lanes	managed lanes	mixed flow lanes	managed lanes	mixed flow lanes	managed lanes
	2035	14.95	14.90	13.47	13.41	9.81	9.80
ABM 2+	2050	15.02	14.96	13.55	13.48	9.81	9.80
	2035	17.78	17.14	15.86	15.42	11.07	10.96
Original	2050	17.65	17.09	15.82	15.39	11.04	10.95

Table 7 shows the estimated VMT and GHG reduction results of the updated pooled ride OMC. Compared with the estimated results of the original OMC, shown in Table 8, the changes in mode specific constant and input data had a notable impact on daily per capita GHG reduction.

The updated calculator estimates a lower impact on GHG reductions due to pooled rides, which is mainly due to the lower mode share of pooled rides measured in the 2019 Transportation Study. Lower managed lane travel time savings estimated from ABM 2+ also affects the GHG reductions, compared to the original calculator. Compared with the updated vanpool OMC, pooled rides are less affected by managed lanes since pooled rides have shorter travel distances than vanpool.

Table 7 Estimated VMT and GHG Reduction Results of the updated pooled ride OMC

Variable	2020	2035	2050	Notes
Plan CO2 Emissions				
Daily CO2 emissions (short tons)	38,881	38,199	38,777	*= Sum of running emissions and trip start emissions trip start emissions*
Daily emissions per capita (lbs.)	22.98	21.10	20.70	*= Daily emissions (short tons) / regional population * 2000 lbs / 1 short ton*
Daily person miles traveled, pooled ride trips				
Work trips, zero car households	153	102	94	
Work trips, one car households	1,221	993	896	*= pooled ride person trips * distance traveled*
Work trips, two+ car households	1,168	956	903	
Non-work trips, zero car households	867	1,039	1,088	calculated over origin-destination Metropolitan Statistical Areas (MSA)
Non-work trips, one car households	6,288	6,714	6,554	
Non-work trips, two+ car households	6,240	6,596	6,707	
Total person miles traveled, pooled ride trips	15,936	16,400	16,242	
Total vehicle miles reduced by pooled rides	10,624	10,933	10,828	*= total person miles * proportion of vehicles eliminated by pooled-riding*
Total vehicle trips reduced by pooled rides	1,918	2,027	2,008	
GHG reductions				
Total daily GHG reductions (short tons)	5.17	5	5	*= vehicle trip reductions * trip start emission factor + VMT reduction * running emission factor*
Daily per capita GHG reductions (lbs./person)	0.00	0.00	0.00	*= per capita GHG emission reductions*
Daily per capita GHG reduction	-0.0133%	-0.0136%	-0.0131%	*= percent change in per capita GHG reduction*

Table 8 Estimated VMT and GHG Reduction Results of the original pooled ride OMC

Variable	2020	2035	2050	Notes
Plan CO2 Emissions				
Daily CO2 emissions (short tons)	38,663	42,139	43,371	*= Sum of running emissions and trip start emissions trip start emissions*
Daily emissions per capita (lbs.)	22.92	22.72	21.87	*= Daily emissions (short tons) / regional population * 2000 lbs / 1 short ton*
Daily person miles traveled, pooled ride trips				
Work trips, zero car households		8,668	11,471	
Work trips, one car households		8,392	9,597	*= pooled ride person trips * distance traveled*
Work trips, two+ car households		2,839	2,911	
Non-work trips, zero car households		14,242	20,251	calculated over origin-destination Metropolitan Statistical Areas (MSA)
Non-work trips, one car households		8,068	9,228	
Non-work trips, two+ car households		2,447	2,609	
Total person miles traveled, pooled ride trips		44,657	56,067	
Total vehicle miles reduced by pooled rides		29,771	37,378	*= total person miles * proportion of vehicles eliminated by pooled-riding*
Total vehicle trips reduced by pooled rides		4,680	5,837	
GHG reductions				
Total daily GHG reductions (short tons)		14	18	*= vehicle trip reductions * trip start emission factor + VMT reduction * running emission factor*
Daily per capita GHG reductions (lbs./person)		0.01	0.01	*= per capita GHG emission reductions*
Daily per capita GHG reduction		-0.03%	-0.04%	*= percent change in per capita GHG reduction*

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Appendix I
SANDAG Regional TDM Ordinance Calculator Review and Comparison

Methodology and Implementation of Transportation Demand Management Ordinance (TDMO) Off-model Calculator

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November 17, 2020

1 Summary

This document describes the development of a new off-model calculator for the San Diego Association of Governments's (SANDAG) 2021 Regional Transportation Plan. We discuss the motivation for the development of this calculator, describe both its methodological design and specific implementation, and briefly discuss preliminary results produced by the calculator using draft data from the 2021 Regional Plan that estimate per capita greenhouse gas (GHG) reductions to range from about 0.44 % in 2035 to 0.67 % in 2050.

Please note that the inputs, assumptions, and emission reduction estimates listed within this methodology are draft and are subject to change pending the development of a final network and land use scenario to inform the 2021 Regional Plan.

2 Background

As part of its 2021 regional transportation plan, SANDAG is developing Transportation Demand Management Ordinance (TDMO) program. Per SANDAG's definition:

> "Transportation Demand Management (TDM) refers to policies and programs designed to help reduce commute traffic congestion. This is typically accomplished through sharing information, encouragement and incentives to help people know about and use all the efficient and sustainable transportation options available to them. Typical TDM programs promote carpooling, vanpooling, public transportation, biking and walking to work, and other alter-

> natives to driving alone. These alternatives, along with parking management, telework, and compressed work schedules, can significantly reduce congestion on our regions roadways. Moreover, TDM ordinances can serve as a tool that governments - cities, counties, regions and states—use to reduce commute trips. They can achieve this through targeting area employers or land use development on new and renovated projects." (SANDAG, 2020)

SANDAG's new Transportation Demand Management Ordinance (TDMO) plan builds upon the the SANDAG iCommute Employer Program that works with over 200 employers on a voluntary basis to implement commuter benefit programs. Since the adoption of the 2015 Regional Plan, the iCommute Employer Program has expanded to a team of seven account executives that work with employers of all sizes throughout the region. Employers survey their employees to track their mode share over time. Employers are rewarded and recognized through the iCommute Diamond Awards for measurably reducing single occupant vehicle trips by employees. On average, the employers that work with iCommute have reduced their drive alone mode share by 10 %. As part of the 2021 Regional Plan, SANDAG is exploring a regional TDMO that would require employers with over 250 employees to implement and monitor a Travel Demand Management (TDM) plan in order to achieve an established average vehicle ridership (AVR). An employer's TDM program could include the following (SANDAG, 2020):

- **Commuter services** Offering programs like secured bike lockers and free rides home in case of an emergency can make it easier for commuters to use transit and other alternatives to driving alone.
- **Financial Subsidies and Incentives** Financial incentives and pre-tax commuter benefits for commuters can lower the out-of-pocket cost for commuters who choose alternatives to driving alone.
- **Marketing, Education, and Outreach** Outreach events, educational campaigns, and marketing strategies help raise awareness of alternative commute options.
- **Parking Management** Employers can offer cash incentives, transit passes in lieu of a parking space, and preferred parking for high-occupancy vehicles can act as an incentive to choosing an alternative commute option. Charging for parking at the workplace can act as a disincentive to drive alone.
- **Telework and Flexible Work Schedules** Employers can develop workplace policies that promote telework, flexible schedules, and/or compressed work schedules in order to reduce peak commute trips.
- **On-Site Amenities** Secured bike lockers and showers can offer convenience for commuters who choose to bike to work.
- **Employer Provided Transit** Can help to serve the first mile/last mile connection

to transit and/or provide direct pooling options for employees traveling from the same direction.

SANDAG proposes to develop and implement the TDMO in phases. In the near term, SANDAG will conduct outreach with employers and stakeholders that will help develop the policy and framework for the Regional TDMO Program. Regional stakeholders include the region's 19 local governments and advisory boards such as the San Diego County Air Pollution Control District. It is anticipated that the later phases would include a pilot period, during which larger employers would initially participate, and a later broader evaluation period with tentative timelines for these phases as follows:

- Near-Term (2020-2025): Outreach and Policy Development
- Mid-Term (2025-2035): "Pilot" approach (800+ employers in the region)
- Long-Term (2035-2050) : Program Evaluation

Since the impact of this type of program cannot be modeled in SANDAG's regional travel demand forecasting model, Activity-Based Model v2+ (ABM2+)[1], due to the varied and qualitative nature of its impacts on commuter mode choice behavior, capturing the impacts of a TDMO program for SANDAG's Sustainable Communities Strategy submission to the California Air Resources Board (CARB) requires the development of an off-model calculator, which we discuss below.

3 Proposed Methodology

The TDMO will be employer-based, meaning that the regulations will require that employers demonstrate that their employees (as a group) are meeting AVR negotiated between the business and SANDAG. SANDAG intends to expand existing iCommute Employer Program offerings to assist employers with implementing and monitoring their TDM programs. Further, it is assumed that the ordinance will only apply to specific employers, namely larger employers with at least some minimum number of employees, currently assumed to be 250 or more with the final threshold dependent on the outcome of the Outreach and Policy Development phase. These employers will be provided with options from a set of TDM strategies, as discussed above, to achieve the target.

The method described below computes how many aggregate reduced drive alone trips and associated vehicle-miles traveled (VMT) will be attributable to large employers (LEs) collectively taking action to meet their AVR individual targets. The approach computes the difference between the estimated drive alone and total commute trips between each

[1] ABM2+ (Resource Systems Group, Inc., 2020) is a state-of-the-art activity-based travel demand model belonging to the Coordinated Travel–Regional Activity Modeling Platform (CT-RAMP) family of models (Davidson et al., 2010).

pair of zones that are associated with LEs in the absence of any TDMO, and compares that to the drive alone totals that would exactly match the AVR target for LEs, which we call a TDMO cap in this discussion. If the estimated difference is greater than the cap, it is assumed that the TDMO program will induce a shift of those excess trips from drive alone to some other mode, thus removing them and their associated VMT from the forecast. To implement this, we assume that we are given the following:

- M is the minimum number of employees an employer must have for the TDMO to apply.
- α is the maximum drive alone share, which is the fraction of an employer's commute trips that can use the drive alone mode if the TDMO applies to that employer. For instance, $\alpha = 0.65$ means that a maximum of 65 % of the employees can drive alone and still have the employer be compliant with the TDMO. This is a direct proxy for AVR.
- B_j is the set of employers in zone j
- x_{ijk} is the number of work trips between zones i and j by all modes for employer $k \in B_j$.
- x_{ijk}^{DA} is the number of work trips between zones i and j for employer $k \in B_j$ using a drive-alone mode.

Let B_j^L be the subset of LEs in zone j (those with M employees or more). Note that $B_j^L \subseteq B_j$.

Now, if the TDMO was applied and effective, then no more than α of the trips associated with each LE in zone j could be drive alone trips. Specifically:

$$\sum_i x_{ijk}^{DA} \leq \alpha \sum_i x_{ijk} \quad , \forall k \in B_j^L, \forall j \tag{1}$$

Since the trip variables x represent behavior in the absence of TDMO, we can rearrange the inequality to define the difference between the TDMO requirement for drive alone trips and what the model predicts as:

$$\sum_i x_{ijk}^{DA} - \sum_i y_{ijk}^{DA} = \alpha \sum_i x_{ijk} \quad , \forall k \in B_j^L, \forall j \tag{2}$$

and rearranging:

$$\begin{aligned} y_{jk}^{DA} &= \sum_i y_{ijk}^{DA} = \sum_i x_{ijk}^{DA} - \alpha \sum_i x_{ijk} \quad , \forall k \in B_j^L, \forall j \\ &= \sum_i y_{ijk}^{DA} = \sum_i \left(x_{ijk}^{DA} - \alpha x_{ijk} \right) \quad , \forall k \in B_j^L, \forall j \end{aligned} \tag{3}$$

where y_{jk}^{DA} is the excess drive alone trips to zone j associated with employer k beyond the limit set by the TDMO.

If y_{jk}^{DA} is positive, that means that the TDMO would require employer k to use TDM programs available to it to reduce its employees' drive alone trips by at least that amount. If it is negative, then employer k's employee work trips to zone j already meet the α threshold and the TDMO would have no impact.

At this point it is worth noting that ABM2+ does not have the resolution to tell us the fraction of work trips between pairs of zones down to the employer level (let alone the drive alone work trips). Instead, ABM2+ will only be able to provide the total number of work and drive alone work trips between each zonal pairing i and j, or x_{ij} and x_{ij}^{DA} respectively. Summing equation 3 over all LEs $k \in B_j^L$ we get:

$$\begin{aligned} y_j^{DA,LE} &= \sum_{k\in B_j^L}\sum_i y_{ijk}^{DA} &&= \sum_{k\in B_j^L}\sum_i \left(x_{ijk}^{DA} - \alpha x_{ijk}\right) \quad ,\forall j \\ &= \sum_i y_{ij}^{DA,LE} &&= \sum_i \left(x_{ij}^{DA,LE} - \alpha x_{ij}^{LE}\right) \quad ,\forall j \end{aligned} \tag{4}$$

where

$y_j^{DA,LE}$ is the excess number of work trips associated with LEs traveling to zone j, which the TDMO will target if it is a positive value.

x_{ij}^{LE} is the number of work trips associated with LEs traveling from zone i to zone j.

$x_{ij}^{DA,LE}$ is the number of drive alone work trips associated with LEs traveling from zone i to zone j.

ABM2+ does not provide x_{ij}^{LE} or $x_{ij}^{DA,LE}$ directly. Instead, we must estimate the fraction of a zone j's total and drive alone trips that are associated with LEs. The most reasonable proxy we have for that is the total number of employees. Specifically, we have:

E_{jk} is the total number of employees in zone j working for employer k.

Now define the total number of employees in zone j as

$$E_j = \sum_{\forall k \in B_j} E_{jk}$$

and the total number of employees in zone j working for LEs as

$$E_j^L = \sum_{\forall k \in B_j^L} E_{jk}$$

If we assume that the total number of trips associated with LEs in a zone is proportional to the fraction of employment associated with LEs in that zone, we can estimate x_{ij}^{LE} or $x_{ij}^{DA,LE}$. Specifically, define the fraction of employment in zone j associated with LEs as

$$\beta_j = \frac{E_j^L}{E_j} \tag{5}$$

The total number of employees in a given zone for all forecast years can be obtained from SANDAG's I-LUDEM employment forecast. However, data on LEs is only available for the base year, and only for employers that reside within SANDAG-designated *employment centers* that are distributed throughout the region. As such, we conservatively assume that all LEs reside within employment centers and compute the ratio β_j on that basis. Then we can define

$$\begin{aligned} x_{ij}^{LE} &= \beta_j x_{ij} \\ x_{ij}^{LE,DA} &= \beta_j x_{ij}^{DA} \end{aligned} \tag{6}$$

Substituting into equation 4, we have

$$\begin{aligned} y_j^{DA,LE} &= \sum_i \left(\beta_j x_{ij}^{DA} - \alpha \beta_j x_{ij} \right) &&, \forall j \\ &= \beta_j \sum_i \left(x_{ij}^{DA} - \alpha x_{ij} \right) &&, \forall j \\ &= \frac{E_j^L}{E_j} \sum_i \left(x_{ij}^{DA} - \alpha x_{ij} \right) &&, \forall j \end{aligned} \tag{7}$$

Where $y_j^{DA,LE}$ represents the required TDMO reduction in trips for zone j defined in terms of total and large employer zonal employment (E_j and E_j^L) and total and drive alone trips to the zone (x_{ij} and x_{ij}^{DA}), both of which are available from ABM2+.

Note that here we are assuming that the behavior of the population working in that zone is consistent across all employers. For example, the collective employers in a given zone j could be meeting the TDMO threshold, but the drive alone trip reductions might be distributed unequally between them. As a simple example, a zone with two equal sized employers might have a 90 % drive alone fraction, but that could be because employer one has 80 % drive alone and employer two has 100 % drive alone. In this case, the TDMO would reduce the drive alone fraction associated with the zone from $\frac{80\,\%+100\,\%}{2} = 90\,\%$ to $\frac{80\,\%+90\,\%}{2} = 85\,\%$. However, since the ABM2+ model won't be able to provide the employer by employer breakdown, we make the more conservative assumption that the share is equal across all employers in the zone.

Note also that since the drive alone totals in the absence of a TDMO might be smaller than what might be required by a TDMO, it is possible that $y_j^{DA,LE}$ might be a negative number, meaning that there are a surplus of non-drive alone trips relative to the TDMO. Since a

TDMO is unlikely to encourage a shift to *more* drive alone trips, this surplus should be disregarded. As such, let's define the required trip reduction for all LEs k in each zone j as

$$z_j = \max\left(y_j^{DA,LE}, 0\right), \forall j$$

and the total reduction in work trips across all zones due to the TDMO as:

$$z = \sum_j z_j \tag{8}$$

Finally, the impacts of some of the the TDMO options, such as regional vanpool program, are already modeled by other off-model calculators, so care is required to avoid double counting the reductions by TDMO and the regional vanpool operations. The most conservative approach is be to modify equation 8 to remove any trip reductions attributable to explicitly modeled programs that would count against the TDMO caps:

$$z = \sum_j \max\left(\left(z_j - \sum_{l \in OM} z'_{jl}\right), 0\right) \tag{9}$$

where

OM is the set of independent off-model calculators representing TDM strategies

z'_{jl} is the trip reduction estimated for zone j by the calculator for TDM strategy l versus the TDMO phasing year[2].

4 Calculating emissions reductions

The method described above computes the total number of trip reductions that will be attributable to the TDMO.

VMT reductions can be obtained by defining:

d_{ij} is the average distance in miles to travel between zones i and j

and weighting the trip reductions in equation 4:

$$v_j^{DA,LE} = \sum_i v_{ij}^{DA,LE} = \sum_i d_{ij}\left(x_{ij}^{DA,LE} - \alpha x_{ij}^{LE}\right) \quad, \forall j \tag{10}$$

[2]Here we note that since the TDMO targets will be set on the basis of a given phasing year, the trip reductions due to other programs such as vanpool and pooled rides (and computed in those calculators) will be computed as the difference between the reductions attributable to that program for the phasing year and the reductions for that program in the target year, because the phasing year assessments will account for trips already participating in those programs.

where:

$v_j^{DA,LE}$ is the VMT reduction attributable to the TDMO for work trips to zone j.

Given total trip reductions $y_j^{DA,LE}$ and total VMT reductions $v_j^{DA,LE}$, emissions factors from EMission FACtors (EMFAC) can be applied to estimate emissions reductions due to cold starts (per trip) and running emissions (by VMT).

5 Implementation

This off-model calculator is implemented as a spreadsheet model in *Microsoft Excel* that uses SANDAG's employment growth forecasts (SANDAG, 2015) and mode- and purpose-specific regional trip forecasts for each scenario year, which are obtained from ABM2+ v14.2.0 as shown in Table 1. As described above, these forecasts are used to determine the share of commute trips by Metropolitan Statistical Area (MSA) associated with LEs that would therefore be subject to TDMO regulation, which is then used to compute the regulated reduction in drive alone trips. Once these reductions are determined and converted into VMT reductions, the emissions factors from the EMFAC 2014 model is applied to compute the reduction in emissions associated with fewer cold start and running emissions.

The detailed steps of the TDMO off-model GHG spreadsheet are as follows:

1. Estimate the fraction of AM and PM trips associated with LEs (see equation 5).
   (a) Estimate eligible employees impacted by TDMO ordinance program based on employment center major statistical area (MSA) analyses
   (b) The fraction of employees impacted for each MSA is the number of employees working for firms with >250 employees divided by the number of employees working for all firms.
   (c) The fraction of AM and PM trips impacted for each MSA pair is assumed to be the same as the fraction of employees associated with LEs at the employment end of the trip. The employment end of trips in a period (the fraction of trips going for which work is the origin and the fraction for which work is the destination) is determined from work trip-directionality analysis of the OD and period obtained from the ABM2+ forecast. The LE work trip fraction is computed as a weighted average of the LE fractions for each side of the MSA OD pair.
2. Forecast the number of drive alone (DA) AM/PM trips associated with LEs for each MSA Origin-Destination (OD) pair, computed as the period-specific fraction of LE

Table 1: Principal Inputs to TDMO GHG Emissions Calculations

Data	**Source(s)**	**Notes**
Regional trips	SANDAG ABM 2+	Regional trips for each scenario year by: • Strategy year • O/D MSAs • Time period (AM, PM) • Trip mode (drive alone, carpool, non-motorized, and transit) • Trip purpose (Work) • Household auto ownership (0, 1, 2+)
Travel time and distance	SANDAG ABM 2+	For each scenario year: • TAZ-to-TAZ drive alone distance, general purpose lanes • TAZ-to-TAZ drive alone travel time, general purpose lanes
Work directionality	SANDAG ABM 2+	For each scenario year: • TAZ-to-TAZ share of work trips traveling TO and FROM work for each OD pair and time period
Large Employer Fraction	Share of employment associated with LEs within in each TAZ	Computed from employment center data detailing the total employment and employment center employment associated with LEs.
Emission factors	EMFAC 2014	For each scenario year: • Trips (cold starts) regional emissions (ton) • Running CO_2 regional emissions (ton) • Regional VMT • Regional trips

OD trips times the forecast number of drive alone OD trips during that period (equation 6).

3. Compute target drive-alone trip share (α) for LE work trips in the AM and PM periods between each MSA origin and destination. This is determined by assuming a 15 % reduction in ABM2+ forecast drive alone shares in 2035 and a 25 % reduction in 2050 (equation 7).

4. Establish LE drive alone trips allowance for each MSA OD pair by applying drive alone reduction targets to drive alone trips associated with LEs. This is computed as target drive alone LE work trip splits [step 3] times the forecast total work trips (from ABM2+) times the large employer fraction [step 1] (also see equation 7).

5. Estimate TDMO trip reductions by assuming that ABM2+ forecast trips exceeding the established drive alone allowance in the target year are reduced by the TDMO. TDMO-required reductions in AM/PM drive alone work trips for each MSA OD pair, which are computed as the difference between the forecast [step 3] and the allowance [step 4]. If this value is less than zero, the ABM2+ forecast reductions exceed the TDMO target, so the TDMO will not reduce additional trips and the reductions are set to zero for this period (see equation 9).

6. Estimate baseline VMT reduction as the TDMO trip reductions [step 5] times average MSA to MSA trip distance based on SANDAG ABM2+ (see equation 10).

7. Deduct other calculator drive alone work trip and VMT reductions (vanpool and pooled rides) between TDMO phasing year (assumed to be 2025 by default, and interpolated if necessary) and target year to avoid double counting. These deductions are computed on a TAZ-to-TAZ basis since the TDMO will operate at the employer level. As such, reductions from existing programs such as vanpool associated with employers in one MSA should not be deducted from TDMO impacts associated with employers in another MSA. In addition, if the performance of an existing program degrades between the phasing year and the future year (e.g., fewer commuters are vanpooling in 2035 versus the phasing year), it is assumed that the impacted employers will need make up that difference in the target year via other TDMO programs.

6 Representative Results

Though the results submitted with SANDAG's regional transportation plan and Sustainable Communities Strategy will depend on final forecast numbers from ABM2+ and related models, Figure 1 shows representative results of from the calculator to illustrate the results of the calculator using draft data. As can be seen, the TDMO calculator estimates a total of 44,559 fewer DA trips in 2035 due to the TDMO (after adjusting for the impacts

Variable	2020	2035	2050
TDMO reduction target	0%	15%	25%
Regional population	3383955	3620349	3746077
Average pooled ride vehicle occupancy	3.0	3.0	3.0

TDMO trip reduction targets

Variable	2020	2035	2050
TDMO trip reductions			
Work trips (AM and PM Periods), all households	0	44,605	67,245

VMT and GHG Reduction Results

Variable	2020	2035	2050
Plan CO2 Emissions			
Daily CO2 emissions (short tons)	38,881	38,199	38,777
Daily emissions per capita (lbs.)	22.98	21.10	20.70
Net vehicle trips reduced by vanpool vs 2025 baseline			
Daily DA trips removed by TDMO			
Total vehicle trips reduced by TDMO requirements	0	44,605	67,245
Vehicle trip reductions from existing pooled rides	43	34	31
Net vehicle trips reduced by pooled rides vs 2025 baseline	-	(6)	(10)
Vehicle trip reductions from existing vanpool	691	770	816
Net vehicle trips reduced by vanpool vs 2025 baseline	-	53	98
Net vehicle trips reduced by TDMO requirements	0	44,559	67,156
Daily person miles traveled, for DA trips removed by TDMO			
Total vehicle miles reduced by TDMO requirements	0	364,902	561,486
VMT reductions from existing pooled rides	1,694	1,367	1,262
Net VMT reduced by pooled rides vs 2025 baseline	-	(218)	(324)
VMT reductions from existing vanpool	33,904	37,668	39,828
Net VMT reduced by vanpool vs 2025 baseline	-	2,509	4,669
Net VMT reduced by TDMO requirements	0	362,611	557,140
GHG reductions			
Total daily GHG reductions (short tons)	0.00	169.90	258.84
Daily per capita GHG reductions (lbs./person)	0.00	0.0939	0.1382
Daily per capita GHG reduction	0.00%	-0.44%	-0.67%

Figure 1: Representative TDMO calculator results using draft input data. Final results for the 2021 Regional Transportation Plan are likely to change.

of programs represented by other calculators). These removed DA trips reduce the total commute VMT by 362,611 and ultimately result in a per-capita VMT reduction of 0.44 %. The reductions attributable to TDMO improve to 0.67 % in the 2050 target year.

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Appendix J
SANDAG Electric Vehicle Programs Calculator Review and Comparison

EV Program Off-Model Methodologies Review

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Summary

This document provides a review of SANDAG's EV off-model calculator in comparison to CARB's recommended methodology as well as the methods employed by the other three large MPO's in California.

Please note that the inputs, assumptions, and emission reduction estimates listed within this methodology are draft and are subject to change pending the development of a final network and land use scenario to inform the 2021 Regional Plan.

Changes to date to SANDAG EV Calculators by ITS-Irvine

ITS-Irvine's review of the SANDAG calculators included assessing what parameter changes were appropriate based upon any changes to the literature since the calculators were developed by Ascent Environmental (2019). Since both of these calculators are integrated into a single spreadsheet, we address the changes for both calculators together.

The core modeling inputs to the EV calculator include:

- EMFAC 2017 fleet characteristics
- EMFAC 2017 VMT
- SANDAG population forecasts
- Core EVI-Pro assumptions regarding charging characteristics
- EVI-Pro model results regarding PEV demand for the SANDAG region

We reviewed these modeling inputs and assumptions and determined that we could not recommend any updates to the EMFAC data (there is not an alternative), nor the EVI-Pro assumptions or model results. In the latter case, since the EVI-Pro model has not been updated since Ascent Environmental's original work, there is no need to re-run the scenarios since the data, and associated trend-line projections will remain the same.

We did, however, update the SANDAG population forecasts and VMT totals using data provided by SANDAG staff in August 2020. These changes had a notable impact because the VMT forecasts have decreased since the updates to the regional model. Ascent's original work (shown in Figure 1) shows both higher population and VMT totals for the 2035 and 2050 target years than the most recent forecast (Figure 2). The specific cells modified were G13:H14.

Figure 1. SANDAG Population and VMT forecasts from Ascent Environmental's original work.

	A	B	C	G	H
9	**EV Off-Model Inputs**				
10	**Years**			**2035**	**2050**
11					
12	**2019 RTP/SCS Forecasts**				
13		Population in SANDAG		3,853,698	4,068,759
14		Daily VMT in SANDAG (2019 RTP/SCS)	mi/day	91,312,706	96,050,942
15		*Daily VMT in SANDAG (EMFAC 2017) (for comparison)*	*mi/day*	*100,763,492*	*107,809,171*
16		*EMFAC/SANDAG VMT Adjustment*		*0.91*	*0.89*
17					

Figure 2. SANDAG Population and VMT forecasts updated August, 2020

	A	B	C	G	H
8					
9	**EV Off-Model Inputs**				
10	**Years**			**2035**	**2050**
11					
12	**2020 RTP/SCS Forecasts**				
13		Population in SANDAG		3,620,349	3,746,077
14		Daily VMT in SANDAG (2019 RTP/SCS)	mi/day	86,652,774	89,296,419
15		*Daily VMT in SANDAG (EMFAC 2017) (for comparison)*	*mi/day*	*100,763,492*	*107,809,171*
16		*EMFAC/SANDAG VMT Adjustment*		*0.86*	*0.83*
17					

These reductions lower the EMFAC/SANDAG VMT Adjustment factor, which in turn increases the reductions attributable to SANDAG's EV programs. These updates improve the total per capita GHG reductions due to EV programs from 0.48% to 0.60% in the "90% CEC scenario."

We note that the SANDAG SCS/RTP is based upon EMFAC 2014 while the EV calculator uses EMFAC 2017 data for fleet and VMT information, including the VMT baseline that is important here. However, this adjustment factor is intended to capture the impact of the deviations between the SCS/RTP forecast and EMFAC and those adjustments will compensate for the differences between EMFAC 2014 and 2017.

The scenario inputs to the EV calculator are:

- The selection of the target PEV/ZEV Population Scenario, which determines the demand for PEVs that, in turn, determines the demand and performance for chargers and vehicles (and their incentives)
- Charger and vehicle incentive levels

The specific scenarios available are described in Ascent Environmental's (2019) technical memorandum:

- **State Targets**: The State Targets under EO B-16-12 and EO B-48-18 to achieve 1.5 million EVs by 2025 and 5 million EVs by 2030 were apportioned to the SANDAG region based on the ratios between the EV population in SANDAG and the state as a whole, as modeled by EMFAC2017.

- **CEC Forecast**: The CEC's forecast scenario is based on what the CEC anticipates the PEV population will be like for the SANDAG region in order to meet State Targets for 2025, including the statewide target of having 250,000 EV chargers statewide by 2025. The CEC forecast scenario also accounts for a variety of economic and organizational factors that influence PEV usage. The model assumes that the CEC forecast trends would continue past 2025.

- **CSE Forecast**: The Center for Sustainable Energy (CSE) Forecast scenario is based on either a linear or second-order polynomial trend of the PEV population in SANDAG based on historical sales. The second-order polynomial forecast is currently the preferred CSE Forecast scenario per SANDAG staff, though the user has the option to change the trend assumption in the background calculations

Though all results discussed in this document have used the scenario “90% of CEC forecasts”, SANDAG may want to experiment with identifying the most favorable of the scenarios based upon agency priorities, which certainly include maximizing GHG reductions, but may also include wanting to control the resulting cost of the incentive program. Between the three options, both the CEC and CSE forecasts are based upon modeling with trends. The CEC trends are extended from the EVI-Pro forecasts, which only go out to 2025. In the modeled time span (2017-2025), the CEC forecasts are likely the most rigorous method for determining the scenario. Beyond that, the use of trend forecasting makes them less reliable. The CSE forecast, which is based upon sales trends also suffers from this potential weakness. In some respects, the State Targets, should they be backed by state policy via regulatory action, may have the best case for use as the target scenario since they represent the statewide goals that are driving policy.

Determining the appropriate incentive levels for an EV program that is 10 years into the future is challenging at best since it would rely on knowing technology costs at that horizon and beyond. CARB has accepted EV programs with incentive levels ranging from $1,500/vehicle for PHEV incentives (MTC 2017) up to $7,500 for PHEV incentives (CARB 2020). As such, we recommend selecting the scenario that maximizes GHG reductions, while setting the incentive levels that are comparable to other MPOs while still meeting SANDAG's regional objectives, priorities, and budgetary targets.

For instance, if you set a $250M cap on SANDAG vehicle incentives for 2035 and assume a specific ratio between BEV, PHEV, and FCEV incentives that matched assumed external incentive levels as in Table 1.

Table 1. Assumed external vehicle incentive levels in the baseline SANDAG EV calculator

Average Incentive per BEV	$/vehicle	$ 2,500
Average Incentive per PHEV	$/vehicle	$ 1,000
Average Incentive per FCEV	$/vehicle	$ 5,000

Then you can solve for the BEV incentive level under forecast different scenarios (e.g., 100% CEC, 100% state mandate, and CSE forecast) that would result in a total of $250M in cumulative vehicle incentives in 2035. The results in Table 2 show computed vehicle incentive levels along with the associated per capita GHG reductions for the RECP, VIP, and total.

Thus, if you adopt the CSE forecast scenario and set a $250M cap, you can obtain a total 1.78% per capita reduction with BEV incentives of $642, PHEV incentives of $257, and FCEV incentives of $1,285.

Table 2. Computed incentive levels and associated GHG reductions for 3 different demand scenarios in the SANDAG EV calculator assuming a $250M vehicle incentive cap by 2035.

Scenario:	**100% state**	**100% CEC**	**CSE forecast**
BEV incentive	$ 623	$ 3,287	$ 642
PHEV incentive	$ 249	$ 1,315	$ 257
FCEV incentive	$ 1,246	$ 6,574	$ 1,285
RECP GHG red	0.00%	0.09%	0.46%
VIP GHG red	1.21%	0.76%	1.32%
Total GHG red	1.21%	0.85%	1.78%

EV Charging Programs

CARB Recommendations

The CARB Sustainable Communities Strategies Program and Evaluation Guidelines document (SCAG 2020a) offers two methodological approaches for computing the GHG reductions associated with Regional EV Charging Programs.

A. Estimate CO2 emission reductions from PHEV eVMT based on estimated average VMT shift per PHEV from gasoline to electricity (cVMT to eVMT) as a result of increased workplace and public charges

B. Estimate CO_2 emission reductions from reduced gasoline consumption based on estimated electricity consumption increase as a result of increased workplace and public charges

SANDAG

SANDAG's Regional EV Charging Program (RECP) calculator uses a version of CARB's method B, focusing on estimating CO_2 emission reductions from reduced gasoline consumption based on estimated electricity consumption increase as a result of increased workplace and public chargers. Specifically:

> "CO_2 reductions from the RECP were based on the difference between the total eVMT supported by a targeted number of all non-residential chargers, including existing and new chargers, in the SANDAG region and the eVMT anticipated in the BAU forecast for the SANDAG region for a given milestone year. The targeted total number of chargers in the SANDAG region was calculated using local PEV-to-charger ratios estimated by CEC's EVI-Pro analysis. EVI-Pro estimates that these ratios would change over time and also vary by PEV type. The targeted total number of chargers would be equal to the sum of all existing chargers as of 2018 and any new chargers added starting from 2018. To estimate the number of chargers needed to be incentivized by SANDAG, the number of existing non-residential chargers" (Ascent Environmental, 2019).

The use of EVI-Pro to estimate the PEV-to-charger ratios is both unique amongst the California MPOs and consequential, as we'll discuss below. The calculated PEV/charger ratio is used to estimate to the total kWh of charging available to the vehicle population and the target population of PEVs (using both EMFAC 2017 estimates and increases due to the sibling vehicle incentive program), which is distributed between BEV and PHEV based on estimates of relative charging time, and then used to determine the shift from cVMT (gas) to eVMT (electric). This shift is counted as off-model VMT reduction and converted to GHG reduction.

More details and specific critiques of the calculator method are included in the SANDAG section of the vehicle incentive calculator comparison section.

Charging Program Discussion

SCAG's EV charger incentive program accounts for a significant reduction in GHG emissions (1.2% per capita) in SCAG's SCS. As such, we thought it would be useful to investigate the difference between SCAG and SANDAG's calculators. Notably, SCAG and SANDAG apply two different methods, with SCAG opting for CARB's method A that computes the average estimated shift from gasoline-based cVMT to electric eVMT and uses that to determine the reduction. SANDAG's method, like MTC's, adopts CARB's method B, which estimates electricity consumption increase due to increased chargers to estimate the cVMT to eVMT shift.

SANDAG's method is the most methodologically complex of the three methods, but is based upon more rigorous modeling of public EV charging infrastructure needed to meet a given PEV target by using the CEC's Evi-Pro model to estimate region-specific infrastructure requirements. Since Evi-Pro only forecasts out to 2025, the infrastructure requirements are projected using a trend analysis. For the 2035 target year (and assuming the default 90% CEC scenario), 10 chargers per PEV is forecast to meet the PEV charging demand. This results in a per-capita reduction due to the RECP of 0.08%. SCAG's calculator assumes 7 chargers per PEV (though the calculator is actually insensitive to this parameter and it is just used to compute the total number of chargers that would be needed). The resulting per-capita reduction is 1.2%.

However, if we override the Evi-Pro calculation of required chargers per PEV in SANDAG's calculator and manually set this ratio to 7 to match SCAG's assumption, the per-capita reduction improves to 0.47% vs the 0.08% reduction obtained from the 10 PEV/charger ratio (in bold) as shown in Table 5. Thus, we can see that SANDAG's calculator is quite sensitive to the PEV/charger ratio. It's worth noting that this would increase the required number of chargers in SANDAG from 19,398 in the (10 veh/charger) Evi-Pro scenario to 28,914 in the SCAG-equivalent (7 veh/charger) calculation. This would obviously increase the cost of the program to SANDAG. We also applied the assumed ratio of 5 vehicle/charger from the 2017 MTC EV charger program and note that this results in the same improvement as the 7 PEV/charger ratio because the available capacity exceeds the demand. Sensitivity analysis shows that the SANDAG EV charger off-model calculator no longer produces improvements at around 7.84 veh/charger (that is, at levels below the 7.84 ratio, the GHG reduction per capita remains at 0.47%).

Table 5. Sensitivity of SANDAG EV RECP calculator to PEV/charger value

MPO	PEV/ charger	Est. Chargers	EMFAC 2017 regional PHEV	Program PHEV (incl VIP impacts)	Gas VMT reduction	GHG reduction per cap
SANDAG	5	40,479	104,064	131,792	1,520,268	0.47%
SANDAG	7	28,914	104,064	131,792	1,520,268	0.47%
SANDAG	**10**	**19,398**	**104,064**	**131,792**	**678,113**	**0.08%**

Since the SCAG methodology is relatively straightforward, we can also apply that methodology to SANDAG's RECP by simply altering the fraction of statewide eVMT that occur in the region. SCAG's fraction per EMFAC 2014. Table 6 summarizes the EMFAC 2014 VMT splits by MPO and is taken directly from SCAG's EV calculator (2020e), and shows that the fraction of statewide eVMT associated with SANDAG is 0.085 (8.5%)---substantially less than SCAG's 48%. However, applying this fraction in SCAG's calculator produces the results in Table 7, which also varies the PEV/charger ratio to show the variation in required chargers. As you can see, applying SCAG's method to SANDAG results in a per-capita GHG reduction of 0.28%---better than the results obtained using Evi-Pro trends for PEV/charge in the SANDAG calculator, but not as good as if SCAG's 10 PEV/charger parameter is used in the SANDAG calculator in lieu of the Evi-Pro trendline.

Table 6. Fraction of Statewide VMT associated with each MPO (SCAG 2020e and EMFAC 2014).

Area	Fract of State VMT
AMBAG	0.017
BCAG	0.004
COFCG	0.016
KCAG	0.004
KCOG	0.027
MCAG	0.008
MCTC	0.005
MTC	0.187
None	0.033
SACOG	0.063
SanDAG	0.085
SBCAG	0.012
SCAG	0.480
SCRTPA	0.006
SJ COG	0.022
SLOCOG	0.009
StanCOG	0.010
TCAG	0.009
TMPO	0.001

Table 7. Application of SCAG EV charger methodology to SANDAG

MPO	State PHEV 2035	Reg. frac	EMFAC region PHEV	PEV/ charger	Estimated Chargers	mi/ PHEV	Gas VMT reduction	per cap
SCAG	1,000,000	48%	480,000	7	68,571	13	6,240,000	1.20%
SANDAG	1,000,000	8.5%	85,000	7	12,143	13	1,105,000	0.28%
SCAG	1,000,000	48%	480,000	10	48,000	13	6,240,000	1.20%
SANDAG	1,000,000	8.5%	85,000	10	8,500	13	1,105,000	0.28%

EV Vehicle Incentive Programs

CARB Recommendations

CARB's recommendations for EV incentive program off-model calculations are summarized as follows:

> "The overall approach to quantifying GHG emission reductions from the Electric Vehicle Incentive strategy is to first establish the total funding allocated to the subsidy/rebate program established by the MPO, as well as the amount(s) offered for individual subsidies/rebates. Once these two values have been set, the total number of new ZEV's that may be purchased under the incentive program can then be estimated. Based on the number of vehicles purchased under the incentive program and average trip lengths for the region, total VMT associated with the incentive program can be calculated. GHG emission reductions associated with the incentive program can then be estimated using the calculated VMT and emission factors derived from the most recent version of EMFAC" (CARB 2019).

SANDAG

SANDAG's EV incentive calculator deviates from the CARB recommendation in that it does not start with a total amount of incentive funding available. Rather, it uses a PEV population target scenario selected by the user. The default scenario assumes 90% of the CEC forecast obtained from EVI-Pro (discussed above in the SANDAG EV charging section). Once the target PEV population is selected, the EV incentive calculator, the "CO2 reductions associated with the VIP are essentially a comparison of the new eVMT that would occur from the additional BEVs and PHEVs incentivized under the program beyond the BAU forecast" (Ascent Environmental 2019). Essentially, instead of determining the number of incentivized vehicles by assuming a total amount of incentive funding and an incentive level per vehicle, this calculator takes the projected PEV demand from forecasts and uses this to determine the number of incentivized vehicles. From that point forward, the calculator follows the CARB methodology. Given either incentive funding available and/or incentives per vehicle, the reciprocal can be calculated directly.

In that this target population is based upon a best-available forecast of regional EV demand, this methodology has significant advantages to the CARB default if realistic projections are the goal. Possible methodological issues with this calculator are that:

- It is not clear that the EVI-Pro projections are sensitive to incentivization levels. Additional funding for EVs may increase demand and therefore the PEV forecast totals that drive the calculator.

- Because the EVI-Pro projections are limited to the year 2025, a trend-line projection is used to estimate demand for the following years. With the rapidly changing EV market in California, it is risky to rely on prior trends to forecast future demand.

With these potential concerns noted, we still feel that the SANDAG calculator's approach to using demand-based forecasts to determine PEV population totals are more reliable than the default CARB methodology. Further, Ascent Environmental's work includes comparisons to EMFAC forecasts that demonstrate consistency.

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Appendix D Attachment 2:

Senate Bill 375 2020 Greenhouse Gas Reduction Estimate

Appendix D Attachment 2: Senate Bill 375 2020 Greenhouse Gas Reduction Estimate

Executive Summary

A central component of San Diego Forward: The 2021 Regional Plan (2021 Regional Plan) and Sustainable Communities Strategy (SCS) is measuring the plan's performance under California Senate Bill 375 (Steinberg, 2008) (SB 375). SB 375 essentially seeks to reduce per capita passenger and light truck greenhouse gas (GHG) emissions when compared to a 2005 baseline. The two compliance years that must be evaluated under SB 375 are 2020 and 2035. For these two years, the California Air Resources Board (CARB) established regional per capita GHG reduction targets for SANDAG from the 2005 base year. The 2020 target is defined as a 15% per capita GHG reduction from 2005 levels.

Reporting SB 375 performance for the year 2020 requires the incorporation of observed data, which became a challenging endeavor due to the COVID-19 pandemic. The SANDAG Series 14 SCS land use pattern and activity-based transportation model (ABM) treated 2020 as a normal, non-COVID year. Performance results directly from ABM are referred to as "unadjusted." This resulted in vehicle miles traveled (VMT) being over-estimated and required modification of existing research tools and methods to provide an adjusted SB 375 VMT and GHG reduction estimate for 2020.

Specifically, the adjustments are focused on three main components: adjusting freeway VMT, adjusting freeway speed distribution, and omitting off-model calculators. The adjustments to freeway VMT and speed, based on observed Caltrans data, were employed to create a new input file for CARB's Emissions Factors (EMFAC) software. EMFAC2014 is used as the platform for SB 375 emissions estimation.

After the adjustment of freeway VMT and freeway speeds for 2020, the 2020 per capita GHG reduction is 18% compared to 2005. The 18% per capita GHG reduction represents a conservative estimate that was limited only to empirically measured changes related to transportation behavior during 2020. While the actual reduction could be greater than 18%, there was insufficient telemetry to accurately quantify additional adjustments.

Introduction

SANDAG's SCS land use pattern and transportation model have been used to evaluate SB 375 performance for the previous two SCS submittals. An ABM can evaluate the performance of many projects, policies, and programs that lead to reductions in per capita VMT. These on-model elements include increased transit service, changes to land use policy, parking policy, freeway Managed Lanes, active transportation infrastructure, user fees, teleworking, and some technology-based asset management that increases roadway reliability. In addition to the existing regional modeling tools, "off-model" evaluation of GHG reduction programs and policies are used in SB 375 performance analysis. Off-model adjustments are used because not all programs and policies to reduce SB 375 category VMT can be precisely measured in the SANDAG ABM. The combination of on- and off-model evaluations is used to develop the SB 375 per capita GHG reduction estimate.

Because 2020 is now a historic year and transportation behavior was heavily influenced by the COVID-19 pandemic, the standard approach of using the land use pattern, ABM, and off-model calculators was insufficient to accurately estimate 2020 passenger vehicle VMT for evaluation of the 2020 SB 375 per capita GHG reduction target. All components of an unadjusted 2020 SB 375 performance evaluation were inventoried and examined. For each component, a determination was made to assign one of three courses of action: keep component as-is, modify the component, or omit the component.

Once the inventory and determinations were complete, components which required modification went through a two-step process of adjusting based on empirical data, then finding a solution on how those adjustments would be reflected in a new EMFAC input file. Each adjustment was tested individually in EMFAC to ensure that the quantitative results of the test accurately reflected the expected qualitative outcome. After EMFAC testing was complete, the EMFAC input file was run in EMFAC version 2014. The EMFAC results, along with other standard adjustments unrelated to COVID-19, were then combined to produce a 2020 SB 375 per capita GHG reduction value.

2020 Senate Bill 375 Greenhouse Gas Reduction Estimation Components

SANDAG Activity-Based Model

SANDAG is using its updated Second-Generation Activity-Based Model (ABM2+) for the analysis of the 2021 Regional Plan. ABM2+ provides a systematic analytical platform and is intensively data-driven so that different alternatives and inputs can be evaluated in an iterative and controlled environment. For SB 375 evaluation, the two primary outputs are VMT and vehicle speed bins (defined as the percentage of vehicles that fall within speeds in 5 mph increments, from 5 mph to 70 mph). Other outputs from ABM2+ are used as inputs to off-model calculators. The VMT and speed bin output from the year 2020 were used to create a custom EMFAC2014 input file. EMFAC2014 is then run in a special SB 375 mode where only VMT and speed bins from light-duty autos are evaluated. Another aspect of EMFAC in SB 375 mode is that a great majority of future fleet vehicle technology is not part of the analysis. This is done for the purposes of minimizing exogenous variables that may interfere with measuring per capita GHG reduction relative to 2005. Because of this, it is important to note that gross GHG output levels from EMFAC2014 output in SB 375 mode are not reflective of all vehicle classes and vehicle technologies. EMFAC2014 SB 375 outputs are only used to evaluate compliance with the regional targets.

Many projects, programs, and policies that seek to reduce light-duty VMT under SB 375 are incorporated into ABM2+. Projects could be new or enhanced transit service, new or enhanced transit Park & Ride locations, addition of dynamically managed lanes on the region's freeway network, additional or enhanced bicycle facilities, and arterial road diets. Programs which can be modeled in ABM2+ include telework and transportation demand management. Policy inputs to ABM2+ can include roadway user fees, transit fares, parking cost, parking locations, congestion pricing, transportation network company (TNC) fees, and land use patterns.

These components are applied consistent with the Regional Plan assumptions for each year of analysis, and their cumulative effects related to SB 375 are reflected in the VMT and speed output once an ABM2+ model run for a given year is complete.

External Regional Travel

The external travel models predict characteristics of all vehicle trips and selected transit trips crossing the San Diego County border. This includes both trips that travel through the region without stopping and trips that are destined for locations within the region. Trips that travel through the region without stopping, along with any associated VMT, are not required in SB 375 evaluation. The external-to-external VMT is excluded in the analysis.

Off-Model Calculators

The GHG reduction benefits from the programs evaluates off-model are excluded from this analysis.

EMFAC Software Version Adjustment

SANDAG used EMFAC2007 to quantify GHG emissions reductions from its first SCS. For the 2021 Regional Plan and SCS, SANDAG is using EMFAC2014 as stipulated by CARB. Using a different EMFAC model version influences estimates and evaluation of SB 375 metrics. CARB staff has developed this methodology to allow SANDAG to adjust the calculation of percent reduction in per capita CO_2 emissions used to meet the established targets when using EMFAC2014 for their third Regional Transportation Plan (RTP)/SCS. This method will neutralize the changes in fleet average emission rates between the version used for the first RTP/SCS and the version used for the second RTP/SCS. The methodology adjusts for the small benefit or disbenefits resulting from the use of a different version of EMFAC by accounting for changes in emission rates and applies an adjustment when quantifying the percent reduction in per capita CO_2 emissions EMFAC2014.

Component Selection For 2020 Adjustment

The 2020 SB 375 GHG analysis adjustment examined two factors. First, whether each component was materially affected by travel changes associated with COVID-19 and, second, whether enough empirical data existed to quantify those travel changes when compared to a non-COVID state of the component. While there may be anecdotal or broad metrics to the changes to travel that occurred due to COVID-19, only robust data should be considered to properly adjust a specific model output component. If this data were unavailable, the component would be either omitted or unchanged from the analysis. Table D2.1 shows an itemized list of components that are considered for 2020 adjustment and how those components compare to an unadjusted analysis.

Table D2.1: Senate Bill 375 Component Comparison

Senate Bill 375 Component Comparison		
Component	**2020 Unadjusted Analysis**	**2020 Adjusted Analysis**
Standard Freeway VMT	✓	—
Freeway VMT Adjustment	—	✓
Standard Arterial VMT	✓	✓
Arterial VMT Adjustment	—	—
External-to-External VMT	✓	✓
Vanpool	✓	—
Carshare	✓	—
Pooled Rides	✓	—
EMFAC Version Adjustment	✓	✓

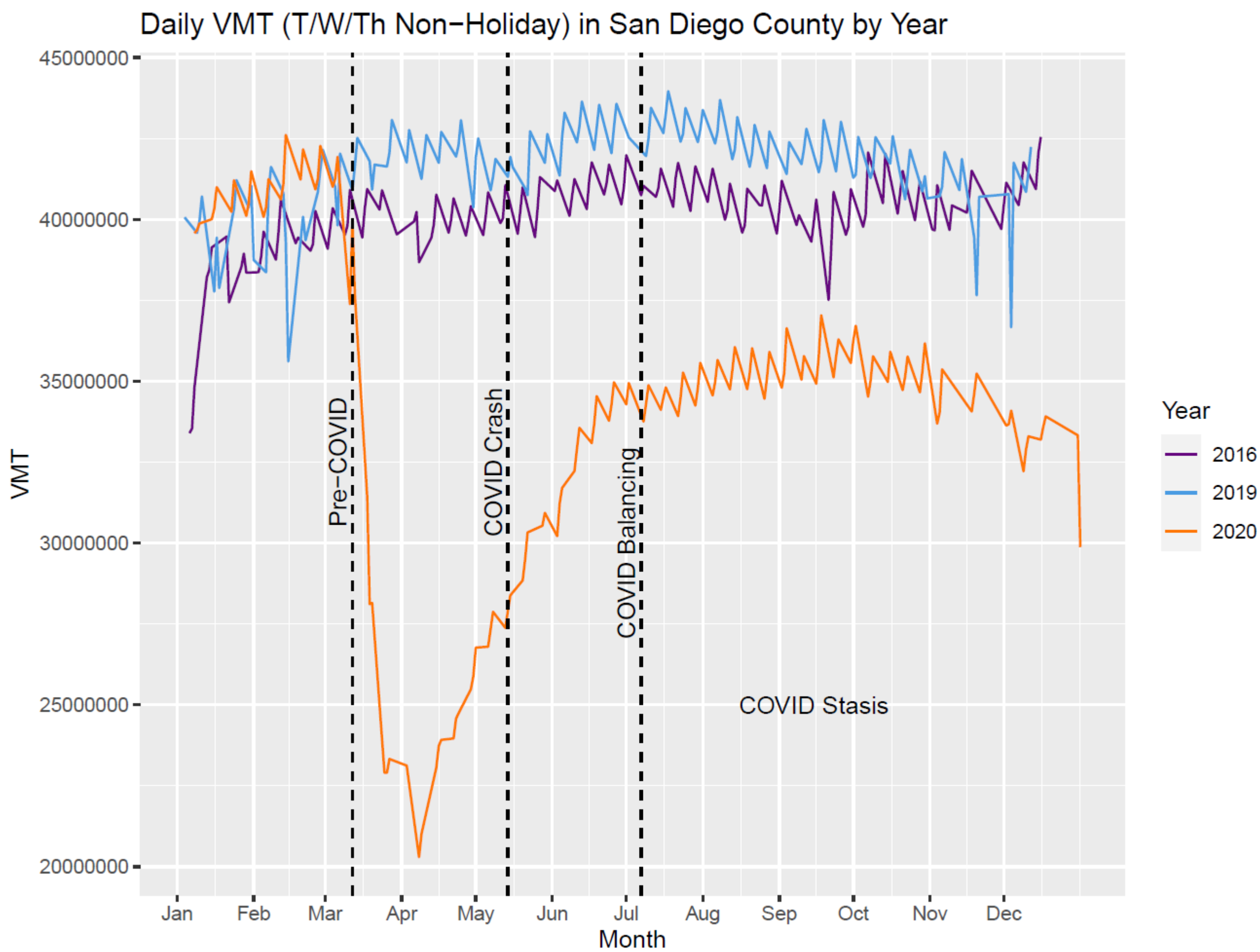
Vehicle Miles Traveled Adjustments

This approach relies on Caltrans Performance Measurement System (PeMS) 2020 freeway VMT data for non-holiday Tuesdays, Wednesdays, and Thursdays to estimate a weighted reduction to pre-COVID 2020 freeway VMT based on post-COVID VMT data. This reduction as a percentage was then applied to ABM2+ VMT results only for freeway facility types. An initial analysis of PeMS freeway data was conducted for three years: 2016, 2019, and 2020. 2016 was selected to compare to the calibrated base year of ABM2+. 2019 was evaluated to compare annual trends in 2019 to pre-COVID trends of 2020. Figure D2.1 shows how the freeway VMT data for 2020 varied substantially. Based on a visual inspection of the data, 2020 was grouped into four periods defined by the changes to freeway VMT in San Diego County. The four periods of pre-COVID, COVID crash, COVID balancing, and COVID stasis were statistically evaluated for structural breaks in the VMT data to determine the exact dates of each period.

While the PeMS VMT data was a reliable resource, there were some limitations. Hardware reliability and changes to commercial travel are two of those limitations. PeMS reports detector health for the equipment that measures freeway travel. For 2020, the average fidelity reported by PeMS for the Tuesday through Thursday was 82%. This figure does not assert that VMT was underestimated by 18% on average, rather those missing samples were interpolated to produce an estimated VMT that is reflective on an entire day of travel. All days that had an observed fidelity of less than 70% were investigated to ensure that no outliers existed in the overall dataset. For commercial travel, there was clear anecdotal evidence that deliveries increased because of COVID-19. PeMS does not classify VMT by vehicle type. It is possible that commercial and goods movement VMT increased in 2020 while light-duty auto travel decreased. Since there is no method to disaggregate light-duty VMT from PeMS data, the conservative approach would be to use the total VMT data to adjust light-duty VMT trends.

Arterial VMT was not able to be adjusted due to lack of empirical data and uncertainty over how increased goods movement and commercial travel interacted with the arterial network in 2020. The variety and amount of arterial facilities differ from freeways enough to not reliably ascribe freeway VMT trends to the arterial network. There is a high likelihood that arterial VMT did decrease due to COVID-19, but not enough data existed to reasonably quantify the reduction. The analysis does not adjust arterial VMT, only freeway VMT.

Figure D2.1: Caltrans Freeway Performance Measurement System Daily Vehicle Miles Traveled in San Diego County by Year



Determining the date ranges for Figure D2.1 was not an arbitrary task. The *strucchange* package in the R programming language was used to mathematically identify the location of multiple breakpoints within the 2020 VMT data. These breakpoints served as the end points for each period of 2020 (pre-COVID, COVID crash, COVID balancing, and COVID stasis). Visually, it was clear that there were three noticeable changes in the time series (i.e., the date partitions that divided each of the four periods) but identifying exactly when those changes occurred could be subject to debate. The *strucchange* package endogenously determines the dates in which these changes occurred. Table D2.2 shows the exact date ranges of each 2020 period along with other time frame units that were considered for analysis. A more detailed description of the structural break analysis can be found in the Additional Background section of this Attachment.

Table D2.2: 2020 Weekday (Tuesday–Wednesday–Thursday) Freeway Vehicle Miles Traveled Groupings by Date Range

2020 Weekday (Tuesday–Wednesday–Thursday) Freeway Vehicle Miles Traveled Groupings by Date Range		
2020 Dates	**Description**	**Average Freeway VMT**
January 1–December 31	Calendar Year	34,003,689
January 1–March 31	Q1	38,055,361
April 1–June 30	Q2	28,687,235
July 1–September 30	Q3	35,171,993
October 1–December 31	Q4	34,322,311
January 1–March 12	Pre-COVID	40,609,642
January 1–March 12	Pre-COVID (median)	40,772,942
March 17–December 31	Post-COVID	32,306,747
March 17–December 31	Post-COVID (median)	34,114,325
March 17–May 14	COVID crash	25,374,455
May 19–July 7	COVID balancing	32,462,977
May 19–July 7	COVID balancing (median)	33,001,344
July 8–December 31	COVID stasis	34,818,292
January 1–March 12 and July 8–December 31	Pre-COVID and COVID stasis	36,561,925

The two time periods considered for analysis of the 2020 freeway VMT adjustment were the pre-COVID and post-COVID median VMT values. Table D2.3 shows that when comparing these two time periods, a 16.3% decline in overall weekday freeway VMT occurred due to COVID-19.

Table D2.3: Preferred VMT Grouping for 2020 Adjustment

Preferred VMT Grouping for 2020 Adjustment		
Pre-COVID VMT (median)	40,772,942	"Normal 2020"
Post-COVID VMT (median)	34,114,325	"Adjusted 2020"
Freeway percent adjustment factor	16.33%	

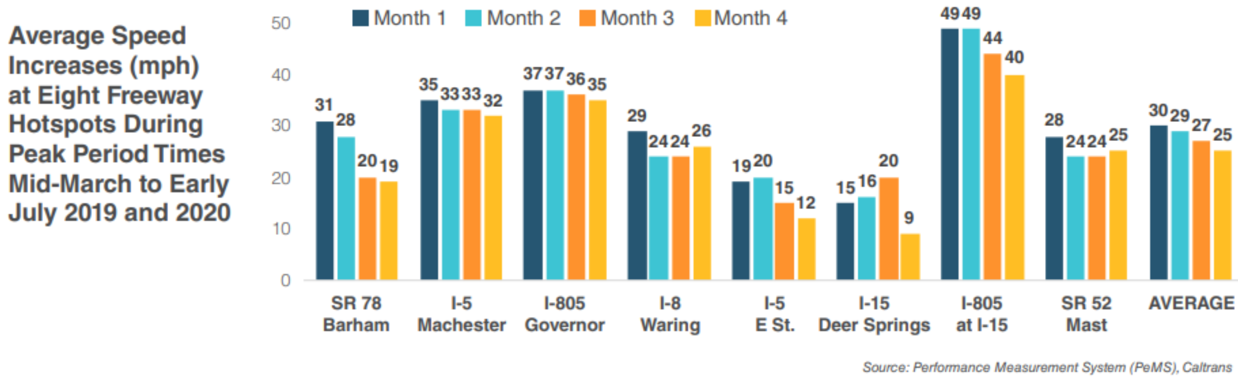
External-to-External VMT Adjustment

The unadjusted SB 375 ABM2+ analysis calculated that 1.0% of light-duty VMT in 2020 should be removed due to that VMT being associated with travel that never stopped inside of San Diego County. While this figure most likely changed during the COVID period in 2020, there was insufficient data to support modifying the analysis from the original value. The most reasonable and prudent course was to leave this 1.0% value unchanged in the adjusted analysis.

Speed Adjustments

Not all travel changes associated with COVID-19 reduced GHG. As freeway VMT was being reduced due to stay at home health orders, those who still chose to make auto trips experienced substantially higher travel speeds on the region's freeways as seen in Figure D2.2. According to standard EMFAC output, high speeds typically result in more CO_2 per mile being emitted from light-duty auto classes. Since the increase in travel speed is a reflection of the near total elimination of severe congestion on the freeway network, it was decided to adjust speed bins in the EMFAC input file by "shifting" VMT from the congested speeds of 35 mph, 40 mph, and 45 mph to the non-congested speeds 55 mph, 60 mph, and 65 mph, respectively. It is important to note that in the speed adjustment step, VMT is conserved but GHG slightly increases.

Figure D2.2: Average Speed Increases (Miles Per Hour) During Peak Periods



EMFAC Version Adjustment

The EMFAC version adjustment applies only to the differences between versions of software and was agnostic toward the differences between pre- and post-COVID. The EMFAC version adjustment for 2020 provided by CARB represents an additional 1.8% of per capita GHG in the analysis.

Omitted Components

The adjusted analysis for 2020 does not consider any GHG reductions from reduced arterial VMT, vanpools, carsharing, or pooled rides. Arterial VMT was not reduced or adjusted down due to insufficient data. PeMS is a robust data source for freeway VMT but has no coverage on arterial streets. While it is anecdotally known that arterial VMT was reduced because of COVID, there was no data to quantify it. Arterial VMT remains unadjusted from a regular, non-COVID, 2020 ABM2+ model run. Vanpool, carshare, and pooled ride GHG reductions were removed altogether because of COVID health and safety restrictions, a substantial increase in telework, and removal of congestion on the freeway network. Had these factors been considered for inclusion, they would have all resulted in a greater GHG reduction for 2020.

EMFAC Input Modification and Testing

Data for freeway VMT and freeway travel speeds was sufficient to use for 2020 adjustment. In order to accurately reflect this, methods had to be created that would take the empirical trends seen for VMT and speed, then apply them to standard 2020 ABM2+ output. These steps were necessary to modify EMFAC2014 input that would reflect the COVID adjustments, but still allow EMFAC2014 to run normally in SB 375 mode.

Freeway VMT adjustment was performed by taking a standard, non-COVID, ABM2+ model run for 2020, and classifying total VMT assigned to the transportation network as either freeway or non-freeway (arterial). This is a necessary step so that the 16.3% reduction cited in Table D2.3 will only be applied to modeled freeway VMT but also allow for the calculation of total VMT reduction. EMFAC2014 does not accept VMT input by facility type, only by vehicle class. The overall VMT percentage reduction is needed so it will only be applied to the VMT from the four relevant SB 375 vehicle classes: Light-Duty Auto (LDA), Light-Duty Truck 1 (LDT1), Light-Duty Truck 2 (LDT2), and Medium-Duty Vehicle (MDV). Table D2.4 shows that the overall VMT reduction is 9.12%. That percentage is then applied to the SB 375 vehicle classifications and their associated fuel types in Table D2.5.

Table D2.4: Application of Caltrans Performance Measurement System Freeway Vehicle Miles Traveled Reduction Factor to ABM2+ Vehicle Miles Traveled

Application of Caltrans Performance Measurement System Freeway Vehicle Miles Traveled Reduction Factor to ABM2+ Vehicle Miles Traveled		
	ABM2+ VMT	**Adjusted VMT**
Freeway	46,872,476	39,217,746
Arterial	37,100,269	37,100,269
Total	83,972,745	76,318,015
SB 375 VMT percent reduction:		9.12%

Table D2.5: EMFAC2014 Senate Bill 375 Vehicle Category Vehicle Miles Traveled Adjustments

EMFAC2014 Senate Bill 375 Vehicle Category Vehicle Miles Traveled Adjustments			
Calendar Year	**Vehicle Classification**	**Unadjusted VMT**	**Adjusted VMT**
2020	LDA – Diesel	559,255	508,275
2020	LDA – Gas	49,742,424	45,208,038
2020	LDT1 – Diesel	3,760	3,417
2020	LDT1 – Gas	3,665,383	3,331,257
2020	LDT2 – Diesel	30,582	27,794
2020	LDT2 – Diesel	15,739,987	14,305,172
2020	MDV – Diesel	174,880	158,939
2020	MDV – Gas	9,298,065	8,450,749

Freeway speed adjustments from ABM2+ output assumed that all modeled freeway VMT at a volume to capacity ratio of greater than 0.85 would have occurred at uncongested speeds. Table D2.6 shows the amount of VMT to be shifted for both the a.m. and p.m. peak periods from slower speed bins to faster speed bins.

Table D2.6: Calculation of Congested Vehicle Miles Traveled Speed Adjustment Using ABM2+ Vehicle Miles Traveled

Calculation of Congested Vehicle Miles Traveled Speed Adjustment Using ABM2+ Vehicle Miles Traveled				
Period	**Total VMT All Roadways**	**Congested VMT Freeway Only**	**Volume to Capacity Ratio Threshold**	**Congested VMT Speed Adjustment Percentage**
a.m.	17,142,006	3,005,695	0.85	17.53%
p.m.	20,631,071	1,545,288	0.85	7.49%

Speed bins are specified in EMFAC for all vehicle types by one-hour increments of time and 5 mile per hour increments of speed. The AM and PM adjustments from ABM2+ freeway data were applied to calculate new speed bin fractions where more VMT is assigned to faster speeds at the expense of slower speeds. Table D2.7 shows these new values. It is worth reminding that the speed adjustment step does not add or remove VMT from the analysis. It is exclusively being shifted from slower to faster speeds.

Table D2.7: EMFAC2014 Speed Adjustments

EMFAC2014 Speed Adjustments								
Unadjusted Speed Fractions								
	Hour of Day	35 mph	40 mph	45 mph	55 mph	60 mph	65 mph	
a.m. Peak	6	0.043	0.035	0.041	0.041	0.064	0.406	
	7	0.090	0.089	0.104	0.091	0.104	0.119	
	8	0.090	0.089	0.104	0.091	0.104	0.119	
p.m. Peak	16	0.064	0.053	0.062	0.042	0.112	0.251	
	17	0.075	0.079	0.101	0.101	0.105	0.130	
	18	0.075	0.079	0.101	0.101	0.105	0.130	
Adjusted Speed Fractions								
		35 mph	40 mph	45 mph	55 mph	60 mph	65 mph	
a.m. Peak	6	0.035	0.029	0.033	0.048	0.070	0.413	17.53%
	7	0.075	0.074	0.085	0.107	0.120	0.138	
	8	0.075	0.074	0.085	0.107	0.120	0.138	
p.m. Peak	16	0.060	0.049	0.057	0.047	0.116	0.256	7.49%
	17	0.070	0.073	0.093	0.107	0.111	0.137	
	18	0.070	0.073	0.093	0.107	0.111	0.137	

After the VMT and speed input modifications were tabulated, testing occurred of each component before both the VMT reduction and speed increase would be applied in the same input file. The testing process consisted of modifying an EMFAC2014 input file for 2020 with only one component for each test. Qualitative expectations would be that when compared to unadjusted, non-COVID, EMFAC output, the VMT only test would reduce SB 375 CO_2 substantially while the speed only test would slightly increase CO_2. The results of the tests were as expected, which gave confidence in an EMFAC analysis which placed both components in the same input file. The test and EMFAC results can be seen in Table D2.8.

Table D2.8: Summary of EMFAC2014 Component Tests and Final Preferred Adjustments

Summary of EMFAC2014 Component Tests and Final Preferred Adjustments					
Scenario	**VMT State**	**Speed State**	**SB 375 VMT**	**SB 375 CO_2 (tons)**	**CO_2 Difference From Unadjusted**
2020 Unadjusted	Non-COVID	Non-COVID	79,214,338	39,275	—
2020 VMT Component	COVID	Non-COVID	71,993,371	35,695	↓ 3,580
2020 Speed Component	Non-COVID	COVID	79,214,338	39,300	↑ 25
2020 VMT and Speed Adjusted	COVID	COVID	71,993,371	35,718	↓ 3,557

Results

The adjustments resulted in a SB 375 per capita reduction over 2005 levels of 17.9%, which meets the CARB established target for the San Diego region of 15%. The results are shown in Table D2.9.

Table D2.9: Senate Bill 375 Analysis Comparison

Senate Bill 375 Analysis Comparison		
	2020 Unadjusted	2020 Adjustment
2020 SB 375 Regional Per Capita Reduction Target	15%	15%
Total SB 375 GHG Per Capita Reduction	10.2%	17.9%
SB 375 VMT	79,214,338	71,993,371
External-to-External Trip Adjustment	1.1%	1.1%
SB 375 Emission/Person (lbs)	23.0	20.9
2005 Baseline Emission/Person (lbs)	26.0	26.0
Per Capita Reduction Before EMFAC Version Adjustment	12.0%	17.9%
EMFAC Version Adjustment % Per Capita	1.8%	1.8%

Additional Background

Structural Breaks Analysis

Recall that 2020 was partitioned into four different periods: pre-COVID, COVID crash, COVID balancing, and COVID stasis. Determining the date ranges for these periods of 2020 was not an arbitrary task. The *strucchange* package in the R programming language[1] was used to algorithimically identify the location of multiple breakpoints within the 2020 VMT data.[2] These breakpoints served as the end points for each period of 2020. Visually, it was clear that there were three noticeable changes in the time series (i.e., the date partitions that divided each of the four periods). 2020 VMT for non-holiday Tuesdays, Wednesdays, and Thursdays started off around the same levels as previous years, but crashed during the onset of the Coronavirus pandemic in the United States. After the initial crash, VMT levels steadily increased before stabilizing and leveling off the rest of the year (albeit still below pre-COVID levels). Identifying exactly when those changes occurred could be subject to debate. The "breakpoints" function within the *strucchange* package endogenously and objectively determines the dates in which these changes occurred.

Given the initial assumption of three partitions, the *strucchange* package looks at all possible partition locations to minimize the sum of squared residuals in each partition and across all partitions. Formally, obtaining these dates to find the breakpoints are to find the set of breakpoints $d_1,\ldots,d_m$ that minimize the objective function below:[3]

$$(d_{1,\ldots,}d_m) = \mathrm{argmin}\,RSS(i_1,\ldots,i_m)$$

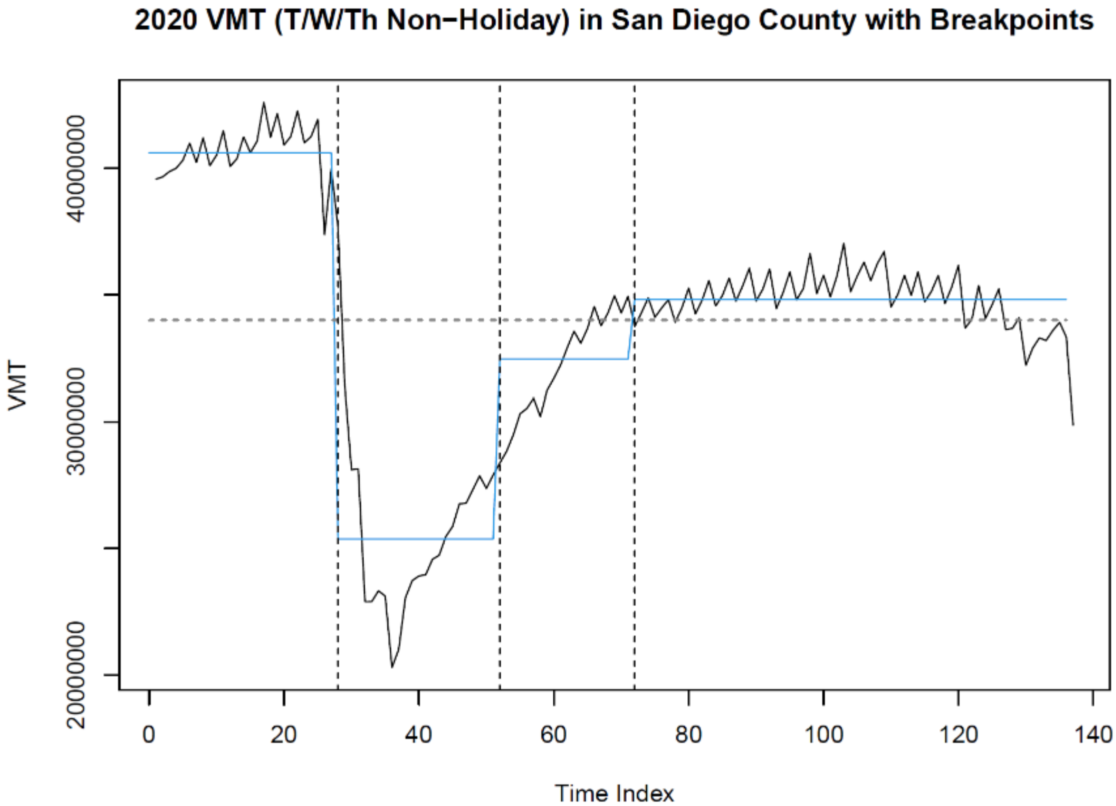
where *RSS* denotes the sum of squared residuals and $i_1,\ldots,i_m$ represents the number of partitions. Informally, we can think of the minimized sum of squared residuals as the line in each partition that minimizes the sum of the squared distances between each observation and the line itself.

1 Achim Zeileis, Friedrich Leisch, Kurt Hornik, and Christian Kleiber, "'strucchange': An R Package for Testing for Structural Change in Linear Regression Models," *Journal of Statistical Software* 7, no. 2 (January 10, 2002): 1–38, jstatsoft.org/v07/i02.

2 Achim Zeileis, Christian Kleiber, Walter Krämer, and Kurt Hornik, "Testing and Dating of Structural Changes in Practice," *Computational Statistics & Data Analysis* 44, no. 1–2 (October 28, 2003): 109–123.

3 See page 112 of Achim Zeileis, Christian Kleiber, Walter Krämer, and Kurt Hornik, "Testing and Dating of Structural Changes in Practice," *Computational Statistics & Data Analysis* 44, no. 1–2 (October 28, 2003): 109–123 for more formal details.

Figure D2.3 2020 Vehicle Miles Traveled (Tuesday–Wednesday–Thursday Non-Holiday) in San Diego County with Breakpoints



In Figure D2.3, it is evident that the three partitions (dotted vertical lines) and the line of best fit that minimizes the sum of squared residuals in each partition (the blue lines). The gray horizontal dotted line is the line of best fit without the partitions. The dates for which the breakpoints occurred were then extracted from the time index by matching the index to the date in the dataset. This time-series analysis was necessary because not only did it give a more accurate picture of what occurred in different points in 2020, but it also mathematically identified when these points occurred.

Alternative Methodologies Considered

Alternatives A, B, and C were considered during the draft 2021 Regional Plan SCS process, which used a combination of off-model and arterial VMT adjustments. As shown in Table D2.10, these alternative methodologies show a range of approaches that could reasonably be taken to evaluate an adjusted 2020 SB 375 GHG reduction considering also arterial VMT reduction. The alternative approach ascribed the arterial VMT reduction as ⅓ or ¼ of the freeway reduction. As explained on page D2-9, arterial VMT was not reduced or adjusted down in the estimation of the 2021 Regional Plan 2020 GHG reduction due to insufficient data since PeMS has no coverage on arterial streets.

Table D2.10: Summary of Draft Alternative Methodologies Considered*

Summary of Draft Alternative Methodologies Considered*				
	2020 Draft Unadjusted	Alternative A	Alternative B	Alternative C
Total SB 375 GHG Per Capita Reduction	11.2%	18.8%	18.6%	18.2%
SB 375 VMT	79,816,845	72,400,233	72,400,233	72,778,130
Total SB 375 CO_2 (tons)	38,861	35,018	35,149	35,580
16.3% Freeway VMT Adjustment	No	Yes	Yes	Yes
Arterial VMT Adjustment (⅓ of freeway percent)	No	Yes	Yes	No
Arterial VMT Adjustment (¼ of freeway percent)	No	No	No	Yes
External-to-External VMT Adjustment	Yes	Yes	Yes	Yes
EMFAC Version Adjustment	Yes	Yes	Yes	Yes
Vanpool Off-Model Adjustment	Yes	Yes	No	No
Carshare Off-Model Adjustment	Yes	Yes	No	No
Pooled Ride/Carpool Off-Model Adjustment	Yes	Yes	No	No

*Based on draft 2021 Regional Plan

Analysis Worksheet

EMFAC 2014	2020 UNADJUSTED	2020 ADJUSTED	
Database Scenario ID	463	463	*REMARKS*
Population	3,383,955	3,383,955	
SB 375 VMT	79,214,338	71,993,371	← 9.12% VMT Adjustment
SB 375 VMT / Person	23.4	21.3	
External to External VMT	832,937	756,973	← 9.12% VMT Adjustment
External to External VMT Reduction	1.1%	1.1%	
SB 375 Emissions (tons)	39,275	35,718	← Adjusted CO2 based on VMT& Speed adjustments
SB 375 GHG Emissions without E-E VMT (tons)	38,862	35,342	
SB 375 Emissions / Person (lbs)	22.97	20.89	
Per Capita Reduction for 2005	**11.7%**	**-19.7%**	
Off-Model Calculators VMT Reduction			
Vanpool	269,805	-	← Removed From Analysis
Carshare	21,764	-	← Removed From Analysis
Carpool	11,660	-	← Removed From Analysis
TDM Ordiance	N/A		
Total VMT reduction	**303,229**	-	
SB 375 VMT / Person Reduction	654.92	-	
Off-Model Calculators - Daily Total GHG Reduction (tons)			
Vanpool	129.2	0.0	
Carshare	10.4	0.0	
Carpool	5.8	0.0	
TDM Ordiance	N/A		
EV Charging Program			
SB 375 Off-Model Emissions Total Reduction (tons)	145.4	0.0	
SB 375 Off-Model Emissions Reduction/ Person (lbs)	0.09	-	
Off-Model GHG Reduction per capita	0.33%	0.00%	
Per Capita Reduction for 2005 with Off-Model Calc	**12.0%**	**19.7%**	
ARB Adjustment for EMFAC 2007 - 2014	-1.8%	-1.8%	
Final Per Capita Reduction for 2005	10.2%	17.9%	← Adjusted Per Capita Reduction
	-10%	**-18%**	
Targets	**-15%**	**-15%**	

Appendix D Attachment 3:

Senate Bill 375 Greenhouse Gas Adjustment Due to Induced Demand

Appendix D Attachment 3: Senate Bill 375 Greenhouse Gas Adjustment Due to Induced Demand

This adjustment to the quantification of carbon dioxide (CO_2) emissions for the SANDAG Sustainable Communities Strategy (SCS) accounts for additional auto travel due to new roadway capacity that may not be fully accounted for in the Second Generation of SANDAG's Activity-Based Model (ABM2+) output. Induced demand occurs when changes in travel demand are a direct or indirect result of new infrastructure investment.

A vast majority of additional lane mileage[1] in the SANDAG SCS comes from an expansion of the region's Managed Lane system. Existing infrastructure is maximized by repurposing shoulders or existing travel lanes to create Managed Lanes where shoulders, high-occupancy vehicle (HOV) travel lanes, or general purpose (GP) travel lanes exist today. Highway projects are limited to the existing footprint. Any exception will be thoroughly analyzed from an environmental and equity perspective. The new lane miles include four different categories of projects:

1. Projects completed since 2016, such as SR 76 from Mission Road to I-15 and the County of San Diego intersection improvement at SR 67/Highland Valley Road/Dye Road
2. Other projects programmed in the Regional Transportation Improvement Program (RTIP) and under construction such as completion of SR 11 as a tolled facility connecting to the planned Otay Mesa East Port of Entry and I-5 North Coast Corridor Managed Lanes from Manchester to Vandegrift Boulevard
3. Projects programmed in the RTIP and slated for implementation such as the SR 52 operational improvements (truck climbing lane from Mast Boulevard to Santo Road and auxiliary lane from I-15 to Santo Road) and the SR 94/SR 125 interchange and arterial operational improvements
4. Projects planned in San Diego Forward: The 2021 Regional Plan (2021 Regional Plan) for future implementation such as SR 78 Managed Lanes and I-5 South Managed Lanes that will support transit services

Currently, the SANDAG SCS land use pattern and the ABM2+ modeling system account for a portion, but not all effects from induced demand. A vehicle miles traveled (VMT) based off-model adjustment was used to quantify the estimated unaccounted-for induced demand. The methodology for this adjustment borrowed elements from the existing induced demand calculator developed by the National Center for Sustainable

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[1] Lane miles are used to measure the total length and lane count of a road. Lane miles are calculated by multiplying the centerline mileage of a road by the number of lanes it has. For example, a 2.5-mile segment of a 4-lane facility represents 10 lane miles.

Transportation (NCST) in conjunction with UC Davis. SANDAG's methodology included adjustments to the calculator to develop more robust elasticities applicable to SANDAG's SCS.[2] To calculate the VMT adjustment, the methodology follows the generally accepted principle that the magnitude of the increase of VMT due to induced demand results from a given increase in GP lane miles. Depending on GP facility classification, the elasticities for this increase are 1.0 or 0.75. The results of the adjustment are an additional 193,286 daily Senate Bill 375 (Steinberg, 2008) (SB 375) VMT from 2016 to 2035, a 0.23% per capita VMT increase, and a corresponding 0.24% CO_2 increase. These differences change the calculation of the SB 375 per capita 2035 reduction by +0.2%, relative to 2005. When applied to the 2050 forecast year, the estimation methodology results in an additional 272,343 daily SB 375 VMT from 2016 to 2050, a 0.32% per capita VMT increase, and a corresponding 0.33% CO_2 increase. These differences change the calculation of the SB 375 per capita 2050 reduction, by +0.3%, relative to 2005.

The steps in the analysis are illustrated in Figure D3.1. The facility inventory step disaggregated all additional major highway corridor lane miles in the plan by facility type: GP, Auxiliary, High-Occupancy Toll (HOT), and Toll. GP lanes are open to all vehicular traffic at all times of day. Auxiliary lanes are sometimes constructed between on- and off-ramps to allow vehicles more time and space to enter or exit the GP lanes. HOT lanes are used in the 2021 Regional Plan as lanes that are free to HOV 3+ users. Single-occupancy vehicles and HOV 2 users must pay a per-mile toll to use the Managed Lanes, and heavy-duty trucks are prohibited. A tollway is open to all vehicular traffic on the condition that all vehicles pay a toll to use the tollway. The inventory of added lane mileage by facility class and type can be seen in Table D3.1. The inventory shows that over 90% of additional capacity in the 2021 Regional Plan is non-GP lane type. This is notable due to GP lanes being the most sensitive to additional VMT.

Corridor level tests were conducted using ABM2+ to quantify how induced demand elasticities vary by facility type. These tests allowed for both the development of relative elasticities for each facility type compared to the GP values of 1.0 and 0.75 and assessment of the amount of short-run induced demand accounted for in ABM2+. Much of the testing was conducted where additional capacity was controlled and only varied by facility type. This testing revealed that non-GP facility types have lower induced demand elasticities.

Further ABM2+ testing was conducted to establish elasticities of VMT-reducing policies in the 2021 Regional Plan. Major policy components include telework increases, a regional road usage charge, the SCS land use pattern, reduced transit fares, and parking cost increases. The total elasticity was split between short- and long-run induced demand so that the level of model accountability for each category (short- and long-run) could be

2 This methodology differs slightly from what was described in the SANDAG SCS technical methodology because of additional ABM2+ testing, which revealed a better methodology to account for elasticities of all non-GP facility types in addition to the inclusion of VMT-reducing policies in the SCS.

applied individually. Based on the available project level research,[3] a 50/50 split between long-run and short-run was applied for the SCS analysis. Long-run induced demand accounts for increases to population and employment around new infrastructure.

The SANDAG SCS land use pattern is based on the California Department of Finance (DOF) population projections series published in January 2020, consistent with Assembly Bill 1086 (Daly, 2017). While the DOF population forecast accounts for demographic and socioeconomic trends, it is agnostic of the infrastructure changes planned in the region. Additionally, SANDAG's sub-regional allocation of population and employment reflected in the SCS land use pattern uses most recent planning assumptions considering local general plans and other factors rather than model-influenced accessibility measures. The NCST induced demand calculator (and research it is based on) accounts for induced demand at the project level, and there is no indication within the tool that regional long-run induced demand occurs at the same elasticity as project-level induced elasticity. Based on the uncertainty within these reasons, accounting for 50% of long-run induced demand is considered appropriate for this analysis.

This analysis is a complete, adequate, and good-faith effort at quantifying induced demand in the SCS. As recommended by the Technical Advisory on Evaluating Transportation Impacts in California Environmental Quality Act (CEQA),[4] the limitations to both this analysis and the modeling system used to inform it are described in this section. The conversion of existing GP lanes to HOT lanes along with an expanded and enhanced transit system, which are known elements that may mitigate the effects of induced demand, were not considered in the calculations of elasticities. Induced demand effects in ABM2+ have limitations related to both model inputs and model performance. Input limitations in the SCS land use pattern allocation occur at the subregional level. The allocation of housing units to subregional areas represents general areas projected for future growth and not specific parcels for future housing development or housing unit type. The exercise of land use authority is reserved to local jurisdictions. The overall SCS land use pattern projection also does not predict economic recessions, pandemics, world/state crises, nor large deviations to exogenous variables. While the ABM2+ model structure does provide for the modeling of special markets and cohorts such as military households, sovereign tribal nations, domestic interregional travel, and travel across the international border with Mexico that has at least one stop in the SANDAG region, these capabilities and model components are limited to the fidelity and frequency of efforts to collect travel surveys and travel information. Certain types of commercial, service, and business travel not easily categorized in a traded industry cluster also present challenges to conducting a sensitivity analysis. Finally, nascent technological changes in the transportation sector (and subsequent effects in the supply chain that result from these changes) are difficult to evaluate within ABM2+.

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3 Susan Handy and Marlon Boarnet, "Impact of Highway Capacity and Induced Travel on Passenger Vehicle Use and Greenhouse Gas Emissions: Policy Brief," California Air Resources Board, September 30, 2014, arb.ca.gov/sites/default/files/2020-06/Impact_of_Highway_Capacity_and_Induced_Travel_on_Passenger_Vehicle_Use_and_Greenhouse_Gas_Emissions_Policy_Brief.pdf.

4 "Technical Advisory on Evaluating Transportation Impacts in CEQA," Governor's Office of Planning and Research, December 2018, opr.ca.gov/docs/20190122-743_Technical_Advisory.pdf.

Figure D3.1: Methodology Flow of Off-Model Vehicle Miles Traveled Adjustment

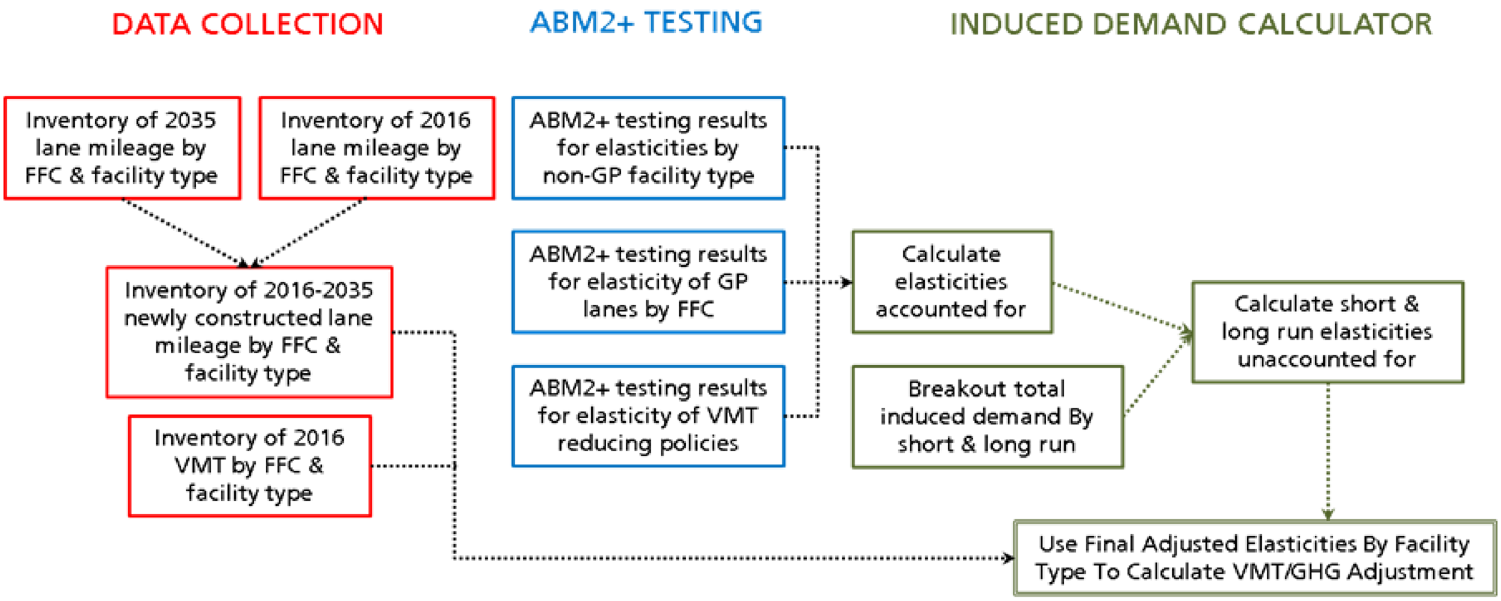

Table D3.1: Inventory of Added Lane Miles, 2016–2035 and 2036–2050, by Facility Class and Type

Inventory of Added Lane Miles, 2016–2035 and 2036–2050, by Facility Class and Type			
Federal Functional Class	**Facility Type**	**2016–2035 Added Lane Miles**	**2036–2050 Added Lane Miles**
Class 1	General Purpose	0	2
Class 1	Auxiliary	21	5
Class 1	Managed	144	32
Class 2	General Purpose	14	0
Class 2	Auxiliary	23	5
Class 2	Managed	59	66
Class 2	Toll	10	0
Class 2	Toll to General Purpose Conversion	0	48
Class 3	General Purpose	14	5

Federal Functional Class 1 = Interstates
Federal Functional Class 2 = Other Freeways and Expressways
Federal Functional Class 3 = Other Principal Arterials