Appendix E: Plan Performance

Contents

List of Tables

List of Figures

Federal Performance Management Targets

Transportation agencies rely on both monitored and forecasted data to support planning and investment decisions. In 2012, federal government enacted the Moving Ahead for Progress in the 21st Century Act (MAP-21), which placed increased emphasis on performance-based planning for both state and regional governments. The federal requirements hold state departments of transportation (e.g., Caltrans) and MPOs accountable for setting performance targets that will ensure transportation dollars are being used effectively and efficiently. Caltrans is required to set and report on progress towards three sets of annual performance measurement targets:

- Safety Performance Management (PM1): Fatalities and Injuries
- Pavement and Bridge Condition Performance Management (PM2): Infrastructure Conditions
- System Performance Management (PM3): Freight movement, congestion, and reliability

This appendix describes each federal performance metric, charts data collected to date, compares that data to currently adopted targets and describes how the MTP/SCS makes investments that support reaching those targets. For some targets, MPO's can either agree to support the State DOT target or establish a numerical target specific to the MPO planning area. Since this federal process started in 2018, SACOG has supported all of Caltrans statewide targets for all three sets of performance metrics. Below are summary tables of SACOG supported state targets for each performance metric.

Table 1 - Safety Performance Management (PM1): Fatalities and Injuries

	Data Source	**5- Yr. Rolling Average Targets**[1]		**Percent Reduction Targets**[1]	
		2018	**2019**	**2018**	**2019**
Number of Fatalities	FARS[2]	3590.8	3445.4	7.69%	3%
Rate of Fatalities (per 100 million VMT)	FARS & HPMS[3]	1.029	0.995	7.69%	3%
Number of Serious Injuries	SWITRS[4]	12,823.4	12,688.1	1.5%	1.5%
Rate of Serious Injuries (per 100 million VMT)	SWITRS & HPMS	3.831	3.661	1.5%	1.5%
Number of Non-Motorized Fatalities and Non-Motorized Severe Injuries	FARS & SWITRS	4271.1	3949.8	10%	3% for Fatalities and 1.5% for Serious Injuries

[1] Caltrans Federal Liaison, https://dot.ca.gov/programs/federal-liaison, Accessed Sept 2019.
[2] Fatality Analysis Reporting System (FARS)
[3] Highway Performance Monitoring System (HPMS) Data
[4] Statewide Integrated Traffic Records System (SWITRS)

Table 2 - Pavement and Bridge Condition Performance Management (PM2): Infrastructure Conditions

	2-year NHS Targets[1] (1/1/2018 – 12/31/2019)		**4-year NHS Targets**[5] (1/1/2020 – 12/31/2021)	
	Good	**Poor**	**Good**	**Poor**
Interstate NHS[2]	45.1%	3.5%	44.5%	3.8%
Non-interstate NHS	28.2%	7.3%	29.9%	7.2%
Bridges on the NHS	69.1%	4.6%	70.5%	4.4%

Table 3 - System Performance Management (PM3): Freight movement, congestion, and reliability

	2017 Baseline Data	**2-year Target**[5]	**4-year Target**[5]
Percent of Reliable Person-Miles Traveled on the Interstate[3]	64.6%	65.1% (+0.5%)	65.6% (+1%)
Percent of Reliable Person-Miles Traveled on the Non-interstate NHS[7]	73.0%	N/A	74.0% (+1%)
Percentage of Interstate System Mileage Providing Reliable Truck Travel Time (Truck Travel Time Reliability Index)[7]	1.69	1.68 (-0.01)	1.67 (-0.02)
Total Emissions Reductions by Applicable Pollutants under the CMAQ Program[4]			
VOC (kg/day)	951.83	961.35 (+1%)	970.87 (+2%)
CO (kg/day)	6869.26	6931.90 (+1%)	7000.54 (+2%)
NOx (kg/day)	1753.36	1770.89 (+1%)	1788.43 (+2%)
PM10 (kg/day)	2431.21	2455.52 (+1%)	2479.83 (+2%)
PM2.5 (kg/day)	904.25	913.29 (+1%)	922.34 (+2%)
Annual Hours of Peak-Hour Excessive Delay Per Capita (PHED), Sacramento UA[7]	14.9 Hours	N/A	14.7 (-1.0%)
Percent of Non-single Occupancy Vehicle (SOV) Travel, Sacramento UA[5]	22.8%	23.3% (+0.5%)	23.8% (+1%)

[1] Caltrans Federal Liaison, https://dot.ca.gov/programs/federal-liaison, Accessed Sept 2019.
[2] Highway Performance Monitoring System (HPMS) Data
[3] National Performance Management Research Data Set (NPMRDS) Analytics Tool https://npmrds.ritis.org/analytics
[4] CMAQ Public Access System (https://fhwaapps.fhwa.dot.gov/cmaq_pub/)
[5] U.S. Census Bureau, 2012-2016 American Community Survey 5-Year Estimates

Safety Performance Management (PM1: Fatalities and Injuries)

As our economy recovers and vehicle travel increases, more people are likely to be seriously injured or die from vehicle collisions. Over the last 10 years, an average of 218 people died in vehicle collisions on our region's roads and highways.[1] In 2016, 285 people died in vehicle collisions, the highest number of annual recorded deaths in the last 10 years and a 21% increase from the prior year.

Figure 1 - 2006 - 2016 Fatal Collisions: **State** vs **Sacramento Region**[2]

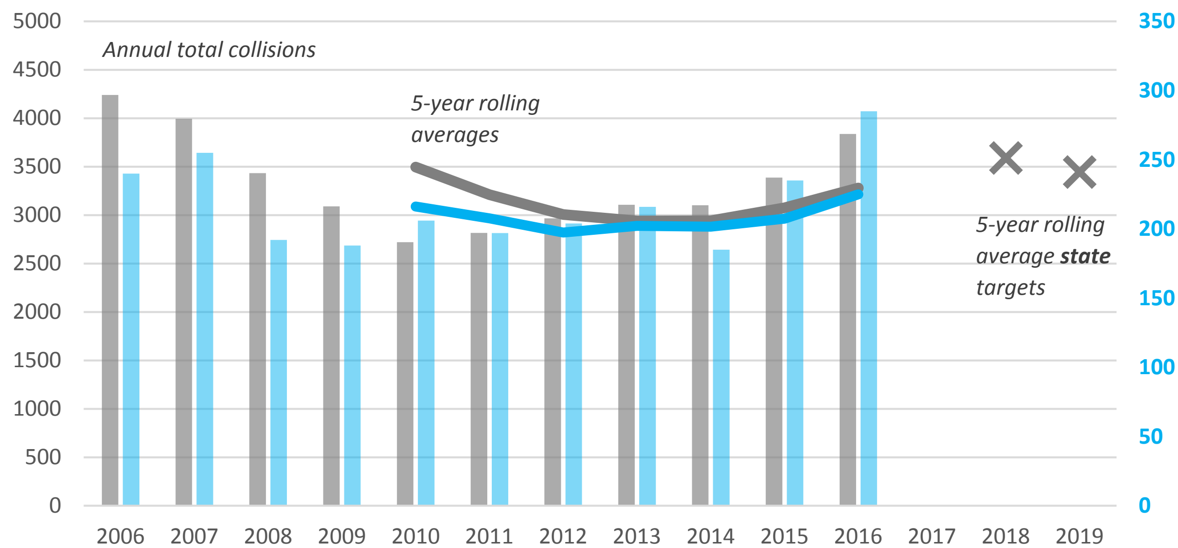
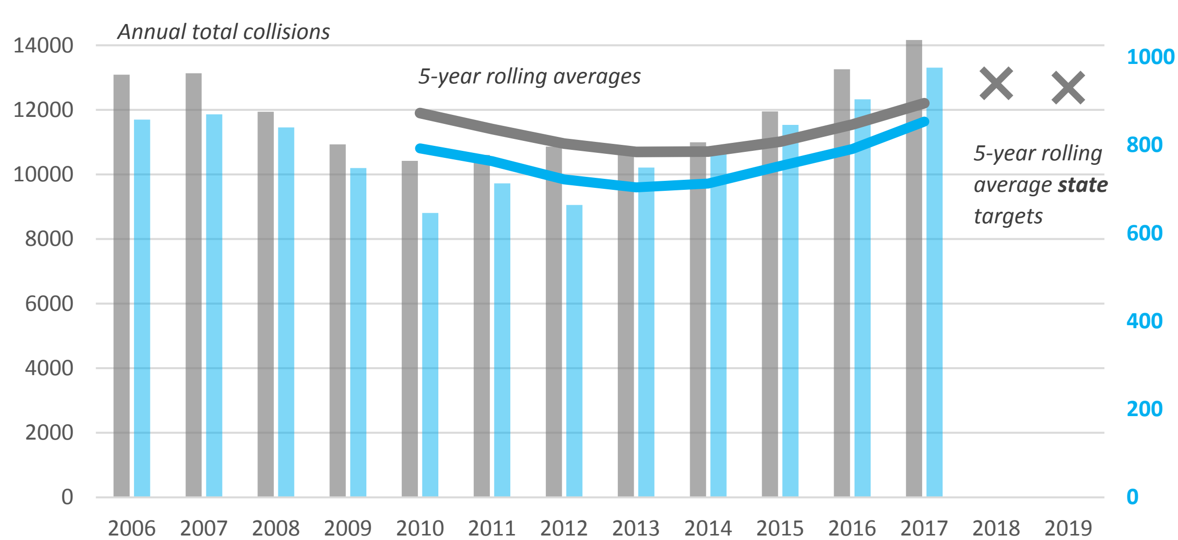


Figure 2 - 2006 - 2016 Serious Injury Collisions: State vs **Sacramento Region**



[1] UC Berkeley Safe Transportation Research and Education Center (SafeTREC) into the Transportation Injury Mapping System (TIMS). TIMS data for SACOG area fatalities use SWITRS data instead of FARS, due to spatial boundaries.

The region's 2016 collision fatality rate has returned to record highs not seen since 2007 of 1.3 fatalities per 100 million vehicle miles traveled (MVMT).[1] This is much higher than the 2016 statewide average of 1.1 fatalities per MVMT of more urban areas, such as the San Diego area with 0.8 fatalities per MVMT. But, the Sacramento region's rate is not as high as more rural areas, such as the Fresno area with 1.7 fatalities per MVMT.

Figure 3 - 2006 - 2016 Fatalities/100 MVMT: **State** vs **Sacramento Region**

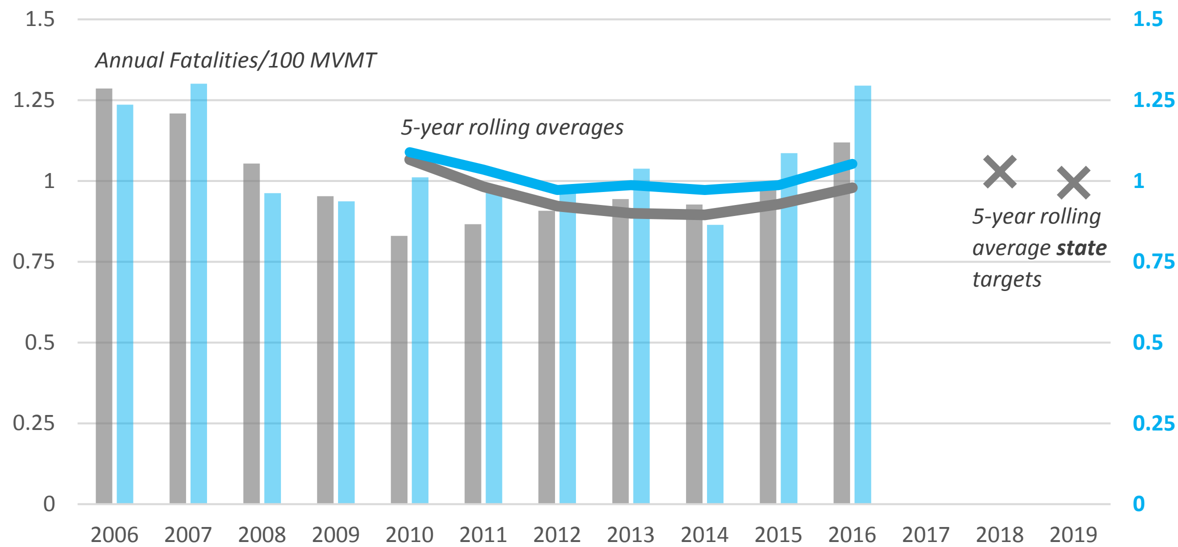
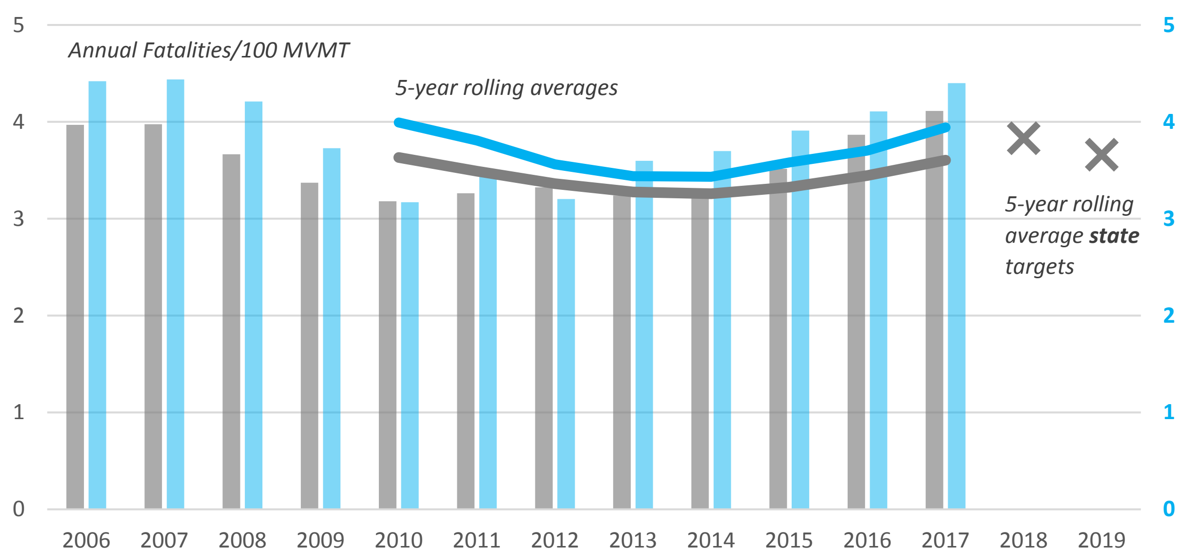


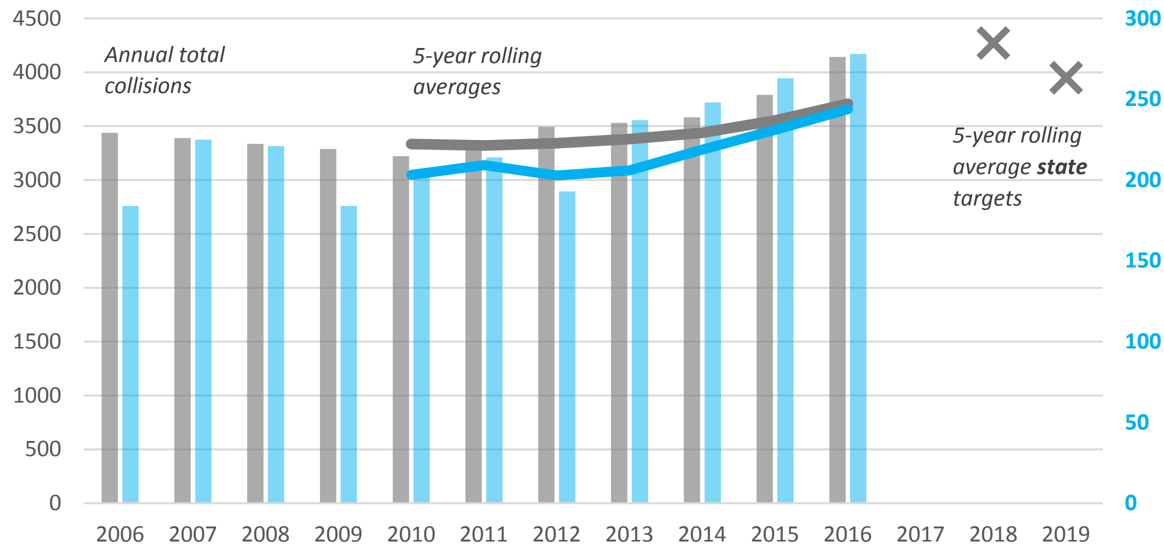
Figure 4 - 2006 - 2016 Serious Injuries/100 MVMT: **State** vs **Sacramento Region**



[1] UC Berkeley Safe Transportation Research and Education Center (SafeTREC) into the Transportation Injury Mapping System (TIMS). TIMS data for SACOG area fatalities use SWITRS data instead of FARS, due to spatial boundaries.

The region's non-motorized fatalities and serious injuries trend closely with state figures, both showing signs of increasing collisions as the economy continues to recover. [1]

Figure 5 - 2006 - 2016 Total Non-Motorized Fatalities and Serious Injuries: **State** vs **Sacramento Region**



Pavement and Bridge Condition Performance Management (PM2: Infrastructure Conditions)

Maintaining our mobility assets in a cost-effective manner is critical to reducing long-term costs for pavement and bridge rehabilitation in the MTP/SCS. The statewide targets for infrastructure condition supported by SACOG include the following 2-year and 4-year targets to maintain interstate, non-interstate and bridges on the National Highway System (NHS) by a percentage of maintained lane miles as shown below: [2]

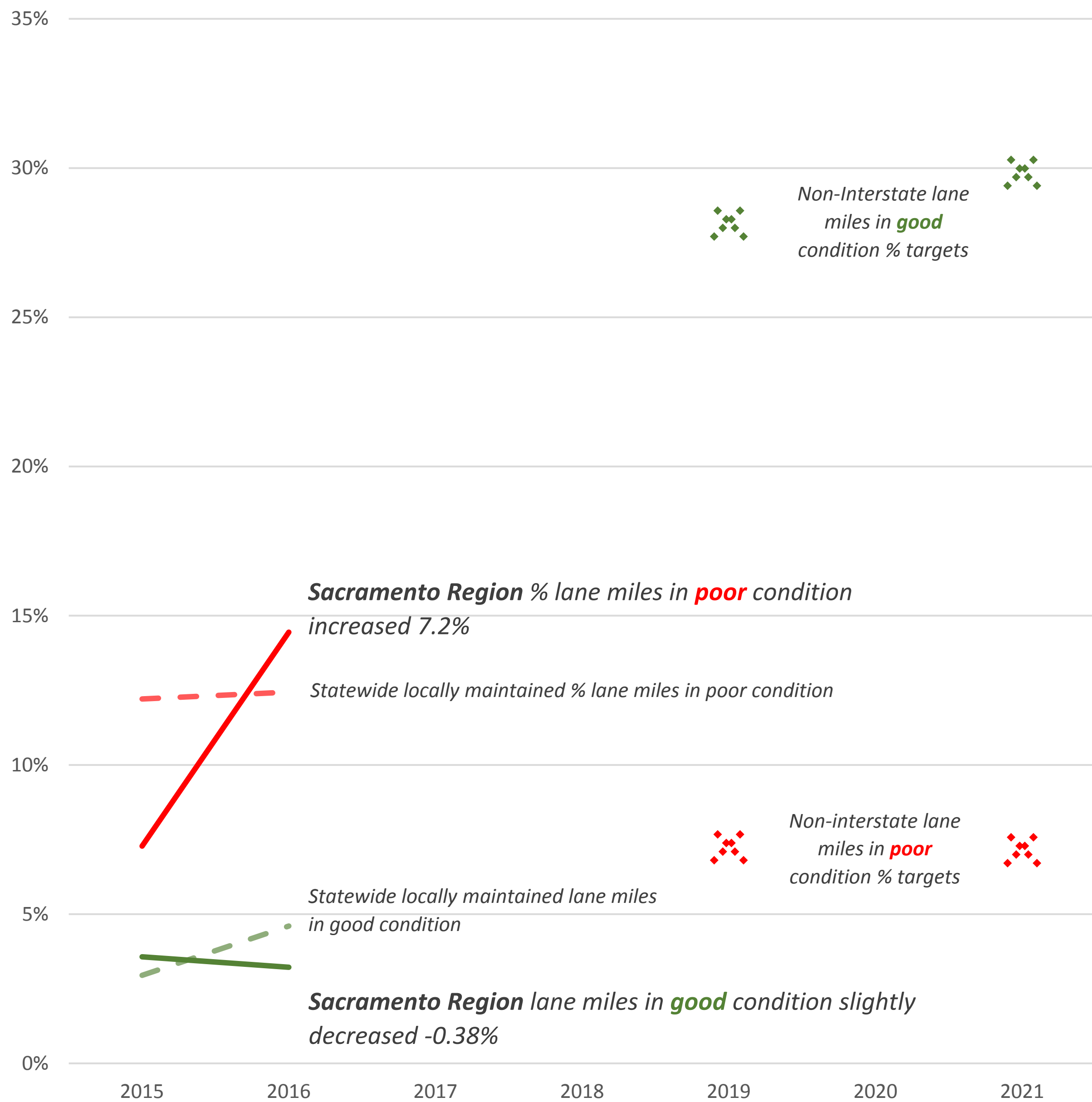
[1] UC Berkeley Safe Transportation Research and Education Center (SafeTREC) into the Transportation Injury Mapping System (TIMS) . TIMS charts for SACOG area fatalities use SWITRS data instead of FARS, due to spatial boundaries.

[2] Highway Performance Monitoring System (HPMS) Data

Figure 6 - 2015 and 2016 **Statewide NHS Interstate and Non-interstate,** Percent of Pavement Lane Miles in Good and Poor Conditions with 2019 two-year targets and 2021 four-year targets

Caltrans NHS data for 2016 and 2015 show that Caltrans made progress increasing State-maintained pavement in “Good” condition and decreasing pavement in “Fair” or “Poor” condition. Locally maintained NHS pavement remains mostly in Fair condition without much progress made.

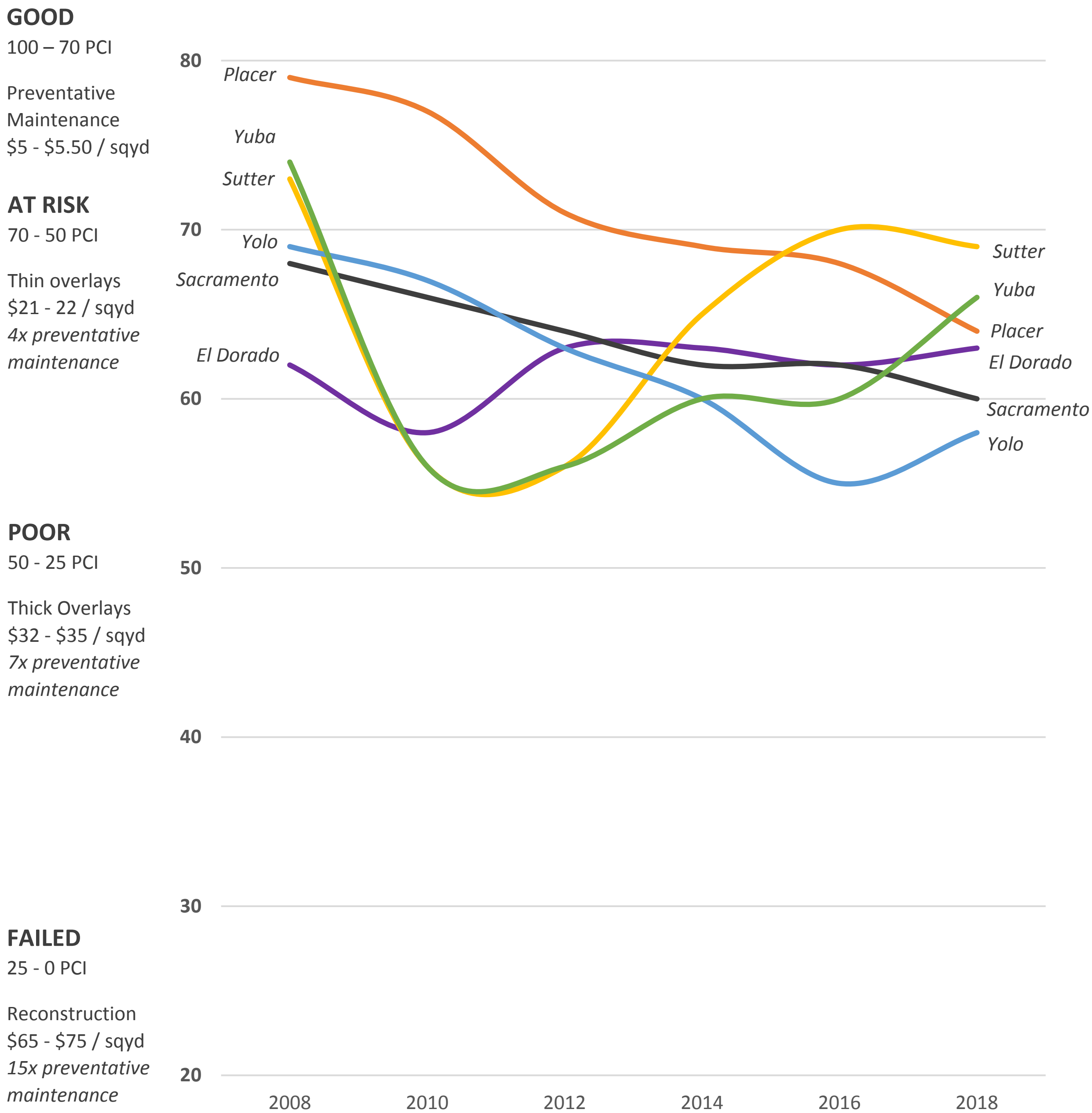
Figure 7 - 2015 and 2016 **Locally Maintained NHS Non-interstate Percent of Pavement Lane Miles**, Statewide vs Sacramento Region, with 2019 two-year targets and 2021 four-year targets



Our region's 1,149 lane miles of locally maintained NHS, mostly principle arterials feeding onto highways, is also mostly in "Fair" condition. However, this pavement is deteriorating rapidly, where 7.2% of pavement in "Good" or "Fair" condition became "Poor" over the course of a single year.

The last 10 years of California Local Streets and Roads reports for our region show that countywide pavement conditions have largely fallen, except for Sutter and Yuba county agencies.[1] The region has managed to prevent average PCI's from falling into Poor or Failed conditions.

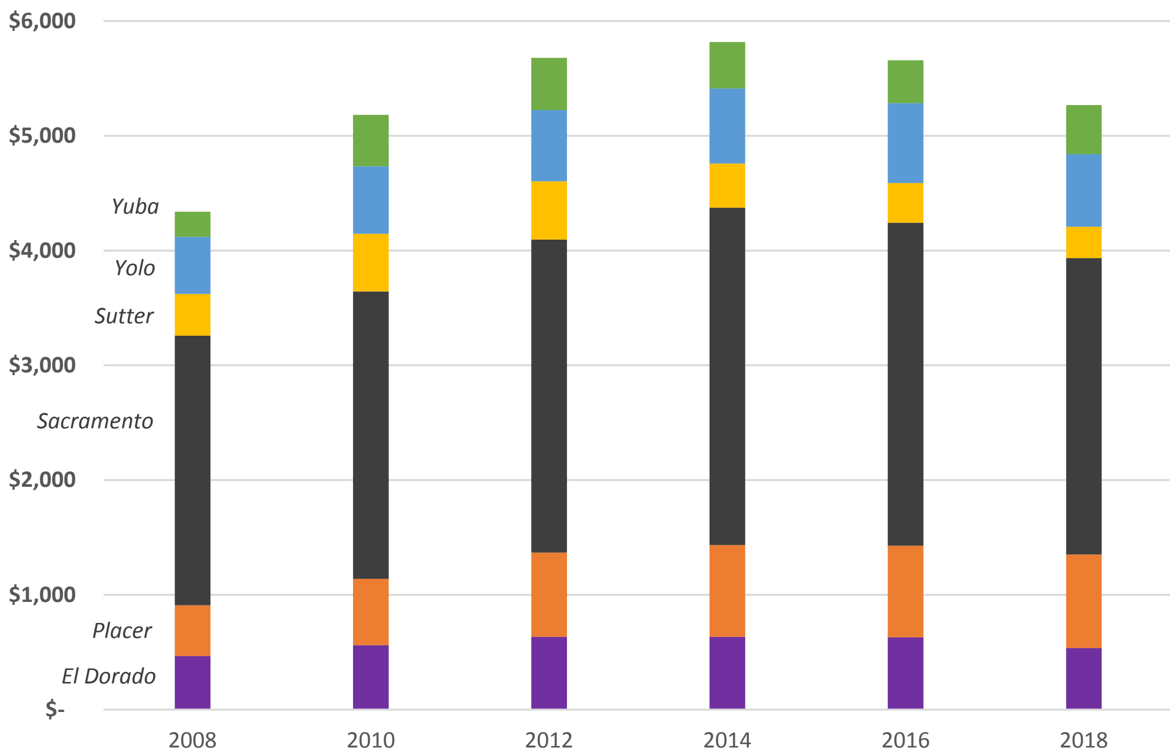
Figure 8 - Local Streets and Roads Pavement Condition Indices (PCI)
2008 to 2018 by County in the Sacramento Region



[1] California Statewide Local Streets and Roads Needs Assessments, 2008 - 2018,, https://www.cacities.org/Member-Engagement/Professional-Departments/Public-Works-Officers-Department/California-Statewide-Local-Streets-and-Roads-Needs.aspx, accessed August 2019.

As pavement conditions fall, costs to maintain pavement go up, but by how much? If you had 10 years to invest the right amount of money to avoid expensive road reconstruction costs of failed pavement, how much money would you need? 10-year pavement rehabilitation and reconstruction needs for the Sacramento Region in 2018 is over $5.2 billion, while peaking in 2014 at $5.8 billion.[1]

Figure 9 - 2008-2018 Local Streets and Road
10-year Pavement Needs (in millions) for the Sacramento Region



This is the cost to reach what the Assessment describes as "Best Management Practices."

> *In order to use taxpayer money wisely, it makes more sense to preserve and maintain roads in good condition than to wait and repair or replace them when they deteriorate or fail. The costs developed in this study are based on achieving a roadway pavement condition called Best Management Practices (BMP). At this condition level, preventive maintenance treatments (i.e., slurry seals, chip seals, thin overlays) are most cost-effective. In addition to costing less, preventive maintenance interferes less with commerce and the public's mobility and is more environmentally friendly than rehabilitation or reconstruction.*[15]

About 30 percent, or $11.6 billion, of the expenditures in the project list go to maintaining and rehabilitating the nearly 30 thousand lane miles of roads and highways in the region.

[1] California Statewide Local Streets and Roads Needs Assessments, 2008 - 2018, https://www.cacities.org/Member-Engagement/Professional-Departments/Public-Works-Officers-Department/California-Statewide-Local-Streets-and-Roads-Needs.aspx, accessed August 2019.

Example projects include:

- Caltrans District 3, “I-80 Pavement Rehabilitation B”, $343 million
- Caltrans District 3, “US 50 Pavement Rehabilitation/Bridge Improvements”, $278 million
- Caltrans District 3, “I-80 Kingvale Pavement Rehabilitation”, $93 million

The plan also includes over $3.9 billion to rehabilitate both local and Caltrans maintained bridges throughout the region, not including bridge capacity and expansion projects.

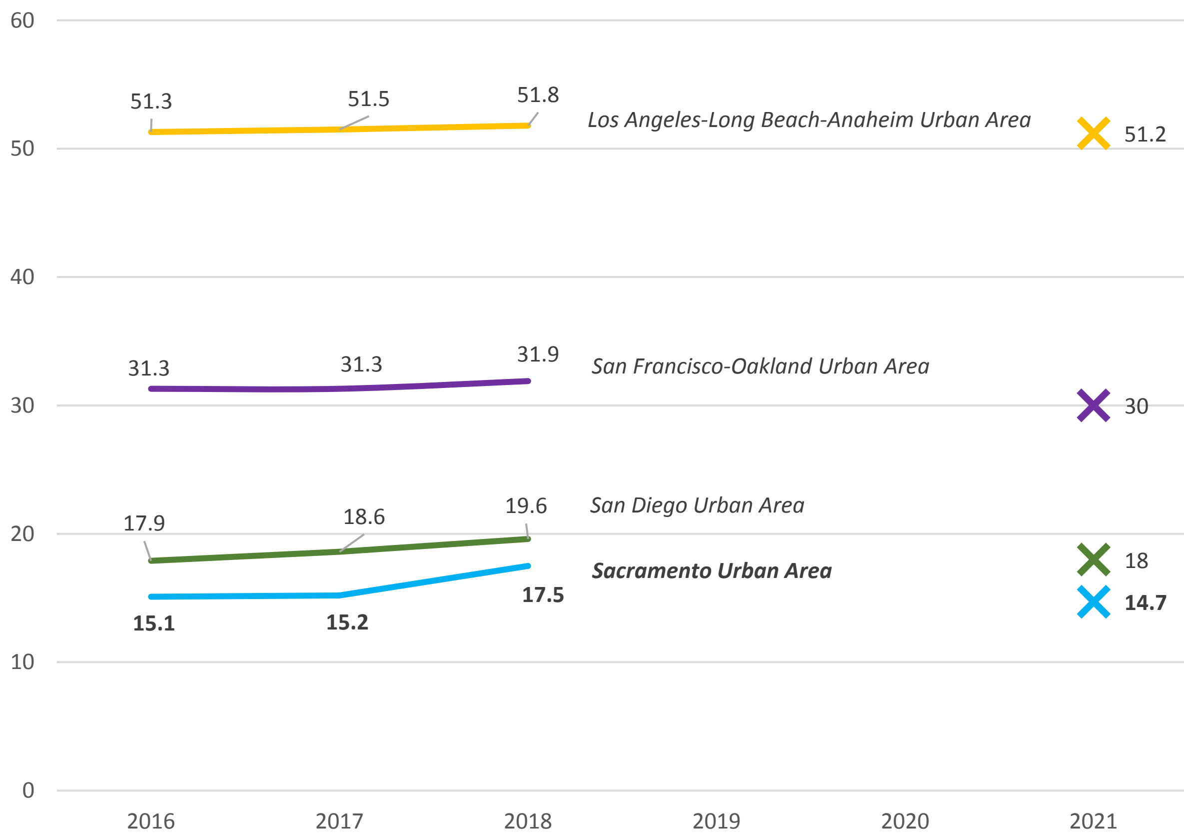
Example projects include:

- City of Sacramento, “I St. Bridge Replacement”, $172 million
- Caltrans District 3, “SR 51 Bridge Deck Replacement”, $164 million
- El Dorado County, “Mt. Murphy Rd/South Fork American River Bridge Replacement”, $32 million

System Performance Management (PM3: Freight movement, congestion, emissions and reliability)

Stuck in rush hour traffic going below the speed limit? How many minutes or hours do you think drivers do that in urban areas? In 2018, the National Performance Management Research Data set (NPMRDS) uses “big data” to calculate how the average commuter in the Sacramento Urban Area spent a total of 15.2 hours that year delayed in rush hour traffic (or about 3.5 minutes of delay per day per 261 work days in a year).[1] SACOG supports meeting this statewide target of reducing excessive delay, currently at 1% after 4 years for 2018. This sets a target for the Sacramento Urbanized area of 14.7 hours of delay.

Figure 10 - Annual Hours of Peak-hour Excessive Delay (PHED) Per Capita for Urbanized Areas in Sacramento, San Francisco, San Diego and Los Angeles with 4-year targets

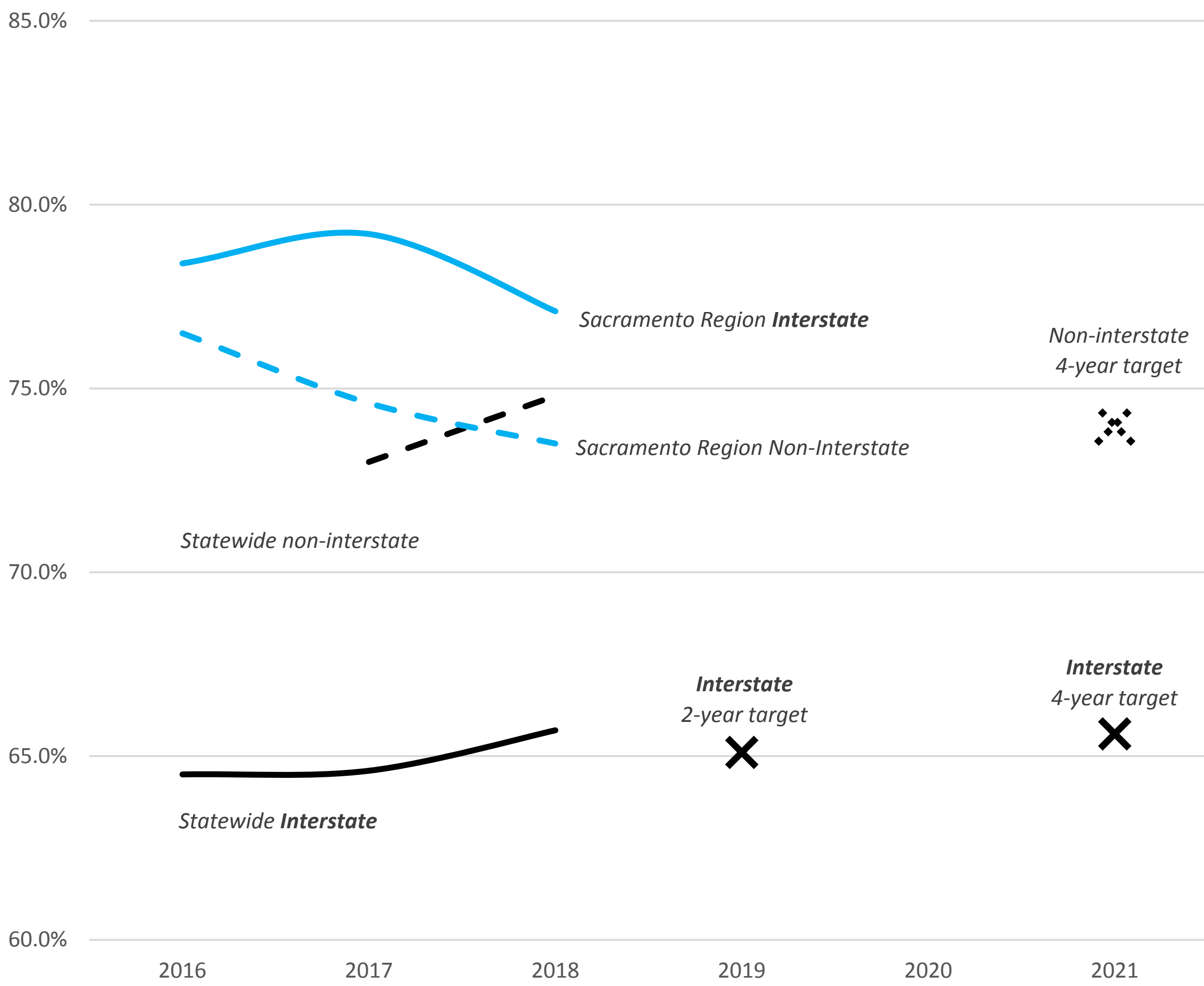


SACOG staff have spot checked the NPMRDS source data and calculations for the Sacramento Urban Area and believe that while the dataset is a useful tool for identifying delayed locations and the length of a delayed segment of highway, staff found multiple locations where the traffic count numbers used for the PHED metric differed significantly from local count data, resulting in inaccurate PHED estimates. SACOG staff plan to continue to work with NPMRDS data managers to improve the dataset’s accuracy, using their online reporting tools.

[1] National Performance Management Research Data Set (NPMRDS) Analytics Tool https://npmrds.ritis.org/analytics

Other targets include increasing the reliability of travel. Imagine someone is planning a trip. They might leave earlier to account for the possibility of unusually bad traffic or collisions (the 80th percentile) instead of typical conditions (the 50th percentile) to make sure they arrive on time. Every mile each person traveled under typical conditions is a reliable person-mile traveled. SACOG supports the statewide target of increasing the percent of reliable person-miles traveled by 1% by 2022, (currently 64% for interstates and 73% for non-interstates in 2017). The interstate system in the Sacramento Region remains more reliable at 77.1% than the statewide average of 65.7% in 2018.[1] However, the non-interstate system in the Sacramento Region appears slightly less reliable at 73.5% than the state overall at 74.8%. Again, SACOG staff continue to review the data behind the NPMRDS to improve the accuracy of these calculations.

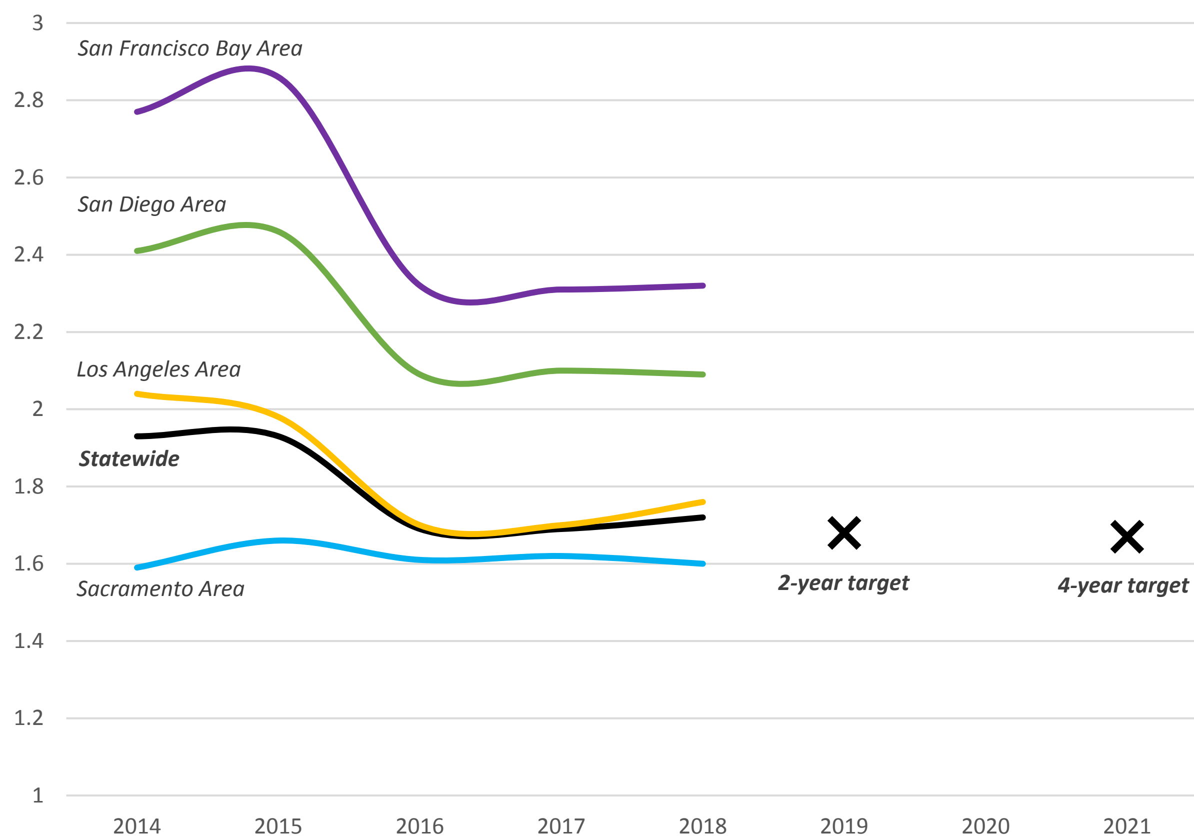
Figure 11 - 2016-2018 Percent of Reliable Person-Miles Traveled in the Sacramento Region vs State, interstate and non-interstate systems with 2-year and 4-year targets



[1] National Performance Management Research Data Set (NPMRDS) Analytics Tool https://npmrds.ritis.org/analytics

Freight reliability is calculated in a similar way, but instead of focusing on hours of delay in rush hour traffic, the Truck Travel Time Reliability is a ratio of greatly delayed truck travel times (95th percentile) divided by typical travel times (50th percentile). A ratio of 1.00 (1/1) would tell you that the worst travel times are the same as the typical travel times. A ratio of 2.00 would tell you that the worst travel times are twice as bad as typical travel times. The chart below shows NPMRDS Truck Travel Time Reliability Indices on interstates for the Sacramento Region have remained relatively stable between 1.60-1.62, which currently meets the 2-year and 4-year state targets of 1.68 and 1.76, respectively.[1]

Figure 12 - 2016-2018 Reliable Truck Travel Time (Ratio of Delay/Typical) in the Sacramento Region vs State, on the interstate and non-interstate systems with 2-year and 4-year targets



Roughly 20 percent, or $6.9 billion, of the expenditures in the project list go to road and highway capital improvements, including road widenings and new roads in growth areas, carpool and managed facilities on highways, and connections for local access to new development areas. The road expansion projects included in the MTP/SCS add about 1,000 lane miles to the regional road and highway system and are phased to align with the forecasted growth in homes and jobs. Of the 1,000 additional lane miles in the plan, more than two-thirds of the system expansion investments occur on existing roads and highways, with the remaining one-third going to new roads that serve new growth in both infill and greenfield areas.

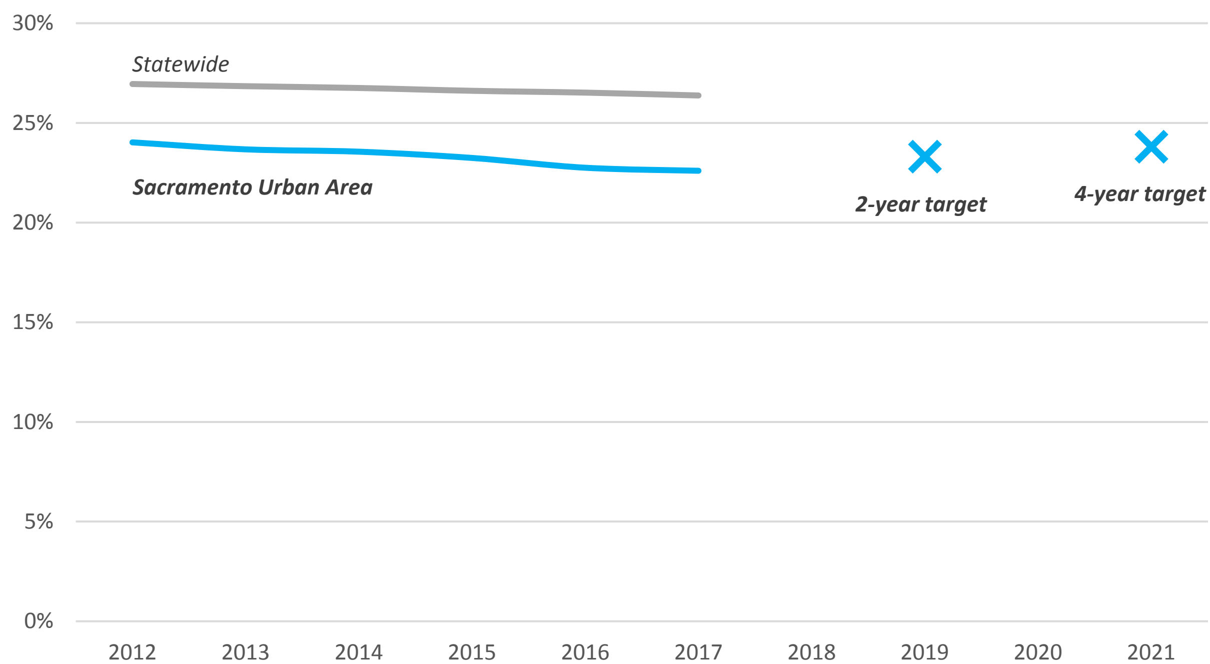
[1] National Performance Management Research Data Set (NPMRDS) Analytics Tool https://npmrds.ritis.org/analytics

Example projects include:

- Caltrans District 3, “Managed lanes on I-5, I-80, SR 99 and Business 80” - $1 billion combined
- Caltrans District 3, “State Route 51 (Capital City) Corridor Improvements: J St to Arden” - $483 million
- City of West Sacramento, “Broadway Bridge”, $255 million
- PCTPA, “I-80/SR 65 Interchange Improvements Phase 2”, $250 million
- City of Sacramento, “Lower American River Crossing”, $150 million
- City of West Sacramento, “Enterprise Crossing”, $125 million

Other performance targets include increasing the percentage of non-single occupancy vehicle travel (e.g., walk, bike, transit, carpool, etc.) by 1%, from 22.8% to 23.8%, by 2022. [1]

Figure 13 - 2012-2017 Percent of Non-Single Occupant Vehicles (SOVs) in the Sacramento Urban Area vs State,1 with 2-year and 4-year targets



About 30 percent, or $10.1 billion, of the total plan budget goes to operating and expanding transit service. The plan emphasizes more commuter and fixed-route bus services, modeled to increase regional bicycle, walk, or transit person trips per capita from 0.41 trips per capita to 0.50 trips per capita, a 23.28%.

Example projects include:

- Sacramento Regional Transit District, “Green Line: MOS2 Township 9 to North Natomas Town Center (CON)”, $390 million

[1] U.S. Census Bureau, 2012-2017 American Community Survey 5-Year Estimates

- Sacramento Regional Transit District, “Hi-bus infrastructure”, $368 million
- City of Sacramento, “Sacramento Intermodal Transportation Facility - Phase 3”, $225 million
- Capitol Corridor JPA, “Sacramento to Roseville Third Main Track - Phase 2”, $195 million
- Sacramento Regional Transit District, “Gold Line Frequency and Service Enhancements”, $195 million
- SACOG, “Sacramento-West Sacramento Downtown/Riverfront Streetcar Project (Phase 1)”, $194 million
- PCTPA, “Placer County - Bus Rapid Transit Capital”, $83 million
- Sacramento Regional Transit District, “Light Rail Low Floor Station Conversions - Gold Line”, $50 million
- Sacramento Regional Transit District, “Circulator Bus/Microtransit Expansion Vehicles”, $9.8 million

The final 16 percent, or $5.3 billion, of the plan include investments in road and highway operational and safety improvements, bicycle and pedestrian facilities, and programs such as transportation demand management (TDM) and community design funding to encourage smart-growth development projects. These expenditures also include pilot funding from the state for the Green Means Go Program, designed to lower greenhouse gases by accelerating infill development, reducing vehicle trips, and facilitating faster electric vehicle deployment.

Example projects include:

- City of Sacramento, “Central City Specific Plan Multi-modal improvements”, $165 million
- City of Sacramento, “River District Transportation Improvements”, $120 million
- City of Rancho Cordova, “Zinfandel Complex Improvements - Phase2”, $46 million
- City of Roseville, “Bicycle Master Plan Class I Trail Buildout”, $45 million
- Yuba County, “Marysville Road Bicycle Lane Project”, $18 million
- City of Citrus Heights, “Saybrook/Misty Creek I-80 Pedestrian/bicycle overpass”, $15 million

Many projects that rehabilitate local streets and roads also plan for the mobility of all users as complete street projects. The MTP/SCS makes provisions for the inclusion of complete streets by including lump sums in the project list for bicycle, pedestrian, and roadway improvements that can improve a roadway’s accessibility to all users and through policies and strategies that encourage complete streets considerations whenever feasible.

Example projects include:

- City of Citrus Heights, “Auburn Blvd Complete Streets (phases 2-5)”, $106 million combined
- City of Rancho Cordova, “Complete Streets Rehabilitation - Sunrise Blvd”, $35 million
- City of Sacramento, “Broadway Complete Street Phase I & 2”, $8 million
- Sacramento County, “Folsom Boulevard Complete Street Improvements, Phase 1”, $5 million

Emissions Reductions by Applicable Pollutants under the CMAQ Program

The investments cited in the 2018 Sacramento Urbanized Area Congestion Mitigation and Air Quality Improvement Program Performance Plan, for the baseline performance period report 2018-2021, contribute to meeting the statewide targets for Total Emissions Reductions by Applicable Pollutants under the CMAQ Program: VOC (kg/day), CO (kg/day), NOx (kg/day), PM10 (kg/day), and PM2.5 (kg/day).

During the current performance period (2018-2021), 59 projects are expected to obligate CMAQ funds. A list of these projects is provided in the table below, and includes a description of how each project is anticipated to contribute towards achieving the performance targets for traffic congestion and on-road mobile source emissions.

Since the statewide baseline conditions reflect CMAQ funded projects that first obligated CMAQ funds between 2014 and 2017, the projects listed in Figure B only reflect CMAQ funded projects during the 2018-2021 performance period.

FHWA notes that reporting emissions benefits for each CMAQ project is not required but “could discuss relevant estimates of emissions reductions in order to demonstrate how the projects will contribute to the relevant targets.” SACOG estimates and records CMAQ project emissions benefits as directed by the California Air Resources Board’s (ARB) 2005 guidance document, “Methods to Find the Cost-Effectiveness of Funding Air Quality Projects for Evaluating Motor Vehicle Registration Fee Projects and CMAQ Projects.” The emissions benefits calculated focus on VOC, NOx, PM10 and PM2.5 criteria pollutants. SACOG does not include estimates of CO emissions benefits at this time, but may do so in the future for traffic signal synchronization projects. The ARB guidance notes that “CO is a localized pollutant and not a regional pollution problem” where CMAQ projects are usually “funded primarily to reduce regional ozone and PM10 and have little impact on localized CO hot spots.” The Air Resources Board does note that “signal coordination projects, however, may be targeted at specific CO hot spots in CO nonattainment areas” and that “reporting CO emission reductions should be limited to targeted projects located in CO nonattainment or maintenance areas.”

Table 4 - Description of Projects in CMAQ Performance Plan for 2018-2021 Performance Period

Title	Lead Agency	1st CMAQ Obligation Year	VOC Benefit kg/day	CO benefit kg/day	NOx Benefit kg/day	PM10 Benefit kg/day	PM2.5 Benefit kg/day	Traffic Congestion Benefit? Peak-hour Excessive Delay	Traffic Congestion Benefit? Non-SOV Mode Share
Bell Road at I-80 Roundabouts	Placer County	2019	0.25		0.19		0.01	Yes	
CNG Bus	Placer County	2018	*	*	*	*	*	Yes	Yes
Cook Riolo Road Pathway	Placer County	2018	0.04		0.02	0.01	0.01		Yes
D W Babcock School Access Improvements	City of Sacramento	2019	0.05		0.03	0.01	0.01		Yes
Downtown Pedestrian Bridge	City of Roseville	2018	0.18		0.11		0.04		Yes
Dry Creek Greenway Trail	City of Roseville	2021	0.09		0.07		0.03		Yes
El Dorado County Fleet Electrification - EV Infrastructure	El Dorado County	2019	0.14		0.15	0.06	0.06		
El Dorado County Fleet Electrification/Hybrid	El Dorado County	2019	0.14		0.15	0.06	0.06		
El Dorado Hills Boulevard Class 1 Trail	El Dorado County	2019	0.08		0.04	0.02	0.02		Yes
El Dorado Trail - Missouri Flat Road Bike/Pedestrian Overcrossing	El Dorado County	2019	0.07		0.04	0.02			Yes
El Dorado Trail Ext. - Los Trampas Dr to Halcon Rd	El Dorado County	2018	0.01						Yes
Fair Oaks Boulevard Improvements, Phase 3	Sacramento County	2019	0.05		0.04	0.02	0.02		Yes

Title	Lead Agency	1st CMAQ Obligation Year	VOC Benefit kg/day	CO benefit kg/day	NOx Benefit kg/day	PM10 Benefit kg/day	PM2.5 Benefit kg/day	Traffic Congestion Benefit? Peak-hour Excessive Delay	Traffic Congestion Benefit? Non-SOV Mode Share
Florin Creek Trail/SOFA Bike & Pedestrian Improvements	Sacramento County	2018	0.01						Yes
Folsom Blvd Complete Streets Phase 5 (Bradshaw to Horn)	City of Rancho Cordova	2020	*	*	*	*	*		Yes
Folsom Blvd. Complete Streets Rehabilitation	City of Sacramento	2018	0.13		0.1	0.06			Yes
Folsom Blvd./Power Inn Rd. Intersection (Ramona Ave Phase I)	City of Sacramento	2018	0.05		0.04	0.02	0.02	Yes	
Folsom Cottage Sidewalk Infill	Sacramento County	2018	1.27		0.77	0.13			Yes
Folsom/Placerville Rail Trail	City of Folsom	2019	0.04		0.03	0.01	0.01		Yes
Franklin Ave. Pedestrian Improvements	City of Yuba City	2019	0.1		0.06	0.02	0.02		Yes
Franklin Cycle Track	City of Sacramento	2019	0.02		0.01	0.01	0.01		Yes
Garfield Ave. Bike Lanes and Pedestrian Connectivity Project	Sacramento County	2018	0.03		0.07	0.01			Yes
Hazel Avenue Sidewalk Improvements	Sacramento County	2018	0.07		0.05	0.02	0.02		Yes
Highway 49 Sidewalk Gap Closure	PCTPA	2018	0.06		0.04		0.01		Yes
I-80 HOV Across the Top	Caltrans D3	2018	67		62	55		Yes	Yes
Laguna Creek Trail and Bruceville Rd Sidewalks	City of Elk Grove	2020	0.08		0.06	0.04	0.04		Yes

Title	Lead Agency	1st CMAQ Obligation Year	VOC Benefit kg/day	CO benefit kg/day	NOx Benefit kg/day	PM10 Benefit kg/day	PM2.5 Benefit kg/day	Traffic Congestion Benefit? Peak-hour Excessive Delay	Traffic Congestion Benefit? Non-SOV Mode Share
Lake Natoma Trail – Gap Closure	City of Folsom	2018	0.01		0.01				Yes
Lincoln Boulevard Streetscape Improvements Project Phase 3	City of Lincoln	2020	0.08		0.05	0.02	0.02		Yes
Live Oak Community Trail Segment 4	City of Live Oak	2019	0.01		0.01				Yes
Mariposa Safe Routes to School Phase 3	City of Citrus Heights	2018	0.01						Yes
Martis Valley Trail	Placer County	2018	0.01		0.01				Yes
Meadowview Rd. Streetscape Phase 1	City of Sacramento	2019	*	*	*	*	*		Yes
Merrychase and Country Club Drive Bicycle and Pedestrian Improvements	El Dorado County	2019	0.04		0.03	0.01	0.01		Yes
Nevada Street Pedestrian & Bicycle Facilities	City of Auburn	2019	0.03		0.02				Yes
New York Creek Trail East - Phase 2	El Dorado County	2018	0.02		0.01				Yes
Oak Street Extension of Miners Ravine Trail	City of Roseville	2020	0.05		0.04		0.01		Yes
Pacific St at Rocklin Road Roundabout	City of Rocklin	2020	0.26		0.21		0.01	Yes	
Placer County Congestion Management Program	PCTPA	2019	11.44		11.59		5.54		Yes
Placer County Freeway Service Patrol	PCTPA	2021	5.62		2.25		0.34	Yes	

Title	Lead Agency	1st CMAQ Obligation Year	VOC Benefit kg/day	CO benefit kg/day	NOx Benefit kg/day	PM10 Benefit kg/day	PM2.5 Benefit kg/day	Traffic Congestion Benefit? Peak-hour Excessive Delay	Traffic Congestion Benefit? Non-SOV Mode Share
Placerville Drive Bicycle and Pedestrian Facilities	City of Placerville	2019	0.08		0.04	0.02	0.02		Yes
S. Auburn St. & I-80 Roundabout	City of Colfax	2018	0.05		0.05		0.01	Yes	
SECAT Program Phase 3	SMAQMD	2018	9		236	21			
Silva Valley Parkway at Harvard Way Intersection Improvements	El Dorado County	2018	0.03		0.02			Yes	
Silva Valley Pkwy Class I/II Bike Path - Harvard Wy to Green Valley Rd	El Dorado County	2018	0.02		0.01				Yes
South Sacramento Parkway Trail - West	City of Sacramento	2019	0.12		0.07	0.02	0.02		Yes
Spare the Air Phase 2	SMAQMD	2018	0.2		0.2				
Spare the Air Phase 3	SMAQMD	2021	0.2		0.2				
Sycamore Park Phase 2 and 3 Bicycle and Pedestrian Overpass	City of West Sacramento	2018	0.02		0.01	0.01	0.01		Yes
Sycamore Trail/Westacre and Bryte Bicycle Routes	City of West Sacramento	2018	0.12		0.06	0.03	0.03		Yes
Town Center Implementation Plan Improvements Phase 4	Town of Loomis	2019	0.03		0.02	0.01	0.01		Yes
Transportation Demand Management (TDM) Phase 3	SACOG	2020	0.54		0.5				Yes
Two Rivers Trail Phase II	City of Sacramento	2019	0.02		0.02	0.02			Yes

Title	Lead Agency	1st CMAQ Obligation Year	VOC Benefit kg/day	CO benefit kg/day	NOx Benefit kg/day	PM10 Benefit kg/day	PM2.5 Benefit kg/day	Traffic Congestion Benefit? Peak-hour Excessive Delay	Traffic Congestion Benefit? Non-SOV Mode Share
Washington Bl/All America City Bl Roundabout	City of Roseville	2020	*	*	*	*	*	Yes	
Washington Blvd/Andora Undercrossing Improvement Project	City of Roseville	2020	0.9		0.51	0.16		Yes	
Washington Boulevard Bikeway and Pedestrian Pathways Project	City of Roseville	2020	0.63		0.45	0.49			Yes
West Main Street Bicycle/Pedestrian Mobility and Safety Improvements	City of Woodland	2018	0.05		0.03	0.01	0.01		Yes
West Woodland SRTS	City of Woodland	2018	0.05		0.04	0.01	0.01		Yes
Western Placerville Interchange (Ray Lawyer Drive Park and Ride Lot)	El Dorado County Transit	2018	0.63		0.45	0.49		Yes	
Western Placerville Interchanges Phase 2	City of Placerville	2018	0.03		0.02			Yes	

2020 RTP Performance

This section describes how implementing the MTP/SCS would result in changes to the region. Regional model outputs are summarized by the following topics with some related to PM2 and PM3 metrics.

- Land Use Patterns
- Housing Mix
- Access to Employment Activities
- Road and highway System (Related to PM2)
- Transit System (Related to PM3)
- Travel Choice and Traffic (Related to PM3)
- Vehicle Miles of Traveled
- Greenhouse Gas Emissions (Related to PM3)

Land Use Patterns

The MTP/SCS includes growth in a variety of communities throughout the region to provide residents with choices on where to live and work. The land use forecast assumes 64 percent of new homes will occur in infill areas, which are characterized in the MTP/SCS as Established Communities and Center and Corridor Communities. By 2040, the MTP/SCS forecasts that more homes, 17 percent of all homes compared to 12 percent in 2016, will be in Center & Corridor Communities where residents access to the greatest mix of amenities, jobs, and transportation options.

Table 5 – Share of Homes by Community Type

Performance Metric	2016 Baseline	Change (2016-2040)	By 2040
Share of homes in Center & Corridor Communities *(percent of total homes in region)*	113,880 *12%*	86,661 *33%*	200,541 *17%*
Share of homes in Established Communities *(percent of total homes in region)*	712,012 *77%*	81,365 *31%*	793,377 *67%*
Share of homes in Developing Communities *(percent of total homes in region)*	20,793 *2%*	89,313 *34%*	110,106 *9%*
Share of homes in Rural Residential Communities *(percent of total homes in region)*	74,438 *8%*	2,789 *1%*	77,227 *7%*
Total Homes	**921,123**	**260,128**	**1,181,251**

Housing Mix

The region has most of its homes today in large-lot, single-family products (60 percent in 2016). The MTP/SCS plans to provide a greater diversity of homes for future residents by increasing the number of small-lot and attached housing available throughout the region. To achieve more housing choices by 2040, the MTP/SCS forecasts 74 percent of new homes over the next 20 years to be small-lot or attached products.

Table 6 – Share of Homes, Rural Residential/Large Lot vs. Small Lot/Attached Homes

Performance Metric	**2016 Baseline**	**Change (2016-2040)**	**By 2040**
Share of homes in rural residential and large-lot single-family homes	553,334	+68,580	621,914
(percent of total homes in region)	*60%*	*26%*	*53%*
Share of homes in small-lot single-family or attached homes	367,789	191,548	559,337
(percent of total homes in region)	*40%*	*74%*	*47%*

Access to Employment Activities

Access, in this instance, means the number of activities a person can reach within a given travel time and mode. Improved access to jobs correlates strongly with lower vehicle miles traveled. Access can be increased in two ways: 1) improving travel speeds, and increasing the area one can reach within 30 minutes; 2) putting more activities closer to homes through more focused growth. The MTP/SCS affects both, through more infill and compact development, reduction of congestion on key corridors for drivers, and improvements to transit service to reduce transit travel times.

The MTP/SCS also greatly improves access to jobs from environmental justice areas. Environmental Justice areas are places in region with concentrations of lower income and/or minority residents, single-parent households, elderly residents, non-English speaking residents, residents with less than high school degrees, and disabled residents.

Table 7 – Access to Jobs from Homes by 30-minute Drive and Transit Times and from Environmental Justice Areas

Performance Metric	**2016 Baseline**	**Change (2016-2040)**	**By 2040**
Jobs within 30-minute drive of homes	377,257	109,539	486,796
Jobs within 30-minute transit of homes	4,829	17,534	22,362
Jobs within 30-minute drive of homes in environmental justice areas	457,670	150,943	608,612
Jobs within 30-minute transit of homes in environmental justice areas	6,670	25,872	32,542

Average VMT per worker to jobs centers captures both trip length and mode of travel. Average VMT per worker can be reduced by shortening the commute, or by shifting more travel into non-vehicle modes like biking or walking. The MTP/SCS shortens commutes, by improving jobs-housing ratios, and enhances non-vehicle and transit modes to jobs centers.

Table 8 - Average Vehicle Miles Traveled per Worker to Jobs Centers

Performance Metric	2016 Baseline	Change (2016-2040)	By 2040
Average vehicle miles traveled per worker to jobs centers	17.4	n/a	15.39

Road and highway System

Increase in lane miles of major roads and highways by about 19 percent compared to 2016. More than two-thirds of this increase is on existing facilities and phased to add capacity as housing and employment growth occur. The MTP/SCS does not include significant road and highway expansion for growth that is anticipated to happen beyond the 20-year period of the plan, but might eventually be needed to accommodate local general plans.

Table 9 - New or Expanded Major Road Lane Miles

Performance Metric	2016 Baseline	Change (2016-2040)	By 2040	Average Lane Miles added per Year
New or Expanded Major Road Lane Miles	6,465	1,258	7,722	52

Transit System

The MTP/SCS doubles transit service hours by 2040 compared to 2016. This service increase comes primarily from commuter and fixed-route buses, with a smaller increment coming from light rail. The transit network in the MTP/SCS emphasizes increased frequencies on productive transit routes near homes to provide faster access to jobs and job centers.

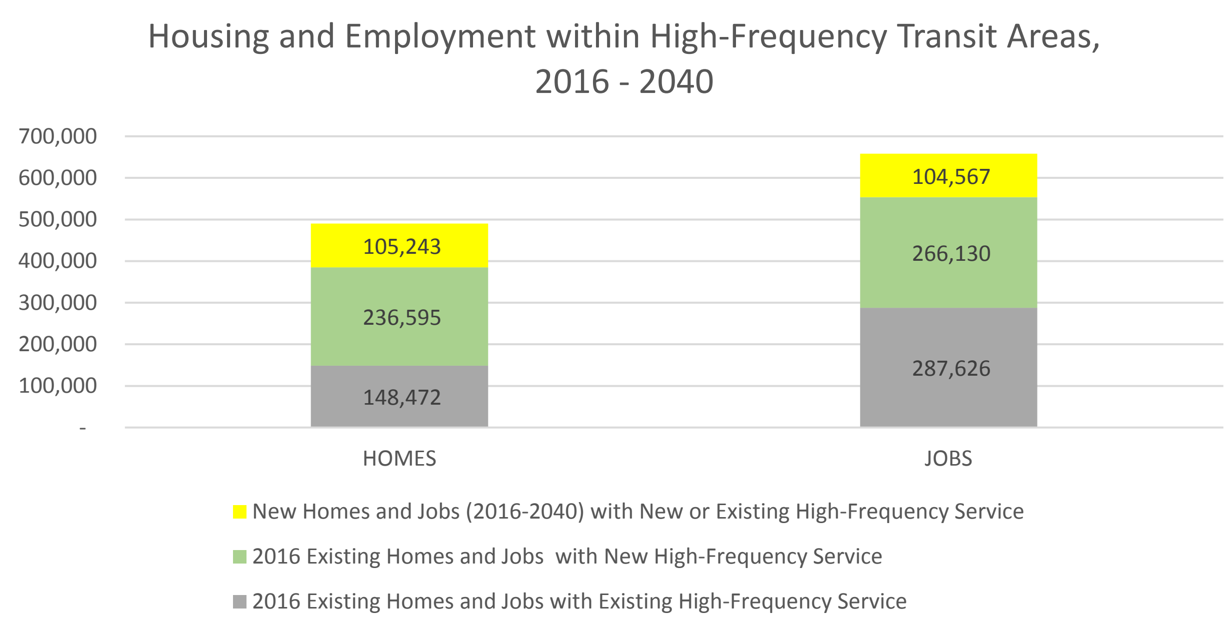
Table 10 - Weekday Transit Revenue Service Hours by Service Type 2016 and 2040 Proposed MTP/SCS

Service Types	2016	2040 MTP/SCS	Change from 2016	
			#	%
Light Rail	301	385	+84	28%
Tram/Streetcar	0	86	+86	N/A
Express Bus	336	826	+490	146%
BRT/Fixed Route Bus	2,962	5,948	+2,986	101%
Shuttle	369	907	+538	146%
Regional Rail	26	57	+31	119%
Regional Total	3,994	8,209	4,215	106%

Population (thousands)	2376.3	2996.8	620.5	26%
Service Hours Per Capita (x 1000)	1.68	2.74	1.1	63%

The numbers of homes and jobs near high-frequency transit service, with vehicles coming at least every 15 minutes, more than double by 2040

Figure 14 - Housing and Employment within High-Frequency Transit Areas, 2016 - 2040



Travel Choice and Traffic

The MTP/SCS provides more opportunities for residents to choose to travel by transit, biking, or walking. This is made possible by developing in a way that allows people to live closer to jobs and amenities and investing in transit, bicycle and pedestrian infrastructure, and programs to encourage options that do not rely on driving.

Table 11 - Non-Auto Mode of Travel for SACOG Region, 2016 and 2040

Performance Metric	**2016 Baseline**	**Change (2016-2040)**	**By 2040**
Share of commute trips by transit, bike or walk to jobs centers	13%	n/a	18%
Mode share for transit, walking and bicycling (percent of all trips)	12%	n/a	14%

Table 12 - Mode of Commute and Non-commute Travel for SACOG Region, 2016 and 2040

Weekday Commute Trips

Mode	2016	2040	Change
Drive Alone	1,702,550	2,038,695	+336,145
Carpool	383,140	481,265	+98,125
Transit	32,005	83,676	+51,671
Bike	51,161	84,677	+33,516
Walk	148,952	227,717	+78,765
Other			
Total	2,317,808	2,916,030	+598,222
Commute Mode Share			
Drive Alone	73.5%	69.9%	-3.5%
Carpool	16.5%	16.5%	-.0%
Transit	1.4%	2.9%	+1.5%
Bike	2.2%	2.9%	+.7%
Walk	6.4%	7.8%	+1.4%
Other	n/a	n/a	n/a
Work At Home Workers	51,264	90,021	+38,757
Total Workers	945,446	1,191,610	+246,164
% Work At Home Workers	5.4%	7.6%	+2.1%

Weekday Non-Commute Trips

Mode	2016	2040	Change
Drive Alone	1,812,523	2,316,096	+503,573
Carpool	3,380,284	4,053,132	+672,848
Transit	69,029	165,753	+96,724
Bike	158,961	213,462	+54,501
Walk	503,336	720,289	+216,953
Other	101,289	101993	+704
Total	5,924,133	7,468,732	+1,544,599
Non-Commute Mode Share			
Drive Alone	30.6%	31.0%	+.4%
Carpool	57.1%	54.3%	-2.8%
Transit	1.2%	2.2%	+1.1%
Bike	2.7%	2.9%	+.2%
Walk	8.5%	9.6%	+1.1%
Other	1.7%	1.4%	-.3%

The MTP/SCS reduces the amount of travel on heavily congested roadways by 2040 in three ways; 1) targeting capacity investments where traffic bottlenecks occur; 2) providing options to take non-driving modes and reducing vehicle demand during peak travel hours; and 3) providing express lanes in some congested corridors, allowing more travelers access to less congested facilities.

Table 13 provides a tabulation of congested VMT in the SACOG region by household-generated, and all other sources including commercial vehicle and external. Household-generated congested VMT per capita declines a little bit from 2016 to 2040, with a decrease of 1.6 percent. Regional total congested VMT per capita declines from 1.56 in 2016 to 1.53 in 2040, a 2.4 percent decrease.

Table 13 - Congested Vehicle Miles Traveled by Source in SACOG Region 2016 and 2040 MTP/SCS

Variable	2016	2040 MTP/SCS
Weekday Congested VMT (CVMT) by Source		
Household-Generated Commute CVMT [1]	1,575,800	1,894,200
Household-Generated Other CVMT [1]	1,335,600	1,717,976
Total Household-Gen. CVMT [1]	2,911,400	3,612,176
Commute Share of HH-Gen CVMT	54%	52%
Commercial Vehicle/Through-Travel CVMT [2]	804,600	961,724
Total CVMT	3,716,000	4,573,900
Per Capita or Per Job Rates		
Population	2,376,300	2,996,800
Household-Generated CVMT per Capita	1.2	1.2
Total CVMT per Capita	1.56	1.53
Percent Changes in CVMT Per Capita or Per Job, compared to 2016		
HH-Generated CVMT per Capita		-1.6%
Total CVMT per Capita		-2.4%

1 Household-generated CVMT is cumulative vehicle travel by residents of the region on roadways which are at-or-above capacity, for their travel within the region. Household-generated CVMT is split into commute and other shares.

2 Commercial vehicle CVMT is cumulative vehicle travel for moving goods, services and freight within the region. It includes commercial travel in passenger vehicles, light trucks, and vans as well as in larger trucks. Externally generated VMT is cumulative vehicle travel from residents outside the region, but who travel to destinations within the region, or travel through the region.

Vehicle Miles Traveled

Table 14 shows VMT by three sources in the region for 2016 and 2040: household-generated, commercial vehicle, and external.

Household-generated, which includes all travel by residents of the region for work, school, shopping and other household purposes, accounts for almost three-quarters of all VMT in all scenarios. Household-generated VMT per capita is projected to decrease from 17.9 miles in 2016 to 16.5 miles by 2040, a decrease of 7.9 percent.

Commute travel includes all travel by workers from home to work and back home, including any intermediate stops for other non-work activities (e.g., to drop off a child at school, to shop, or to attend to personal business). It accounts for about 44% of total household-generated VMT.

Commercial vehicle travel includes vehicles of all types which are transporting services or goods on road-ways within the SACOG region. This source of VMT is not just bigger, multi-axle trucks—it includes transportation of services (e.g. office equipment repair, plumbers, home delivery) which may use smaller vans or even passenger vehicles, as well as small-to-medium sized trucks.

Combining all sources of VMT, including external and through travel VMT, forecasted VMT per capita declines from 24.6 miles to 23.3 miles from 2016 to 2040, a 5.3 percent decrease.

Table 14 - Vehicle Miles Traveled by Source in SACOG Region 2016 and 2040 MTP/SCS

Variable	2016	2040 MTP/SCS
Weekday VMT by Source		
Household-Generated Commute VMT [1]	18,879,600	21,668,600
Household-Generated Other VMT [1]	23,700,000	27,810,200
Total Household-Gen. VMT [1]	42,579,600	49,478,800
Commute Share of HH-Gen VMT	44%	44%
Commercial Vehicle VMT [2]	9,216,100	11,639,800
Through-Travel VMT [3]	6,644,100	8,706,400
Total VMT	**58,439,800**	**69,825,000**
Per Capita or Per Job Rates		
Population	2,376,300	2,996,800
Jobs	1,060,700	1,332,300
Household-Generated VMT per Capita	17.9	16.5
Commercial Vehicle VMT per Job	8.7	8.7
Total VMT per Capita	24.6	23.3
Percent Changes in VMT Per Capita or Per Job, compared to 2016		
HH-Generated VMT per Capita		-7.9%
Commercial Vehicle VMT per Job		0.6%
Total VMT per Capita		-5.3%

Source: SACOG, September 2019.

[1] Includes travel by residents of households within the SACOG region, plus travel within the SACOG region by households outside the region. Total household-generated VMT is split into commute (i.e., all VMT generated by workers going from home to work and back, with any stops along the way), and other (all non-commute).

[2] Commercial vehicle VMT is cumulative vehicle travel for moving goods, services and freight within the region. It includes commercial travel in passenger vehicles, light trucks, and vans as well as in larger trucks.

[3] Through-travel VMT is all travel on roadways passing through the SACOG region.

Greenhouse Gas Emissions

The assumptions and indicators described in the MTP/SCS offer the best path to achieving the 19 percent per capita greenhouse gas (GHG) emissions reduction target assigned to SACOG by the California Air Resources Board (CARB). Table 15 provides the bottom line calculation of the GHG reduction, which is subject to review of CARB, upon adoption of the SCS by SACOG. A more detailed breakdown of the GHG reduction is provided below.

Table 15 – SB 375 Greenhouse Gas Emissions Reduction

Performance Metric	2005 Baseline	2040 MTP/SCS	% of Reduction
Weekday passenger vehicle CO2 emissions (percent change per capita from 2005)	23.2	18.9	-19%

The SB 375 GHG emissions reduction target is unique, in that the base year (2005) and horizon year (2035) are different than the base year and horizon year for the proposed MTP/SCS, and the formula for calculating the reduction is very complicated. All aspects of the target are determined by the California Air Resources Board (CARB). Several fundamentals of the calculation are worth noting, though. The calculation is based on vehicle activities forecasted by SACSIM19 travel demand model, with vehicle fleet forecasts and emissions calculated using versions of the state's EMFAC emissions models[20]. Both models (SACSIM19 and EMAC) are required to calculate the target, with EMFAC being used as a post-process to each SACSIM19 model run needed to calculate the emissions. In short, the MTP/SCS factors generating the GHG reduction can be reasonably approximated, but there is no precise way of calculating the exact contribution of each factor precisely.

Given these limitations, though, there is a strong interest in understanding the connection between the target and specific factors and effects that are included in the proposed MTP/SCS. Table 16 provides an accounting of these factors and effects.

Table 16 --Breakdown of SB 375 GHG Reduction Factors

		Approx. Reduction
MTP/SCS Policy & Program – Related Factors		
	Increased Non-SOV Mode Share	6%
	Shortened Vehicle Trips	5%
	Pricing & Pay-As-You-Go Fees	2-3%
	ITS & TSM	+/- 0.5%
	Local EV Programs	+/- 0.5%
Exogenous Factors		
	Aging Population	2%
	Increase in Auto Cost	3%
Total Reduction		+/-19%

Source: SACOG, 2019.

For the factors related to the policies and programs of the MTP/SCS, the approach to estimating the approximate share of the GHG reduction are described below.

- For increased Non-SOV mode share, the trip length and increase in trip rate for transit, bike and walk trips was calculated for year 2005 and year 2035 using the SACSIM19 model, and the increase in person miles traveled by these modes was used to calculate the share for modeled

[20] In setting the original SB 375 targets in 2010, CARB was very careful to focus the target on factors related to land use, transportation, and reduction in VMT, rather than changes to the vehicle fleet, power sources, fuels, etc. The fleet and fuel factors were the focus areas of statewide programs. In order to focus SB 375 on land use, transportation and VMT reduction, a special set of emission rates were added to EMFAC, that factor out the changes related to the state fleet and fuel programs, and those rates are used by all MPOs for SB 375 implementation purposes.

travel. To this share was added an off-model increment for transportation demand management programs, and a small share for increased micro-mobility use.

- For shortened vehicle trips, the average trip length for all auto mode trips (SOV and carpool), and the decrease in average trip length was used to calculated a share of GHG reduction.
- For facility pricing, and mileage-based or Pay-As-You-Go (PAYGO) fees, the additional cost of auto travel for both programs was calculated as an average related to a non-priced alternative, and the increment was translated into a VMT impact using a VMT elasticity.
- For ITS and TSM, the impact of more robust deployment of these programs, relative to 2005, were assessed using the "Moving Cooler" document.
- For the impact of local EV deployment programs, which are locally funded programs to increase the rate of EV market penetration within the SACOG region were qualitatively assessed, and translated into percentage change in GHG, over-and-above the much larger state programs.
    - For the last two factors, the technical assumptions and calculations have been reviewed by CARB as part of the 2012 and 2016 Sustainable Community Strategy submissions.

The SB 375 GHG emissions reduction also includes factors that have little to do with the proposed MTP/SCS in terms of implementation. These factors that are largely outside the control of MPOs or their local member agencies are often labeled "exogenous" factors. Two major exogenous factors affecting GHG emissions are:

- Aging population—the share of persons 65-years-or-older is forecasted to increase from 13 percent in 2016 to 21 percent by 2040. Older persons travel less, and generate less VMT and GHG emissions from that travel, than younger persons.
- Increase in auto cost—the basic cost of operating an automobile was forecasted to increase over the timeline of the proposed MTP/SCS, and this increase accounts for a part of the GHG reduction. This increase is based on forecasted cost of fuel, changes to the efficiency of the passenger vehicle fleet, and changes to the non-fuel operating costs like tires, maintenance and repair, averaged to a per-mile cost. This part of the vehicle cost excludes "policy" costs like facility-based pricing, and PAYGO fees.

The fact that a part of the 19 percent GHG reductions is generated by exogenous factors, rather than policies or programs of the MTP/SCS, is not new. When the SB 375 targets were set in 2010, those factors were part of the calculation of the targets, and that fact was re-confirmed when the targets were re-set by CARB in 2018.

The "factors" referenced in Table 16 are driven by many specific policies and actions included in the proposed MTP/SCS. The complex relationship between the many specific policies and actions in the proposed MTP/SCS, and the grouped "factors" for which GHG reductions were approximated above, is provided in Table 17.

Table 17 – MTP/SCS Policies and Actions Contributing to GHG Reduction

2020 MTP/SCS Policy or Action	Shortened Vehicle Trips	Increased Transit, Bike, Walk Trips	Pricing & PAYGO	ITS/TSM	Local EV
Policies					
3--Support more seamless travel through better traveler information for trip planning, reliable service and coordination between operators for transit, shared mobility and other first/last mile connections.		X			
4--Support piloting innovations in new mobility and transit service and programs.		X			
6--Support innovative education and transportation demand management programs covering all parts of the region, to offer a variety of choices to driving alone.		X			
7--Pursue new funding and planning opportunities to support electric vehicle infrastructure and programs for both private vehicles and public transit fleets.					X
8--Support transit agencies looking to secure funds to improve the frequency, span, and coverage of productive transit service.		X			
11-- Initiate a leadership role in testing and piloting roadway pricing mechanisms, such as facility-based tolling and mileage-based fees, in partnership with the state, federal, and local agencies and private sector organizations.			X		

2020 MTP/SCS Policy or Action	Shortened Vehicle Trips	Increased Transit, Bike, Walk Trips	Pricing & PAYGO	ITS/TSM	Local EV
12--Take steps to implement tolling or pricing of specific lanes on major facilities, such as freeways, to improve traffic management, reliability, and operations of those facilities and to help raise funding for the cost of building and maintaining large capital investments.			X	X	
13--New major capital projects on the region's freeways should examine pricing options to both manage demand and provide a financing mechanism for capital costs.			X	X	
14-- Revenues generated from facility-based pricing should be used to build and maintain a regional network of paid express lanes and, where surplus revenue is available, on strategic transit services (e.g. express buses) or other mobility solutions that can reduce vehicle miles traveled and provide multiple travel options along priced corridors.		X			
24--Invest in bicycle and pedestrian infrastructure to encourage healthy, active transportation trips and provide recreational opportunities for residents and visitors.		X			
27--Invest in transportation improvements that improve access to major economic assets and job centers.	X				
28--Prioritize investments in transportation improvements that reduce greenhouse gas emissions and vehicle miles traveled.	X	X	X	X	X
Actions					
Secure funding and implement the Green Means Go Pilot Program to encourage infill development.	X	X			X

2020 MTP/SCS Policy or Action	Shortened Vehicle Trips	Increased Transit, Bike, Walk Trips	Pricing & PAYGO	ITS/TSM	Local EV
Provide data, research, analysis, incentives, and other support to housing-rich communities actively trying to promote job growth and jobs-rich communities to promote housing growth.	X	X			
Develop a Regional Housing Needs Plan with action steps and incentives that put member agencies in a better position to accelerate infill housing production.	X	X			
Continue to provide incentives, tools, and other project support to grow regional jobs and housing. Examples include the Economic Prosperity Plan, Housing Policy Toolkit, SB 375 and SB 743 CEQA streamlining.	X	X			
Continue to provide technical assistance to support urban, suburban, and rural community revitalization. Examples include Civic Lab Year 2, Rural Main Streets Technical Assistance, and the Transit Oriented Development Action Plan.	X	X			
Continue to assist transit and local agencies to find ways to develop, test, and pilot new mobility services such as microtransit, bike share, and other services. Examples include Civic Lab Year 1, bike share, and Citrus Heights microtransit pilot.		X			
Lead a collaborative effort to shape a vision of next generation transit for the region that includes strategies to integrate traditional transit services with new mobility options.		X			
Develop and implement new employer- and residential-based transportation demand management programs. Examples include TDM mini grants for piloting ideas.		X			

2020 MTP/SCS Policy or Action	Shortened Vehicle Trips	Increased Transit, Bike, Walk Trips	Pricing & PAYGO	ITS/TSM	Local EV
Partner with cities and transit operators undergoing updates to transit plans, service changes, and transit-oriented development efforts. Examples include SacRT Forward, Transit Asset Management Planning, and Transit-Oriented Development Action Plan.		X			
Actively support transit agencies in securing funding to improve transit stations and replace aging bus and light rail vehicles. Examples include 2018 SECAT program changes to fund zero-emission buses and transit funding awards from state Senate Bill 1 competitive grant programs.		X			
Work with Caltrans and other local partners to identify options for governance and administration of revenues from facility-based pricing, in coordination with ongoing managed lane studies.			X		
Work with regional partners to develop pilots focused on innovative tolling and PAYGO concepts.			X		
Collaborate with the state and metropolitan planning organizations on efforts to study mileage fees as a replacement to fuel taxes.			X		
Support local agencies in pursuing options to implement new local fees and taxes dedicated to transportation improvements.			X		

Travel Demand Forecasting Model

SACOG utilized its regional travel demand model to compare the proposed MTP/SCS for 2040 conditions to the 2016 baseline conditions. SACOG's primary model is the Sacramento Regional Activity-Based Simulation Model or "SACSIM". SACOG periodically updates and improves SACSIM, and releases versions of the model and data for use by member agencies when the MTP/SCS is adopted, with versions numbered according to the year the version was finalized. SACSIM15 was used for the 2016 MTP/SCS. SACSIM19 was used for the analysis of this proposed MTP/SCS.

Sections below will cover high level descriptions and summaries about model structure, model calibration, validation, sensitivity test, and treatment of travel induced by additional road way capacity. Full model documentation with details about every component of SACSIM19 will be available when 2020 MTP/SCS is adopted in the spring of 2020.

Model Structure

SACSIM includes four sub-models for predicting travel demand. The major sub-model is "DAYSIM," which is an advanced-practice activity-based tour sub-model for predicting household-generated travel. DAYSIM is a demand micro-simulation, which represents travel activities as tours, or series of trips, connecting the activities a person engages in during the course of a normal day. DAYSIM allows for detailed representation of key factors influencing household-generated travel, such as detailed characteristics of land use in the region, age of residents, household income, cost of fuel, and other factors.

SACSIM also includes a more conventional, state-of-practice sub-model for predicting commercial vehicle travel. Two classes of commercial vehicles are modeled: two-axle commercial vehicles, and three-plus-axle commercial vehicles. Two-axle commercial vehicles include a wide range of vehicles, ranging from a passenger vehicle, which might be used to transport a computer repair person and their tools and equipment to an office to perform a repair, to a relatively small truck delivering produce to a restaurant or store. Three-plus-axle commercial vehicles also include a wide array of vehicles, ranging from medium-sized delivery trucks to large, five-axle tractor-trailer combinations. The common element tying these vehicles together is that they are used to transport goods and services, and are not used for personal (household-generated) travel.

SACSIM also includes state-of-practice sub-models for predicting air passenger ground access to the Sacramento International Airport, and for predicting external travel (including travel by residents of the region to locations outside the region, residents outside the region traveling to locations within the region, and travel that goes through the region, but does not stop within the region).

Vehicle or transit passenger trips are assigned to detailed computer representations of the region's highway and transit networks using state-of-practice software and programs. The resulting assignments are used for evaluation of vehicle miles of travel (VMT) on roadways, congested travel on roadways, and travel on the region' transit system.

The analysis period of SACSIM is a “typical weekday.” A typical weekday is intended to represent weekday conditions during a non-summer month (i.e., a time period when most workers are at work, rather than on vacation, and when schools are normally in session). Where annual or other time periods are required, typical weekday estimates of travel are scaled to represent those time periods.

For each round of the MTP/SCS the SACSIM version is a adjusted to capture observed travel behaviors. SACSIM also goes through periodical coding updates to address new policy requirements during the planning process. Every new version of SACSIM is then thoroughly inspected over to ensure model performance. SACSIM19 was used for the analysis of this proposed MTP/SCS. SACSIM19 is adjusted to capture observed travel behavior in the MTP/SCS base year (2016 for project). The process of measuring the degree to which the model captures observed travel in the base year is known as “validation”. This step is undertaken in compliance with guidelines provided by the California Transportation Commission. In addition to validation, sensitivity testing is performed to ensure that SACSIM is appropriately sensitive to key factors affecting travel (e.g. cost of travel, household income, age, etc.).

Public Access to Model and Data

The updated SACSIM modeling scripts and data files are made available for review and comment by local member agencies and the transportation consulting community in the following ways:

- SACOG maintains a basic description of the SACSIM on its website for the public at large to get a basic understanding of the model and its uses, and to connect members of the public to SACOG staff members that can provide additional information as needed. https://www.sacog.org/modeling
- SACOG hosted a SACSIM19 users’ conference in January 2019. The conference included a one-day session providing a general overview of the SACSIM19 model, directed at non-modeling planning professionals and representatives of community and advocate groups in the morning session, and a deeper dive into SACSIM19 model functionality for transportation planners and modelers in the afternoon session. Input from the attendees was solicited on the usefulness of the users’ conference as a way of disseminating information on SACSIM19, and on user preferences for improvements to SACSIM19 moving forward. https://www.sacog.org/pod/travel-demand-model-user-conference
- SACOG implemented a formal beta-test process, call for participants announced in November 2018, group starting in January 2019 and ending in March 2019. The beta-test process allowed for early access to the draft SACSIM19 for learning and testing purposes. 10 organizations and firms participated. The beta-test included a one-day training session on SACSIM19, technical support as needed, and bi-weekly teleconferences calls to check in on testing progress and to address questions or issues experienced by the beta testers. More information about beta testing can be found under https://www.sacog.org/pod/travel-demand-model-beta-testing-group
- Early release of the SACSIM19 MTP/SCS draft preferred scenario land use and transportation network files, and data files, scripts and executables to local agencies and their consultants, for use in reviewing the MTP/SCS and to provide a baseline for undertaking analysis of local projects. Agencies took advantage of this release of the draft MTP/SCS on projects such as the Placer Sacramento Gateway Plan, Caltrans Managed Lanes studies.

- Modeling changes were presented to ARB staff in discussions related to the proposed technical methodology for assessment of greenhouse gases for implementation of SB 375, pursuant to Section 65080 of the Government Code.

Major Changes between SACSIM15 and SACSIM19

SB 375 has placed an emphasis on enhanced regional transportation and land use modeling and Proposition 84 funds have been awarded to California MPOs to expedite the development and enhancements of their regional transportation and land use modeling tools and methods necessary to comply with SB 375. While many MPOs will focus their initial efforts on enhancements to four-step trip-based models, SACOG is already at the cutting-edge of tour/activity-based models with the Sacramento Activity-Based Travel Simulation Model (SACSIM). As part of the SB 375 model enhancement effort, SACOG has completed a phased multi-year model improvement program. Major changes between SACSIM15 and SACSIM19 are shown in Table 18.

Table 18 – Major Improvements in SACSIM19

Feature	Used for…	SACSIM15	SACSIM19	Change in Modeling
New generation DAYSIM with updated choice models and software structure	Simulation of individual's daily travel activities	Software constraints on number of skims allowed.	Re-estimated choice models; Fully object-originated programming; Shadow pricing to maintain supply/demand of work and school locations	Easy to use & add network skims by modes, VOT classes, time periods; better estimation / forecasting of travel patterns etc
Proximity buffering (# of households, jobs, K12 enrollments, etc within travel distance of each parcel)	Modeling attractiveness of parcels as destinations	-Simple radial buffers (¼ & ½ mile) -Unweighted (i.e. activities at far edge of buffer count same as near edges	-Buffers based on network distance -Buffers decay weighted—closer activities count more	-Captures linearity of many activities clustered along major arterials -Captures accessibility "shadows" created by freeways, rivers, etc.
Valuation of time (VOT)	-Assessing trade-offs between cost of travel and time of travel -Useful for any model—but necessary to correctly model pricing	-Three levels of VOT, based on household (HH) income range -All members of high income HH have high VOT -All members of low income HH have low VOT	-Distributed VOT -VOT varies for all persons -Higher VOT more likely for high income HH… -…but VOT mixes across HH income -Some high income have low VOT, some low income have high VOT	-Necessary for implementation of pricing -Necessary for fairly capturing equity impacts of pricing -Causes some trade-offs on shorter, slower routes and longer, faster routes

Feature	Used for…	SACSIM15	SACSIM19	Change in Modeling
Transit and Traffic Assignment Time Periods	-Identify peak hour travel -Congestion levels, accessibility, boarding/alighting during peak hours of travel.	4 daily transit periods 4 daily traffic periods (AM,MD,PM,NT)	5 daily transit periods 9 daily traffic periods	-Better control over hourly diurnal flows.
Vehicle Equivalence on Traffic Assignment (weighting trucks more heavily in estimates of congestion)	-Identifying congested segments and bottlenecks -Reflecting higher congestion impact of bigger trucks	No weighting of bigger trucks	-passenger vehicles =1 -smaller commercial vehicles = 1.5 -3+ axle commercial vehicles = 2.0	-Better practice—called out in last peer review -Overall higher congestion levels
Transit sub-modes (rail, commuter bus, standard fixed route bus)	-Reflecting preferences for different types of transit in mode choice	-Transit mode choice only accounts for mode of access (drive vs. walk) -All transit treated generically	-Continue to account for mode of access -Sub-modes allowed as part of mode choice (rail, commuter bus, fixed route bus)	Better balance of transit trips & boardings amongst the sub-modes
Facility-based Pricing	Modeling toll roads, high-occupancy/toll roads, express lanes	n/a	Full suite of options for modeling toll facilities with dynamic tolling and occupancy class exceptions. User settings for minima/maxima tolls, tolling periods, etc.	New functionality, allows for modeling the impact of tolling on travel behavior and on revenue
Pay-As-You-Go Pricing (PAYGO)	Modeling of mileage-based user fees	Limited to single-point auto-operating cost, inclusive of PAYGO. Fixed by time period, geography. Does not affect path-building.	PAYGO added as roadway network variable, captured in path-building and skims. Can vary by time period or geography.	Captures effects of PAYGO more realistically, and affects path-building and skims for auto modes.

Source: SACOG, 2019.

Model Calibration

DAYSIM is the core of SACSIM and is consisted of two modules: long term and short term choices. Both modules are consisted of a series of nested choice models. In operation, given the households' residence, DAYSIM runs long term module first and simulates people's long term choices such as usual work and school locations, and auto ownership, and then run short term choice module such as day pattern, main destination, tour mode, trip mode etc. With this hierarchical or nested choice structure, the lower level choices were affected or constrained by upper choices. For examples:

- Choices of usual locations for work and school affect the choices of work and tour destinations, since the usual locations are the most likely destinations.
- Auto ownership affects both day pattern and tour (and trip) mode choice, by generating auto ownership market segments used in the model.

In SACSIM19, all DAYSIM choice models were re-estimated using the new parcel data, skim data and the expanded 2000 survey. Mode choice models were calibrated to 2018 survey as shown in Table 19.

Table 19 – Mode Share in 2016 Model Comparing to 2018 Household Travel Survey

Mode	2018 HTS	2016 Model
Walk	7.7%	7.8%
Bike	2.3%	2.5%
Carpool	45.5%	45.1%
Drive Alone	42.1%	42.1%
Transit	1.2%	1.2%
Other (School Bus,Taxi etc.)	1.2%	1.2%

Source: SACOG, 2019

Validation of Highway Assignment

Model Validation provides systematic checks to establish a confidence level in a travel demand model. Validation efforts focus on model components used for major performance indicators for forecasting. SACSIM19 validation focuses on highway traffic assignment, transit assignment, and sensitivity testing. SACSIM19 full model documentation will provide thorough information on all model variable components that influence results. The intent of this section is to provide high level validation results to assess SACSIM19 performance. Because SACSIM19 forecasts do not only cover roadway design, but also air quality and conformity analysis, temporal validation was included to assess model relationship to represent multiple time periods.

SACSIM19 traffic count model validation was performed on the highway assignment for the MTP/SCS base year 2016. Twenty-four-hour traffic counts are collected throughout the SACOG region. Since counts come in various temporal resolution, formatting, and collection techniques such as using roadway tube counts, turning movement at intersection, ongoing sensors, or annual monitoring reports, a subset of those counts are processed and used to represent a typical weekday traffic count to compare with model volumes. Table 20 provides a regional validation summary for SACSIM19 forecasted 2016 traffic volumes compared to CTC recommended guidelines for MPO travel demand models[21]. 2005 SACSIM19 back-cast comparison is also included. The 2005 back-cast serves as both a temporal validation of SACSIM19 and an additional model validation to our air quality and conformity analysis base year. Both 2005 and 2016 are within all guideline statistic performance indicator thresholds.

Table 20 – SACSIM19 and CTC Guidelines on Highway Assignment Validation

Guideline	Threshold	2005	2016
% of Locations w/ Model < Max Deviation	>75%	86%	78%
Correlation Coefficient	> 0.88	0.95	0.97
RMSE for Daily Traffic Assignment	<0.40	0.36	0.38

Source: SACOG, 2019

While these regional guidelines serve an important role for model validation, they are only a partial indication of model performance. Highway facility classification determine how much traffic volume can travel on a given roadway at a point of time. The facility classification determines road capacity levels measured as how many vehicles per hour per lane (vphpl) a facility can sustain operations; this is a major contributor to model performance. Table 21 provides a comparison of forecasted 2016 model volumes to traffic counts by facility type. The table includes comparisons of average weekday volumes.

Table 22 includes SACSIM19 back-cast traffic volume to counts from 2005. This back-cast comparison serves as both the temporal validation of SACSIM19 and the base year for air quality and conformity analysis[22]. Count locations and quantities vary between 2005 and 2016 due to different collection efforts and available data at that time. Multiple validation tables by functional class also serve as supplementary source of count data for locations of facility types that may have a smaller count samples one year and provide additional model confidence.

[21] California Transportation Commission, *2017 Regional Guidelines for MPOs*, p.49.
[22] *Code of Federal Regulations,* Title 40, Sec.93.122

Table 21 – Weekday Highway Volume Validation By Functional Class of Roadway

Functional Class	No. of Road Sections	Sum of Counts	Sum of Model (if Counted)	Validation Ratio	Avg. Link Error	RMSE
Freeway	371	21,477,673	20,565,616	0.96	0.13	0.18
Expressway	7	88,286	114,724	1.30	0.54	0.63
Major Arterial	571	8,310,889	9,057,658	1.09	0.29	0.38
Minor Arterial	463	4,477,209	4,438,807	0.99	0.30	0.44
Collector	425	1,434,337	1,284,906	0.90	0.53	0.79
Ramp	10	54,413	75,661	1.39	1.05	1.22
Rural Highway	24	148,190	144,000	0.97	0.17	0.20
Rural Art./Coll.	325	1,150,651	1,113,827	0.97	0.37	0.51
Total	2,196	37,141,648	36,795,199	0.99	0.24	0.38

Source: SACOG, 2019

Table 22 – 2005 Weekday Highway Volume Validation by Functional Class of Roadway

Functional Class	No. of Road Sections	Sum of Counts	Sum of Model (if Counted)	Validation Ratio	Avg. Link Error	RMSE
Freeway	189	10,772,487	11,092,769	1.03	0.15	0.22
Expressway	12	353,236	305,954	0.87	0.16	0.34
Major Arterial	296	4,903,641	5,014,035	1.02	0.21	0.28
Minor Arterial	172	1,789,679	1,558,188	0.87	0.29	0.38
Collector	118	630,976	505,006	0.80	0.40	0.56
Ramp	264	1,199,460	1,114,769	0.93	0.53	0.85
Rural Highway	76	325,402	363,834	1.12	0.28	0.40
Rural Art./Coll.	138	511,391	543,470	1.06	0.36	0.49
Total	1,265	20,486,272	20,498,025	1.00	0.22	0.36

Source: SACOG, 2019

Validation of vehicle miles traveled (VMT) by travel demand models to estimates of observed VMT gathered through the Highway Performance Monitoring System (HPMS) is required by federal statute for agencies like SACOG which implement air quality conformity analysis[23]. VMT is also identified as an important performance indictor for tracking progress of the SCS.[24]

This requirement has been more generally applied for validation of travel demand models used for other purposes. For example, validation to HPMS is identified as a key recommended validation task in the FHWA guidance on validation of travel demand models[25]. That said, there are differences between the VMT estimates developed for HPMS and those estimated using SACSIM19: HPMS is an "annual average" estimate, that is intended to capture the average for 365 days of travel. SACSIM19 is a "typical weekday" estimate, that is intended to capture mid-week days during spring and fall months. In areas with a high percentage of weekend travel (e.g. areas with a high percentage of recreational travel), or in areas with extreme variations in seasonal travel (e.g. areas with a high percentage of seasonal recreational travel, or other seasonal activities like agriculture) the differences between HPMS and SACSIM19 could be significant.

Table 23 reports the comparison of SACSIM19 estimates of VMT to HPMS-sourced estimates. At region level, SACSIM19 estimates line up very closely with HPMS-sourced estimates, with less than two percent difference for each of the validation years (2005, 2016). Additionally, at region level, the changes to total and per capita VMT forecasted by SACSIM19 correspond to the changes observed in HPMS data. Between 2005 and 2016, both HPMS and SACSIM19 data show a decline. HPMS data shows a 2 percent decline in VMT per capita, compared to a SACSIM19 4 percent decline. Both changes are in the correct direction and the correct order of magnitude.

Table 23 – Comparison of Daily Vehicle Miles Traveled Estimates: HPMS and SACSIM19

	2005		2016		Validation Ratio	
County	HPMS[1]	SACSIM	HPMS[1]	SACSIM	2005	2016
El Dorado[2]	3,941	4,420	4,095	3,842	1.12	0.94
Placer[2]	8,581	9,276	9,161	10,101	1.08	1.10
Sacramento	32,145	32,035	35,652	34,560	1.00	0.97
Sutter	2,374	1,758	2,672	2,228	0.74	0.83
Yolo	5,683	5,151	6,071	5,842	0.91	0.96
Yuba	1,849	1,853	1,928	1,866	1.00	0.97
	54,573	54,493	59,579	58,439	1.00	0.98

[23] Ibid.
[24] California Transportation Commission, *2017 Regional Guidelines for MPOs*, p.23.
[25] Federal Highway Administration, *Model Validation and Reasonableness Checking Manual*, 2010 edition. http://tmip.fhwa.dot.gov/resources/clearinghouse/1397

Population	2,140		2,376				
VMT per Capita	25.5	25.5	25.1	24.6		1.00	0.98

Source: SACOG, 2019

[1] HPMS estimates of VMT from the Caltrans *California Public Road Data* reports.

[2] Adjusted from whole county data from El Dorado and Placer Counties to the non-Tahoe-Basin portions.

[3] VMT and Population represented in thousand

Validation of Transit Assignment

SACSIM19 changed from SACSIM15 by:

- Adding a transit sub-mode component to skimming and mode choice models. The three sub-modes are light rail, commuter bus, and local bus. This change allows SACSIM19 to better capture the differences between these modes in terms of speed, comfort, etc.
- Creating different transit fares based on a person's age and student status, instead of assuming a flat average fare.
- Splitting the 6pm-11pm evening service period into two separate periods, 6pm-8pm and 8pm-11pm, to better capture differences in transit services between early and later evening.

SACSIM first predicts how many trips people will take on transit, then assigns those trips to routes in the transit network and estimates each route's total boardings. A single trip can entail multiple boardings, e.g., one transit trip that requires one transfer results in two boardings. SACOG staff performed validation tests for both total transit trip share and transit assignment, i.e., how many boardings those trips resulted in, for each transit sub-mode (rail, local bus, and commuter bus).

As shown in Table 19 under model calibration, transit trip share (1.2%) in 2016 model was calibrated to and validated against SACOG's 2018 household travel survey (HTS).

Below, Table 24 summarizes transit assignment validation results. Generally, SACSIM19 overpredicted boardings by about 22 percent for all three transit sub-modes. Although the difference in observed versus modeled boardings is substantial, it does not affect the model's VMT and emissions estimates, which are based on transit trips rather than boardings. And since, as described above, SACSIM19's transit trip share is very close to observed trip share, we consider its VMT and emissions estimates to be reasonable.

Table 24 – Weekday Transit Passenger Boardings and Vehicle Service Hours by Service Type: Comparison of Model to Counts

	Daily Pass. Boardings			**Weekday Vehicle Service Hours**		
Service Types	Observed	Model (raw)	Validation	Observed	Model	Validation
Year 2016						
Light Rail	41,732	51,189	1.23	301	317	1.05
Fixed Route Bus	73,323	89,533	1.22	3,319	2,663	0.80
Commuter Bus	5,093	6,324	1.24	321	482	1.50
Total	120,148	147,046	1.22	3,940	3,462	0.88

Source: SACOG, September 2019.
Note: Model estimates included only for lines for which observed boardings data were available from operators.

We also validated SACSIM19's estimate of vehicle service hours (VSH) against observed base year VSH. As Table 28 shows, modeled VSH overall was about 12 percent lower than observed VSH. However, this varied by sub-mode, with modeled VSH exceeding observed by only five percent for light rail, significantly exceeding observed VSH for commuter bus by about 50 percent, and falling short of observed local bus VSH by about 20 percent.

Sensitivity Tests

Sensitivity testing measures how sensitive model outputs are to changes in specified model inputs, e.g., the sensitivity of predicted vehicle-miles traveled (VMT) to changes in the assumed per-mile auto operating cost. We quantify sensitivity as the elasticity of the output with respect to the input. Conceptually, elasticity can be defined as:

Elasticity of output with respect to input = percent change in output / percent change in input

E.g., if a 10% increase in auto operating cost led to a 1% decrease in VMT, we would say the elasticity of VMT with respect to auto operating cost is -0.01/0.1, or -0.1.

Using elasticity, we estimated the model's sensitivity to the following inputs with respect to the indicated outputs as shown in Table 25.

Table 25 – List of Variables in Sensitivity Test

Model input variables tested	**Model output values checked for sensitivity**
Auto operating cost	Total person-trips, vehicle trips, VMT, CVMT, transit person-trips, bike + walk person trips
Transit fare	
Off-street parking price	
Household income	

Where possible, we then compared the model's elasticity to observed elasticities to see if the model's elasticity was similar in magnitude (big vs. small) and direction (negative elasticity value vs. positive value). We considered the model sensitivity for a given input-output relationship to be reasonable if its elasticity was in the same direction and roughly same magnitude as elasticities that have been observed in the real world. Table 26 below is an example showing the elasticity of modeled VMT with respect to each of the tested model inputs compared with the range of observed elasticities for VMT.

Table 26 – List of Variables in Sensitivity Test

Model input variables tested	Modeled elasticity of VMT with respect to input variable	Range of observed elasticities of VMT with respect to input variable
Auto operating cost	-0.135	-0.38 to -0.03
Transit fare	+0.001	Small, positive in sign[1]
Off-street parking price	-0.005	Smaller magnitude than -0.04, negative in sign[2]
Household income	+0.12	+0.05 to +0.18

[1]None of the studies we reviewed explicitly quantified the relationship between transit fare levels and VMT, but we assumed a modest positive elasticity assuming that as transit fares increase, some riders will choose to drive instead, increasing VMT.

[2]-0.04 was the lowest sensitivity among the studies we reviewed. However, all studies looked at parking in local areas with generally limited free parking (e.g., downtowns, college campuses, etc.), while our elasticity reflects the entire region, which in most areas has ample free parking. Given the generally available substitute of free parking at a regional level, we suspect changes to parking price will have more modest effects on VMT than those found in the studies we reviewed.

While we were unable to test for all possible input-output combinations, mainly because of a lack of real-world elasticities to compare against, SACSIM's elasticities were generally reasonable. A more complete description of SACSIM elasticity testing, along with specific findings, will be available in the SACSIM19 model documentation.

Facility-Based and Pay-as-You-Go Pricing Testing

Pricing corridors and a VMT user fee are strategies implemented to meet 2020 MTP/SCS key performance targets. Express lanes along major corridors are included to improve traffic management and reliability throughout the region. A mileage-based or Pay-As-You-Go (PAYGo) fee charge is implemented as a sustainable replacement to the gas tax and manage transportation network efficiently and equitably.

Both corridor pricing and user fee are a new feature to SACSIM19. Around the country, implementation of travel modeling software to capture express lanes, in particular, is recognized as a very complex challenge, so testing of these features is critical. Testing of these new features included sensitivity testing and reasonable-ness checking, based on guidelines provided by state and federal agencies[26]. In addition to SACOG's testing, the beta-test group and early release of the draft SACSIM19 software and data files, described above in the "Public Access to the Model and Data" section, provided significant additional critical review of these new features. Testing focused on the high-occupancy/toll (HOT) and

[26] Federal Highway Administration, *Model Validation and Reasonableness Checking Manual*, 2010 edition. http://tmip.fhwa.dot.gov/resources/clearinghouse/1397

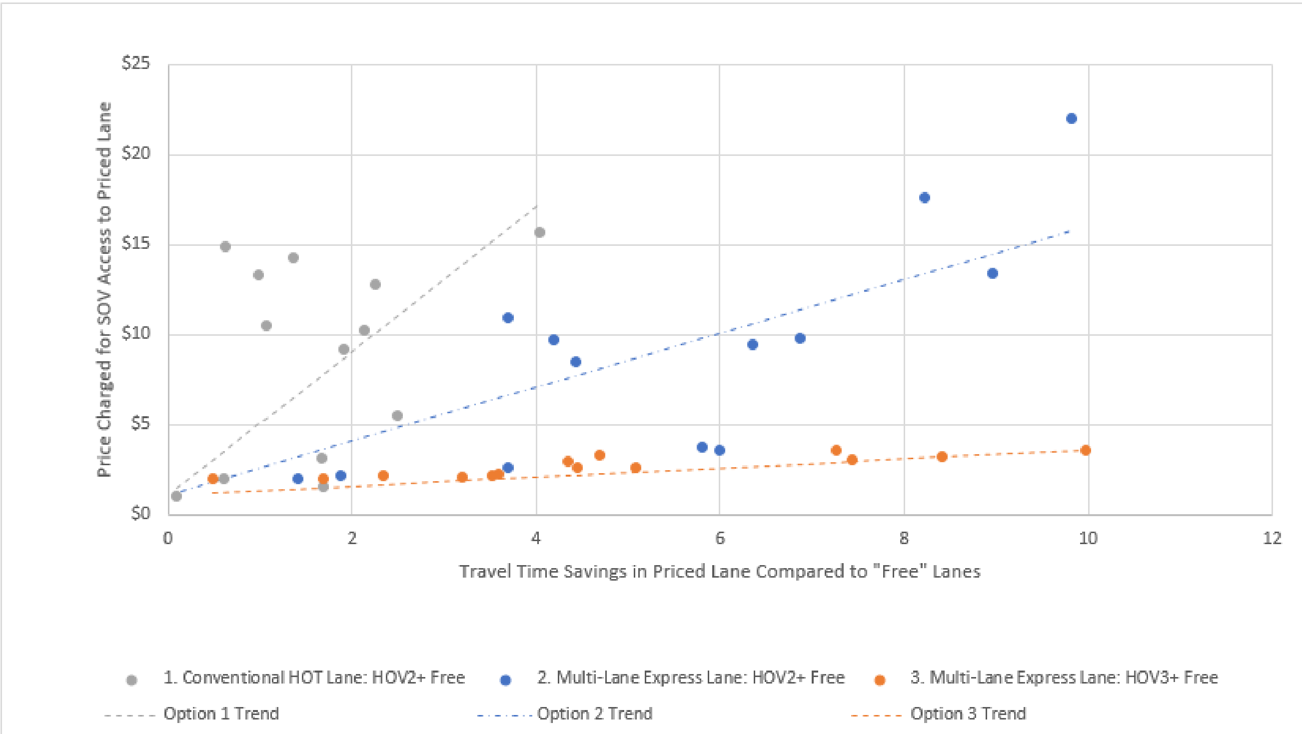
express lanes facility pricing, because those facilities are the major priced facilities included in the proposed MTP/SCS. HOT lanes, for purposes of this document, are conventional, one-lane HOV lanes, which allow priced access to drive alone vehicles or trucks. Express lanes, for purposes of this document, are generally multi-lane facilities that may allow HOV2 or HOV3+ vehicles access at reduced (or no) price, but allows priced access to drive alone vehicles and trucks. SACSIM19 has the capability to model "all-tolled" roadway facilities, however—given that no all-tolled facilities are included in the propose MTP/SCS, testing mainly focused around HOT and express lanes.

For HOT or express lanes facilities, SACSIM19 pricing software was developed to represent different rules on free versus paid access to HOT or express lanes. The general framework of the software is to iteratively identify a balance point between price of access, based on the rules for access for a given project, that ensures some level of travel time savings for the HOT or express lane, relative to the "free" parallel lanes. Testing focused on two dimensions: sensitivity of price-setting to time savings; and variations on the relationship between price and time savings, based on the rules governing access to the priced facility. Testing results for three options:

- A conventional HOT lane, with HOV2 and HOV3+ vehicles allowed access for free, and drive alone vehicles and trucks accessing for a price. Available capacity for priced access to the HOT lane is the smallest for this option, because in the highest demand corridors, HOV2 and HOV3+ vehicle nearly fill up the lane. In order to limit the number of drive alone vehicles and trucks that can access the facility, the prices may have a drastic increase surge.
- A conventional 2-lane express facility, with HOV2 and HOV3+ vehicles accessing the facility free, and drive alone vehicles and trucks accessing the facility for a price. Because the facility has two lanes per direction, rather than one, there is generally more capacity to offer for priced access, and prices tend to be somewhat lower than the HOT lane option.
- An express lane option that allows free access to HOV3+ vehicles only, and priced access to HOV2 and drive alone vehicles, and trucks. This option prices off many HOV2s, so the amount of capacity available for priced access is the highest of the three options, and the prices tend to be the lowest of the three.

Figure 15 graphically illustrates the results of the of the three test options, across 14 test corridors. Shown in the figure is the comparison of corridor time savings (defined as the number minutes saved in the priced lane, compared to the parallel free lane) and average price charged to access the priced lane (or lanes). For all three options, the expected relationship showing price increasing with time savings offered by the priced facility is evident. The three options differed very widely, and in expected ways, on the magnitude of price and its volatility across the corridors within each option. Option 1, the conventional HOT lane, showed the highest prices (average just under $10) relative to time saved, largely because in the highest priced corridors, very little-to-no capacity was available to priced access, and virtually all potential users had to be priced off. Table 27 provides option-level tallies, and shows that of users of the HOT lane, only 2 percent paid their way into the lane—98 percent had access for free. At the other end of the spectrum is option 3, the express lane, which allowed free access only to HOV3+ vehicles. This option offered priced access to the largest number of users, and the prices charged were the lowest at under $3 average, and 50 percent of the users paying. Option 2 (express lane with free access to HOV2 and HOV3+ vehicles) splits the difference between Options 1 and 3.

Figure 15—Price Versus Time Savings for Three Managed Lane Options



Source: SACOG, 2019.

Table 27 – Managed Lane/Pricing Tests

	Facility Pricing Scenario	Drivers Accessing Time Savings for Free	Drivers Accessing Time Savings with Toll	Travel Time Savings in Priced Lane (minutes)	Average Toll Rate per Mile	Average SOV Toll Facility Price	VMT Accessing Travel Time Savings (thousands)	Percent VMT Accessing Travel Time Savings	Percent VMT Accessing Travel Time Savings and Paying Toll
1	Conventional HOT Lane	HOV2+	SOV, Truck	-1.5	$0.89	$9.71	974	21%	2%
2	Multi-Lane Express Lane	HOV2+	SOV, Truck	-5.1	$0.58	$9.68	1,170	27%	11%
3	Multi-Lane Express Lane	**HOV3+**	**HOV2, SOV, Truck**	-4.7	$0.36	$2.89	877	21%	50%

SACOG, 2019

Suggested by one of the beta-testers of the new SACSIM19 pricing features was testing around extreme pricing values. The specific suggestion was to test a range of pricing for access to a facility up to $100, which is recognized as an unreasonably high price for an actual project. Testing around extreme values is informative for software testing, and not as a potential actual project proposal. A test of this nature was conducted based on change in travel decisions comparing a range in pricing, time of day, and demand of a particular route. Table 28 shows testing along Interstate 80 over the Causeway between Davis and Sacramento. Three scenarios of an all-lane tolled facility are compared at different pricing rates: $5, $25, and $100 dollars. It is important to note that ALL of these pricing rates were set purely for testing purposes, and that actual rates for a proposed express lane project will be the subject of extensive project development work, public input, and policy debate. It is also important to note that the test scenario was based on all-lanes tolling, as opposed to express lanes, where a "free" option always exists. The $5 dollar rate shows a shift of 31 percent of vehicles use alternative routes. At $25, almost 90 percent of traffic avoided the facility. At $100 dollars, the price is so extreme the facility is effectively closed down, and all traffic avoids it. This test shows SACSIM19 highway assignment is sensitive to the level of pricing added to a facility as different persons have a range of valuation of time with respect to their preferred routing choices.

Table 28 – All Lane Pricing Sensitivity to Extreme Values Test

SACSIM19	DAILY					
	Causeway EB			Causeway WB		
2035	Quantity	Change	% Change	Quantity	Change	% Change
2035 Base	95,242	0	0.00%	95,974	0	0.00%
$5 Toll, All Time Periods, Mainline & HOV	64,162	-31,080	-32.60%	65,496	-30,478	-31.80%
$25 Toll, All Time Periods, Mainline & HOV	10,334	-84,908	-89.10%	11,825	-84,149	-87.70%
$100 Toll, All Time Periods, Mainline & HOV	19	-95,223	-100.00%	16	-95,958	-100.00%

Source: SACOG, 2019.

In addition to corridor pricing, a mileage-based user fee was also tested. Table 29 shows sensitivity testing on different mileage based user fee rates based on time of day and location. A discounted fee was applied for rural areas and off peak hours with less congestion. When the user fee increase, the household VMT and Congested VMT decrease. The orders of magnitude of decrease changes based on the rate showing the model is sensitive to different user fee rates.

Table 29 – User Fee Sensitivity Testing

Scenario	HH VMT % Change from Base	HH Congested VMT % Change from Base
No user fee – Baseline	0.0%	0.0%
1/2 cent peak/off peak rural/urban user fee	-0.3%	-1.9%
2/4 cent peak/off peak rural/urban user fee	-1.5%	-8.2%

SACOG, 2019
Scenarios for Sensitivity Testing only and do not reflect the 2020 MTP/SCS preferred scenario.

Treatment of Travel Induced by Addition of New Roadway Capacity

Research suggests that provision of new roadway capacity, all other things being equal, can itself result in generating additional vehicle travel. This phenomenon is often labeled "induced travel," and is in reality composed of many different effects. Those effects fall into two general categories:

- Short-term effects--changes in the near term to individual and household travel behavior due to a new or expanded roadway. All of the short-term effects are the result of travel on the new or expanded roadway being faster or more reliable than the prior condition:

    - Driving slightly out of one's way in order to use a new facility, compared to prior routes;
    - Shifting trips made by walking, biking, transit, or some non-private-vehicle mode to a private vehicle; or
    - Making more trips using a vehicle compared to the prior condition.

- Long-term effects—changes in long-term individual or household choices, or causing new growth and development in areas where options to driving are a few, or where the density and mix of uses require longer-than-average (regional) vehicle trips:

    - An individual deciding to relocate his or her place of residence from an area where lower-than-average vehicle use is required, to an area where higher-than-average vehicle use is required, simply because new roadway capacity makes the move more attractive.
    - A property owner or developer deciding to build in an area where higher-than-average vehicle use is required for future residents, simply because new roadway capacity makes that area more marketable and valuable to future homebuyers.

The proposed MTP/SCS includes policies focused on limiting the potential impact of induced travel. Almost $9 billion of the $35 billion budget is anticipated to go to expanding the transportation system. Of this capacity budget, $6.8 billion will go to road and highway expansion projects, including operational, safety, and multi-modal elements as part of large capital projects. The $6.8 billion in capacity projects were selected from nominations of over $12 billion. More than two-thirds of the $6.8 billion will be invested in existing, rather than new, streets and roads. These investments implement **Policy 18** of the plan, which states that "system expansion investments that are not directly paid for by new development should be focused on fixing major bottlenecks that exist today, and/or incentivize development opportunities in infill areas."

Screening questions related to project phasing were used to assess the relative need for the $12 billion in nominated highway capacity projects for the proposed MTP/SCS. The screening questions were also intended to assist in synchronizing roadway capacity investments to areas with significant existing needs, or areas with significant planned growth.[47] The screening questions included: 1) is there evidence of significant congestion on the roadway, either in the base year or in the planning horizon year?; 2) where a capacity increase is proposed, is the scale of the capacity increase similar to the scale of the growth in demand?; and 3) with the proposed capacity increase in place, is the roadway well-utilized in peak periods in the planning horizon year? The screening process started with a "Discussion Scenario" short list of about $6 billion in capacity projects, among the $12 billion in nominated.

For example, if a capacity project was nominated for roadway segment "A," and there was no evidence of congestion on Segment A in either the base year or the future year, the project was identified for exclusion from the proposed plan. Similarly, if the nominated project for segment "A" was widening from two lanes (one in each direction) to six lanes (three in each direction), the nominated project increased capacity by 200 percent. If the 2040 demand on segment "A" only increased 20 percent, the nominated project was flagged for potential exclusion from the proposed MTP/SCS, or for potential down-scaling of the nominated project. Though it is impossible to boil all project decisions down to a formula, the screening questions did serve as flags for projects that could be excluded. The screening criteria were only one input into decisions on project inclusion—other criteria included safety, project readiness, financial capacity of the sponsoring agency to fund the project, connection of the project to other committed projects in the MTP/SCS, and other factors.

The model's ability to capture short-term induced travel effects was assessed through simple sensitivity tests, shown on Table 30. The tests were structured to add (or reduce) roadway capacity from a base model run, and assess the changes to model outputs resulting from the changes to roadway capacity. These tests focus on short term effects described above, because the land uses are held constant between the base and test scenarios, and the test effects include only the short term effects. Three changes were assessed: the effect of roadway capacity on travel speed ("Speed w.r.t. Lane Mi" in the table); the effect of speed on VMT ("VMT w.r.t. Speed"); and the effect of roadway capacity on VMT ("VMT w.r.t. Lane Mi"). Elasticity values based on historic research were assembled for each of the effects. For the "primary" effects (the effect of roadway capacity on speed, and the effect of speed on VMT), only one study was found (Cervero, 2002). For the "combined" effect (effect of roadway capacity on VMT), a range of values based on historic research were found (Handy & Boarnet, 2014). Based on the primary effects, the range of calculated elasticities were reasonable. The combined effects fell at the low end of the range based on historic research (+0.06 for the "expand" tests, +0.16 for the "reduce" tests, compared to a range of +0.1 to +0.6).

There are constraints on the ability to represent the effects captured as "short term" effects in the historic research using fixed land use scenario travel models. The travel model tests were based on very large increments in roadway capacity, with completely fixed population, employment, costs, etc.—these are the sorts of test that can be done with a travel model, and cannot be replicated in the real world. For the historic research on induced travel, all factors change, and the ability to control for those changes is based on the availability and quality of year-over-year data. Additionally for the historic research, the year-over-year changes in highway capacity tend to be very small compared to the model tests, which added (or reduced) 6 to 11 percent of major roadway capacity in the tests. For example, the "expand" tests (#1a and #2), 13 to 24 years of roadway capacity increments were added to the "base". In many cases, capacity is added in locations were little to no demand exists in the "base", and where the roadways in the "base" are not congested. For these tests, the "elasticities" of speed with respect to roadway capacity are lower, simply because many of the capacity expanded roadways were no faster than the base condition. More nuanced highway capacity increments for the model testing may result in different estimates of sensitivity.

Long term induced travel effects are even more difficult to assess in a travel model than the short term effects, because, as described above, the dynamics of transportation system development, growth, and demographic change that resulted in the observed estimates of induced travel in historic research may be included in the forecasting and project selection that go into the development of the MTP/SCS. Additionally, when comparing change in roadway capacity, growth and VMT over a long span of time, the effects of many factors that affect VMT must be accounted for (e.g. age, costs of travel, urban form, etc.)—these variables, to differing degrees, were controlled for statistically in historic research and analysis of induced travel. For the testing of short term sensitivity to highway capacity, those factors were taken out of play by holding land use, demographics, costs, etc. constant in the model. To evaluate the long-term effects, these factors, by definition, cannot be held constant.

For purposes on this assessment, the following framework was applied:

1. Major factors affecting VMT, both policy and exogenous, which were assumed to be largely independent of each other (i.e. not highly correlated), were identified. Factors that are highly correlated (i.e. the vary in similar ways) could result in double-counting factors.
2. For each major factor, model inputs corresponding to the factor were assembled for base year (2016) and horizon year (2040), and percentage changes were calculated for each.
3. A range of elasticities, based on historic research, were identified. The primary reference for this was a detailed meta-analysis prepared by Ewing & Cervero (2011), which provided ranges of reasonable values, but also provided details on individual studies to allow identification of specific studies most comparable to the SACSIM19 household generated VMT metric.
4. The range of VMT elasticities for each major factor were applied to the changes in model inputs calculated in step #2 to calculate a range of expected changes based on the elasticities.
5. The elasticity-calculated VMT changes were summed, and compared to the SACSIM forecasted changes. For total household-generated VMT, the expectation on change, all else being equal, would be the change in household population (26%). The elasticity-calculated VMT changes were summed, and added to the population change. For household-generated VMT per capita or per household (the two most common "rate" metrics relevant to the historic research on VMT elasticities), the change in total population is controlled through the rate calculation. For the per capita and per household rates, the elasticity-calculated VMT changes were summed alone.
6. The assessment compares the SACSIM19 forecasted changes to VMT to the range of changes based on the elasticity calculations, with reasonability of the forecasts determined by where the forecasts fall in the range.

Table 31 presents the details of this assessment. Major factors affecting VMT through the 2016-to-2040 forecast period are:

- Regional auto accessibility, quantifying the number of activities (jobs being the most commonly used) within a given travel time. Historic research has consistently shown that increasing auto accessibility correlates significantly with reduced VMT. The theory, in short, is that having more options for activities around a household, members of a household can find more distance-efficient ways of meeting their needs for work, shopping, etc. Regional accessibility is the most powerful of the land use / transportation factors affecting VMT. For purposes of this assessment, the number of jobs within 30 minutes peak period drive time was used. The range of elasticities used for this factor was -0.17 to -0.31.
- Regional transit accessibility, which is definitionally the same as the auto measure, but the travel time is based on transit rather than auto. The change in the regional average transit accessibility for the proposed MTP/SCS is extreme (450%), but is focused on a much smaller area within the region than auto accessibility, and is out-of-scale for the likely variations in

transit accessibility in the historic research—for this reason, the change was bounded to 50% for this assessment. The range of elasticities used for this factor was -0.03 to -0.04.

- Density is also a significant factor in predicting VMT, with historic research consistently showing higher density correlating with lower VMT. The metric used to represent change in density in the SACOG land use forecasts was net residential density (i.e. the number of dwellings divided by the net developed residential acreage). This factor is correlated with accessibility. Defining density using net developed acreage, rather than gross area, helps to minimize this correlation. The change in net residential density was also bounded to 50% to reduce the potential correlation with accessibility. The range of elasticities used for this factor was -0.04 to -0.07.
- The cost of traveling by car also has a significant negative effect on VMT. The per mile cost of auto travel, based on forecasts of costs of gasoline, changes to the efficiency of vehicles, and the changes to variable costs of maintaining a vehicle, increase from about 19 cents per mile to 25 cents per mile over the forecast period. The range of elasticities used for this factor was -0.17 to -0.31.
- Aging is also a significant factor affecting VMT over the forecast period of the proposed MTP/SCS. In general, older persons travel less than younger persons, all else being equal. The percentage of persons aged 65-and-over increases from about 13 percent in 2016 to 21 percent by 2040. Persons 65-and-over travel about 20 percent less than persons younger than 65, and this change was "translated" into an expected change to VMT.
- The final factor affecting VMT considered was induced travel. As discussed above, the change in highway capacity, measured by the number of land miles of arterial-and-above roadways, has been shown through historic research to increase VMT, even controlling for many of the factors discussed above. The range of elasticities used for this analysis was +0.6 to +1.0.

For purposes of summing VMT effects from the factors above, the first five factors are all indirect (i.e. increases cause a decrease in VMT). The induced travel effect is direct (i.e. increases in lane mileage cause an increase in VMT). The "low" end of the range of effects was based on low sensitivity in terms of reducing VMT. For this reason, the "low" end combined the lowest of the indirect effects in absolute value, and the highest induced travel elasticity. For this low end, the potential for reducing VMT through the indirect effects (accessibility, density, cost, aging) is the lowest, and the direct, induced travel effect is the highest (+1.0). The high end of the range combines the reverse (i.e. the highest absolute magnitude indirect effects, and the lowest direct effect). From these calculations, the changes in VMT could be: as high as +24% in total household-generated VMT, and -2% in VMT per capita or per household; or as low as +7% in total VMT, and -19% in per capita or per household VMT. The forecasted changes using SACSIM19 were +16% in total household-generated VMT, -8% in per capita VMT, and -10% in per household VMT. The SACSIM19 forecasts fall in the middle of the range of expected changes based on the elasticity calculations.

Table 30 – SACSIM19 Assessment Results of Short-Term Induced Travel Effects

			Changes (% from Base)			Calculated Elasticities		
Test/Test Factor	**Base**	**Test**	**Speed**	**Lane Miles**	**VMT**	**Speed w.r.t. LaneMi**	**VMT w.r.t. Speed**	**VMT w.r.t. LaneMi**
Test 1a: Expanded Roadway								
Landuse/Populaton	2027	2027	+1.2%	+5.6%	+0.3%	+0.21	+0.26	+0.06
Roadway Network	2027	2040						
Test 1b: Reduced Roadway								
Landuse/Populaton	2027	2027	-2.5%	-5.6%	-0.9%	+0.44	+0.37	+0.16
Roadway Network	2027	2016						
Test 2: Expanded Roadway								
Landuse/Populaton	2016	2016	+3.8%	+11.9%	+1.1%	+0.32	+0.29	+0.09
Roadway Network	2016	2040						
Test 3: Reduced Roadway								
Landuse/Populaton	2040	2040	-5.0%	-10.6%	-1.6%	+0.47	+0.33	+0.16
Roadway Network	2040	2016						
Range of Values from Historic Research						+0.42	+0.24	+0.1 to +0.6

Source: SACOG, 2019.

Table 31 – SACOG Growth Forecasted and SACSIM19 Assessment of Long-Term Induced Travel

Model Input	**2016**	**2040**	**Difference**	**% Change/1/**						
Household Population	2,376,311	2,996,832	+620,521	26%						
Households	881,799	1,136,599	+254,800	29%						
					Range of Elasticities[2]			**Elasticities Applied**		
Other factors affecting VMT:					**Low**	**High**	**Avg.**	**Low**	**High**	**Avg.**
Accessibility (jobs w/in 30' drive)	377,257	486,796	+109,539	+29%	-0.17	-0.31	-0.20	-5%	-9%	-6%
Transit Accessibility (jobs w/in 30' transit)	4,000	22,000	+18,000	+450%	-0.03	-0.04	-0.03	-2%	-2%	-2%
Density (DU's per net res. Acre)	1.2	2	+0.8	+67%	-0.04	-0.07	-0.05	-2%	-4%	-3%
Aging (% of Pop > 65 yrs)	13%	21%	+8%	+62%	-0.15	-0.25	-0.20	-1%	-2%	-2%
Auto Operating Cost (Yr 2017 cents/mile)	19	25	+6	+32%	-0.13	-0.30	-0.18	-4%	-9%	-6%
Lane Miles of Capacity--Arterial & Above Roadways	8,290	9,275	+985	+12%	+1.00	+0.60	+0.70	+12%	+7%	+8%
Model VMT Outputs								Sum of Applied Elas. /3/		

SACOG Total Weekday Household-Generated VMT	42,580	49,479	+6,899	+16%	+24%	+7%	+17%
HG VMT per capita	17.9	16.5	-1.4	-8%	-2%	-19%	-9%
HG VMT per HH	48.3	43.5	-4.8	-10%			

Source: SACOG, 2019

Notes:

[1]Bounded to no greater than 50% to match reasonable range of changes

[2] Range of elasticities based on available meta-studies

Potential Limitations to Travel Demand Model

While the SACSIM model represents ranges from state of practice to advanced practice in travel modeling, travel behavior and the transportation systems are changing quickly in response to emerging trends, new technologies, and different preferences. Some of the new travel options and technologies emerging in the SACOG region are discussed below. Additionally, information about how technology is affecting travel is accumulating over time. Some of these emergent changes that could influence future travel forecasts include:

- Substitution of internet shopping and home delivery for some shopping or meal-related.
- Substitution of telework for commute travel.
- New travel modes and choices:
  - TNCs, car share, bike share, scooter share, and on-demand micro transit have increased the travel options available to travelers in the SACOG region and have contributed to changes in traditional travel demand relationships.
  - Automation of vehicles—both passenger vehicles and commercial vehicles and trucks are evolving to include more automation. Research, development and deployment testing is proceeding on fully AV, for which no human driver would be required, and the vehicle itself can navigate the roadways take people or goods where they need to go. Forecasts of how quickly research and development and deployment testing will transition to fully deployment and marketing of fully AV vary widely both on the pace of the transition, and the market acceptance of fully autonomous operation. More uncertainty exists for the behavioral response to AVs. In terms of impact on the transportation system and the environment, a scenario of concern would be one in which AVs are privately owned, like most vehicles are currently, but the automated function of the vehicles would entice users to travel more.
  - Connected vehicles (CVs)—can communicate wirelessly with its surroundings including other vehicles, bicyclists, pedestrians, roadway infrastructure (i.e., traffic signals, toll facilities, traffic management facilities, etc.) and the internet. The influence that CVs may have is still speculative but includes potential for reductions in collisions and congestion and greater overall network performance optimization.

SACSIM does not explicitly capture the above-mentioned new modes of travel and emerging trends in travel behavior. Through validation of the model to 2016 conditions, the cumulative effect of the new modes and changes are reflected in the resulting travel demand estimates, but the underlying behavioral impact of the modes are not modeled. Significant uncertainties exist at the present time, that prevent explicit modeling of these new modes and emerging trends for the analysis of the proposed MTP/SCS. Future deployment level of new modes of travel are not known. For example, Uber and Lyft have both significantly increased the number of trips they serve, but both continue run large operating losses, and are reliant on venture capital investments to cover the losses. A sustainable business model may require significant changes to services offered and prices charged, both of which could affect the trajectory of use and impact on travel behavior. Similar issues apply to bike share services.

The impact of new modes on individual and household travel behavior is not fully understood, and is the subject of ongoing research. Limitations on accessing utilization data directly from TNC vendors, in particular, is a known issue constraining the ability to fully understand the impact of those services. Regulatory and legislative efforts to address the limits on access are underway in California and elsewhere, but these efforts will take time. Only a few household travel surveys, including the 2018 SHTS, have surveyed TNC use in detail, and the e-assist JUMP bikes were introduced partway through the 2018 SHTS. Other major research studies focused on TNC use, and TNC driver behavior, are just being launched in California, but the data collection has not even started, much less the analysis of the data. Until this sort of research is completed, there is no effective way to incorporate even the known new modes into travel demand models.

SACOG is participating in some of the ongoing monitoring and research on the deployment and impact of new modes of travel, and will incorporate analysis findings related to individual and household travel behavior into later versions of SACSIM.

AV, Shared Mobility & CV Scenario Analysis

SACOG's regional travel forecasting model, SACSIM, can test different scenarios on the market penetration of AVs (i.e. the percentage of households owning an AV) and the degree to which AVs are shared (i.e. "hired" by users like a present-day TNC) as opposed to being owned as private personal/household vehicles. The scenario testing functionality was built based on the following behavioral assumptions regarding AVs and vehicle sharing:

- AVs are likely to reduce the perceived cost of time spent in a vehicle, because travelers in AVs can engage in other activities.
- Owned AVs within a household can be "re-purposed" to serve more residents within the same household (i.e. an owned AV can be used by one worker to get to work, travel with no occupant back to the household and serve another household member's trip).
- AVs in general are likely to reduce the number of vehicles privately owned.

  - If AVs are owned and used privately, the fact that a single vehicle can be re-purposed to serve several household members reduces the need for each household member to have his/her own personal vehicle.
  - If AVs are not widely owned privately, but are widely available for shared use, households can avoid purchasing a vehicle altogether, or can use a shared AV like a TNC to fill in if a household vehicle is being used by another household member.
- If AVs are widely deployed and widely shared, they will compete with transit, especially for shorter trips.

Five future scenarios have been tested, based three factors:

- AV adoption rate—this is the percentage of privately-owned vehicles that are AVs. Owning AVs within a household has several effects in the modeling. Household AVs are more heavily used (e.g. the same vehicle may drop off one household member at work, and return home to serve another household member going to a different activity, like school). The greater utility of the AV makes owning fewer vehicles possible for some households—but it also results in "zero occupant" vehicle trips.
- Connected vehicle effects on highway capacity--as AVs become more prevalent, highways could potentially operate more efficiently and at higher capacity, by "platooning" of AVs through connected vehicle technology. In the modeling, this factor results in reduced congestion and faster travel speeds.
- TNC (shared vehicle) utilization rate--expressed as the percentage of vehicle trips made using TNCs rather than driving a privately-owned vehicle. In the modeling, this factor results in lower vehicle ownership, and greater reliance on TNCs for shorter trips that may otherwise be served by transit, biking or walking.

There are many other primary and secondary factors and uncertainties not included in these five tests: effects of AVs and TNCs on the market for paid parking; variations in the impact of AVs on the "cost" of time spent in a vehicle; uncertainties on the future costs of AV and TNC use relative to other modes; and other factors.

Table 32 compares the outcomes of the five scenarios described below:

• **Scenario 1** is essentially a "baseline" for these tests, with the future looking essentially like today: no AVs, no CV effects on highway capacity, and very low TNC usage.

• **Scenario 2** assumes a very slow rate of adoption of AVs, with only about 4 percent of privately owned vehicles being AVs. At this low level, the potential effects of CVs on highway capacity would not occur. TNC use in this scenario is high at 9 percent of all personal vehicle trips—though no firm estimates of TNC mode share for all trips exists for other regions, some evidence suggests this is approximately the level of TNC use in San Francisco today. Because the shifts in this scenario are relatively modest, the changes relative to Scenario #1 are also relatively small, and the overall impact of VMT is negligible. The biggest impact is on vehicle ownership, which drops by about 12 percent compared to Scenario 1.

Table 32 – Comparison of AV/TNC Testing Scenarios

	#1	#2	#3	#4	#5
	Future Looks kind of Like Today	Slow AV Adoption, TNC Share Growing Fast	AV Adoption & TNC Share Growing Slightly Faster	Full AV Adoption, Some CV Effects; TNC Share Growing Fast	Full AV & CV Adoption; TNCs Are Dominant Vehicle Mode
Autonomous Vehicle, Connected Vehicle, TNC Factors					
AV Market Penetration	0%	4%	21%	89%	88%
Connected Vehicle Effects - Roadway Capacity/1/	n/a	n/a	n/a	10% to 20% Increased	20% to 50% Increased
% of Vehicle Trips by TNC Mode	<1%	9%	17%	13%	53%
Outcome Metrics		**Change from Scenario #1**			
Household-Generate VMT (millions)	48.7	+0%	+3%	+16%	+9%
HHG VMT per Capita	17.09	+0%	+3%	+16%	+9%
Bike/Walk Mode Share	11.6%	-7%	-17%	-24%	-59%
Transit Mode Share	1.8%	+2%	-12%	-34%	-66%
Private Auto Mode Share	86.0%	-10%	-17%	-11%	-52%
Vehicles Per Household	1.81	-12%	-20%	-32%	-40%
Roadway VMT (millions)	71.7	+0%	+2%	+13%	+7%
Congested VMT % of Total Roadway VMT	6.4%	+0%	+6%	-30%	-60%

Source: SACOG, 2019.

/1/ For scenario #4 and #5, assumed freeway capacity will be increased more 20% or 50%, while 10% or 20% for all other roadways.

• **Scenario 3** assumes a faster rate of AV adoption (21 percent) and greater willingness to use TNCs (17 percent). For this scenario, no CV highway capacity effects were assumed. The higher reliance on TNCs shifted more trips from bike, walk, and transit. For both AVs and TNCs, the higher rate of zero-occupant trips generated by re-positioning both household AVs and TNC providers resulted in a small increase in VMT compared to scenario 1.

• **Scenario 4** assumes that AVs are owned by nearly all households (89%), but used largely privately, so TNC usage is relatively low (13 percent). In this scenario, AVs are essentially used as chauffeurs by most households, shuttling various household members to different activities, and often dead-heading to serve another household member. At this high level of AV adoption, some of the effects of CVs on highway capacity were assumed, with a 10 to 20 percent increase in capacity relative to Scenario 1. Mode shifts from bike, walk and transit to vehicle modes is greater for this scenario, and household-generated VMT increases by 16 percent compared to Scenario 1. Congestion on the roadways decreases sharply, due to the CV effects.

• **Scenario 5** assumes both high AV adoption, high TNC usage, and the largest CV effects on highway capacity. The impact on vehicle ownership is the greatest (-40%), and the increased usage of TNCs offsets somewhat the number of zero-occupant vehicle trips—so the increase in VMT (+9%) is lower than Scenario 4.

Take-aways from this testing:

- Testing of three factors (AV market penetration, shared vehicle use, and changes to highway capacity) showed a wide range of potential impact to the MTP/SCS—most of which showed increases in VMT and likely increases in GHG. Only Scenario 2 showed no significant increase in VMT.

- Testing also showed that while the biggest shifts in numbers of trips to TNC modes came from private auto modes, the impacts of the shifts on transit, biking and walking were significant, ranging from a negligible change (Scenario 2) to over 50 percent reduction (Scenario 5).

- There are limitations to the modeling and scenario testing. There is no explicit representation of the supply side, or vehicle side, of AVs, and "deadheading" (AVs that are traveling empty en route to pick up a passenger) are not part of the scenario testing. Until the supply side is represented, additional research could be a way to make scenarios "smarter" and more connected. With scenario testing, modelers provide the inputs and assumptions, so the models can be limited in their results. As a next step, SACOG is exploring how to account for deadhead travel for TNCs in its models.