Caltrans Sustainable Communities Grant to
Southern California Association of Governments

Transportation Broadband Strategies to Reduce Vehicle Miles Traveled and Greenhouse Gases Project

SCAG Overall Work Program No: 155-4863U8.01

April 2022

Caltrans Sustainable Communities Grant to
Southern California Association of Governments
Overall Summary

The Potential of Broadband Ubiquitous Deployment and Universal Adoption to Reduce Vehicle Trip Generation to Decrease Greenhouse Gas Emissions

Introduction and Overview

The California Department of Transportation (Caltrans) awarded a Sustainable Communities Grant to the Southern California Association of Governments (SCAG) to study the potential of broadband ubiquitous deployment and universal adoption to reduce vehicle trip generation, and associated vehicle miles traveled (VMT), to decrease greenhouse gas (GHG) emissions to help fight climate change. Broadband is a generic term for high-speed Internet infrastructure that includes both wireline and wireless technology networks. This study is a groundbreaking investigation of the potential of "broadband as a green strategy" to reduce traffic congestion and decrease impacts on the environment. The study included a comprehensive set of methodologies to determine with intellectual integrity a qualitative and quantitative projection of the potential for broadband to reduce VMT and GHG that can be used by policymakers and regulators. This is vital because the California Air Resources Board (CARB) has assigned to SCAG a target of reducing GHG by 19%. The Overall Conclusion is:

> Broadband is a "green strategy" to reduce VMT and GHG qualitatively with a quantitative benefit to reduce GHG by 1-15%.

Therefore, SCAG may use this Overall Conclusion as part of a compendium of information and data to incorporate strategies for broadband ubiquitous deployment and universal adoption into the Regional Transportation Plan and the Sustainable Communities Plan.

Study Research Partners and Scope of Work

The Caltrans Grant supported a Scope of Work that included SCAG and Civic Leadership Partners with expertise in closing the Digital Divide (the Challenge) through Digital Inclusion (the Process) to achieve Digital Equity (the Result). The Civic Leadership Partners included the 4 Regional Broadband Consortia (RBCs) funded by the California Public Utilities Commission (CPUC) in the SCAG Region and the California Emerging Technology Fund (CETF). The Civic Leadership Partners were responsible for: Data Collection; Community Outreach (including the establishment of an Expert Advisory Committee); Community Engagement and Stakeholder Surveys and Convenings; and Focus Groups and Surveys. The Grant also supported engagement of Technical Consultants to analyze Socio-Economic Data and Transportation System Performance Data.

Civic Leadership Partners
- Inland Empire Regional Broadband Consortium (IERBC)
- Broadband Consortium of the Pacific Coast (BCPC)
- Los Angeles Digital Equity Action League (LA DEAL)
- Southern Border Broadband Consortium (SBBC)
- California Emerging Technology Fund (CETF)

Technical Consultants
- Magellan Advisors
- DKS Associates

The Expert Advisory Committee was composed of 25 highly-respected professionals with an extraordinary spectrum of knowledge and experience collectively to ensure the integrity of the study methodologies and to review the findings and conclusions. Attached is a Roster of the Expert Advisory Committee, which met 5 times, including a subcommittee Peer Review Group. The Expert Advisors also reviewed interim work products to provide feedback and input.

It should be kept in mind that the Caltrans Grant with the original Scope of Work was awarded before the COVID-19 pandemic and issuance of emergency shelter-in-place orders. Thus, all activities that were planned to be in-person had to be revised to implement approximately equivalent approaches to obtain comparable results. SCAG, Civic Leadership Partners, and Technical Consultants were able to pivot and adjust to complete the study successfully.

Study Research Findings

The Technical Consultants presented their analyses and conclusions in a Final Report titled Transportation Broadband Strategies to Reduce VMT and GHG which is Attachment A. The Technical Consultants concluded that the potential to reduce GHG emissions is 1-15%.

The Civic Leadership Partners research methodologies and findings are summarized below and the work products are inventoried in Attachment B. All of the results confirm there is a tangible potential to reduce vehicle trips with associated VMT and GHG through broadband ubiquitous deployment and universal adoption. The actual realized percentage of GHG reduction will depend upon the level and intensity of proactive leadership from the public and private sectors.

Summary of Data Collection

The Regional Broadband Consortia (RBCs) and California Emerging Technology Fund (CETF) gathered the following data to inform the study. All of the data collected indicate a willingness by residents to reduce vehicle trips with significant segments still unconnected (not online) and/or underconnected (smartphone only) who would reduce trips if feasible.

- Broadband and Environmental Benefit Data and Literature Report
  Martha van Rooijen, Executive Director, Inland Empire Regional Broadband Consortium

- 2021 Statewide Survey on Broadband Adoption
  Conducted by the University of Southern California (USC) and Sponsored by CETF

- Report on the Digital Divide: Deep Analysis of American Community Survey Census Data
  Jamshid Damooei, Ph.D., (Damooei Global Research), California Lutheran University

- Online Access for Residents Receiving Medi-Cal, CalFresh, School Lunch Program Benefits
  Regional Broadband Consortia Outreach to Counties and County Offices of Education

- Collection of Other Relevant Studies
  Regional Broadband Consortia Identification and Analysis of Other Relevant Data

Broadband and Environmental Benefit Data and Literature Report

This report, prepared by Martha van Rooijen, IERBC Executive Director, is a comprehensive review of all research literature and published articles about the relationship between vehicle trip reduction and decreases in GHG. It is a foundational work product required for the Caltrans Grant. The report is organized in 5 Sections:

1. Foundational Reference Documents for Caltrans Broadband Grant
2. California Specific Reports and Data (VMT, GHG, Broadband)
3. National Data, Articles, Research
4. Industry Centric Information
   - Telecommuting
   - Telehealth
   - Distance Learning
   - Broadband – Internet of Things
   - Energy
5. Online Data Tools

Major observations from the literature review include:

- There is data and research available supporting the use of the Internet based technologies to reduce VMT and GHG, yet there has been no significant rally from leadership, or from business and government agencies, to strongly support or promote telecommuting, and other online services, as a high-value transportation demand management (TDM) strategy.

- The average person is not hearing about new innovative TDM policies and programs that focus on telecommuting, telehealth, and distance learning based on technology advancements derived from higher Internet service in order to reduce VMT, GHG and, ultimately, benefit climate change or other quality of life issues. The studies are not being elevated in public policy making.

- Although, the majority of the research over the past 20 years concludes it is clear telecommuting, made possible from increased and higher quality internet service, will reduce traffic congestion, VMT, and GHG, the rate of telecommuting has been stable at about 5% of all workers, including the self-employed and farmers.

- The instant drain on broadband service from all of these sectors moving online so suddenly, even in areas that had been perceived as served somewhat adequately, brings attention to the need to pursue higher level broadband service, and to start outlining as many benefits as possible of doing so, including the reduction of VMT and GHG to improve traffic congestion and the environment.

- It is therefore timely to be studying the concept of connecting broadband planning and deployment to transportation investments as a TDM strategy. It will be relevant to the community to be looking at how online activities, such as telecommuting and telehealth, that are possible through strong, reliable, and reasonably priced Internet service, could be utilized as a robust TDM strategy resulting in reduced VMT and GHG.

Examples of research literature and published reports informing these observations are:

Understanding Travel Behavior Report
Federal Highway Administration (FHWA)
University of California, Berkeley – Transportation Sustainability Research Center
Booz Allen Hamilton, March 2016
Abstract: This report presents a research scan of the state of knowledge in transportation, with 249 cited references and studies, to enhance understanding of travel behavior and various influencing factors on future travel. The report discusses emerging information technology and its impact on new mobility options.
Reference: https://www.fhwa.dot.gov/policy/otps/travel_behavior_research_scan.pdf

Does Telecommuting Reduce Vehicle Miles Traveled?
University of California, Davis, Department of Civil and Environmental Engineering
Institute of Transportation Studies, July 2004
Abstract**:** This study examines the impact of telecommuting on passenger vehicle-miles traveled (VMT) through a multivariate time series analysis of aggregate nationwide data spanning 1966-1999 for all variables except telecommuting, and 1988-1998 for telecommuting. The study assessed the change in annual VMT per telecommuter as well as VMT per telecommuting occasion, *for 1998*. The models suggest that telecommuting reduces VMT, with 94% confidence. Together with independent external evidence, the results suggest a reduction in annual VMT on the order of 0.8% or less. Reference: https://escholarship.org/uc/item/74t9663f

Employer Transportation Demand Management (TDM) Programs
Oregon Department of Transportation, Mosaic Transportation Planning Tool and Framework, 2010
Abstract**:** Employer TDM programs help meet local goals for vehicle miles traveled (VMT) and congestion reduction, environmental stewardship, and quality of life.
The Oregon Dept. of Transportation includes Telecommuting as part of recommended TDM programs. Reference: https://www.oregon.gov/ODOT/Planning/

Review of the Literature on Telecommuting & Its Implications for Vehicle Travel and Emissions, Resources for the Future, Washington D.C., December 2010
Abstract: A review of 20 empirical studies of telecommuting, all of which focus on the trip reduction perspective. The studies include earlier ones with smaller datasets, such as some pilot studies of individual employers, and more recent studies based on broader surveys of both telecommuters and non-telecommuters.
Although an individual telecommuter may experience a sharp reduction in VMT, total benefits depend on how many people are telecommuting, how often they are doing so, and the duration of telecommuting. Note: Review included analyzing data from a 2002 SCAG Survey of telecommuters and non-telecommuters.

2021 Statewide Survey on Broadband Adoption

The Statewide Survey on Broadband Adoption was established by CETF in 2008 and conducted by independent research institutions to interview approximately 1,600 California households representative of overall population. The 2021 Statewide Survey was conducted by USC and included new questions specifically designed to provide data for the Caltrans Grant study regarding the willingness of residents to reduce vehicle trips by using the Internet. This work product (sample of 1,650 households) is an in-kind contribution ($225,000) to the study.

Major relevant findings from the 2021 Statewide Survey on Broadband Adoption are:

- Southern California is catching up with statewide broadband adoption rates, but has significant potential to get more households online that can result in vehicle trip reduction.
  - Statewide Broadband Adoption Rate: 91% (6% Smartphone Only) – 9% Unconnected
  - Los Angeles County Region: 89% (8% Smartphone Only) – 11% Unconnected
  - Inland Empire Region: 92% (5% Smartphone Only) – 8% Unconnected
  - Orange and San Diego Counties Region: 89% (3% Smartphone Only) – 11% Unconnected
  - Low-Income Households: 82% (11% Smartphone Only) – 18% Unconnected
  - Latino Households: 84% (8% Smartphone Only) – 16% Unconnected
  - Spanish-Speaking Households: 75% (10% Smartphone Only) – 25% Unconnected
  - Seniors 65 Years or Older: 77% (5% Smartphone Only) – 23% Unconnected
  - High School Non-Graduates: 63% (12% Smartphone Only) – 37% Unconnected
- 53% of respondents prefer to work remotely 3-5 days per week. 31% prefer to work remotely fulltime. Only 18% would chose traditional in-person workplace.
- However, 57% identified as “essential workers” with less ability to work remotely.

- Majority of low-income households (62%) are not aware of affordable broadband offers: only 38% are aware and just 24% of those households have subscribed (a net 9%).
- 95% of respondents say distance learning and telehealth will replace some vehicle trips.
- Los Angeles County shows the lowest level of telehealth participation at 46%. The Bay Area shows the highest level of telehealth engagement at 58%, followed in descending order by the Inland Empire, Orange and San Diego Counties and the Central Valley.

> *"These 2021 Statewide Survey findings build momentum for the deployment of high-speed internet infrastructure so that we can not only offset vehicle trips, reduce greenhouse gas emissions, and relieve traffic congestion, but ultimately provide all of our communities equitable access to healthcare and the education that the internet provides."*
> Kome Ajise, Executive Director, Southern California Association of Governments

<u>Report on the Digital Divide: Deep Analysis of American Community Survey Census Data</u>

This report is an extensive analysis of census data to determine associations between socioeconomic demographic factors and the Digital Divide, which identifies specific zip codes that comprise a roadmap for both ubiquitous deployment and universal adoption, especially outreach to get online all low-income households with appropriate computing devices. All RBCs contributed to the study conducted by Jamshid Damooei, Ph.D., (Damooei Global Research), California Lutheran University, to provide detailed data for their respective County or Counties.

Highlights of the study findings include:

- The impact of poverty is undeniable and is an impediment to progress. Lower educational performance is highly correlated with the level of household income. Having access to the Internet and the ability to use the necessary devices with high performance is, and will remain, a condition for receiving quality educational services.
- There are a large number of zip codes for which more than 30% of the households pay more for Internet service than is considered "affordable" in relation to income. Within these zip codes 65% of the households have an affordability problem.
- Latinos are at a far greater disadvantage than the white-alone ethnic group.
- Los Angeles County has the greatest severity of unaffordability.
- Imperial County is also faced with a disproportionate level of problems and obstacles.

<u>Online Access for Residents Receiving Medi-Cal, CalFresh, School Lunch Program Benefits</u>

A major facet of investigation to determine the potential to reduce vehicle trips through broadband ubiquitous deployment and universal adoption is to assess the feasibility for those who are unconnected or underconnected, most of who are low-income households, to reduce vehicle trips. There are "3 big populations" who are unconnected and underconnected; they are households eligible for: Medi-Cal; CalFresh; National School Lunch Program (NSLP). A proxy for the untapped potential to reduce trips is the number (and percentage) of email addresses on file with responsible Public Agencies for these 3 big populations eligible for public assistance.

Each RBC reached out to their respective: (a) County or Counties to obtain data regarding Medi-Cal and CalFresh recipients; and (b) County Office of Education (COE) regarding NSLP students. The RBCs also requested information re NSLP students from large School Districts. USC estimates that 2.55M households in the SCAG Region were eligible for the Emergency Broadband Benefit (EBB) Program and, therefore, at least this many households are eligible for the new Affordable Connectivity Program (ACP). It is axiomatic that: (1) If low-income households are not online, then they cannot use the Internet to offset vehicle trips; and (2) If public agencies do not collect email addresses for households receiving public assistance, then they cannot communicate with them online to help reduce vehicle trips.

The following are the overarching observations from this data collection effort:

- Public Agencies generally don't obtain email addresses of recipients and don't communicate online with public assistance HHs. However, once engaged, Public Agencies are willing to consider changing policies and practices
- The collection and availability of email addresses online varies by County:
  - Imperial County: 20%-27%
  - Inland Empire (Riverside and San Bernardino Counties): 1%-18%.
  - Los Angeles County: 36% Medi-Cal; 53% CalFresh
  - Ventura County: 41%-52%
- Public Agencies could reduce vehicle trips for 50%-80% recipients if they collected email addresses (and assisted households without email addresses to get connected with affordable home Internet service such as ACP), and proactively communicated online with recipients.

<u>Collection of Other Relevant Studies</u>

The Broadband Consortium of the Pacific Coast (BCPC) shared an analysis of Ventura County census data by Dr. Damooei regarding the nature of the Digital Divide and disadvantaged households which showed a lot of value from a deep dive into census data. Thus, each RBC contributed to a deep analysis of the census data for their County or Counties, as reported above.

Another example of other relevant studies identified by RBCs is that the Los Angeles Digital Equity Action League (LA DEAL), for which the Los Angeles County Economic Development Corporation (LAEDC) is the fiscal agent, conducted community questionnaires in the City of Lynwood and the unincorporated community of Willowbrook and found that low-income residents were paying approximately 5.2% of their public utility expenditures for home Internet service, which exceeds the national guidelines of 2%. This finding aligns with the study by Dr. Damooei.

Community Engagement, Stakeholder Surveys and Stakeholder Forums

Description of Methodology

CETF and the RBCs developed a comprehensive Stakeholder Survey which was approved by SCAG. To achieve comparable stakeholder input as envisioned in the original Work Plan, each RBC committed to obtaining 15 Surveys from each of 3 Primary Stakeholder Groups for a total of 45 Surveys and no less than 180 Surveys in the SCAG Region:

- Private-Sector Business
- Public Agency or Service Provider
- Education or Health Organization

Each RBC identified a target list of at least 15 Leaders in each Primary Stakeholder Group and distributed the Survey directly to them as well as to all their contacts. A total of 251 Surveys representative of the Primary Stakeholder Groups were obtained with a good cross-section geographically from the SCAG Region.

Findings

The complete findings from the Stakeholder Surveys are included in Attachment B. The following are the highlights most relevant for the promulgation of public policy:

- All Stakeholders support a level of remote working; hybrid and flexible work arrangements are preferred, rather than a specific number of days weekly.
- Private-Sector Business Leaders identified their top strategy to reduce trips as "Construction of high-speed internet infrastructure throughout the region to connect all locations." followed by "Employer Tax Credits to implement Telecommuting."
- Public Agencies or Service Providers and Education or Healthcare Leaders identified their top strategy as, "Assisting clients, customers, students and patients with securing affordable home internet service and a computing device."
- Overall, "Policymakers" in each Primary Stakeholder Group are taking a lead in identifying top trip reduction strategies with "Policy Advisors" either slightly ahead of them or having to catch up to the Policymakers, depending on the Stakeholder Group.
- Lack of high-speed Internet infrastructure limits the number of employees who can work remotely for all Stakeholder Groups: 40.6% Private-Sector Business; 50.6% Public Agencies or Service Provider; and 56.4% Education or Health Organization.
- There is potential for additional vehicle trip reduction among all Primary Stakeholder Groups.
- Top-Rated Strategies for reducing vehicle trips reflect need for both "deployment" and "adoption"—both high-speed Internet infrastructure and assistance to get all households online with affordable home Internet service and a computing device.

All respondents to the Survey were invited to an online Stakeholder Forum to discuss the results and explore strategies for reducing vehicle trips to reduce GHG and help fight climate change. The results of the Stakeholder Forums are summarized as part of the record for the Grant. Overall, the Stakeholder Forums underscored the value of engaging Civic Leaders to think together about actions to reduce vehicle trips to help fight climate change.

Focus Group Interviews

Description of Methodology

CETF and the RBCs developed a Focus Group Interview Questionnaire and Guide to obtain input from at least 20 low-income households in each area, or at least 80 Interviews in the SCAG Region. The purpose of the Interviews was to assess the willingness of low-income households to reduce vehicle trips if they were connected at home to high-speed Internet service at an affordable price with sufficient digital proficiency. To achieve comparable input as in-person Focus Groups envisioned in the original Work Plan, each RBC committed to conducting at least 10 Interviews from 2 distinct and geographically-diverse segments of low-income residents. Interviewees were provided a $20 gift card for participating. As a result, a total of 91 Interviews were completed.

Findings

The complete findings from the Focus Group Interviews are included in Attachment B. The following are the finding highlights most relevant for the promulgation of public policy:

- The majority (74.7%) of low-income households interviewed who are connected to the Internet pay more than $25 per month. Only 20.9% subscribe to an affordable offer.
- Less than 20% of those not subscribing to an affordable home Internet service have heard about an affordable offer (such as EBB or ACP, LifeLine, or ISP offers).
- For those interviewed households aware of affordable offers but who had not subscribed, only 1% said the offers were too costly. The most-frequently cited reason (12.1% of households interviewed) was that it was unclear how to sign up, followed by: lack of trust in the ISPs; had been upsold; and didn't get sufficient help from ISPs.
- Interviewed households rated the importance of the following factors or assistance in subscribing to home Internet service (on a scale of 1-5, with 5 being the highest):
  - Affordable Home Internet Service: 3.38
  - Improved Internet Infrastructure: 3.35
  - Affordable Computer: 1.67
  - Digital Literacy Training for Family: 1.25
- Significant percentages of interviewed households said they could reduce vehicle trips by being connected to the Internet, ranging from 70.3% for paying bills to 20.9% for getting public benefits.

Overall, the Focus Group Interviews confirmed that there is a significant potential to reduce vehicle trips by getting online all low-income households with ubiquitous deployment and universal adoption, notwithstanding the fact lower-income residents are disproportionately classified as essential workers with less flexibility to work remotely. Low-income residents recognize the potential to reduce vehicle trips for a wide range of purposes aside from work. However, there needs to be both improved deployment of high-speed infrastructure into high-poverty census tracts and substantive assistance for low-income households to achieve broadband adoption, including: (a) increased public awareness about available affordable home internet service, such as ACP; (b) computing devices; and (c) digital literacy training.

Overall Observations and Conclusions

All of the activities associated with this study reveal an emerging sense of a "new normal" among stakeholders and residents that access to the Internet is essential and that Digital Equity is an imperative. Further, all of the data collection and analysis by the Technical Consultants and Civic Leadership Partners conclude there can be tangible reduction in vehicle trips and associated decreases in VMT and GHG as a result of broadband <u>ubiquitous deployment</u> and <u>universal adoption</u>. However, the amount of GHG decrease to help address climate change that can be derived from broadband "as a green strategy" depends on policy and practice leadership from public and private stakeholders through a focused initiative with quantified goals.

The following are the 10 Overall Observations and Conclusions:

- There are high levels of interest, engagement, and urgency by stakeholders with an imperative to develop both regional and local broadband strategies.
- There is a need for a regional strategy to include and embrace local governments that are willing to work together on middle-mile and last-mile deployment and adoption.
- All sectors in the SCAG region support a level of remote working, with a preference for hybrid and flexible work arrangements rather than a specific number of days each week.
- The private sector identified the top strategy to reduce trip generation as "Construction of High-Speed Internet Infrastructure Throughout the Region to Connect All Locations".
- The private sector next top-rated strategy is "Employer Tax Credits to Implement Telecommuting".
- Public Agencies, Service Providers, Education, and Healthcare Sectors Identified the top strategy to reduce trip generation as "Assisting Clients, Customers, Students and Patients with Securing Affordable Home Internet Service and a Computing Device".
- Land use planning must accommodate broadband as part of essential infrastructure and community amenities to ensure public safety and quality of life. This will require land use planners and regulators to think about incorporating broadband into all new projects to help reduce trip generation and ensure Digital Equity.
- Low-income individuals, who are more likely to be frontline "essential" workers and have less opportunity to work remotely, could reduce trips and VMT with more awareness and education about how to access affordable home Internet services and sufficient digital skills proficiency to navigate the Internet to access services.
- There is still a need for more education with both the public and private sectors to optimize vehicle trip generation. People are just now beginning to "connect the dots" between broadband and air quality.
- Caltrans and CARB should jointly fund additional analysis to refine the estimate of the potential for decreasing GHG emissions through reduction of trip generation because of broadband ubiquitous deployment and universal adoption.

These Overall Observations and Conclusions point to "push" and "pull" strategies for both broadband deployment and adoption. The concept of "push" relates to public and private policy to provide an external force to change practice. The concept of "pull" relates to public and private organizational internal practices to shape and reinforce policy to become the "norm" or societal culture. The following Recommendations embrace both "push" and "pull" strategies.

Recommendations

The following 5 Recommendations promote policy "push" and community "pull" strategies for broadband ubiquitous deployment and universal adoption.

- Affirm substantively that telework (especially hybrid and flexible work arrangements) are here to stay. Validate that public and private employers have embraced this concept as the "new normal" and there is no desire or intent to return to old behaviors (post pandemic). Optimize telehealth and distancing learning for both reduction of trip generation and quality experiences for participants.

- Accelerate deployment of high-speed Internet infrastructure. Evaluate the perceived gap in broadband infrastructure by the private sector to determine and quantify if the need is middle-mile construction (connecting facilities) or last-mile deployment (connecting employees to work)—or both—and identify the obstacles and solutions.
  [Deployment: Policy Push]

- Incent employers to achieve target outcomes. Consider fostering a "tipping point" for telework to be the "new norm" and the extent to which it can be triggered locally or needs to occur at higher levels.
  [Deployment: Community Pull]

- Develop and adopt policies, strategies and programs to promote adoption of technology and home Internet use to optimize opportunities to reduce vehicle trips. Identify specific processes for how municipalities, hospitals, and schools can accelerate use and support training for digital skills competency.
  [Adoption: Policy Push]

- Design and implement a pilot project (and then expand if demonstrated to be effective) a true stakeholder-driven, collaborative approach to transforming neighborhoods that achieves and accelerates adoption to get online all households. Ideally, use investment in middle-mile infrastructure as a catalyst for last-mile deployment and adoption.
  [Adoption: Community Pull]

Caltrans should fund the next phase of investment to engage relevant State Agencies to work with SCAG, CARB, Transportation Agencies, Regional Broadband Consortia, and public and private stakeholders to develop and implement a strategic plan to achieve an agreed-upon reduction of greenhouse gas emissions through ubiquitous deployment and universal adoption of broadband as a "green strategy" to reduce vehicle trips.

Southern California Association of Governments
Transportation Broadband Strategies to Reduce VMT and GHG
Expert Advisory Committee

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Attachment A

SOUTHERN CALIFORNIA ASSOCIATION OF GOVERNMENTS

Transportation Broadband Strategies to Reduce VMT and GHG

March 25, 2022

Magellan ADVISORS

DKS

Contents

Table of Figures

Table of Tables

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California Emerging Technology Fund (CETF)

The Inland Empire Regional Broadband Consortium (IERBC)

The Broadband Consortium of the Pacific Coast (BCPC)

The Southern Border Broadband Consortium (SBBC)

PURPOSE OF THE STUDY

In 2019, Southern California Association of Governments (SCAG) was awarded a Caltrans Sustainable Communities grant to determine the feasibility of accelerating Digital Inclusion (broadband deployment and adoption) as a "green strategy" to reduce Vehicle Miles Traveled (VMT), improve mobility, and quantify the potential for contributing to the SCAG region's GHG (Greenhouse Gas) emissions reduction goals.

TECHNICAL CONSULTANTS

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Executive Summary

It is logical to presume telecommuting reduces vehicle trips, particularly at times of peak congestion, and would therefore reduce vehicle emissions. In addition, it is reasonable to believe telecommuting depends on high speed, always on internet service commonly called broadband. Taken together, there is a strong case for providing broadband as means to reduce transportation demand, vehicle miles traveled (VMT), and greenhouse gas (GHG) emissions. A specific case could be made for including broadband infrastructure in transportation projects to reduce the cost of broadband development.

These ideas were empirically tested for the study. Lockdown during the COVID-19 pandemic of 2020-2021 created a test case for this purpose. Analysis of vehicular travel during that period indicates telecommuting would yield between 2% and 15% reductions in VMT and GHG. Analysis of construction costs finds 80% reduction in deployment costs of conduit for broadband infrastructure when it is incorporated into transportation projects.

Data generated by cell phones as people traveled over the study period was used to determine the amounts and locations of change in travel behavior. The origin-destination pairs for trips were aggregated to transportation analysis zones (TAZs). Census block groups, which are analogous to TAZ, were designated as “broadband” or “not broadband” based on internet subscriptions estimates from the American Community Survey. The block groups were mapped to TAZs then correlated changes in travel to broadband status. Finally, with the assistance of SCAG’s traffic modeling team, it was estimated how improved broadband status would increase telecommuting, thereby reducing VMT and GHG, using the regional activity-based travel demand model.

During the pandemic there was substantial reduction in VMT due to shelter-in-place (SIP) behaviors. Generally, only essential workers traveled to work. Non-essential workers worked from home, substituting broadband for their commutes. This phenomenon was evident in the travel data, especially during morning (AM) and evening (PM) peak travel times. Origin data told us how many trips were generated in each TAZ over time. Broadband TAZ had larger reductions in travel more during SIP periods than non-broadband TAZ, which also tended to be less affluent and have more essential workers.

The 2045 SCAG Activity Based Travel Model was developed and used to forecast transportation demand across the region. It is highly complex, incorporating numerous factors such as demographics and land use. Broadband and telecommuting considerations were added to the model to estimate impact on VMT and GHG in four scenarios:

A. 2045 Future Baseline: the "preferred scenario" travel behavior forecast for the regional transportation prior to the pandemic,
B. 2045 Non-Broadband Expansion Increment–Shelter in Place Behavior (NBEI-SIPB): non-broadband areas increase telecommuting to match broadband areas' travel behavior during shelter-in-place periods of the pandemic,
C. 2045 Non-Broadband Expansion Increment - Upper Bound Behavior (NBEI-UBB): all non-essential workers in non-broadband areas all telecommute,
D. 2045 Total Broadband – Upper Bound Behavior (TB-UBB) Regionwide: all non-essential workers in all areas of the region telecommute.

Impacts of increased telecommuting on VMT and GHG were estimated as a 2% to 15% reduction based on the results of these scenarios. The percent reduction of regional vehicle hours of travel during the AM/PM peak periods respectively is summarized in the table below.

Table 1. Peak Period Vehicle Hours of Travel Comparison

	Period	
	AM	PM
2045 Baseline	2,950,217	4,345,241
2045 Increment SIP	2,843,388	4,213,802
2045 Increment UBB	2,814,035	4,099,249
2045 Total UB	1,978,484	2,802,368
Increment SIP Diff	-106,829	-131,438
Increment UBB Diff	-136,182	-245,991
Total UBB Diff	-971,733	-1,542,873
Increment SIP % Reduction	-3.8%	-3.1%
Increment UBB % Reduction	-4.8%	-6.0%
Total UBB % Reduction	-49.1%	-55.1%

Roadways in the region that benefited most from this reduction include:

- Interstate 10
- Interstate 110
- Interstate 605
- Interstate 710
- State Road 215
- State Road 91
- State Road 72
- State Road 42
- North Waterman
- South Atlantic Blvd
- Riverside Dr
- East 7th St
- Figueroa St
- West 120th St

To achieve these reductions, broadband expansion would need to be accompanied by employers making major changes in their operations and policies. Use of broadband as a substitute for other trips such as to school or shopping was not included in these estimates. It is reasonable to believe such behavior would also have impacts on VMT and GHG. Lack of broadband is a potential roadblock to reducing travel for other purposes.

Installing conduit in the public rights of way in conjunction with transportation improvement projects and initiatives can greatly reduce the cost of broadband development. There are various ways to fund such projects, such as simply including conduit as a standard component of transportation construction projects. The conduit could be leased to generate funding for digital inclusion, including telecommuting programs. CETF and the broadband consortia convened discussions with community members about these issues in parallel with this research. Published under a separate cover, the community input provides qualitative insights into sentiments about such programs.

1. Introduction: The Potential Benefits of Transportation Broadband Strategy

Southern California Association of Governments (SCAG), with the California Emerging Technology Fund (CETF) and Southern California Regional Broadband Consortia, contracted with Magellan Advisors, along with DKS Associates, to study the relationship between broadband availability and reduced Vehicle Miles Traveled (VMT) and Greenhouse Gas Emissions (GHG). The focus of the study is inclusion of broadband in transportation facilities, planning, and projects. This should (a) reduce costs to deploy broadband, especially in rural and disadvantaged communities, which then (b) provides a substitute for commuting and other trips, thereby reducing VMT and GHG emissions.

The implication is that developing broadband infrastructure can be an important transportation demand management strategy (TDM) that also creates more equitable access to education, healthcare, and jobs. Planning for broadband and including communications network infrastructure in public rights-of-way on interstates, state highways, bridges, regional roads, and local streets should be standard practice in transportation. Broadband should be an eligible transportation project cost, a standard TDM measure, and included in the concept and construction of complete streets.

This report summarizes insights from prior analyses and provides local socio-economic context before analyzing primary data collected during the COVID-19 pandemic to determine the impact of telecommuting on VMT and GHG emissions. This analysis is then used to project long-term impacts of full broadband deployment. Lastly, we analyze costs and funding strategies for including broadband in transportation projects. The two essential questions we address are:

1. What is the relationship between broadband and GHG emissions? Does broadband substitute for travel—specifically commuting to work—thereby reducing VMT and, consequently GHG emissions?
2. What are the costs to incorporate communications network infrastructure in transportation projects and how might this impact capital investment necessary to offer broadband?

Prior to the COVID-19 pandemic about 5% of all workers telecommuted. During the first peak of COVID-19, that jumped to around 40%, with some reports much higher. Trips to school, medical, local government, and retail and service destinations also greatly decreased. Approximately 20% of the workforce will continue to telecommute at least one day per week post-COVID-19. While telecommuters may add trips to their routines due to their flexible schedule, it is also possible that they may combine trips and/or make them at non-peak times. Use of distance learning, telehealth, online government, and other online services post- pandemic are likely to continue, driving the need for broadband while reducing demand for local travel. The purpose of this report is to help close the gaps in practice, policy, and leadership for a comprehensive vision or strategy to develop broadband as a means to reduce VMT and GHG emissions.

The bulk of costs to deploy broadband comes from construction costs, especially labor. These costs are often highest for disadvantaged and rural communities, leading them to be under-served—to have no or few options for broadband available. Internet service providers must absorb these costs to reach prospective subscribers, then are disinclined to make the infrastructure available to potential competitors. Communications network infrastructure—conduit, fiber, and other physical assets—may be incorporated into many transportation projects at a small marginal cost. It is an investment that adds value to and capitalizes on the public right-of-way as it reduces traffic congestion and enables traffic management.

The pandemic has starkly highlighted the severe need for broadband, which is driving policy, planning, and deployment to improve access, costs, and options. This study examines how this interacts with transportation. The two are clearly related in their use of the public rights-of-way. Broadband as a substitute for travel adds another layer of interaction between the two. New state and federal funds to improve and update infrastructure creates other financial and practical connections. Broadband, mobility, and quality of life are issues that matter to all residents across the region. By clearly showing the environmental and socio-economic benefits of including broadband in transportation projects, we hope to change practices and integrate public strategies for both.

TELECOMMUTING BENEFITS LITERATURE REVIEW[1]

In 2017, companies FlexJobs and Global Workspace Analytics reported that the 3.9 million workers who work from home at least half the week avoided 7.8 billion VMT, 530 million vehicle trips, and 3 million tons of greenhouse gases. This translates to a reduction of 2000 personal vehicle miles (or a 20% over US VMT average of 9800 miles) per year.

[1] This sub-section was produced by DKS Associates.

To better understand the reported benefits of telecommuting on reducing VMT and emissions, six relevant literature sources were reviewed. With the emergence of intelligent transportation systems (ITS) and domestic telecommunications applications, numerous home-based and center-based telecommuting demonstration projects were conducted in California and Washington during the 1990s. A selection, based on those highlighted by Handy, et al. (2013) and others, are given in Table 2 below.

Table 2: Transportation Safety SCAG Regional Targets

Authors and Year	Participants and Methodology	VMT Findings
Kitamura, R Mokhtarian, PL, Pendyala, RM, Goulias, KG, 1991	California State Employees Two three-day travel diary surveys 73 telecommuting employees and 45 associated household members, 65 control group employees and 36 associated control household members	A home-based telecommute had a 76.1% personal VMT reduction per telecommuter per telecommuting day, and a 48.1% reduction per household per telecommuter per telecommuting day
Henderson, DK, Mokhtarian, PL, 1996	Mix of employees from public and private employers both at-home and at a telework center Travel diaries taken during the Puget Sound Demonstration Project 96 home telecommuters 8 regional telework center telecommuters and 41 control group members	Telecommuting from home decreased commute VMT by 90.3% and personal daily VMT by 66.5% per telecommuter per telecommuting day Telecommuting from a telework center reduced commute VMT by 62% and personal daily VMT by 53.7% per telecommuter per telecommuting day
Balepur, PN, Varma, KV, Mokhtarian, PL, 1998	Travel diaries and entry-and-exit logs 24 participants, affiliations unknown, who used California Neighborhood Telecenters	Telecommuting to a telework center reduced commute VMT by 77.2% and personal daily VMT by 64.8% per telecommuter per telecommuting day
Koenig, BE, Henderson, DK, Mokhtarian, PL, 1996	Participants in the State of California Telecommuting Pilot Project, which were State employees drawn from across various state agencies,	Telecommuting reduced average telecommuter VMT by 77% on telecommuting days

Authors and Year	Participants and Methodology	VMT Findings
	primarily in the Sacramento and San Francisco Bay areas. Travel diaries 40 telecommuters and 58 control group members	

The Koenig, et al. study also reviewed the environmental impacts of telework, finding a reduction of 48% in total organic gases (hydrocarbons), 64% in carbon monoxide, 69% in nitrogen dioxides, and 78% in particulate matter on telework days compared to non-telework days. A 2004 review of studies by Walls and Safirova concluded that for those working from home, telecommuters reduced trips taken by 27% to 51% versus non-telecommuting days, and telecommute days reduced VMT by 53% to 77% for telecommuters.

An important caveat is that these studies were largely program specific (i.e., applied to a single employer) and are specific to only the home-based work trip. Hence, the percentages cited would not directly translate to regional benefits. Henderson and Mokhtarian (1996), for instance, warn that their Puget Sound study participants were not representative of the wider workforce in important ways, and that caution should be used when extrapolating their results. Koenig, et al. (1998) note that their VMT savings are likely larger than representative, since their telecommuters had longer commutes than the regional average. Changes to commute/travel patterns and technology in intervening decade(s) is also likely to change the feasibility and capacity of teleworking on a regional level.

Based on the literature review reported in Effects of Travel Reduction and Efficient Driving on Transportation: Energy Use and Greenhouse Gas Emissions (U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, March 2013), regional benefits of telecommuting and resulting expected energy use and GHG emission reduction effects vary widely from strategy to strategy. The estimated impact of individual strategies on surface transportation energy use and GHG emissions ranges from less than 1% to a few percent. The study estimated the cumulative effect (i.e., regional benefit) when travel behavior strategies are combined to result in a 7% to 15% reduction in energy use and emissions by 2030.

Insights to the potential regional VMT and GHG reduction benefits of telecommuting can be made by considering the regional travel behavior changes that occurred during the COVID-19 pandemic shelter-in-place orders. The extent of telecommuting was directly tied to the definitions of essential versus non-essential workers. In a Rand Corporation study: The COVID-19 Pandemic and the Changing

Nature of Work Lose Your Job, Show Up to Work, or Telecommute? (Rand Corporation, Philip Armour, Katherine Grace Carman, Kathleen J. Mullen, Shanthi Nataraj, June 2020) surveys of on 1,049 workers demonstrate how telecommuting arrangements vary significantly by occupation (see Table 3).

Larger questions remain about the wider applicability of telecommuting research. The effects of telecommuting on emissions can remain uncertain depending on the scope definition (O'Brien and Alibadi, 2020). Scoping transportation, office buildings, residential building, information and communication technology, and telecommuting impacts over time, rather than relying on short term personal travel diaries, should create more realistic estimates of net emissions. As for VMT alone, rebound effects like the dispersion of residential location (resulting in seldom-driven but longer-distanced commutes), increased non-work travel, and intra-household dynamics leading to additional vehicle use, should ideally be accounted for. However, most studies in the literature fail to do so (Hook et al. 2020).

The Broadband and Environmental Benefit Data and Literature Review prepared by Inland Empire Regional Broadband Consortium is provided as an appendix to this final report.

Table 3. Telecommuting Arrangements Vary Widely by Occupation[2]

	Percentage of Workers in Each Telecommuting Category in May 2020		
Occupational Area	None	Some	Only
Protective service	96%	2%	2%
Production	96%	1%	3%
Construction and extraction	94%	3%	3%
Food preparation and serving related	92%	8%	0%
Transportation and material moving	90%	7%	3%
Building and grounds cleaning and	87%	0%	13%

[2] SOURCE: Authors' calculations based on 1,049 responses from the ALP survey conducted May 1–6, 2020. The exact wording of the question to determine telecommuting status was "In the past seven days, on how many days were you required to leave your home to do your MAIN job?" Exclusive telecommuting was defined as never being required to leave home to do a main job. Some telecommuting was defined as having to leave home to do a main job at least once, but also working from home at least once. No telecommuting was defined as not being able to telecommute or not working from home at all. Occupations are based on information from the ALP's household information survey fielded in February 2020. The sample is limited to workers reporting that they were working at the same main job as in February 2020. The farming, fishing, and forestry occupation is excluded because fewer than ten respondents reported working this occupation. Some rows do not sum to 100 percent because of rounding.

Occupational Area	Percentage of Workers in Each Telecommuting Category in May 2020		
	None	Some	Only
Installation, maintenance, and repair	81%	17%	2%
Health care practitioners and technical	73%	8%	19%
Personal care and service	69%	5%	26%
Sales and related	58%	10%	33%
Community and social service	51%	26%	24%
Health care support	50%	7%	43%
Management	37%	36%	27%
Office and administrative support	30%	28%	42%
Arts, design, entertainment, media, sports	21%	11%	68%
Life, physical, and social science	12%	41%	46%
Business and financial operations	12%	11%	77%
Educational instruction and library	11%	18%	72%
Architecture and engineering	6%	9%	84%
Computer and mathematical	6%	11%	83%
Legal	3%	26%	71%
Overall	**46%**	**14%**	**40%**

2. Regional Socio-Economic Overview

To understand broadband, VMT, and GHG emissions in context, we analyzed US Census Bureau estimates[3] of socio-economic characteristics of the SCAG region for 2019, comparing them to prior years and to the nation as a whole.

POPULATION

The 2019 total population for the SCAG region was 18,892,651, which was 5.8% of the nation's population. The population of the region increased by 796,555 between 2010 and 2019, for an annual growth rate of 0.48% and aggregate 5.8% growth. While Los Angeles was the largest in terms of population (and was the most populous county in the nation), Orange County had the greatest population density, and Riverside had the fastest growth (see Table 4).

Table 4. Population, Density, and Growth of SCAG Counties Compared

County	2019 Population	Population Density	2010-2019 Annual Growth Rate
Imperial	181,215	40.4	0.37%
Los Angeles	10,039,107	2,112.2	0.23%
Orange	3,175,692	3,349.9	0.56%
Riverside	2,470,546	338.3	1.28%
San Bernardino	2,180,085	108.4	0.73%
Ventura	846,006	383.2	0.27%

It is notable that the counties of the SCAG region vary greatly in size. San Bernardino, in particular, at 20,105 square miles, is the largest county in the country. Riverside is relatively large at 7,303 square miles but small in comparison. Imperial and Los Angeles counties are similar size—4,482 and 4,753 square miles, respectively. Ventura is relatively large compared to all other counties: It has 2,208 square miles and the national average is 1,124. Orange County is by far the smallest at 948 square miles, but it is still larger than the average county in a third of the United States.

[3] Unless otherwise noted all statistics were sourced from

AGE

The population of the region was generally younger than the nation, particularly Imperial and San Bernardino counties, as shown in Figure 1. Los Angeles and Orange counties had relatively large populations of working age adults. Ventura was comparable to the nation as a whole in terms of age distribution and had the highest percentage of older adults for the region.

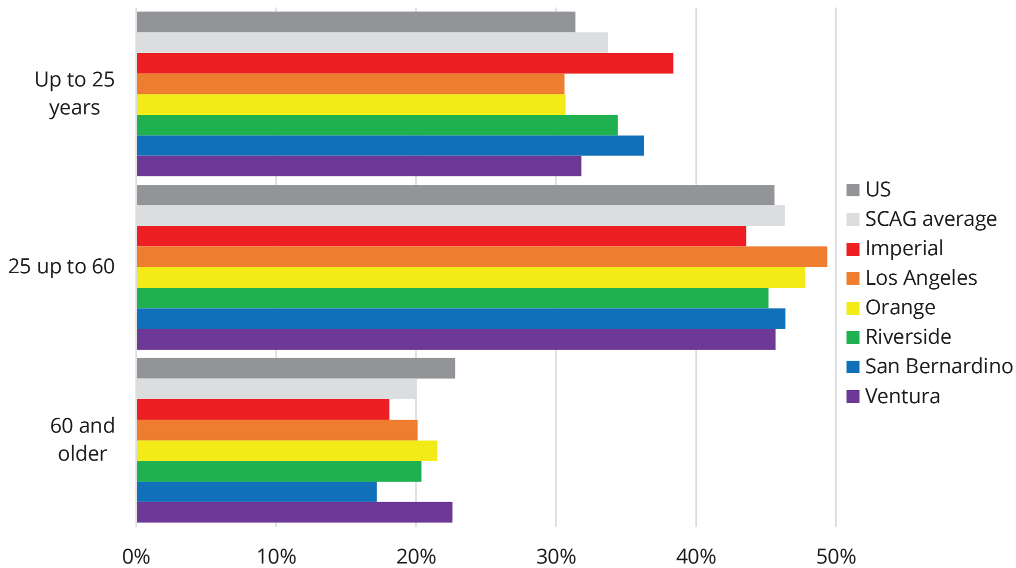

Figure 1. Age Distribution of Populations Compared

ETHNICITY AND RACE

The region was more racially diverse than the nation, particularly for persons of Hispanic or Latino heritage. Ventura County was the exception, with a substantially larger portion of the population of white races than the nation and relatively small portion of Hispanic/Latino persons relative to the region. Nearly 90% of the population of Imperial County, in contrast, was Hispanic/Latino. Los Angeles had the lowest percentage of white population. Orange County had the largest percent of the population of Asian descent, followed by Los Angeles, particularly relative to the nation, while Imperial had relatively few.

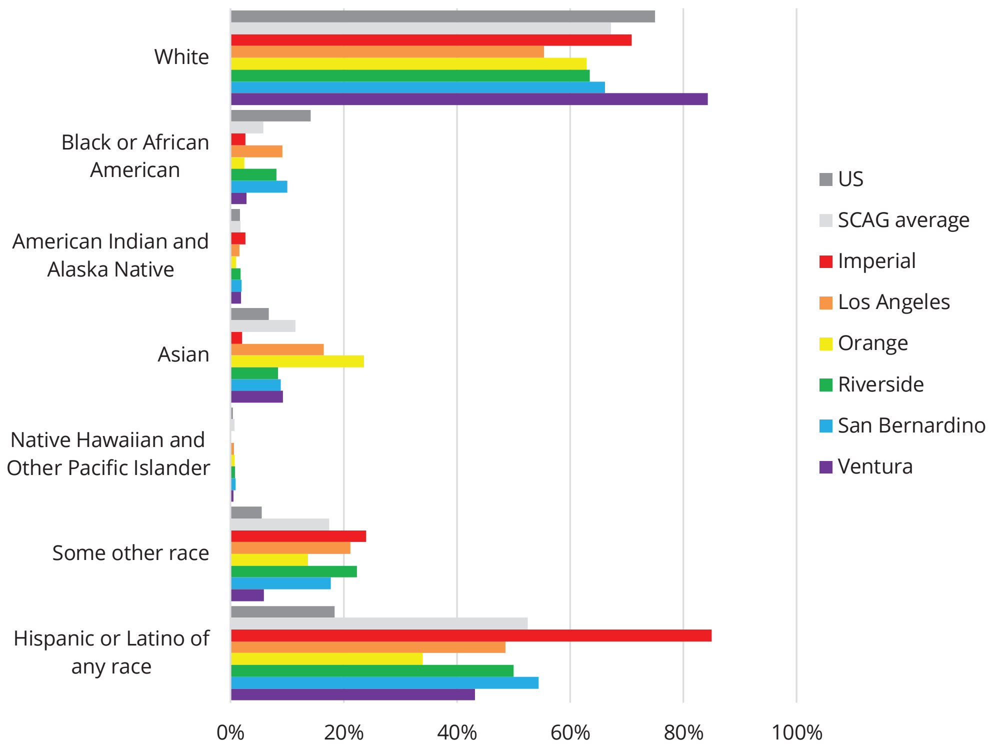

Figure 2. Racial Distribution of Populations Compared[4]

EDUCATIONAL ATTAINMENT

Generally, residents of the region are more educated than the nation as a whole. That said, as shown in Figure 3, four of the six counties—Imperial, Los Angeles, Riverside, and San Bernardino—had relatively more of the population with no more than a high school degree. Fifty-two percent of Imperial County's population over 25 with income were in this category, compared with 38% for the U.S. Orange and Ventura counties have the largest percentages with high levels of academic achievement. Riverside and San Bernardino were relatively strong in associates degrees or some college but no degree. Orange County stood out for the percent of the populace with a doctoral or other professional degree—15.2% compared to 10.1% for the SCAG region and 12.8% for the nation.

[4] Total percentage across racial categories are greater than 100% due to persons of more than one race in the population.

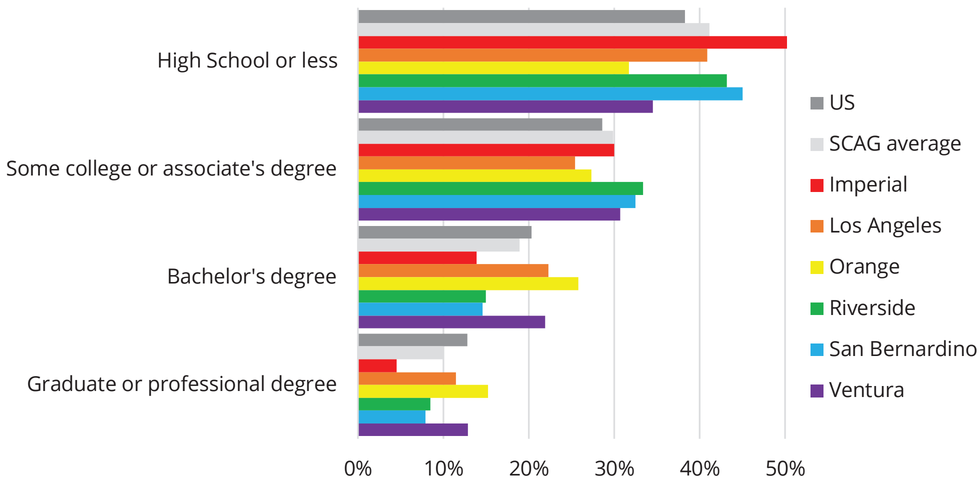

Figure 3. Percentage of Population over 25 with Earnings by Educational Achievement Compared

INCOME

The region's residents generally had generally had higher incomes, as shown in Table 5**Error! Not a valid bookmark self-reference.**, except for persons with less than high school education, which brought the overall median earnings for the region ($41,211) below the national median ($41,801). No high school completion meant lower income for residents of Imperial County, where they earned 67% of the national median income for persons with that level of educational achievement. In contrast, persons with high school education in Imperial County well exceeded the national median pay. See Figure 4. Ventura and Orange counties tended to have the highest wages, particularly for persons with college education.

Table 5. Median Earnings by Level of Educational Attainment Compared

	Median Income	
Educational Attainment	U.S.	SCAG
All levels	$41,801	$41,211
Less than high school graduate	$25,876	$24,639
High school graduate (includes equivalency)	$31,956	$33,135
Some college or associate's degree	$38,125	$39,928
Bachelor's degree	$56,344	$56,780
Graduate or professional degree	$75,495	$81,048

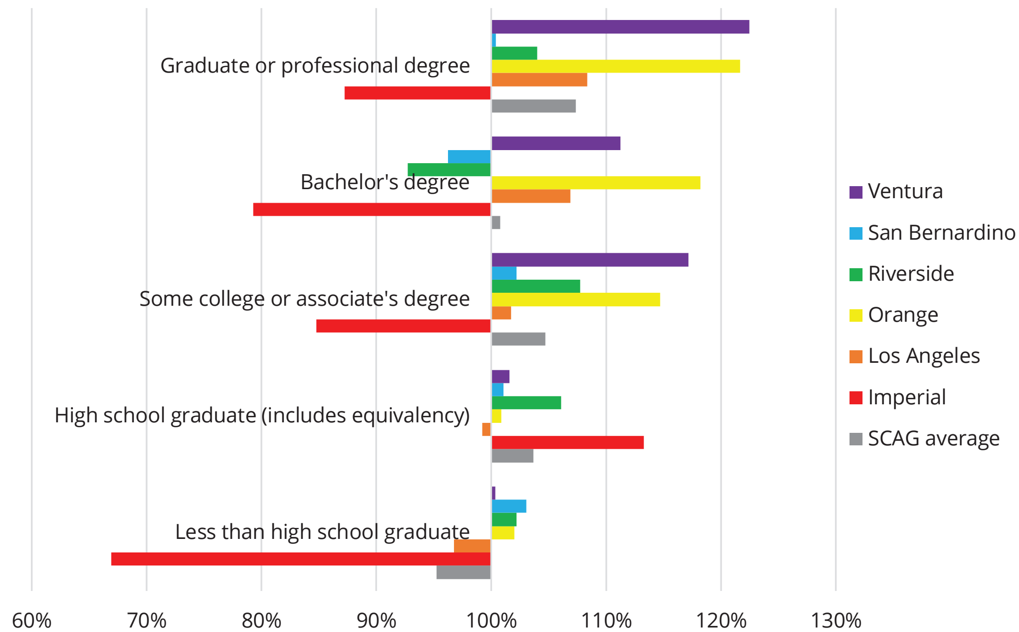

Figure 4. Percentage of US Median Income (=100%) by Educational Achievement Compared

Given the income levels, it is not surprising that Imperial County surpassed the state and region for the percentage of families with income below the poverty level, and, as shown in Figure 5, was the only area to see an increase in this statistic in recent history. Ventura and Orange counties were well below the nation in poverty and Los Angeles has seen the largest decrease.

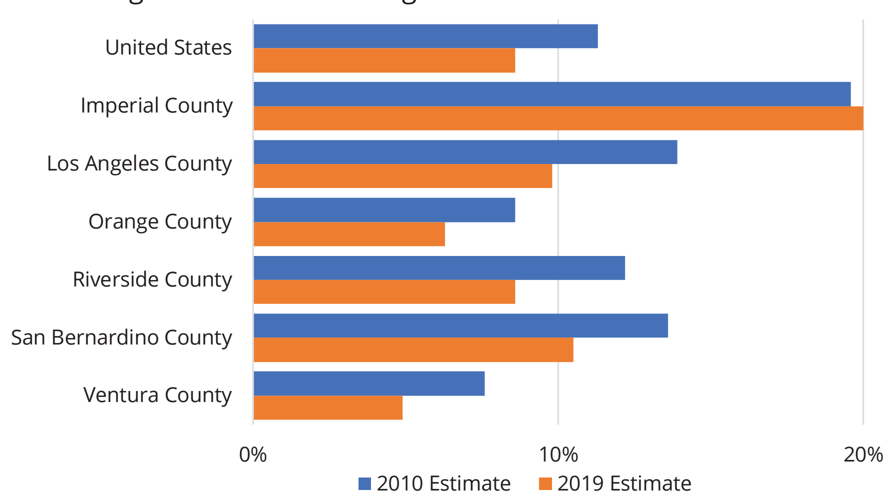

Figure 5. Percentage of Families with Income Below the Poverty Level

OCCUPATION

A comparison of occupation shown in Figure 6 reveals that Los Angeles, with over five million civilian employed residents, has the largest workforce, and Imperial has the smallest at just over 60,000. Overall, the most people are employed in business management, science, or arts occupations. Only Orange County exceeds the nation for the percentage of these occupations, though. The region exceeds the nation in natural resource, construction, and maintenance, sales and office, and service occupations.

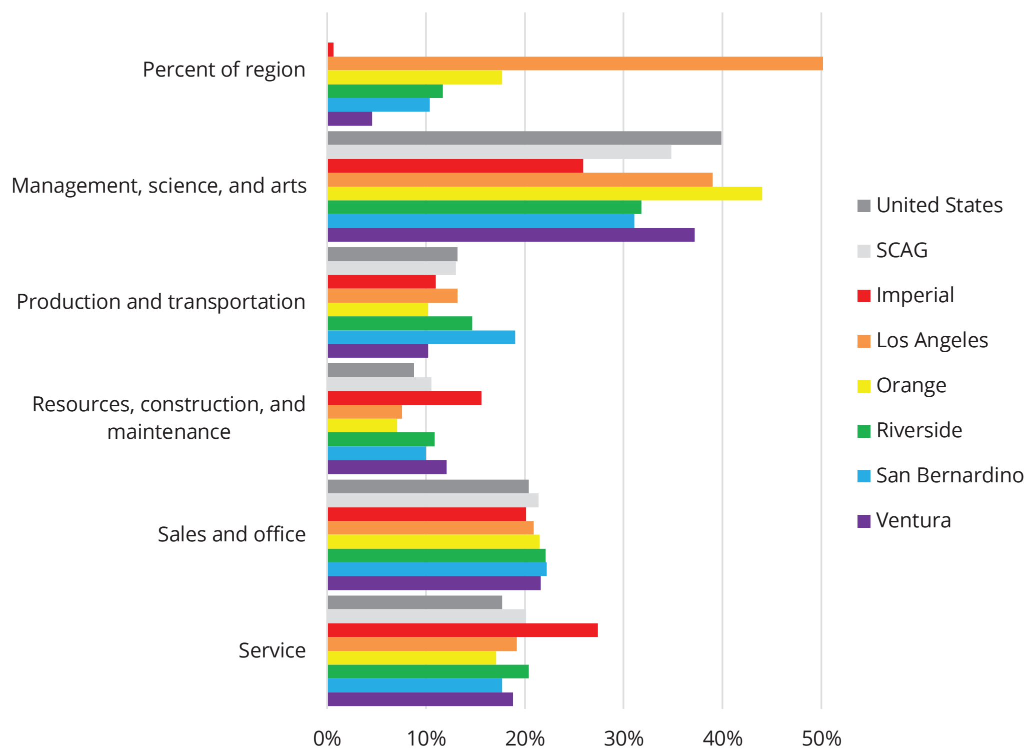

Figure 6. Percentage of Working Population by Occupational Area Compared

Table 6. Employment Location Quotient by Economic Sector for the SCAG Region and its Six Counties

Economic Sector	SCAG Region	Imperial	Los Angeles	Orange	Riverside	San Bernardino	Ventura
Accommodation and food services	*1.17*	*1.13*	*1.11*	*1.11*	*1.48*	*1.01*	*1.19*
Administrative and support services	0.66	0.36	0.67	0.77	0.73	0.68	0.72
Agriculture, forestry, fishing and hunting	*3.04*	*14.35*	0.15	0.16	*1.22*	0.26	*2.12*
Arts, entertainment, and recreation	*1.28*	0.57	*1.40*	*2.20*	*1.46*	*1.10*	0.94
Construction	*1.15*	0.81	0.71	*1.27*	*1.90*	*1.09*	*1.12*
Educational services	0.77	0.24	*1.44*	0.74	0.65	0.72	0.84
Finance and insurance	0.71	0.46	0.80	*1.19*	0.38	0.51	0.90
Health care and social assistance	0.96	*1.17*	0.96	0.74	0.90	1.04	0.98
Industries not classified	1.00	-	*1.99*	0.82	1.03	0.91	*1.23*
Information	0.84	0.39	*1.87*	0.93	0.45	0.61	0.76
Management of companies and enterprises	0.57	0.12	0.80	*1.25*	0.21	0.42	0.62
Manufacturing	0.96	0.96	0.90	*1.06*	0.85	0.94	1.05
Mining, quarrying, and oil and gas extraction	0.51	*2.04*	0.14	0.07	0.10	0.22	0.49
Other services (except public administration)	0.89	0.71	*1.03*	0.89	0.93	0.90	0.91
Professional, scientific, and technical services	0.81	0.39	*1.11*	*1.27*	0.52	0.41	*1.16*

Economic Sector	SCAG Region	Imperial	Los Angeles	Orange	Riverside	San Bernardino	Ventura
Real estate and rental and leasing	*1.24*	*1.32*	*1.45*	*1.72*	*1.03*	0.89	*1.01*
Retail trade	*1.27*	*2.07*	0.90	0.82	*1.34*	*1.25*	*1.27*
Transportation and warehousing	*1.32*	*1.21*	*1.17*	0.51	*1.56*	*2.95*	0.53
Utilities	1.00	*2.64*	0.73	0.37	0.46	*1.14*	0.64
Wholesale trade	*1.33*	*1.32*	*1.37*	*1.54*	*1.04*	*1.51*	*1.20*

Table 7. Percentages of U.S. Average Annual Pay by Economic Sector for the SCAG Region and its Six Counties, Sorted from Highest to Lowest Percentage for the Region

Economic Sector	Average Annual Pay	SCAG	Imperial	Los Angeles	Orange	Riverside	San Bernardino	Ventura
All sectors	**$55,858**	**106%**	**67%**	**113%**	**111%**	**76%**	**83%**	**102%**
Arts, entertainment, and recreation	$37,599	193%	60%	281%	112%	73%	83%	82%
Industries not classified	$31,680	122%	NA	130%	131%	82%	68%	61%
Real estate and related	$58,313	116%	58%	118%	126%	82%	92%	100%
Mining and related	$94,862	114%	90%	140%	62%	93%	79%	97%
Retail trade	$29,983	114%	87%	118%	117%	106%	105%	107%
Accommodation and food services	$21,077	114%	88%	118%	113%	112%	93%	101%
Utilities	$111,910	111%	91%	116%	103%	106%	100%	116%
Finance and insurance	$106,614	110%	49%	122%	104%	64%	66%	91%

Economic Sector	Average Annual Pay	SCAG	Imperial	Los Angeles	Orange	Riverside	San Bernardino	Ventura
All sectors	**$55,858**	**106%**	**67%**	**113%**	**111%**	**76%**	**83%**	**102%**
Health care and social assistance	$52,224	110%	88%	112%	108%	102%	115%	102%
Information	$112,479	108%	45%	116%	96%	46%	70%	61%
Professional, scientific, and technical services	$91,007	106%	44%	110%	104%	64%	63%	152%
Transportation and warehousing	$52,369	105%	82%	117%	102%	89%	85%	92%
Manufacturing	$61,127	104%	65%	106%	113%	87%	88%	107%
Construction	$64,917	102%	83%	101%	114%	88%	99%	90%
Other services (except public administration)	$35,079	102%	77%	107%	97%	90%	94%	90%
Educational services	$41,289	99%	66%	104%	88%	73%	83%	84%
Administrative and support services	$43,552	97%	92%	98%	108%	75%	85%	90%
Agriculture and related	$46,235	96%	78%	77%	95%	117%	74%	109%
Wholesale trade	$75,118	94%	70%	89%	114%	79%	78%	108%
Management of companies and enterprises	$114,474	88%	51%	90%	89%	65%	61%	111%

Table 8. Percentage of U.S. Average Pay by Occupational Area for the SCAG Region and its Six Counties, Sorted from Highest to Lowest Percentage for the Region Sorted by Percentage for the Region.

Occupational Area	U.S. Average Annual Pay	SCAG	Imperial	Los Angeles	Orange	Riverside-San Bernardino	Ventura
All Occupations	$56,310	**118%**	105%	**127%**	**124%**	**113%**	119%
Protective Service	$52,220	128%	145%	128%	114%	115%	138%
Educational Instruction and Library	$59,810	120%	115%	126%	125%	119%	116%
Food Preparation and Serving Related	$27,650	120%	116%	124%	125%	117%	118%
Personal Care and Service	$32,610	119%	106%	127%	121%	109%	134%
Community and Social Service	$52,180	118%	110%	123%	115%	120%	122%
Healthcare Practitioners and Technical	$85,900	118%	111%	122%	120%	119%	120%
Building and Grounds Cleaning and Maintenance	$32,760	118%	110%	123%	120%	119%	119%
Construction and Extraction	$53,940	114%	110%	120%	122%	108%	111%
Installation, Maintenance, and Repair	$52,360	111%	105%	115%	116%	108%	112%
Healthcare Support	$32,250	110%	100%	112%	115%	109%	115%
Life, Physical, and Social Science	$79,360	109%	99%	120%	108%	108%	112%
Legal	$112,320	109%	84%	123%	135%	105%	99%
Office and Administrative Support	$42,390	109%	98%	115%	115%	106%	111%

Occupational Area	U.S. Average Annual Pay	SCAG	Imperial	Los Angeles	Orange	Riverside-San Bernardino	Ventura
All Occupations	**$56,310**	**118%**	105%	127%	124%	**113%**	119%
Architecture and Engineering	$90,300	107%	91%	115%	115%	102%	113%
Arts, Design, Entertainment, Sports, and Media	$64,400	106%	85%	141%	111%	96%	97%
Sales and Related	$45,750	105%	87%	112%	124%	99%	103%
Production	$41,760	105%	110%	104%	105%	101%	105%
Transportation and Material Moving	$39,680	104%	102%	114%	100%	103%	100%
Farming, Fishing, and Forestry	$33,310	103%	100%	113%	112%	96%	96%
Management	$126,480	101%	83%	111%	114%	93%	102%
Business and Financial Operations	$80,680	99%	89%	109%	103%	92%	104%
Computer and Mathematical	$96,770	98%	73%	107%	104%	93%	112%

EMPLOYMENT

In terms of employment in various sectors, the SCAG region far exceeded the nation in agricultural industries overwhelmingly due to Imperial County. Table 6 shows location quotients[5] for each county and the region as a whole. While only 1.8% of Imperial County employees were extractive industries, that far outstrips the nation. A more substantial 25% of Imperial County's employees were in retail, which also far exceeded the nation. The region overall was strong in wholesale trade, transportation and warehousing, art, entertainment and recreation, retail, and real estate and leasing, in that order.

The largest location quotient other than agriculture in Imperial was transportation and warehousing in San Bernardino County with 12% of the workforce. Riverside had relatively high employment in construction but also transportation and warehousing and accommodations and food services. Information and unclassified industries were strong sectors for Los Angeles. Orange County was particularly strong in arts, entertainment, and recreation, real estate, and wholesale trade employment.

Emerging Industries

Comparing sector location quotients at prior and recent times shows which industries are growing (or declining) relative to the rest of the nation. Mining and related industry in Imperial County had the strongest relative growth, but it was a small (1.0%) portion of the economy and the sector lost strength in San Bernardino and Ventura Counties. A similar situation was evident for utilities, which gained strength in Los Angeles County, and Riverside and Orange counties, while losing in San Bernardino and Ventura counties, but had a small portion of employment.

Transportation and warehousing gained strength in San Bernardino, building on recent history. This growth occurred to a lesser extent in Riverside but was enough to indicate an emerging industry. Orange County had the clearest case of emerging industry in the arts, recreation, and culture sector. Although relatively weak in Imperial County, the sector gained substantially there. Finance was also relatively weak but had substantial growth in Imperial, as did real estate and related, which were historically strong in that county.

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[5] A location quotient is the percentage of employees in a sector for a county divided by the percentage for the nation. A location quotient of 1.0 means the county is equivalent to the nation. Values greater than one means the county has relatively more employees in that sector, and fewer employees are evident in number less that 1. The larger the value, the more extreme the difference.

PAY

On average across all sectors, pay in SCAG was 109% of the nation, as shown in Table 7, based on U.S. Census estimates for 2019. Data for 2021 from the State of California Employment Development Office[6] compared to similar data for the nation,[7] indicates even higher relative pay—118% of the nation on average for all occupations. Data summarized in Table 8 shows relative pay for the region and counties (the State of California combines Riverside and San Bernardino counties) with particularly high levels (≥120% of national average) highlighted.

Residents of the region were generally paid more than their counterparts elsewhere in the country. Pay was relatively highest in Los Angeles, especially for arts, entertainment, and recreation companies. Protective services was the relatively highest paying occupation. Los Angeles and Orange counties had numerous occupations, generally more labor-intensive and lower paying professions, that earned substantially more than the national average. Other relatively high wage industries were real estate, accommodations and food services, and retail trade. Unclassified firms paid relatively well as did industries with relatively small employee bases (e.g., mining).

Some of the region's major sectors, specifically accommodations and food services, were among the sectors with the lowest average pay, although local pay was generally higher than the national average. Pay in the information sector was relatively low across the region except for Los Angeles. Finance, retail, transportation, and utilities were also paid relatively well in Los Angeles but not other parts of the region. Arts and media occupations paid well above average in Los Angeles. Overall, employees in Imperial County were paid two thirds of national average and in Riverside they were paid three quarters the national average.

COMMUTING

Over three quarters of employed persons commuted to work by driving alone. As illustrated in Figure 7, the region overall and all counties except Los Angeles had higher than average percentage of population commuting by car. Los Angeles had the highest percentage of transit riders, exceeding the national average as well as the rest of the region. Imperial had the largest percentage of carpoolers and walkers. The region was slightly above average for percentage of employed persons working from home. Orange County had substantially higher percentage of telecommuters than other counties, the

[6] Data sourced from https://www.labormarketinfo.edd.ca.gov/data/oes-employment-and-wages.html#OES.
[7] Data sourced from https://www.bls.gov/oes/current/oes_nat.htm.

region, or the U.S. overall. These mode share trends have remained fairly constant since 1980 with the exception of telecommuting which has increased by approximately 400% in the SCAG Region since 1980 – increasing from approximately 1% to 5%.

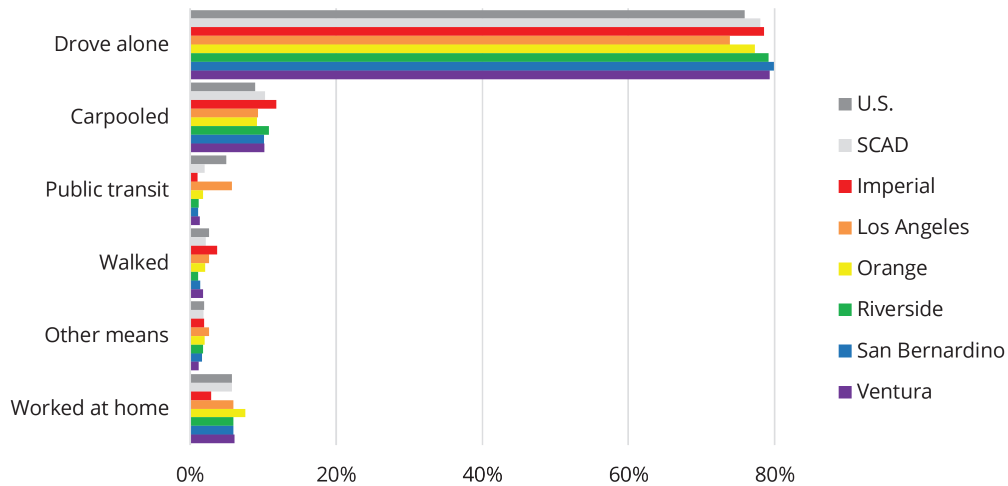

Figure 7. Percentage of Working Population by Methods of Commuting to Work for the Nation, SCAG Region, and Six Counties Compared

Riverside had the longest commute times. See Table 9. Imperial County commuters had the shortest drive but also some of the largest increases in commute time over recent years. The SCAG region overall increase in percentage of commuters was greater than the nation—over 20% growth for Riverside and San Bernardino counties. The region increased the percentage of telecommuters and walkers but had substantial decreases in public transit and carpooling. These estimates were for 2019, prior to the COVID-19 pandemic and associated changes in travel.

Table 9. Mean Travel Time to Work and 2010-2019 Change by Areas

Area	Mean travel time to work (minutes)	Change 2010-2019
United States	27.6	9.1%
SCAG Region	30.0	12.3%
Imperial County	23.7	15.0%
Los Angeles County	32.8	13.9%
Orange County	28.3	9.3%
Riverside County	35.7	12.6%
San Bernardino County	31.9	8.5%

Ventura County	27.8	15.8%

REGIONAL SUMMARY

SCAG is a very diverse region—from very rural areas on the east to some of the most densely populated areas in the country on the west, with both the largest county and the most populous county in the United States. The region generally gained population in recent years but some parts of the region—particularly Riverside County—grew relatively quickly while others—dense Los Angeles as well as rural Ventura and Imperial counties—grew slower than the nation.

While the region was generally younger, more diverse, and better educated than other parts of the country, demographics vary greatly across the region. Imperial and San Bernardino had relatively young population, while Ventura was generally older. Hispanic culture was pervasive in Los Angeles but not so much in Orange. In contrast Orange County has a far larger Asian population that the country and the region. Ventura County had the largest percentage of white residents, exceeding most of the nation.

Los Angeles and Orange counties had relatively well-educated and large working age populations. Most areas of the region had relatively high pay, particularly for better-educated workers. Ventura and Orange counties were especially notable for this. Los Angeles and Orange counties had large talent pools. In contrast, educated workers in Imperial County lagged far behind their peers in pay. Generally, Los Angeles had most of the regional workforce, especially in management occupations.

The region's economy varied widely from overwhelming dominance of agriculture in Imperial County to distinctive strengths in the transportation (San Bernardino) and information (Los Angeles) sectors. The clearest evidence of emerging industry was arts, culture, and recreation in Orange County. Generally, health care and social assistance employment strengthened slightly throughout the region, while administrative and management services generally declined.

Commuting was pervasive and increased in all counties, well ahead of the nation. Somewhat fewer people worked from home in Imperial County, and somewhat more in Orange County, but the region generally matched the nation on this demographic. Public transit use for commuting across the region was well below national levels, although it was relatively high in Los Angeles. Given all of the above, Los Angeles, Orange, and Ventura counties seem prime for greater adoption of telecommuting. The more rural counties lacked the occupations most amenable to telecommuting. Riverside, which had the longest commutes, along with Los Angeles and San Berdarndino, was best poised for workforce development to enable telecommuting.

3. Current Broadband Availability

To ascertain the impact of broadband substituting for trips, it is necessary to identify where broadband is, and is not, available. Broadband availability (BA) is the critical intervening variable for determining the relationship between broadband in transportation and reduction of VMT. BA varies across geography: Some places have abundant, fast, inexpensive broadband. Other places are broadband deficient: Consumers have high prices, low speeds, and no options.

ASSESSING BROADBAND AVAILABILITY

Broadband availability can be assessed in terms of speed—bandwidth or throughput as measured as megabits per second (Mbps)—and costs. Ideally, BA data includes some information about speed, if only “faster than” or “slower than” a benchmark. The data should also include some cost information. BA data must include geographic location. Ideally, this would be a specific, geo-codable street address. It may be aggregated to the Census block level, which is the smallest geographic unit of the Census. The entire country is divided into Census blocks along geographic and political lines. The actual population in a block may vary from zero to several hundred or thousands of people, depending on the location.

Whether BA results from transportation-related strategies is largely dependent on the actions of private companies. Thus, data on private companies leasing or otherwise using network infrastructure deployed as part of transportation projects would be ideal. Some of this data resides in government agencies along with data on deployment of network infrastructure (i.e., permits). Providers could be directly asked about the likelihood of using network infrastructure deployed as part of transportation projects, but it is practically impossible to be sure of this information: People aren’t always forthright and plans and priorities change.

As discussed below, VMT will be analyzed by Transportation Analysis Zones (TAZ), which typically have a population of around 3,000 people, although that varies substantially, and are constructed of Census blocks. Therefore, BA data may be reported at the TAZ level. Similarly, Census block groups are comprised of blocks and have populations of approximately 600 to 3,000 persons. While block groups don’t align perfectly with TAZ, they generally align, so BA data may be reported at that level.

Census tracts are larger geographic areas. While they are comprised of Census blocks, and relatively permanent boundaries, they are typically defined locally and do not necessarily align with TAZ. ZIP codes have similar characteristics and issues. Both Census tracts and ZIP code areas are too large to effectively characterize availability. Therefore, BA data should not be aggregated to these geographic levels.

Broadband availability doesn't necessarily mean adoption or use, particularly as a substitute for travel. Broadband may be available but too expensive, particularly relative to income, so people may not actually subscribe to the service, which is the effective definition of "adoption." A subscription to a broadband service does not necessarily mean it is used for a particular purpose such as telecommuting, telehealth, or virtual schooling. Ideally, we would have data indicating level and type of broadband use. Broadband use indicates availability but any data on use must be geo-referenced at some level to analyze impact on vehicle travel.

SOURCES OF DATA ON BROADBAND AVAILABILITY

BA data is available from multiple sources. The ultimate sources of this data are either service providers or consumers. Provider data indicates what the company nominally offers in the area. Generally, the provider must offer a service to at least one location in an area for it to be considered served. Information provided annually by providers to the Federal Communications Commission (FCC) via form 477 is possibly the most notable source of BA data from providers.[8] Reported down to the Census block level, this data is notoriously inaccurate.[9] The 477 data does not include information about adoption or use. The California Public Utilities Commission (CPUC) collects availability data from providers, which it thoroughly validates and reports at the block level.[10]

The CPUC also collects information on adoption (subscriptions) but that is only reported to the block group level due to data privacy and propriety concerns. The Census Bureau collects information on what type(s) of computer, internet, and telephone, if any, households have but that, too, is reported only to the block group level.[11]

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[8] See https://broadbandmap.fcc.gov/#/ and https://www.fcc.gov/general/broadband-deployment-data-fcc-form-477 for details on this data source.

[9] See https://www.bbcmag.com/law-and-policy/broadband-mapping-is-a-mess-no-one-knows-what-to-do-about-it for one of many discussions about the issues with this data.

[10] See https://www.broadbandmap.ca.gov/ for an interactive map of the CPUC data.

[11] Specifically, "Presence and Types of Internet Subscriptions in Household," which is table B28002, part of the American Community Survey topic (universe) of "Households," for 2019 5-Year Estimates Detailed Tables, is located at https://data.census.gov/cedsci/table?t=Telephone,%20Computer,%20and%20Internet%20Access&tid=ACSDT5Y2019.B28002&hidePreview=true.

Most consumer sourced data come from individuals running a speed test. The CPUC does this via its CalSPEED program.[12] The CPUC reports point data for CalSPEED results via the state's broadband map. Unfortunately, there are relatively few such points, possibly because this speed test is done via an app that must be downloaded to the individual's computer or smart phone. Multiple organizations provide web-based speed tests, including Cloudflare,[13] Fusion Connect (formerly Speakeasy),[14] GEO Partners,[15] M-Lab,[16] an initiative of the non-profit, Code for Science & Society,[17] Ookla,[18] and Speedof.Me.[19]

The speed tests typically use a computer's IP address to estimate the physical location. Some tests, specifically the version of the M-Lab test offered by the National Digital Inclusion Alliance, pull data from the participant's browser's location services. The respondent must have location services enabled and should agree to sharing this information. Beyond that, speed tests cannot automatically determine a respondent's geographic location, so it is necessary to ask the respondent to provide an address.

The availability of data from speed tests varies. Most provide speed tests and resulting data for a fee to providers and public agencies. The National Telecommunications and Information Agency (NTIA) sources speed test data from Ookla, as well as M-Lab. This data is only viewable online not readily available to be incorporated into geographic information system (GIS) mapping for analysis.[20] Generally, these organizations are opaque about how they conduct their speed tests and generate results. Cloudflare is an internet performance and security service that operates an extensive core network, which it uses as infrastructure for its speed test. Unfortunately, Cloudflare does not collect

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[12] Visit http://www.calspeed.org/about.html for more information about the CPUC speed test.
[13] Cloudflare's speed test is online at https://speed.cloudflare.com/, and the company's website is https://www.cloudflare.com/.
[14] See https://www.speakeasy.net/ for more information about the company and visit https://www.speakeasy.net/speedtest/ to run their speed test.
[15] GEO Partners only provides their speed test to public agencies, some of which are listed on their website, is https://geopartnersllc.com/.
[16] Find M-Lab's speed test at https://speed.measurementlab.net/#/, a more complete survey that captures geo-location at https://speed.digitalinclusion.org/, and additional information about the organization at https://www.measurementlab.net/about/.
[17] Visit https://codeforscience.org/ for more information.
[18] See https://www.speedtest.net/ for Ookla's speed test and visit https://www.ookla.com/ to find out more about the company.
[19] Online at https://speedof.me/.
[20] Users can only export data for specific geographies in CSV format. Visit https://broadbandusa.maps.arcgis.com/apps/webappviewer/index.html?id=ba2dcd585f5e43cba41b7c1ebf2a43d0 to view the map.

location data and their data is not readily available. M-Lab is the only organization that makes its data readily available.[21]

ASSESSING BROADBAND AVAILABILITY

Given the issues discussed above, the best data source for current purposes is the U.S. Census Bureau's American Community Survey, specifically Table B28002, "Presence and Types of Internet Subscriptions in Household." A full analysis of this data to identify where broadband is available and where potential broadband infrastructure expansions would be useful is included in section 6, "Transportation Broadband Investment, Penetration, and Impacts on VMT and GHG Emissions," below.

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[21] Go to http://shredtechular.github.io/m-lab.github.io/faq/ for information about how to directly access M-Lab's speed test data.

4. Transportation System Performance Analysis

To identify transportation-related factors that contribute to greenhouse gas (GHG) emissions influence VMT, transportation system performance data was reviewed and analyzed based on several information sources including SCAG's activity-based model (ABM). This section[22] summarizes the analysis results. SCAG's ABM adopts a true activity-based approach by focusing explicitly on activity episode generation and their characteristics. Key ABM model characteristics include:

- Creates robust socio-economic characteristics for each person and for each household in the SCAG region.
- Simulates daily activities and travel patterns of all individuals in the region, as affected by transportation system level of services.
- Predicts decisions "whether, when, where, for how long, with whom and in what sequence" to participate in activities.
- Simulates the effects of transportation and land development investments and policies on the quality (time and cost) and quantity (traffic volume, congestion, and vehicle miles traveled) of travel by different modes (walk, bike, transit, and auto).
- Generates performance indicators, conformity analysis, and environmental justice analysis for the 2016 RTP/SCS. It is being developed to be capable of analyzing the impact of infrastructure investment, land use development, pricing policy, active transportation, high speed rail, and travel demand management.

Existing Data Evaluation

For this study, the project team worked with SCAG staff to exam the 2016 baseline and 2045 future year transportation system performances using SCAG ABM. The results are presented below. The project team also collected safety metrics from the Connect Socal Performance Measure Report. The safety metrics are presented here as well. To better understand the effects of telecommunicating on VMT and emission, the project team reviewed some past studies and summarized major findings in Section 1 of this report.

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[22] This section of the report was developed by DKS Associates, Inc.

LEVEL OF CONGESTION

The project team examined SCAG ABM 2016 network wide annual vehicle miles travelled (VMT), vehicle hours travelled (VHT), vehicle hours delay (VHD) and volume to capacity ratio (V/C) along all links within the roadway network. The results are shown in Table 10.

Table 10: SCAG ABM 2016 Level of Congestion Metrics

	VMT	VHT	VHD
PASSENGER VEHICLES	427,205,797	12,170,601	2,484,014
LIGHT TRUCKS	5,877,749	134,496	25,694
MEDIUM TRUCKS	4,345,778	100,475	18,443
HEAVY TRUCKS	20,960,500	409,955	68,076
TOTAL	**458,389,824**	**12,815,527**	**2,596,227**

Overall, in 2016, over 458 million vehicle miles were travelled within the SCAG region. The annual delay is about 2.6 million vehicle hours.

The V/C ratios during the AM and PM peak periods are plotted and shown in Figure 8 and Figure 9, respectively. As shown in these two figures, PM peak is more congested than AM and the most congested is the City of Los Angeles area. Interstate Highway (IH) 5 also sees significant congestion during both AM and PM peak periods.

Figure 10 is an exhibit from the Connect SoCal Performance Measures Technical Report (ConnectSoCal.org, 2020) which demonstrates the SCAG region freeway PM peak speed in 2016.

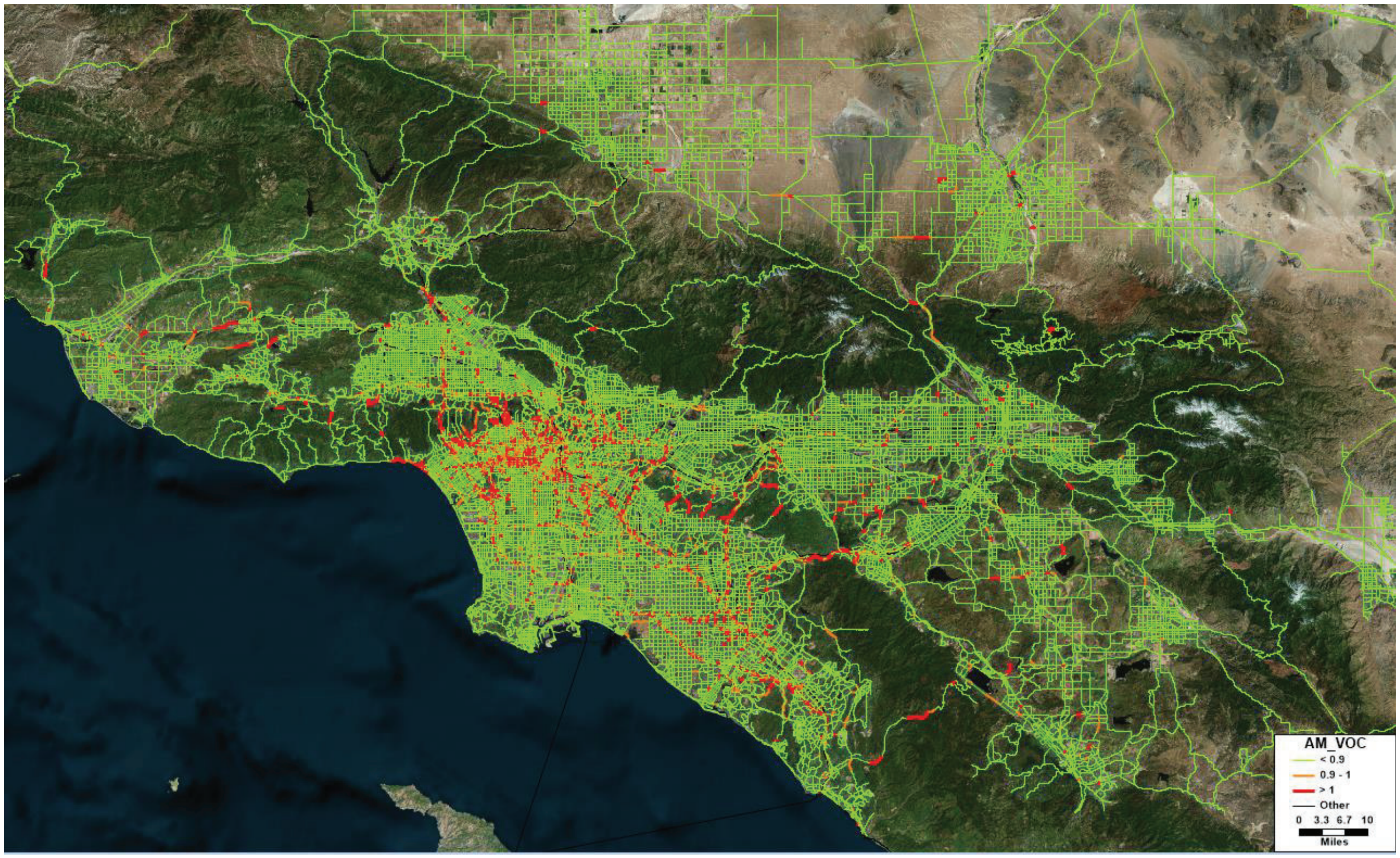

Figure 8. SCAG ABM AM V/C Plot: Base Year 2016

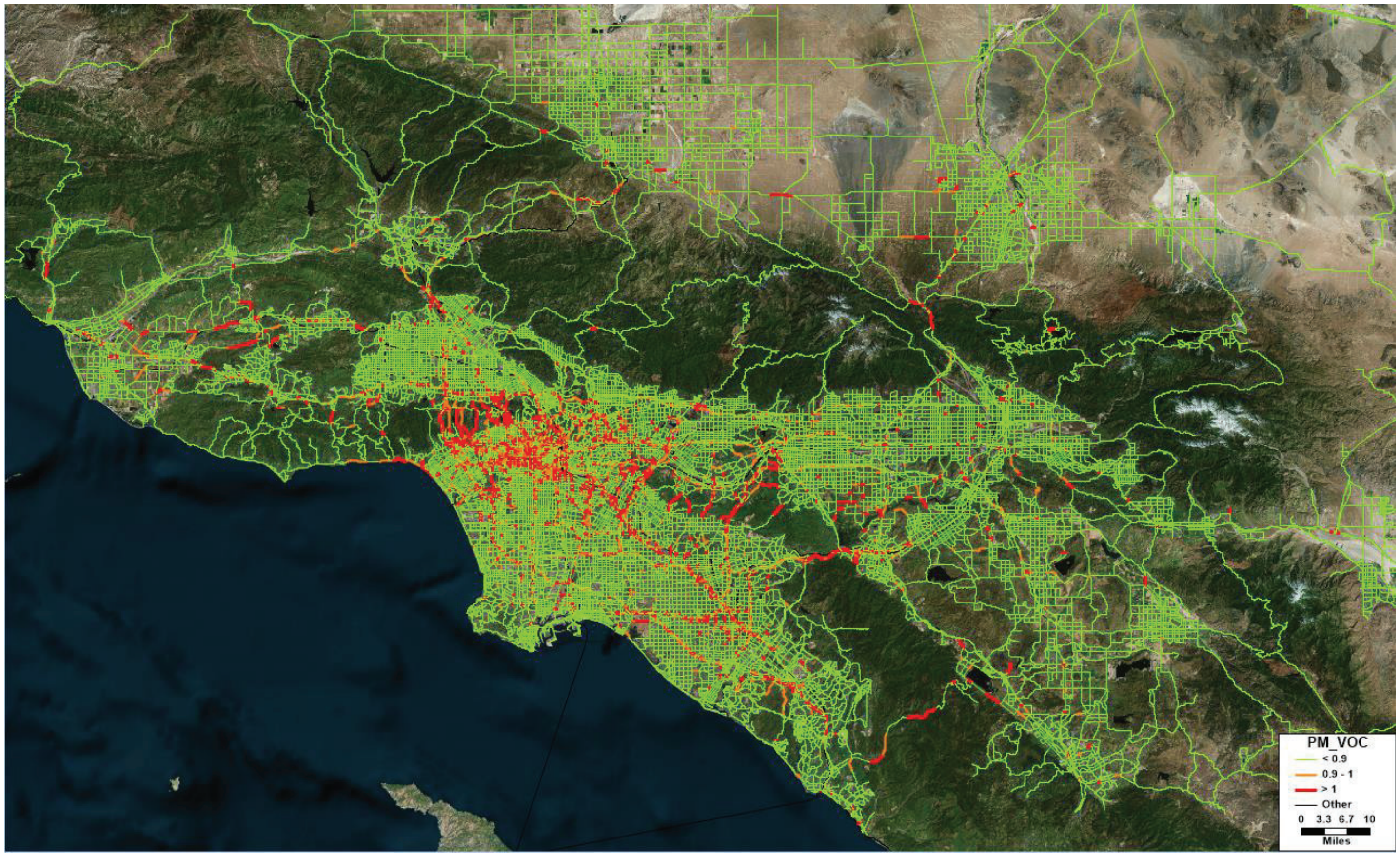

Figure 9. SCAG ABM PM V/C Plot: Base Year 2016

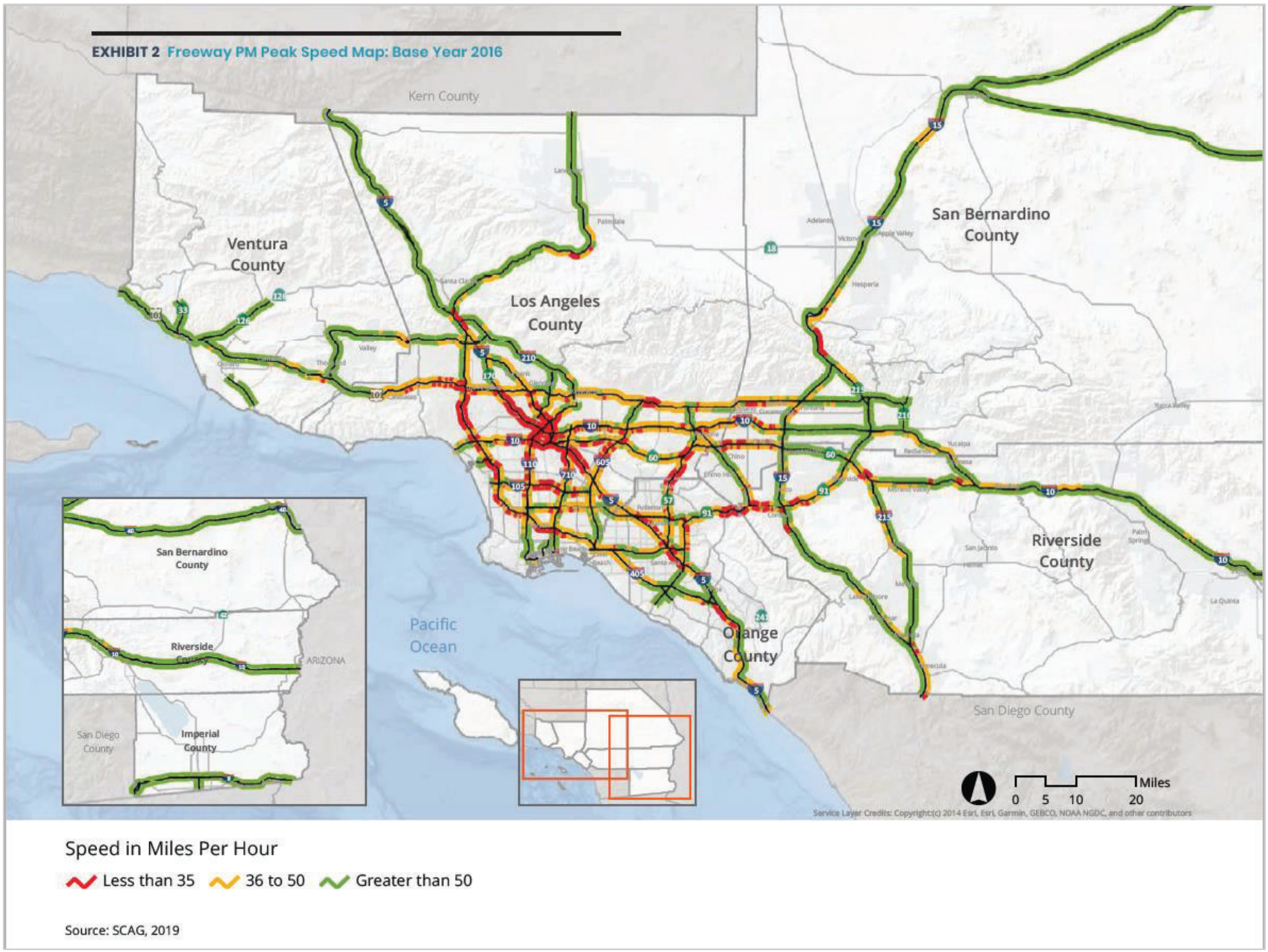

Figure 10. FREEWAY PM PEAK SPEED MAP: Base Year 2016

ORIGIN-DESTINATION

Trip characteristics of the 374 SCAG travel demand model Transportation Analysis Zones (TAZs) identified as having low quality broadband access were evaluated using StreetLight data.[23] This section outlines the trip characteristics of the origin and destination trips of the 374 zones to and from all the zones in the SCAG model area.

Origins

The data estimates 965,385 trips from the identified zones in the p.m. peak period (3 p.m. to 7 p.m.).

- The average number of trips between two specific TAZs is 5
- The maximum number of trips between two specific TAZs is 4,328
- The average proportion of Home Based Work trips between zones[24] is 19 percent
- The average proportion of Home Based Other trips between zones2 is 46 percent
- The average proportion of Non-home based trips is 35 percent

Destinations

The data estimates 926,196 trips to the identified zones in the p.m. peak period (3 p.m. to 7 p.m.).

- The average number of trips between two specific TAZs is 9
- The maximum number of trips between two specific TAZs is 4,335
- The average proportion of Home Based Work trips between zones2 is 18 percent
- The average proportion of Home Based Other trips between zones2 is 47 percent
- The average proportion of Non-home based trips is 35 percent

Trip length statistics[25]

- The weighted average (by volume) trip length is 6.5 miles for trips starting in the analysis zones
- The weighted average (by volume) trip length is 5.5 miles for trips destined to the analysis zones
- The minimum trip length (excluding trips within a single TAZ) is 0.2 miles
- The maximum trip length is 218.8 miles

[23] Identification of non-broadband areas is outlined in the Broadband Quality Methodology memorandum 10/20/21

[24] Based on OD pairs with more than 20 trips.

[25] Trip length statistics were calculated from the SCAG Regional Model using non-zero OD pairs from Streetlight. This provides a point of comparison between the existing conditions baseline and the broadband sensitivity analysis which will rely solely on output from the SCAG regional model.

These summary statistics provide a description of baseline traffic conditions and patterns for origin and destination demand in the analysis zones. They will inform the adjustments made to the origin-destination matrix to account for the improvements to broadband accessibility which will be discussed in a later memorandum.

SAFETY

On average, each year in Southern California, 1,450 people are killed, 5,500 are seriously injured, and 124,000 are injured in traffic collisions (SCAG, 2021). Each year, SCAG works with the state to develop annual safety targets to comply with federal requirements. They work together to assess fatalities and serious injuries on all public roads and set safety targets at the statewide and regional levels. Table 11 lists the 2021 transportation system safety targets for the SCAG region (SCAG, 2021) along with the 2016 baseline 5 year rolling average and 2017 single year data (ConnectSocal.org, 2020).

SCAG is now working towards achieving annual reductions of 3.5 percent in fatalities and serious injuries until 2050 (roughly aligning with the horizon year of Connect SoCal, 2045), at which time the region is targeted to experience zero traffic-related fatalities.

Table 11. Transportation Safety SCAG Regional Targets

PERFORMANCE MEASURE	2016 BASELIINE 5-YEAR ROLLING AVERAGE	2017 SINGLE YEAR	2021 SCAG REGIONAL TARGET[26]
NUMBER OF FATALITIES	1,403	1,505	1,622
FATALITY RATE (PER 100 MILLION VMT)	0.88	0.906	1.32
NUMBER OF SERIOUS INJURIES	5,044	6,386	6,672
SERIOUS INJURY RATE (PER 100 MILLION VMT)	3.162	3.843	5.45
TOTAL NUMBER OF NON-MOTORIZED FATALITIES + SERIOUS INJURIES	2,046	2,118	2,212

Note: Figures refer to number of victims, not number of collisions

26

5. Broadband in Transportation Projects

Inclusion of broadband infrastructure, specifically conduit, in transportation projects is a general tactic for increasing broadband availability. Essentially, this tactic is to capitalize on public expenditures to reduce capital expenses for private companies. There are aspects, or more specific tactics, to this: One tactic is simply to minimize deployment costs for both public and private efforts. The second is to acquire or reallocate funding to projects that deploy network infrastructure. This section is a detailed consideration of both.

COSTS ESTIMATES AND COST REDUCTION TACTICS

The costs to deploy conduit, based on recent schedules of value for CalTrans projects, are summarized in Table 12. Conduit might be deployed as a standalone project or as part of another, larger project involving excavation, creating an open trench. Full deployment cost is 26 times greater than open trench deployment due to labor and project overhead costs. Overall, based on these assumptions, installing conduit as part of a transportation project will reduce total costs by 83% from over $310K per mile to under $55k.

Table 12. Cost to Deploy Conduit in Highway Rights-of-Way

	Each or Per Foot	Per Mile
Conduit Full Deployment	$51.84	$273,702
PVC conduit	$3.20	$33,825
Pull boxes	$1,998.96	$9,994.79
Conduit Full Deployment Cost		**$317,522**
Open Trench Deployment	$2.00	$10,560
PVC conduit	$3.20	$33,825
Pull boxes	$1,998.96	$9,994.79
Open Trench Deployment Cost		**$54,380**

The conduit itself is continuous plastic (PVC) in 1.5” to 3” in diameter. It costs $3.20 per linear foot on average. Typically, at least two conduits would be deployed together. A pull box, which costs about $2,000 each, is required every 1,000 to 1,500 feet or 5 per mile on average. These components fully meet standards set by the Institute of Electrical and Electronics Engineers (IEEE), Building Industry Consulting Services International (BICSI), National Electrical Contractors Association (NECA), American National Standards Institute (ANSI), and Telecommunications Industry Association (TIA).

Cost Reduction Tactics

The most basic cost reduction tactic is to place conduit in the ground whenever a trench is dug. Many transportation projects involve excavation or other ground disturbance that doesn't necessarily involve a trench, per se—installing a sidewalk or resurfacing a road, for examples. The key to joint build opportunities is that some element of a transportation project might reduce the cost of network construction. Traffic rerouting costs may be eliminated, for example, and engineering costs substantially reduced by literally building broadband into transportation projects. In most cases, "joint build" literally involves different parties building different things at the same time. While this can greatly reduce overall costs, as discussed below, it requires substantial coordination.

The other cost reduction tactic is "value engineering," which is a methodical approach to delivering required functionality at the lowest possible cost. It is a practically universal practice in telecommunications. The major issue with value engineering is that by eliminating components or features not required for immediate purposes, infrastructure may require extensive rework to accommodate additional purposes in the future. For example, fiber routes are often value-engineered to serve specific sites, which involves selecting the shortest, least-cost route and minimizing physical access points along it, regardless of other sites (or future sites) in the area. Consequently, adding sites near such a route effectively requires a new build, whereas a route designed to accommodate additional sites and growth could be extended at minimal costs.

OPTIONS FOR FUNDING BROADBAND IN TRANSPORTATION PROJECTS

A major option for funding broadband in transportation projects is simply to include conduit in any project that meets basic criteria, such as "more than 300 lineal feet" and/or "involves ground clear more that 6 inches deep and 3 feet wide." While the conduit would need additional excavation to be placed 36" below surface, this would cause relatively a small marginal increase in project costs but huge cost savings for deploying fiber-optic cable. Changes in federal and state policies are required to allow use of transportation assets and funds for broadband and to make conduit a standard component of projects. There would need to be specific rules and/or on-going governance to ensure conduit isn't dropped from projects due to cost overruns or similar issues.

California Assembly Bill 41 requires the Department of Transportation, as part of those projects that are funded by a specified item of the Budget Act of 2021 and that are located in priority areas, to use the project planning phase to ensure that construction projects include the installation of conduits capable of supporting fiber-optic communication cables. It also requires the CPUC, in collaboration with other relevant state agencies and stakeholders, to maintain and update a statewide, publicly accessible, and interactive map showing the accessibility of broadband service in the state.

Capital Improvements to Other Infrastructure

While transportation capital improvements are prime opportunities to deploy network infrastructure, other capital improvements may also be opportunities to deploy network infrastructure. Power and water utility improvements are potentially even a better fit with broadband than transportation. Development of and improvements to public facilities can also be excellent opportunities to economically deploy network infrastructure. Many schools have high-capacity connections today due to public subsidies to private providers. Ironically, students and their families around the schools often remain underserved because the providers had no reason to build or improve access infrastructure for the community. Numerous school districts around the country are leveraging capital improvements to facilities to extend access. Local governments are using similar tactics with community centers, fire stations, parks, et cetera

Development Agreements, Joint Build, and Other Partnerships

Transportation agencies could partner with private companies to deploy conduit and other network infrastructure. Generally, this would involve an agreement on how the infrastructure assets might be used, under what circumstances specific assets would be deployed, and how any expenses and revenue would be allocated to the partners. By the same token, federal and state transportation agencies may more actively partner with city, county, and regional agencies.

As directed by California Senate Bill 156, state agencies including the California Public Utilities Commission and California Department of Technology are planning a statewide middle-mile network with multiple routes through the SCAG region. It should be possible to identify numerous cost efficiencies and joint build opportunities by engaging in this middle-mile network planning. It is almost certain that large amounts of private capital will mobilize in parallel with this effort. Local public investment will be necessary to capitalize on the state middle mile network and attract private investment.

The private partner(s) would need to be involved in planning activities to identify joint build opportunities and ways in which projects would need to be modified to accommodate broadband. There would also have to be on-going coordination at both executive and front-line levels. The public agencies involved would need to monitor, if not directly manage, use of the asset. To the extent that local jurisdictions partner with state and federal agencies, they will need capacity to manage those relationships and monitor use of jointly owned or shared assets.

Real estate developers might also be included in these arrangements. Many jurisdictions include conduit, if not fiber, as conditions for development. Typically, the developer absorbs the capital expense and passes it on to buyers as part of the purchase price then deeds the network assets over to the jurisdiction just as with easements, lights, roads, and sidewalks. As with other partnership options, this tactic requires the jurisdiction to ensure plans include network assets as appropriate and track use of the public assets.

Grants and Low-cost Loans

Not only are the equipment, materials, and services required for broadband rather costly, money to pay for those items can be quite costly. Indeed, the cost of money in the form of finance fees and interest can be the largest cost for broadband development. There are multiple grants and low-cost loans available for broadband development. Most notably, both the American Rescue Plan Act (ARPA) and the Infrastructure Investment and Jobs Act (IIJA) include funding for network infrastructure. The State of California allocated $540M of ARPA funds for capital Projects. It has established a RAISE Transportation Fund[27] totaling $100M total, providing up to $25M per project. The U.S. Departments of Agriculture and Commerce offer financial support for broadband. Some of these programs, particularly those that fund actual construction, are only available for rural areas and require applicants or their partners to have an established broadband business.

State of California broadband policy is very supportive of broadband infrastructure expansion. Governor Newsom's Executive Order on broadband policy explicitly directs state agencies to seek to close the "Digital Divide", which includes support for local government broadband deployments. The recently ratified California Senate Bill 156 contains provisions which fund and allow middle-mile facilities to be provided by municipal authorities. The Broadband Loan Loss Reserve Fund authorized by SB 156 will support necessary borrowing to construct middle-mile facilities although the fund is not yet operational (SB 156 was just recently signed into law) and the CPUC has not yet developed the required rules and regulations.

Revenue Generation

Broadband can fund itself. Network infrastructure consists of valuable real assets that can be leased for use. The entity that owns the assets can supplement them with network equipment to provide broadband services directly to consumers or to internet service providers. Of course, this requires establishing a fully staffed broadband enterprise with all necessary ancillary assets and systems—buildings, software, vehicles, et cetera—or

[27] The Rebuilding American Infrastructure with Sustainability and Equity discretionary grant program was established under the IIJA through the US Department of Transportation.

partnering with an existing provider. While this increases the upfront investment, it is the approach most likely to generate excess revenue to support broadband expansion.

6. Transportation Broadband Investment, Penetration, and Impacts on VMT and GHG Emissions

This section[28] presents the results of the analysis performed to quantify the potential for VMT and GHG emission reduction benefits resulting from expanded broadband access, coupled with assumed employer-based policies for telecommuting flexibility, for non-essential workers in the SCAG region. The process to screen Transportation Analysis Zones (TAZ) associated with broadband access is first described. TAZs identified as having low or no broadband were identified. The Home-Based-Work trip generation of the non-broadband TAZs were then modified based on the expected benefit of improved broadband. Three future scenarios were developed and reflected by modifying the future year SCAG regional activity-based travel demand model trip tables. The SCAG model results provide the potential transportation system VMT reduction benefit of improved broadband in the SCAG region associated with journey-to-work trips. The VMT results were then input into the California Air Resources Board emissions model EMFAC to determine the on-road mobile source GHG emission reductions of each scenario.

STEP 1: PRE-SCREENING AT THE BLOCK GROUP LEVEL

Census table B28011 “Internet Subscriptions in Household” contains information on the status of internet service in households. This table was used to index each block group by the proportion of households with a broadband internet connection. The broadband status for each block group is based on a ratio of the percentage of households with broadband internet to the percentage of households with slow or no internet access, i.e., the area's “Broadband Index.” If more than 50 percent of households within a block group had a broadband connection, then it was considered a broadband block group. Block groups without population were automatically removed. A block group with a Broadband Index greater than 0.0 is considered a “broadband block group” and those with an index equal to or less than 0.0 is considered a “non-broadband block group.”

This binary cutline was used to classify each block group. These block groups were then aggregated to the TAZ level (using the TAZ 1 layer in the SCAG regional travel demand model). The same relationship was applied again at this geography and TAZs with less than 50 percent of the households from a served block group with broadband were retained (Broadband Index of <0.5). The TAZs with parent non-broadband block groups

[28] This section was produced by DKS Associates.

represent higher density underserved areas. These TAZs are referred to as "Non-Broadband TAZs" and are shaded as teal in Figures 11-14.

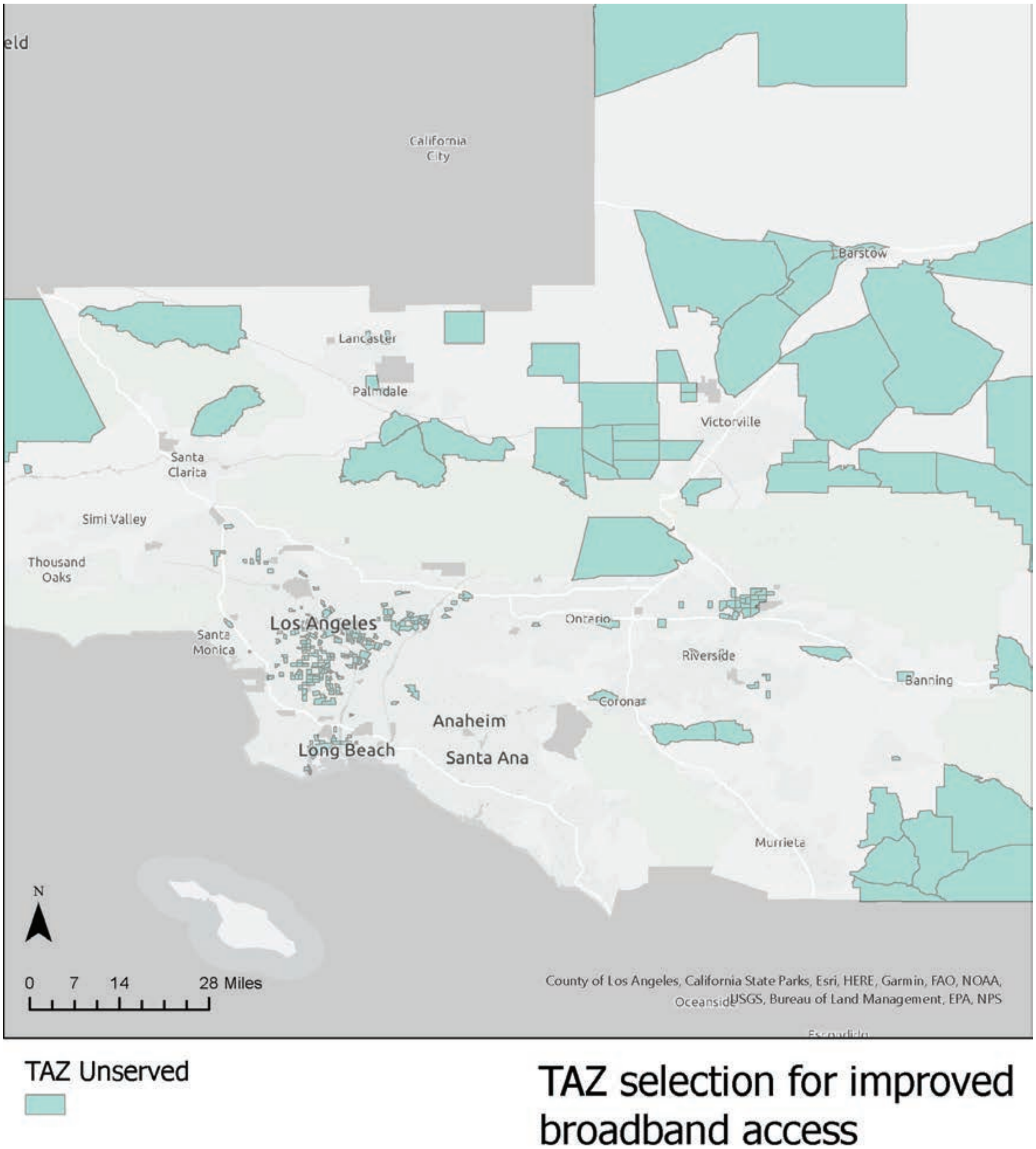

Figure 11. Non-Broadband Areas (shown in Teal): Region

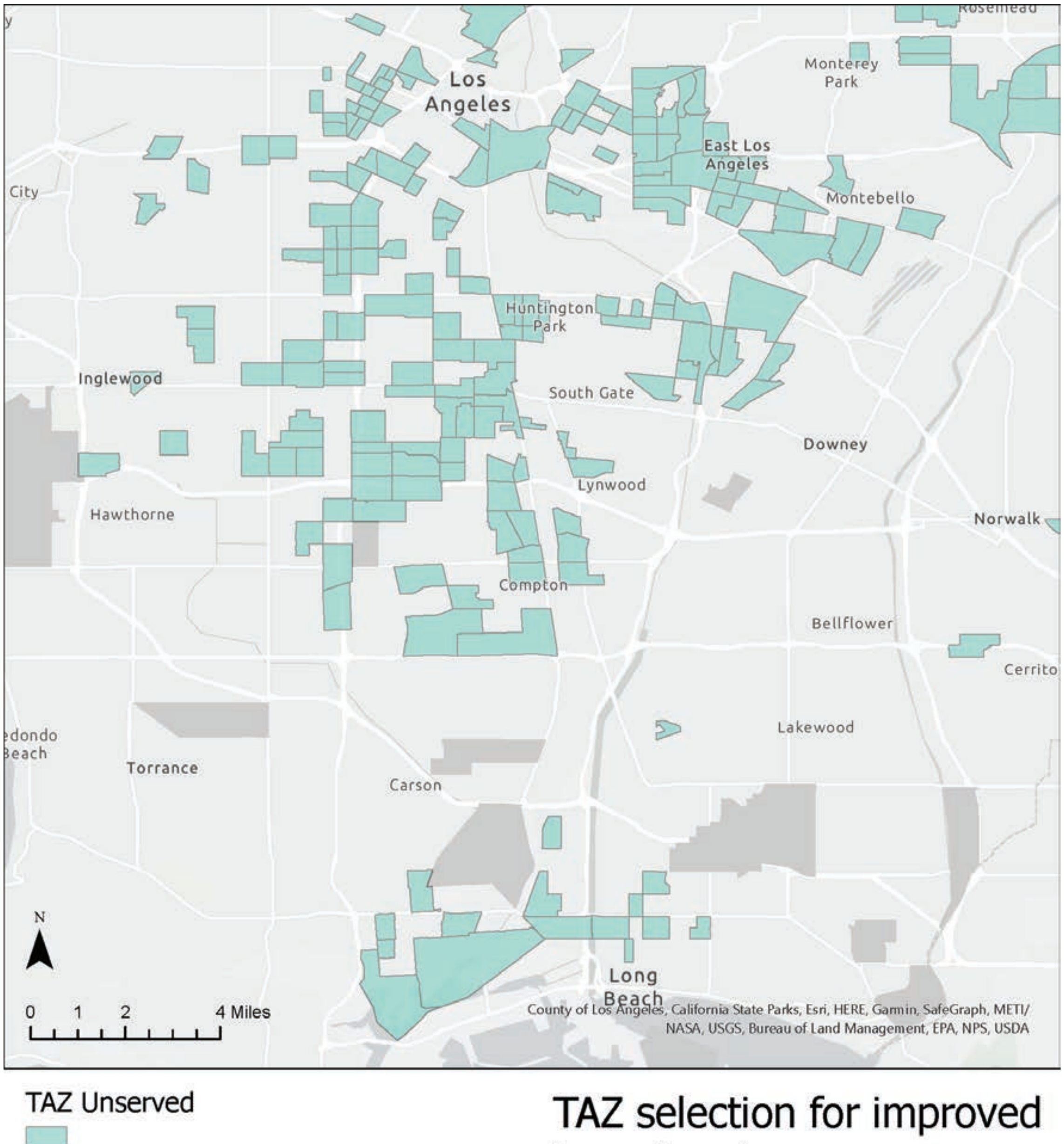

Figure 12. Non-Broadband Areas (shown in Teal): South LA/Long Beach Sub-Area

Figure 13. Non-Broadband Areas (shown in Teal): San Bernardino Sub-Area

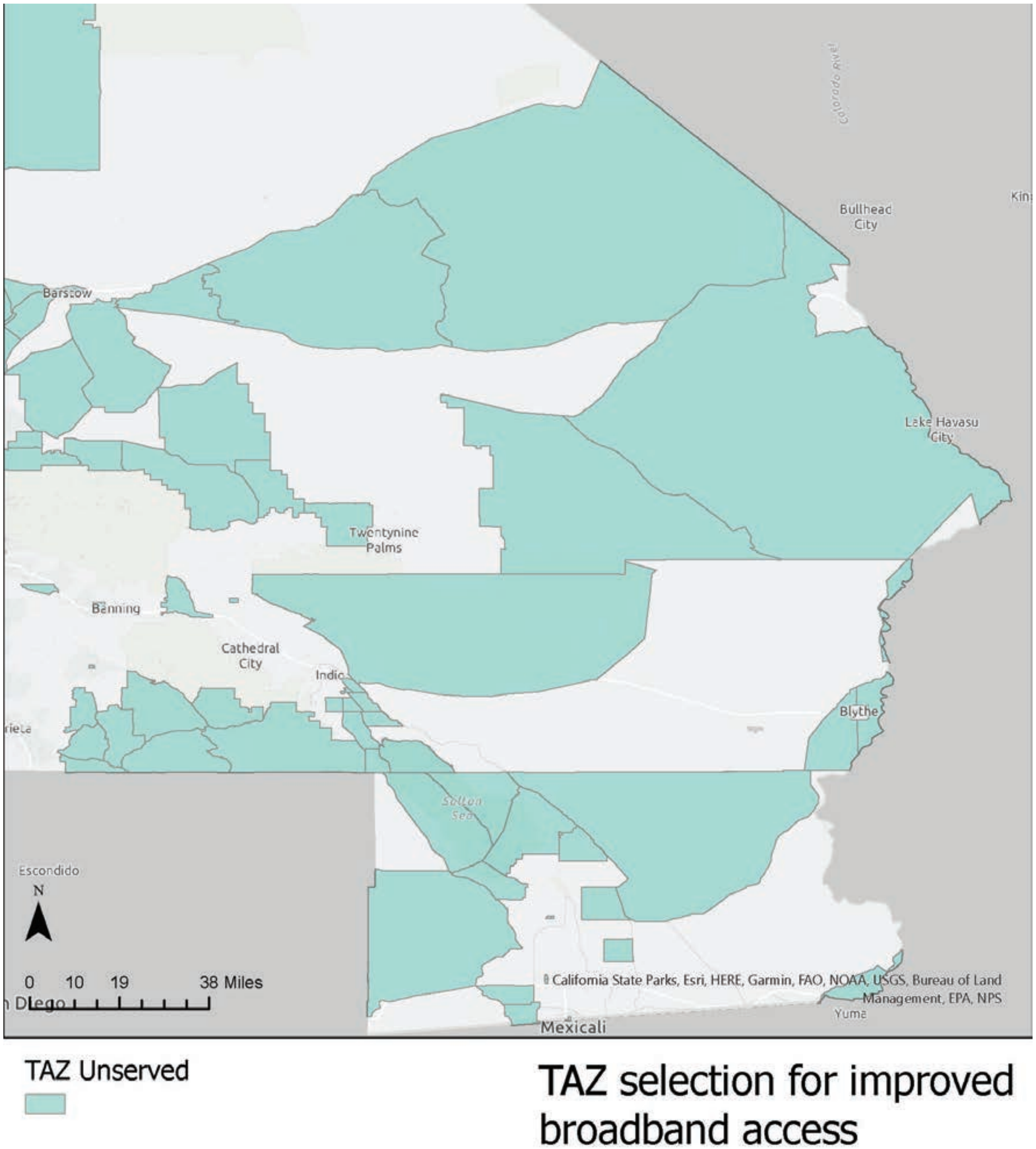

Figure 14. Non-Broadband Areas (shown in Teal): Imperial/Riverside Sub-Area

STEP 2: HOUSEHOLD BROADBAND ADOPTION BY TAZ

With the underserved TAZs identified, the proportion of the households within each zone were calculated. This calculation relied upon the same census data table B28011, with data at the block group level, and aggregated to the TAZ level. These TAZs and their characteristics are shown in Appendix A. There are 374 non-broadband TAZs identified with an average broadband service ratio of 43 percent (unweighted). The total number of households projected to locate in these TAZs is 441,712. This represents 5.8% of the total households in the SCAG region under 2045 conditions.

Region-wide the median total households for income distribution per TAZ are 458, 476, 410, and 141 for low income, median income, high income, and very high income, TAZs respectively (see Figure 15). Within the sample of non-broadband TAZs the median total households for income distribution are 605, 394, 174, and 45 (see Figure 16). These results show that within the non-broadband zones there is a significantly higher proportion of low-income households.

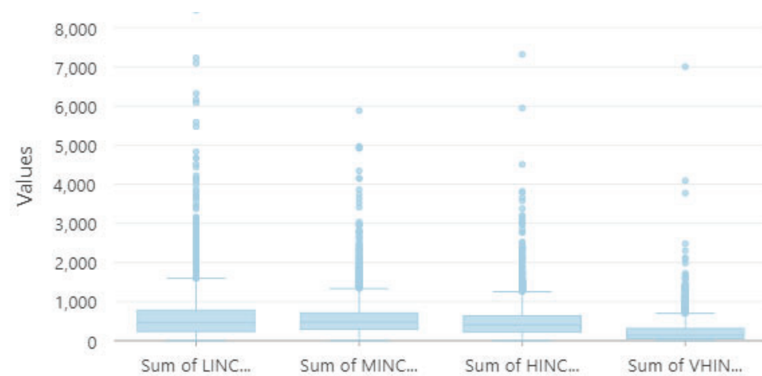

Figure 15. Household median Income Distribution

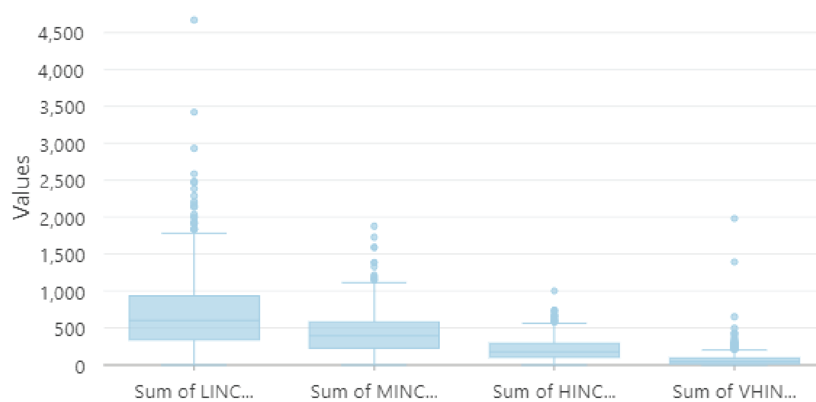

Figure 16. Non-broadband Median Income Distribution

STEP 3: MODEL ADJUSTMENTS

Given that some workers will have the flexibility to work remotely at home, assuming adequate broadband service, while others (i.e., essential workers) will be unable to work remotely regardless of their household broadband status, the overall benefit to the transportation system will be related to the proportion of essential versus non-essential workers in each TAZ. In addition, two different behavior scenarios were assumed to examine the potential benefit of broadband expansion.

1. The **Shelter in Place Behavior (SIPB)** proportion was determined using location-based services data from StreetLight Data. Using time intervals from various closing and reopening periods during the COVID-19 pandemic, origin-destination volumes between the non-broadband TAZs and all other zones were collected. The average difference, relative to traffic volumes in 2019, was used to create an initial factor. This factor was further adjusted using the proportion of home-based work (HBW) trips between zones.
2. The **Upper Bound Behavior (UBB)** proportion was determined using the classification from the Department of Homeland Security – Cybersecurity and Infrastructure Security Agency for the North American Industry Classification System (NAICS) and the number of workers in each NAICS category in the SCAG model TAZ. Non-essential workers' preferences and employer flexibility to work remotely is assumed to be 100 percent.

Based on these two travel behavior responses, the AM and PM peak auto trips[29] in the 2045 SCAG Activity Based Travel Model origin-destination (OD) trip table were factored at the TAZ level to yield the following three potential broadband commuter markets:

1. **Non-Broadband Expansion Increment – Shelter in Place Behavior (NBEI-SIPB):** This scenario reflects changes to the SCAG travel demand model trip matrices using the SIPB factor for each underserved TAZ. This analysis reflects the potential incremental change in vehicle activity assuming quality broadband service is expanded to non-broadband areas and the mixed adoption of worker preference emulates the empirically observed travel characteristics during the various shelter-in-place order inflection points experienced during the COVID-19 pandemic in 2020 and 2021. This analysis reflects only the incremental benefit resulting from adoption within current non-broadband areas. It does not assume any benefits associated with areas currently served by broadband in the SCAG region.
2. **Non-Broadband Expansion Increment - Upper Bound Behavior (NBEI-UBB):** This scenario reflects changes to the SCAG travel demand model trip matrices using

[29] Off-peak matrices are not factored.

the UBB factor for each underserved TAZ. This analysis shows the potential change in vehicle activity assuming quality broadband service is expanded to non-broadband areas and 100 percent of non-essential worker's preference and employer flexibility to work remotely is achieved. This analysis reflects only the incremental benefit resulting from adoption within current non-broadband areas.

3. **Total Broadband – Upper Bound Behavior (TB-UBB):** This scenario reflects changes to the SCAG travel demand model trip matrices using the UBB factor for **all TAZs independent of existing broadband status**. This analysis shows the change in travel patterns that could be expected from 100 percent broadband adoption and 100 percent non-essential worker's preference and employer telecommute flexibility in both broadband and non-broadband areas.

STEP 4: SCENARIO ANALYSIS

The three factored trip tables described above were submitted to SCAG for model execution. Each of the scenarios below were executed independently to isolate their relative benefits.

E. 2045 Future Baseline - Pre-Pandemic Travel Behavior – SCAG RTP/SCS Preferred Scenario
F. 2045 Non-Broadband Expansion Increment – Shelter in Place Behavior
G. 2045 Non-Broadband Expansion Increment – Upper Bound Behavior
H. 2045 Total Broadband – Upper Bound Behavior (region wide)

The following travel and operational metrics of Scenarios B-D was compared with Scenario A to determine the relative benefits of each scenario. This includes an assessment of how optimistic the upper bound market scenarios are relative to travel behavior observed during the shelter-in-place restrictions.

- Vehicle Miles of Travel (Regionwide)
- Vehicle Hours of Travel (Regionwide)
- Volume Difference Plots of SCAG Network

STEP 5: TRANSPORTATION SYSTEM BENEFIT RESULTS

Network difference plots shown in Figures 17-22 show the change in traffic volume on roadways resulting from each broadband scenario (Scenarios B-D) relative to the future baseline condition (Scenario A) during the AM and PM peak period respectively. Based on these plots, key roadways in the system projected to yield the highest trip and VMT reduction benefit resulting from greater broadband adoption were identified (shown with a green band). These roadways and projected volume reductions are provided in each figure. For Scenarios B and C (Expansion Increment Figures 17-20), the most heavily utilized roadways serve areas (i.e., TAZs) that have a disproportionately greater proportion of disadvantaged households relative to areas currently served by broadband. These include I-10, I-110, I-605, I-710, SR 215, SR 91, SR 72, SR 42 and several local arterials (North Waterman, South Atlantic Boulevard, Riverside Drive, East 7th, Figueroa Street, West 120th). With less volume and therefore less VMT, it can be surmised that peak period operations would improve (i.e., less delay) and with less conflict exposure (i.e., less VMT), collision rates would also decrease suggesting a safety benefit, or at minimum, a neutral safety implication on these facilities.

Table 13 provides the percent reduction of regional vehicle hours of travel during the AM/PM peak periods respectively. Based on the results, peak period vehicle hours of travel decrease between 3-6% under the incremental scenarios (B and C) and between 50-55% under the regionwide upper bound scenario (D).

Table 13. Peak Period Vehicle Hours of Travel Comparison

	Period	
	AM	PM
2045 Baseline	2,950,217	4,345,241
2045 Increment SIP	2,843,388	4,213,802
2045 Increment UBB	2,814,035	4,099,249
2045 Total UB	1,978,484	2,802,368
Increment SIP Diff	-106,829	-131,438
Increment UBB Diff	-136,182	-245,991
Total UBB Diff	-971,733	-1,542,873
Increment SIP % Reduction	-3.8%	-3.1%
Increment UBB % Reduction	-4.8%	-6.0%
Total UBB % Reduction	-49.1%	-55.1%

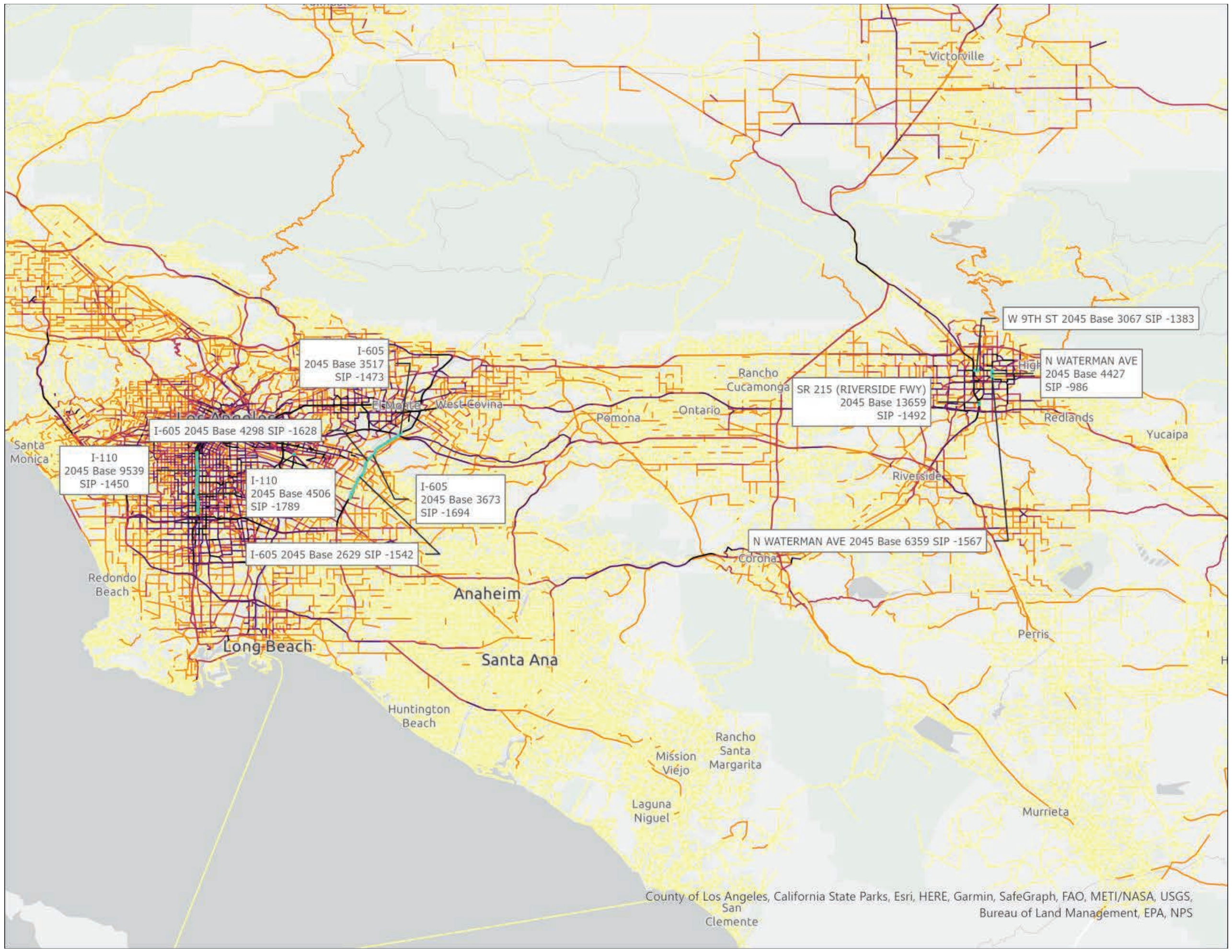

Figure 17. 2045 AM Peak Period Volume Difference Plot: Non-Broadband Expansion Increment – Shelter in Place Behavior vs. Future Baseline

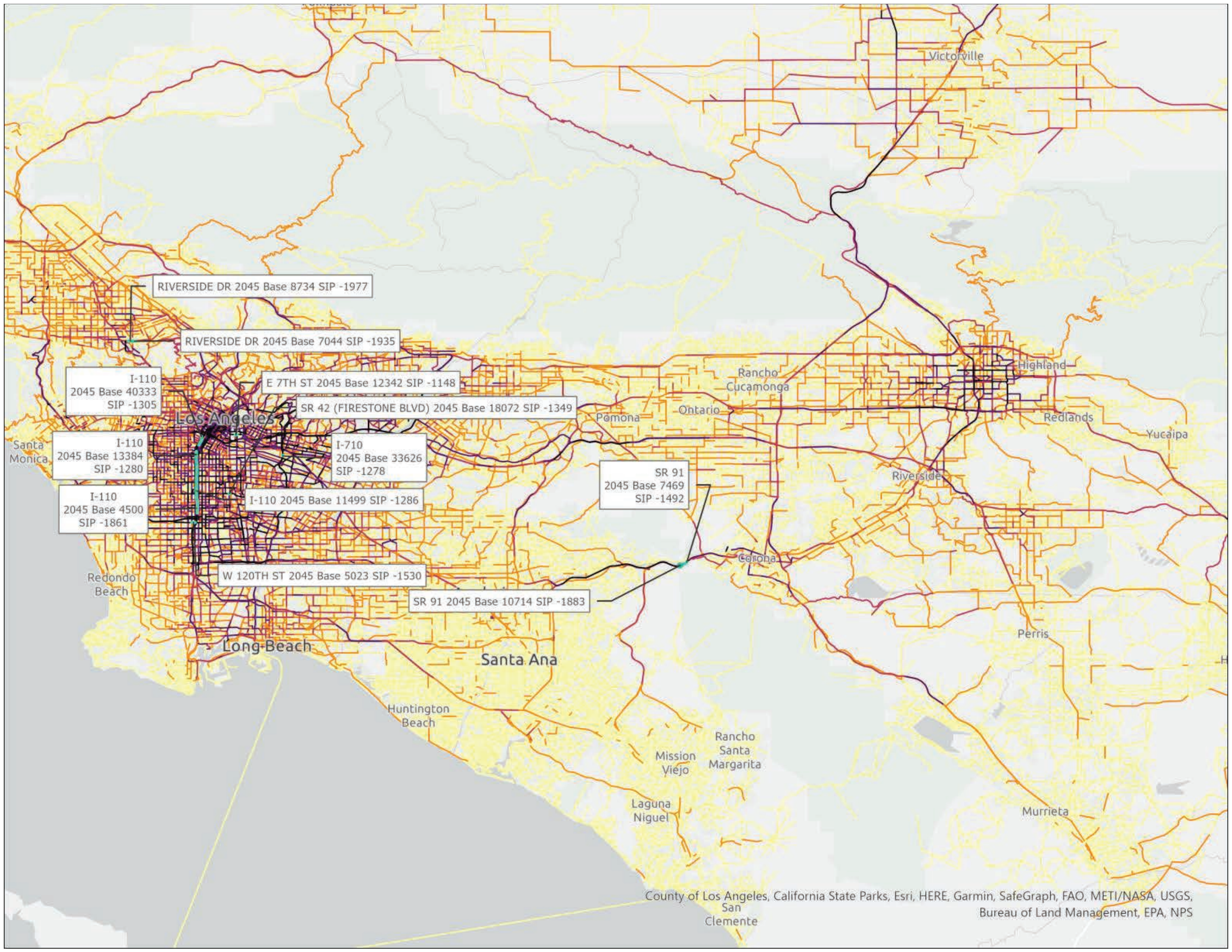

Figure 18. 2045 PM Peak Period Volume Difference Plot: Non-Broadband Expansion Increment – Shelter in Place Behavior vs. Future Baseline

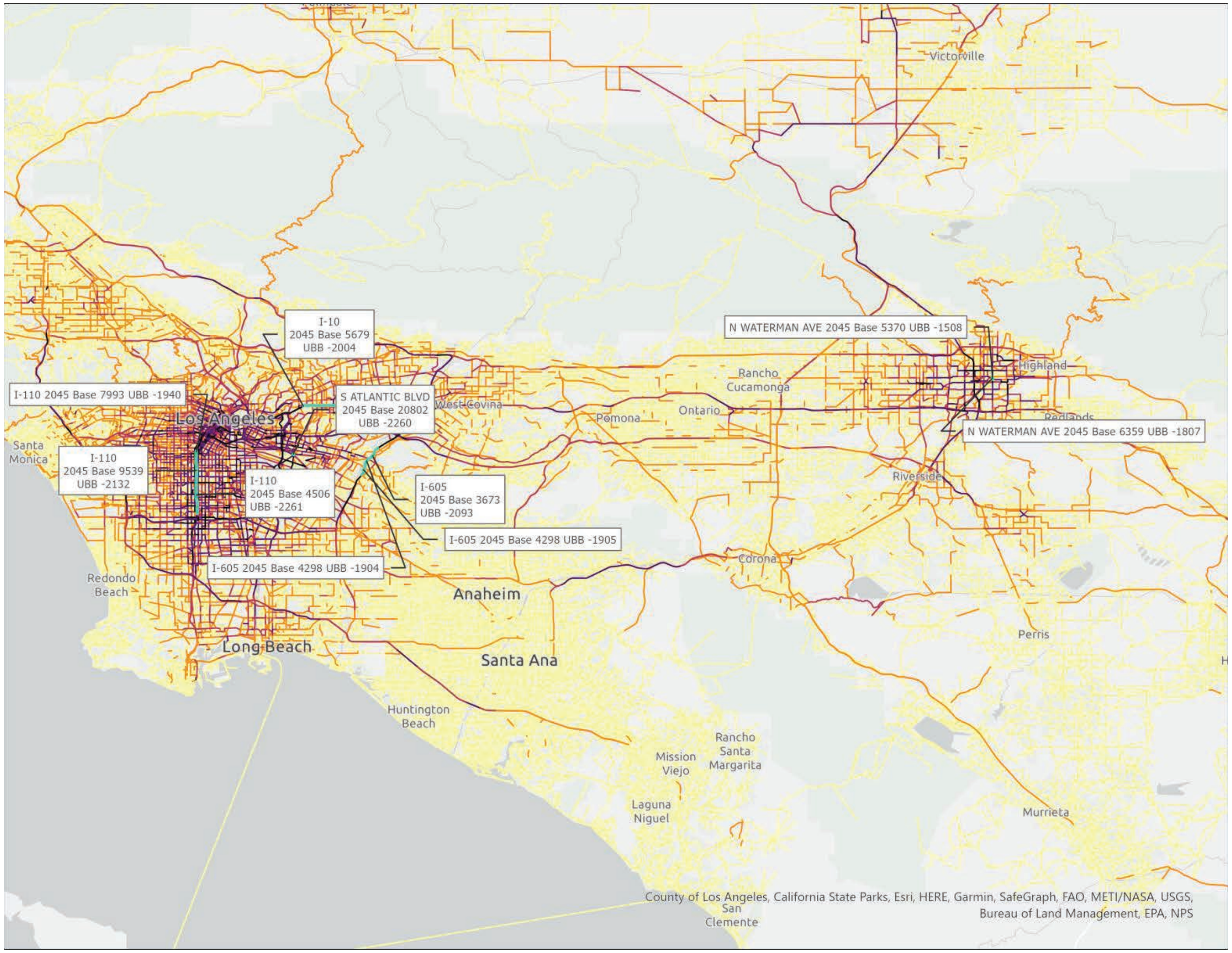

Figure 19. 2045 AM Peak Period Volume Difference Plot: Non-Broadband Expansion Increment - Upper Bound Behavior vs. Future Baseline

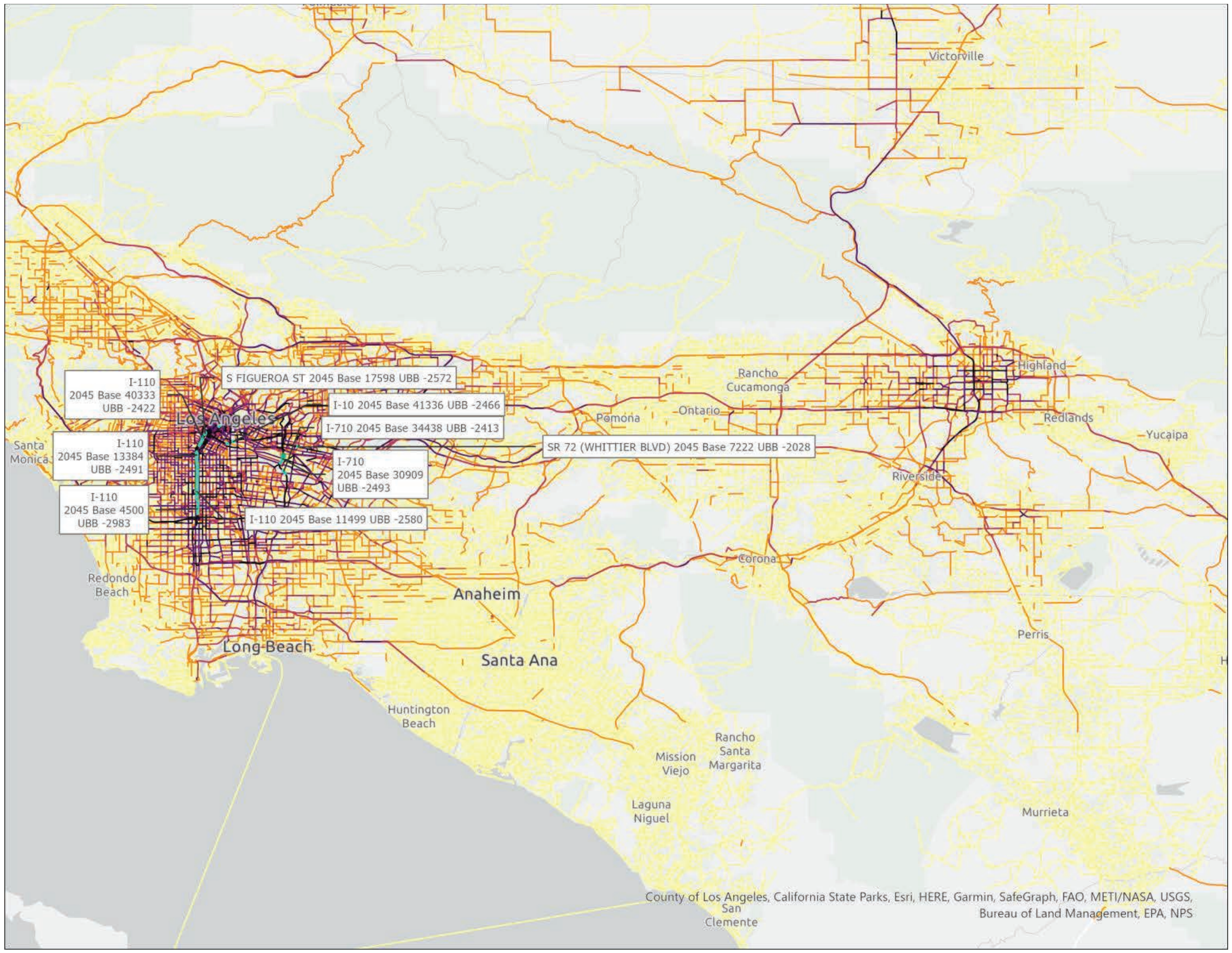

Figure 20. 2045 PM Peak Period Volume Difference Plot: Non-Broadband Expansion Increment - Upper Bound Behavior vs. Future Baseline

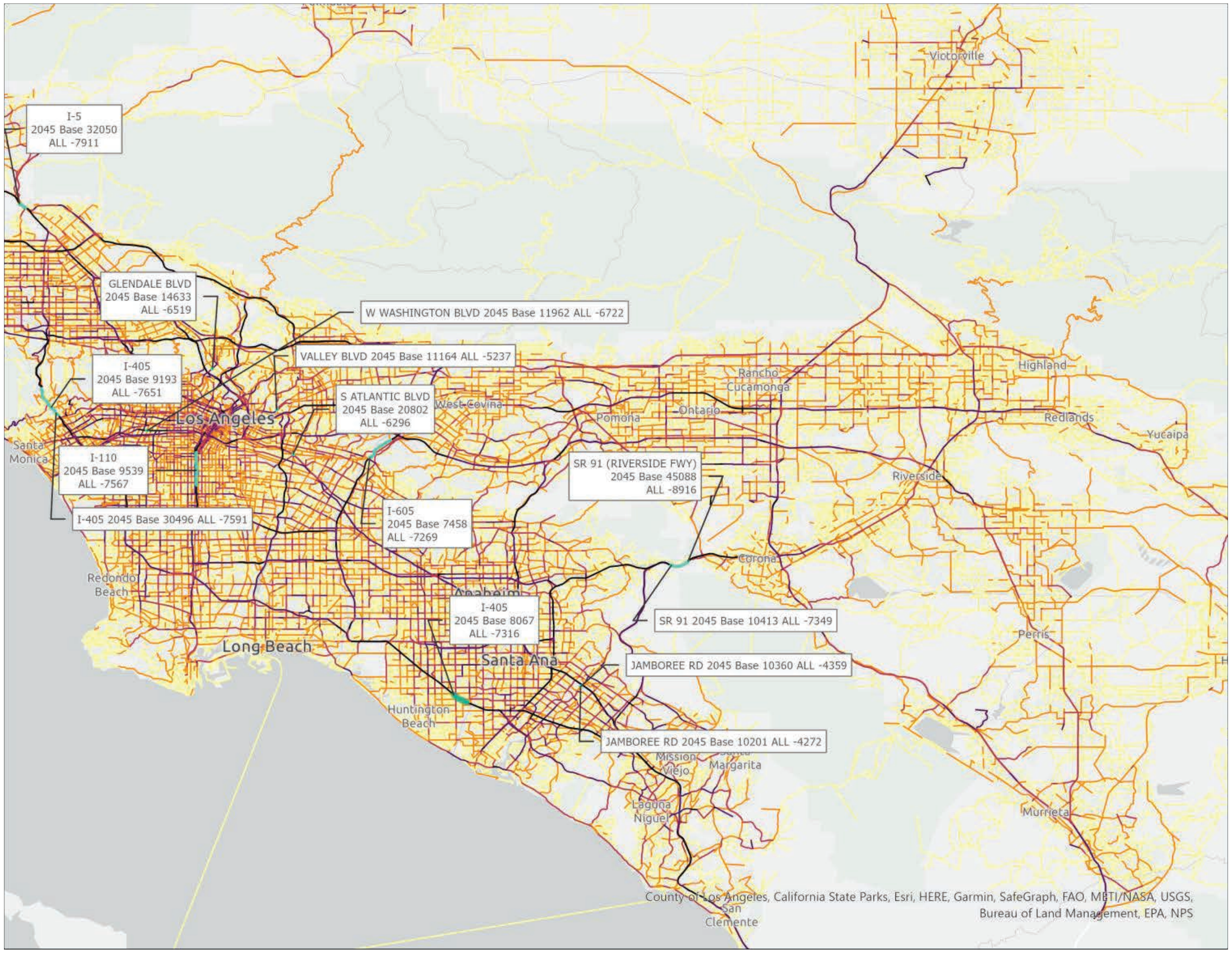

Figure 21. 2045 AM Peak Period Volume Difference Plot: Total Broadband – Upper Bound Behavior vs. Future Baseline

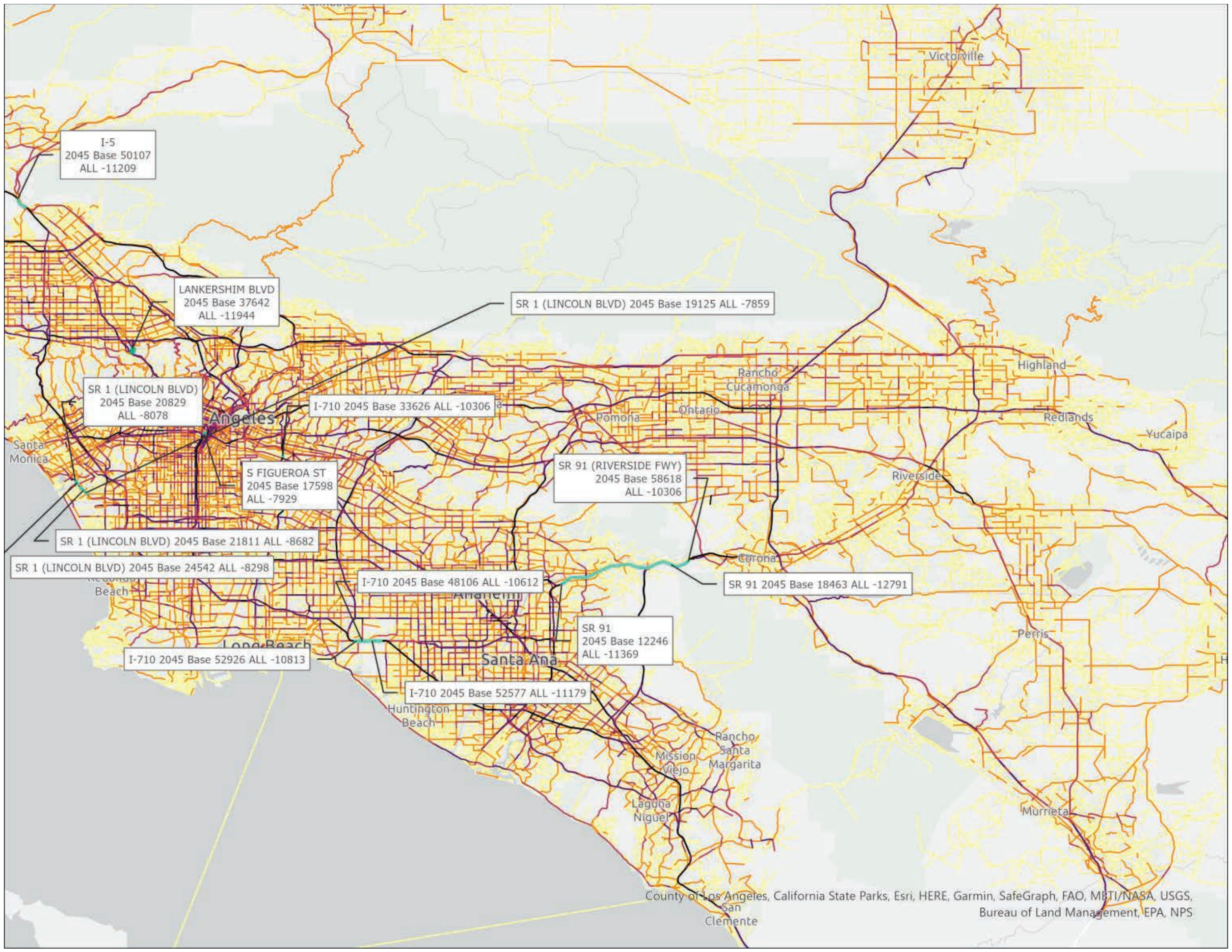

Figure 22. 2045 PM Peak Period Volume Difference Plot: Total Broadband – Upper Bound Behavior vs. Future Baseline

VMT AND EMFAC GHG RESULTS

The VMT results for Scenarios A, B, C, and D were stratified by speed class based on SCAG's regional VMT by speed class distribution used for on-road mobile source emissions estimates/inventories. Total on-road mobile source emissions of carbon dioxide (i.e., GHG) associated with each scenario was generated using the latest emissions model EMFAC2021 developed by the California Air Resources Board. The deltas between the three broadband scenarios (Scenarios B-D) relative to the future baseline (Scenario A) yield the relative benefit of these futures. The VMT and CO_2 reduction results are provided in Table 14.

Table 14. SCAG Travel Demand Model Reassignment Results

Scenario	Total VMT LDA/LDT	Percent Change of Total VMT	CO_2 (tons per day)	Percent Change of Total CO_2
A: 2045 Baseline	459,090,327	-	164,369	-
B: 2045 NBEI-SIPB	454,523,915	-1.00%	163,009	-0.89%
C: 2045 NBEI-UBB	451,795,887	-1.61%	162,185	-1.43%
D: 2045 TB-UBB	400,444,110	-14.65%	148,397	-11.48%

Results indicate that broadband expansion into areas of the SCAG region that currently do not have access to quality broadband service (as defined in this study) could result in daily VMT reductions of between 4.6 million and 7.3 million depending on travel behavior and employer telecommuting policies for non-essential workers. These absolute reductions equate to a 1-2 percent reduction of regionwide daily VMT. These relative benefits should be expected given that this analysis focused exclusively on a single trip purpose – the Home-Based Work trip whose activity predominantly occurs during a sub-set of a given weekday (i.e., AM and PM peak period or approximately six hours). Benefits of other trip purposes that could benefit from broadband expansion to reduce vehicle trips (e.g., tele-shop or tele-health) are not reflected in this analysis.

In addition, based on the operative definition of broadband vs. non-broadband area used in this analysis, expansion into currently underserved areas is projected to augment broadband service to just 6 percent of total households in the SCAG region by 2045. These non-broadband areas are characterized as having disproportionately greater disadvantaged households and therefore a larger proportion of essential workers. The commuting characteristics of essential workers will not be affected by broadband access.

Analyzing the SCAG region as a whole (including both current broadband and non-broadband areas) and assuming 100 percent of non-essential workers telecommuting, daily VMT reductions approach 59 million which translates to nearly a 15% reduction. This should be considered the upper bound on what is possible from broadband expansion and supportive polices in the SCAG region.

The CO_2 emission reductions resulting from broadband expansion into areas of the SCAG region that currently do not have access to quality broadband service range between 0.9-1.5%. The regionwide upper bound analysis yields a percent reduction of CO_2 of 11.5%. The projected VMT reductions result in lower percentage reductions of daily CO_2 emission reductions given that the VMT reductions were applied to only the Light-Duty Auto (LDA) and Light-Duty Truck (LDT-1 and LDT-2) vehicle class and technology groups which are lower emitting vehicles. Also, by 2045 the light-duty vehicle fleet demographics/composition will reflect a relatively cleaner fleet that what exists today (i.e., fleet turnover from the market penetration of newer cleaner light-duty vehicles over time).

NEXT STEPS

The following analyses are logical enhancements or follow-ups to the analysis described above.

Refine the Definition of Broadband Availability

This analysis based the definition of broadband availability using a "Broadband Index" based on Census estimates of the number of households with various types of internet subscriptions. A block group with a Broadband Index greater than 0.0—more than 50 percent of households within that block group had an internet connection considered to be broadband—is considered a "broadband block group." Those with an index equal to or less than 0.0 is considered a "non-broadband block group." Block groups without population were automatically removed.

This binary cutline was used to classify each block group for analysis. Greater granularity was beyond the scope of this study due to limited data. A more meaningful definition of broadband availability would be based on multiple criteria, including cost and speed/throughput. More importantly, since broadband is provisioned to and utilized at specific locations—locations right next to one another can have very different internet service options—a more refined analysis requires address specific data on available and taken services. Analysis should begin at the finest level—the "customer premise"—which can then be aggregated to block, block group, TAZ, and other geographic levels. This would improve the accuracy of the analysis and its usefulness for informing policy.

Additional Scenario for Next Cycle SCAG RTP/SCS

"Scenario A: 2045 Future Baseline - Pre-Pandemic Travel Behavior" reflects SCAG's most recent Preferred Scenario.[30] The plan reflects significant investments in alternatives to single occupancy auto use including transit and active transportation. By 2040, over 170,000 miles of bus routes and 72,000 miles of transit rail will be added to the system. This will allow over 45 percent of the total household growth and 55 percent of total employment growth to locate within high-quality transit areas. In 2018, the California Air Resources Board (CARB) revised SCAG's GHG emission reduction target from -13% by 2035 relative to 2005 levels to -19%. Achieving additional VMT and therefore GHG emission reductions to meet this target and future adjustments to the target by CARB are critical measures of the plan's success.

GHG emission reductions resulting from broadband expansion is an obvious programmatic strategy that SCAG can credit towards achieving these state mandated targets. Scenarios B and C of this analysis serve to isolate the potential benefit of expanding broadband to unserved areas. Scenario D reflects the upper bound of both broadband expansion and permissive telecommuting policies regionwide and would not suffice as a SCS scenario. It would be appropriate to analyze an additional scenario— "Total Broadband – Shelter in Place Behavior"—as it represents a more plausible future and could be more acceptable to CARB. Based on this analysis, such a scenario should yield between 2-15% VMT and GHG reductions.

Include Additional Trip Purposes and Other Time Periods

This analysis was applied to a single trip purpose – the home based work trip. This was primarily due to readily available information sources on telecommuting and telecommuting benefits. More importantly, empirical traffic data and cell-data was also available to gauge the effects of the COVID-19 Pandemic Shelter-In-Place restrictions on AM/PM peak period travel behavior – which is dominated by commuter activity. However, to capture the full VMT and GHG reduction benefits of broadband expansion other trip purposes amendable to telecommunications should be analyzed. This includes, but is not limited to tele-shopping, tele-health, and tele-school trips. Academic research on travel behavior during the COVID-19 Pandemic being conducted at USC and UC Davis concurrent with this study would have certainly provided insights to inform assumptions to establish a defensible

[30] The Preferred Scenario in SCAG's Regional Transportation Plan and Sustainable Community Strategy (RTP/SGS), Connect SoCal, is the operative combination of planned transportation improvements coupled with the preferred land use scenario.

framework for analysis. This research was not available for use in this study but when published could be used to augment the breadth of analysis described herein.

Incorporation of Facility-Based Telework Strategies

A considerable body of research, demonstration projects, and pilot studies were performed in the 1980s and 1990's in the SCAG region that was focused primarily on promoting telework at large employment sites. This was primarily driven by the rules adopted by the South Coast Air Quality Management District to establish indirect source review for land uses (i.e., Regulation 15, Rule 2202 – On-Road Motor Vehicle Mitigation Options, etc.) to comply with state and federal air quality requirements in affect at the time in the SCAG region. In recent years the facility-based concept has expanded to residential development and residential development patterns (i.e., Tele-villages, Neighborhood Centers etc.).

Given that this study was specifically oriented toward residential home-access to broadband (versus work-site oriented) and applied at a regional scale, facility-based strategies that focus on expanding applications once broadband access is established at a given location was beyond the scope of this study. Although typically examined at different scales of analysis (site vs. region), facility-based telework strategies would be a logical adjunct for further study of the potential VMT and GHG reduction benefits of broadband – specifically applications, uses and policies related broadband.

Border-Crossing Commuters

This study did not address border-crossing commuters and therefore the potential VMT and GHG reduction benefits of broadband expansion for those non-essential workers who must cross the border between the United States and Mexico.

7. Conclusions and Implications

Telecommuting clearly reduces VMT and has a substantial impact on GHG reduction. If broadband were expanded in underserved areas, identified in Figures 11-14 [in section 6], and all non-essential workers telecommuted, there would a 15% reduction in VMT, and GHG emissions would be reduced 11.5%. While this scenario is unlikely, this analysis does not account for broadband replacing travel for other purposes than commuting (doctor visits, school, shopping, et cetera). Nor does it consider how essential workers' travel might be impacted by these changes or complementary improvements such as intelligent traffic management and lower emission vehicles.

Including network infrastructure assets in transportation projects is much more economical than deploying them as stand-alone projects. The cost to drop conduit in an open trench is only about 1/6 the cost of deploying it as a standalone construction project. Even with the cost of fiber, this equates to effectively cutting the cost of backbone or middle-mile infrastructure development in half. Presuming conduits were included in transportation projects through areas underserved by broadband, costs for providers to expand their geographic coverage and improve service offerings would be substantially reduced. Figures 11-14 point to locations within the SCAG region where broadband infrastructure expansion would be beneficial.

Assets deployed in transportation projects may be incorporated into systems for providing retail broadband and other network services to the area around those projects. The assets must be accessible to providers and must comport with providers' build models and overall strategy. In most situations, network assets deployed as part of transportation plans will comprise only a fraction of the infrastructure necessary to deliver services to the customer. Such reductions in barriers to market entry may not be enough to drive expansion by private companies. Public investment intentionally aligned with market demand as well as public priorities for broadband and digital inclusion is likely necessary to increase availability.

Even with increased broadband availability, actual reductions in VMT and GHG emissions will depend on changes in employers' policies and practices as well as adoption by consumers and use for telecommuting and other purposes that substitute for vehicular travel. Digitalization is the process of replacing labor-intensive manual activities with automated functions, including changes that reduce the need for driving. Internet service providers are more likely to invest in areas with programs to promote digitalization because it translates into more revenue for them.

The comprehensive maps of the region in this report illustrate to the extent possible how the SCAG region is served by broadband. Along with the conclusion that a significant portion of the SCAG region is underserved, the analysis highlights the profound limitations of available data. There is no detailed data on where broadband is deployed, what services are offered, and what it costs. Data on the geographic distribution of adoption and use are also lacking. The most consistent, valid source of data—the Census Bureau's American Community Survey—is not localized to a level necessary for assessing broadband access. Data from other sources is inconsistent or of dubious validity. Address-level information about current demand, infrastructure, and services would enable investment and effective policy making.

APPENDIX A. UNDERSERVED BROADBAND TAZS

T1_TAZ	BROAD _PER	LINC_H H	MINC_ HH	HINC_ HH	VHINC _HH	SFDU	MFDU	LINC_ WRK	MINC_ WRK	HINC_ WRK	TOT_E MP	TOTLO W_EM P	TOTME D_EMP	TOTHI G_EMP
43594000	41%	326	165	243	30	367	397	248	114	103	308	151	62	95
53995000	46%	273	171	91	11	417	129	295	175	28	348	219	103	26
43595000	36%	15	42	43	0	43	57	42	9	14	18	9	6	3
53885000	15%	56	33	14	4	23	84	43	36	5	18	4	7	7
43589000	38%	496	187	54	28	666	99	472	104	46	230	138	58	34
43597000	34%	54	40	15	5	57	57	6	2	1	20	6	11	3
43579000	3%	205	56	15	1	83	194	258	25	3	119	46	32	41
14003000	46%	567	208	328	167	1210	60	842	362	438	1660	1080	298	282
43470000	12%	512	477	172	80	581	660	142	61	33	471	263	137	71
43585000	32%	107	93	35	4	137	102	127	49	16	92	8	22	62
53994000	21%	21	5	3	3	30	2	8	8	3	0	0	0	0
53882000	19%	19	9	5	0	21	12	26	10	0	111	39	16	56
43577000	5%	1064	391	219	56	550	1180	778	176	111	807	412	247	148
43582000	21%	0	0	1	0	1	0	0	1	0	0	0	0	0
14001000	22%	1136	624	316	16	1406	686	1594	607	75	342	190	31	121
14004000	46%	18	15	5	0	32	6	20	11	1	15	7	5	3
43469000	26%	253	343	186	36	408	410	169	101	35	202	63	72	67
43596000	47%	170	79	67	118	391	43	32	22	29	107	46	16	45
43467000	34%	325	284	84	36	402	327	85	75	17	184	96	45	43
43444000	25%	127	58	29	8	55	167	98	40	23	77	65	7	5
43443000	49%	210	262	266	126	553	311	244	253	175	313	150	72	91
14105000	30%	4	8	1	0	4	9	16	7	0	0	0	0	0
43576000	49%	65	17	4	0	26	60	18	1	1	6	2	3	1
14109000	20%	616	160	142	5	611	312	737	173	31	1917	803	620	494
14006000	33%	1395	858	1001	178	2810	622	2072	1614	632	159	116	36	7

T1_TAZ	BROAD _PER	LINC_H H	MINC_ HH	HINC_ HH	VHINC _HH	SFDU	MFDU	LINC_ WRK	MINC_ WRK	HINC_ WRK	TOT_E MP	TOTLO W_EM P	TOTME D_EMP	TOTHI G_EMP
43442000	27%	170	204	261	152	545	242	224	214	186	361	160	92	109
14096000	29%	15	27	18	6	43	23	19	27	14	118	50	43	25
14100000	10%	8	9	4	3	17	7	5	7	5	53	14	16	23
14086000	13%	17	22	0	1	31	9	54	7	1	1221	175	267	779
14013000	34%	67	26	12	5	63	47	105	22	8	64	12	18	34
14014000	0%	35	12	16	5	40	28	39	19	10	49	20	19	10
14074000	43%	223	68	23	1	121	194	251	54	8	5847	2836	1484	1527
14007000	44%	60	47	48	19	67	107	85	62	37	345	103	112	130
14076000	49%	1604	875	361	200	1218	1822	3514	800	276	1682	715	398	569
14039000	53%	1273	434	212	25	822	1122	2038	417	76	6364	2855	1737	1772
14040000	47%	1173	281	137	16	311	1296	2022	254	20	5578	2297	1535	1746
14042000	47%	307	98	169	29	238	365	450	145	81	1000	624	253	123
14054000	49%	449	211	111	2	429	344	689	189	24	807	366	203	238
53878000	51%	534	225	116	18	690	203	400	193	41	1148	254	239	655
53915000	49%	600	719	621	220	1903	257	639	615	365	404	223	124	57
20345000	11%	21	14	11	3	39	10	23	19	8	5	2	1	2
53897000	14%	213	185	114	21	529	4	597	189	69	0	0	0	0
53889000	38%	225	146	45	13	329	100	304	84	31	329	73	88	168
53894000	24%	225	587	298	15	825	300	591	504	137	8	5	3	0
53887000	46%	696	367	172	118	686	667	854	321	198	151	93	33	25
20347000	6%	78	51	26	17	150	22	113	69	33	2071	535	493	1043
43216000	27%	405	532	449	247	1468	165	575	432	409	260	80	62	118
43299000	50%	445	552	443	174	1317	297	1046	626	360	114	58	42	14
53900000	56%	446	611	376	66	1293	206	844	590	214	440	243	79	118
53893000	39%	869	587	346	32	1070	764	1156	565	180	658	314	154	190
53892000	54%	197	357	723	104	1103	278	289	527	599	1105	703	176	226
53888000	37%	187	362	128	431	978	130	342	130	473	179	148	19	12
53858000	29%	263	312	241	126	859	83	434	288	254	204	130	37	37

T1_TAZ	BROAD_PER	LINC_HH	MINC_HH	HINC_HH	VHINC_HH	SFDU	MFDU	LINC_WRK	MINC_WRK	HINC_WRK	TOT_EMP	TOTLOW_EMP	TOTMED_EMP	TOTHIG_EMP
53907000	41%	175	353	181	96	695	110	371	306	183	187	64	47	76
43181000	48%	273	332	353	149	935	172	1148	678	247	5661	2024	1662	1975
43235000	48%	1081	377	206	50	178	1536	1244	313	21	9931	3813	2499	3619
43246000	43%	2141	931	329	318	753	2966	1662	394	269	5864	2094	1669	2101
43243000	46%	394	530	220	86	555	675	1515	477	160	491	156	120	215
43143000	60%	575	281	151	35	637	405	1251	300	63	549	269	145	135
53729000	52%	796	290	213	28	678	649	1330	355	25	10018	4261	2768	2989
60001000	34%	208	88	86	23	355	50	112	57	37	72	24	22	26
60052000	33%	734	391	308	294	252	1475	679	196	354	1315	424	346	545
20281000	46%	109	105	79	28	238	83	162	128	70	14918	6047	3716	5155
20336000	34%	65	49	19	3	123	13	144	23	15	92	41	28	23
20264000	34%	40	21	12	8	65	16	72	26	14	39	17	20	2
20365000	45%	646	472	491	203	813	999	833	451	454	8679	4269	2196	2214
20313000	42%	2289	710	121	284	589	2815	631	822	324	5176	2508	1012	1656
20509000	43%	178	376	191	173	119	799	726	366	225	14060	4492	3601	5967
20521000	51%	693	542	171	13	25	1394	1797	425	43	2034	905	519	610
60102000	44%	170	135	108	83	436	60	398	117	74	1189	307	370	512
60097000	41%	121	221	61	7	104	306	394	100	30	1356	472	686	198
60074000	53%	1128	1329	540	306	872	2431	4742	1004	372	858	224	176	458
60206000	48%	538	838	670	651	1569	1128	1688	784	779	2850	1064	691	1095
20785000	35%	5	21	8	0	20	14	231	12	15	4293	698	1122	2473
20371000	50%	900	522	164	46	594	1038	1495	387	81	1608	784	420	404
20391000	23%	158	193	221	34	563	43	194	255	153	332	200	77	55
20373000	29%	4	8	13	23	43	5	27	34	34	14	12	2	0
20378000	30%	107	45	159	46	151	206	138	160	120	38	9	11	18
22299000	48%	162	257	154	77	601	49	904	285	85	1501	635	507	359
22317000	57%	336	617	520	62	1128	407	1853	780	178	4011	1106	987	1918
22288000	52%	864	607	508	118	564	1533	1551	735	317	3094	1666	736	692

T1_TAZ	BROAD_PER	LINC_HH	MINC_HH	HINC_HH	VHINC_HH	SFDU	MFDU	LINC_WRK	MINC_WRK	HINC_WRK	TOT_EMP	TOTLOW_EMP	TOTMED_EMP	TOTHIG_EMP
22318000	36%	354	229	115	76	316	458	762	264	126	1604	500	462	642
22280000	49%	358	407	268	18	693	358	1864	333	29	990	498	258	234
22237000	34%	226	159	60	24	152	317	596	110	42	899	394	202	303
22236000	49%	1148	869	317	37	954	1417	3709	420	51	2128	841	538	749
53672000	38%	170	352	157	35	243	471	1139	298	73	15833	5792	4337	5704
22156000	52%	654	695	510	82	312	1629	1129	744	315	3322	1369	831	1122
22207000	44%	694	568	193	40	473	1022	2202	365	67	410	193	109	108
22213000	40%	512	333	83	26	283	671	872	251	67	2761	1089	725	947
22239000	60%	365	480	315	75	604	631	1460	470	193	740	204	337	199
22234000	45%	635	486	181	37	557	782	2099	309	56	917	472	219	226
20985000	47%	907	398	106	16	81	1346	1507	290	52	1077	796	95	186
22027000	49%	411	361	150	43	481	484	1225	268	95	1467	670	367	430
22158000	49%	1101	853	736	206	910	1986	1998	982	565	3197	1720	709	768
22141000	53%	684	435	204	79	225	1177	1318	468	46	1265	694	275	296
22173000	52%	1094	753	739	182	1315	1453	2567	1011	464	4282	2585	852	845
21067000	52%	943	271	139	32	55	1330	1349	271	67	563	345	92	126
22016000	46%	81	29	104	5	49	170	142	76	64	1969	1145	382	442
21965000	53%	624	458	83	28	282	911	1460	238	38	593	398	111	84
21369000	41%	30	0	1	4	10	25	54	5	5	7072	2984	2165	1923
21378000	45%	1070	865	288	119	102	2240	1887	599	354	2355	1044	682	629
21354000	51%	639	325	173	53	301	889	1560	315	92	5439	1772	1331	2336
21367000	46%	257	38	5	35	13	322	341	66	45	991	337	243	411
21394000	53%	1093	510	151	55	140	1669	1447	378	178	1234	727	317	190
21404000	60%	1074	711	292	68	478	1667	1666	589	291	1493	696	400	397
21334000	54%	351	443	180	7	289	692	1343	370	45	225	161	57	7
21337000	53%	185	374	221	94	316	558	1048	342	162	2028	639	454	935
21346000	56%	262	461	404	57	781	403	1312	527	212	952	475	208	269
21352000	55%	472	419	224	35	621	529	1529	364	90	370	198	123	49

T1_TAZ	BROAD_PER	LINC_HH	MINC_HH	HINC_HH	VHINC_HH	SFDU	MFDU	LINC_WRK	MINC_WRK	HINC_WRK	TOT_EMP	TOTLOW_EMP	TOTMED_EMP	TOTHIG_EMP
21402000	46%	1079	547	228	34	211	1677	1837	433	146	1139	427	222	490
21368000	55%	491	419	323	44	103	1174	770	831	53	162	54	25	83
21595000	46%	490	429	262	96	623	654	1772	445	143	5077	1609	1359	2109
21586000	43%	608	537	338	180	772	891	1473	678	457	1637	815	442	380
21628000	49%	602	430	163	46	651	590	1782	327	32	755	545	150	60
21622000	48%	499	687	191	21	685	713	1774	505	58	697	473	141	83
21583000	42%	314	259	115	3	400	291	937	196	12	853	291	225	337
21617000	47%	695	518	291	51	361	1194	2367	503	66	211	142	51	18
21579000	44%	632	634	252	42	825	735	1722	520	102	562	281	140	141
21574000	50%	1209	683	279	64	1166	1069	2323	600	168	233	181	21	31
21572000	43%	1934	1060	251	358	1569	2034	1411	595	356	747	386	142	219
21580000	60%	269	153	119	6	347	200	762	184	14	276	92	62	122
21576000	42%	484	287	142	18	500	431	1217	256	34	504	224	174	106
21618000	48%	275	186	67	8	127	409	812	127	8	276	171	77	28
21564000	42%	1012	589	257	116	866	1108	2437	511	54	507	280	106	121
21542000	49%	553	531	426	28	916	622	1899	648	90	183	90	30	63
21543000	48%	818	596	263	104	709	1072	1449	546	140	327	293	33	1
21637000	43%	854	429	305	30	436	1182	2546	381	29	1429	855	305	269
21549000	53%	958	625	188	142	986	927	1951	444	90	1009	511	222	276
21539000	50%	647	527	174	78	526	900	1224	333	122	1428	659	367	402
21510000	39%	663	368	63	23	338	779	1187	146	27	937	412	217	308
21570000	46%	903	330	120	68	456	965	1692	205	66	604	338	99	167
21538000	30%	774	199	27	64	145	919	620	111	79	444	278	90	76
21516000	36%	609	297	172	57	744	391	1450	279	17	345	212	74	59
21588000	49%	268	148	62	11	209	280	677	103	6	31	30	1	0
21567000	52%	1073	781	282	96	946	1286	2314	465	130	1045	556	279	210
21511000	47%	1365	820	184	65	1030	1404	2808	414	75	712	490	105	117
21566000	50%	1100	1007	485	108	830	1870	2207	941	187	1080	603	224	253

T1_TAZ	BROAD_PER	LINC_HH	MINC_HH	HINC_HH	VHINC_HH	SFDU	MFDU	LINC_WRK	MINC_WRK	HINC_WRK	TOT_EMP	TOTLOW_EMP	TOTMED_EMP	TOTHIG_EMP
21541000	45%	1780	1389	640	185	1141	2853	2727	1008	389	1016	492	285	239
21594000	36%	1022	423	98	18	133	1428	1847	201	35	1266	666	423	177
21577000	38%	615	297	73	15	257	743	1584	130	13	1017	456	326	235
21533000	37%	1916	1056	464	180	881	2735	2619	1036	198	1548	503	458	587
21508000	50%	1194	729	221	140	883	1401	2296	477	129	5320	2700	1328	1292
21575000	42%	374	219	141	1	266	469	1043	184	20	1707	651	469	587
21558000	36%	570	139	75	9	196	597	1185	82	9	781	390	184	207
21592000	46%	1149	299	255	122	152	1673	1305	436	125	2802	1657	692	453
21578000	56%	415	208	75	17	182	533	996	145	17	447	190	121	136
21587000	36%	4671	1879	608	1983	43	9098	1123	725	2358	29174	11597	7655	9922
21620000	39%	566	58	299	338	22	1239	481	279	599	281	202	61	18
21625000	46%	307	435	153	252	200	947	665	344	434	5242	2122	1674	1446
21619000	54%	104	329	124	125	238	444	346	113	282	754	385	148	221
21626000	51%	589	285	136	84	198	896	975	251	175	1327	756	318	253
21650000	51%	85	343	123	191	467	275	176	215	108	76	68	8	0
22010000	53%	1187	219	262	494	60	2102	221	272	725	4231	1820	1112	1299
21331000	57%	480	445	338	69	335	997	923	538	236	1458	534	370	554
21333000	51%	444	356	290	103	598	595	1459	513	123	384	320	39	25
21165000	53%	542	620	105	108	486	889	1821	421	156	859	373	232	254
21201000	55%	606	406	259	6	502	775	1958	403	22	699	211	153	335
21191000	35%	732	453	133	41	96	1263	335	395	58	2567	1271	564	732
21226000	55%	610	541	410	44	951	654	1427	545	175	509	310	90	109
21235000	42%	576	401	290	61	523	805	1572	477	130	642	319	118	205
21234000	51%	1135	677	374	185	837	1534	2488	709	374	498	347	59	92
21231000	49%	406	400	296	79	814	367	1120	457	140	501	195	98	208
20955000	49%	2483	1146	473	190	469	3823	2773	1075	353	1020	627	212	181
20959000	47%	1404	545	316	51	578	1738	1473	543	189	1195	598	273	324
21248000	46%	757	408	244	18	385	1042	1184	409	158	187	163	18	6

T1_TAZ	BROAD_PER	LINC_HH	MINC_HH	HINC_HH	VHINC_HH	SFDU	MFDU	LINC_WRK	MINC_WRK	HINC_WRK	TOT_EMP	TOTLOW_EMP	TOTMED_EMP	TOTHIG_EMP
20939000	47%	2141	1195	415	68	50	3769	2291	987	236	528	309	102	117
21489000	47%	984	621	202	28	956	879	2237	349	54	1241	733	230	278
21493000	44%	369	326	101	51	360	487	978	204	51	392	278	51	63
21038000	46%	1601	752	361	212	1283	1643	1558	814	229	789	504	169	116
21492000	44%	1218	640	138	91	852	1235	2152	439	91	1195	707	288	200
21491000	42%	1002	960	135	144	476	1765	1497	501	152	588	286	118	184
21498000	54%	791	890	212	97	1246	744	1432	592	135	924	370	244	310
20940000	51%	1041	570	319	50	543	1437	1369	553	174	461	295	101	65
21515000	46%	1023	649	145	125	893	1049	1945	376	111	1081	544	314	223
21518000	52%	1412	1052	362	96	1008	1914	2210	667	137	630	351	145	134
20957000	54%	1438	667	353	139	320	2277	1079	574	352	1231	661	304	266
21094000	50%	1315	449	165	69	352	1646	1729	366	122	917	458	293	166
20994000	59%	1583	483	325	118	290	2219	1488	474	303	1751	705	593	453
21095000	51%	1511	474	129	45	427	1732	2156	324	70	595	401	120	74
20824000	46%	625	299	17	24	26	939	1719	75	48	103	89	9	5
21530000	50%	612	618	561	59	1560	290	2195	751	134	4978	1814	1337	1827
21240000	50%	443	321	239	22	431	594	1269	351	70	1434	489	468	477
21241000	48%	1336	860	267	43	823	1683	3211	617	68	504	290	103	111
21243000	59%	593	582	401	44	681	939	1745	614	173	1872	767	440	665
21551000	46%	335	211	183	0	582	147	878	186	65	427	162	90	175
21246000	51%	337	444	252	89	840	282	1108	408	142	2622	898	736	988
21521000	50%	555	363	418	39	658	717	720	654	137	1780	709	481	590
21039000	49%	629	489	364	45	861	666	1391	451	163	951	544	153	254
21069000	46%	804	492	204	37	328	1209	1451	345	102	434	322	84	28
21081000	56%	775	403	227	21	657	769	1874	358	53	693	312	276	105
21104000	48%	920	485	254	66	762	963	2124	420	118	1128	649	213	266
21043000	41%	538	227	119	25	361	548	1169	200	20	501	223	108	170
21074000	43%	915	368	139	35	211	1246	1736	247	82	1789	943	303	543

T1_TAZ	BROAD_PER	LINC_HH	MINC_HH	HINC_HH	VHINC_HH	SFDU	MFDU	LINC_WRK	MINC_WRK	HINC_WRK	TOT_EMP	TOTLOW_EMP	TOTMED_EMP	TOTHIG_EMP
21073000	41%	1100	413	85	32	171	1459	1736	240	55	408	163	107	138
21072000	44%	733	367	106	28	251	983	1324	191	51	495	226	119	150
21099000	35%	826	361	152	21	347	1013	1507	238	61	253	164	46	43
21107000	51%	1075	629	214	45	670	1293	2923	316	63	711	461	157	93
21109000	34%	479	91	24	1	27	568	947	49	201	4174	1571	1111	1492
21108000	47%	1099	444	115	19	450	1227	2195	200	39	1217	528	398	291
21505000	41%	605	315	139	58	509	608	1813	186	56	378	241	64	73
21523000	51%	503	322	222	22	474	595	1719	271	32	610	301	158	151
21071000	56%	1201	382	165	230	83	1895	2227	466	219	1430	621	357	452
21532000	40%	622	356	126	30	508	626	1526	200	37	890	522	131	237
21545000	52%	503	360	100	10	454	519	1590	152	12	382	181	92	109
21020000	46%	1037	589	229	222	331	1746	1799	243	335	762	492	143	127
21082000	46%	493	308	275	44	131	989	1052	386	133	840	379	282	179
21914000	58%	1623	428	305	144	99	2401	3345	524	264	1804	579	491	734
21537000	48%	492	410	73	19	265	729	1489	152	23	737	343	184	210
21065000	51%	1016	382	127	40	183	1382	1212	251	98	1350	625	426	299
21083000	30%	802	272	36	21	156	975	1442	101	46	504	211	180	113
21905000	45%	604	171	42	14	63	768	1099	77	17	362	185	121	56
21912000	30%	900	262	106	19	103	1184	1590	152	43	760	334	222	204
21906000	44%	695	287	20	23	27	998	1033	137	28	875	328	430	117
21915000	40%	570	315	47	45	92	885	1430	166	39	303	162	112	29
21070000	49%	1098	525	150	55	40	1788	1760	253	125	1186	648	252	286
21910000	41%	1174	553	85	45	29	1828	1764	293	65	1827	827	562	438
21919000	31%	1107	408	69	22	27	1579	1930	210	28	690	315	262	113
21909000	47%	1360	432	157	30	82	1897	1962	286	92	921	658	171	92
20998000	58%	1067	634	477	98	1124	1152	1409	738	249	625	411	118	96
21101000	46%	796	408	119	52	316	1059	1775	227	57	469	241	110	118
21520000	44%	600	227	105	12	264	680	1361	141	16	518	307	106	105

T1_TAZ	BROAD_PER	LINC_HH	MINC_HH	HINC_HH	VHINC_HH	SFDU	MFDU	LINC_WRK	MINC_WRK	HINC_WRK	TOT_EMP	TOTLOW_EMP	TOTMED_EMP	TOTHIG_EMP
21929000	38%	731	706	267	136	50	1790	668	512	377	4188	1699	1113	1376
21916000	44%	1031	118	174	90	68	1345	905	127	178	1244	429	290	525
21553000	32%	186	32	11	37	3	263	56	20	22	9300	3063	2881	3356
21939000	48%	828	592	380	126	1	1925	741	538	455	2824	926	718	1180
21927000	42%	1182	346	106	49	57	1626	1756	199	76	1827	879	446	502
21555000	21%	4830	1024	115	1394	18	7345	1879	627	1570	12922	5170	3448	4304
21940000	52%	1999	981	374	300	200	3454	3385	848	389	2201	811	545	845
21923000	32%	1192	393	111	45	21	1720	1994	216	68	1557	960	376	221
21926000	33%	492	238	95	64	17	872	1282	169	85	2197	1169	595	433
21922000	42%	1244	356	33	39	25	1647	1781	145	24	772	557	115	100
21920000	42%	936	376	59	36	30	1377	1303	218	52	3168	1172	749	1247
21935000	48%	2038	507	165	81	42	2749	3125	339	116	437	230	94	113
21928000	35%	1130	517	108	31	41	1745	1920	318	46	345	219	110	16
21423000	46%	836	470	426	47	360	1419	1515	703	150	1665	536	417	712
21390000	50%	900	424	120	134	16	1562	756	379	250	1299	731	269	299
21822000	59%	138	257	277	72	682	62	965	347	154	1491	726	290	475
21872000	0%	0	0	0	0	0	0	0	0	0	13869	4359	3785	5725
21726000	51%	469	292	89	17	391	476	1050	178	18	829	298	226	305
21683000	45%	544	493	150	60	331	916	1695	352	75	1328	705	353	270
21711000	48%	811	732	293	52	939	949	2573	542	63	1366	735	297	334
22201000	54%	254	395	239	24	596	316	1383	312	62	4170	1659	1118	1393
22221000	51%	653	644	210	77	684	900	2318	406	86	4108	1819	1264	1025
22165000	50%	435	399	173	35	571	471	1373	296	54	888	597	158	133
22164000	41%	650	664	383	61	946	812	2225	637	105	725	424	158	143
22195000	34%	277	157	92	37	150	413	893	163	38	3756	1991	861	904
22204000	46%	656	706	354	399	926	1189	1820	810	490	1028	460	246	322
22215000	49%	263	534	139	102	386	652	934	419	191	519	257	116	146
22224000	48%	700	701	147	43	487	1104	2075	375	60	1125	400	299	426

T1_TAZ	BROAD_PER	LINC_HH	MINC_HH	HINC_HH	VHINC_HH	SFDU	MFDU	LINC_WRK	MINC_WRK	HINC_WRK	TOT_EMP	TOTLOW_EMP	TOTMED_EMP	TOTHIG_EMP
22222000	52%	1836	1176	434	246	848	2844	1463	1015	359	5603	2468	1219	1916
22228000	38%	801	653	227	42	369	1354	1746	536	97	541	371	105	65
21752000	46%	1106	540	458	84	612	1576	2053	684	177	1904	969	459	476
22184000	56%	778	944	536	253	1445	1066	2276	992	367	2210	1062	527	621
21743000	53%	339	379	156	28	325	577	878	322	60	1258	693	362	203
21744000	40%	621	380	335	56	492	900	1346	477	131	4725	1376	1260	2089
21737000	35%	537	468	294	35	889	445	1771	498	59	538	368	113	57
21730000	36%	601	508	266	72	753	694	1902	477	110	1740	1003	461	276
21727000	42%	437	443	304	9	411	782	741	460	88	2721	1019	561	1141
21716000	38%	634	490	251	38	736	677	1702	461	60	1854	967	475	412
21746000	49%	431	301	196	39	305	662	857	357	60	1748	718	508	522
21735000	52%	903	580	315	24	900	922	2541	495	46	494	406	64	24
21720000	48%	457	370	214	11	611	441	1479	336	47	207	118	29	60
21706000	33%	841	652	266	100	929	930	2128	535	137	1483	697	346	440
21407000	38%	537	204	16	33	18	772	1074	21	40	85	80	5	0
21733000	45%	704	424	180	34	671	671	1973	341	33	1010	456	222	332
21731000	34%	16	7	13	1	24	13	52	16	1	11316	3729	3212	4375
21734000	37%	108	28	12	36	88	96	272	61	25	19099	7690	6409	5000
21719000	46%	761	552	218	30	902	659	2268	410	37	1285	841	247	197
21715000	50%	185	136	152	21	265	229	589	234	56	2639	1396	951	292
21651000	51%	310	331	60	76	382	395	1018	167	78	434	155	87	192
21709000	50%	312	128	59	12	262	249	657	99	22	5493	2404	1820	1269
21722000	42%	638	489	221	50	571	827	1822	423	61	1326	713	367	246
21717000	48%	561	494	179	15	805	444	1746	318	28	379	233	116	30
21688000	50%	878	592	233	28	1132	599	2951	336	46	1308	493	379	436
21692000	45%	748	490	318	51	762	845	2244	476	133	1098	722	259	117
21699000	37%	218	204	154	5	374	207	759	238	23	2178	738	631	809
21707000	41%	995	746	372	67	1150	1030	3023	655	83	692	469	158	65

T1_TAZ	BROAD_PER	LINC_HH	MINC_HH	HINC_HH	VHINC_HH	SFDU	MFDU	LINC_WRK	MINC_WRK	HINC_WRK	TOT_EMP	TOTLOW_EMP	TOTMED_EMP	TOTHIG_EMP
21698000	29%	644	339	160	50	439	754	1419	282	84	457	236	84	137
21697000	40%	768	356	183	17	712	612	1494	327	39	409	275	47	87
21681000	38%	487	309	208	59	620	443	1446	354	84	202	192	10	0
21684000	47%	750	673	307	40	858	912	2422	543	85	229	99	82	48
21718000	43%	489	296	147	77	437	572	1346	354	96	463	381	82	0
21705000	49%	477	344	199	37	605	452	1279	396	53	712	265	328	119
21602000	47%	806	364	153	41	310	1054	1716	324	63	477	311	104	62
21671000	57%	484	464	148	13	463	646	1393	330	21	1565	1045	393	127
21703000	49%	447	491	172	13	496	627	1664	315	20	231	114	40	77
21694000	40%	583	363	152	9	477	630	1484	262	18	679	348	128	203
21693000	46%	476	373	138	7	456	538	1535	238	11	138	80	44	14
21677000	51%	320	180	83	33	224	392	820	168	31	156	84	32	40
22039000	47%	411	241	72	86	313	497	832	124	120	1390	596	300	494
21642000	48%	549	130	153	213	324	721	94	211	417	493	189	213	91
21665000	52%	452	311	283	258	690	614	967	241	400	294	170	64	60
21652000	59%	430	97	108	294	296	633	87	116	602	102	94	8	0
21634000	48%	787	309	232	193	446	1075	1199	357	298	2921	897	730	1294
21704000	45%	355	289	272	76	503	489	1177	423	130	311	111	66	134
21687000	34%	760	584	254	53	779	872	2262	463	91	1267	521	310	436
21686000	44%	796	587	144	104	663	968	1956	397	99	658	319	186	153
21680000	49%	836	621	272	65	940	854	2021	519	102	1147	750	285	112
20568000	45%	563	388	257	116	381	943	1521	485	152	596	305	118	173
20593000	59%	818	747	442	83	1072	1018	3165	758	159	2130	1083	498	549
20580000	49%	876	790	411	72	362	1787	1646	795	251	888	465	211	212
20591000	54%	842	434	91	75	181	1261	1839	313	99	1845	750	481	614
20592000	38%	566	429	147	13	118	1037	1416	307	52	2271	858	655	758
20619000	45%	628	578	466	44	516	1200	1546	742	217	1293	687	318	288
20606000	37%	526	388	114	30	197	861	1301	274	61	1300	529	332	439

T1_TAZ	BROAD_PER	LINC_HH	MINC_HH	HINC_HH	VHINC_HH	SFDU	MFDU	LINC_WRK	MINC_WRK	HINC_WRK	TOT_EMP	TOTLOW_EMP	TOTMED_EMP	TOTHIG_EMP
20676000	49%	106	330	291	47	450	324	752	350	76	1419	434	373	612
21958000	53%	1036	916	442	114	404	2104	2138	838	291	5892	3192	999	1701
21982000	47%	650	515	171	65	218	1183	1267	417	129	4049	1647	1201	1201
22004000	60%	449	344	214	59	498	568	1232	329	103	836	349	242	245
22187000	57%	581	681	555	136	926	1027	1547	914	367	1277	585	332	360
22203000	57%	737	563	608	112	68	1952	1055	798	442	3158	1198	736	1224
20369000	48%	2385	616	90	90	164	3017	2601	280	187	2995	1405	666	924
43148000	49%	16	24	9	3	23	29	53	15	6	20012	5887	5301	8824
22427000	40%	537	547	214	41	526	813	1986	373	79	353	183	85	85
53713000	46%	30	58	39	13	126	14	120	72	21	3006	871	839	1296
20312000	47%	357	692	244	56	690	659	1267	391	128	465	279	76	110
20323000	56%	952	912	582	76	1729	793	1697	1064	301	1032	659	248	125
20317000	37%	3423	836	229	289	914	3863	1488	483	207	5630	2250	1356	2024
53879000	14%	382	326	97	1	386	420	394	232	18	172	65	64	43
53976000	19%	142	59	17	3	137	84	95	65	0	137	38	38	61
53959000	19%	236	91	71	0	237	161	226	114	10	70	42	21	7
53944000	17%	331	101	89	12	402	131	321	156	24	1294	382	303	609
53965000	44%	481	265	225	49	916	104	448	305	95	281	160	58	63
53962000	47%	677	632	324	6	1339	300	801	579	63	1244	525	360	359
53969000	35%	2588	1113	219	173	1920	2173	1314	522	134	11099	4653	2885	3561
53903000	39%	1844	603	186	90	1435	1288	2106	402	132	602	196	141	265
53978000	30%	55	26	9	2	64	28	44	29	1	0	0	0	0
53977000	26%	444	214	117	16	735	56	335	203	32	102	79	10	13
53974000	19%	916	293	144	62	1274	141	752	257	116	1067	300	248	519
53961000	42%	382	372	242	55	930	121	472	344	143	169	112	33	24
53983000	26%	845	277	185	66	1290	83	555	302	116	181	132	18	31
53989000	23%	810	519	341	31	1496	205	679	505	90	440	96	98	246
43471000	40%	128	117	14	5	185	79	43	6	2	4	0	1	3

T1_TAZ	BROAD_PER	LINC_HH	MINC_HH	HINC_HH	VHINC_HH	SFDU	MFDU	LINC_WRK	MINC_WRK	HINC_WRK	TOT_EMP	TOTLOW_EMP	TOTMED_EMP	TOTHIG_EMP
53963000	27%	211	198	109	68	462	124	241	162	111	112	67	25	20
43456000	58%	1421	1087	583	137	1935	1293	1527	852	302	5812	2236	1540	2036
53821000	44%	548	596	329	96	565	1004	1289	622	158	335	139	82	114
53812000	56%	1129	883	317	20	1896	453	2573	890	40	530	420	96	14
53754000	46%	2468	1596	659	430	2981	2172	1504	1805	336	1722	816	374	532
53806000	35%	228	78	41	15	343	19	389	65	28	2879	1057	823	999
53810000	38%	2931	1152	296	46	1191	3234	2766	719	97	5495	2360	1542	1593
53805000	45%	637	252	71	16	214	762	975	167	37	933	398	402	133
53815000	52%	868	418	251	16	1072	481	2005	438	31	748	322	172	254
53793000	43%	2000	1073	286	272	1137	2494	2471	819	381	3859	1816	1144	899
53803000	40%	987	473	194	31	1114	571	1664	323	58	6169	2133	1508	2528
53781000	38%	422	271	118	6	704	113	858	209	21	1043	491	254	298
53773000	48%	477	179	47	1	450	254	939	52	2	1395	527	420	448
53765000	48%	1105	850	474	49	2032	446	1995	800	176	1291	511	308	472
53763000	50%	1035	1217	507	176	1172	1763	2108	1153	349	389	133	106	150
53796000	39%	39	43	28	2	100	12	74	36	16	7550	2374	2096	3080
53785000	51%	354	142	19	18	469	64	577	51	21	2755	929	675	1151
53795000	16%	210	121	27	2	149	211	369	64	4	10701	4134	2888	3679
53783000	43%	690	286	103	2	591	490	1222	184	17	5145	2344	1346	1455
53778000	53%	2212	971	415	252	2908	942	3330	882	382	4628	1992	1245	1391
43446000	48%	562	233	343	153	403	888	335	132	173	763	308	206	249
43267000	48%	268	338	235	16	228	629	713	281	116	6959	2789	2036	2134
43279000	46%	2181	1727	689	24	359	4262	1346	1449	445	4028	1681	1101	1246
53772000	30%	688	476	207	114	546	939	364	225	193	5296	2196	1397	1703
43282000	57%	547	543	146	33	940	329	1222	380	110	84	73	6	5
43373000	53%	909	520	232	36	1045	652	928	375	86	2070	824	592	654
53776000	44%	680	479	102	95	1131	225	1244	256	98	1021	484	276	261
53790000	23%	805	79	6	13	77	826	555	36	3	12391	4059	3105	5227

T1_TAZ	BROAD_PER	LINC_HH	MINC_HH	HINC_HH	VHINC_HH	SFDU	MFDU	LINC_WRK	MINC_WRK	HINC_WRK	TOT_EMP	TOTLOW_EMP	TOTMED_EMP	TOTHIG_EMP
53800000	45%	1839	434	168	71	402	2110	1406	355	156	4452	1688	1108	1656
53902000	37%	1480	1385	659	268	2565	1227	2787	1048	460	989	287	246	456
43492000	47%	1912	1587	581	215	3403	892	1892	1205	196	2746	1128	725	893
53970000	45%	201	130	73	28	406	26	188	133	34	6198	2577	1652	1969
43575000	20%	359	203	89	11	365	297	790	155	37	1332	314	332	686
43580000	32%	1503	798	485	247	1244	1789	3412	1030	362	658	429	106	123
43578000	19%	232	133	51	11	202	225	303	66	23	3598	1507	1186	905
43574000	42%	1252	856	286	123	1494	1023	1850	525	229	828	422	190	216
43563000	36%	511	189	118	57	480	395	929	202	75	3468	1493	809	1166
43567000	42%	208	214	80	28	356	174	481	129	37	1188	390	463	335
43570000	27%	827	556	249	84	1258	458	979	391	191	1818	748	474	596
43559000	42%	1038	318	110	28	657	837	1462	226	49	2042	948	499	595
43590000	48%	525	280	84	55	381	563	918	147	49	1718	911	367	440

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Transportation Broadband Strategies to Reduce VMT and GHG Emissions

Southern California Association of Governments

Magellan Advisors, LLC
DKS Associates

March 18, 2022

Agenda

Introductions
Project Objectives
Demographics
Environmental Impacts of Broadband
Transportation System Performance
Analysis of Broadband Impacts on VMT and GHG
Broadband in Transportation Projects
Conclusions
Next Steps

Introductions

Magellan Advisors, LLC

Jory Wolf
VP Digital Innovation

Greg Laudeman, Ed.D.
Senior Consultant

Melanie Downing
Consultant

DKS Associates

Alan Clelland
ITS/CV Leader

Randy Johnson
Senior Transportation Engineer

Jim Damkowitch
Managing Director DKS Sacramento

Introductions

Inland Empire Regional Broadband Consortium

SCAG
INNOVATING FOR A BETTER TOMORROW

CETF
CALIFORNIA EMERGING TECHNOLOGY FUND

BCPC
BROADBAND CONSORTIUM PACIFIC COAST

LA DEAL
LA DIGITAL EQUITY ACTION LEAGUE

SBBC

Magellan ADVISORS DKS

Project Objectives

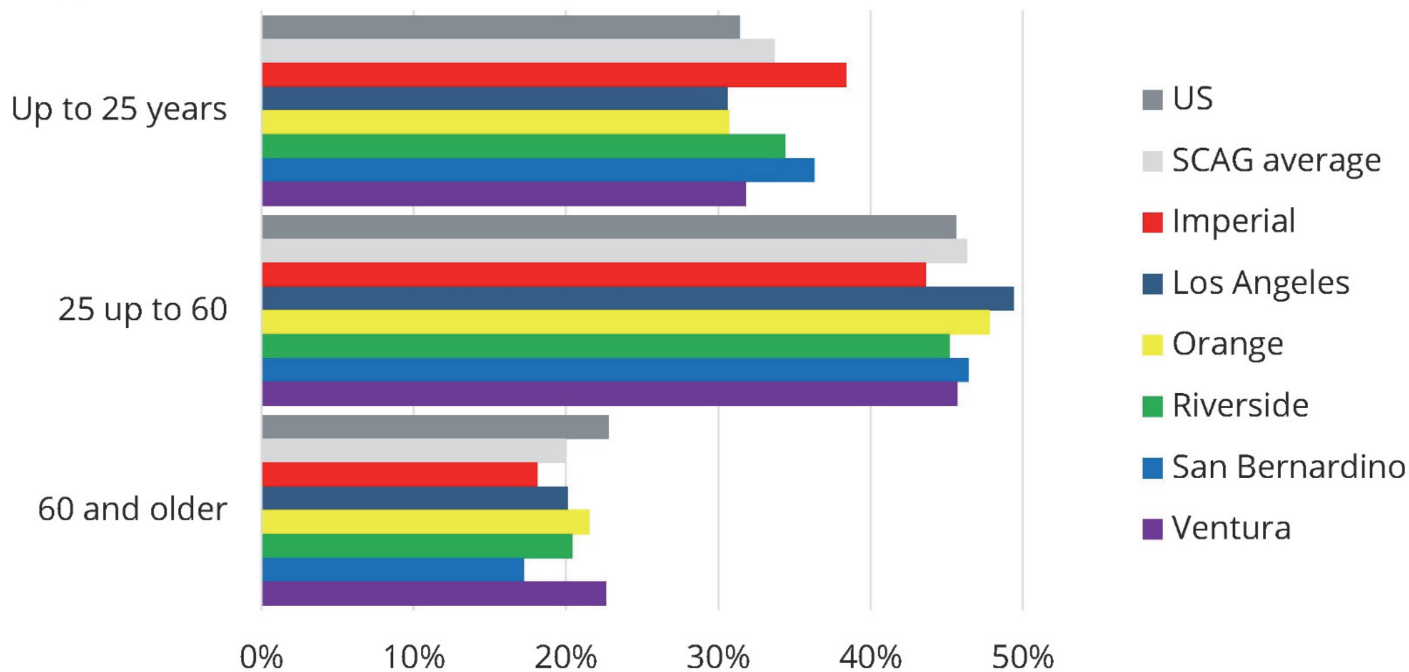
Determine how broadband availability impacts VMT and GHG emissions.

- Estimate how VMT and GHG emissions may be reduced as broadband is used as a substitute for travel.

Determine how integrated broadband and transportation planning can increase broadband availability.

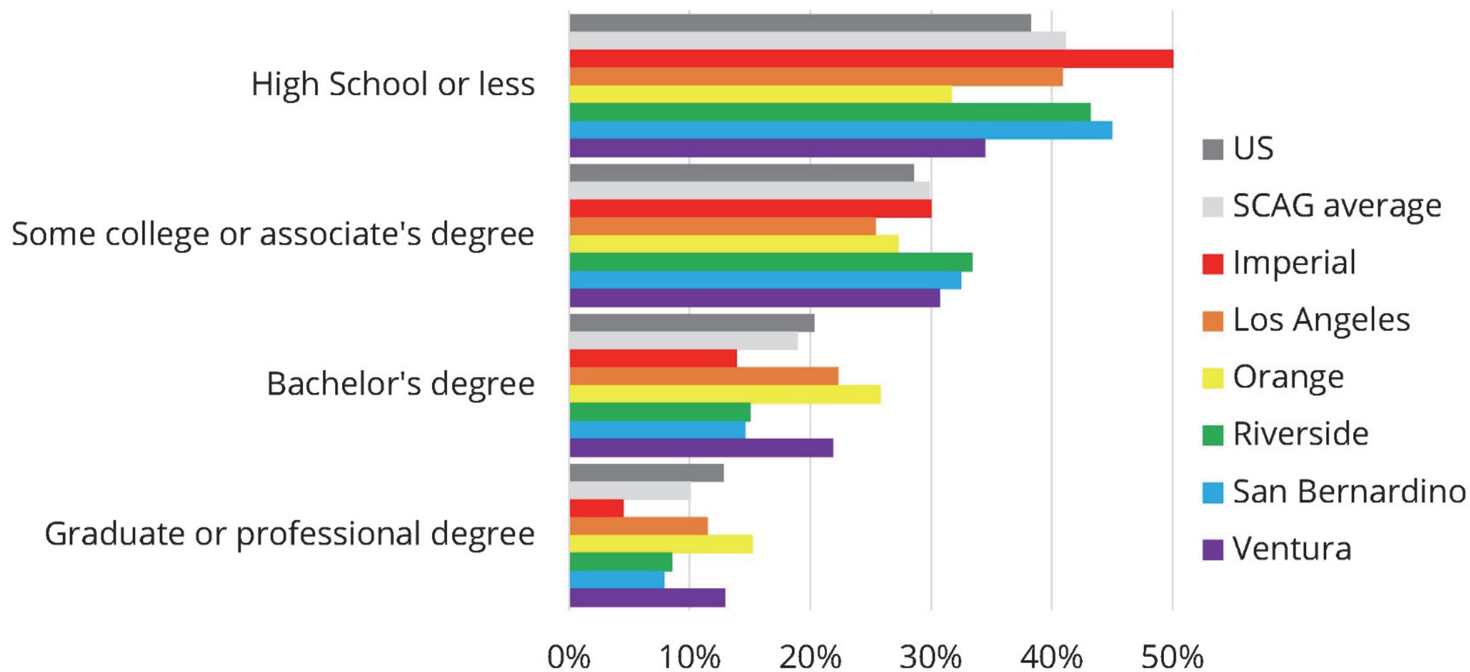
- Identify cost and funding strategies for including broadband in transportation projects.

Age



Magellan ADVISORS DKS

Education

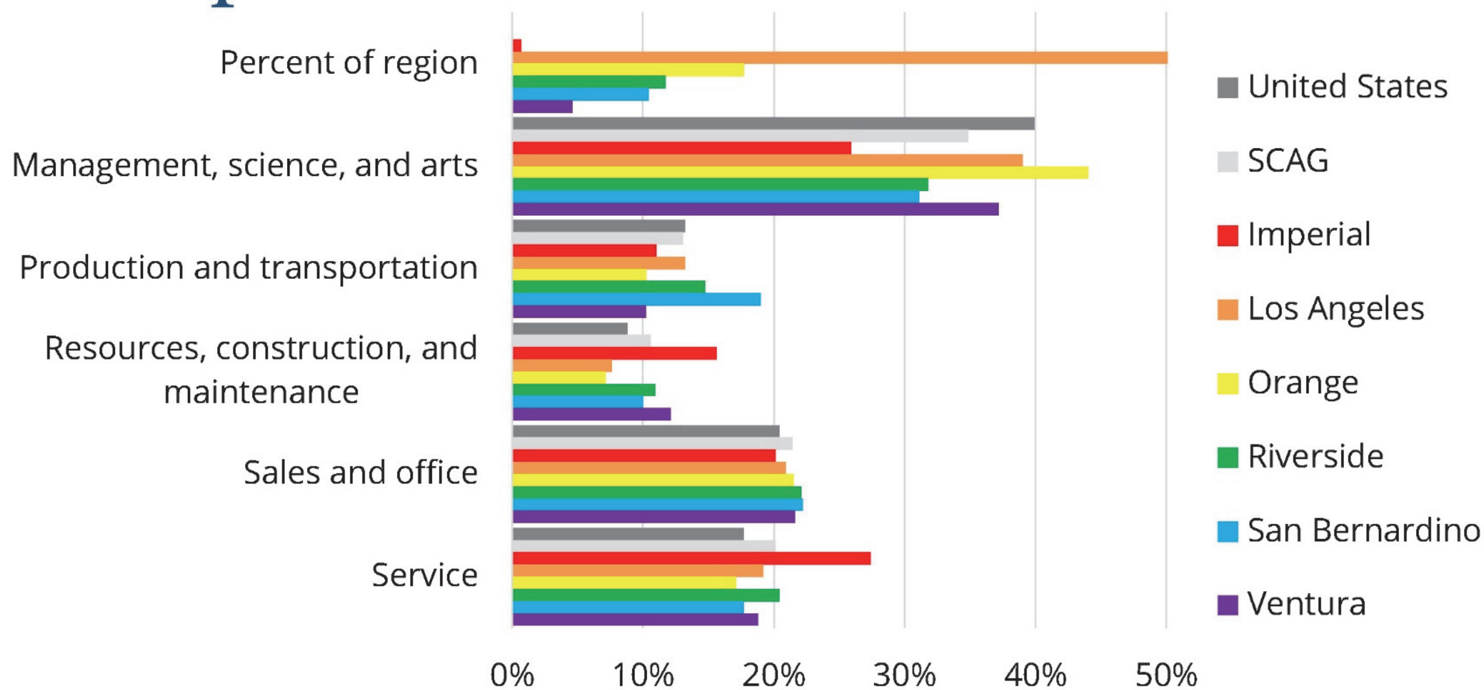


High School or less
Some college or associate's degree
Bachelor's degree
Graduate or professional degree
0%
10%
20%
30%
40%
50%
US
SCAG average
Imperial
Los Angeles
Orange
Riverside
San Bernardino
Ventura

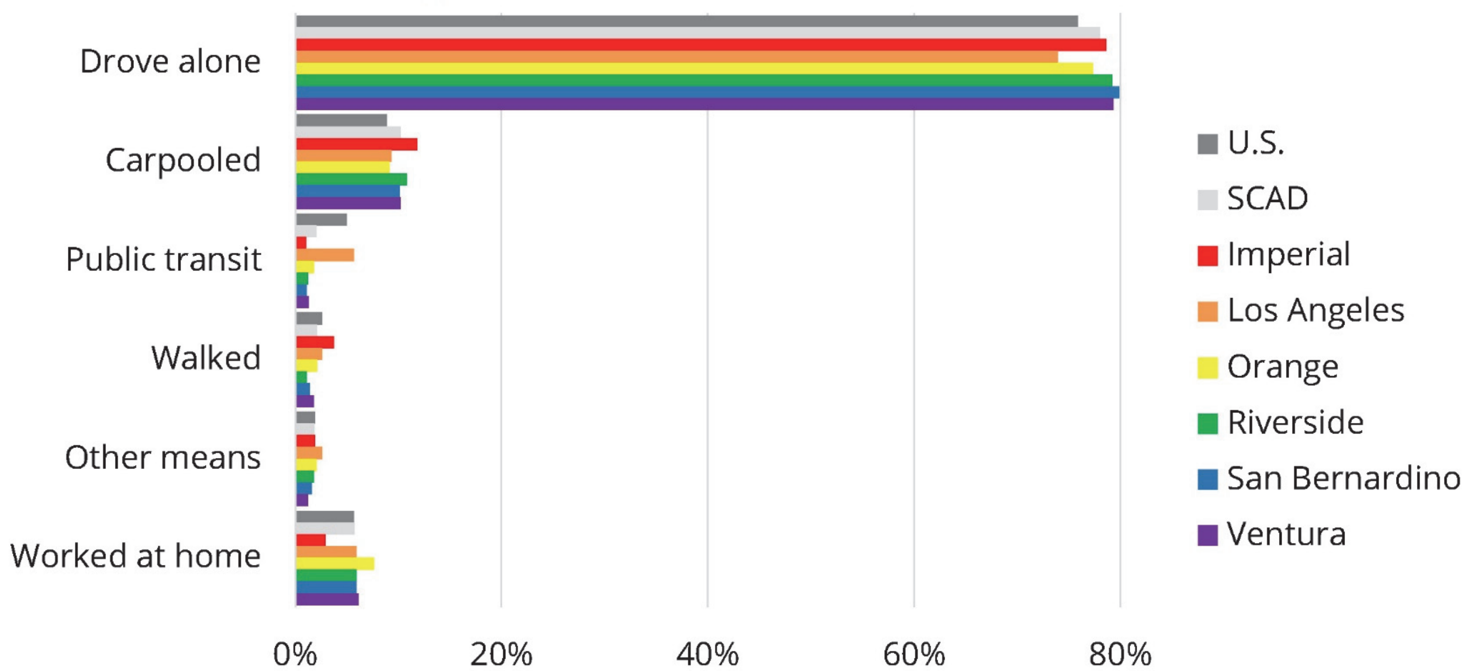
Income by Education

Educational Attainment	Median Income U.S.	Median Income SCAG
All levels	$41,801	$41,211
Less than high school graduate	$25,876	$24,639
High school graduate (includes equivalency)	$31,956	$33,135
Some college or associate’s degree	$38,125	$39,928
Bachelor's degree	$56,344	$56,780
Graduate or professional degree	$75,495	$81,048

Occupation


Percent of region
Management, science, and arts
Production and transportation
Resources, construction, and maintenance
Sales and office
Service
0%
10%
20%
30%
40%
50%
United States
SCAG
Imperial
Los Angeles
Orange
Riverside
San Bernardino
Ventura

Commuting


Drove alone
Carpooled
Public transit
Walked
Other means
Worked at home
0%
20%
40%
60%
80%
U.S.
SCAD
Imperial
Los Angeles
Orange
Riverside
San Bernardino
Ventura

Demographics

Highlights for the SCAG Region Compared to the Nation

- Includes both the U.S.'s largest and most populous counties
- Highly economically and socially diverse
- Generally younger and less educated
- Comparable incomes but more likely to be in sales and service occupations
- More likely to commute by car and for longer durations

Environmental Impacts of Broadband

42 Professional and Academic Publications, 1990's – Present

Confirm VMT and Air Quality Benefits

Scale a Key Differentiator for Applicability

- Majority of empirically-based publications were Facility-Based (Single/Small sample of Employers and not representative of the wider workforce)
- No Differentiation of Essential vs. Non-Essential Workers
- Majority were survey-based – again typically Facility-Based

Eleven of "most-relevant" sources cited in Report

- Regional Benefits of Telecommuting
- Regional Emission Reduction Benefit Range: 1 - 15% Reduction

Transportation System Performance

Baseline Performance Assessment

Level of Congestion (VMT; VHT; VHD)

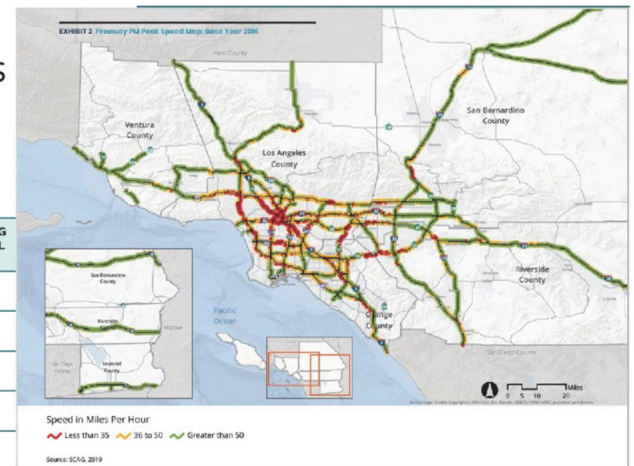
- Volume/Capacity Plots
- Speed Plots

	VMT	VHT	VHD
PASSENGER VEHICLES	427,205,797	12,170,601	2,484,014
LIGHT TRUCKS	5,877,749	134,496	25,694
MEDIUM TRUCKS	4,345,778	100,475	18,443
HEAVY TRUCKS	20,960,500	409,955	68,076
TOTAL	**458,389,824**	**12,815,527**	**2,596,227**

Identified Non-Broadband Areas (TAZs)

Origin-Destination of Trips from Non-Broadband TAZs

- Streetlight Data from SCAG
- Home-Based Work Trips (19% of total trips)
- Average Trip Length – Approximately 6 miles

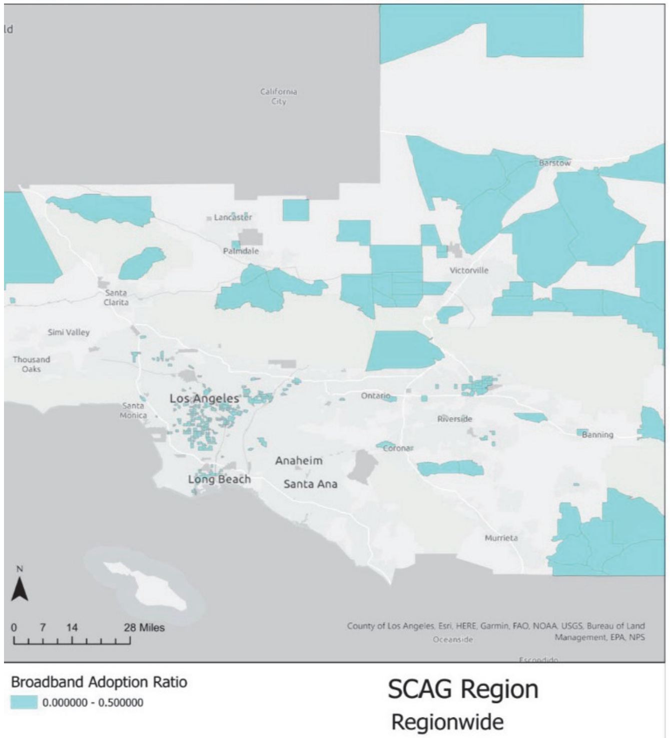


Safety

- Federal PMs

PERFORMANCE MEASURE	2016 BASELIINE 5-YEAR ROLLING AVERAGE	2017 SINGLE YEAR	2021 SCAG REGIONAL TARGET[1]
NUMBER OF FATALITIES	1,403	1,505	1,622
FATALITY RATE (PER 100 MILLION VMT)	0.88	0.906	1.32
NUMBER OF SERIOUS INJURIES	5,044	6,386	6,672
SERIOUS INJURY RATE (PER 100 MILLION VMT)	3.162	3.843	5.45
TOTAL NUMBER OF NON-MOTORIZED FATALITIES + SERIOUS INJURIES	2,046	2,118	2,212

Magellan Advisors DKS

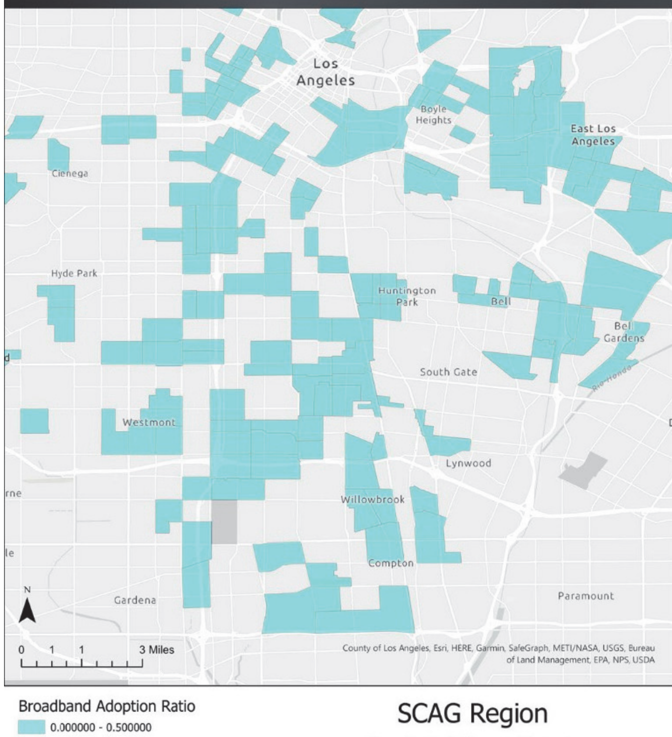


Broadband Expansion Market Assessment

Pre-screening at the block group level
- Census table B28011 "Internet Subscriptions in Household"
- If Block Group < 50 percent of households: Non-Broadband-0
- If Block Group > 50 percent of households: Broadband-1
- Aggregate Block Groups to the TAZ level
- If TAZ < 50 percent of households: Non-Broadband-0
- If TAZ > 50 percent of households: Broadband-1

Total households: 441,712 (5.8% of Total HH in 2045)

Non-broadband TAZs have significantly higher proportion of low-income households.



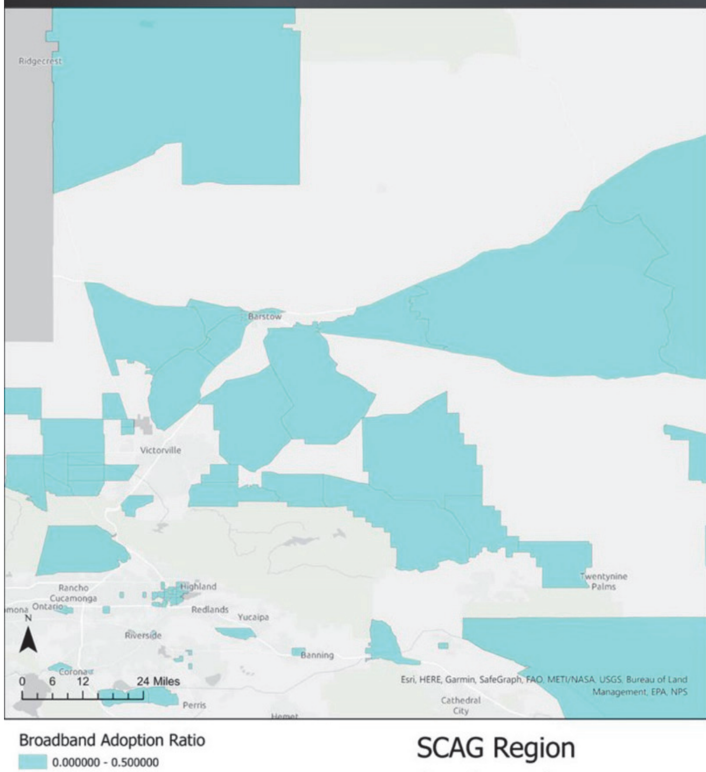
SCAG Region
South LA/Long Beach

Broadband Expansion Market Assessment

Essential verses Non-essential Workers

- NAICS Code
- 387 Sub-Sectors

Major Sector	Percent Essential
Agriculture	100%
Construction	100%
Manufacturing	92%
Wholesale Trade	70%
Retail Trade	70%
Transportation and Warehousing	100%
Information	88%
Finance Insurance Real Estate	66%
Professional Scientific and Technical	52%
Education	83%
Arts Entertainment Recreation	59%
Other Service	57%
Public Administration	60%



SCAG Region
San Bernardino

Broadband Scenarios

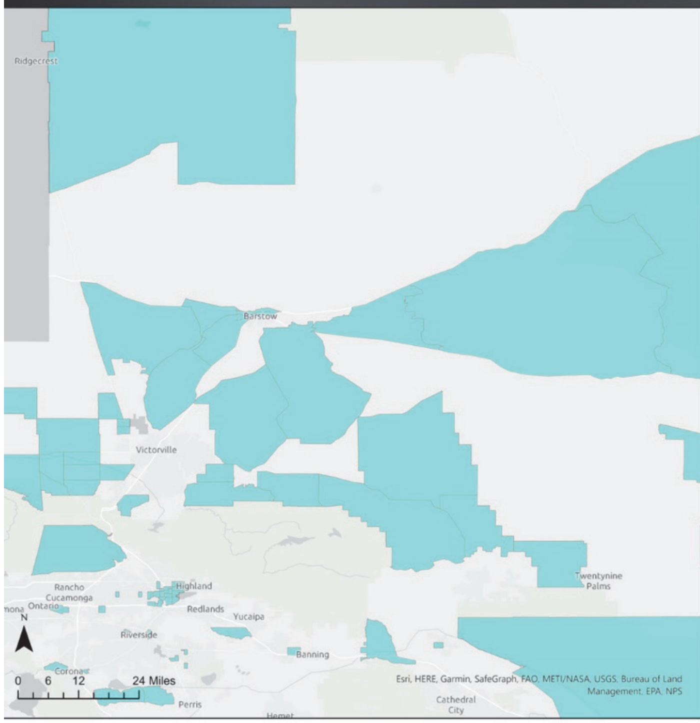
Shelter in Place Behavior

- StreetLight Data & PeMS Data.
- Shelter-In-Place Orders (closing and reopening periods) during the COVID-19 pandemic. AM / PM Peak Period.
- HBW origin-destination volumes between the Non-Broadband TAZs and all other zones.
- Passenger Vehicles Only

Upper Bound Behavior

- Non-Essential Workers (NAICS Analysis)
- Non-Broadband TAZs and Broadband TAZs
- Passenger Vehicles Only

Magellan Advisors DKS



SCAG Region
San Bernardino

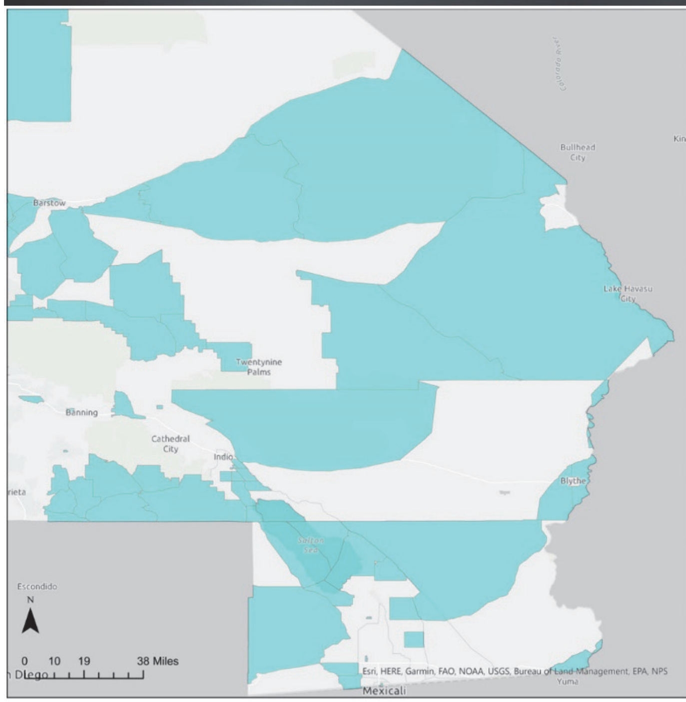
Broadband Scenarios: 2045

A. Future Baseline - Pre-Pandemic Travel Behavior – SCAG Connect SoCal (RTP/SCS) Preferred Scenario

B. Non-Broadband Expansion Increment – Shelter in Place Behavior: Modified SCAG O-D Trip Matrix

C. Non-Broadband Expansion Increment - Upper Bound Behavior: Modified SCAG O-D Trip Matrix

D. Total Broadband - Upper Bound Behavior (Regionwide): Modified SCAG O-D Trip Matrix
- Vehicle Miles of Travel (Regionwide)
- Vehicle Hours of Travel (Regionwide)
- Volume Difference Plots of SCAG Network



SCAG Region
Imperial/Riverside

Analysis of Broadband Impacts on VMT and GHG

SCENARIO	TOTAL VMT LDA/LDT	PERCENT CHANGE OF TOTAL VMT	CO2 (TONS PER DAY)	PERCENT CHANGE OF TOTAL CO2
A: 2045 BASELINE	459,090,327	-	164,369	-
B: 2045 NBEI-SIPB	454,523,915	-1.00%	163,009	-0.89%
C: 2045 NBEI-UBB	451,795,887	-1.61%	162,185	-1.43%
D: 2045 TB-UBB	400,444,110	-14.65%	148,397	-11.48%

Broadband Expansion (Scenario B and C): Isolates Increment

- Daily VMT reductions between **4.6** million to **7.3** million (**1 - 2** %) CO_2
- Reduction between **1,360 – 2,184** tons/day (**1 – 1.5**%)

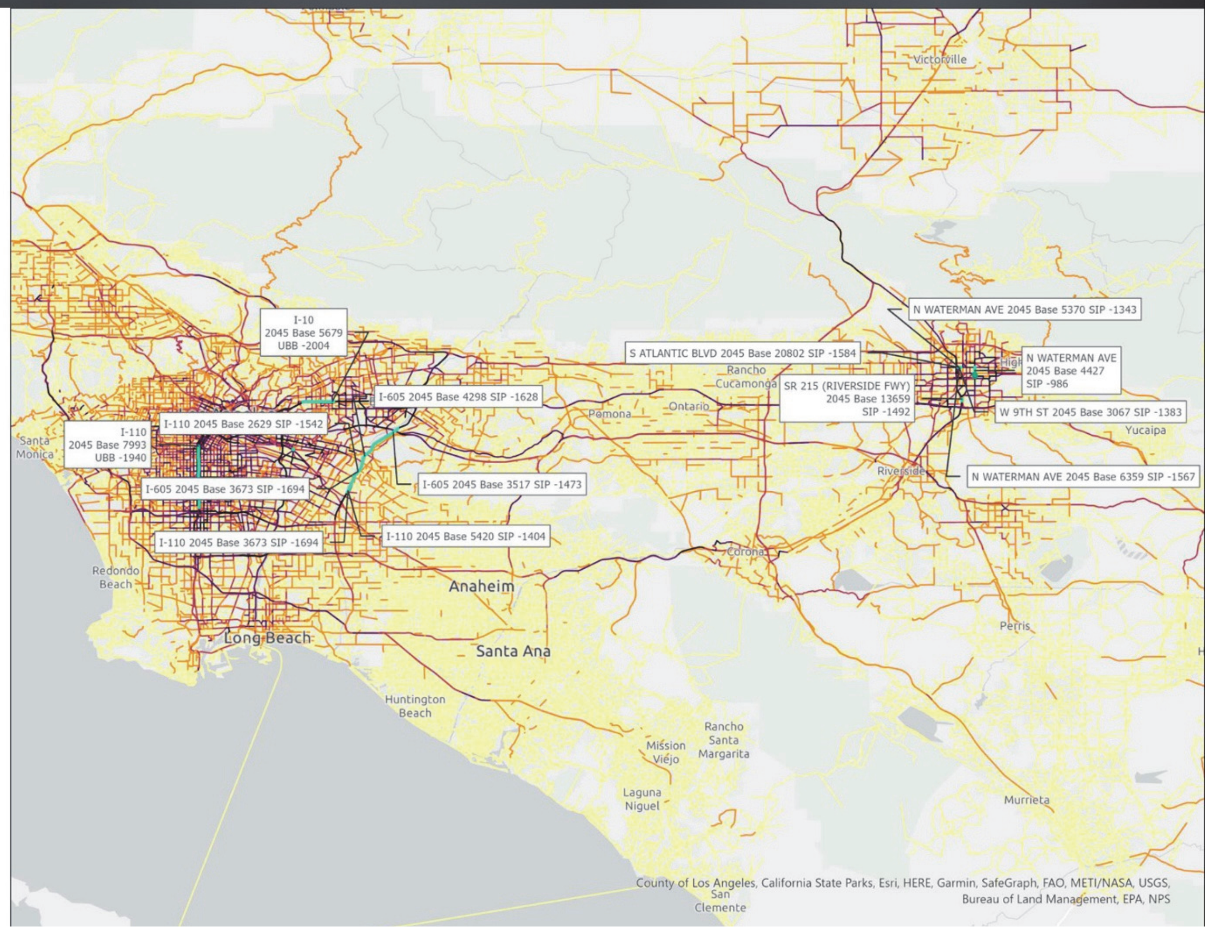
Total Region (Scenario D): All Non-Essential Workers Telecommute

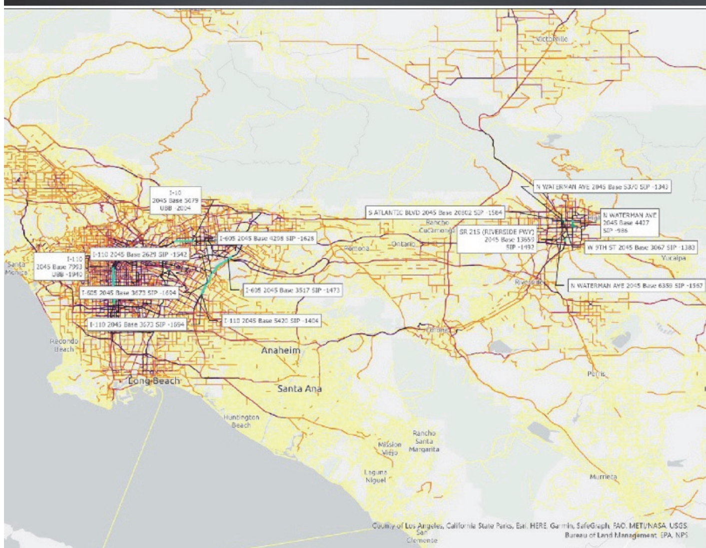
- Daily VMT reductions up to **59** million (**15** % reduction)
- CO2 Reduction of up to **15,972** tons/day (**11.5**% reduction)

Volume Difference Plots

AM/PM Peak Hour Roadway Volumes (Scenario B or C) relative to Connect SoCal RTP/SCS (Scenario A).

Most heavily utilized roadways (shown as green) that serve non-broadband areas (i.e., TAZs)





Analysis of Broadband Impacts on VMT and GHG

Most Benefiting Roadways from Broadband Expansion to Non-Broadband Areas:

- I-10
- I-110
- I-605
- I-710
- SR 215
- SR 91
- SR 72
- SR 42
- North Waterman
- South Atlantic Blvd
- Riverside Dr
- East 7th St
- Figueroa St
- West 120th St

For Further Study

Refine Definition of Non-Broadband Areas

- Access / Adoption / Speed
- Apply Continuous Scale vs. Binary
- Finer spatial granularity

Include Additional Trip Purposes and Other Time Periods (Non-Peak Periods)

- Tele-Shopping
- Tele-Health

Reflect Current Academic Research

- UC Davis Research
- USC Research

Analyze Additional Scenario (E) Total Broadband – Shelter-In-Place Behavior

- Anticipated Benefit: Between 2 – 15 % VMT and GHG Emission Reduction
- Connect SoCal (2024 RTP/SCS Update) - contribute to SCAG Region's GHG Emission Targets

Broadband in Transportation Projects

Conduit Installation in Road RoW, per mile

- Full cost: $317,522
- Open trench cost: $54,380
- *Open trench represents approximately 80% savings over full installation*
- Value engineering and other cost reduction tactics notwithstanding

Funding Options

- Capital improvements and other infrastructure
  - Conduit as a protected, standard line item in all projects
  - Means to manage and capitalize on assets
- Development conditioning, joint build, and partnerships
  - Close coordination and customer relations with service providers
- Grants and low-cost loans
- Revenue Generation

Conclusions 1

- Broadband use can substitute for travel to significantly impact GHG emissions.
- Including network infrastructure in transportation projects substantially decreases capital expenses and facilitates market entry by broadband providers.
- Non-Broadband Areas (as defined in this study) within the SCAG region have a higher proportion of disadvantage households and a higher percentage of essential workers. Household market of Non-Broadband Areas represent 6% of total households in the SCAG Region in 2045.
- Targeting Non-Broadband Areas (as defined in this study) will reduce VMT and GHG emissions associate with commuting by 1 - 2%. Upper bound benefit for entire region assuming employer telecommuting policies emulate policies during COVID-19 for non-essential workers is 15%.

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Conclusions 2

- Close coordination and collaborative planning is necessary to ensure transportation broadband strategies are successful at increasing availability and reducing broadband service costs.
- Increased telecommuting and other uses of broadband to reduce transportation demand depend on public and private policies and programs.
- More complete and detailed data on assets and demand—particularly geo-data—are needed to effectively focus public investment for the greatest impact on VMT and GHG reductions.

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Next Steps

Conduct additional research, per "Further Study"

Build on recent state policy changes to promote broadband in transportation planning

- Define the practice of including network infrastructure in planning
- Identify means to promulgate the practice

Establish forums for collaboration between network companies and public officials

- Focus on Development, Planning, and Public Works

Develop programs to increase telecommuting and transformation of essential jobs

- Engage major employers and real estate developers

Caltrans Sustainable Communities Grant to
Southern California Association of Governments

Transportation Broadband Strategies to Reduce Vehicle Miles Traveled and Greenhouse Gases Project

SCAG Overall Work Program No: 155-4863U8.01

April 2022

Attachment B

Caltrans Sustainable Communities Grant to Southern California Association of Governments
California Emerging Technology Fund and Regional Broadband Consortia
Inventory of Work Products
Data Collection, Stakeholder Surveys and Forums, and Focus Group Interviews
The Potential of Ubiquitous Broadband to Reduce Trip Generation
to Reduce Greenhouse Gas (GHG) Emissions

Task	Work Product	Partner
Research Literature Review		
Task 3.1: Review Existing Published Literature	Broadband and Environmental Benefit Data and Literature Report	IERBC
Data Collection		
Task 4.1: Data Collection	2021 Statewide Survey on Broadband Adoption (Conducted by USC, Sponsored by CETF) ($225,000 In-Kind Contribution)	CETF
Tasks 4.1, 4.2, 4.3, 4.4 Data Collection	Report on the Digital Divide: Deep Analysis of American Community Survey Census Data Jamshid Damooei, Ph.D., (Damooei Global Research), California Lutheran University	BCPC IERBC LA DEAL SBBC
Tasks 4.1: Data Collection	Summary Report on Data from Counties and County Offices of Education (COEs) for "Big 3" Eligible Populations: Medi-Cal; CalFresh; NSLP	CETF
Task 4.1: Data Collection Data for Inland Empire	Summary Report on "Big 3" Data from Riverside and San Bernardino Counties and Data Summary Table	IERB
Task 4.2: Data Collection Data for Ventura County	Summary Report on "Big 3" Data from Ventura County with Data Summary	BCPC

Task 4.3: Data Collection Data for Los Angeles County	Summary Report on "Big 3" Data from Los Angeles County with Data Summary	LA DEAL
Task 4.4: Data Collection Data for Imperial County	Summary Report on "Big 3" Data from Imperial County Data Summary Table	SBBC
Community Engagement and Stakeholder Convenings		
Tasks 5.2, 5.3, 5.4, 5.5	Working Framework for Stakeholder Outreach and Focus Groups	CETF
Tasks 5.2, 5.3, 5.4, 5.5	Stakeholder Survey (SurveyMonkey Form)	CETF
Tasks 5.2, 5.3, 5.4, 5.5	Stakeholder Survey Results for SCAG Region (PowerPoint Presentation)	CETF
Task 5.2: Community Engagement and Stakeholder Convenings – Inland Empire	Stakeholder Survey Results for Inland Empire (PowerPoint Presentation)	IERBC
Task 5.3: Community Engagement and Stakeholder Convenings – Ventura County	Stakeholder Survey Results for Ventura County (PowerPoint Presentation)	BCPC
Task 5.4: Community Engagement and Stakeholder Convenings – LA County	Stakeholder Survey Results for Los Angeles County (PowerPoint Presentation)	LA DEAL
Task 5.5: Community Engagement and Stakeholder Convenings – Imperial County	Stakeholder Survey Results for Imperial County (PowerPoint Presentation)	SBBC
Task 5.2: Community Engagement and Stakeholder Convenings – Inland Empire	Stakeholder Forum Summary Report for Inland Empire (Conducted January 20, 2022)	IERBC
Task 5.3: Community Engagement and Stakeholder Convenings – Ventura County	Stakeholder Forum Summary Report for Ventura County (Conducted January 27, 2022)	BCPC
Task 5.4: Community Engagement and Stakeholder Convenings – LA County	Stakeholder Forum Summary Report for Los Angeles County (Conducted January 25, 2022)	LA DEAL
Task 5.5: Community Engagement and Stakeholder Convenings – Imperial County	Stakeholder Forum Summary Report for Imperial County (Conducted January 26, 2022)	SBBC
Tasks 5.6, 5.7, 5.8, 5.9 Focus Group Interviews	Focus Group Framework, Interview Guide and Interview Questions	CETF
Tasks 5.6, 5.7, 5.8, 5.9 Focus Group Interviews	Focus Group Interviews Results SCAG Region (PowerPoint Presentation)	CETF
Task 5.6: Focus Group Interviews – Inland Empire	Focus Group Interviews Summary Report for Inland Empire	IERBC
Task 5.7: Focus Group Interviews – Ventura County	Focus Group Interviews Summary Report for Ventura County	BCPC

Task 5.8: Focus Groups Interviews – LA County	Focus Groups Interviews Summary Report for Los Angeles County	LA DEAL
Task 5.9: Focus Groups Interviews – Imperial County	Focus Group Interviews Summary Report for Imperial County	SBBC
Task 5.10: Website and Content Management	Website page (CETF website) dedicated to Caltrans Grant to SCAG Study	IERBC CETF
Final Report		
Tasks 6.1, 6.3: Quantification and Analysis to show Broadband VMT and GHG Reduction	Development of templates for analysis and reports of Data Collection, Stakeholder Surveys and Forums, and Focus Group Interviews. Compilation of data and analysis for SCAG and Technical Consultants.	CETF IERBC
Task 7.1: Review and Edit Draft Report	Review of Technical Consultants Draft Report and provision of written feedback to SCAG.	CETF IERBC
Task 7.2: Feedback from Expert Advisory Committee	Distribution of Technical Consultants Draft Report and compilation of feedback.	IERBC CETF
Task 8.1: Final Report Distributed	Preparation, posting, and printing of Final Report and distribution to partners and stakeholders.	IERBC CETF
Expert Advisory Committee		
Task 5.1: Expert Advisory Committee	Formation of Expert Advisory Committee (EAC): Identification, recruitment, and confirmation of members of the Expert Advisory Committee, including Letters of Invitation and preparation of Roster of Expert Advisory Committee	CETF IERBC BCPC SBBC SCAG
June 11, 2022	Expert Advisory Committee Meeting Agenda	CETF
	Minutes of June 11, 2022 EAC Meeting	CETF
January 12, 2022	Expert Advisory Committee Progress Report and Review of Stakeholder Survey	CETF
January 21, 2022	Expert Advisory Committee Meeting Agenda	CETF
	Minutes of January 21, 2022 EAC Meeting	CETF
February 16, 2022	EAC Peer Review Group Meeting	CETF
	Notes from EAC Peer Review Group Meeting	CETF
February 25, 2022	Expert Advisory Committee Meeting Agenda	CETF
	Minutes of February 25, 2022 EAC Meeting	CETF
March 11, 2022	Distribution of Technical Consultants Draft Report to EAC with Request for Review and Feedback	CETF
March 17, 2022	Compilation of EAC Review and Feedback and Distribution to EAC for March 18, 2022 Meeting	CETF
March 18, 2022	Expert Advisory Committee Meeting Agenda	CETF
	Minutes of March 18, 2022 EAC Meeting	CETF
Work Products Website **https://www.cetfund.org/report/caltrans-sustainable-communities-grant/**		

Note: IERBC entered into vendor agreements with LA DEAL for Los Angeles County Tasks and CETF for other Tasks.

Caltrans Sustainable Communities Grant to Southern California Association of Governments

Stakeholder Survey Key Insights

Inland Empire Regional Broadband Consortium

SCAG
INNOVATING FOR A BETTER TOMORROW

CETF
CALIFORNIA EMERGING TECHNOLOGY FUND

BCPC
BROADBAND CONSORTIUM PACIFIC COAST

LA DEAL
LA DIGITAL EQUITY ACTION LEAGUE

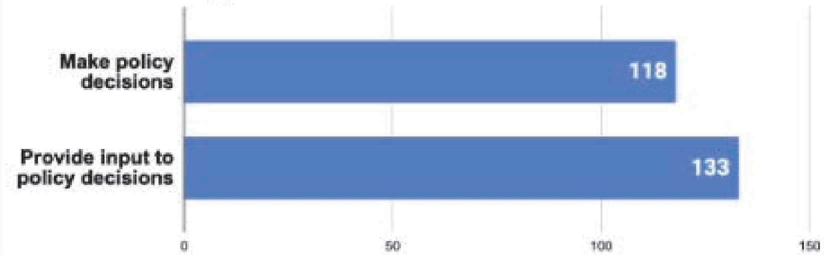
SBBC

SCAG Region - Overview of Stakeholders

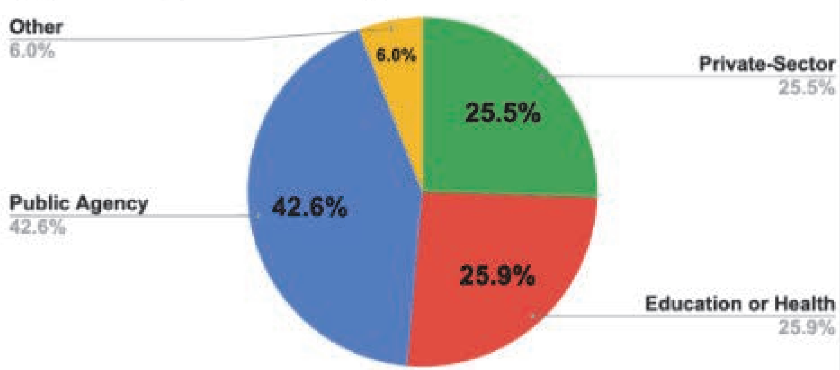
Total Respondents

251

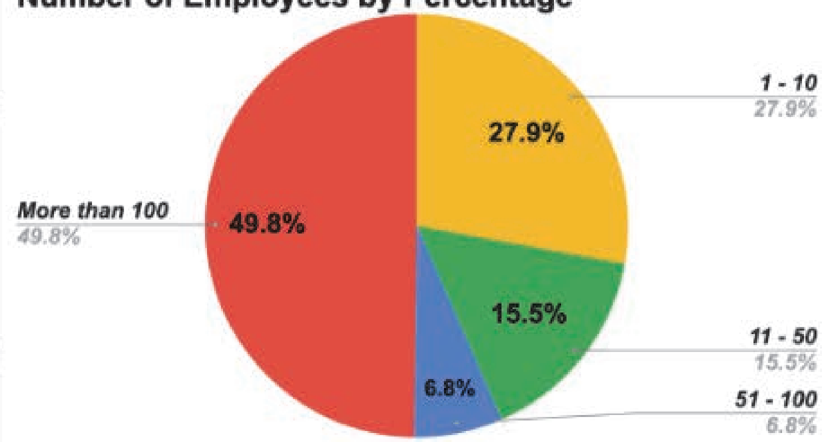
Role for Policy Decisions



Type of Organization Represented



Number of Employees by Percentage

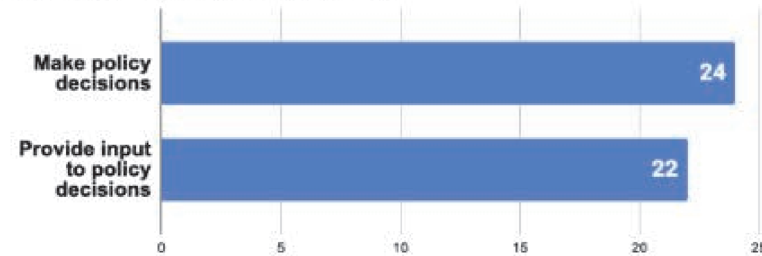


Imperial County - Overview of Stakeholders

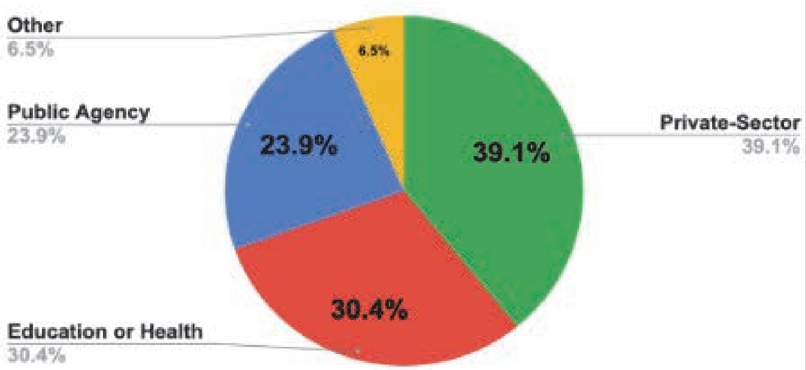
Total Respondents

46

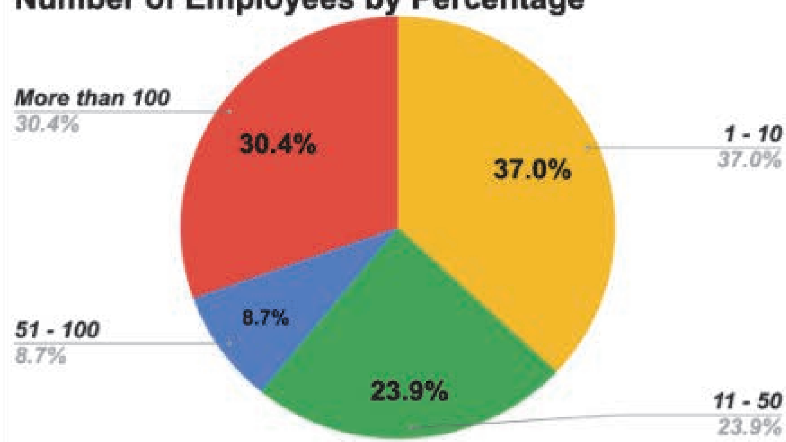
Role for Policy Decisions



Type of Organization Represented



Number of Employees by Percentage

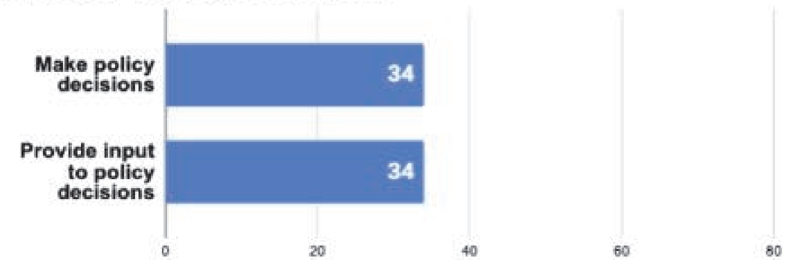


Inland Empire - Overview of Stakeholders

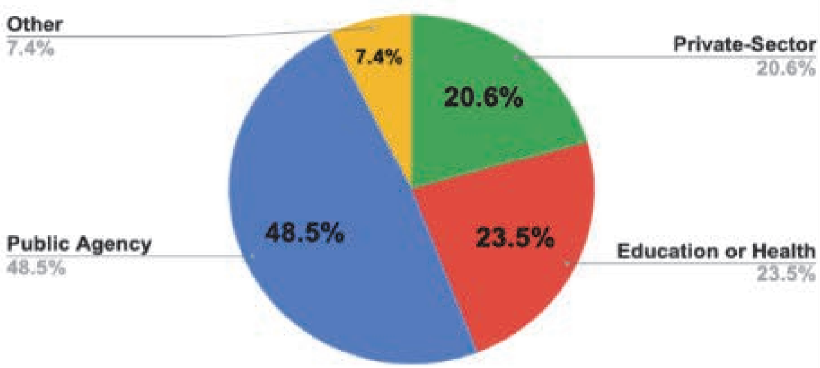
Total Respondents

68

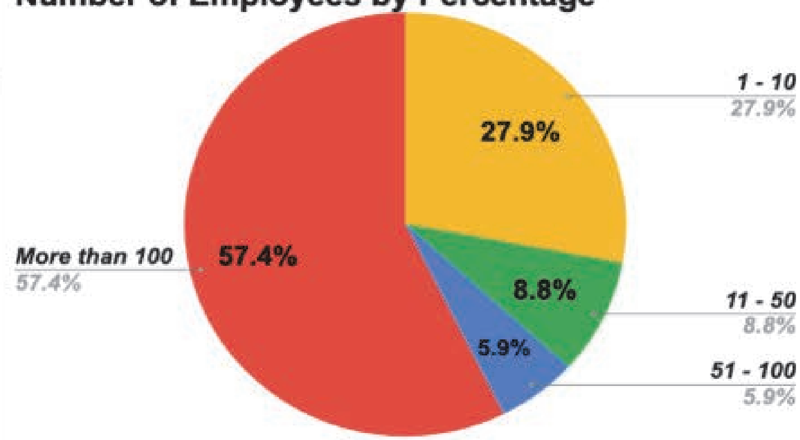
Role for Policy Decisions



Type of Organization Represented



Number of Employees by Percentage

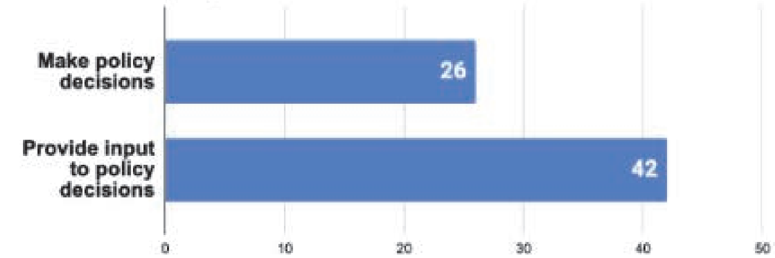


Los Angeles - Overview of Stakeholders

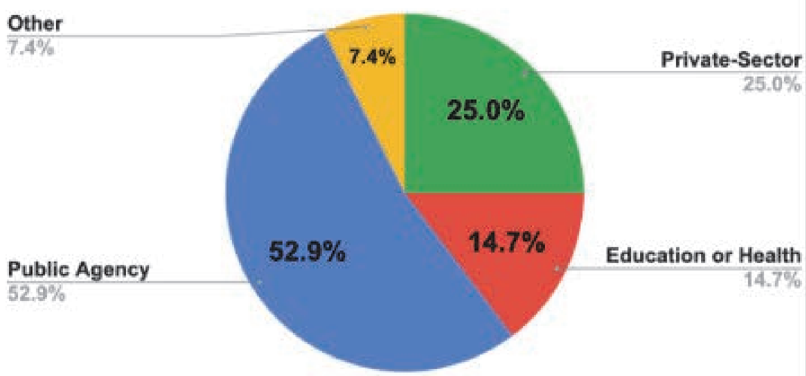
Total Respondents

68

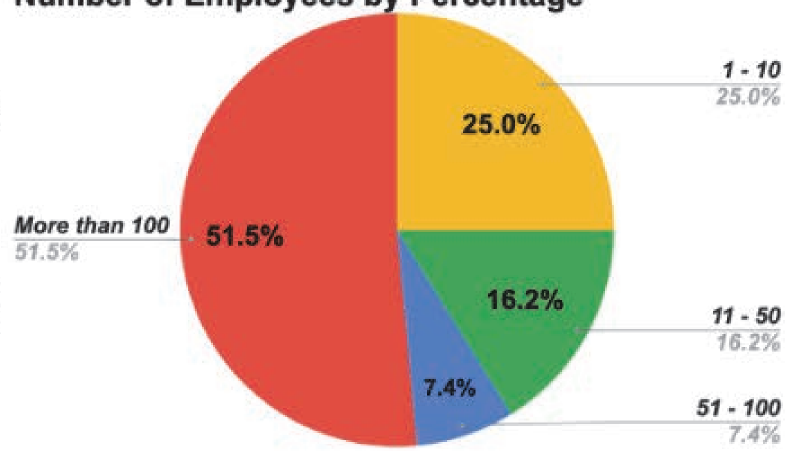
Role for Policy Decisions



Type of Organization Represented



Number of Employees by Percentage

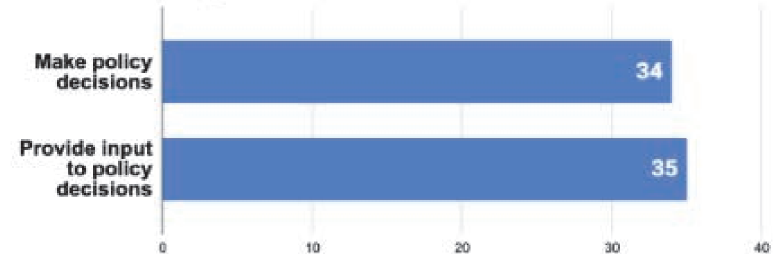


Ventura County - Overview of Stakeholders

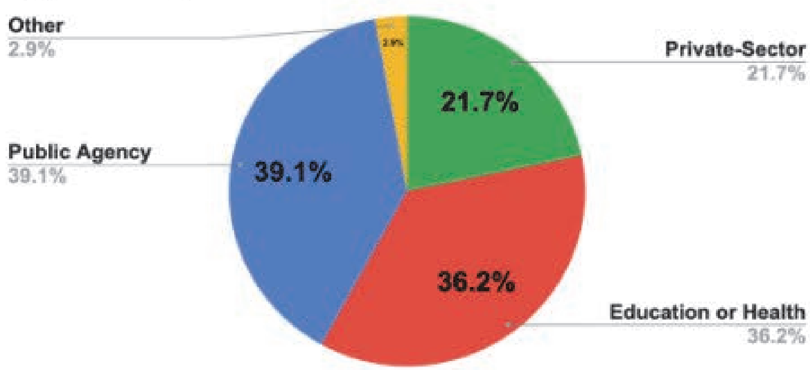
Total Respondents

69

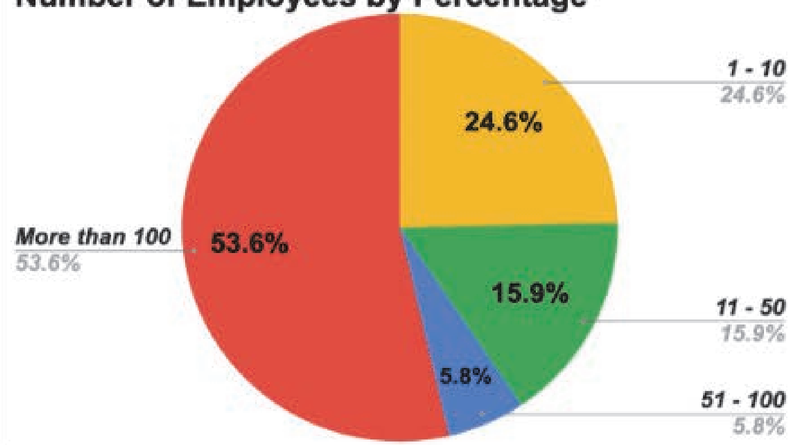
Role for Policy Decisions



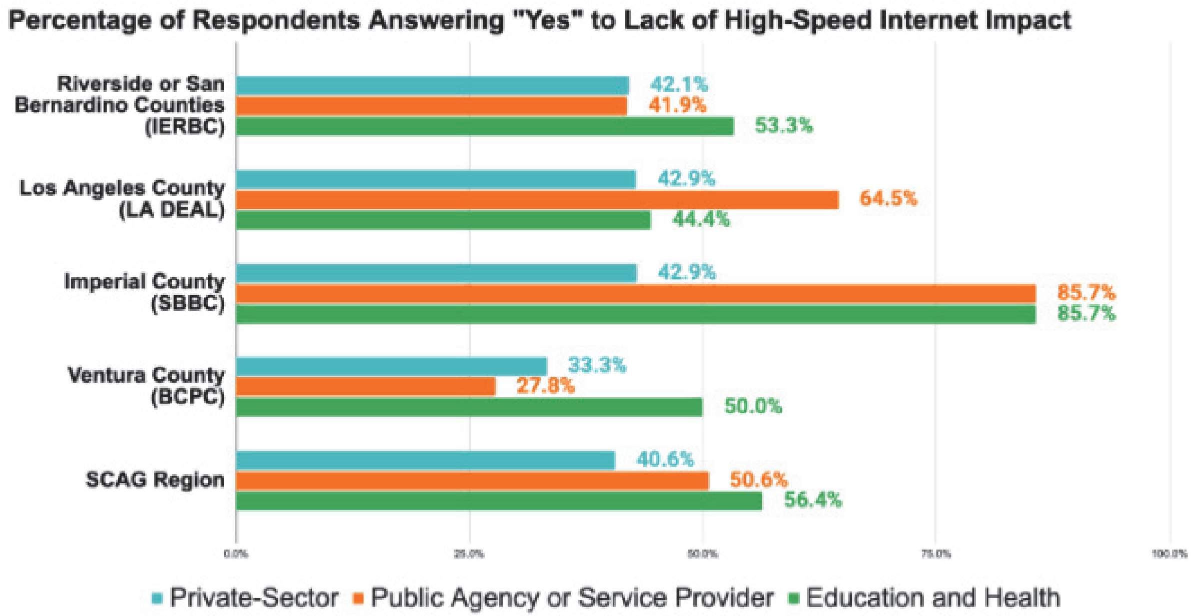
Type of Organization Represented



Number of Employees by Percentage



Impact of Lack of High-Speed Internet

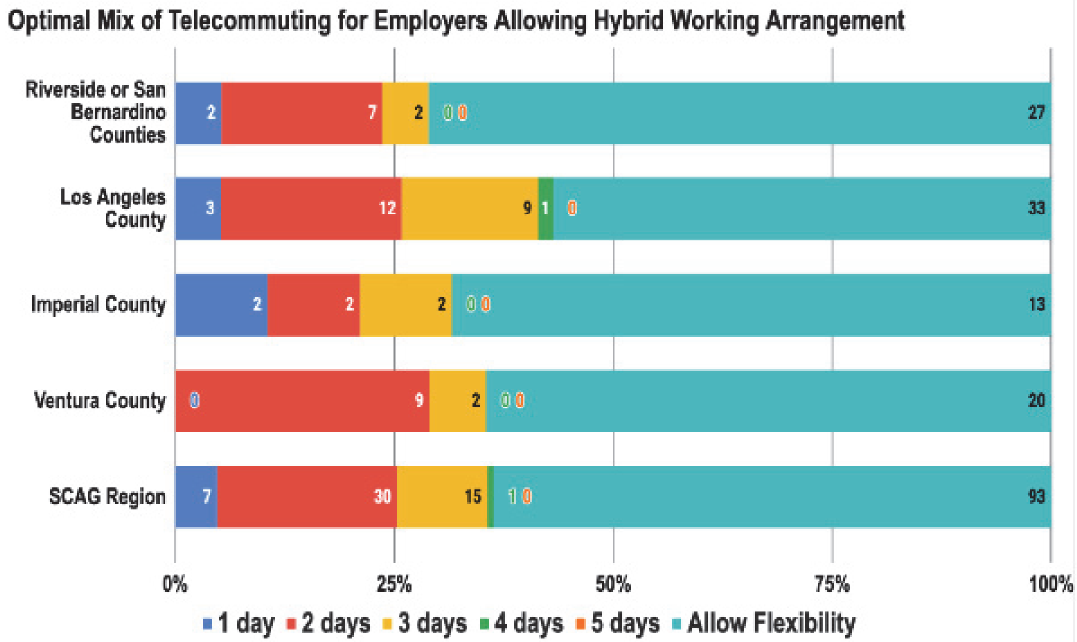


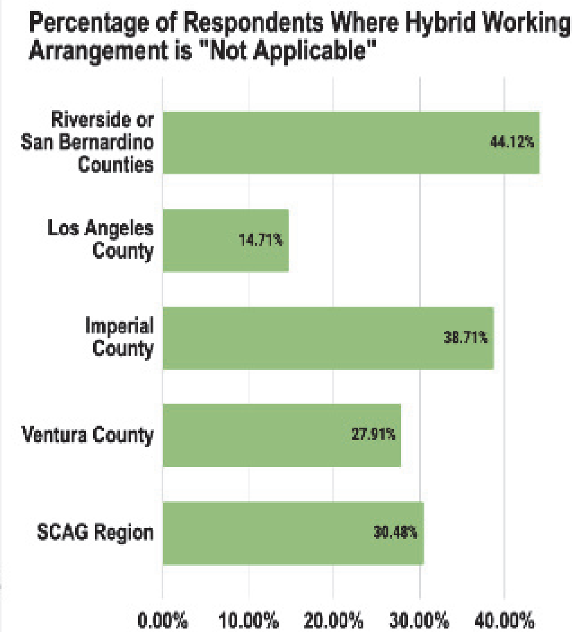
Private-Sector Business:
Does the lack of high-speed Internet infrastructure throughout your region limit the number of employees who can work remotely.

Public Agency or Service Provider:
Does the lack of high-speed Internet infrastructure throughout your region limit the number of employees who can work remotely and the number of clients or customers who can receive your services online?

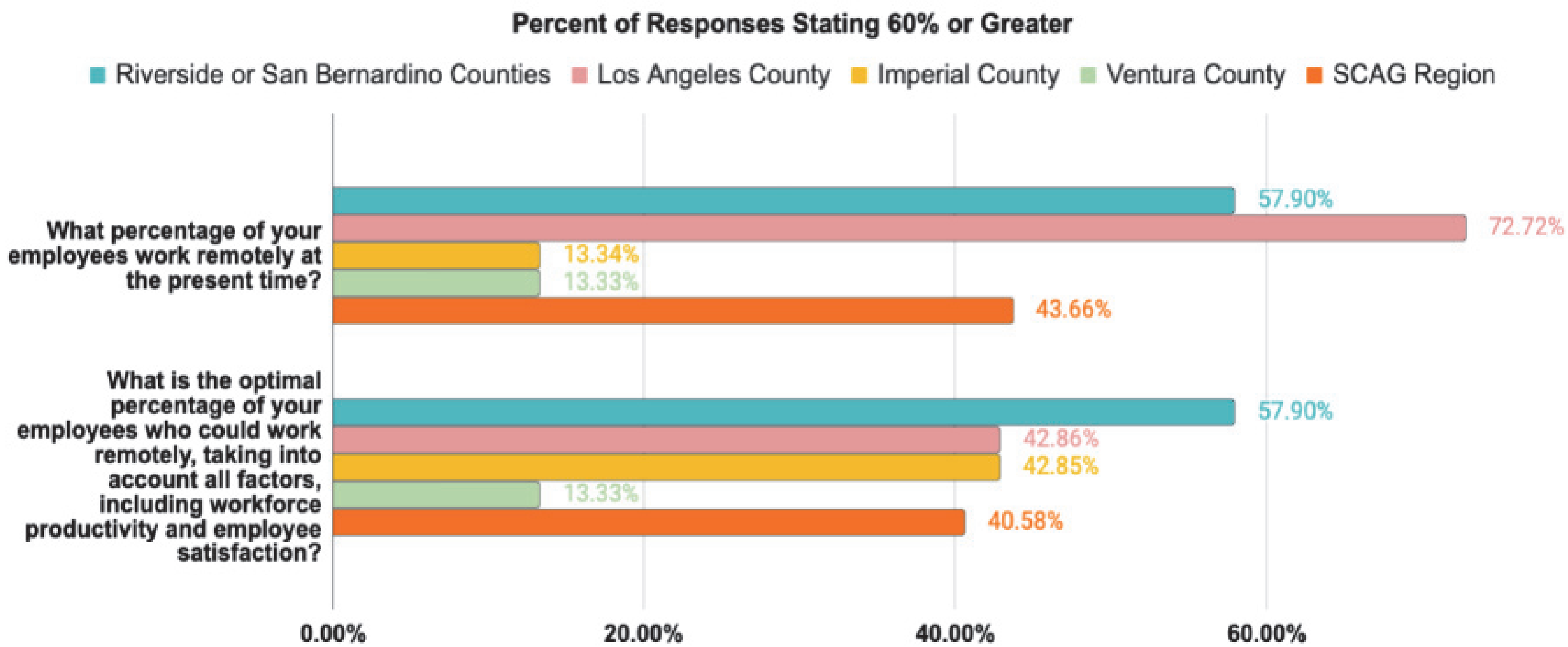
Education or Health Organization:
Does the lack of high-speed Internet infrastructure throughout your region limit the number of employees who can work remotely and the number of clients or customers who can receive your services online?

Optimal Mix of Telecommuting

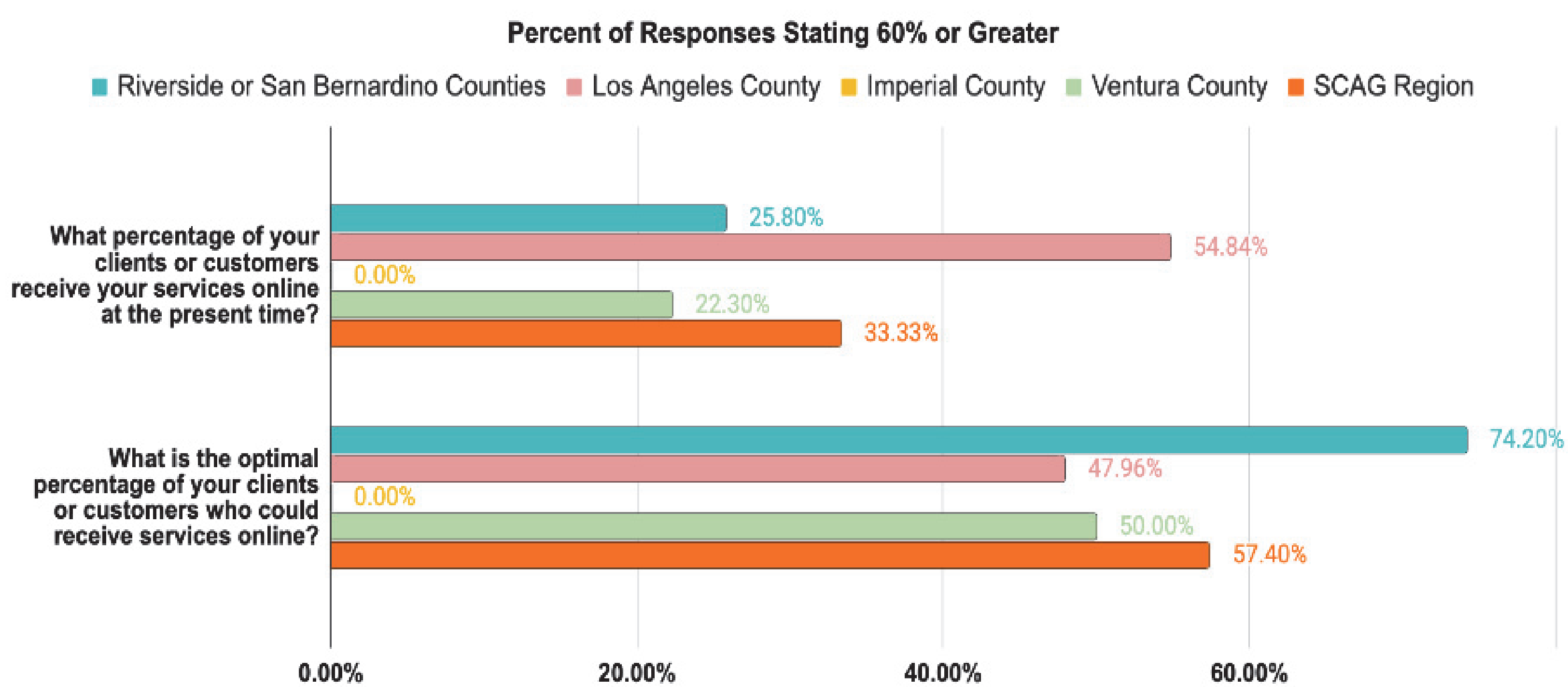




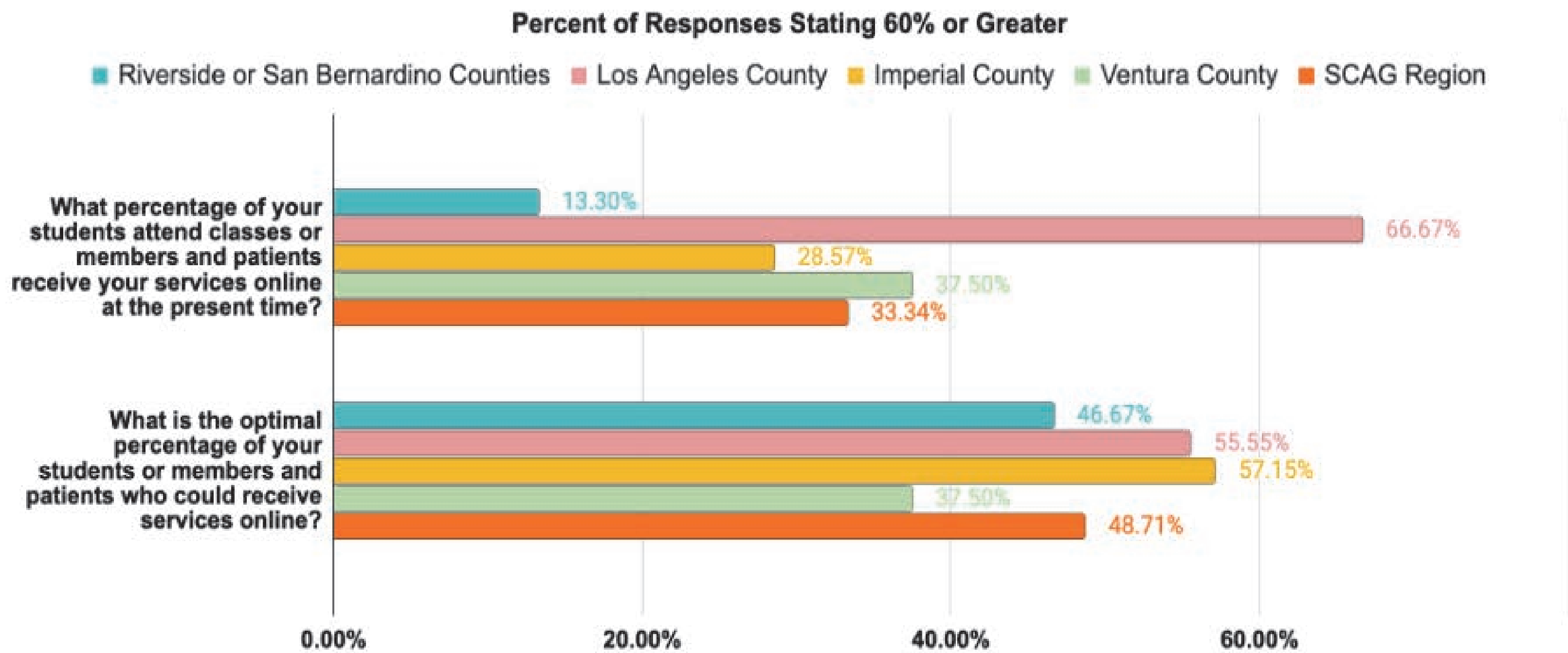
Private-Sector Business - Optimal Percent of Remote Employees



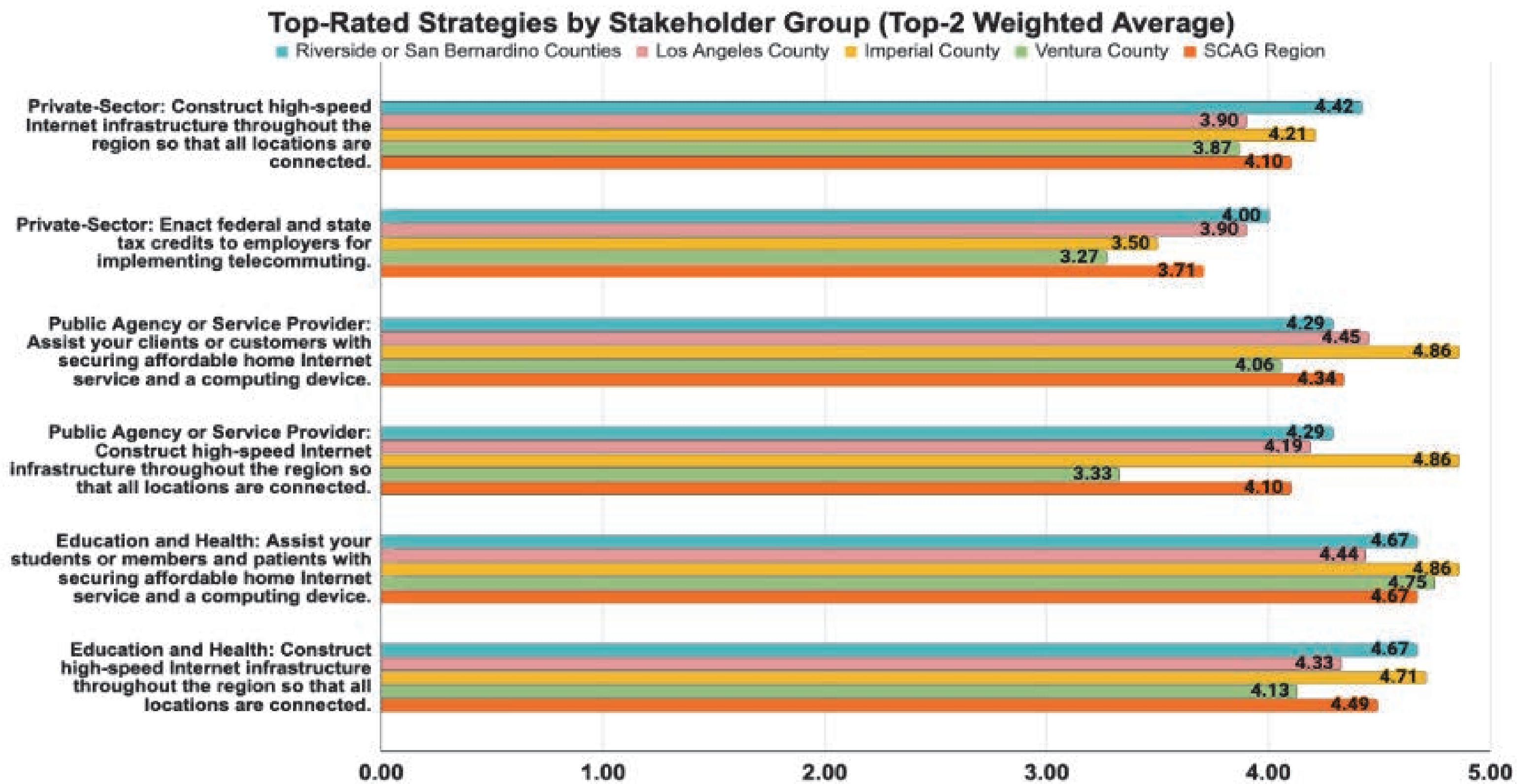
Public Agency or Service Provider - Optimal Percent of Remote Services



Education or Health - Optimal Percent of Remote Services

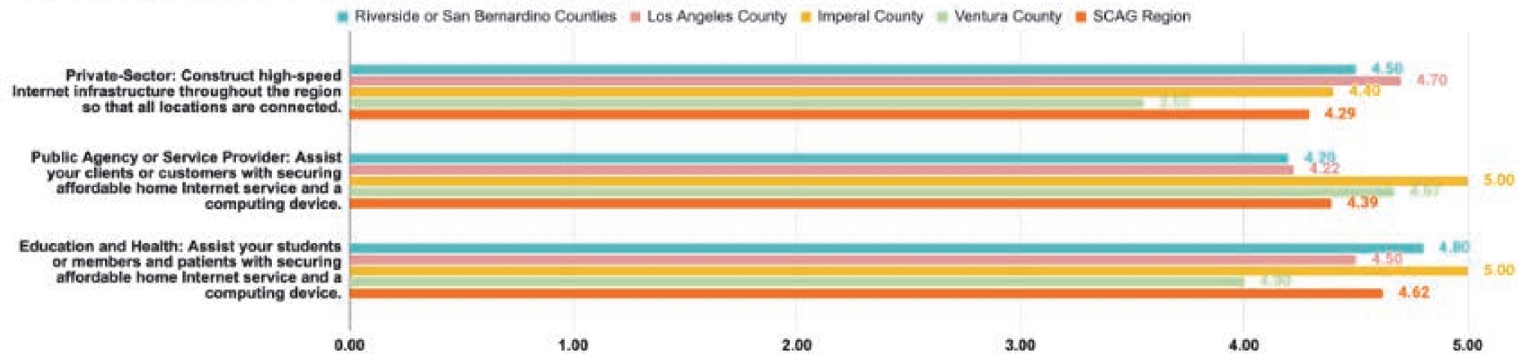


Top-Rated Strategies to Reduce Vehicle Trips by Stakeholders

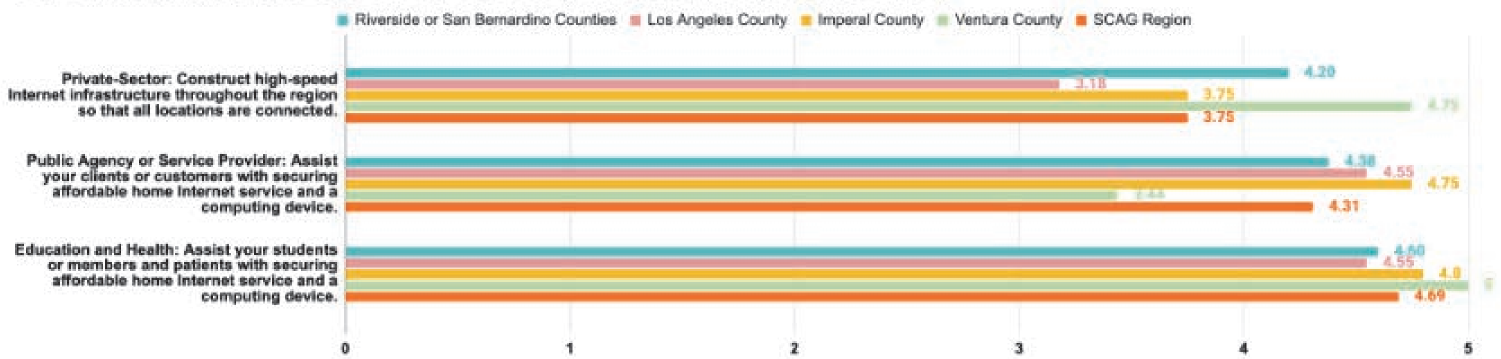


Top-Rated Strategies Comparing Policymakers and Policy Advisors

Top Strategy by Stakeholder Group for Policymakers (Weighted Average)



Top Strategy by Stakeholder Group for Policy Advisors (Weighted Average)



Focus Group Interviews of Low-Income Residents

Inland Empire Regional Broadband Consortium

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CALIFORNIA EMERGING TECHNOLOGY FUND

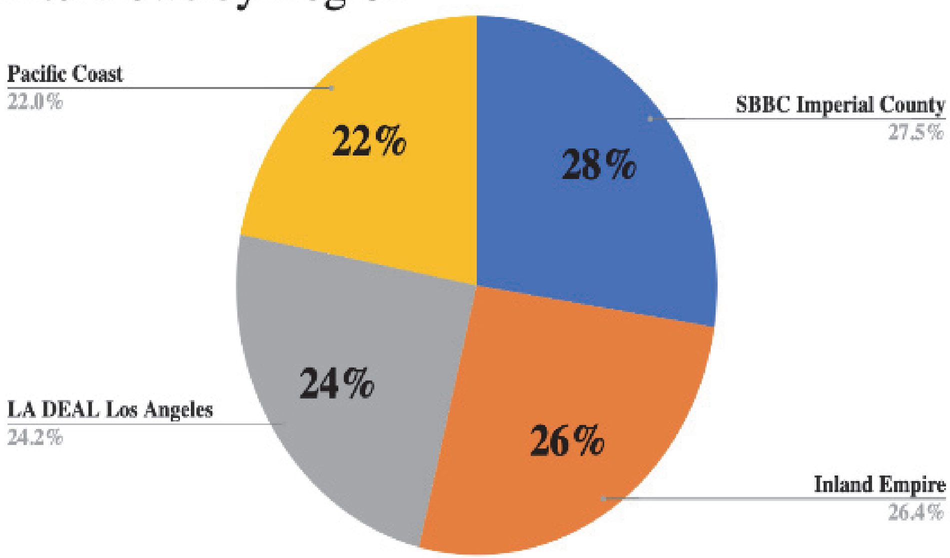
BCPC
BROADBAND CONSORTIUM PACIFIC COAST

LA DEAL
LA DIGITAL EQUITY ACTION LEAGUE

SBBC

Overview of Geographic Source of Interviews

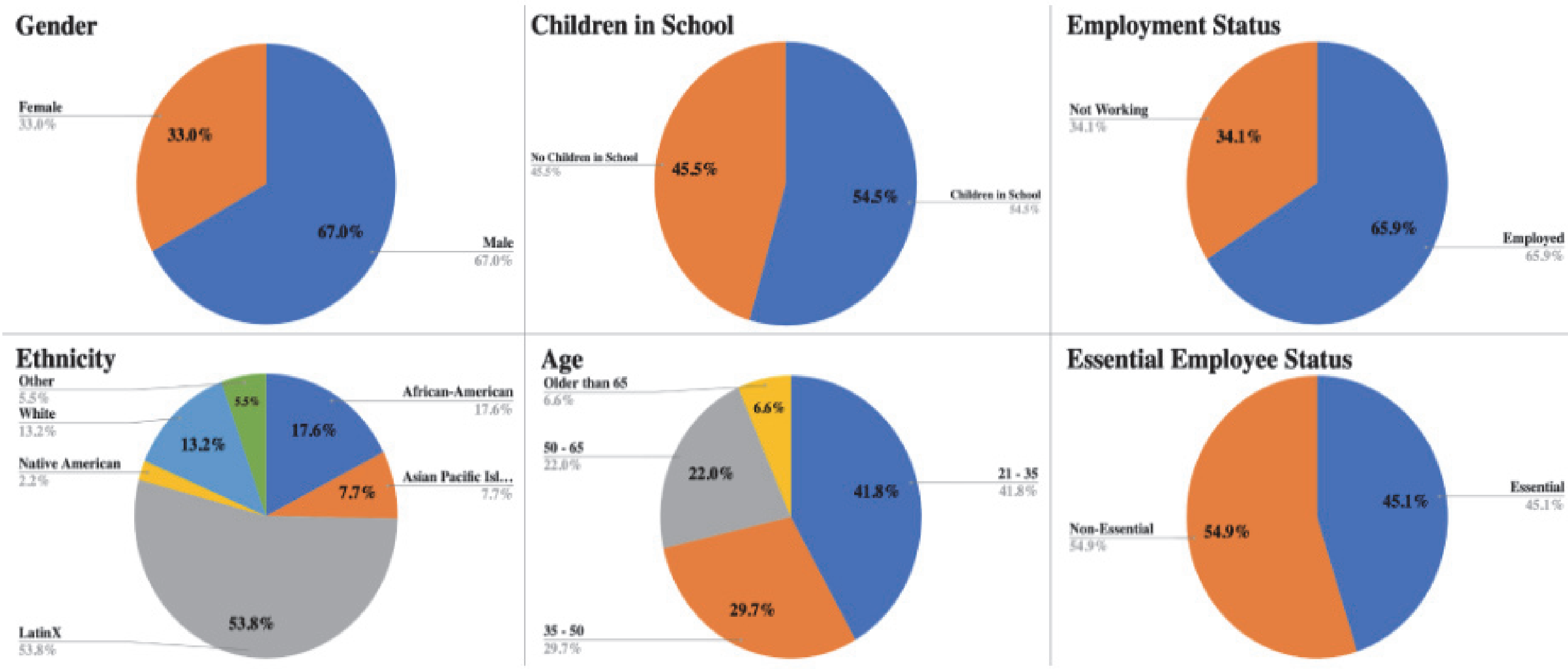
Interviews by Region



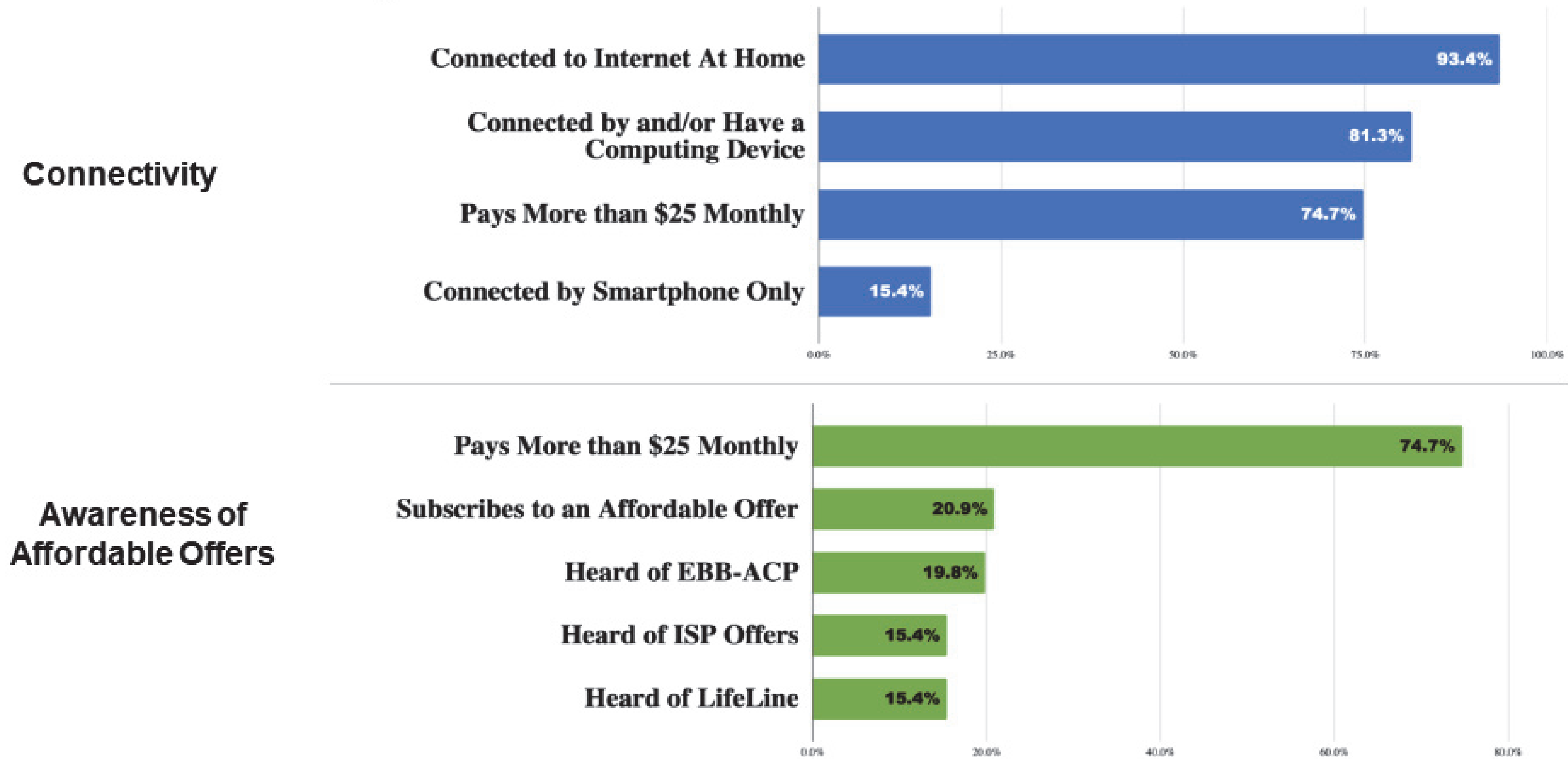
Total Interviews

91

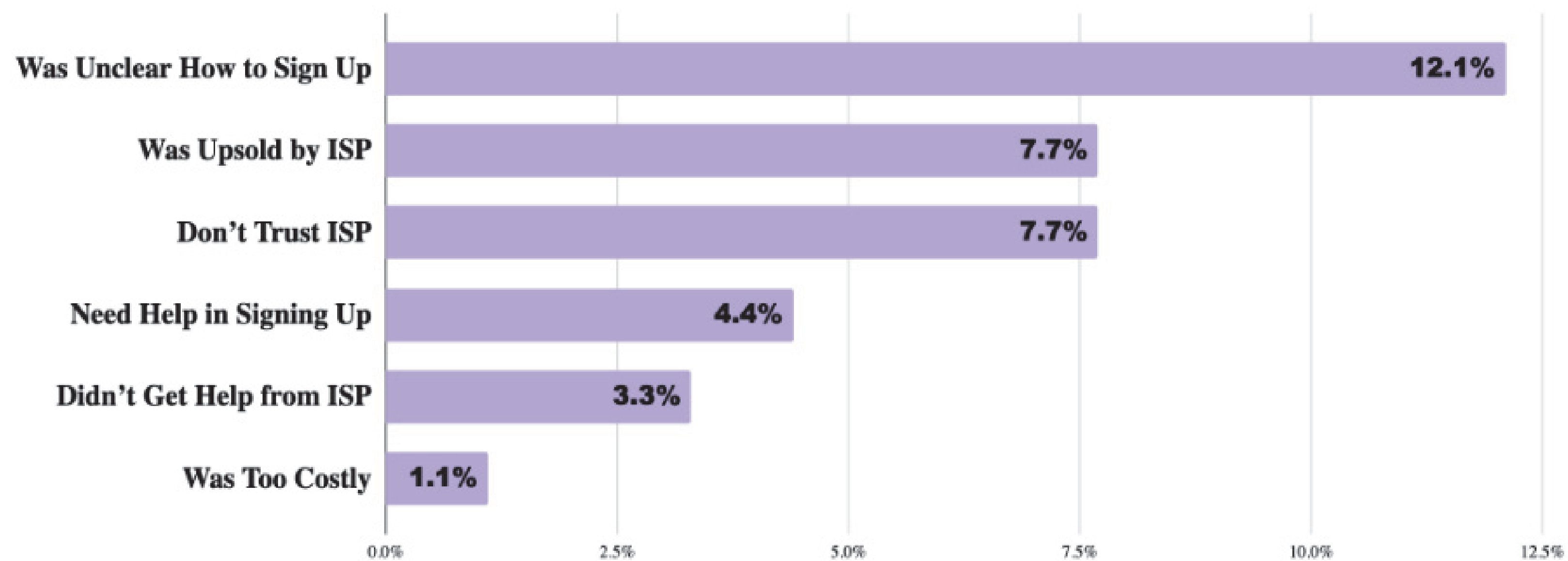
Demographics of Interviewees



Connectivity and Awareness of Affordable Offers

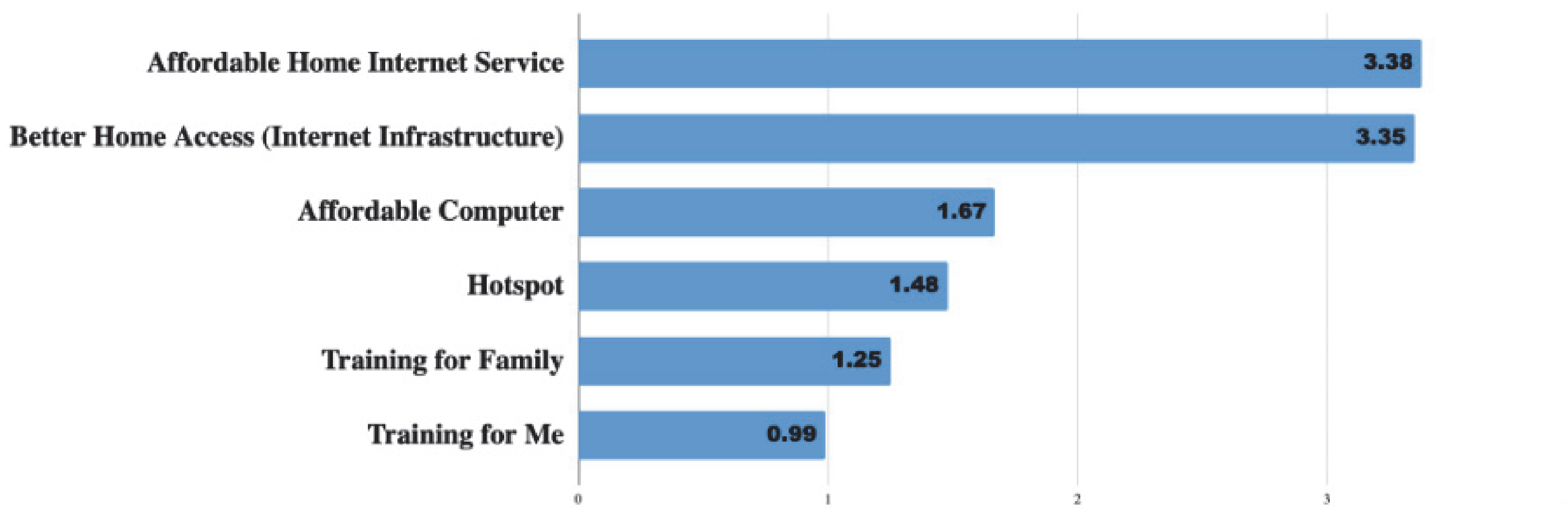


Reasons for Not Subscribing to an Affordable Service

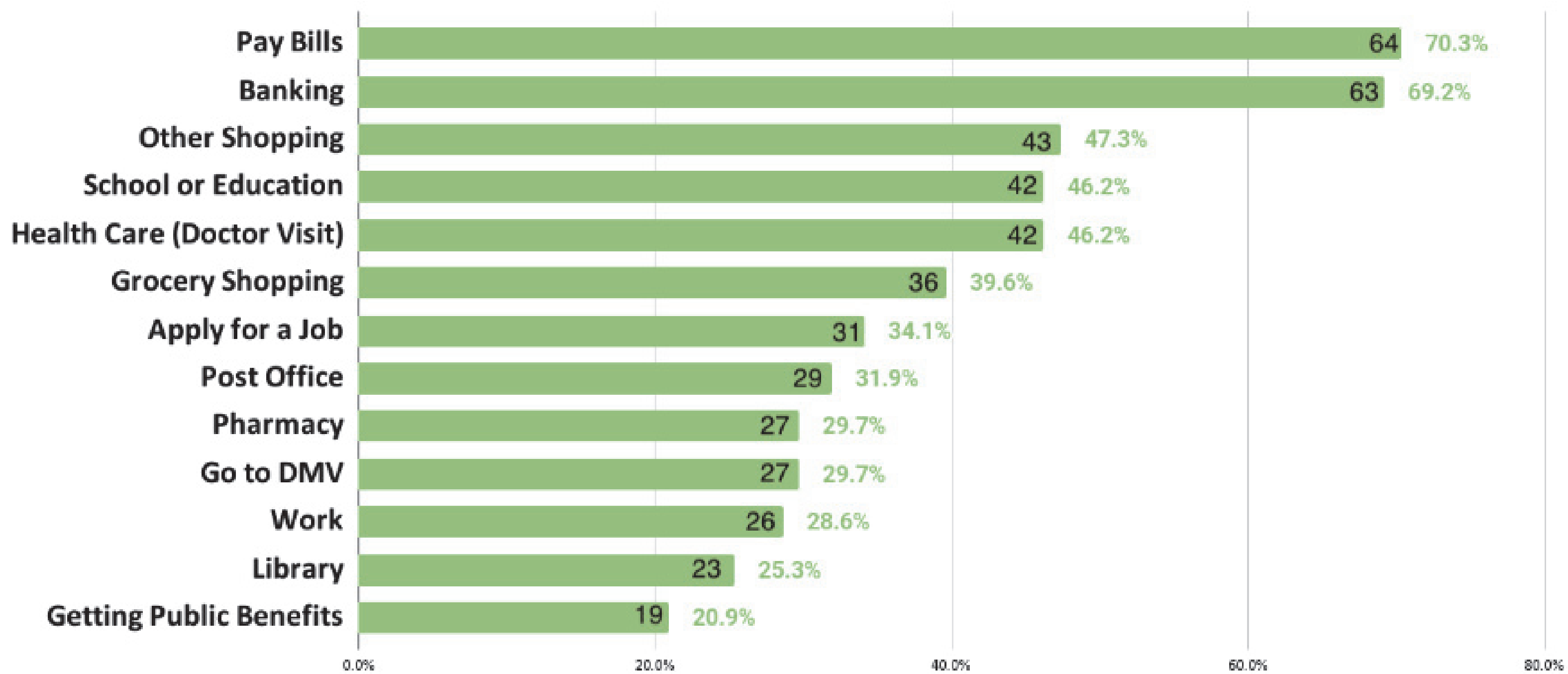


Kinds of Assistance That Would Make it Easier to Connect to the Internet

(Rated 1-5, with 5 Being Most Helpful)



Kinds of Vehicle Trips That Can Be Reduced



Broadband and Environmental Benefit Data and Literature Report

SCAG Caltrans Broadband Grant Task 3:1:
Review Broadband and Environmental Benefit Data and Literature

Prepared by Inland Empire Regional Broadband Consortium

November 12, 2020

(Final Version March 16, 2021)

Table of Contents

Summary

A. Report Organization

The Broadband and Environmental Benefit Data and Literature Report is organized in the following sections:

1. Section 1:

Foundational Reference Documents used for the Caltrans Broadband Grant

The documents in this section are provided as reference as they create the foundation as to why SCAG, with CETF and Southern California Regional Broadband Consortia, are studying the relationship between improved broadband and reduced Vehicle Miles Traveled (VMT) and Greenhouse Gas Emissions (GHG).

The foundational documents help provide the context on why there should be a nexus found between improved broadband through the utilization of public road rights-of-way as a public investment and benefit for broadband users, especially in rural and disadvantaged communities, and reduced VMT and GHG which broadband service expansion is determined a legitimate, and even preferred, Transportation Demand Management (TDM) strategy to mitigate traffic and environmental impacts, and protect the public investment in state and local highways.

Ultimately, planning for broadband and including broadband conduit as an eligible project cost in public rights of way on interstates, state highways, bridges, regional roads, and local streets should be considered a standard TDM measure and be included in the modern concept of designing and building complete streets.

The foundational documents include groundbreaking work done by the California Emerging Technology Fund (CETF), the existing Smart Mobility Framework and Wired Broadband Guidelines from Caltrans, Corridor Plans done by Caltrans and the California Transportation Commission (CTC).

2. **Section 2:**

   California Specific Reports and Data addressing VMT, GHG, and Broadband

   This section includes the current draft of the California Broadband Council (CBC) Broadband Action Plan as it is a directive from the Governor's recent "Broadband for All" Executive Order.

   Studies and reports from California based government and organizations flesh out this section with important work from SCAG and UC Davis, as well as additional Caltrans Reports that address technology, mobility, and reductions in VMT and GHG using a variety of methods, including internet-based solutions such as telecommuting.

   Reference documents are included for context from the Governor's Office of Planning and Research (OPR) regarding CEQA's updated VMT standard and GHG standards for reviewing impacts of transportation projects, land-use developments, etc.

3. **National Data, Articles, and Research**

   Reports focusing on internet usage resulting in VMT and GHG reductions are included from national sources, including the Federal Highway Administration (FHWA), U.S. Department of Energy, Ohio Department of Transportation, US Ignite, and the American Consumer.

4. **Industry Centric Information, covering Telecommuting, Telehealth, Distance Learning, and the Internet of Things (IoT)**

   This section includes research from RAND, UC Davis, UC San Diego, San Jose State University Mineta Transportation Institute, Cornell University, Oregon Department of Transportation, and various academic and research journals.

   In preparing this report, it is clear there are plenty of academic research and government agency reports about internet use leading to VMT and GHG reductions. In fact, this topic has been richly studied in California, nationally, and beyond for many years. The many studies include looking at the effect on VMT and GHG, as well as other environmental and community benefits from telecommuting, telehealth, and distance learning.

   There has been interest in also studying potential benefits from the Internet of Things (IoT) concept related to components and services used in our everyday life becoming connected to the internet through the cloud via smartphone and other computer apps. E.g., security systems, cameras, speakers for two-way conversation, lighting switches, thermostats, appliances, banking, product, groceries, and meal delivery, etc.

As more routine, everyday items become automated, will there be a significant reduction of trips with associated reductions in GHG, or will there be an increase of delivery trips offsetting trip reduction?

The use of online services by government and the advent of more online shopping, meal delivery and services also could be quantified into potential reductions in VMT and GHG.

5. Online Data Tools

A sample of online data tools is provided to show that there are agencies, including the California Transportation Authority, SCAG, and the County of Los Angeles are providing annual traffic data, GIS data, and VMT and GHG information.

There are numerous online calculators for determining how variables impact VMT and GHG. The Street Lights calculator is shown as it is a newly minted “Post-COVID-19 Climate Impact Calculator.”

B. Findings, Identification of Information, and Data Gaps

Although, the majority of the research over the past 20 years concludes it is clear telecommuting, made possible from increased and higher quality internet service, will reduce traffic congestion, VMT, and GHG, the rate of telecommuting has been stable at about 5% of all workers, including the self-employed and farmers.

There are some recent studies that claim people who telecommute eventually add more driving into their routine due to their flexible schedule, such as errands and school-related trips, but these also minimize that those trips are most likely at non-peak hour, and errands may be grouped up into one longer errand trip. These studies almost appear to be done with a contrarian vain as there are studies over such a long period that confirm positive environmental benefits and reduced VMT and GHG from telecommuting.

It has been found that during the first peak of COVID-19, the workforce was telecommuting at around 40% with some reports much higher. Approximately 20% of the workforce will continue to telecommute, post-COVID-19, either all week, a few days a week, or even one day per week. There will need to be more reporting on the level of distance learning, telehealth, online government, and other online services post-pandemic.

Why were telecommute rates so low prior to COVID-19? It is not a lack of data, research, or the availability of internet service, that has kept the telecommuting percentage at 5% for so many years.

It appears more likely that study after study may be sitting on shelves and dormant in academic journals. The studies on this topic seem to have been used to create additional studies, without commensurate advances in public or private sector policy.

There is data and research available supporting the use of the internet based technologies to reduce VMT and GHG, yet there has been no significant rally from leadership, nor from business and government agencies, to strongly support or promote telecommuting, and other online services, as a high-value TDM method.

The average person is not hearing about new innovative TDM policies and programs that focus on telecommuting, telehealth, and distance learning based on technology advancements derived from higher internet service in order to reduce VMT, GHG and ultimately benefit climate change or other quality of life issues.

The studies are not being elevated to much in the way of public policy making. There is interest in broadband as a VMT mitigation strategy as a subject matter, but it seems to stay in the research phase and never get out the academia or government agency door.

Going through the documentation, data, and literature, rather than a research or data gap, it looks like there is more of *a leadership, policy, and action gap,* and a need for much more community outreach and education, when it comes to connecting the dots of improved broadband leading to reduced VMT and GHG as a viable TDM strategy.

Who knew the data and information is out there and available? What is missing is policy, programs and a strong community understanding of why internet based activities such as telecommuting, telehealth, and distance learning lead to reduced VMT and GHG, which in turn are good for the environment and climate change, as well as help sustain the transportation system.

Further, since the issue is being continually studied without action from the studies, the community is missing out on incentives to utilize internet-based solutions to reduce VMT and GHG as none are being pushed forward by policy makers and transportation leaders.

In addition, if leadership takes action and develops clear and understandable VMT and GHG reduction TMD strategies related to telecommuting, internet service providers (ISPs) would have more pressure to improve their service as they would be viewed as integral to reducing VMT and GHG, helping with climate change.

Transportation projects would be expected to consider broadband in their rights-of-way to further accelerate deployment, especially in underserved rural and disadvantaged communities. The cost of broadband planning and leveraging the transportation system for broadband deployment—systems that are owned by the public—would not be a big policy concern or question. It would be as simple as a complete street includes broadband planning to reduce VMT and GHG as a standard TDM strategy

The COVID-19 pandemic response has proved out that the technology and internet service for many does in fact exist at the level to be able to use telecommuting, telehealth, distance learning (not all education, but as an option), online government and services as a regular TDM strategy to reduce VMT and GHG. It has also shown where there are serious broadband service gaps, no service at all, and significant pricing issues that need to be addressed, especially if the internet is to become an important TDM strategy embraced within the community, including the disadvantaged.

COVID-19 shows the severe need for improved broadband policy, planning, deployment, access, and cost options in order to roll-out these TDM strategies in areas where internet service poor and suffer from the digital divide. Many more people and places are affected by the digital divide than was thought before the COVID-19 pandemic pulled the curtain back on just how many are unserved and underserved.

COVID-19 revealed that the broadband technology needs significant improvement for a massive online shift to telecommuting, telehealth, and distance learning. This information is helpful to show why pursuit of roadway rights-of-way at all levels in the State for broadband planning and deployment should be considered for transportation funding, especially in underserved, disadvantaged communities.

With COVID-19 pandemic hitting in early 2020, suddenly the only option for many to keep working, teaching, and learning was to move quickly to telecommuting and distance learning.

The health care sector also moved online, with the previous insurance payment barrier being removed at the federal level so that telehealth—phone and virtual appointments--could quickly replace physical appointments. The medical community ramped up as fast as they could to roll out telehealth options, which became the only option for many seeking appointments with their healthcare providers.

The government also moved as many services as they could online, including public meetings, workshops, and conferences. Private industry also moved conferences and events to virtual platforms.

Online shopping and meal delivery services increased dramatically. It will be interesting to learn how VMT and GHG was affected by an increase in the service and delivery (logistics) sector during the COVID-19 pandemic, and if there are continuing trends from many changes made based upon use of available technology and broadband applications.

This one-time shift in behaviors, based upon the COVID-19 health crisis, to move so much online, revealed the good, the bad, and the ugly of the current internet system. This situation now provides a platform to support why broadband needs to be elevated in public policy. The increase in online usage derived from the health crisis will most likely result in many, who did not previously and were not planning to embrace online options for work, school, healthcare, and other services, to be interested in continuing on this path. To what level is not yet known.

The instant drain on broadband service from all of these sectors moving online so suddenly, even in areas that had been perceived as served somewhat adequately, brings attention to the need to pursue higher level broadband service, and to start outlining as many benefits as possible of doing so, including the reduction of VMT and GHG to improve traffic congestion and the environment.

It is therefore timely to be studying the concept of connecting broadband planning and deployment to transportation investments as a TDM strategy. It will be relevant to the community to be looking at how online activities such as telecommuting, telehealth, etc., that are possible through strong, reliable, and reasonably priced internet service, could be utilized as a robust TDM strategy resulting in reduced VMT and GHG.

The SCAG technical consultant, once on board, will be preparing a socio-economic analysis, as well as transportation system performance data analysis which will be the basis for the final Transportation Broadband Strategies to Reduce VMT and GHG Report. This analysis will be able to capture information on changed online behaviors and perceptions from the pandemic.

SCAG's technical consultant will review the information provided in this report and identify additional data that will be needed. It will most likely be information that SCAG and other government agencies have related to vehicle mile trip data and other data sets. The Regional Broadband Consortiums will also provide data from their regions as needed.

Based upon consultation with SCAG's technical consultant, Regional Consortiums will pursue community engagement, stakeholder convenings, and focus group surveys that will also provide data about how the community perceives their internet service related to telecommuting, telehealth, distance learning, etc. and how they feel about the role their internet usage and behavior can play as a TDM strategy to reduce VMT and GHG to improve the environment.

Section 1 – Foundational Reference Documents for Caltrans Broadband Grant

1. Title: Broadband as a Green Strategy Policy Brief

Source: California Emerging Technology Fund (CETF)

Reference: https://www.cetfund.org/report/2012-broadband-as-a-green-strategy-policy-brief/

Date: 2012

Attachment: "A1"

Abstract: Broadband (high-speed Internet access) is an essential 21st Century Infrastructure and a necessity for California's future global competitiveness, prosperity, and high quality of life. The use of diverse broadband-driven applications also has the potential to reduce greenhouse gas (GHG) emissions and energy consumption, helping meet local, state, and federal air quality standards.

2. Title: Broadband as a Green Strategy Report: Understanding How the Internet Can Shrink Our Carbon Footprint

Source: CETF

Reference: https://www.cetfund.org/report/green-benefits/

https://www.cetfund.org/report/broadband-as-a-green-strategy-understanding-how-the-internet-can-shrink-our-carbon-footprint/

Date: 2014

Attachment: "A2"

Abstract: Broadband is part of the Information and Communication Technology (ICT) sector, which is a large consumer of energy and emitter of greenhouse gases (GHG). By 2020, the sector is projected to be responsible for 2.3 percent of total global emissions.

The proliferation of smart devices and cloud computing infrastructure, combined with the Internet becoming a foundation for the global economy, assures that power consumption and emissions of the ICT sector will continue to grow.

ICT is changing dramatically the way people work, learn, play, shop, connect, and mobilize.

Affordable, accessible broadband is critical for California to meet its GHG emissions goals to help reduce impacts on the environment and improve the quality of life for all.

3. Title: **California General Plan Guidelines**

Source: Governor's Office of Planning and Research (OPR)

Reference: https://opr.ca.gov/planning/general-plan/

Date: 2017 and 2020

Attachment: "A3"

Abstract: Broadband and "Dig Once" policies are included in the 2017 Circulation Element and Healthy Communities Section Guidelines (Pages 81, 82 and 211 and the 2020 updated Environmental Justice Element (Page 22) to consider broadband for public facilities.

4. Title: **2018 Comprehensive Multimodal Corridor Plan**

Source: California Transportation Commission (CTC)

Reference: https://catc.ca.gov/programs/sb1/solutions-for-congested-corridors-program/comprehensive-multimodal-corridor-plan-guidelines

Date: December 2018

Attachment: "A4"

Abstract: California's Solutions for Congested Corridors Program was adopted in 2017 to fund projects that make specific performance improvements that are part of a comprehensive corridor plan designed to reduce congestion in highly traveled corridors by providing more transportation choices while preserving the character of the local community and creating opportunities for neighborhood enhancement projects.

The 2018 Comprehensive Multimodal Corridor Plan provides a unique opportunity for Caltrans and its partners to undertake collaborative planning to address strategic development of technology and other infrastructure needs.

The collaborative identification of strategic corridors to accommodate existing and future broadband internet needs and to further implementation of "Dig Once" policies facilitates the use of technology and broadband to reduce vehicle miles traveled, improve mobility, and reduce congestion.

Technologies such as real-time, web, and mobile enabled trip planning, and ride sourcing services are changing how people travel. The advent of connected autonomous, and electric vehicles will also transform the movement of people and freight. The corridor planning process offers an opportunity to leverage existing Information Technology Systems (ITS) and identify future technology needs.

5. Title: **Caltrans Corridor Planning Process Guide**

Source: Caltrans

Reference: https://dot.ca.gov/programs/transportation-planning/multi-modal-system-planning/system-planning/corridor-planning-process-guide

Date: February 2020

Attachment: "A5"

Abstract: Existing and expected land use and demographics should be summarized at the corridor level. This includes a brief description of the Place Types within the corridor area, as well as a general description of local and regional land use, demographic characteristics, broadband, environmental, and development plans.

A range of Place Types appropriate for description in Corridor Plans are listed within Caltrans Smart Mobility Framework.

6. Title: **Caltrans Incorporating Wired Broadband Facility on State Highway Right-of-Way User Guide**

Source: Caltrans

Reference: https://dot.ca.gov/programs/design/wired-broadband

Date: 2018

Attachment: "A6"

Abstract: California Assembly Bill 1549 (Wood, Chapter 505, Statutes of 2016) requires that Caltrans, during the planning phase of specified Caltrans-led highway construction projects, notify broadband deployment companies and organizations on its Internet Web site of transportation projects that involve construction methods suitable for the installation of broadband. Upon notification from Caltrans, companies or organizations working on broadband deployment may collaborate with Caltrans to install a broadband conduit as part of a project.

The bill also required Caltrans, in consultation with Broadband Stakeholders, to develop guidelines to facilitate the installation of broadband conduit on State highway right-of-way on or before January 1, 2018.

The Caltrans Wired Broadband Facility on State Highway Right-of-Way User Guide provides methodology for Internet Service Providers (ISPs) to access Caltrans facilities for broadband deployment.

7. Title: **Caltrans Smart Mobility Framework**

Source: Caltrans

Reference: https://dot.ca.gov/programs/transportation-planning/office-of-smart-mobility-climate-change/smart-mobility-active-transportation/smart-mobility-framework

Date: 2010

Attachment: "A7"

Abstract: Caltrans Smart Mobility Framework (SMF) is a planning guide that furthers integration of smart growth concepts into transportation planning in California. SMF responds to the transportation needs of the State's people and businesses, addresses climate change, advances social equity and environmental Justice, supports economic and community development, and reduces per capita vehicle miles traveled.

SMF helps achieve California's mandate to find solutions to climate change and the need to reduce greenhouse gas (GHG) emissions and per capita vehicle miles traveled (VMT).

Reduced per capita auto use will lower emissions of GHG gas and conventional pollutants, reduce petroleum consumption and associated household transportation costs, and minimize negative impacts on air quality, water quality, and noise environments.

Achieving the State's goals for reduction of GHG and VMT requires a positive and integrated approach to our transportation future.

Section 2 - California Specific Reports and Data (VMT, GHG, and Broadband)

1. Title: **Draft California Broadband Action Plan**

Source: California Broadband Council (CBC)

Reference: https://broadbandcouncil.ca.gov/action-plan/

Date: 2020

Attachment: *"A8"*

Abstract: California Executive Order N-73-20 requires the development of a California State Broadband Action Plan. Outreach has been underway for a few months. The California Broadband Council will discuss the Draft Broadband Action Plan at its November and December meetings.

2. Title: **SCAG Connect SoCal Plan**

Source: SCAG

Reference: https://www.connectsocal.org/Pages/Connect-SoCal-Final-Plan.aspx

Date: September 2020

Attachment *"A9"*

Abstract: Connect SoCal is a long-range visioning plan that builds upon and expands land use and transportation strategies established over several planning cycles to increase mobility options and achieve a more sustainable growth pattern. It charts a path toward a more mobile, sustainable, and prosperous region by making connections between transportation networks, between planning strategies and between the people whose collaboration can improve the quality of life for Southern Californians.

3. Title: **COVID-19 Transportation Impact in the SCAG Region Power Point and Report**

Source: SCAG

Reference: https://www.connectsocal.org/Pages/Connect-SoCal-Final-Plan.aspx

Date: September 2020

Attachment *"A10"*

Abstract: Vehicle miles traveled (VMT) on the region's arterial and highway network declined by nearly 80 percent in early April (using January 2020 as benchmark). VMT on the freeway network alone dropped by nearly 50 percent in early April over prior year. VMT began increasing again by mid-April. Total VMT is now nearing pre-pandemic levels.

4. Title: **Caltrans Greenhouse Gas Emissions and Mitigation Report**

Source: Caltrans

Reference: https://dot.ca.gov/-/media/dot-media/programs/transportation-planning/documents/office-of-smart-mobility-and-climate-change/ghg-emissions-and-mitigation-report-final-august-2-2020-revision9-9-2020-a11y.pdf

Date: August 2020

Attachment “A11”

Abstract: Historically, Caltrans focused its investments towards expanding the highway system to meet the demands of a growing population and economy and increased vehicle ownership and use. Today, expansion of the highway system has slowed, and the focus has shifted to managing the system effectively. This paradigm calls for evaluating new highway projects in terms of their ability to move people rather than vehicles, and to support a multimodal system that offers travel choices and better reliability.

The shift in focus away from maximizing vehicle throughput is also reflected in the passage of SB 743, which calls for replacing vehicle delay and level of service as the mechanism for evaluating transportation impacts under the California Environmental Quality Act (CEQA). Because it plans, builds, and operates most of the state’s highway system, Caltrans has some unique opportunities to influence on-road vehicle travel in the state.

These opportunities include the provision of multimodal transportation systems that provide viable alternatives to vehicle travel, roadway pricing and other approaches to manage demand, and avoiding new highway capacity additions that result in substantial induced vehicle travel, leading to higher VMT and GHG emissions. The phenomenon of induced vehicle travel is widely accepted and well documented, and it can often lead to an increase in VMT and GHG emissions when highway capacity is expanded, including through the addition of HOV and express lanes.

5. Title: **Technical Advisory on Evaluating Transportation Impacts in CEQA**

Source: California Governor’s Office Planning and Research (OPR)

Reference: https://opr.ca.gov/docs/20190122-743_Technical_Advisory.pdf

Date: December 2018

Attachment: “A12”

Abstract: This technical advisory serves professional planners, land use officials, and CEQA practitioners. OPR issues technical assistance on issues that broadly affect the practice of land use planning and the California Environmental Quality Act (CEQA). The purpose of this document is to provide advice and recommendations, which agencies and other entities may use at their discretion. This document does not alter lead agency discretion in preparing environmental documents subject to CEQA.

6. Title: **Future of Mobility White Paper – CA Transportation Plan 2050**

Source: Caltrans

Reference: https://ctp2050.com/wp-content/uploads/2020/10/CTP2050_Future_of_Mobility_White_Paper.pdf

https://tsrc.berkeley.edu/future-mobility-white-paper

Date: January 2018

Attachment *"A13"*

Abstract: Transportation is undergoing a transformative revolution. Trending technologies and competitive markets re accelerating innovation in the field at faster rates than previously predicted. As such, California is required to renew its long-range comprehensive transportations plan. Key broadband related points:

- Increasingly, as transportation networks rely on wireless services and technologies, equitable mobility will depend on access to broadband Internet, smartphones, and bank accounts.
- Information and Communications Technology (ICT), including current U.S. technology penetration levels and ICT's role in enabling shared mobility and automated vehicles.
- The use of Global Positioning System (GPS) applications, especially on mobile devices with access to mobile Internet services, has revolutionized real-time and on-demand transportation services. And the number of Internet-connected vehicles is expected to grow rapidly.

7. Title: **Cutting Greenhouse Emission Is Only the Beginning: A Literature Review of the Co-Benefits of Reducing Vehicle Miles Traveled.**

Source: National Center for Sustainable Transportation/UC Davis

Reference: https://escholarship.org/content/qt4h5494vr/qt4h5494vr.pdf

Date: March 2017

Attachment: "A14"

Abstract: Traditional evaluation of the transportation system focuses on automobile traffic flow and congestion reduction. However, this paradigm is shifting. In an effort to combat global warming and reduce greenhouse gas (GHG) emissions, a number of cities, regions, and states across the United States have begun to deemphasize vehicle delay metrics such as automobile Level of Service (LOS). In their place, policymakers are considering alternative transportation impact metrics that more closely approximate the true environmental impacts of driving. One metric increasingly coming into use is the total amount of driving or VMT.

8. Title: A Framework for Projecting the Potential Statewide Vehicle Miles Traveled (VMT) Reduction from State-Level Strategies in California

Source: National Center for Sustainable Transportation/UC Davis

Reference: https://escholarship.org/uc/item/2z48105j

Date: March 2017

Attachment: "A15"

Abstract: This white paper examines the evidence available and assumptions needed for projecting statewide Vehicle Miles Traveled (VMT) reductions for each category of strategies. The goal is to provide a framework for projecting the magnitude of reductions that the state might expect for the different strategies. This framework helps to illuminate the sequence of events that would produce VMT reductions and highlights important gaps in knowledge that increases the uncertainty of the projections. The evidence justifies state action on these strategies: the available evidence shows that the strategies considered in this paper are likely to reduce VMT if promoted by state policy.

9. Title: Driving Change – Reducing Vehicle Miles Traveled in California

Source: Public Policy Institute of California (PPIC)

Reference: https://www.ppic.org/publication/driving-change-reducing-vehicle-miles-traveled-in-california/

Date: February 17, 2011

Attachment: "A16"

Abstract: Senate Bill (SB) 375, adopted in 2008, calls on regional transportation planning agencies and local governments to develop strategies for reducing GHG from passenger vehicles by reducing per capita VMT. Specific strategies, traditionally used to reduce traffic congestion and improve air quality, are to be employed to help reduce emissions.

Section 3 - National Data, Articles, Research

1. Title: Broadband Models for Unserved and Underserved Communities

Source: US Ignite

Reference: https://www.us-ignite.org/wp-content/uploads/2020/07/USIgnite_Altman-Solon_Whitepaper-on-Broadband-Models_FINAL_7-9-2020.pdf

Date: July 9, 2020

Attachment: "A17"

Abstract: A white paper from US Ignite and Altman Solon, explores the various models that cities can employ to connect their residents and businesses.

The paper covers five approaches that communities can take to improve Internet access, from full private broadband to full municipal broadband with varying types of public-private partnerships in between. Of all the well-connected American cities (where 50% of residents have access to 250 Megabits per second broadband speeds), the paper finds that 8% are served a form of municipal network.

To help local government officials figure out which model is right for their community, US Ignite and Altman Solon include a number of helpful charts, decision trees, and other considerations.

2. Title: Innovate Ohio DOT Digital Infrastructure and Access Strategy

Source: Ohio Department of Transportation (Ohio DOT)

Reference: http://www.dot.state.oh.us/Divisions/ContractAdmin/Contracts/PurchDocs/601-20a.pdf

Date: September 25, 2019

Attachment: "A18"

Abstract: Innovate Ohio, in partnership with the Ohio Department of Transportation, issued a 16-page broadband access report on September 24 – a report commissioned at the behest of Ohio Governor Mike DeWine (R) in June – to provide a strategic plan for "improving and expanding broadband" across the state. The key finding of that report is that the rights-of-way along state-owned interstate highways "hold considerable value" that can be "leveraged in order to expand broadband."

3. Title: **Understanding Travel Behavior**

Source: Federal Highway Administration (FHWA)

Reference: https://www.fhwa.dot.gov/policy/otps/travel_behavior_research_scan.pdf0

Date: March 2016

Attachment: "A19"

Abstract: Travel behavior is undergoing a period of significant change in the United States, and this change is beginning to reveal itself in long-standing measures of transportation. While the United States is still heavily dependent on the personal automobile for mobility, changes in technology, demographics, economics, and attitudes are transforming how mobility is attained. At the same time, advances in information technology are opening new ways for transportation activity to be measured more comprehensively. These transformative trends are reshaping how we think about transportation policy, operations, and planning.

This report presents a research scan of the state of knowledge in transportation to enhance understanding of travel behavior and various influencing factors on future travel. It provides an overview of the current state of travel behavior as measured today, as well as background on the current understanding from literature in travel behavior research. It also explores what is known about the socio-demographic portrait of Americans and how demographics influence travel behavior.

The report discusses emerging information technology and its impact on new mobility options. It also presents emerging methodologies and new forms of data that show significant potential to improve the resolution and comprehensiveness of travel behavior information. Finally, it identifies gaps in understanding that could be addressed in the future with appropriate applications of emerging data and technological resources.

4. Title: **Addressing Effects of Travel Reduction and Efficient Driving on Transportation Energy Use and Emissions.**

Source: U.S. Dept of Energy

Reference: https://www.nrel.gov/docs/fy13osti/55635.pdf

Date: March 2013

Attachment: "A20"

Abstract: Numerous transportation strategies are directed at reducing energy use and greenhouse gas (GHG) emission by changing the behavior of individual drivers or travelers. These behavioral changes may have the effect of reducing travel, shifting travel to more efficient modes, or improving the efficiency of existing travel. This report reviews and summarizes the literature on relationships between these strategies and transportation-related energy use and GHG emissions. This report summarizes historical findings documented in existing literature, as well as recent efforts that had not previously been reported, and highlights and interprets that literature for information most relevant to an energy perspective.

5. Title: Broadband Services: Economic and Environmental Benefits

Source: The American Consumer Institute

Reference: https://www.theamericanconsumer.org/2007/10/broadband-services-economic-and-environmental-benefits/

Date: October 31, 2007

Attachment: "A21"

Abstract: The purpose of this paper is to investigate the use of advanced technologies, including broadband services and telecommunications technologies, and their specific effects on energy use and the environment. This study adds to the discussion of how to reduce greenhouse gas emissions by documenting the reductions that can be realized by the widespread delivery of broadband services in the U.S. Current carbon dioxide emissions in the U.S. hover around 7.9 billion tons and are growing.[2] This study finds that wide adoption and use of broadband applications can achieve a net reduction of 1 billion tons of greenhouse gas over 10 years, which, if converted into energy saved, would constitute 11% of annual U.S. oil imports.

Section 4 – Industry Centric Information

Telecommuting

1. Title: (Re)Awakening to the benefits and climate impacts of telework during COVID-19

Source: UC San Diego, A Capstone Project

Reference:

https://escholarship.org/content/qt7nf8k2q6/qt7nf8k2q6_noSplash_30708910e19831fd3d84c41a96ad5050.pdf

Date: June 12, 2020

Attachment “A22”

Abstract: During the COVID-19 pandemic, millions of employees have shifted to working from home, either full-time or part-time. Prolonged quarantine measures put in place in response to the current global health crisis have forced businesses, both essential and non-essential, to adapt to their workforces stuck at home and no longer able to come into the office.

In order to keep their workforce employed, engaged and productive in a prolonged quarantine environment, employers have adapted by enabling large portions of their previous in-office workforce to work remotely from home. The history of working from home, also commonly referred to as telework or telecommuting, is one of mixed success and mixed support; however, when left with few alternatives, businesses are embracing the potentials of a remote workforce.

The increase in employees working from home has directly impacted short-term environmental air quality and reduced greenhouse gas (GHG) contributions due to a reduction in employee transportation requirements. In short, people are driving less, and the environment is benefiting.

Additional potential benefits from the increase in employees working outside the office include reductions in office electricity consumption, water consumption, and waste generation, as well as cost savings due to potential reductions in total office footprint requirements.

This capstone explores the overall environmental impacts, long-term climate implications, return on investment and success strategies for an increasingly remote workforce.

2. Title: The COVID-19 Pandemic and the Changing Nature of Work Lose Your Job, Show Up to Work, or Telecommute?

Source: RAND

Reference: https://www.rand.org/pubs/research_reports/RRA308-4.html

Date: June 2020

Attachment: "A23"

Abstract: Stay-at-home orders save lives, but the extent to which they threaten livelihoods depends on the nature of one's work. How much has the ability to work from home mitigated the economic effects of the coronavirus disease 2019 (COVID-19) pandemic? In the first week of May 2020, RAND researchers conducted a survey of more than 2,000 individuals in the nationally representative RAND American Life Panel (ALP) to find out how their lives changed as a result of the pandemic. The report focuses on 1,277 individuals who were working for pay or profit in February 2020.

3. Title: US COVID-19 mitigation efforts resulting in significant decline in traffic, emissions, and fuel-tax revenues

Source: UC Davis, Road Ecology Center

Reference: https://www.greencarcongress.com/2020/05/20200502-ucd.html

Date: May 2, 2020

Attachment "A24"

Abstract: Findings were that total US vehicle miles traveled (VMT) at the county and state level declined by 61% to 90% following the various government stay-at-home orders in response to the COVID-19 pandemic. Using data from Street Light, the researchers estimated changes in daily VMT across the US before and after government shelter-in-place guidance. The difference amounted to a drop from 103 billion miles in early March to 29 billion miles during the second week of April. All states reduced their vehicle miles traveled by at least 60%.

The authors used the VMT data to calculate that emissions of US greenhouse gas (GHG) emissions were reduced by 4% in total and by 13% from transportation in the almost 8 weeks since many stay-at-home orders went into effect.

4. Title: Caltrans Sustainability Director: What Benefits Telecommuting may bring are still very much unknown

Source: California Streetsblog

Reference: https://cal.streetsblog.org/2020/08/04/what-benefits-telecommuting-may-bring-are-still-very-much-unknown/

Date: August 4, 2020

Attachment: "A25"

Abstract: Article quotes Ellen Greenberg who recently took the job of Sustainability Director for Caltrans, She is quoted as saying within Caltrans, there's been an amazing shift, and that before the pandemic, despite some encouragement, telecommuting had very low adoption rates among the almost 21,000 people who work for the Caltrans. "But we found that we could do this," and at one point almost 90% of Caltrans office employees – which are maybe two-thirds of their work force – were working from home.

In addition, Sam Speroni, a UCLA graduate student who is preparing a research review for Caltrans, has found little consistency among pre-COVID-19 research results. These have generally been based on limited data samples and usually focused on specific questions such as environmental benefits, worker productivity, or potential technologies. "I have been surprised at a number of things I've been learning," said Speroni. "One is how incoherent and inconsistent existing research is. You could find a study that comes to one conclusion, and a different one that says the opposite."

"New trip making habits are likely to emerge," said Greenberg, "so telework does not 'zero out' VMT." In general, people have a kind of mental travel budget – how much time they are willing to, or want to, spend traveling. For many years researchers who have studied this have pinned the "ideal commute" at about twenty minutes. That goes for car, transit, bike, or walking commutes – people generally seem to like about a twenty minute distance between home and work.

Also, "people are accustomed to using that time for driving," said Greenberg, and although not having to drive in rush hour traffic could be a huge stress reducer, it does not mean people do not want to drive at all. In fact, they may shift their driving to a different time. That has implications for traffic congestion, if it means lower peak-hour traffic volumes (and potentially higher off-peak traffic), which is not a bad outcome. But it means little for reducing VMT.

5. Title: **The "GO-Virtual Initiative": Using Flexible Workplace Practices to Reduce Traffic Congestion, Increase Economic Development, and Provide More Access to Affordable Housing Choices in the South Bay Region of Los Angeles County**

Source: San Jose State University (SJSU)/Mineta Transportation Institute

Reference: https://transweb.sjsu.edu/sites/default/files/1860-Prager-Flexible-Workplaces-South-Bay_0.pdf

Date: August 2019

Attachment: "A26"

Abstract: The "GO-Virtual Initiative": Using Flexible Workplace Practices to Reduce Traffic Congestion, Increase Economic Development, and Provide More Access to Affordable Housing Choices in the South Bay Region of Los Angeles County Flexible workplace practices (FWPs) such as telework, flexible scheduling, and the use of co-working spaces have the potential to address problems of congestion, pollution, and lack of housing affordability in the South Bay region of Los Angeles County.

However, trends in the adoption of FWPs—especially of working from home—across the region do not appear to be increasing as much as expected, despite advances in technology, changing worker demands, and evolving workplace cultures. In the South Bay and Los Angeles, commute times and the proportion of residents driving alone to work have increased as the economy has grown. As alternatives to driving alone to work, employees appear to face the choices of using public transit if more accessible, or carpooling if the journey is longer; however, both of these modes of transportation have declined in usage in recent years.

Instead, the only alternative to driving alone that has increased in frequency in the South Bay and Los Angeles County in recent years is working from home, which is most likely concentrated among residents in locations with higher education levels or occupations that are more appropriate. Prior literature has provided numerous insights here, finding that conditions are region-specific, and that occupational and industry constraints combine with manager resistance and employee concerns over work-life balance to limit the expansion of FWP. The authors of this study contribute to the literature by focusing on the obstacles to expansion of FWP among South Bay organizations, as well as by comparing the projected impacts of potential government interventions in this space.

The authors explore these issues with methods innovative to the field, including a combination of surveys and expert elicitation focus groups that includes numerous types of FWP, especially the inclusion of co-working spaces as a strategy. Participants in the survey and focus groups perceived the major obstacles to expansion to be a combination of managerial and executive resistance, alongside occupational constraints. Participants perceived government subsidies and incentives as both having a good combination of costs and impacts, possibly to be used to encourage the use of private co-working spaces, which offer a market solution that balances the benefits of traditional at-home telework and collaborative workplaces. Telework remains a cost-effective approach to reducing commute-related emissions, and hence more aggressive programs, such as telework facilities exchanges, expansion of South Coast Air Quality Management District mandates, and incentives for workforce training and program implementation may be needed to achieve broader climate action and local pollution targets.

6. Title: 5 Stats about Telecommuting's Environmental Impact

Source: Flexjobs

Reference: https://www.flexjobs.com/blog/post/telecommuting-sustainability-how-telecommuting-is-a-green-job/

Date: April 16, 2019

Attachment: "A27"

Abstract: Remote work is looked to for solving problems with work-life balance, employee retention, and productivity. But is it also a way to reduce negative impacts on the environment, and to create a more sustainable way to work?

These five stats about telecommuting's environmental impact say it is.

1. Commuting contributes greatly to the second-largest sources of United States GHG.
2. Company offices are part of the fourth-largest contributor to GHG.
3. Remote workers today have the same impact on air quality as planting a forest of trees.
4. Remote work helps people avoid the personal health risks from environmental pollution.
5. Remote work positively impacts environment *and* bottom line of companies that allow it.

7. Title: Employer Transportation Demand Management (TDM) Programs

Source: Oregon Department of Transportation

Reference: https://www.oregon.gov/ODOT/Planning/Documents/Mosaic-Employer-based-TDM-Programs.pdf

Date: 2010

Attachment: "A28"

Abstract: Employer TDM programs help meet local goals for vehicle miles traveled (VMT) and congestion reduction, environmental stewardship, and quality of life.

An 82-program sample of employer TDM programs found he average empirically based estimate of site-specific vehicle trip reduction impacts for employer support programs alone is 4% to 5% vehicle trip reduction (VTR). Those TDM programs that provided transportation services were considerably more effective as a group in reducing vehicle trips (22% program VTR).

8. Title: **Does Telecommuting Reduce Vehicle Miles Traveled? An Aggregate Time Series Analysis for the U.S.**

Source: UC Davis

Reference: https://escholarship.org/uc/item/74t9663f

Date: July 2004

Attachment: "A29"

Abstract: This study examines the impact of telecommuting on passenger vehicle-miles traveled (VMT) through a multivariate time series analysis of aggregate nationwide data spanning 1966-1999 for all variables except telecommuting, and 1988-1998 for telecommuting. The analysis was conducted in two stages. In the first stage, VMT (1966-1999) was modeled as a function of conventional variables representing economic activity, transportation price, transportation supply and socio-demographics. In the second stage, the residuals of the first stage (1988-1998) were modeled as a function of the number of telecommuters.

We also assessed the change in annual VMT per telecommuter as well as VMT per telecommuting occasion, for 1998. The models suggest that telecommuting reduces VMT, with 94% confidence. Together with independent external evidence, the results suggest a reduction in annual VMT on the order of 0.8% or less.

Even with impacts that small, when informally compared to similar reductions in VMT due to public transit ridership, telecommuting appears to be far more cost-effective in terms of public sector expenditures.

9. Title: **Review of the Literature on Telecommuting and Its Implications for Vehicle Travel and Emissions**

Source: Resources for the Future

Reference: https://media.rff.org/documents/RFF-DP-04-44.pdf

Date: December 2004

Attachment: "A30"

Abstract: A review of 20 empirical studies of telecommuting, all of which focus on the trip reduction perspective. The studies include earlier ones with smaller datasets, such as some pilot studies of individual employers, and more recent studies based on broader surveys of both telecommuters and non-telecommuters. Focus is on the results of the studies with respect to participation and frequency of telecommuting, the effects on vehicle-miles-traveled (VMT) and trips, and in some cases, the impacts on emissions and air quality.

Most studies of VMT and trip reductions from telecommuting show that telecommuters significantly reduce both daily trips and VMT. Not only does commute VMT fall, but non-commute VMT appears to fall in some cases as well. The studies of VMT, however, tend to focus on the reductions for individual employees who choose to telecommute.

Although an individual telecommuter may experience a sharp reduction in VMT, total benefits depend on how many people are telecommuting, how often they are doing so, and the duration of telecommuting. More research is needed with larger and more broadly based datasets across employers that include both individual employee characteristics and employer and job characteristics. This would allow a better analysis of telecommuting choice and frequency as well as more reliable estimates of VMT and emissions impacts.

10. Title: Employer Transportation Demand Management (TDM) Programs

Source: Journal of the Air & Waste Management Association

Reference: https://www.oregon.gov/ODOT/Planning/Documents/Mosaic-Employer-based-TDM-Programs.pdf

Date: 1996

Attachment: "A31"

Abstract: Analysis of the travel diary data and the emissions model output supports the hypothesis that telecommuting has beneficial transportation and air quality impacts. The most important results are that telecommuting decreases the number of daily trips (by 30%), the vehicle-miles traveled (VMT) (by 63%), and the number of cold starts (by 44%), especially those taking place in early morning. These reductions are shown to have a large effect on daily emissions, with a 50% to 60% decrease in pollutants generated by a telecommuter's personal vehicle use on a telecommuting day.

These net savings are almost entirely due to the elimination of commute trips, as non-commute trips increased by 0.33 trips per person-day (9% of the total trips), and the non-commute VMT increased by 2.2 miles.

Telecommuting is one of many Transportation Demand Management (TDM) strategies being considered by policy makers to reduce congestion levels and improve air quality. As one of the first studies to directly measure the impacts of telecommuting on vehicle emissions levels, this research contributes to a new body of data on the air quality impacts of telecommuting.

The findings support the hypothesis that telecommuting benefits both air quality and congestion. The methodology presented may be applied to other TDMs to analyze the comparative impacts of each strategy. This information will help policy makers identify the most effective congestion reduction and air quality improvement approaches. As telecommuting adoption moves into the mainstream, its net impacts are still expected to be beneficial—a reduction in VMT and in emissions.

Telehealth

11. Title: **Virtual Intensive Outpatient Outcomes: Preliminary Findings**

Source: Hazelden Betty Ford Foundation/Butler Center for Research

Reference: https://www.hazeldenbettyford.org/education/bcr/addiction-research/virtual-intensive-outpatient-outcomes

Date: September 2020

Attachment *"A32"*

Abstract: Hazelden Betty Ford had piloted a telehealth addiction treatment prior to the COVID-19 pandemic with a one year timeline for implementation. Due to the virus, their timeline accelerated, and they pivoted the majority of their intensive outpatient (IOP) services from in-person to virtual at the beginning of the pandemic. In order to better understand what works in virtual services and for whom, they undertook an evaluation of the virtual IOP services. Overall, the preliminary findings indicate that virtual IOP services have been as effective as in-person IOP treatment.

12. Title: **Broadband Internet Access Is a Social Determinant of Health**

Source: American Journal of Public Health (AJPH)

Reference: https://mobroadband.org/wp-content/uploads/sites/44/2020/07/Broadband-Access-and-Social-Determinants-of-Health.pdf

Date: August 2020

Attachment *"A33"*

Abstract: Now, more than ever, broadband Internet access (BIA) must be recognized as a social determinant of health. Disparities in access should be treated as a public health issue because they affect "the health of people and communities where they live, learn, work and play." The COVID-19 pandemic demonstrates that lack of BIA influences each of the six social determinant of health domains defined by the American Medical Association. It also affects an additional domain, which is particularly pertinent during a pandemic—access to credible information. Reduced BIA, particularly during this pandemic, has the potential to exacerbate this country's existing health disparities because it disproportionately affects those who are already vulnerable. Indeed, those who are older, are racial/ ethnic minorities, have lower incomes, are less educated, or live in rural areas may experience worse health outcomes under normal circumstances and are even less able to access health enhancing resources during social-distancing orders.

Without BIA, patients cannot fully use telehealth in all its forms: asynchronous messaging via patient portals, remote monitoring devices such as blood pressure monitors, or synchronous video connections to consult with a physician. Telephone calls are an alternative to video visits, but because they permit only audio communication, they limit possible interactions between patients and health care professionals. Variation in BIA reliability also presents challenges to technical visit quality. Some patients, even those with BIA, have declined to use these technologies because of difficulties with digital literacy or privacy concerns.

13. Title: **Eco-Friendly Benefits of Telehealth Visits**

Source: BioFriendlyPlanet.com

Reference: https://biofriendlyplanet.com/green-ideas/eco-friendly/eco-friendly-benefits-of-telehealth-visits/

Date: July 21, 2020

Attachment *"A34"*

Abstract: The current COVID-19 pandemic has forced everyone to change their usual routines, and the medical industry is no exception. Patients and providers have created and adapted to new systems so medical care can continue as safely as possible. One of those new systems is telehealth.

Patients can now see their providers over virtual appointments either with a video call or a typical voice call. Telehealth is a fantastic option, especially while going out and being in close proximity to other people is not advised, but other benefits to telehealth might be less obvious. This new technology is providing an excellent service, but it is also helping our planet.

14. Title: **Impact of the digital divide in the age of COVID-19**

Source: Journal of the American Medical Informatics Association

Reference: https://academic.oup.com/jamia/article/27/7/1147/5826352

Date: April 28, 2020

Attachment *"A35"*

Abstract: Due to COVID-19, by early March 2020, the need for an immediate adaptation of our clinical care delivery system was clear. Within a week, clinics had transitioned from in-person visits to telehealth involving telephone or video. Screening processes for COVID-19 were quickly made available on a free online platform through which at-risk individuals were directed to drive-through centers for in-person testing.

The problem was that many of our patients could not access the online system.
In our roles as directors of free clinics, we have become intimately involved with the complexity inherent to the care of underserved populations, including how seemingly innovative programs can sometimes not meet their intended goals.

As our main hospital system was transitioning to telehealth-based care, we were rapidly trying to put measures into place at our free clinics that would ensure that our patients did not lose their access to health care. It quickly became apparent that the newly built telehealth systems created additional access hurdles for our free clinic patients, and we would soon learn that pockets existed within the larger population that were impacted by these barriers. As is often the case, those whose access was impeded were the most vulnerable to poor health outcomes related to COVID-19.

This was not unique to our community, and in fact it was repeated throughout the country when other hospital systems transitioned to telehealth as a sensible and efficient way to deliver health care while implementing social distancing to combat the spread of COVID-19. Simultaneously, the diminished accessibility to technology based on various societal and social factors, sometimes referred to as the digital gap or digital divide, was being exposed at a critical time in a public health crisis. Frighteningly, there were no measures at the ready to address it.

Regarding the patient populations seen in our free clinics, our first concern was physical access to Internet services, defined largely by built environment factors. Our homeless population lacked reliable Internet access outside of the technology center at the clinic. About a third of those served at the rural CARES clinic site do not have Internet access in their homes. This is not unlike the Federal Communications Commission report in 2018 showing that within the United States, 31% of rural households still lack access to broadband Internet.

A combination of technology and in-person services has been found to help address some of this disparity, and in our case, a direct combination of the 2 types of service proved necessary.

Distance Learning

15. Title: School is starting – and the broadband gap will be a massive problem

Source: CNET

Reference: https://www.cnet.com/news/back-to-school-season-is-here-but-the-homework-gap-is-still-a-massive-problem/

Date: August 26, 2020

Attachment: "A36"

Abstract: The digital divide means millions of American children do not have broadband connections at home, even as their schools hold virtual classes.

This shift online has shined a light on a long-standing problem that has only gotten more severe in the age of the coronavirus: the so-called homework gap. The country has wrestled with a digital divide for decades, but the pandemic has exposed some of the most vulnerable populations: Students from poorer urban areas and remote rural districts, with minorities disproportionately hurt by lack of access to connectivity.

Schools are being forced to tackle the digital divide problem in their districts, becoming experts in complex broadband options seemingly overnight. That is on top of grappling with how to make sure their low-income students are fed and healthy, and navigating archaic regulations controlling how they receive funding. Various schools around the country have relied on emergency relief funds from the CARES Act to purchase devices and hotspots for students, while others have begged the public and businesses for help funding equipment.

This article outlines the hardships that school districts are facing across all of California, and nationally.

16. Title: **Distance Learning is Good for the Environment: Savings in GHG Emissions**

Source: Online Journal of Distance Learning Administration/University of West Georgia

Reference: https://www.westga.edu/~distance/ojdla/winter144/campbell_campell144.html

Date: 2011

Attachment: "A37"

Abstract: Distance learning is associated with a variety of benefits such as reduced use of campus facilities, increased accessibility, and control of disease transmission. In this study, we explore an additional benefit: mitigation of anthropogenic carbon dioxide emissions contributing to global climate change.

A survey was presented to 500 students enrolled in online courses on three college campuses. Students who commuted by personal car were asked to estimate whether taking the course online resulted in fewer driving trips to campus.

The environmental consequences of the estimated reduction in commute trips were assessed by calculating the CO2 emissions savings associated with reduced consumption of gasoline.

The results indicate that offering a lower-division class of 100 students with an online format leads to reduced CO2 emissions of 5-10 tons per semester, and knowledge of such an environmental benefit leads to enhanced student satisfaction with distance learning.

Broadband – Internet of Things

17. Title: **Greening Internet of Things for Smart Everythings with A Green Environment Life: A Survey and Future Prospects**

Source: Cornell University

Reference: https://arxiv.org/abs/1805.00844

Date: May 2, 2018

Attachment: "A38"

Abstract: Tremendous technology development in the field of Internet of Things (IoT) has changed the way we work and live. Although the numerous advantages of IoT are enriching our society, it should be reminded that the IoT also consumes energy, embraces toxic pollution and E-waste. These place new stress on the environments and smart world. In order to increase the benefits and reduce the harm of IoT, there is an increasing desire to move toward green IoT.

Green IoT is seen as the future of IoT that is environmentally friendly. To achieve that, it is necessary to put a lot of measures to reduce carbon footprint, conserve fewer resources, and promote efficient techniques for energy usage. It is the reason for moving towards green IoT, where the machines, communications, sensors, clouds, and internet are alongside energy efficiency and reducing carbon emission. This paper presents a thorough survey of the current on-going research work and potential technologies of green IoT with an intention to provide some clues for future green IoT research.

Energy

18. Title: **Understanding the Impacts of COVID-19 on Global CO2 Emissions**

Source: IEA Data, Global Energy Review

References: https://www.iea.org/news/after-steep-drop-in-early-2020-global-carbon-dioxide-emissions-have-rebounded-strongly

https://www.iea.org/articles/global-energy-review-co2-emissions-in-2020

Date: March 2, 2021

Attachment: "A39"

Abstract: After a steep drop in early 2020, Global Carbon Dioxide Emissions have rebounded strongly. Global energy-related CO2 emissions were 2% higher in December 2020 than in the same month a year earlier, according to IEA data, driven by economic recovery and a lack of clean energy policies.

The COVID-19 pandemic resulted in the largest-ever decline in global emissions. The COVID-19 pandemic and resulting economic crisis had an impact on almost every aspect of how energy is produced, supplied, and consumed around the world. The pandemic defined energy and emissions trends in 2020 – it drove down fossil fuel consumption for much of the year, whereas renewables and electric vehicles, two of the main building blocks of clean energy transitions, were largely immune. As primary energy demand dropped nearly 4% in 2020, global energy-related CO2 emissions fell by 5.8% according to the latest statistical data, the largest annual percentage decline since World War II. In absolute terms, the decline in emissions of almost 2 000 million tons of CO2 is without precedent in human history – broadly speaking, this is the equivalent of removing all of the European Union's emissions from the global total. Demand for fossil fuels was hardest hit in 2020 – especially oil, which plunged 8.6%, and coal, which dropped by 4%. Oil's annual decline was its largest ever, accounting for more than half of the drop in global emissions. Global emissions from oil use plummeted by well over 1 100 Mt CO2, down from around 11 400 Mt in 2019. The drop in road transport activity accounted for 50% of the decline in global oil demand, and the slump in the aviation sector for around 35%. Meanwhile, low-carbon fuels and technologies, in particular, solar PV and wind, reached their highest ever annual share of the global energy mix, increasing it by more than one percentage point to over 20%.

A common theme across all economies is the scale of the impact of the pandemic and lockdown measures on transport activity. The decline in CO2 emissions from oil use in the transport sector accounted for well over 50% of the total global drop in CO2 emissions in 2020, with restrictions on movement at local and international levels leading to a near 1 100 Mt drop in emissions from the sector, down almost 14% from 2019 levels. With various travel advisories and border restrictions, international aviation was the sector hardest hit in 2020, with global flight activity reaching a low in April 2020 of 70% below the level in the same month a year earlier. In contrast to pre-crisis levels, emissions from international aviation fell by almost 45% or 265 Mt CO2 across the year to a level last seen in 1999. This decline is equivalent to taking around 100 million conventional cars off the road.

Section 5 - Online Data Tools

1. Title: Annual Miles Traveled

Source: California Transportation Authority

Reference: https://data.ca.gov/dataset/annual-miles-traveled

Abstract: The Traffic Data Branch produces a Monthly Vehicle Miles of Travel (MVMT) report (often called the "Trend" report). This report estimates the number of vehicle miles that motorists traveled on California State Highways using a sampling of up to 20 traffic monitoring sites. Various roadway types are used to calculate VMT. The Monthly Vehicle Miles of Travel report for the California State Highway System gives the estimated vehicle miles driven and the resulting percentage changes in travel. The "Percentage of Change in Travel" charts are for driven over a three-year period.

2. Title: SCAG GIS Open Data Portal

Source: California Transportation Authority

Reference: https://gisdata-scag.opendata.arcgis.com/

Abstract: SCAG collects and allows open access to a variety of data sets, including census, environment, land-use, transportation, planning, and modeling.

3. Title: Total & Average Daily per Capita Vehicle Miles Traveled in LA County

Source: County of Los Angeles

Reference: https://data.lacounty.gov/dataset/Total-and-Average-Daily-per-Capita-Vehicle-Miles-T/ba5z-qxm7

Abstract: VMT Data in LA based on total and average daily vehicle traveled in LA, 2005 to 2017

4. Title: Special Report – Post COVID-19 Climate Impact Calculator

Source: Street Light Data

Reference: https://www.streetlightdata.com/special-report-post-covid-climate-impact-calculator/

Abstract: Much has been made of the environmental-impact “silver lining” of the COVID-19 pandemic stay-home orders. Plummeting traffic volume has created lower carbon output and greenhouse gas emissions, with previously congested and smog-choked cities reporting cleaner air and more abundant wildlife.

Streetlight Data has been tracking reduced vehicle miles traveled (VMT) totals across the country since March. And as the Brookings Institution recently found when analyzing our data, VMT has not been this low since 1998.