



Policy Briefs: Effects of Transportation and Land Use Policies and Strategies on Vehicle Use & Greenhouse Gas Emissions

Public Seminar - May 1, 2025

Policy Briefs Seminar Agenda

1. **Project overview:** John David Beutler
2. **Research process from the Principal Investigator:** Dillon Fitch-Polse
3. **Research team findings:** Susan Handy, Andre Comandon, Susie Pike, Jamey Volker, Elisa Barbour, Dillon Fitch-Polse
4. **Equity advisory team findings:** Ruben Abrica, Jesus Barajas, tamika butler, Rio Oxas, Moses Stites, JC Garcia
5. **Strategy comparison table:** Dillon Fitch-Polse
6. **Questions & answers**
7. **Next steps and conclusion:** John David Beutler

Project Summary / Abstract

The primary goal of this project is to **examine a select group of strategies** with the greatest **potential for reducing vehicle miles traveled (VMT) and greenhouse gas (GHG) emissions** by **synthesizing existing research**. UC Davis will consider a wide variety of **characteristics** associated with the selected strategies including the parallel goal of **improving social equity**. The long-term objectives for this project include the improvement of local, regional, and state strategies for reducing VMT. These objectives will be achieved through revisions to regional Sustainable Community Strategies (SCSs) and other transportation policies.

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Existing & New Policy Briefs

Research on Effects of Transportation and Land Use-Related Policies

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CARB staff collaborated with researchers at the University of California at Davis and University of Southern California to examine the existing scientific literature on the effects of key transportation- and land use-related policies as strategies to reduce vehicle miles traveled and greenhouse gas emissions. The goal of this effort is to help strengthen the technical underpinnings of regional planning processes, and identify important data gaps and research needs in support of SB 375.

The culmination of this collaborative effort is presented for each policy in the tables below. This includes two documents; a policy brief and a more detailed technical background document for practitioners. These materials may be used to help inform development of, and potential improvements to, the analytical models and tools used by metropolitan planning organizations and other public agencies for SB 375 implementation.

Susan Handy, Ph.D., UC Davis, discussed the results of research that support the policy briefs and technical background documents at a CARB research seminar held on October 7, 2014. [More Information](#)

<https://ww2.arb.ca.gov/our-work/programs/sustainable-communities-program/research-effects-transportation-and-land-use>

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Project timeline

- 2022** - Develop **Long List** of potential policy briefs
- 2023** - Refine topics to create **Short List** of briefs to work on
 - Create **template** for new briefs
 - Assemble **team** of researchers and equity advisory committee
 - Begin drafting and evaluating **briefs**
- 2024** - **Continue** drafting and evaluating briefs
- 2025** - Project completion and availability online

New and updated briefs

Automated (autonomous) vehicles	Residential density (including infill housing, rental protections)
Bike-share, scooter-share / micromobility	Road user pricing (including cordon pricing)
Car sharing	Roadway capacity and induced travel (new brief online)
Distance to transit	Seamless transit, ease of payment
Employer-based trip reduction (new brief online)	Street (or network) connectivity
Employment density (new brief online)	Telecommuting (new brief online)
Jobs-housing balance	Telemedicine / telehealth
Local scale land use mix / neighborhood accessibility	TNC / transit partnerships & MaaS
Microtransit (on demand)	Transit fare policies including free transit
Mobility hubs	Transit-oriented development (including renter protections)
New managed lanes / express lanes / HOV lanes / HOT lanes	Urban growth boundaries & land conservation (new version online)
Parking pricing	VMT fee / TNC fee (including gas prices)
Regional accessibility	Voluntary travel behavior change programs

Team Effort

Support

John David Beutler
And all CARB staff reviewers
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Writing and Review Process Changes

- Added outreach from author to equity advisor before reading and writing (not always done)
- Added meetings with authors and equity advisors as necessary during the editing phase
- Ran out of budget and time for second equity review of all briefs (need to budget more for equity committee in the future)
- Added a series of production steps to ensure high-standard of documents are accessibility

Research Synthesis

- Method: targeted literature searching, not exhaustive
- Selection of best studies from both internal (causal) validity, and external (generalizability) validity for California
- Documenting effect sizes, extent, synergy, equity

Effect Sizes

- Looking for % change in VMT for unit change in strategy
- Units of strategies are often different
- Sometimes other outcomes related to VMT depending on strategy
- Different measurement techniques, even within one strategy
- Difficult to compare because of different units

Strategy Extent

- How wide of a population could this strategy impact?
- Example of a large effect size and small extent
 - Travel behavior change program at one employer
- Example of small effect size and large extent
 - Increases in employment density throughout the city
- Also consider potential speed of implementation

Synergy

- How do other strategies support or work against a given strategy?
- For example, volunteer behavior change programs will be more effective with concurrent investments in public transit, walking, and bicycling

Equity

- Aim to report direct and indirect effects of strategies on social equity and justice
- If studies do not contain evidence, propose a starting place to consider equity and justice for each strategy
- Consider the context of the strategy
 - For example, compounded challenged inherently facing rural communities (both unincorporated and incorporated)
- Highlight the need for more research centered on equity and justice impacts

Strategies - 1

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Employment Density

Employment density is usually measured as the number of jobs per unit of land area (e.g., jobs per acres, employees per square foot). Employment densities may include changes to zoning ordinances to allow more non-residential uses, increases to building floorspace on each parcel, and reductions in parking requirements.

Outcome (units)	Interventions	Effect Size (range)	Extent	Synergy	Equity
VMT	Employees per Acre	Elasticity of -0.03	<ul style="list-style-type: none">• Greatest potential for VMT reduction in job-poor, low-density areas.• Changes to land-use policies plus financial incentives and infrastructure investments can increase employment densities.• Long-term strategy.	<ul style="list-style-type: none">• Land use policies that encourage concentrations of shopping and service destinations• High-quality transit service to employment centers.	<ul style="list-style-type: none">• Potential to increase access to jobs, depending on types of jobs.• Local measures needed to prevent displacement of current residents and gentrification.

Telecommuting

Telecommuting, also known as remote working, is the practice of working from home by employees who have a regular workplace.

Outcome (units)	Interventions	Effect Size (range)	Extent	Synergy	Equity
Person miles traveled (PMT)	For telecommuters on telecommuting days	-9.1%	<ul style="list-style-type: none">• Possible for employees whose work does not require physical presence.• Significant increase post-COVID, but some office presence often required.• As of 2022, 10.9% of US workers had option to telecommute.	<ul style="list-style-type: none">• Land use policies that promote neighborhood services.• Bicycle and pedestrian strategies.	<ul style="list-style-type: none">• Many low-wage jobs do not offer the possibility of telecommuting.

Land Conservation/Urban Growth Boundaries

Urban growth boundaries are a strategy for limiting the outward expansion of urbanized areas by discouraging, prohibiting, or preventing development outside of the boundary.

Outcome (units)	Interventions	Effect Size (range)	Extent	Synergy	Equity
VMT	Adoption of urban growth boundary (UGB) Acres of land conserved	Not available. Evidence suggests that VMT per capita is lower in urbanized areas that are more compact.	UGBs widely used by cities and counties in California. Land conservation used as a strategy to implement UGBs.	<ul style="list-style-type: none">• Growth boundaries most effective when implemented in conjunction with other growth management policies, e.g. infill development.• Land conservation not tied to a growth management program can increase VMT.	<ul style="list-style-type: none">• UGBs can increase housing costs and contribute to displacement• UGBs may reduce the cost burden of transportation by shortening travel distances.

Car Sharing

Carsharing services rent cars to their members for short periods of time, billing by the minute, hour, or day.

Outcome (units)	Interventions	Effect Size (range)	Extent	Synergy	Equity
Household VMT	Car sharing membership	<p>Evidence suggests that net effect of car sharing is a reduction in car ownership and VMT.</p> <p>Based on one study: -6 to -16%</p>	<ul style="list-style-type: none">• Car sharing services found in at least 384 US cities.• Can be implemented in urban, suburban, and rural areas.	<ul style="list-style-type: none">• Likely to be most effective in areas with good transit, walking, and biking options.• Population and employment density can support higher density of car-sharing vehicles.• Services can be included in mobility hubs and mobility wallets.	<ul style="list-style-type: none">• Services provide access to cars for households that cannot afford to own.• Can make it easier to reach health care and other critical services.• Public subsidies may be needed to ensure affordability and usability for low-income households.

Mobility Hubs

Mobility hubs provide coordinated access to public transit, bike share, car share, and other means of travel in a single location. They are designed to provide safe, comfortable, convenient, and accessible spaces for seamlessly transferring between modes.

Outcome (units)	Interventions	Effect Size (range)	Extent	Synergy	Equity
VMT	Construction of mobility hub	Not available.	<ul style="list-style-type: none">• Can be developed in places where transit routes converge.• Transit centers can be converted to mobility hubs with addition of access to bike-share, car-share, ride-hail, and other services.	<ul style="list-style-type: none">• Greater impact if implemented in conjunction with transit, bicycle, and pedestrian improvements.• Land use strategies can increase effectiveness of mobility hubs.	<ul style="list-style-type: none">• Help to improve quality of travel by modes other than driving.• Increase low-cost options for accessing destinations.• Incorporation of public services can enhance benefits to disadvantaged communities.

Strategies - 2

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Residential density

Density increases occur either as a result of infill development or when new development is at higher densities than existing development, either through market forces or through policy incentives such as zoning or land use regulation changes.

Outcome (units)	Interventions	Effect Size (range)	Extent	Synergy	Equity
Per capita or per household VMT	Population or housing unit density (e.g., persons per square mile).	<p>Reduction in VMT:</p> <ul style="list-style-type: none"> • between 4% and 12% associated with a doubling of density. • Studies that account for self-selection into dense areas estimate reductions as high as 22%. 	Most studies use the neighborhood (Census Tract, Block Group, or radius).	<p>Density is associated with:</p> <ul style="list-style-type: none"> • Proximity to downtown or employment centers • access to transit • mixed land uses • supportive walking environments <p>Changing multiple land use variables at once likely results in VMT reductions that are more than the sum of individual land use effect sizes.</p>	<p>Equity gains or mitigation of inequitable impacts of densification can be achieved when:</p> <ul style="list-style-type: none"> • Affordable housing is available for lower wage workers who may be displaced as a result of densification. • Housing cost are kept stable to prevent sacrificing other necessary expenses (e.g., health care)

Road pricing

Road pricing is a form of travel demand management designed to affect the amount, time, or place that people drive. Road charges are levied through tolls, cordons, or based on distance driven.

Outcome (units)	Interventions	Effect Size (range)	Extent	Synergy	Equity
Traffic volume/number of trips crossing toll/cordon	Fee at the toll or cordon	<p>A 10% increase in the toll fees:</p> <ul style="list-style-type: none">• 3% decrease in traffic volume at the tolled facility. <p>A 10% increase in cordon pricing:</p> <ul style="list-style-type: none">• 4.5 and 9% decrease in trips entering the area.	<ul style="list-style-type: none">• For tolls, the extent is the road segment.• Cordon pricing applies to a defined area, usually the center of a city.	<p>Synergy with public transit, especially for cordon pricing.</p> <p>In the absence of public transit the effect of cordon pricing weakens over time; the effect strengthens where pricing revenues support transit.</p>	<p>The equity effect depends on the availability of alternatives, like transit, which provide a cheaper replacement and exemptions or discounts to ensure a more progressive pricing.</p>

Gas taxes, distance-based charges, and TNC charges

Gas taxes, distance-based charges, and Transport Network Companies (TNC) charges are all types of fees that affect the overall cost of driving.

Outcome (units)	Interventions	Effect Size (range)	Extent	Synergy	Equity
<ul style="list-style-type: none"> Aggregate gas consumption and household VMT. Number of trips fees on transportation network companies. 	<ul style="list-style-type: none"> Change in the price of gas (sometimes translated to cost of driving per mile) change in the gas tax rate change in the charge per mile traveled. Change in congestion fees for TNC. 	<p>A 10% increase in the price of gas:</p> <ul style="list-style-type: none"> 2% to 3% decrease in gas consumption <p>A 10% increase in cost of driving:</p> <ul style="list-style-type: none"> 1% to 1.5% decrease 	<p>Nationally with some variation between states and local governments.</p>	<p>Pairing of a distance-based charging or TNC fees with a congestion pricing structure. This expands the purpose of DBC to include travel demand management and pollution reduction.</p>	<ul style="list-style-type: none"> Lower-income drivers pay a greater share of their income in gas taxes despite driving less. They are also more responsive to increases in the cost of driving, which can result in the cutting of essential travel. Redistribution programs or an income-based fee structure for DBC can mitigate the regressive nature of gas taxes. TNC charges have complex equity effects that can affect users and drivers.

Equitable Jobs-Housing Fit and Travel Demand

Jobs-housing balance: When the number of housing units is close to the number of jobs within a given area, people’s travel distance to and from work will be reduced.

Jobs-housing fit: when the housing is affordable to the people working in the area.

Outcome (units)	Interventions	Effect Size (range)	Extent	Synergy	Equity
Household VMT or commute VMT	<p>Jobs-housing balance:</p> <ul style="list-style-type: none"> the ratio of jobs to housing units <p>Jobs-housing fit:</p> <ul style="list-style-type: none"> the ratio of jobs by wage level to housing affordable to each wage level. 	<p>A 10% increase in the jobs-housing balance:</p> <ul style="list-style-type: none"> 0 to 3.5% VMT reduction. <p>A one standard deviation change in jobs-housing fit:</p> <ul style="list-style-type: none"> 9% decrease in commute distance. 	An area within 6-10 miles of household’s location.	<ul style="list-style-type: none"> The presence of nearby retail and other complementary land use can strengthen the effects of balance. The location of jobs within a region or city can greatly enhance the effect of jobs-housing balance by improving the viability of commuting by transit and reducing commute distances. 	Increasing housing costs have pushed many to live in locations farther from job centers and transit.

Strategies - 3

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Transit Fare Policies

Free and reduced fare (FAR) programs reduce or remove transit fare payment for passengers.

Outcome (units)	Interventions	Effect Size (range)	Extent	Synergy	Equity
Ridership	Change in fares, typically fare increases	Fare increases: -0.66 to -0.30; fare decreases or fare free: 32% to 200% increase (ridership)	<ul style="list-style-type: none">• Lower starting fare values and fare-free implementation in large urban areas may lead to lower ridership increases.• Ridership changes may be greater for off-peak travel.	<ul style="list-style-type: none">• May make service more efficient and reduce boarding and dwell time.• Reduced parking demand from unlimited access (university pass) programs may reduce parking demand (and thereby reduce supply and potentially further reducing driving).	<ul style="list-style-type: none">• Fare-free transit can:• improve transit's availability for lower-income groups,• remove fare-enforcement activities, and• reduce the burdens associated with qualification for means-based discounts.• All improvements to equity in transit.

Seamless Transit, Ease of Payment

Seamless transit strategies allow for easier and more efficient transit trip planning and payment.

Outcome (units)	Interventions	Effect Size (range)	Extent	Synergy	Equity
Ridership or mode use	Presence of seamless transit strategy	Integrated fares: 2.19% to 18.6% (unlinked trips); Realtime information: 1.7% to 17.1% (boardings and 1-way trips)	Key differences include real-time information having less impact for commuter rail vs. bus (Brakewood et al. 2015) and the reduced ability to implement real-time vehicle location information in rural/hilly areas due to connectivity.	<ul style="list-style-type: none">• Reduced traveler stress and/or improved comfort, convenience, and perceptions of transit service.• Paired with other efforts may strengthen impacts.• Improved efficiency by speeding up boarding, reducing idling times, and simplification of some backend systems.	<ul style="list-style-type: none">• Seamless transit can make transit service more convenient, but• the availability of some seamless travel features themselves, and/or the resulting benefits may vary across the population or different types of transit users.

TNC/Transit partnerships & MaaS

TNC partnerships with transit implement programs that subsidize TNC trips when they connect to/from transit, occur during non-service hours, or otherwise fill a gap that is not well served by fixed-route transit.

Outcome (units)	Interventions	Effect Size (range)	Extent	Synergy	Equity
Ridership or mode use	Presence of a partnership	50 percentage point reduction in auto mode share (Shen et al. 2021); 27% of sample decreased auto use	Population density is important for uptake. Regional service is likely more useful or effective than local service.	<ul style="list-style-type: none">• In areas where transit service is improved in coordination with a TNC program transit use may increase to a greater extent.• May also occur with improvements to trip planning, payment integration, or other features that make the entire system easier to use.	<ul style="list-style-type: none">• These programs can improve safety (safer connections, especially at night) and improve mobility and access to opportunities, particularly for transit-reliant groups.• But, like other technology-based transportation options, there may be limits on who has access to smartphones or data plans to support smartphone and thereby program use.• Additionally, smartphone and digital payment literacy can be barriers.

Microtransit (On demand)

Microtransit is a shared-ride, on-demand form of transit that offers point-to-point service within specified areas and times.

Outcome (units)	Interventions	Effect Size (range)	Extent	Synergy	Equity
Fixed-route or microtransit ridership or mode use	Presence of microtransit	25% to 28% (of sample) would decrease driving	One study finds that the use of microtransit and corresponding VMT are related to a number of factors, including employment and household density, income, street network, transit stop density, and car ownership (from Rath et al. 2023). Matching the service design to the locale is likely important for uptake and use.	Can serve first/last mile trips and thereby increase transit use.	<ul style="list-style-type: none">• Microtransit may improve transportation access and thereby mobility.• It may provide new options for those who use paratransit or those in rural areas.• In many instances, however it requires smartphone and digital payments literacy, which may make it less accessible for some users.

Strategies - 4

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Roadway Capacity/Induced Travel

Expanding roadways – by constructing new roadways or adding lanes to existing roadways – tends to induce auto travel (increase VMT).

Outcome (units)	Interventions	Effect Size (range)	Extent	Equity
VMT	Adding roadway lane miles	<p>Short-run elasticity (1-3 years): 0.3-0.8</p> <p>Long-run elasticity (3-10 years): ~1.0</p>	<ul style="list-style-type: none"> Capacity expansions cause a net increase in total VMT, not just a shift between roads. Similar elasticities for class 1-4 facilities, though class 1 interstate highways likely have the highest elasticity and local roads (class 7) likely have the lowest. Induced travel occurs in both urban and rural areas. Congestion is not a prerequisite for induced travel. HOV and HOT lanes have similar effects as general-purpose lane expansions 	<ul style="list-style-type: none"> Capacity expansions disproportionately burden people of color and lower-income people, during both construction and operation. Benefits, if any, are more likely to accrue to white and higher-income people. Lower-income groups travel less by car and less at peak times.

New Managed Lanes

Managed lanes include high-occupancy vehicle (HOV) lanes, high-occupancy toll (HOT) lanes, and pure toll lanes. Adding new managed lanes tends to induce auto travel (increase VMT).

Outcome (units)	Interventions	Effect Size and Extent	Equity
VMT	Adding new managed lane miles (not converting existing lanes)	<ul style="list-style-type: none">• Overall, similar induced travel effects as general-purpose lane expansions.• HOT or pure toll lanes could induce more VMT than adding a general-purpose lane on hyper-congested roadways.• Tolloed lanes could have lower elasticities if they are priced prohibitively.	<ul style="list-style-type: none">• Capacity expansions of any type disproportionately burden people of color and lower-income people, during both construction and operation.• Benefits, if any, are more likely to accrue to white and higher-income people. Lower-income groups travel less by car and less at peak times.• Tolling revenues can be used to help offset the burden on lower-income drivers, such as by subsidizing non-auto travel modes.• However, tolling revenues are usually used primarily to cover the construction and operating costs of the managed lanes, which can leave little left over for public transit subsidies or other purposes

Parking Pricing

Increasing existing parking prices, charging for parking that is currently offered for free, or offering alternatives to free parking (e.g., parking cash-outs) have the potential to reduce.

Outcome (units)	Interventions	Effect Size (range)	Extent	Synergy	Equity
<ul style="list-style-type: none"> • Parking volume • VMT 	<ul style="list-style-type: none"> • Increasing the price of parking • Parking cash-out programs • Adaptive pricing 	<ul style="list-style-type: none"> • Regular pricing: Elasticity for commute trips: -0.5; Elasticity for non-commute trips: -0.3 • Parking cash-out: 12% reduction in VMT/capita • Adaptive pricing: Likely, but uncertain, reduction in both parking volume and VMT 	<ul style="list-style-type: none"> • Fast-acting – effects seen quickly after implementation • Adaptable • Possibly lower effects in suburban or rural areas 	<ul style="list-style-type: none"> • Work in concert with other parking restrictions (e.g., residential parking maximums and residential parking permits) to prevent spillover and effect travel behavior changes 	<ul style="list-style-type: none"> • Nominally regressive, but not necessarily in aggregate – lower-income commuters much less likely to drive to work than higher-income commuters • Parking pricing can promote transportation equity by compensating those who are disproportionately affected or subsidizing non-auto travel modes

Distance to Transit

Our brief focuses on how the distance between residences and transit stations and stops – a key indicator of transit access – affects VMT.

Outcome (units)	Interventions	Effect Size (range)	Extent	Synergy	Equity
Household VMT	Distance from residences to transit	<ul style="list-style-type: none">Elasticity of -0.05 (1.25% reduction in household VMT per mile closer to transit stop) from meta-analysesPerhaps a greater elasticity for bus transit, but a lower maximum effect due to the smaller effect radius	<ul style="list-style-type: none">Effect radius for rail transit: ~4 milesEffect radius for bus transit: ~1 mile	<ul style="list-style-type: none">Greater effect on VMT with higher quality transit service, lower transit cost, access to more destinations, and higher cost or greater inconvenience of auto use	<ul style="list-style-type: none">Distance to transit is a measurement, not itself an implementable strategy, so equity effects are unclear.Equity effects (e.g., displacement and gentrification) of strategies to increase transit access (like TOD) are examined in separate policy briefs

Strategies - 5

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Land use mix (local accessibility)

Land-use mix (LUM), or mixed-use development, can be defined as accommodating more than one type of function within a building, a set of buildings, or a specific local area. These functions can be delineated in categories such as residential, office, retail, and personal services, as well as parks and open space.

Outcome (units)	Interventions	Effect Size (range)	Extent	Synergy	Equity
VMT per person or household (sometimes for work and non-work trips separately)	<ul style="list-style-type: none"> • Most commonly measured using an entropy (balance) index, or sometimes as JHB in a given local area • The area boundary is (preferably) measured using dynamic buffers but often for bureaucratic units such as tracts, zip codes 	<ul style="list-style-type: none"> • Average elasticities from Ewing and Cervero (2010) and Stevens (2017) meta-analyses: -0.09 and -0.03, respectively • Elasticities from four post-2000 US studies with comparable methods (entropy index, dynamic buffers): -0.04 to -0.10 	<ul style="list-style-type: none"> • Land use mix is widely advocated as a sustainability measure, so as to place trip origins and destinations in closer proximity. • Many localities have adopted mixed-use zoning (3/4s of California cities) 	<ul style="list-style-type: none"> • Perhaps the main co-benefit and synergy is with the facilitation of walking, biking, and transit use • The impact of LUM is greater for inducing walking trips than for VMT reduction • Transit use increases when compact, mixed land uses are located nearby 	<ul style="list-style-type: none"> • Since low-income people tend to drive less and use transit and walk more than higher-income people, they benefit from local accessibility • Measured in terms of physical street connectivity, socially vulnerable populations do not experience lower accessibility than others, but considered in relation to other factors including street greenery, sidewalk conditions, and safety factors including exposure to crime threats, they do • Furthermore, socially vulnerable groups are disadvantaged in accessibility to certain destinations including shopping and supermarkets

Regional accessibility

Regional accessibility describes the ease with which destinations can be reached throughout an urban region. The proximity of trip origins, residences in particular, to potential destinations such as jobs or shops, and the nature of the transportation links between them, together determine accessibility.

Outcome (units)	Interventions	Effect Size (range)	Extent	Synergy	Equity
VMT per person or household (sometimes for work and non-work trips separately)	<ul style="list-style-type: none"> • Research commonly focuses on commuting by automobile or transit • The most basic measure is the distance from a residence to the CBD • Cumulative opportunities measures are also common, counting potential destinations (typically jobs) within a certain distance or travel time from a residence • Sometimes an impedance factor is used to discount destinations at further distances 	<ul style="list-style-type: none"> • Average elasticity from Ewing and Cervero (2010) and Stevens (2017) meta-analyses: -0.20 • Elasticities from two US studies that employed a gravity measure (recommended): -0.10 and -0.13 	<ul style="list-style-type: none"> • Regional accessibility reflects the interaction of transportation and land use at the local, intermediate, and regional scales • For longer trips, carpooling and transit are the main modes that can compete with SOVs • Transit use depends on network accessibility (e.g. # jobs accessible w/in a 30-minute trip), but this in turn depends on desirable destinations being located near multiple transit stops 	<ul style="list-style-type: none"> • Especially when coordinated over time, transit and TOD can be mutually supportive and synergistic, which could enhance transit accessibility • Job growth in inner-ring suburbs could also possibly help • Synergy is also possible with pricing strategies for roadways and parking 	<ul style="list-style-type: none"> • Low-income and non-white households do not, on average, experience lower regional accessibility traceable to residential location, reflecting historic policies and conditions • But many equity advocates call for a redistributive justice approach to identify and provide minimum levels of adequate regional transit accessibility to all transit-dependent households • Strategies to support equitable TOD, such as by supporting affordable housing near transit and designing safe, convenient transit access, can help ensure transit availability for those who need it

Transit-Oriented Development (TOD)

TOD has been defined as “a compact, mixed-use community, centered around a transit station that - by design - invites residents, workers, and shoppers to drive their cars less and ride mass transit more” (Bernick and Cervero, 1997).

Outcome (units)	Interventions	Effect Size (range)	Extent	Synergy	Equity
VMT per person or household	<ul style="list-style-type: none"> TODs are transit-proximate areas characterized by high density, mix of land uses, and street connectivity While TOD is most often considered at a local scale, some practitioners and scholars expand the concept to encompass transit corridors or even full metro areas TOD can be distinguished from TAD - transit-proximate areas that lack density, mixed land use, and/or walkability 	<ul style="list-style-type: none"> Substantial average differences in household VMT are found between TOD residents vs. non-TOD residents, falling between 28% and 41% TOD-versus-TAD differences slightly exceed transit-adjacent versus non-transit adjacent differences 	<ul style="list-style-type: none"> Although many researchers have examined travel behavior for any areas near transit, fewer have distinguished TODs from TADs One national study of 549 station areas found that TODs, with high values for density, land use mix, and walkability, comprised only 13% of them Much land located near transit, even in central cities, is zoned for low-density development 	<ul style="list-style-type: none"> Potential co-benefits and synergies of TOD pertain to public health, economic efficiency/ productivity, and community integration and vibrancy Pricing policies, such as for parking, can support TOD, along with zoning and financing to promote compact mixed-use development, reduce parking requirements, and support affordable housing, to help make TOD more viable and equitable 	<ul style="list-style-type: none"> Low-income households generally benefit income-wise from living in TODs, because lower transportation costs in TOD zones generally outweigh higher housing costs The difference in VMT between TOD versus non-TOD residents is higher for high-income than low-income households, leading scholars to conclude that new market-rate TOD housing is an effective VMT reduction strategy But protections are needed to ensure that low-income residents are not displaced in gentrifying TOD areas

Strategies - 6

Automated (autonomous) vehicles	Residential density (including infill housing, rental protections)
Bike-share, scooter-share / micromobility	Road user pricing (including cordon pricing)
Car sharing	Roadway capacity and induced travel (new brief online)
Distance to transit	Seamless transit, ease of payment
Employer-based trip reduction (new brief online)	Street (or network) connectivity
Employment density (new brief online)	Telecommuting (new brief online)
Jobs-housing balance	Telemedicine / telehealth
Local scale land use mix / neighborhood accessibility	TNC / transit partnerships & MaaS
Microtransit (on demand)	Transit fare policies including free transit
Mobility hubs	Transit-oriented development (including renter protections)
New managed lanes / express lanes / HOV lanes / HOT lanes	Urban growth boundaries & land conservation (new version online)
Parking pricing	VMT fee / TNC fee (including gas prices)
Regional accessibility	Voluntary travel behavior change programs

Employer-based trip reduction

Commuter benefits provided by employers or local and regional agencies such as: **alternative mode services** (e.g., carpool facilitation, vanpool, carsharing), **monetary incentives** (e.g., mode-specific payments or subsidies, such as discounts for transit, and parking cash-out), **worksite facilities supporting active travel** (e.g., showers, lockers, and bicycle parking), **flexible work hours**, and **information and marketing campaigns**.

Outcome (units)	Interventions	Effect Size (range)	Extent	Synergy	Equity
Work commuting VMT (miles) of participants, sometimes regionwide or per employee per year	Variety of program types <ul style="list-style-type: none"> Ebike and Bike lending Financial incentives Transit subsidies Mobility services Parking cash-out 	Reduction in VMT: 4-76% (participant) 4-12% (workplace) 1-2% (regional)	<ul style="list-style-type: none"> Direct benefits at the employee scale Co-benefits for surrounding populations Quick implementation and quick effects Limited ability to scale since at the employer level 	<ul style="list-style-type: none"> walking and bicycling infrastructure transit quality access to work 	Equity gains are more likely to occur when... <ul style="list-style-type: none"> equity is a leading principle in the access and benefits of the programs to employees state laws require employers to provide such commuter benefits they support workers who live in car dependent situations because of historical racial and economic burdens.

Voluntary travel behavior change programs

A range of travel demand management techniques designed to encourage carpooling, taking transit, walking, and biking. This is accomplished through **outreach and education** that targets individual attitudes, goals, and behaviors; increasing awareness of the impacts of travel choices; and equipping travelers with the skills necessary to analyze and alter their travel behavior (Fujii et al., 2009; Steg 2003).

Outcome (units)	Interventions	Effect Size (range)	Extent	Synergy	Equity
VMT	Variety of program types (unitless)	Reduction in VMT 5-9%	<ul style="list-style-type: none">• Quick and Cheap• Cost effective for rapid benefit accrual at participant level	<ul style="list-style-type: none">• Transit and active transportation investments• Best where destination accessibility is high	<ul style="list-style-type: none">• Great potential for social equity gains• Authentic and culturally specific outreach is necessary (e.g., multiple languages using plain language)

Street (or network) connectivity

Describes the transportation connections that link each of the points in a community with one another (from gridded streets to fragmented networks with loops and long block lengths). The structure of the street network is often a proxy for the transportation and land use characteristics of the design era.

Outcome (units)	Interventions	Effect Size (range)	Extent	Synergy	Equity
VMT per person or household (sometimes for work and non-work trips separately)	Variety (e.g., percent of 3- or 4-way intersections, average block length, street links per sq. mile, mean nodal degree, etc.)	VMT change for 1% increase in "connectivity" as defined by source: ~ -0.12% (range from -0.3% to -0.03% trimming top and bottom 3 studies)	<ul style="list-style-type: none">• Densifying existing networks and ensuring new networks are well connected must be pervasive in regions to expect VMT reduction• Slow to accrue benefits• Some evidence suggests the VMT reduction benefits grow over time	<ul style="list-style-type: none">• Increased population density and land use mix.• Without appropriate residential and destination densities, increasing street connectivity may have limited car use reduction, instead only making driving easier by providing more travel routes.	<ul style="list-style-type: none">• Largely unknown and difficult to estimate. More research is needed on the relationship between network connectivity and both social equity and environmental justice

Bike-share, scooter-share/ micromobility

One-way rental of bicycles, e-bicycles, and e-scooters. Docked forms of the service include permanent fixed parking, locking, and sometimes charging locations, while dockless (free floating) services have no such fixed infrastructure but have varying rules about parking

Outcome (units)	Interventions	Effect Size (range)	Extent	Synergy	Equity
VMT reduction per micromobility trip	Presence of micromobility vehicle	VMT reduction: ~0.5 miles per micromobility trip (range: 0.21 to 0.68 miles trimming top and bottom 2 results)	<ul style="list-style-type: none">• Need dense and mixed use areas where destination accessibility is within a few miles• Micromobility services continue to grow in terms of trips made in the US at a rapid rate, although that rate is slowing	<ul style="list-style-type: none">• land use strategies that densify and mix uses in urban areas• Integrating micromobility services with existing public transportation systems	<ul style="list-style-type: none">• Mixed evidence about which service type provides greater access to underserved neighborhoods• Geofencing technology could exacerbate existing inequities if used to halt the use of vehicles in low-income communities of color• More research is needed to examine meaningful change in structural transportation inequities from micromobility

Telemedicine/Telehealth

Use of information communication technology (ICT) to provide healthcare services to patients. This service acts as a substitute for face-to-face (FTF) outpatient services which require travel by patients to medical facilities.

Outcome (units)	Interventions	Effect Size (range)	Extent	Synergy	Equity
Travel reduction (miles) per visit	Telemedicine in place of in-person health care visits (outpatient)	Travel reduction: ~18 miles	<ul style="list-style-type: none">• Telemedicine grew rapidly with the COVID-19 pandemic but growth has recently slowed• Some evidence suggests the rate of health care visits is roughly 18% virtual• One study suggests that nearly 50 million additional telemedicine visits nationally (US) per year could be made if inequities were addressed	<ul style="list-style-type: none">• May be synergy with telecommuting if one or the other provides more comfort with meeting remotely	<ul style="list-style-type: none">• Urban residents use telehealth more than rural residents, even though VMT reduction benefits are greater per visit for rural residents.• Use of telehealth is also lower for low-income patients and patients on Medicare.• Inequities in telemedicine use may be tied to lower access to broadband internet, telemedicine opportunities, and other barriers.

Autonomous Vehicle

Rapidly developing technology that performs a variety of vehicle driving functions ranging from adaptive cruise control to full automated (driverless) control. AVs are **not** by themselves a VMT reduction strategy. **Policies and regulations** of AV deployment can function as levers for VMT reduction.

Outcome (units)	Interventions	Effect Size (range)	Extent	Synergy	Equity
VMT	Personally owned and shared, partial and fully automated	<p>VMT increase:</p> <p>Personally owned L4 ~ 30% (range of 13% to 83%)</p> <p>PAV ~24% (range of 14% to 29%)</p>	<ul style="list-style-type: none"> • AV technology is rapidly deploying, but projections are mixed about the speed of market penetration. • There is potential for wide private adoption of AVs, although costs that are (expected to be many times greater than current cars) may slow adoption penetration. • Shared fleets are likely to be more widely available before private AVs. 	<ul style="list-style-type: none"> • Existing pricing strategies for reducing congestion and VMT reported in other briefs from this series (e.g., facility-based, cordon, zonal, and distance-based) • Other more stringent regulations could include mandating AVs be shared in the form of buses and shuttles to ensure ride pooling 	<p>Concerns include...</p> <ul style="list-style-type: none"> • Inequitable design of AVs in terms of safety, particularly bias of software in detecting pedestrians uniformly, particularly detection bias of those who are Black or dark colored skin, children, women, etc. • potential job loss for ridehail drivers, delivery industry, and transportation industry including bus, train, or truck operators if AVs replace those jobs. <p>However, AVs may also provide equity benefits....</p> <ul style="list-style-type: none"> • AVs may provide access to destinations for people that are mobility challenged (e.g., disabled, no vehicle access, rural).

Reflections on Equity in the Policy Briefs

- City planning and transportation planning have a history of systemic injustice
- VMT reduction strategies have the potential to repair injustices, but also the potential to exacerbate existing injustices
- A need for authentic community engagement
- Equity in the briefs have a common basis in the lack of representation of low-income neighborhoods and communities of color in past and present policy decisions
- Need to address short-term negative effects on equity and justice for individuals and communities from such strategies
- Each brief serves as a starting point for considering equity and justice
- These briefs are also a call for future research to center the perspectives of people most affected by these strategies to fully illuminate their implications for social equity, health disparities, and justice

DRAFT Strategy Comparison (Warning: Difficult to compare strategies)

- Considering effect size, extent, ease, and certainty
- Largest potential for land use strategies and pricing
- Nothing acts independently, some strategies require coordination (transit fares and distance with land use changes)
- Some strategies are not likely VMT reducing
- Some can be implemented relatively quickly to meet 2035 targets
- **This is a way to help think about strategies, it is not a recipe for prioritization!**

Topic	Effect Size	Extent	Ease to implement	Certainty
Regional accessibility	Large	Large	Difficult	High
VMT fee/TNC fee (incl. research on gas price)	Large	Large	Difficult	Moderate
Road user pricing (incl. Cordon Pricing)	Moderate	Large	Difficult	High
Employment density	Moderate	Large	Difficult	Low
Jobs-housing balance	Moderate	Large	Difficult	Low
Street (or network) connectivity	Moderate	Large	Difficult	Moderate
Telecommuting	Moderate	Large	Easy	Moderate
Local scale Land use mix/ neighborhood accessibility	Moderate	Large	Difficult	High
Residential density (incl. Infill housing, rental protections)	Large	Moderate	Difficult	Moderate
Transit-oriented development (TOD) (incl. renter protections)	Large	Moderate	Difficult	Moderate
Transit fare policies including free transit	Large	Moderate	Easy	Low
Distance to transit (Transit access)	Moderate	Moderate	Difficult	Low
Seamless transit, ease of payment	Moderate	Moderate	Easy	Low
Parking pricing	Moderate	Moderate	Moderate	Moderate
Car sharing	Large	Small	Easy	Low
Voluntary travel behavior change programs	Large	Small	Easy	Moderate
TNC/Transit partnerships & MaaS	Moderate	Small	Easy	Low
Microtransit (On demand)	Small	Small	Easy	Low
Employer-based trip reduction	Large	Small	Easy	Moderate
Telemedicine/Telehealth	Large	Small	Easy	High
Bike-share, scooter-share/ micromobility	Small	Small	Easy	Moderate
Land conservation policies/ Urban growth boundaries	Unknown	Large	Moderate	Low
Mobility hubs	Unknown	Small	Moderate	Low
New managed lanes/Express lanes / HOV lanes/HOT lanes	NOT VMT Reducing	Large	Easy	Moderate
Highway capacity/ Induced travel	NOT VMT Reducing	Large	Moderate	High
Autonomous vehicles	NOT VMT Reducing	Large	Easy	Low

DRAFT Strategy Comparison + Speed

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Conclusion

Next steps:

- Finalize the remaining briefs for placement online

Additional questions or comments:

- Email John - john.beutler@arb.ca.gov

Thanks for attending!