POLICY BRIEF

CALIFORNIA
AIR RESOURCES BOARD

Managed Lanes

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Program Description

This project reviews and summarizes empirical evidence for a selection of transportation and land use policies, infrastructure investments, demand management programs, and pricing policies for reducing vehicle miles traveled (VMT) and greenhouse gas (GHG) emissions. The project explicitly considers social equity (fairness that accounts for differences in opportunity) and justice (equity of social systems) for the strategies and their outcomes. Each brief identifies the best available evidence in the peer-reviewed academic literature and has detailed discussions of study selection and methodological issues.

VMT and GHG emissions reduction is shown by effect size, defined as the amount of change in VMT (or other measures of travel behavior) per unit of the strategy, e.g., a unit increase in density. Effect sizes can be used to predict the outcome of a proposed policy or strategy. They can be in absolute terms (e.g., VMT reduced), but are more commonly in relative terms (e.g., percent VMT reduced). Relative effect sizes are often reported as the percent change in the outcome divided by the percent change in the strategy, also called an elasticity.

Summary

Strategy Description

Roadway capacity expansions in California—particularly on freeways and highways—are increasingly implemented through the addition of managed lanes rather than general-purpose lanes. Managed lanes include high-occupancy vehicle (HOV) lanes, high-occupancy toll (HOT) lanes, and pure toll lanes. However, managed lanes, like general-purpose lanes, can induce additional vehicle travel – a net increase in vehicle miles traveled (VMT) across the roadway network due to an increase in roadway capacity.

Behavioral Effect Size and Extent

The empirical evidence suggests that managed lanes might have similar induced travel effects as general-purpose lane expansions. On very congested roadways, adding an HOT or pure toll lane could induce greater VMT than adding a general-purpose lane. On the other hand, tolled lanes could have lower elasticities than general-purpose lanes if they are priced so prohibitively that very few people decide to take them.

Equity Effects

In general, the evidence indicates that roadway capacity expansions of any type disproportionately burden people of color and lower-income people, while their benefits (if any, once induced VMT is accounted for) are more likely to accrue to white and higher-income people.

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Congestion mitigation has fewer advantages for lower-income groups because lower-income workers and travelers travel less by car generally. They also travel less at peak times due to scheduling and their trip distances are often shorter, so the benefits of flow improvements are limited.

Tolling revenues can be used to help offset the burden imposed on lower-income drivers, such as by subsidizing non-auto travel modes or providing a transportation credit to lower-income households. 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.

Strategy Description

Roadway capacity expansions—particularly on freeways and highways—are increasingly implemented through the addition of managed lanes rather than general-purpose lanes. For purposes of this brief, we define managed lanes as high-occupancy vehicle (HOV) lanes, high-occupancy toll (HOT) lanes, and pure toll lanes. HOV lanes are restricted to vehicles with a certain number of occupants (often 2+ or 3+ occupants, but sometimes more). HOT lanes are available to both high-occupancy vehicles (free of charge) and vehicles below the occupancy threshold that pay the requisite toll. Pure toll lanes are only available to vehicles that pay a toll and (generally) public transit vehicles. The usage restrictions for all types of managed lanes can vary by hour, by period, by day, or dynamically according to traffic conditions.

For the most part, managed lanes in the United States are still constructed anew. While some projects in California are considering managed lane conversion alternatives, these types of projects have yet to be implemented and studied. This brief focuses on new managed lanes, rather than conversions. Comandon and Boarnet (2025) discuss in a separate policy brief the impacts of altering the tolls on existing toll roads, instituting cordon pricing, changing cordon pricing amounts, and VMT-based pricing schemes.

Overall, as of 2021, there were 2,872 HOV lane miles, 1,142 HOT lane miles, and 716 miles of express toll lanes in the US, 38% of which were in California (Federal Highway Administration, 2021). That compares to more than 200,000 lane miles of interstate highways and more than 8 million miles of total roadways across the US. Nonetheless, new managed lanes constitute a growing share of capacity expansion projects in California and elsewhere. For example, nearly 43% of the through lane miles added to the California State Highway System between July 2018 and June 2023 were managed lanes (Caltrans, 2025a). This makes it increasingly important to understand how they affect automobile use and its attendant impacts.

In general, empirical research demonstrates that as roadway supply increases vehicle miles traveled (VMT) generally does, too. This is the "induced travel" effect—a net increase in VMT across the roadway network due to an increase in roadway capacity, which ultimately erodes any initial increases in travel speeds and causes increased greenhouse gas emissions. A pressing question for managed lanes is whether they cause more or less induced travel than expansions of general-purpose lanes (lanes with no monetary or occupancy-related access restrictions).

Strategy Effects

Behavioral Effect Size and Extent

The magnitude of the induced travel effect is often measured as the elasticity of VMT with respect to lane miles, as shown in Equation 1. The elasticity is the percentage increase in VMT in the studied area that results from a 1% increase in lane miles in that area. An elasticity of 1.0 means that VMT will increase by the same percentage as the increase in lane miles.

$$\text{Elasticity} = \frac{\%\ \text{Change in VMT}}{\%\ \text{Change in Lane Miles}} \quad \text{(Eq. 1)}$$

Most empirical studies of induced travel use aggregate VMT and lane mile data for both general-purpose and managed lanes. This results in blended elasticity estimates for all lane types combined, though the vast majority of lane miles were – and still are – general-purpose. The results from these studies indicate a longer-run induced travel elasticity of close to 1.0 across the four primary facility types studied – interstate highways, other freeways and expressways, principal arterials, and minor arterials – albeit a potentially greater elasticity for expansions of interstate highways (Volker & Handy, 2022).

However, very few studies have attempted to isolate induced travel effects from managed lanes, as previous literature reviews confirm (Anderson et al., 2021; Shewmake, 2012; Volker & Handy, 2022). Most studies of the induced travel effects of managed lane additions rely on simulations using travel demand models or related methods (Dahlgren, 1998; Johnston & Ceerla, 1996; Rodier & Johnston, 1997). We found only one study that directly estimated induced travel elasticities for managed lane additions using empirical data (Anderson et al., 2021).

Anderson et al. (2021) used time series loop detector data to estimate the short-run effects on traffic flows of four capacity expansion projects in California. One project added an HOT lane to I-580 in Alameda County in 2016. Another project added an HOV lane and connecting bridges to I-405 in Orange County in 2014. A third project added one general-purpose lane and one HOV lane to I-215 in San Bernardino County in 2010. The fourth project – the Caldecott Tunnel Fourth Bore – added two general-purpose lanes (both in the off-peak direction) to State Route 24 in Alameda and Contra Costa counties. The authors also analyzed the traffic flow changes at comparison sites without lane expansions to help control for unobservable factors influencing traffic flows at the study sites.[1]

Using regression analyses that controlled for monthly, weekly, and daily traffic patterns, Anderson et al. (2021) found statistically significant short-run increases in total traffic volumes[2] – and thus, VMT – on all four facilities post expansion. By contrast, their analysis of the comparison sites showed smaller (and sometimes negative) changes in traffic flows over the same time periods. As a result, the authors concluded that most of the observed flow increases on the expanded facilities likely reflected induced travel due to the expansions, while other factors were "unlikely to explain more than a small fraction" of the flow increases (Anderson et al., 2021, p. 54). That allowed the authors to estimate "implied" induced travel elasticities for the four study sites, calculated as the ratio of the percentage change in total traffic flows (across all lanes combined) to the percentage change in total lanes. Table 1 shows the implied short-run elasticities (one- or two-year time period) for the four study sites.

[1] The comparison sites were in the same counties as the study sites, but the authors attempted to choose comparison locations that were "unlikely to be traversed by trips that also cross the study site of interest, so as to avoid capturing any direct impacts of the lane expansions" (Anderson et al. 2021, p. 13).

[2] This equals total traffic volume in all lanes combined for the expanded stretch of each facility. For the I-580 expansion, the authors were not able to observe data in the HOT lane that was added. So, the documented flow increases were on the existing general-purpose lanes only. The percent increases would have been even greater if the HOT lane flow data had been included.

Table 1: Implied Elasticity Estimates for the Four Study Sites from Anderson et al. (2021)

Expansion Project Name	Roadway	County	Year of Expansion	Type of Expansion	Change in Total Lanes	Change in Total Flows	Implied Short-run Elasticity
I-580 Express Lanes	I-580 (class 1 interstate)	Alameda	2016	One new HOT lane	+25% (4 to 5)	+17.5%	0.700
West County Connectors	I-405 (class 1 interstate)	Orange	2014	One new HOV lane and new connectors	+14% (7 to 8)	+11.8%	0.843
San Bernardino Widening Project	I-215 (class 1 interstate)	San Bernardino	2010	One new HOV lane and one new general-purpose lane	+67% (3 to 5)	+22.4%	0.334
Caldecott Tunnel Fourth Bore	SR-24 (class 2 highway)	Alameda and Contra Costa	2013	Two new general-purpose lanes	+100% (2 to 4)	+15.2%	0.152

Overall, Anderson et al. (2021, p. 65) found that the “implied elasticities [were] similar across different types of lane expansions, and in all cases within the range of estimates from previous studies” (like those summarized in Table 1). Because these are facility-level estimates, they do not account for the wider regional effects on travel, including route diversions from alternate routes (a potential reduction in travel elsewhere) and longer trips (an increase in travel elsewhere), as the authors note. However, the available evidence indicates at most a minimal substitution effect (Duranton & Turner, 2011; Handy & Boarnet, 2014), suggesting that Anderson et al.’s (2021) results might, if anything, underestimate the induced travel effect. In sum, although the study’s facility-level analyses do not capture the expansion projects’ full regional effects on travel and are not necessarily generalizable to other locations, the results nonetheless indicate that the induced travel effect for HOV and HOT lanes can be just as large as the effect for general-purpose lanes.

Two additional pieces of empirical evidence from California support those conclusions. First, Bento et al. (2014) analyzed loop detector data from all freeways with HOV lanes in the Los Angeles metro areas at the beginning and the end of a policy that allowed vehicles with a “clean air vehicle” sticker to use HOV lanes alongside high-occupancy vehicles. Using a regression discontinuity model, they found statistically significant short-run increases in traffic flows on the region’s HOV lanes, but no statistically significant change in flows on the general-purpose lanes. The authors concluded that while “policymakers may have expected congestion decreases in the mainline to be a potential benefit of the policy, these results are suggestive of the presence of induced demand” (Bento et al., 2014, p. 19).

Second, Caltrans loop detector data from 2024 show that the average annual traffic flows on the state’s HOV and HOT lanes were higher than on the adjacent general-purpose lanes. Flows on the HOV and HOT lanes averaged 1,046 vehicles/hour/lane across the morning and afternoon peak periods (5am-10am, 3pm-8pm), about 2% higher than on the adjacent general-purpose lanes during the same time periods (1,029 vehicles/hour/lane) (California Department of Transportation, 2025b). The similar flows indicate that, despite their access restrictions, HOV and HOT lanes will eventually reach similar flows as general-purpose lanes during periods of peak congestion. That in turn suggests that adding HOV and HOT lanes has similar induced travel effects (elasticities) to general-purpose lane expansions, assuming that traffic flows in the general-purpose lanes do not decrease after the managed lane addition. The findings from both Anderson et al. (2021) and Bento et al. (2014) support that assumption.

The induced travel effects of the third category of managed lanes – pure toll lanes – are less certain. Pure toll lanes could have anywhere from zero induced travel effect (if they are priced so prohibitively that no one uses them) to a greater induced travel effect than general-purpose lanes if they are priced so as to prevent the roadway from becoming hypercongested – the point where traffic becomes so dense that both speed and flows decrease (Small & Chu, 2003). We only found one empirical study that accounts for tolling. Garcia-López et al. (2020) estimated induced travel elasticities for highway expansions in the 545 largest metropolitan areas (functional urban areas) in Europe. The study authors estimated separate elasticities based on the extent of tolling on each region's highways, ranging from a maximum elasticity of 1.9 in regions without tolls to an elasticity of 0.3 in regions with tolls on all their highways. They estimated an elasticity of at least 1.0 in regions with tolls on less than 56% of their highways (Garcia-López et al., 2020, p. 14). However, the authors did not account for the amount of the tolls.

Overall, the available empirical evidence suggests that new HOV and HOT lanes might have similar induced travel effects as general-purpose lane expansions. Furthermore, because HOT lanes allow more vehicles than HOV lanes (high-occupancy vehicles plus drivers willing to pay to use the lane), they would logically have at least as large of induced travel effects as HOV lanes. Indeed, on very congested roadways, adding an HOT or pure toll lane could induce greater VMT than adding a general-purpose lane, assuming the lanes are priced so as to prevent the roadway from becoming hypercongested – the point where traffic becomes so dense that both speed and flows decrease (Small & Chu, 2003). However, tolled lanes could have lower elasticities than general-purpose lanes if they are priced so prohibitively that very few people decide to take them.

Equity Effects

Building additional roadway capacity of any type can have major equity implications. In general, the evidence indicates that roadway capacity expansions disproportionately burden people of color and lower-income people, while their benefits (if any, once induced VMT is accounted for) are more likely to accrue to white and higher-income people.

People living close to high-traffic roadways, including freeways and highways, are more likely to have lower incomes and more likely to be people of color (Antonczak et al., 2023; Manville & Goldman, 2018; Loukaitou-Sideris et al., 2023). For example, Antonczak et al. (2023) investigated the sociodemographic disparities in exposure to high vehicular traffic volumes in the US. Using a proximity-based analysis, they found that 31.8% of the non-white US population and 33.2% of the Hispanic or Latino population live within 500 meters of a roadway with at least 25,000 average annual daily vehicular trips, compared to only 19.1% of the white population. Using a traffic density-based analysis, they found that non-white and lower-income people are more likely to live in Census blocks with higher traffic density. They found that nearly 90% of US counties have statistically significant racial and/or income disparities in exposure to vehicular traffic. Another study examined the sociodemographics of the residents in the 10 most congested urbanized areas in the US, including two in California (Manville & Goldman, 2018). They found that in the Los Angeles and San Francisco urbanized areas, respectively, the share of people in poverty was 43 and 23 percent greater in "freeway dominated" Census block groups than in Census blocks with no freeways, while the share of black residents was 32 and 79 percent higher and the share of non-white residents was 24 and 59 percent higher. Overall, the empirical evidence indicates that people of color and lower-income people are more likely to be exposed to the negative effects of both the construction (or expansion) and operation of freeways and highways.

With respect to construction, building or expanding freeways and highways often entails the acquisition (usually via eminent domain) and demolition of adjacent structures, including housing. For example, between July 2018 and June 2023, lane addition projects on the California State Highway System displaced 317 housing units and 306 businesses (Caltrans, 2025a). Multiple studies show that people of color were disproportionately displaced by the original construction of highways across the US and continue to be disproportionately displaced by their expansion. For example, Loukaitou-Sideris et al. (2023) examined the historical impacts of highway construction in four places in California: Pasadena, Pacoima, Sacramento, and San Jose. For all four locations, they found that most residents displaced by highway construction were people of color (Loukaitou-Sideris et al., 2023). Meanwhile, a Los Angeles Times investigation using data maintained by the Federal Highway Administration found that "expansions of existing freeways through cities have inflicted a second round of dislocation and disruption on largely Black and now Latino communities" (Dillon & Poston, 2021). In California, they found that the largest highway projects constructed between 1991 and 2021 displaced the residents of 1,254 homes, all of which were located in areas that were majority non-white or had a share of non-white residents that exceeded the non-white share in the surrounding counties by more than 10 percentage points, according to Census data (Poston & Dillon, 2021). Environmental impact reviews for planned highway expansion projects predict similarly disproportionate displacement effects on lower-income households and people of color. For example, the Draft Environmental Impact Report for the now-defunct I-710 Corridor Project proposed in Los Angeles County acknowledged that the project would have displaced residents in an area with a "large proportion of minority and low-income populations" (California Department of Transportation & Los Angeles County Metropolitan Transportation Authority, 2012, p. 3.3-40).

With respect to operation, people living close to freeways and highways bear the brunt of vehicular air pollution (Houston et al., 2004; Rioux et al., 2010; Rowangould, 2013), noise, economic decline, and other negative externalities (see Loukaitou-Sideris et al., 2023 for a summary and related studies). In addition, those negative externalities often reduce the property values for home and business owners near freeways and highways (Loukaitou-Sideris et al., 2023). Because people living close to freeways and highways are more likely to have lower incomes and more likely to be people of color (Antonczak et al., 2023; Manville & Goldman, 2018), they are more likely to suffer from negative externalities like these.

On the other hand, building additional roadway capacity could theoretically benefit those people of color and lower-income households living close to the expanded roadways in the form of increased automobility and possibly economic opportunity (at least in the short run, pending rebounding congestion due to induced travel). However, the empirical evidence indicates that managed lanes tend to disproportionately benefit higher-income people (Levinson, 2010). Manville and Goldman (2018) found that people living in "freeway dominated" Census block groups drive less, are less likely to commute by personal auto, and are much less likely to own vehicles than people living in Census blocks without freeways. They also found using the Census' Integrated Public Use Microdata Sample survey data that commuters in poverty are both less likely to drive than non-poor commuters and less likely to drive during the morning peak period, which is when the primary automobility benefits from highway expansion projects would theoretically be realized, in the absence of significant induced VMT (Manville & Goldman, 2018). This indicates that the primary putative benefits of highway expansions flow disproportionately to higher-income people. Congestion mitigation has fewer advantages for lower-income groups because lower-income workers and travelers travel less by car at peak times due to scheduling and trip distances are often shorter so the benefits of flow improvements are limited (Lachapelle & Boisjoly, 2022).

In the same way that lower-income people are less likely to benefit from highway expansions, they are also less likely to be burdened by any tolls imposed on the new facilities, such as with HOT lanes or toll lanes (Manville & Goldman, 2018). Tolling remains nominally regressive - it is relatively more expensive at the margins for lower-income drivers. But tolling is less likely to affect lower-income than higher-income drivers because tolls are usually imposed at peak commute hours when lower-income drivers are less likely to drive. Lower-income drivers would also still have the option of staying on the existing non-tolled lanes - they would not benefit from any increased speed on the toll lane, but they also would not have to pay to use the road they were already using. That tradeoff was one reason that early users of the I-15 HOT lanes in San Diego perceived the system as fair (Supernak et al., 2002).

Furthermore, tolling revenues can be used to help offset the residual burden imposed on lower-income drivers, such as by subsidizing non-auto travel modes or providing a mode-agnostic transportation credit to lower-income households that could even be used to pay for roadway tolls, such as suggested by Manville et al. (2022). However, tolling revenues are usually used first and foremost to cover the construction costs of the managed lanes, which can leave little left over for public transit subsidies or other purposes, as Lee (2023) recently detailed through interviews with multiple policy actors, including state and local transportation agency officials and a local elected official.

On a broader level, tolling is a less regressive way of funding transportation infrastructure than some other funding mechanisms when considering the effects on all lower-income residents in a region, rather than just lower-income drivers. For example, Schweitzer and Taylor (2008) compared the cost burdens on lower-income residents of a tolled road in Orange County (State Route 91) and the county's local option transportation sales tax. They found that, on average, lower-income residents pay more out-of-pocket with a sales tax.

Comandon and Boarnet (2025) further discuss tolling-related equity issues in their companion brief on road user pricing.

Confidence

Evidence Quality

Overall, the empirical literature on managed lanes is high quality, but limited.

Caveats

The primary caveat is that the implied elasticities estimated by Anderson et al. (2021) are facility-level. They do not account for the wider regional effects on travel, including route diversions from alternate routes and longer trips. However, the available evidence indicates at most a minimal substitution effect (Duranton & Turner, 2011; Handy & Boarnet, 2014), suggesting that Anderson et al.'s (2021) results might, if anything, underestimate the induced travel effect.

Technical & Background Information

Study Selection

Numerous prior reviews discuss the induced travel literature in great depth and breadth (Cairns et al., 1998; Cervero, 2002; Currie & Delbosc, 2010; United States Environmental Protection Agency, 2002; Goodwin, 1996; Handy & Boarnet, 2014; Hymel, 2019; Noland & Hanson, 2013; Noland & Lem, 2002; Volker & Handy, 2022; WSP, 2018), including some that address managed lanes specifically (Anderson et al., 2021; Shewmake, 2012; Volker & Handy, 2022). We used those reviews as a starting point for our targeted summary of the literature on the induced travel effects of managed lanes in this brief. We also conducted an updated search of literature to identify more recent studies and potentially relevant studies omitted by past reviews. To identify sources, we searched Google Scholar in the spring of 2024 using the following search terms:

> (“induced travel” OR “induced demand”) AND (“VMT” OR “VKT”) AND (“managed lanes” OR “express lanes” OR “HOT lanes” OR “HOV lanes” OR “toll”).

We also reviewed the reference lists from the selected sources to identify additional studies that did not appear in our web searches. We focused on peer-reviewed studies or high-quality “gray” literature that examined the induced travel effect of managed lanes using empirical data.

Methodological Considerations

A primary difficulty in assessing the induced travel effects of managed lanes is that there are so few managed lane miles compared to general-purpose lane miles. That makes it difficult to ascertain the network-wide effects of managed lanes vis-à-vis general-purpose lanes in an area-wide study. However, as discussed above, facility-level studies can still provide a useful first-order assessment of the induced travel effects of managed lanes.

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