POLICY BRIEF

Roadway Capacity and Induced Travel

Jamey M. B. Volker
UC Davis

April 2025

Equity review by Jesus M. Barajas

Project 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

Building additional roadway capacity—via constructing entirely new roadways or extending or adding lanes to existing roadways—is often proposed as a solution to traffic congestion and even as a way to reduce greenhouse gas (GHG) emissions. The logic for the latter is that increasing roadway capacity is assumed to increase average vehicle speeds. Increasing average vehicle speeds can improve fuel efficiency (up to a point), particularly for vehicles with internal combustion engines, and thus reduce per-mile emissions of GHGs (Barth & Boriboonsomsin, 2009). But that logic largely ignores the fact that the amount that people drive tends to increase when driving times decrease, which increases vehicle miles traveled (VMT) and reduces any initial speed increases from the roadway expansion.

Empirical research demonstrates that as roadway supply increases (i.e., there is more space on the road) the amount of vehicle miles traveled (VMT) on that road and across the region generally does, too. This is the “induced travel” effect (sometimes also called “induced demand”)—a net increase in VMT across the roadway network due to an increase in roadway capacity, which erodes any initial increases in travel speeds within three to 10 years and causes increased GHG emissions. Thus, increasing roadway capacity will generally not reduce VMT or GHG emissions and is not a recommended strategy.

Behavioral Effect Size

A roadway capacity expansion of 10% is likely to increase total VMT by 3% to 8% in the short-run

DOI: 10.7922/G20K26W2

and 8% to 10% or more in the long-run. Increased capacity can lead to increased VMT in the short-run in several ways: if people shift from other transportation modes to driving, if people shift from carpooling to driving solo, if drivers make longer trips (by using longer routes and/or choosing more distant destinations), or if drivers make more frequent trips. In the longer term, increased capacity can lead people to live farther away from where they work (or vice versa), cause businesses to relocate to more distant locations, spur land use development farther from urban centers to accommodate the changing preferences and travel patterns, and even stimulate population growth in the region. The reviewed studies indicate that the full impact of capacity expansion on VMT materializes within three to 10 years. The studies mostly focused on major roadways including interstates, other freeways and expressways, principal arterials, and minor arterials and show a potentially greater effect for interstates. Expansions of collector streets and local roads are also likely to induce VMT, though the empirical evidence as to the relative magnitude of the effect is limited.

Strategy Extent

Capacity expansion leads to a net increase in total VMT, not simply a shift in VMT from one road to another. Evidence shows that the additional traffic on the new or widened highway is not simply traffic that shifted from slower and more congested roads but is actually an overall increase in VMT. For example, one study found "no conclusive evidence that increases in state highway lane-miles have affected traffic on other roads" (Hansen & Huang, 1997, p. 205), while a more recent study concluded that "increasing lane kilometers for one type of road diverts little traffic from other types of roads" (Duranton & Turner, 2011, p. 2616).

Research shows that induced travel occurs in both urban and rural areas and on roadways with different levels of existing congestion. Indeed, induced travel can be expected to occur anytime a project increases average travel speed, increases travel time reliability, makes driving on the roadway appear safer or feel less stressful, or provides access to previously inaccessible areas. However, the induced travel effect might be slightly smaller in rural areas, at least in the short run. Conversely, the limited available evidence indicates that metropolitan areas with higher baseline levels of congestion could potentially have lower elasticities than metro areas with less congestion, but the body of research is far too limited to be conclusive one way or the other.

The available empirical evidence suggests that new high-occupancy vehicle (HOV) and high-occupancy toll (HOT) lanes have similar induced travel effects as general purpose lane expansions. One recent study looked at two projects that added HOV lanes and one that added a HOT lane and showed that the additions resulted in increased traffic flows at similar levels to new general-purpose lanes. Other available evidence tends to support this conclusion. However, additional research could show more definitively whether there are any differences in effect between general-purpose, HOV, HOT, and traditional toll lanes.

Equity Effects

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

Strategy Description

Building additional roadway capacity—via constructing entirely new roadways or extending or adding lanes to existing roadways—is often proposed as a solution to traffic congestion and even as a way to reduce greenhouse gas (GHG) emissions. The logic for the latter is that increasing roadway capacity is assumed to increase average vehicle speeds, which can improve vehicle fuel efficiency (up to a point), particularly for vehicles with internal combustion engines, and thus reduce per-mile emissions of GHGs (Barth & Boriboonsomsin, 2009). But that logic largely ignores the fact that the amount that people drive tends to increase when driving times decrease, which increases vehicle miles traveled (VMT) and reduces any initial speed increases from the roadway expansion.

The basic economic principles of supply and demand explain this phenomenon. Adding capacity increases the average travel speed on the roadway (at least in the short term), increases travel time reliability, makes driving on the roadway appear safer or feel less stressful, or provides access to previously inaccessible areas. All of these reduce the perceived "cost" of driving. And when the cost of driving goes down, the quantity of driving goes up (Figure 1).

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 GHG emissions.

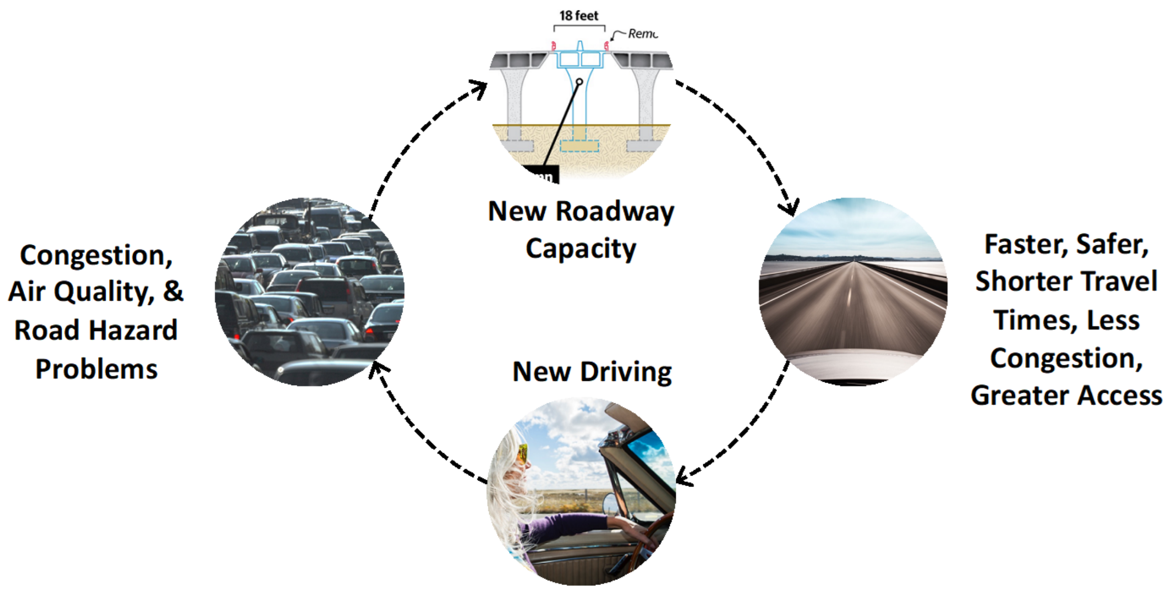

Figure 1. Induced Vehicle Travel Effect of Roadway Capacity Expansions

Strategy Effects

Behavioral Effect Size

Area-wide studies typically measure the magnitude of the induced travel effect 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.

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

The studies typically obtain elasticity estimates by using the logarithm of both VMT and lane miles in their regression models. Using the logarithmic form, the regression coefficients can be interpreted as elasticities. For example, a 1.0 coefficient on the lane miles variable would indicate a 1.0 elasticity of VMT with respect to lane miles.

Table 1, in the Appendix, summarizes the 12 studies we reviewed. Studies in the US are more generalizable within the US and thus more relevant to California policy and practice. However, we also include at the bottom of the table the studies we found from other countries that met our selection criteria.

The area-wide studies summarized in Table 1 consistently find an induced travel effect from roadway capacity expansions, even after controlling for a wide variety of other factors affecting VMT and attempting to correct for the endogeneity of roadway capacity. Short-run elasticity estimates range from 0.07-0.76 in the US and 0.07-0.99 across all studies. Longer-run elasticity estimates range from 0.26-1.06 in the US and 0.26-1.34 across all studies.

Those elasticity ranges tighten substantially when the two studies that used all road types (including local roads)—Su (2011) and González and Marrero (2012)—are excluded. Excluding those two studies, the range of short-run elasticities shrinks to 0.28-0.76 in the US and 0.28-0.99 across all studies. The range of longer-run elasticities narrows to 0.77-1.06 in the US and 0.77-1.34 across all studies. One reason the elasticities estimated in Su (2011) and González and Marrero (2012) might be outliers is that both studies include local roads (the lowest FHWA facility class – class 7). Local roads typically constitute the bulk of the roadway network yet they tend to provide the least per-mile improvement in travel speed or access, as indicated by the fact that they generally have the lowest VMT densities of all roadway classes. As a result, the elasticity of VMT with respect to roadway capacity is likely lower (though not zero) for local roads than for higher road classifications (Noland, 2001).

Contrary to expectations, the only other study that included local roads in its dataset (Chen & Klaiber, 2020) estimated a short-run elasticity of 0.99 for urban roads in prefecture-level cities in China, much higher than the short-run elasticities of 0.07 and 0.11-0.17 estimated respectively by Su (2011) and González and Marrero (2012) for all road types in the US and Spain. However, the circumstances of Chen and Klaiber's (2020) study were unique. As the authors note, the "rapid adjustment in traffic over our relatively short time period is likely related to the economic setting in China" (p. 10), where vehicle ownership increased tenfold between 2000 and 2020, a period encompassing the study years (p. 2). The authors did not separately control for vehicle ownership in their regression models, so the relatively high elasticity (0.99) they estimated could well reflect a vehicle ownership effect unrelated to roadway capacity expansions as well as induced travel from the expansions.

Apart from Su (2011), González and Marrero (2012), and Chen and Klaiber (2020), every other study focused on roadways equivalent to FHWA classes 1-4 (interstate highways, other freeways and expressways, principal arterials, and minor arterials). Three studies used data from facilities equivalent to classes 1-3 (Cervero & Hansen, 2002; Fulton et al., 2000; Hymel, 2019). Two studies looked at class 1-4 facilities (Graham et al., 2014; Noland & Cowart, 2000). One study estimated an elasticity just for class 3 and 4 facilities (Melo et al., 2012). And three studies focused on class 1-equivalent facilities (Duranton & Turner, 2011; Hsu & Zhang, 2014) or class 1 and 2 facilities (Garcia-López et al., 2020). Some of the studies included additional facility types in some of their models, but not in the models that accounted for the endogeneity of roadway capacity, which are the focus of this summary. Overall, the six studies that included class 3 and/or 4 facilities estimated short-run elasticities between 0.28-0.76 and longer-run elasticities between 0.77-1.06. The three studies that looked only at class 1 and/or 2 facilities estimated longer-run elasticities of 1.03-1.34. These results indicate a longer-run induced travel elasticity of close to 1.0 across all four facility types, albeit a potentially greater elasticity for expansions of class 1 facilities than class 2-4 roadways.

Co-Benefits

Given the induced travel effect, roadway capacity expansion has limited potential as a strategy for reducing congestion. The additional vehicle travel induced by capacity expansion increases GHG emissions as well as other environmental effects, including increased air, water, and noise pollution. On the other hand, capacity expansion can generate economic and social benefits, at least in the short run (Allen & Arkolakis, 2014; Duranton & Turner, 2012). The additional benefits derive from potential travel time savings and the fact that the expanded roadway is carrying more people, each of whom benefits from his or her travel and any improved ability to access destinations (at least in the short run). However, the empirical evidence indicates that roadway capacity expansions do not actually have much net effect on the economy in the long run. The evidence is clear that roadway expansions tend to cause people and economic activity to spread out (Baum-Snow, 2007; Chandra & Thompson, 2000; Duranton et al., 2020; Ewing, 2008). However, any increases in economic activity in one area tend to either be (1) offset by decreases in economic activity in neighboring areas, as Chandra and Thompson (2000) found in their study of rural counties with interstate highways, or (2) outweighed by the costs of building and maintaining the new roadway capacity (Duranton et al., 2020; Duranton & Turner, 2012). Other studies have found minimal economic effects from specific capacity expansion projects (Funderberg et al., 2010; Metz, 2021) or metropolitan area-level changes in roadway lane miles (Baum-Snow, 2019).

Strategy Extent – The Role of Context

The elasticities estimated by area-wide studies, like those summarized in Table 1, capture the average induced travel effect across the studied geographies and roadway types. Even though the studies control for other factors that affect VMT besides roadway capacity, the induced travel effect size can still vary across both geographies and road types. For example, as discussed above, expansions of higher-classification roadways (e.g., class 1 interstates) might have a greater induced travel effect (higher elasticity) than expansions of lower-classification facilities, though capacity expansions of any roadway type would be expected to induce at least some travel. With respect to geography, the induced travel effect is often assumed to be greater in urban areas and, more generally, areas with greater traffic congestion. We first explore the impact of existing congestion levels on induced travel effect size, then we discuss the differences between urban and rural areas.

Existing Congestion Levels

Roadway capacity expansion is often proposed as a solution to traffic congestion, but induced travel does not only occur in congested areas.

Induced travel can be expected to occur wherever an expansion project reduces the perceived "cost" of driving. Deakin et al. (2020) and Noland and Hanson (2013) came to similar conclusions in their reviews of the literature and theory on induced travel.

That said, Deakin et al. (2020) and others also suggest that the magnitude of the induced travel effect (elasticity) might still differ based on existing congestion levels, with, for example, potentially lower short-run elasticities in relatively uncongested rural areas. However, very few studies have attempted to answer this question empirically.

Chang et al. (2020) is the lone study we found that attempts to tackle the issue empirically, but it uses a flawed proxy for baseline congestion levels – total initial VMT in each metropolitan region. The authors used the same data and instrumental variables as Duranton and Turner (2011), but employed instrumental variable quantile regression (IVQR) rather than 2-stage least squares regression. The putative benefit of the IVQR approach is that it allowed the authors to "evaluate the impact of changes in the stock of interstate highways on the conditional distribution of VMT, not just the impact on the conditional mean" (Chang et al., 2020, p. 1). They found that all else equal (original lane miles, population, etc.), regions with higher initial levels of total VMT had lower induced travel elasticities, ranging from an elasticity of 0.8 for regions in the 90th percentile for total VMT to 1.45 for regions in the 10th percentile. However, the elasticity estimates were generally not precise enough to reject the hypothesis that the effects were the same (or different from 1.0) across the different percentile partitions. Furthermore, total metropolitan area VMT is a flawed proxy for congestion – it accounts for neither VMT density (e.g., VMT/lane mile) nor when during the day the VMT is occurring.

Duranton and Turner (2011) themselves did not directly examine whether the induced travel effect is greater in congested areas. However, they did find a weak downward trend in estimated elasticities over time (from 1983-2003, during which time average congestion increased). They suggested that this could indicate a greater induced travel effect "when roads are not congested" (Duranton & Turner, 2011, p. 2634).

Noland and Cowart (2000) also did not directly examine whether induced travel elasticities vary based on existing levels of congestion. Instead, they used their induced travel regression results to forecast VMT growth over a 15-year period for class 1-4 roadways in all major metropolitan areas in the US, assuming that the growth rates for lane miles, population, income, and fuel cost all remained the same as they were for original study period (1982-1996). They found that the percentage of VMT growth due to induced travel (from capacity expansions) did "not appear to be affected by either existing congestion or the relative size of the metropolitan area" (Noland & Cowart, 2000, p. 386).

In sum, the limited available evidence indicates that metropolitan areas with higher baseline levels of traffic congestion could potentially have lower elasticities than metro areas with less congestion, but the body of research is far too limited to be conclusive one way or the other. Additional investigation of this issue is needed.

Rural vs. Urban

The induced travel effect is often assumed to be greater in urban areas, in large part due to the aforementioned assumption that the effect increases with congestion. However, as discussed above, induced travel can be expected to occur wherever an expansion project reduces the perceived "cost" of driving, including by increasing the average travel speed on the roadway (regardless of initial congestion levels), increasing travel time reliability, making driving on the roadway appear safer or feel less stressful, or providing access to previously inaccessible areas regardless of initial congestion levels. Those effects can all occur in rural areas, too, regardless of generally lower congestion levels than in urban areas. Deakin et al. (2020, p. 3) illustrated useful examples of induced travel occurring in uncongested rural areas. The empirical research also suggests that induced travel happens in rural areas.

Noland (2001)[1] was the earliest study we found that estimated separate induced travel elasticities for rural roads and urban roads. The author used seemingly unrelated regression with panel data (1984-1996) from the US to estimate elasticities at the state level for three categories of roads (encompassing class 1-6 roadways) in both urban and rural areas. The author found that the short-run elasticities for all road types were larger in urban areas than rural areas, but that the longer-run elasticities were nearly the same. The author found slightly larger longer-term elasticities in urban areas than in rural areas for class 1 and 2 roads combined (~0.8 v. ~0.75) and class 3 and 4 roads combined (~0.8 v. ~0.7), but slightly smaller elasticities for class 5 and 6 facilities combined (~1.1 v. ~1.2). The author concluded that while short-term elasticities might be lower in rural areas, the longer-term elasticities could be relatively similar because capacity expansions can trigger “fundamental land use changes that increase VMT in both urban and rural areas” (p. 63). Those land use changes are increasingly well documented in the literature (Aïkous et al., 2023). For example, Aïkous et al. (2023) examined the how the expansion of Highway 30 to the south of Montréal between 2000 and 2019 affected the construction of new industrial and commercial buildings. They found that the highway expansion increased the probability of new commercial and industrial construction close to the highway access ramps, despite the fact that the expanded route was scattered with agricultural use parcels that were protected by law from non-agricultural development (Aïkous et al., 2023).

Like Noland (2001), Rentziou et al. (2012) also used seemingly unrelated regression to estimate short-run induced travel elasticities at the state level for class 1-5 facilities in both urban and rural areas in the US. They found, like Noland (2001), that the short-run elasticities in urban areas were larger than in rural areas across all roadway types. However, as noted above, this study used passenger VMT not total VMT (which includes heavy truck VMT), and thus did not estimate the full induced VMT effect. Nor did the authors estimate longer-run elasticities.

Duranton and Turner’s (2011) study is also relevant, even though it looked only at roadways within metropolitan statistical areas (MSAs). The authors used OLS regression with cross-sectional data to estimate and compare induced travel elasticities for all class 1 interstate highways within MSAs, interstates within the urbanized portions of MSAs, and interstates within the non-urbanized portions of MSAs. They found large elasticities for all three geographies (ranging from 0.71 to 1.06), but slightly larger elasticities for interstates within the urbanized areas (0.92-1.06) than interstates within the non-urbanized portions (0.81-0.85).

Fulton et al. (2000) did not directly examine whether elasticities differ in rural areas versus urban areas, but the study is still relevant. The authors estimated county-level induced travel elasticities for class 1-3 roads in Maryland, North Carolina, Virginia, and the Washington DC/Baltimore area. The authors did not

[1] We did not include the Noland (2001) study in Table 1 because it did not correct for the endogeneity of roadway capacity in its estimates of induced travel elasticities. Nonetheless, the study still found similar short-term elasticities (~0.2-0.5) and long-term elasticities to (~0.7->1.0) to those estimated in the studies that did control for the simultaneity bias.

explicitly differentiate between urban and rural roads, but they did estimate separate elasticities for each of the four areas in addition to elasticities from all geographies combined. In interpreting their results, the authors concluded that the "similar results in urban (DC/Baltimore) and mostly rural (North Carolina) areas suggest that both short run congestion effects and longer run land use/growth effects may be important contributors to induced demand" (Fulton et al., 2000, p. 13). That echoes Noland's (2001) conclusion from his nationwide study.

Overall, the empirical research suggests that induced travel occurs in both urban and rural areas, though the elasticities might be slightly smaller in rural areas, at least in the short run. There is better empirical evidence here than on the issue of whether and how induced travel elasticities vary based on initial congestion levels. However, more (and more recent) studies would help flesh out whether and how the induced travel effect changes in rural versus urban contexts.

Differences Based on Lane Type

Roadway capacity expansions—particularly on freeways and highways—are increasingly done with managed lanes rather than general-purpose lanes. For purposes of this report, 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. Because new managed lanes constitute a growing share of capacity expansion projects in California and elsewhere, it is important to understand whether they cause more or less induced travel than general-purpose lane expansions.

Most empirical studies of induced travel, like those summarized in Table 2, 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. Very few studies have attempted to isolate induced travel effects by lane type, as previous literature reviews confirm (Shewmake, 2012; Anderson et al., 2021). 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.

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 flows 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 estimated "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.

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 discussed above indicates at most a minimal substitution effect, 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, California Department of Transportation (2022) loop detector data from 2019 show that the average annual traffic flows on the state's HOV and HOT lanes were nearly as high as on the adjacent general-purpose lanes. Flows on the HOV and HOT lanes averaged 952 vehicles/hour/lane across the morning and afternoon peak periods (5am-10am, 3pm-8pm), which is 13% lower than on the adjacent general-purpose lanes during the same time periods (1,099 vehicles/hour/lane) (California Department of Transportation, 2022). This indicates that, despite their access restrictions, HOV and HOT lanes might eventually reach similar flows as general-purpose lanes during periods of peak congestion. That in turn suggests that adding HOV and HOT lanes has had 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 theoretically 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 hypercongestion – the point where traffic becomes so dense that both speed and flows decrease (Small & Chu, 2003). We only found one empirical study that accounted 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, as summarized in Table 1. As part of their analysis, the 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 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 hypercongestion – the point where traffic becomes so dense that both speed and flows decrease (Small & Chu, 2003). 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. However, the empirical literature on managed lanes is limited and more research is needed to better flesh out any differences.

Note that this brief focuses on the induced travel effects of expanding roadways generally, though it includes some discussion of managed lanes. Volker (2024) examines the specific effects of managed lanes in more detail in a separate brief. Comandon and Boarnet (2024) discuss the effects of road user pricing in a third brief.

Equity

We found zero studies on the equity effects of induced travel, specifically. However, building additional roadway capacity, particularly freeways and highways, 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.

Recent research indicates that 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 United States. 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 and operation of freeways and highways.

With respect to construction, building or expanding freeways and highways often entails the acquisition (often via eminent domain) and demolition of adjacent structures, including housing. 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 (Dillon & Poston, 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 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 (which could potentially occur in the short run, pending rebounding congestion due to induced travel). However, 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). Indeed, highways and freeways can have the opposite effect on access to opportunity to for lower-income households and people of color by disconnecting their neighborhoods from the area's economic core, as Loukaitou-Sideris et al. (2023) found in the case of the construction of I-280 and I-680 in San Jose.

This brief does not discuss specific equity-related effects of managed lanes and roadway pricing. Those are examined in related briefs by Volker (2024) and Comandon and Boarnet (2024), respectively.

Confidence

Evidence Quality

The quality of the evidence linking roadway capacity expansion to VMT increases is high, particularly the studies listed in Table 1. Those studies use sound econometric methods to estimate induced travel elasticities, controlling for factors affecting VMT other than roadway capacity. For example, nearly every study controlled in some form for population and income, half the studies controlled for fuel cost, and one quarter controlled for elements of physical geography. Every study also attempted to correct for the endogeneity of roadway capacity—the possibility that VMT growth can cause roadway capacity expansion and not just the other way around. The fact that most of the studies arrive at similar elasticity estimates despite using a range of statistical estimation strategies also increases confidence in the results.

Caveats

In addition to the context-based caveats discussed above, a key question in determining the induced travel effect size is whether increased VMT on the expanded roadways is partially offset by decreases in VMT on other roads (i.e., where VMT is effectively diverted from other roads). A major benefit of area-wide studies, like those summarized in Table 1, is that they allow researchers to capture the net change in VMT across the entire area where travel behavior is likely to change in response to a capacity expansion. Handy and Boarnet (2014, pp. 2-3) concluded in a previous review of the induced travel literature that "[r]egion- or county-level analysis may be most effective in capturing the effect of the shifting of travel from one roadway to another in determining the net effect of capacity expansions." However, most studies only include a subset of roadways within the studied regions, as discussed above. For example, three of the studies listed in Table 1 used data from facilities equivalent to classes 1-3 (Cervero & Hansen, 2002; Fulton et al., 2000; Hymel, 2019), two studies looked at class 1-4 facilities (Graham et al., 2014; Noland & Cowart, 2000), one study estimated an elasticity just for class 3 and 4 facilities (Melo et al., 2012), and three studies focused on class 1-equivalent facilities. While all of those studies found a net increase in VMT on the studied facilities, it is conceivable that some of the increased VMT was diverted from—and not replaced on—other types of roadways in the region (e.g., minor arterials [class 4], major collectors [class 5], minor collectors [class 6], and local roads [class 7]). However, the few studies that have attempted to quantify this have found at most a minimal substitution effect.

Technical & Background Information

Study Selection

Numerous prior reviews discuss the induced travel literature in great depth and breadth (Anderson et al., 2021; 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; WSP, 2018). We used those reviews as a starting point for our targeted summary of the literature in this report, which focuses on studies that estimated an elasticity of VMT (or VKT, vehicle kilometers traveled) with respect to roadway capacity using empirical data. We also conducted our own search of literature to identify more recent studies and potentially relevant studies omitted by past reviews. To identify sources, we initially searched Google Scholar in the summer and fall of 2023 using the following search terms:

(“induced travel” OR “induced demand”) AND (“elasticity”) AND (“VMT” OR “VKT”)

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 that either examined the induced travel literature or estimated induced travel elasticities using empirical data. However, we also included high-quality “gray” literature relevant to the more understudied questions we discuss in this report (e.g., the effect of existing congestion levels and managed lanes on the induced travel effect size).

We focused on studies that (1) estimated an elasticity of VMT (or VKT) with respect to lane miles (or kilometers), (2) used a regional unit of analysis (i.e., counties, urbanized areas, metropolitan areas, or states in the United States, or equivalent spatial units in countries outside the US), (3) controlled for factors affecting VMT other than roadway capacity, and (4) attempted to account for the endogeneity of roadway capacity.

Methodological Considerations

Every study shown in Table 1 controlled for factors affecting VMT other than roadway capacity. For example, nearly every study controlled in some form for population and income, half the studies controlled for fuel cost, and one quarter controlled for elements of physical geography. More than half the studies also included regional and/or year fixed effects in their regression models to capture the effects on VMT of unmeasured variables associated with a specific region or time period.

Every study also attempted to correct for the endogeneity of roadway capacity—the possibility that VMT growth can cause roadway capacity expansion and not just the other way around. A detailed discussion of the methods used to control for endogeneity is beyond the scope of this report, but most studies attempted to isolate the causal effect of roadway capacity on VMT using instrumental variables (IV). The basic idea is to first build a regression model to estimate lane miles in the study regions, then use the predicted lane miles to model the effect of roadway capacity on VMT. The best-vetted approaches have used external instruments—variables that are strongly correlated with roadway capacity but uncorrelated with VMT—that passed tests for weak or invalid instrument bias. Those studies include Duranton and Turner (2011), Hsu and Zhang (2014), and Garcia-López et al. (2020), which relied on external instruments related to historical roadway networks or transportation plans, as well as Hymel (2019), which relied on a proxy for a state’s power in federal transportation policymaking (cumulative delegate-years of membership in House and Senate transportation committees). All four of those studies—two in the US, one in Japan, and one in Europe—estimated longer-term induced travel elasticities exceeding 1.0. All four studies also estimated large, albeit smaller, elasticities (ranging from 0.7-1.1) using OLS regressions that did not correct for endogeneity.

References

Aïkous, M., Dubé, J., Brunelle, C., & Champagne, M. (2023). Highway Expansion and Impacts on Land Use Changes: An Event Study Approach. Transportation Research Part D, 119 (2023): 103730. https://doi.org/10.1016/j.trd.2023.103730

Allen, T., & Arkolakis, C. (2014). Trade and the Topography of the Spatial Economy. Quarterly Journal of Economics, 129(3), 1085-1140. https://doi.org/10.1093/qje/qju016

Anderson, M. L., Davis, L. W., & Safavi, L. (2021). Estimating Induced Travel from Capacity Expansions on Congested Corridors. California Air Resources Board and California Environmental Protection Agency. Retrieved from https://ww2.arb.ca.gov/sites/default/files/2021-04/18RD022.pdf

Antonczak, B., Thompson, T. M., DePaola, M. W., & Rowangould, G. (2023). 2020 Near-Roadway Population Census, Traffic Exposure and Equity in the United States. Transportation Research Part D, 125 (2023) 103965. https://doi.org/10.1016/j.trd.2023.103965

Barth, M., & Boriboonsomsin, K. (2009). Traffic Congestion and Greenhouse Gases. ACCESS Magazine, 1(35). https://escholarship.org/content/qt3vz7t3db/qt3vz7t3db.pdf

Baum-Snow, N. (2019). Urban Transport Expansions and Changes in the Spatial Structure of U.S. Cities: Implications for Productivity and Welfare. Review of Economics and Statistics, 102(5), 929-945. https://doi.org/10.1162/rest_a_00855

Baum-Snow, N. (2007). Did Highways Cause Suburbanization? Quarterly Journal of Economics, 122(2), 775-805. https://doi.org/10.1162/qjec.122.2.775

Bento, A., Kaffine, D., Roth, K, & Zaragoza-Watkins, M. (2014). The Effects of Regulation in the Presence of Multiple Unpriced Externalities: Evidence from the Transportation Sector. American Economic Journal: Economic Policy, 6(3), 1-29. http://dx.doi.org/10.1257/pol.6.3.1

Cairns, S., Hass-Klau, C., & Goodwin, P. (1998). Traffic Impact of Highway Capacity Reductions: Assessment of the Evidence. London: Landor Publishing.

California Department of Transportation. (2022). 2019 PeMS data (Managed Facilities>Facility Comparison report).

California Department of Transportation & Los Angeles County Transportation Authority. (June 2012). I-710 Corridor Project: Draft Environmental Impact Statement and Section 4(f) Evaluation. Retrieved from https://libraryarchives.metro.net/DPGTL/eirs/i-710-corridor-project/2012-i-710-corridor-project-draft-eir-eis.html

Cervero, R. (2002). Induced Travel Demand: Research Design, Empirical Evidence, and Normative Policies. Journal of Planning Literature, 17(1), 3-20. https://doi.org/10.1177/088122017001001

Cervero, R., & Hansen, M. (2002). Induced Travel Demand and Induced Road Investment: A Simultaneous Equation Analysis. Journal of Transport Economics and Policy, 36(3), 469-490. Retrieved from https://www.jstor.org/stable/20053915

Chandra, A., & Thompson, E. (2000). Does Public Infrastructure Affect Economic Activity? Evidence from the Rural Interstate Highway System. Regional Science and Urban Economics, 30(4), 457-490. https://doi.org/10.1016/S0166-0462(00)00040-5

Chang, H., Indra, D., & Maiti, A. (2020). Does Building Highways Reduce Traffic Congestion? Working paper. Retrieved from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3674793

Chen, W., & Klaiber, H. A. (2020). Does Road Expansion Induce Traffic? An Evaluation of Vehicle-Kilometers Traveled in China. Journal of Environmental Economics and Management, 104(102387). https://doi.org/10.1016/j.jeem.2020.102387

Comandon, A., & Boarnet, M. G. (2024). Impacts of Road User Pricing on Passenger Vehicle Use and Greenhouse Gas Emissions. California Air Resources Board.

Currie, G., & Delbosc, A. (2010). Literature Review of Induced Travel (ITLS-WP-10-16). University of Sydney Institute of Transport and Logistics Studies. Retrieved from https://ses.library.usyd.edu.au/handle/2123/19480

Dahlgren, J. (1998). High Occupancy Vehicle Lanes: Not Always More Effective than General Purpose Lanes. Transportation Research Part A, 32(2), 99-114. https://doi.org/10.1016/S0965-8564(97)00021-9

Deakin, E., Dock, F., Garry, G., Handy, S., McNally, M., Sall, E., Skabardonis, A., & Walker, J. (2020). Calculating and Forecasting Induced Vehicle Miles of Travel Resulting from Highway Projects: Findings and Recommendations from an Expert Panel. California Department of Transportation. https://dot.ca.gov/-/media/dot-media/programs/transportation-planning/documents/sb-743/2020-09-21-sb-743-expert-panel-rpt-fnl-a11y.pdf

Dillon, L., & Poston, B. (2021, November 11). Freeways Force out Residents in Communities of Color – Again. Los Angeles Times. Retrieved from https://www.latimes.com/projects/us-freeway-highway-expansion-black-latino-communities/

Duranton, G., Nagpal, G., & Turner, M. (2020). Transportation Infrastructure in the US. National Bureau of Economic Research. Working Paper 27254. Retrieved from https://www.nber.org/papers/w27254

Duranton, G., & Turner, M. (2012). Urban Growth and Transportation. Review of Economic Studies, 79:1407-1440. https://doi.org/10.1093/restud/rds010

Duranton, G., & Turner, M. (2011). The Fundamental Law of Road Congestion: Evidence from US Cities. American Economic Review, 101:2616–2652. https://doi.org/10.1257/aer.101.6.2616

Ewing, R. (2008). Highway-Induced Development: Research Results for Metropolitan Areas. Transportation Research Record: Journal of the Transportation Research Board, 2067, 101-109. https://doi.org/10.3141/2067-12

Fulton, L. M., Noland, R. B., Meszler, D. J., & Thomas, J. V. (2000). A Statistical Analysis of Induced Travel Effects in the U.S. Mid-Atlantic Region. Journal of Transportation and Statistics, 3(1). https://doi.org/10.21949/1501618

Funderburg, R., Nixon, H., Boarnet, M., & Ferguson, G. (2010). New Highways and Land Use Change: Results from a Quasi-Experimental Research Design. Transportation Research A, 44(2), 76-98. https://doi.org/10.1016/j.tra.2009.11.003

Garcia-López, M., Pasidis, I., & Viladecans-Marsal, E. (2020). Congestion in Highways When Tolls and Railroads Matter: Evidence from European Cities. Working paper. Retrieved from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3785888

González, R. M., & Marrero, G. A. (2012). Induced Road Traffic in Spanish Regions: A Dynamic Panel Data Model. Transportation Research Part A, 46(3), 435-445. https://doi.org/10.1016/j.tra.2011.11.003

Goodwin, P. G. (1996). Empirical Evidence on Induced Travel: A Review and Synthesis. Transportation, 23: 35-54. https://doi.org/10.1007/BF00166218

Graham, D. J., McCoy, E. J., & Stephens, D. A. (2014). Quantifying Causal Effects of Road Network Capacity Expansions on Traffic Volume and Density via a Mixed Model Propensity Score Estimator. Journal of the American Statistical Association, 109(508), 1440-1449. https://doi.org/10.1080/01621459.2014.956871

Handy, S., & Boarnet, M. G. (2014). Impact of Highway Capacity and Induced Travel on Passenger Vehicle Use and Greenhouse Gas Emissions. California Air Resources Board and California Environmental Protect Agency. Technical Background Document. Retrieved from https://ww2.arb.ca.gov/sites/default/files/2020-06/Impact_of_Highway_Capacity_and_Induced_Travel_on_Passenger_Vehicle_Use_and_Greenhouse_Gas_Emissions_Technical_Background_Document.pdf

Hansen, M., & Huang, Y. (1997). Road Supply and Traffic in California Urban Areas. Transportation Research Part A, 31(3), 205-218. https://doi.org/10.1016/S0965-8564(96)00019-5

Houston, D., Wu, J., Ong, P., & Winer, A. (2004). Structural Disparities of Urban Traffic in Southern California: Implications for Vehicle-related Air Pollution Exposure in Minority and High-poverty Neighborhoods. Journal of Urban Affairs, 26(5):565-592. https://doi.org/10.1111/j.0735-2166.2004.00215.x

Hsu, W., & Zhang, H. (2014). The Fundamental Law of Highway Congestion Revisited: Evidence from National Expressways in Japan. Journal of Urban Economics, 81: 65-76. https://doi.org/10.1016/j.jue.2014.02.002

Hymel, K. (2019). If You Build It, They Will Drive: Measuring Induced Demand for Vehicle Travel in Urban Areas. Transport Policy, 76: 57-66. https://doi.org/10.1016/j.tranpol.2018.12.006

Johnston, R. A., & Ceerla, R. (1996). The Effects of New High-Occupancy Vehicle Lanes on Travel and Emissions. Transportation Research Part A, 30(1), 35-50. https://doi.org/10.1016/0965-8564(95)00009-7

Lachapelle, U., & Boisjoly, G. (2022). The Equity Implications of Highway Development and Expansion: Four Indicators. Findings. https://doi.org/10.32866/001c.33180

Loukaitou-Sideris, A., Handy, S. L., Ong, P. M., Barajas, J. B., Wasserman, J. L., Pech, C., Sanchez, J. C. G., Ramirez, A. F., Jain, A., Proussaloglou, E., Nguyen, A., Turner, K., Fitzgibbon, A., Kaeppelin, F., Ramirez, F., & Arenas, M. (2023). The Implications of Freeway Siting in California: Four Case Studies on the Effects of Freeways on Neighborhoods of Color. Pacific Southwest Region University Transportation Center. Retrieved from https://escholarship.org/content/qt0jm2d235/qt0jm2d235.pdf

Manville, M., & Goldman, E. (2018). Would Congestion Pricing Harm the Poor? Do Free Roads Help the Poor? Journal of Planning Education and Research, 38(3):329-344. https://doi.org/10.1177/0739456X17696

Melo, P. C., Graham, D. J. & Canavan, S. (2012). Effects of Road Investments on Economic Output and Induced Travel Demand: Evidence for Urbanized Areas in the United States. Transportation Research Record: Journal of the Transportation Research Board, 2297: 163–171. https://doi.org/10.3141/2297-20

Metz, D. (2021). Economic Benefits of Road Widening: Discrepancy between Outturn and Forecast. Transportation Research Part A, 147(1), 312-319. https://doi.org/10.1016/j.tra.2021.03.023

Noland, R. B. (2001). Relationships between Highway Capacity and Induced Vehicle Travel. Transportation Research Part A, 35(1), 47-72. https://doi.org/10.1016/S0965-8564(99)00047-6

Noland, R. B., & Cowart, W. A. (2000). Analysis of Metropolitan Highway Capacity and the Growth in Vehicle Miles of Travel. Transportation, 27: 363-390. https://doi.org/10.1023/A:1005288826997

Noland, R. B., & Hanson, C. S. (2013). How Does Induced Travel Affect Sustainable Transportation Policy? In Renne, J. L., & Fields, B. (Eds.), Transport Beyond Oil (pp. 70-85). Washington, DC: Island Press.

Noland, R. B., & Lem, L. L. (2002). A Review of the Evidence for Induced Travel and Changes in Transportation and Environmental Policy in the US and the UK. Transportation Research Part D, 7(1), 1-26. https://doi.org/10.1016/S1361-9209(01)00009-8

Rentziou, A., Gkritza, K., & Souleyrette, R. R. (2012). VMT, Energy Consumption, and GHG Emissions Forecasting for Passenger Transportation. Transportation Research Part A, 46(3), 487-500. https://doi.org/10.1016/j.tra.2011.11.009

Rioux, C., Gute, D., Brugge D., Peterson, S., & Parmenter, B. (2010). Characterizing Urban Traffic Exposure Using Transportation Planning Tools. Journal of Urban Health, 87(2), 167-188. https://doi.org/10.1007/s11524-009-9419-7

Rodier, C. J., & Johnston, R. A. (1997). Travel, Emissions, and Welfare Effects of Travel Demand Management Measures. Transportation Research Record: Journal of the Transportation Research Board, 1598: 18-24. https://doi.org/10.3141/1598-03

Rowangould, G. M. (2013). A Census of the US Near-road Population: Public Health and Environmental Justice Considerations. Transportation Research Part D, 25(2013):59-67. http://dx.doi.org/10.1016/j.trd.2013.08.003

Shewmake, S. (2012). Can Carpooling Clear the Road and Clean the Air? Evidence from the Literature on the Impact of HOV Lanes on VMT and Air Pollution. Journal of Planning Literature, 27(4), 363-374. https://doi.org/10.1177/0885412212451028

Small, K. A., & Chu. X. (2003). Hypercongestion. Journal of Transport Economics and Policy, 37(3):319-352. Retrieved from https://www.jstor.org/stable/pdf/20053940.pdf

Su, Q. (2011). Induced Motor Vehicle Travel from Improved Fuel Efficiency and Road Expansion. Energy Policy, 39(11), 7257-7264. https://doi.org/10.1016/j.enpol.2011.08.047

United States Environmental Protection Agency. (2002). Guidebook on Induced Travel Demand.

Volker, J. M. B. (2024). Managed Lanes. California Air Resources Board.

WSP. (2018). Latest Evidence on Induced Travel Demand: An Evidence Review. UK Department for Transport.

Appendix

Table 1. Empirical Estimates of Induced Travel Elasticities from Area-Wide Studies[2,3]

Authors	Geography	Unit of Analysis	Study Years	Roadway Types	Controls [2]	Estimation Strategy[3]		Elasticities	
						Identification	Estimator	Short Run	Longer Run
Fulton et al. (2000)	United States (Maryland, North Carolina, Virginia, Washington, DC)	Counties	1985–1995	Interstate highways, state highways, other state-maintained primary roads (class 1-3)	Population, income per capita, county fixed effects, year fixed effects	Lagged growth in highway capacity (internal instrument)	2-stage least squares regression	0.46–0.51	—
Noland & Cowart (2000)	United States	Urbanized areas	1982–1986	Interstate highways, other freeways and expressways, principal arterials, minor arterials (class 1-4)	Population density, fuel cost, income per capita, urbanized area fixed effects, year fixed effects	Urbanized land area (external instrument)	2-stage least squares regression	0.28–0.76	—
Cervero & Hansen (2002)	United States (California)	Urbanized counties (counties within metropolitan statistical areas)	1976–1997	State-maintained freeways, arterials, and other major thoroughfares (class 1-3)	Population, fuel cost, income per capita, employment density, county fixed effects	Measures of topography and weather, air quality, and politics (external instruments)	3-stage least squares regression	0.59	0.79 (5 year)

[2] Regarding the column "Controls": The Federal Highway Administration (FHWA) uses a seven-level system to classify roadways according to their function (regardless of ownership or jurisdiction), starting with interstate highways (class 1) and ending with the lowest-capacity and lowest-speed roads, local roads (class 7). Those classifications are shown in parentheses where they were discernable from a study's documentation.

[3] Regarding the columns under "Estimation Strategy": Most of the studies compared multiple estimators and model specifications, many of which did not account for the endogeneity of roadway capacity. The table attempts to summarize the preferred estimators and elasticities reported by the studies' authors for the models that attempted to control for endogeneity.

Authors	Geography	Unit of Analysis	Study Years	Roadway Types	Controls [2]	Estimation Strategy[3]		Elasticities	
						Identification	Estimator	Short Run	Longer Run
Duranton & Turner (2011)	United States	Metropolitan statistical areas	1983–2003	Interstate highways (class 1)	Population, Census divisions, elevation range, terrain ruggedness index, heating degree days, cooling degree days, sprawl index	1947 interstate highway plan, 1898 railroad routes, mapped major exploration routes from 1835-1850 (external instruments)	2-stage least squares regression	—	1.03 (10 year)
Su (2011)	United States	States	2001–2008	All roads (class 1-7)	Population, fuel cost, income, vehicles per capita, congestion (annual hours of delay per capita), average vehicle fuel economy, numerous others	Lagged levels and differences in the values of the dependent and independent variables (internal instruments)	Generalized method of moments	0.07	0.26
Melo et al. (2012)	United States	Urbanized areas	1982–2010	Principal arterials, minor arterials (class 3-4)	Congestion (total hours of delay per peak-period traveler), gross domestic product per capita	Lagged levels and differences in the values of the dependent and independent variables (internal instruments)	Generalized method of moments	—	0.98
Graham et al. (2014)	United States	Urbanized areas	1985–2010	Interstate highways, other freeways and expressways, principal arterials, minor arterials (class 1-4)	Population growth, income per capita, fuel cost, congestion (annual hours of delay per VMT), network composition (freeway lane miles/arterial lane miles), traffic composition (arterial VMT/freeway VMT), mode share (annual public transit passenger miles), metropolitan wage per year, employment level, metropolitan share of manufacturing jobs, year fixed effects	Lagged levels and differences in the values of the dependent and independent variables (internal instruments)	Generalized propensity score	—	0.77

Authors	Geography	Unit of Analysis	Study Years	Roadway Types	Controls [2]	Estimation Strategy[3]		Elasticities	
						Identification	Estimator	Short Run	Longer Run
Hymel (2019)	United States	States	1981–2015	Freeways and other limited-access roads	Population, unemployment level, income per capita, fuel cost, state fixed effects, year fixed effects	Cumulative delegate-years of membership in House and Senate transportation committees (external instruments)	2-stage least squares regression	0.32–0.37	0.89–1.06
González & Marrero (2012)	Spain	Autonomous communities (16 regions; similar to US states)	1998-2006	All roads	Population, gross domestic product per capita, fuel cost, vehicles per capita, regional fixed effects	Lagged levels and differences in the values of the dependent and independent variables (internal instruments)	Generalized method of moments	0.11–0.17	0.27–0.31
Hsu & Zhang (2014)	Japan	Urban employment areas (similar to US metropolitan statistical areas)	1990–2005	National expressways (like class 1 US interstate highways)	Population, per capita income, regional fixed effects	1987 national expressway network plan (external instrument)	2-stage least squares regression	—	1.24–1.30 (3-5 year)
							Limited-information maximum likelihood	—	1.24–1.34 (3-5 year)
Chen & Klaiber (2020)	China	Prefecture-level cities (similar to US metropolitan statistical areas)	2011–2014	Urban roads ("paved roads with a width of at least 3.5 m;" excludes highways)	Population, land area, regional gross domestic product, disposable income per capita, regional fixed effects, year fixed effects	Footprint of 1984 municipal roads, footprint of 162 routes of highways, time-varying instrument capturing competitive effects from investment in other cities (external instruments)	2-stage least squares regression	0.99	—

Authors	Geography	Unit of Analysis	Study Years	Roadway Types	Controls [2]	Estimation Strategy[3]		Elasticities	
						Identification	Estimator	Short Run	Longer Run
Garcia-López et al. (2020)	Europe (29 countries)	Functional urban area (similar to US metropolitan statistical areas)	1985–2005	Highways (E-Road network)	Population, 1960 population, 1970 population, 1980 population, gross domestic product, unemployment rate, industrial composition, total land area, suburbanization index, altitude, elevation range, terrain ruggedness index, distance to nearest coast, historical major cities, regional fixed effects, year fixed effects, country fixed effects	Map of ancient Roman roads in Europe	Limited-information maximum likelihood	—	1.21 (5 year)