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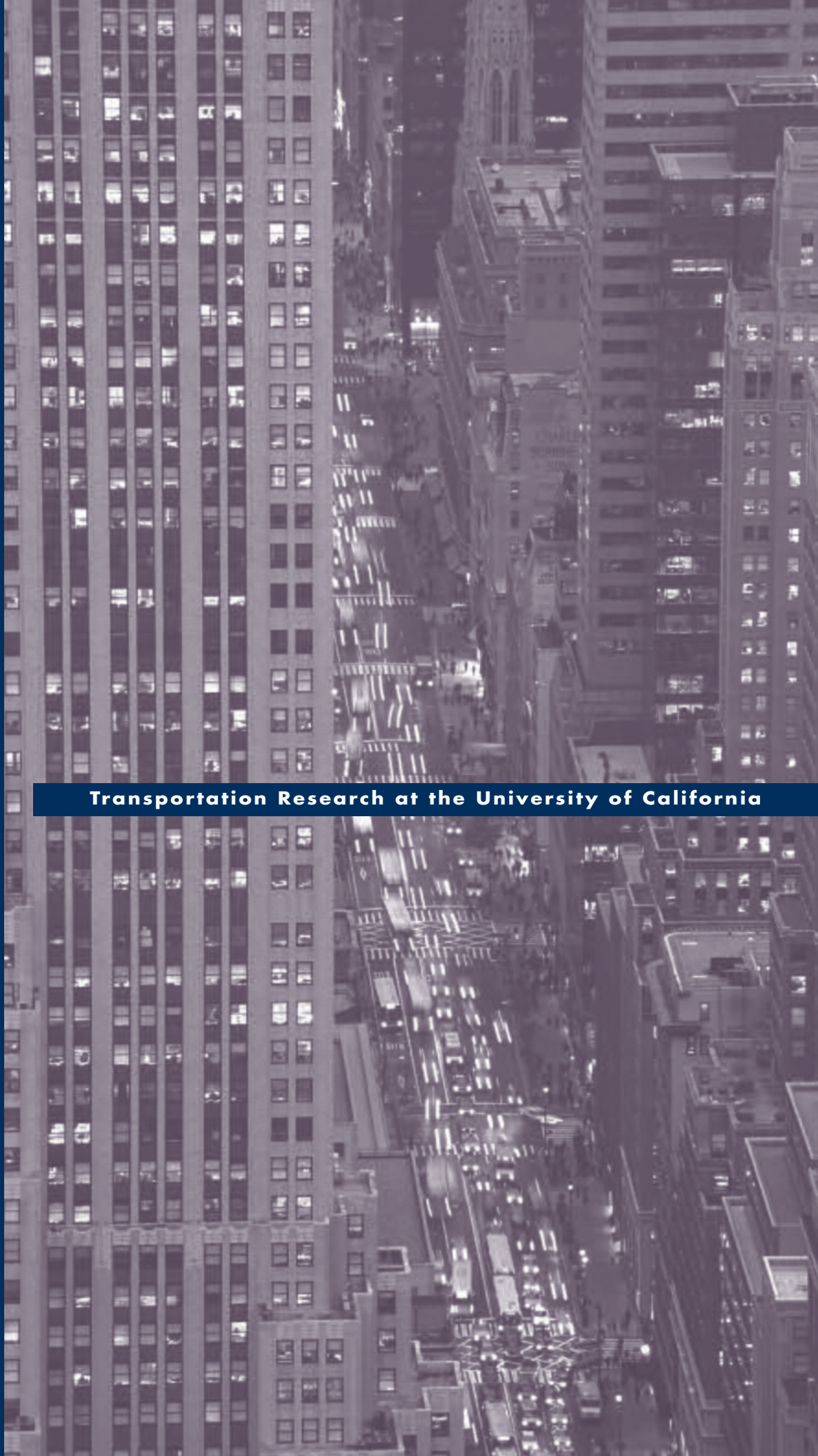
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Transportation Research at the University of California



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ACCESS moves to LA

With this issue, ACCESS moves from Berkeley to UCLA. Now that we are in Los Angeles, it is fitting that three of the five essays in this issue deal with freeways or traffic congestion. Freeway congestion is a hallmark of LA—a certainty like death and taxes, a source of frustration and resignation, and a convenient excuse for those of us who tend to be late.

Congestion is hardly unique to Southern California, of course. Congestion occurs in every large metropolitan area, and its ubiquity sometimes prevents us from seeing what a strange beast it really is. Like many social problems, congestion is large, highly visible, and getting worse; unlike many social problems, its costs fall disproportionately on the middle and upper classes. Twice a day, all across the United States, a large portion of our infrastructure—our road system—temporarily malfunctions from overuse. That we tolerate such regular breakdowns is rather remarkable. It's hard to imagine anyone being so forgiving if the lights went out twice a day, or if our sewers backed up morning and night. Yet every day the scene on our freeways resembles mass evacuation from a natural disaster, and everyone seems to regard it as inevitable.

Why are we so accepting of congestion? One answer, and I don't think it's the whole answer, is that over the years we have been sold a variety of policies that were supposed to fight congestion but failed to solve the problem. We have built rail systems and carpool lanes and higher-density developments, but our traffic has just gotten worse. So now we are cynical. Suppose you were sick and your doctor repeatedly prescribed expensive medicines that failed to cure your ailments. Maybe your doctor made a mistake, or prescribed these medicines because they tasted better than the medicine that would cure you. Either way you wouldn't get better. Indeed, you might start to think your illness was incurable, and that the best approach was to learn to live with it.

Transportation policy in the United States is a cabinet full of mislabeled medicine. Few transportation interventions significantly reduce congestion, but many of them pretend to. All of us are to blame for this confused state of affairs. Few of us like

congestion, but most of us like driving. So we are happy to believe that seemingly painless policies will make congestion go away. If only congestion were the result of something other than our own driving (really, if only it were the result of someone else doing something they shouldn't), the problem would be marvelously easy to solve.

Unfortunately, chronic traffic congestion is the result of too much driving. Specifically, congestion is the result of too many people driving in the same place at the same time. And that's all it is. Congestion is not the result of insufficient transit use, or of people's unwillingness to walk or bike. It is not the result of cities being too dense or not dense enough. It is not the result of jobs being too far from homes. The world might be a better place if more people biked or walked or rode transit or lived closer to work, but that has little to do with congestion. Congestion is simply the result of excess demand for the available road space.

What to do? We could build more roads, but that's something many of us, for reasons good and bad, are reluctant to do. Once new roads are off the table, however, we are left with an unpleasant fact: any policy that doesn't directly reduce peak hour driving won't reduce congestion. That doesn't mean the policy isn't worthwhile for other reasons; it only means it won't decongest traffic. Hence we arrive at a place where what works practically fails politically. What elected official wants to charge voters to drive? Politically, the easiest thing to do about congestion is nothing.

The mission of ACCESS, whether on the topic of congestion or any other transportation issue, is to dispel confusion and wishful thinking. Our goal is to take the often obscure results of technical research and translate them into language that policymakers will understand. Academics sometimes complain that elected officials don't listen to them enough. But elected officials, busy with the hard and messy task of making policy, often feel that academics, by writing only for each other, have relegated themselves to the sidelines. In Berkeley, Access was founded to help academics step onto the playing field. We hope to continue that mission in Los Angeles.

Michael Manville

TRAFFIC CONGESTION AND GREENHOUSE GASES

BY MATTHEW BARTH AND KANOK BORIBOONSOMSIN

SURFACE TRANSPORTATION IN THE UNITED STATES IS A LARGE source of greenhouse gas emissions, and therefore a large contributor to global climate change. Roughly a third of America's carbon dioxide (CO₂) emissions come from moving people or goods, and 80 percent of these emissions are from cars and trucks. To reduce CO₂ emissions from the transportation sector, policy makers are primarily pushing for more efficient vehicles, alternative fuels, and reducing vehicle miles traveled (VMT). Those who promote vehicle improvements have

focused on building lighter and smaller vehicles (while maintaining safety), improving powertrain efficiency, and introducing alternative technologies such as hybrid and fuel cell vehicles. Alternative fuel possibilities include many low-carbon options such as biofuels and synthetic fuels.

Policy makers have placed less attention on reducing CO₂ emissions by reducing traffic congestion. As traffic congestion increases, so too do fuel consumption and CO₂ emissions. Therefore, congestion mitigation programs should reduce CO₂ emissions. The key question is *how big* of an emissions reduction we can get by reducing congestion. This question is difficult to answer, because CO₂ emissions, and the fuel consumption that causes them, are very sensitive to several factors. These factors include individual driving behavior,



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vehicle and roadway types, and traffic conditions. Because of these factors, a table that estimates CO₂ emissions based only on a single variable, such as trip distance, cannot provide an accurate estimate. Rather, a comprehensive methodology that takes advantage of the latest vehicle activity measurements and detailed vehicle emission factors can create a more accurate emissions inventory for different types of vehicles and different levels of traffic congestion. With this methodology, we can accurately estimate how congestion mitigation programs will reduce CO₂ emissions.

DRIVING PATTERNS AND EMISSIONS

A typical driving trip consists of idling, accelerating, cruising, and decelerating. The proportion of a trip spent in these different stages will depend on the driver's behavior (e.g., aggressive vs. mild driving habits), the roadway type (e.g., freeway vs. arterial), and the level of traffic congestion. We can graphically display these factors through a vehicle velocity profile, a chart that shows speed over time (see Figure 1). The amount of CO₂ that is emitted during the trip will differ based on these different factors. Given a specific velocity profile and detailed information on the vehicle, we can estimate the CO₂ emissions using a vehicle emissions model. Researchers at the University of California, Riverside (UCR) have developed these emissions models for different vehicle types. We have collected a large amount of data both in the laboratory and on the road in real-world traffic (see Figure 2). These well-validated models provide the foundation for estimating the CO₂ emissions under different driving conditions with a wide variety of vehicles.

FIGURE 1

Typical vehicle velocity patterns for different roadway types and conditions

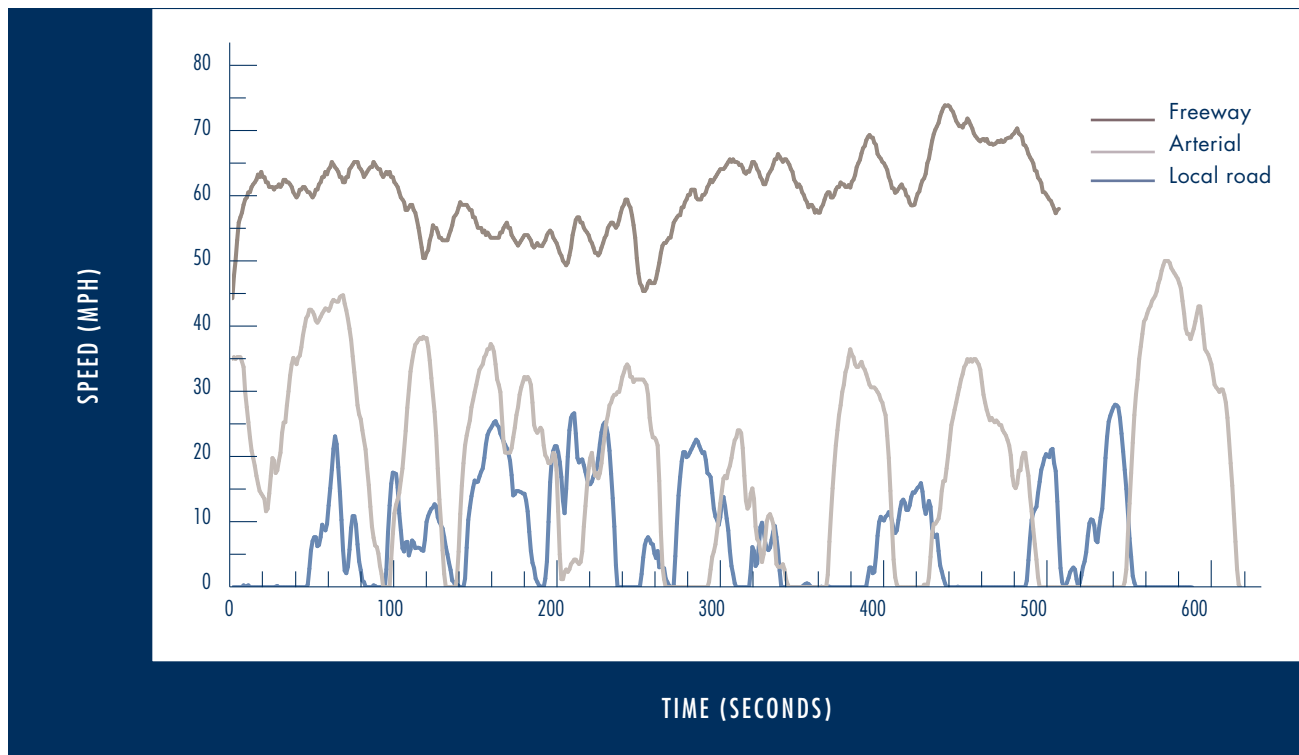


FIGURE 2

Vehicle emissions testing using a) a laboratory dynamometer, and b) an on-board portable emissions measurement system

FIGURE 3

GPS datalogger being installed on the dashboard of a vehicle



MEASURING VEHICLE ACTIVITY

Travel survey projects carried out around the world have measured typical driving patterns for particular areas. These vehicle activity datasets usually consist of velocity profiles from a sampling of vehicles, typically collected from Global Positioning System (GPS) dataloggers. These dataloggers (see Figure 3) measure a vehicle's position and velocity on a second-by-second basis. The Southern California Association of Governments (SCAG), for example, conducted a post-census travel survey in 2001 that consisted of 467 representative households with 626 vehicles, where over 28,000 miles of data were collected. UCR researchers have taken this data set, along with several others, and have amassed a large vehicle activity database that represents typical driving patterns.

This large vehicle activity database allows us to directly apply individual representative trip patterns to the comprehensive emissions model and then determine the emission values for each trip. As an example, if we take a large number of car trip patterns in Los Angeles and apply it to an emissions model for a modern passenger car, we can develop a histogram of the CO₂ emissions for each trip in the database. This histogram is shown in Figure 4, which shows that most trips produce about 330 grams per mile (g/mi) of CO₂ emissions, corresponding to approximately 26 miles per gallon of fuel economy. Other trips, however, produced far less or far more CO₂ emissions per mile, depending on the specific driving pattern. This variation comes from the driver's behavior, the roadway type, and the level of traffic congestion. Further, other vehicle types will have quite different CO₂ emissions depending on their weight, power, and other vehicle factors.

SPEED-BASED EMISSION FACTORS

Emission factors are commonly associated with average speed, and researchers often use average speed as a traffic performance measure. It is possible to create these speed-based emission factors (in terms of grams per mile) by simply taking the accumulated vehicle activity database and running each individual trip through the emission models. What results is a single emissions value associated with the average speed of the trip. We can

FIGURE 4

CO₂ emissions histogram for a representative database of trips in Southern California

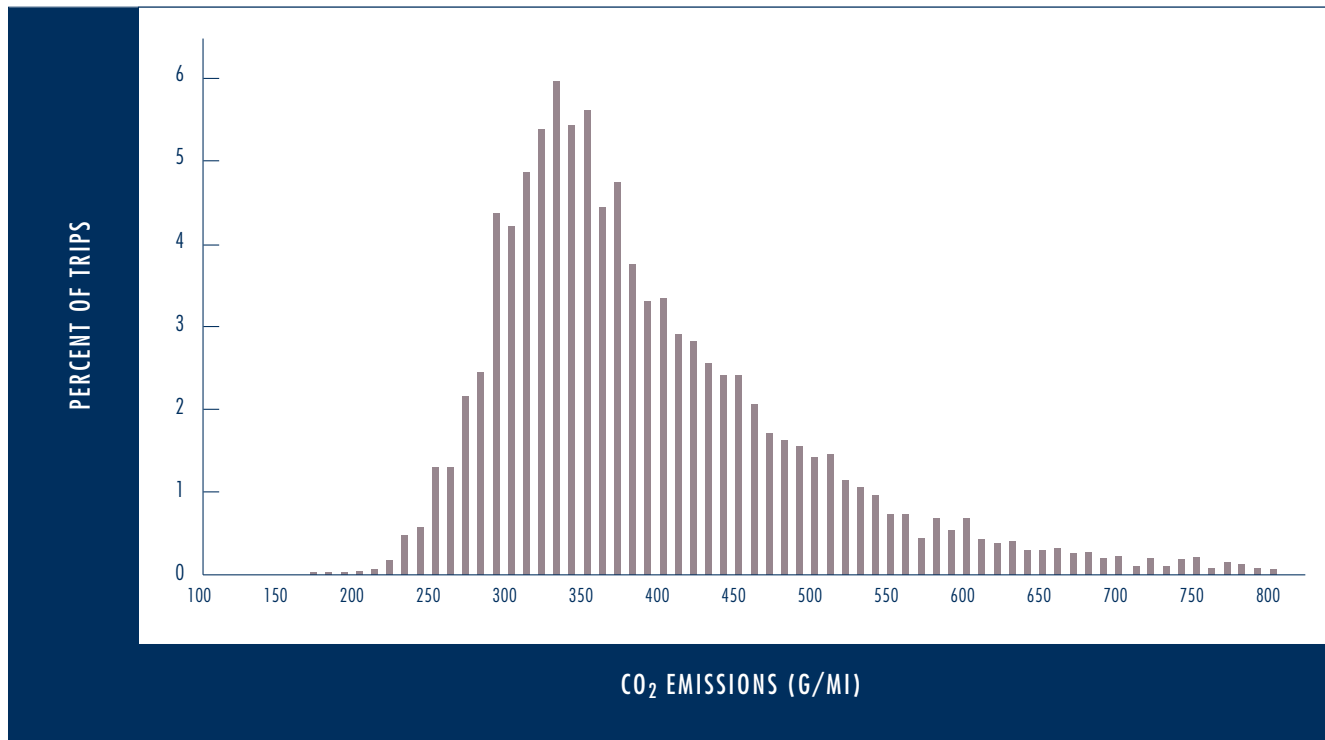
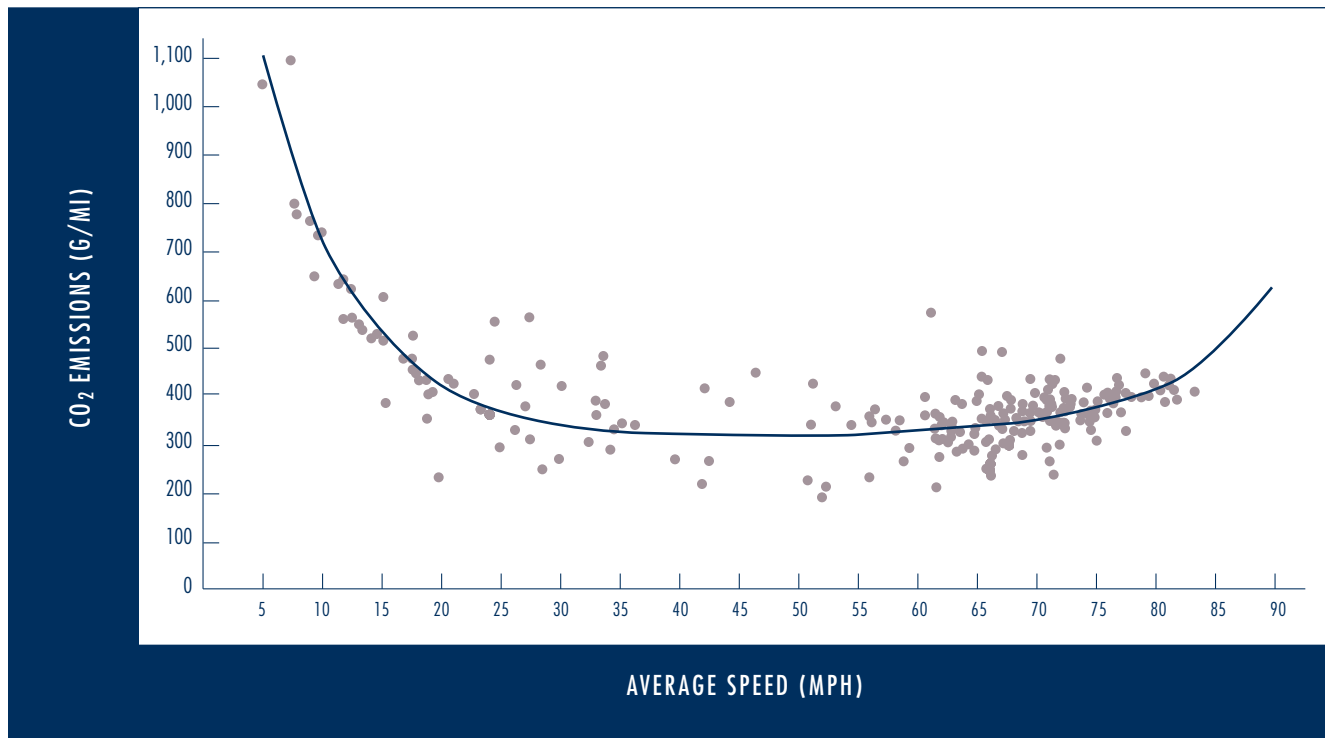


FIGURE 5

Emission-speed plot of individual trips or trip segments





split the trip into smaller segments representing the time spent on freeways, major surface streets, and residential streets. We can then associate an emissions value with the average speed of that particular trip segment.

If we now take those emission values and plot them against their different average speeds, we get a “U”-shaped pattern as shown in Figure 5. We can then fit a line to this pattern, resulting in a typical emissions-speed curve. The concept of the emissions-speed curve can serve as the foundation for relating emissions to vehicle activity. In fact, a large family of curves can now be established for different roadway types, and even different levels of congestion, given that these factors can be determined and included in the vehicle activity database. Furthermore, we can also establish separate families of emissions-speed curves for different vehicle types by adjusting the emission models. We can even establish an emissions-speed curve for the vehicle fleet composition typically found on the road.

This family of emissions-speed curves illustrates several key ideas. Very low average speeds generally represent stop-and-go driving, and vehicles do not travel far. Therefore, the emission rates per mile are quite high. (When a car’s engine is running but it is not moving, its emission rate per mile reaches infinity.) Conversely, when vehicles travel at much higher speeds, they demand very high engine loads, which require more fuel, and which therefore lead to high CO₂ emission rates. As a result, this emissions-speed curve has a distinctive parabolic shape, with high emission rates on both ends and low emission rates at moderate speeds of around 40 to 60 mph.

POTENTIAL EMISSIONS REDUCTIONS

The upper line in Figure 6 shows a representative emissions-speed curve for typical traffic. We can use this curve to examine how different traffic management techniques can affect vehicle emissions such as CO₂. The lower line represents the approximate lower bound of CO₂ emissions for vehicles traveling at a constant steady-state speed.

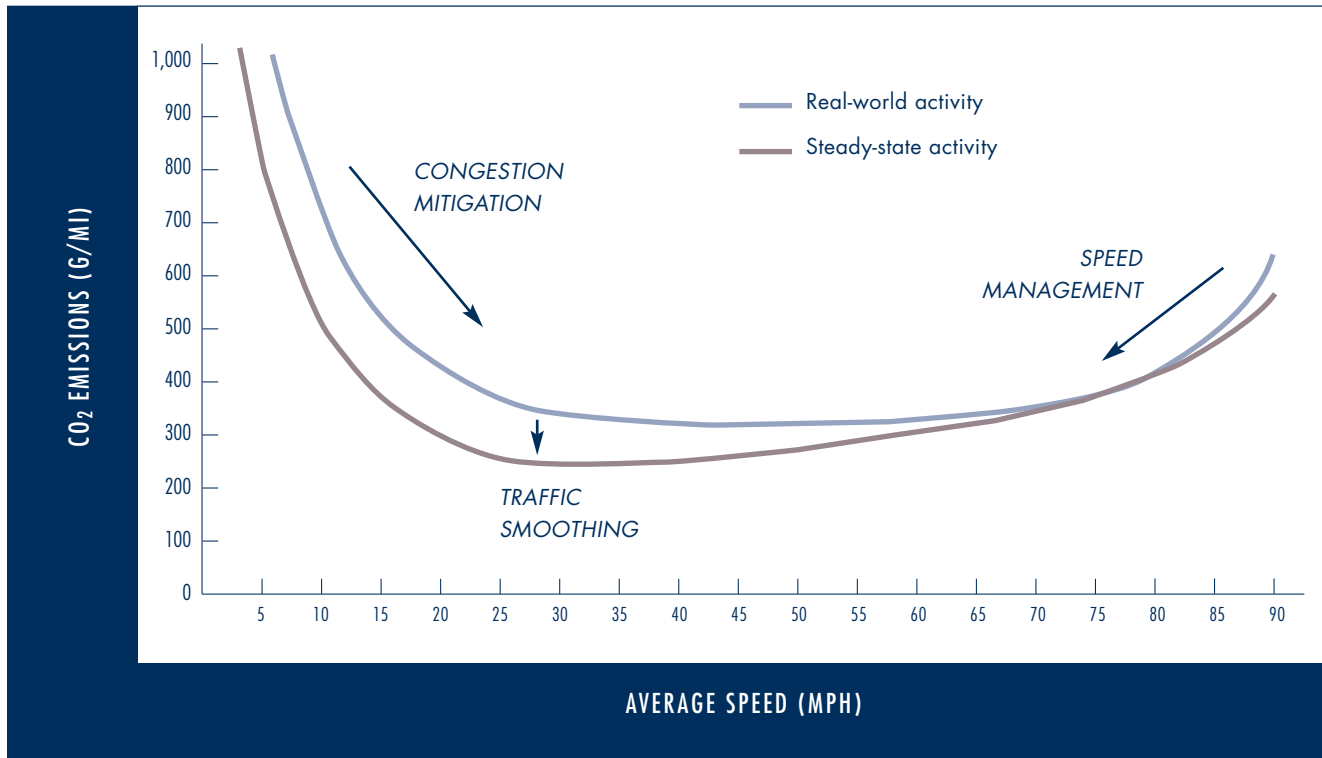
Several important results can be derived from Figure 6:

- If congestion reduces the average vehicle speed below 45 mph (for a freeway scenario), CO₂ emissions increase. Vehicles spend more time on the road, which results in higher CO₂ emissions. Therefore, in this scenario, congestion mitigation programs will directly reduce CO₂ emissions.
- If moderate congestion brings average speeds down from a free-flow speed over 70 mph to a slower speed of 45 to 55 mph, this moderate congestion can *reduce* CO₂ emissions. If congestion mitigation raises average traffic speed to above about 65 miles per hour, it can *increase* CO₂ emissions. And, of course, speeds above 65 or 70 also make the roadway more dangerous.
- Smoothing the stop-and-go pattern of traffic so that cars move at a relatively constant speed will reduce CO₂ emissions.

Figure 6 also illustrates three primary traffic operational improvement techniques that can directly lower CO₂ emissions. *Congestion mitigation* increases average traffic speeds from slower, heavily-congested speeds; examples of congestion mitigation include ramp metering, incident-management programs, and congestion pricing. *Speed management* reduces excessively high speeds to safer speeds; examples of this approach include direct enforcement by police and Intelligent Speed Adaptation (ISA) where top speeds are capped

FIGURE 6

Possible use of traffic operation strategies in reducing on-road CO₂ emissions



based on specific traffic conditions. *Traffic smoothing* reduces the number and intensity of accelerations and decelerations; examples include variable speed limits, dynamic ISA, and congestion pricing.

COUPLING EMISSIONS-SPEED CURVES TO TRAFFIC PERFORMANCE DATA

Estimating emissions as a function of speed allows us to use the resulting emissions-speed curves directly with traffic performance measurements. For example, if loop sensors in a roadway can measure traffic volume and average speed, we can use these parameters in conjunction with the emissions-speed curve to estimate overall traffic-related emissions for that location. The process is relatively simple: the average traffic speed for a link is used to index the emissions-speed curves that correspond to the vehicle fleet mix on that roadway. By weighting the emission values by the vehicle fleet mix and then multiplying by the total volume of traffic, we can estimate the total emissions for that roadway link. If the emissions for all the links are then combined, we can estimate an overall traffic-related emissions inventory for the region.

To illustrate this estimation, we have examined the Los Angeles freeway network. The LA freeway system has a rich set of embedded loop sensors that measure traffic parameters (speed, density, and volume) throughout the network. We used the loop-sensor data to generate emissions-speed curves for the average fleet mix of the region. We then used these emissions-speed curves together with the traffic performance measures to estimate real-time CO₂ emissions along individual freeway segments.

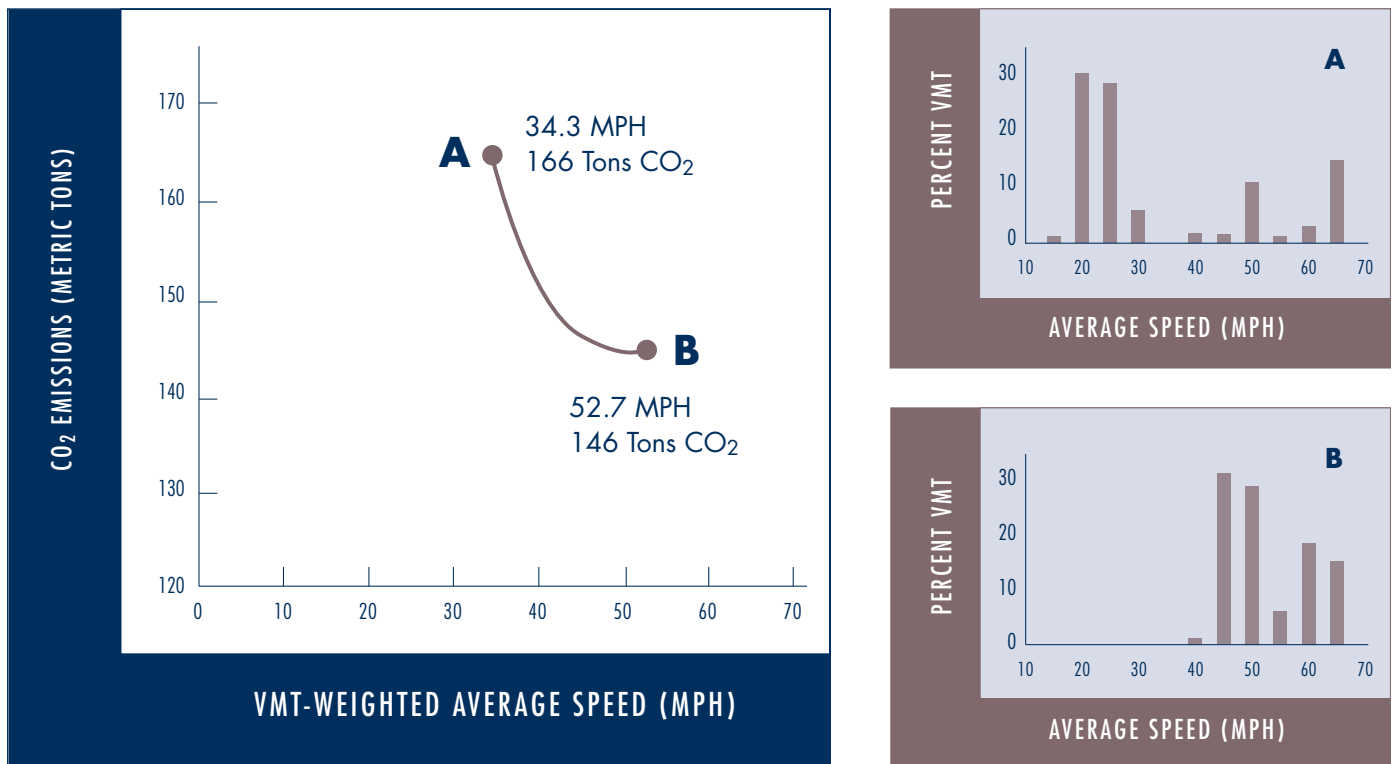
VEHICLE SPEED HISTOGRAMS AND CO₂ REDUCTIONS

Our next research goal was to estimate current levels of congestion and then estimate how much different congestion management programs could reduce CO₂ emissions. To illustrate this, we first develop vehicle-speed histograms for particular locations and time-frames using data from the traffic performance measurement system. For example, in Figure 7 we have examined the average traffic conditions on a downtown LA segment of Interstate 110 northbound between 4 p.m. and 5 p.m., for the month of March 2007. We then created a histogram of average traffic speed, showing the vehicle miles traveled (VMT) in each speed bin. Due to congested conditions, a significant portion of the traffic was moving in the 20 to 30 mph range. For these conditions, we can calculate that the congested traffic for this one-hour time period on this segment of freeway emits approximately 166 metric tons of CO₂.

Congestion mitigation programs that increase the overall traffic speed should reduce these CO₂ emissions. As shown in Figure 7, if we improve the overall average traffic speed by approximately 20 mph, the speed histogram would change, resulting in a reduction of 21 metric tons of CO₂, a 12 percent drop. We can then apply this methodology for additional roadway segments in the network.

FIGURE 7

Potential CO₂ emissions savings through congestion mitigation on Interstate-110 in downtown Los Angeles. The curved line indicates incremental improvements from 35 to 55 mph.





CONCLUSION

There are many reasons to fight traffic congestion. Congestion wastes time and money, and it increases the risks of accidents and localized pollutants like particulate matter. But potentially the most serious, if also the least immediate, consequence of traffic congestion is increased emissions of greenhouse gases.

Although many people understand that driving contributes to greenhouse gas emissions, the measurement of this phenomenon has been surprisingly crude, often associating carbon emissions only with trip distance, without accounting for how carbon emissions change with vehicle speed.

In our research, we have developed a more finely grained way to measure the relationship between driving and carbon emissions, and this allows us to develop better estimates of how congestion-management techniques can help fight global warming. Specifically, we have estimated how three improvements in managing traffic operations can reduce CO₂ emissions:

- *Congestion mitigation* strategies that reduce severe congestion and increase traffic speeds (e.g. ramp metering, incident management, and congestion pricing);
- *Speed management* strategies that bring down excessive speeds to more moderate speeds of approximately 55 mph (e.g. enforcement and ISA); and
- *Traffic smoothing* strategies that reduce the number and intensity of acceleration and deceleration events (e.g. variable speed limits and ISA).

Using typical conditions on Southern California freeways as an example, our research has shown that each of the three traffic-management strategies above could reduce CO₂ emissions by 7 to 12 percent. All three strategies in combination could reduce CO₂ emissions by approximately 30 percent. ♦

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Airport Congestion Management: Prices or Quantities?

BY JAN BRUECKNER

AIR TRAVEL DELAYS HAVE HIT NEW HIGHS IN THE US since 2000, although passenger traffic and airport congestion have temporarily fallen during the current recession. Similar delays continue to plague European airlines. Although weather is a major source of delays, US Department of Transportation data show that the volume of traffic is also a major cause. What can be done about this airport congestion and the resulting delays?

One remedy is to invest in infrastructure, but new runways take a considerable amount of time to build, and they are expensive. Technological improvements in air traffic control could also increase the capacity of the nation's airspace and reduce the impact of bad weather. A third remedy is demand management, either through congestion pricing or restrictions on airport slots (rights to land and take off).



Under congestion pricing, the landing fees paid by airlines would rise at peak hours, and in response, airlines would move some flights to off-peak periods.

Current landing fees paid by airlines depend only on aircraft weight and do not vary by time of day. Under congestion pricing, the landing fees paid by airlines would rise at peak hours, and in response, airlines would move some flights to off-peak periods. Under a slot system, by contrast, flights cannot exceed the total available number of hourly slots, so that a cap on slots limits peak congestion. One way to set up a slot system is to distribute the slots among the airlines and then allow trading, a system analogous to the cap-and-trade approach to pollution reduction. Such a system currently exists at four congested US airports (LaGuardia, JFK, O'Hare and Reagan-National). Another possibility is to distribute the slots via an auction mechanism. An airport's entire stock of slots can be auctioned anew each year, or the auction can involve just a portion of the total. In 2008, the Federal Aviation Administration proposed such a partial auction for the New York area airports, with a small percentage of the airlines' grandfathered slot holdings taken back each year and sold to the highest bidders. The airlines strongly objected (they were being asked to pay for something they now hold for free), and the FAA recently withdrew its auction proposal.

Although this recent defeat for government policymakers darkens the near-term prospects for adoption of new demand-management approaches, airport congestion is a long-term problem that will eventually require systematic intervention to control demands on airport capacity. As a result, it is important to gain a better conceptual understanding of the different approaches to congestion management.

CONGESTION PRICING

The theory of congestion pricing was developed for roads. Economists recognized that peak road usage is excessive because individual users do not take into account the delays imposed on all other users. Charging a congestion toll equal to the cost of the external delays each user generates will appropriately restrict peak use.

Congestion pricing follows the same logic when applied to airlines, with one important difference. Individual road users are *atomistic*; each driver is a small part of the total traffic on the road. By contrast, the airlines using a congested airport are typically *nonatomistic*; most individual airlines account for an appreciable share of the total traffic at the airport. This difference matters for airport congestion tolls, since a nonatomistic airline, unlike an atomistic driver, takes into account a portion of the congestion caused by each of its flights. Specifically, the airline *considers the congestion each flight imposes on all the other flights it operates*. In other words, it recognizes that scheduling an extra peak-hour flight will slow down its existing flights, possibly making the airline reluctant to add the flight.

The airline's partial internalization of congestion means that the congestion externality is not as severe with airports as it is with roads. The overscheduling of flights is thus not as excessive as the overuse of a rush-hour freeway. As a result, airport congestion tolls can be less punitive than in the context of road congestion tolls. Just as with road pricing, the airport toll is based on the marginal congestion damage (MCD) from an extra flight, which equals the increase in operating cost for all the affected airlines plus the value of the lost time for their passengers. But because the airline internalizes some of its congestion, the toll does not equal the full MCD, as it would in the road case. It instead equals the MCD multiplied by *one minus the carrier's flight share*, which equals the portion of the extra congestion that is

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not internalized by the airline. The formula thus charges the carrier only for the congestion it imposes on other airlines, exempting the congestion it imposes on itself.

For example, at an airport served by three identical airlines, each would pay a congestion toll equal to MCD times $2/3$, reflecting the fact that $2/3$ of the congestion from an extra flight falls on other carriers. MCD varies over the day, being high at peak hours and low (even zero) in the off-peak periods. Thus, the toll computed by this formula will vary over the day, disappearing when the airport is not crowded.

This toll rule produces a surprising result when applied at an airport where carriers control different flight shares. Because the airport's largest carrier internalizes much of the congestion from an extra flight, it will pay a low toll. By contrast, because a small carrier feels only small portion of the congestion created by its operation of an extra flight, it will pay a high toll. For example, given that Delta operates more than 70 percent of Atlanta's flights, it should pay a low toll per flight (equal to $0.30 \cdot \text{MCD}$), while AirTran, which operates around 10 percent of the airport's flights, should pay a large toll ($0.90 \cdot \text{MCD}$).

While this toll pattern is justified on the grounds of economic efficiency, it might be politically infeasible. Small carriers would fiercely oppose a rule that appears to subject them to an unfair burden, regardless of the economic logic. As a result, any practical implementation of congestion pricing might have to adopt a second-best approach, levying the same toll on all carriers. While a uniform toll would approximate an efficient pricing system at airports where flight shares are similar across most carriers (e.g., Boston), such a toll would distort

the pattern of flights at airports dominated by one or two carriers. Since the congestion penalty placed on large carriers would be too high, they would be under pressure to shrink or reorganize their operations more than they should. Small carriers, meanwhile, with congestion penalties being too low, would not feel enough pressure to change their operations.

All these ideas apply, however, only if airlines do in fact internalize their own self-imposed congestion, and not everyone believes they do. Economist Joseph Daniel, for instance, has written a number of papers (with a variety of coauthors) suggesting that the airlines do not internalize congestion costs. Daniel's argument is based on the behavior of the "competitive fringe," a set of carriers operating a small portion of an airport's flights and perceiving no impact on overall congestion from their decisions. Daniel argues that if a large carrier cuts back its flights to reduce self-imposed congestion, then small fringe carriers will fill the resulting gap, leaving overall congestion unchanged. Since the large carrier reaps no benefits from limiting its peak flights, it will have no incentive to do so. In effect, the carrier will seem to behave irrationally, appearing not to recognize that it congests itself. But given the potential offsetting response of the fringe carriers, such behavior is rational.

So do airlines internalize congestion or not? The empirical evidence is mixed. Some studies find no evidence of internalization, while others (including some of my own work) suggest the opposite. If internalization does not occur, then all carriers should be charged the same congestion toll regardless of their size. In effect, the road-pricing model reasserts itself, with each carrier charged MCD per flight, unadjusted for flight shares. Thus, the toll rule is immune to the unfairness critique levied against the previous formula, given that it will not generate asymmetric tolls. But, if congestion is indeed internalized, the toll liabilities faced by the carriers under this formula are too high, and they will excessively shrink and reorganize their traffic.

SLOT SYSTEMS

Rather than deciding what congestion toll to charge, the airport authority under a slot system decides on how many slots to make available. This decision must be made for each time interval over the day (usually in 30 minute increments). Under a trading system like those in place at some congested US airports, the chosen slot total is distributed without charge among the carriers according to some allocation rule, with reallocations possible via trade. Initial slot allocations in the US were determined years ago, but continuous trading (usually involving leases, not sales, of slots) has redirected many slots to new users.

Before making any decisions about flight volumes and slot trades, carriers know that the overall congestion level at the airport is fixed and independent of their choices. The reason is that a slot system fixes in advance the total number of slots allocated for each time interval, thus determining the airport's total flight volume and congestion level. By contrast, since carriers under congestion pricing are free to operate as many flights as they like provided they pay the toll, the overall level of airport congestion will respond to their choices. The overall flight volume, and thus the level of congestion, is not fixed in advance.

Since congestion impacts cease to be a carrier's concern under a slot-trading system, the complications caused by internalization of congestion (particularly the need for carrier-specific tolls) vanish. As long as the airport authority distributes the right total number of slots, the trading process guarantees that the slots are distributed correctly among carriers. A single slot-trading price suffices, with no need for prices tailored to individual airlines. In effect, as long as the airport authority chooses the slot total (and thus the overall congestion



Rather than deciding what congestion toll to charge, the airport authority under a slot system decides on how many slots to make available.

level) correctly, market forces ensure that carriers' individual slot holdings and flight volumes are right.

Theoretically, the same conclusions apply to a slot-auction system. Assuming the airport authority auctions the same number of slots as it would have distributed for free under a trading system, the two systems result in the same allocation of slots and flight volumes across carriers. The auction price is also the same as the equilibrium slot-trading price, which turns out to equal MCD. Note, however, that while the auction revenue accrues to the airport, no revenue is earned when slots are freely distributed (though money does change hands between carriers).

A further virtue of both slot systems is that their performance does not depend on whether the airlines internalize congestion. Since the fixed slot total makes congestion irrelevant to the airline's choices, whether or not its effects are internalized is of no consequence. By contrast, the correct toll structure depends crucially on whether internalization occurs.

Economist Joseph Daniel identifies one potential downside to slot systems, however. He argues that, given their wide 30-minute time window, slots are too crude an instrument to properly attack airport congestion. Daniel argues that small scheduling changes at hub airports (such as spreading out clustered departures by 10 minutes) can greatly reduce congestion. Congestion tolls that vary minute by minute, he argues, would most effectively generate such changes.

IMPLICATIONS

What do we learn from this discussion? One important lesson is that the current slot system for congestion management at airports may be better than recognized. Provided that airport authorities have chosen the right slot totals, and provided that the slot-trading system works in the manner envisioned in the theory, the outcome is equivalent to the one emerging under a more elaborate congestion-pricing system.

Whether slot totals are correctly set is a matter of debate. In the recent decision for New York airports, the airlines argued that the FAA chose hourly totals that were too restrictive. Generally, conservative slot decisions may limit congestion too much, excessively restricting peak-hour airport access to travelers who need it, and policymakers should bear this principle in mind.

Whether the slot-trading system works properly is also a matter of debate. In proposing its partial auction scheme for the New York airports, the FAA acted on a suspicion that trading volumes are inadequate and slot allocations need to be scrambled via an auction. A recent study by Hideki Fukui of slot-trading patterns over the late 1990s, however, did not find clear evidence of anti-competitive behavior, which casts some doubt on the existence of a major problem. Nevertheless, proposals for enhancing the performance of the slot market are welcome, including the replacement of bilateral trading with a web-based, central clearinghouse that hides identities of buyers and sellers. With such improvements and the proper choice of slot totals by policymakers, the current system may be adequate for airport congestion management as air travel resumes its long-run upward trend. ♦





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Moving Los Angeles

BY PAUL SORENSEN

PEOPLE OFTEN COMPLAIN ABOUT TRAFFIC IN LOS ANGELES, and with good reason. The Texas Transportation Institute publishes annual traffic statistics for metropolitan areas across the United States, and the greater Los Angeles region routinely tops the list for such measures as total congestion delays and congestion delays per peak-period traveler. Against this backdrop, RAND was recently asked to evaluate and recommend near-term strategies that could meaningfully reduce LA's traffic within a period of five years or less. Note that this timeframe precludes land use policies, which take longer to bear fruit, and major infrastructure investments. In addressing this question, we found it helpful (a) to review general insights from the transportation literature on the causes and potential cures for traffic congestion, and (b) to diagnose the specific local conditions that contribute to the notoriously severe congestion in Los Angeles.



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WHAT DO WE KNOW ABOUT TRAFFIC CONGESTION

Traffic congestion is a long-standing urban problem, and researchers have studied it for many years. The resulting literature offers many valuable insights relevant to Los Angeles, along with other cities.

Congestion results from an imbalance between the supply of road capacity and the demand for driving during peak travel hours. Potential solutions thus include managing peak-hour driving demand or boosting road supply. Until supply and demand are brought into closer alignment, congestion will resolve the imbalance by making drivers wait their turn to use the road.

Growth in demand has far exceeded growth in supply in recent decades. One reason demand so often outstrips supply is that vehicle miles traveled (VMT) have been growing much faster than the nation's road supply for decades. We no longer build roads the way we used to, but we drive more than ever—in Los Angeles and across the nation. Figure 1 provides an aggregate view of this trend, comparing growth in road lane miles, population, the economy as measured by gross domestic product (GDP), and VMT in the US since 1970. Over this period, the supply of lane miles has been relatively stagnant, while growth in VMT has far exceeded growth in the population and in fact tracks quite closely with GDP.

Transportation revenue shortfalls preclude “building our way out of congestion.” Looking at the data in Figure 1, one might conclude that investing more in road capacity would be a sensible response to the rapid growth in travel. But even setting aside concerns related to climate change, energy security, and sprawl, we simply do not have the available resources to significantly expand capacity. Federal and state gas taxes provide the lion's share of highway and transit funding in the United States. These are typically levied on a cents-per-gallon basis and are not indexed to either inflation or improved fuel economy. The California gas tax was last raised in 1994, and Congress has not increased the federal gas tax since 1993. As a result, we now collect far less real revenue per mile of vehicle travel than in years past.

FIGURE 1

Growth in lane miles, population, GDP and VMT for the United States since 1970

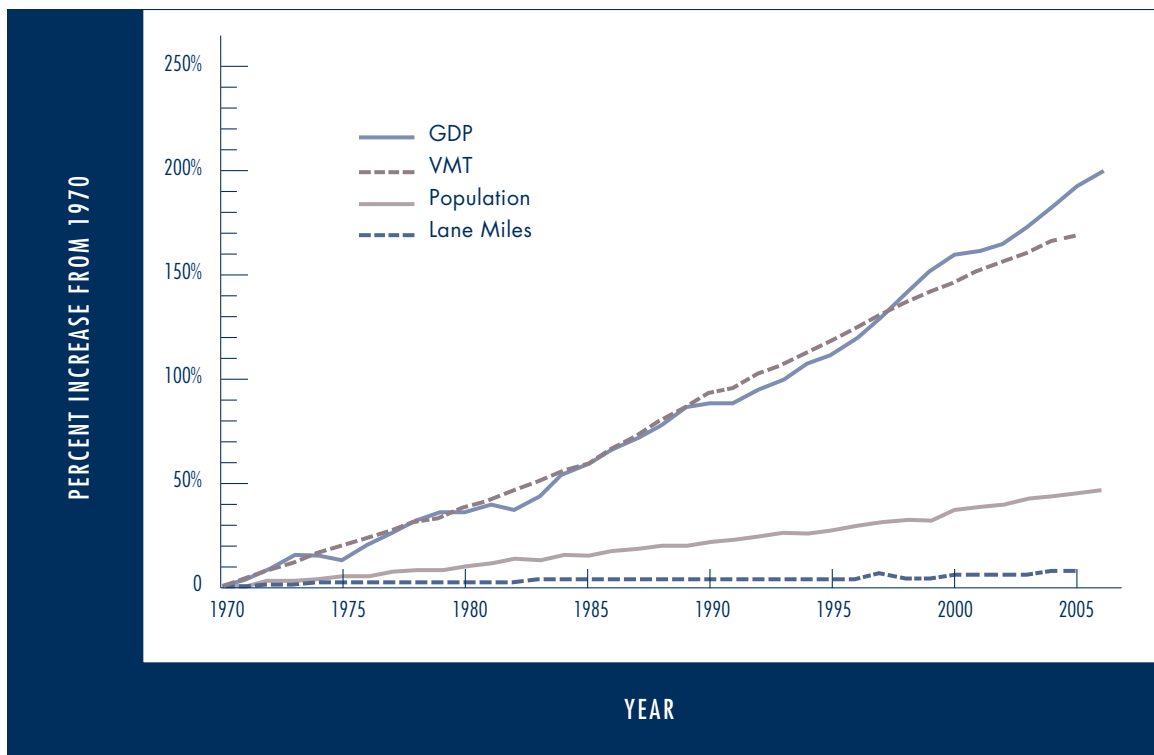


FIGURE 2

Combined effects of inflation and fuel economy improvements on real California gas tax revenues per mile of travel

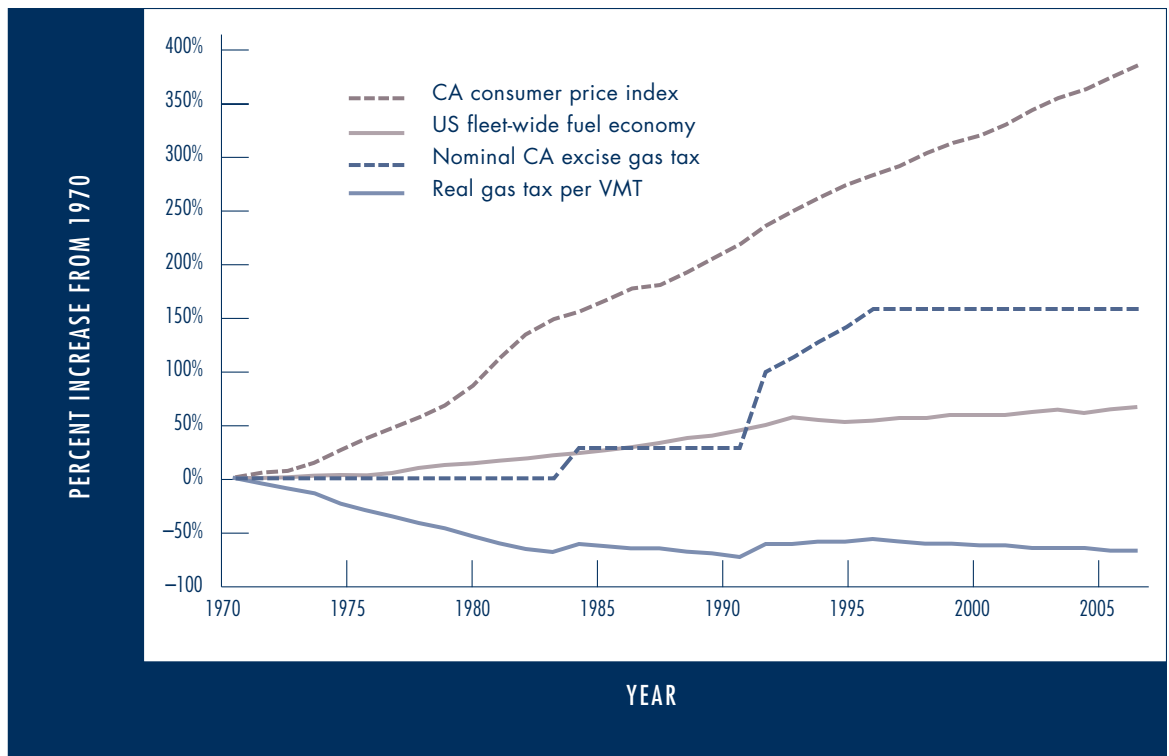


Figure 2 illustrates the steady erosion in the value of the California excise gas tax over the past four decades. In 1970, California’s gas tax was 7 cents per gallon. Since then, it has been increased several times and now stands at 18 cents per gallon—a nominal increase of about 160 percent. Yet over the same period, the Consumer Price Index has increased about 400 percent, while average vehicle fuel economy has increased by about 65 percent. Taking all of these factors into consideration, the California excise gas tax currently nets about two-thirds less real revenue per mile of travel than in 1970. In short, the gas tax no longer buys what it used to, and this severely restricts our ability to build new roads. (Note that California also charges sales taxes on gasoline; though intended to fund transit, this revenue source has often been diverted to the state’s general fund to cover budgetary shortfalls.)

Few congestion-reduction strategies remain effective over the longer term. Even if we had the money to build new roads, we would have to contend with the fact that most strategies for reducing congestion—including road-building—become less effective over time. The gradual erosion of congestion improvements comes from a phenomenon called “triple convergence.” In short, when traffic conditions on a roadway improve in the peak hours, additional travelers tend to converge on the new capacity from (1) other times of travel, (2) other routes of travel, or (3) other modes of travel, slowly eroding the initial benefits from reduced peak-hour congestion. This phenomenon applies broadly; it may occur, for instance, in response to the development of new lane capacity, a new subway line that lures some drivers out of their cars, or ridesharing programs that increase the number of travelers in each vehicle. Any measure that improves traffic flow during the peak hours also attracts additional drivers to take advantage of the improved conditions. While such strategies may promote greater aggregate mobility, their ability to relieve peak-hour congestion in the busiest areas and corridors will be short-lived.



Failure to charge the full costs associated with automotive travel inflates the demand for driving. If it is not possible to build our way out of congestion, it becomes necessary to focus on demand. One reason why the significant growth in VMT in recent decades has been relatively unconstrained is that driving, from an economic perspective, is under-priced. While driving creates environmental and social costs, such as harmful emissions and additional congestion delays for others, we are not as individual motorists forced to confront these costs; rather, they are passed along to society at large. Because driving is under-priced, we tend to overuse road space; that is, we make many trips for which total costs (including external costs passed on to others) exceed total benefits. In theoretical terms, this overuse reduces social welfare. In practical terms, it leads to greater traffic congestion, poorer air quality, and increased greenhouse gas emissions.

Pricing strategies not only reduce the demand for driving, but are also the only strategies that can produce sustainable reductions in traffic congestion. The only anti-congestion measures that can overcome the effects of triple convergence involve the use of pricing: charging more to drive and/or park in the busiest areas or corridors during peak hours. Pricing forces drivers to confront (internalize) the aforementioned externalities associated with automotive travel. Drivers, when faced with these extra costs, are motivated to change their travel behavior in ways that will reduce overuse of road capacity. The reason triple convergence does not undermine pricing strategies is that the same peak-hour charges that encourage some to change their travel patterns also deter others from converging on the freed capacity. Pricing strategies can help raise revenue as well, and by preventing congestion they facilitate more efficient use of existing capacity.

Even small changes in driving can lead to large changes in congestion. The relationship between the number of vehicles and their travel speed is non-linear. When only a few cars



are on the road, more can be added without having much effect on travel speed. When the road is already crowded, on the other hand, adding only a few more cars can trigger congestion, significantly reducing travel speed and the number of vehicles that can pass in a given time period. Conversely, when a road is already congested—as many in Los Angeles are—reducing the number of cars by even a small amount can often produce much larger reductions in congestion delays. Encouragingly, this implies that demand-side strategies need only stimulate modest changes in travel behavior to achieve significant results.

WHAT MAKES LA TRAFFIC SO SEVERE?

To further inform the development of suitable strategies to reduce congestion in Los Angeles, we took a closer look at some of the underlying factors that contribute to the region's congestion. What is it about Los Angeles, specifically, that leads to the most severe congestion in the nation, and what implications does this have for the types of strategies that might offer the greatest prospects for reducing congestion?

COMMON MISCONCEPTIONS

There is an inherent appeal in simple explanations, but traffic is a complex matter. Many of the most obvious hypotheses for the severity of congestion in Los Angeles therefore prove to be either inaccurate or incomplete.

Excessive per-capita driving is not the problem. Los Angeles and car culture are closely associated in popular discourse, with the relationship between Southern Californians and their cars often described as a love affair. Yet among the 14 largest metropolitan regions in the country, Los Angeles ranks just fifth in per-capita VMT, fifth in per-capita auto ownership,

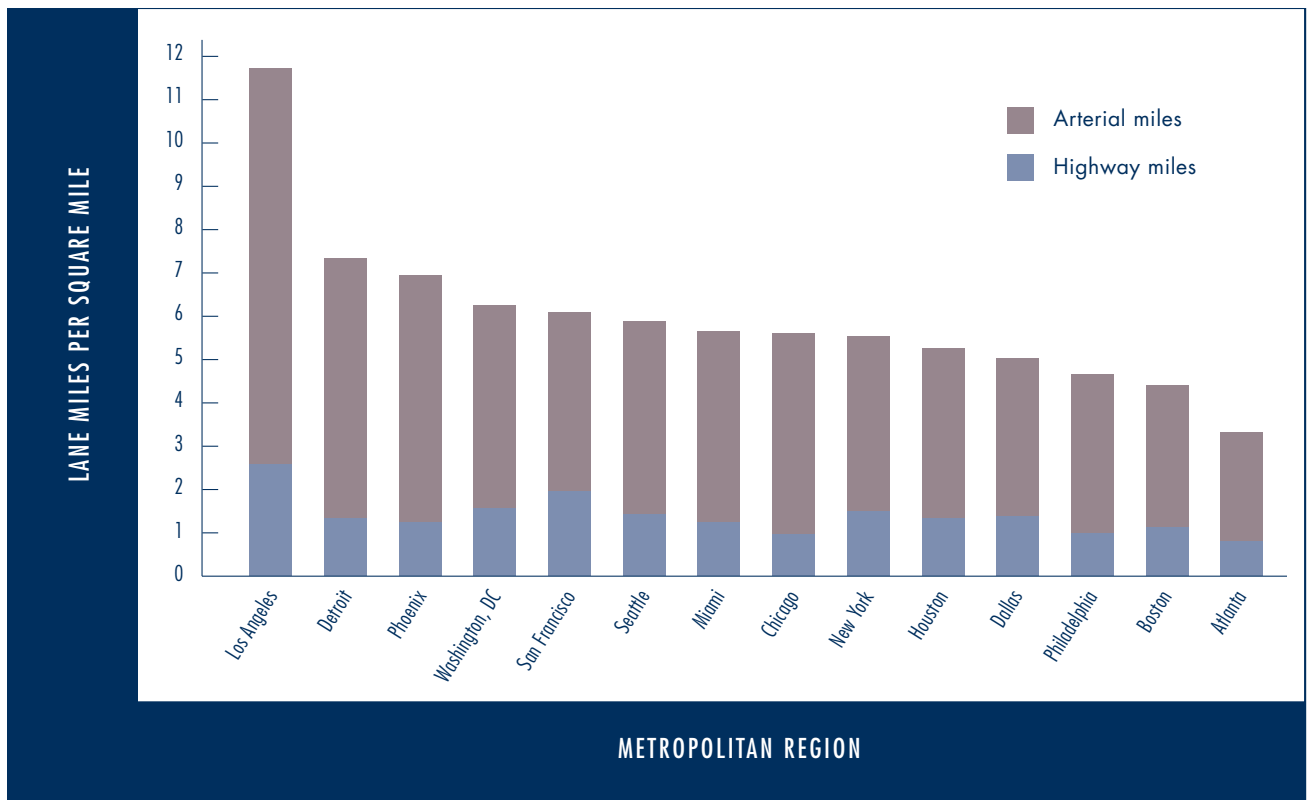


FIGURE 3
Lane mile supply in major metropolitan regions in 2007

and ninth in the percentage of employees who drive to work alone.

Inadequate road capacity is not the problem. Figure 3 shows that Los Angeles has by far the densest road network among the nation’s 14 largest metropolitan areas, providing over 50 percent more lane miles per square mile than Detroit, its nearest competitor. Even when framed in terms of lane miles per capita, Los Angeles still ranks eighth among the 14 largest metropolitan regions. Moreover, transportation agencies in the LA region have implemented sophisticated programs such as ramp metering and synchronized traffic signals to operate the road system efficiently.

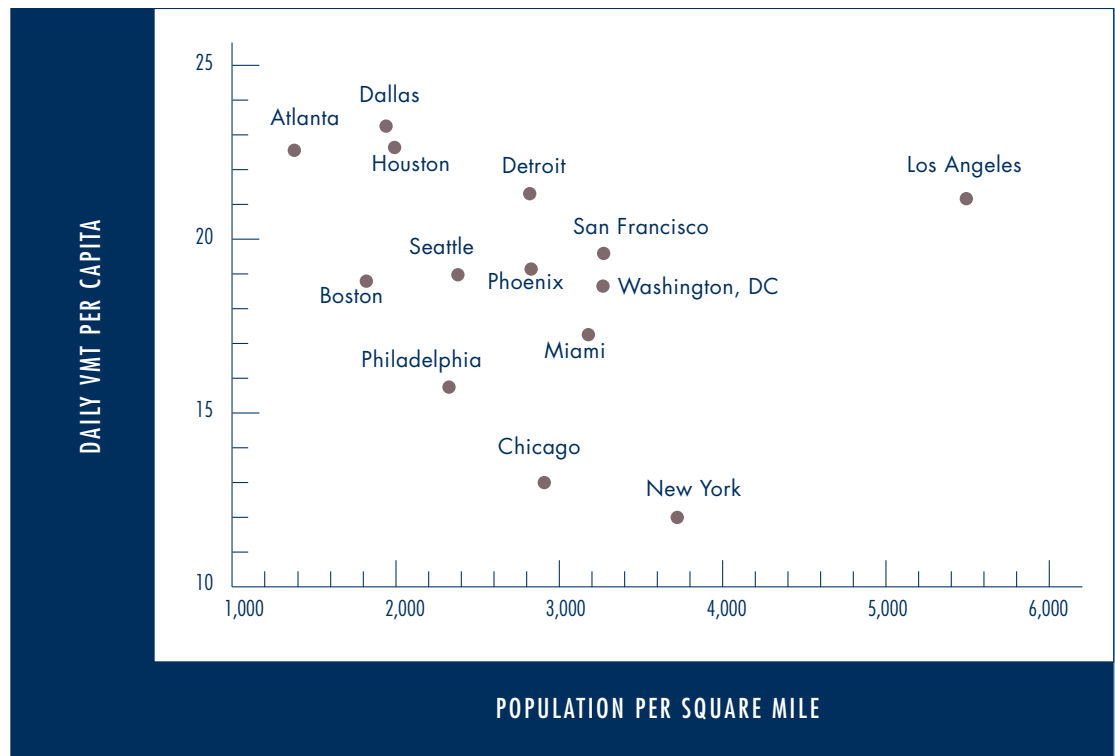
Lack of transit service is not the problem. Los Angeles has an extensive transit system in comparison to many other urban areas. Of the 14 largest metropolitan regions, Los Angeles ranks second in total bus service miles, first in bus service miles per square mile, third in bus service miles per capita, fifth in total rail transit track miles (including commuter rail, light rail, and subways), seventh in rail transit track miles per square mile, and seventh in rail transit track miles per capita.

HIGH REGIONAL POPULATION DENSITY IS A KEY CONTRIBUTOR TO CONGESTION IN LOS ANGELES

The possible explanations above are inaccurate or incomplete because they fail to take into consideration the region’s high population density. Despite its reputation for sprawl, Los Angeles is quite densely populated at the regional scale. While downtown Los Angeles isn’t as dense as, say, Manhattan or downtown Chicago, the suburbs surrounding Los Angeles are much denser than the suburbs surrounding other major cites. As a result, Los Angeles is the densest metropolitan area in the country.

FIGURE 4

Population density vs. daily per-capita VMT in major metropolitan areas in 2007



As density increases, individuals tend to drive less on a per-capita basis. Trip origins and destinations are closer together, leading to shorter car trips, and people can rely on alternatives such as walking, biking, or transit for a larger share of trips. Yet this reduction in per-capita driving can be overwhelmed by the fact that many more drivers are competing for the same road space, thus intensifying traffic congestion. The net effect is that greater population density tends to exacerbate congestion—think downtown Manhattan—and Los Angeles is very dense.

High population density can also combine with other factors to make congestion worse. We mentioned earlier that Los Angeles residents do not drive more than residents of other large areas. It turns out, however, that they drive a lot on a per-capita basis considering the region's density; in other words, Angelenos do not seem to curtail their driving as much as one might expect in response to higher density. Figure 5 compares regional population density with daily per-capita VMT for the country's largest 14 metropolitan regions.

Looking across the different regions shown in the figure, there is a fairly consistent relationship in which per-capita VMT declines with regional density. Los Angeles is clearly an outlier. The only other large metropolitan regions in the country with higher per-capita VMT (Atlanta, Dallas, Houston, and Detroit) are all much less dense than Los Angeles. For regions in which the level of density approaches that of Los Angeles (San Francisco, Washington and New York), per-capita VMT is much lower. We thus see a confluence of three density-related factors that in combination help to explain the severity of congestion in Los Angeles: (1) congestion is likely to rise with increased population density; (2) Los Angeles is much denser than its peers at the regional level; and (3) Los Angeles exhibits a surprisingly high level of per-capita VMT relative to its density.

WHY ANGELENOS DRIVE SO MUCH RELATIVE TO THE REGION'S DENSITY

The preceding analysis begs the question: just why do Angelenos drive so much more than one would expect given the region's high population density? While there may be many contributing factors, we underscore two in particular that suggest appropriate policy responses.

First, compared to other large metropolitan areas, and especially in relation to the density of the region, Los Angeles offers abundant and inexpensive parking, and this encourages more people to drive. In such areas as San Francisco, a deliberate effort by planners to reduce private vehicle use limits the number of parking spaces that may be included in a new development. In contrast, most Los Angeles jurisdictions require developers to provide some minimum number of parking spaces based on project type and scale, thus ensuring that parking will remain cheap and abundant and reinforcing auto-dependency. The near-term policy implication is that efforts to introduce pricing should encompass parking along with road use. Over the longer term, there are many additional land use reforms related to parking that could be valuable.

Second, land use patterns in Los Angeles are more polycentric (characterized by multiple centers) than in most other major US cities, making it harder to develop a fast and effective transit system that encourages drivers to leave their cars at home. Rather than a single dominant downtown area as one might find in New York or Chicago, Los Angeles has numerous high-density clusters scattered throughout the region—places such as downtown Los Angeles, Santa Monica, Century City, Long Beach, Glendale, and Pasadena. This means that the transit network will require more links in order to connect all of the dispersed population clusters and job centers with one another. Though Los Angeles has constructed significant light rail and subway track mileage over the past several decades, there are still obvious gaps in the network's coverage, such as between downtown Los Angeles and the Westside. In addition, the fact that population and jobs are spread out across more centers increases the difficulty of attracting sufficient ridership on any given link to justify the significant investment required for transit lines with dedicated right-of-way.

Absent dedicated right-of-way, transit must rely on bus service that is slowed by surrounding traffic. Consider that even with such improvements as traffic signal prioritization and less frequent stops, Metro "Rapid" buses traveling the Wilshire corridor still average just 11 miles per hour during daytime hours—clearly insufficient to lure many drivers from their cars. Though some strategic rail investments may be merited over the longer term, a valuable—and much less costly—intermediate step would be to provide bus-only lanes on the arterial network to speed bus service in high-density transit corridors.

PROMISING NEAR-TERM POLICY OPTIONS FOR LOS ANGELES

Drawing upon the preceding general and LA-specific insights, we developed an integrated policy framework that appears to offer the greatest prospects for relieving traffic congestion and improving transportation options in the region. The framework encompasses three key components.

Rely on pricing to manage peak-hour demand, raise needed revenue, and promote more efficient use of existing capacity. Managing the demand for peak-hour travel represents the only realistic option for reducing traffic congestion in Los Angeles, and only pricing strategies can resist the effects of triple convergence and thus remain effective over the longer term. Pricing will also raise revenue to fund needed transportation improvements and





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enhance the throughput capacity of existing facilities.

Significantly improve transit and other alternative modes. Certain forms of pricing may introduce equity concerns. Providing faster and more convenient alternatives to driving will help to reduce such concerns, and will also benefit those in the region who already travel by modes other than the automobile.

Continue to improve the efficiency of the road network, but shift the emphasis from moving cars to moving people. Though Los Angeles has already implemented strategies such as signal timing and freeway ramp metering, there are still opportunities for improvement. From a policy perspective, however, the critical issue here is the focus on moving people rather than moving cars. This implies, for instance, that if an arterial lane can carry more passengers as a bus-only lane than as a mixed-flow lane then it should be converted to bus-only operation. This idea, developed in San Francisco and elsewhere, is often described as a "transit first" priority, though it may be more accurate to think of it as a "people first" priority.

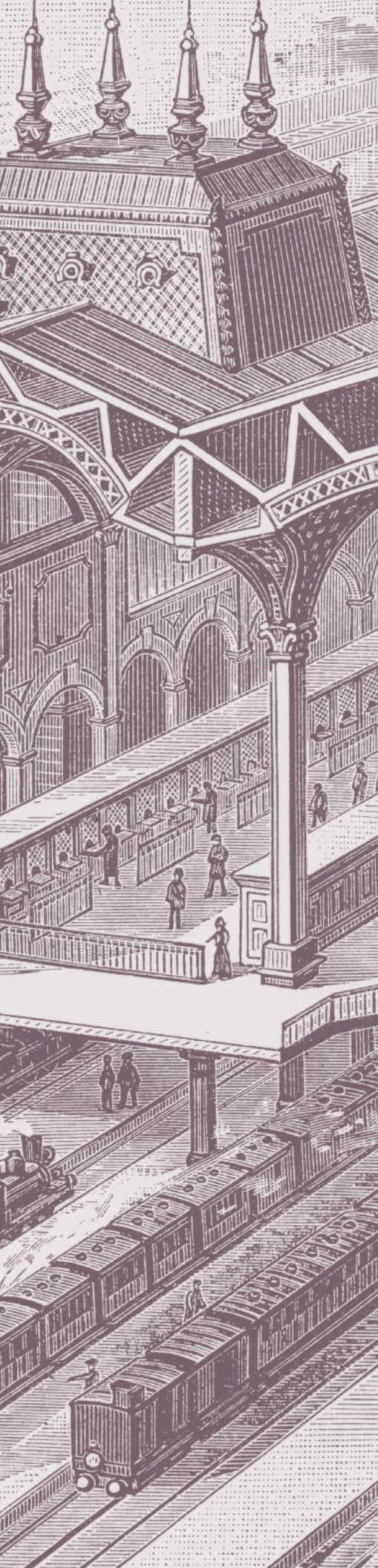
With this framework in mind, we evaluated 27 potential short-term strategies and ultimately recommended 10 complementary measures for Los Angeles that collectively support the above framework.

1. Develop a network of high occupancy/toll (HOT) lanes
2. Implement variable curb parking rates in commercial centers
3. Enforce the state's existing parking cash-out law
4. Promote ride-sharing, telecommuting, and flexible work hours
5. Implement deep-discount transit passes
6. Expand bus rapid transit (BRT) with bus-only lanes
7. Develop a regionally connected bicycle network
8. Improve signal timing and control where deficient
9. Restrict curb parking on busy thoroughfares
10. Create a network of paired one-way streets

Perhaps the most noteworthy characteristic of the specific recommendations is that many—particularly those that involve pricing—are certain to stir controversy. As already noted, traffic congestion is a longstanding urban challenge, and for years decisionmakers have implemented more politically palatable measures such as adding new lanes, synchronizing traffic lights, metering freeway ramps, building subways and light rail, and instituting voluntary rideshare programs. While such efforts help, traffic has still grown worse, and it is clear that we now face more difficult choices. Though the public is slowly becoming more familiar with the concept of pricing, all too commonly the debate centers on whether we should implement pricing strategies or instead pursue other measures for reducing congestion. The appropriate question to ask, given the pervasive effects of triple convergence, is whether we would prefer as a society to implement pricing in conjunction with complementary strategies or instead content ourselves with even more traffic congestion in the coming years. ♦

Acknowledgments

James A. Thomas, the Los Angeles County Metropolitan Transportation Authority, the Music Center of Los Angeles County, and the RAND Corporation provided funds for this study. FAST, a recently-formed advocacy coalition, is currently working to build public support for many of the recommendations in the study; see www.fastla.org.



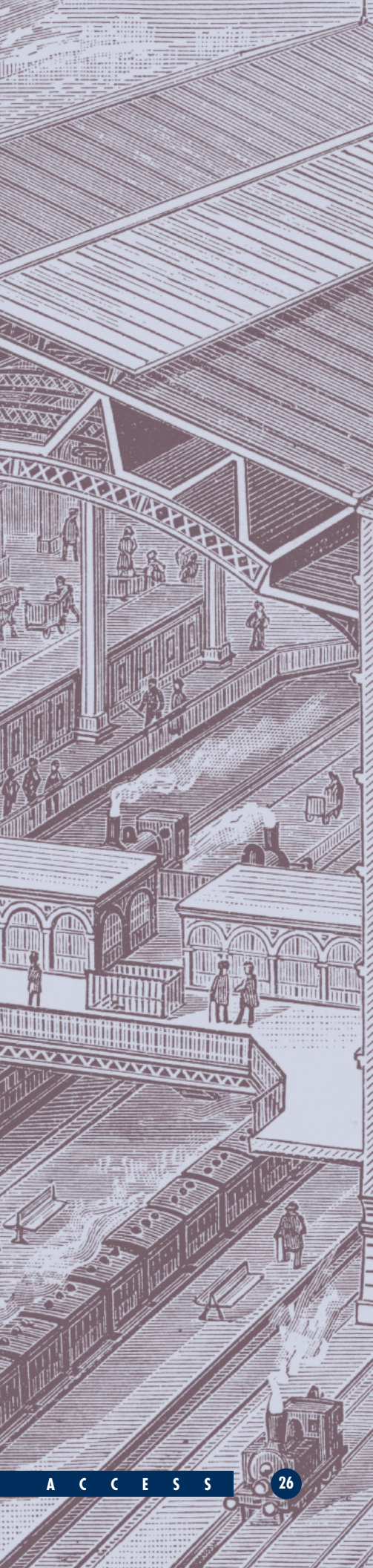
TOD and Carsharing: A Natural Marriage

BY ROBERT CERVERO

TRANSIT ORIENTED DEVELOPMENT (TOD) IS arguably the most cogent and acceptable form of smart growth. Almost everyone “gets” TOD. Politicians, professionals, and lay citizens alike understand that if there is any logical place to promote compact, mixed-use development, it is around transit stations.

The benefits of TOD are largely borne out by empirical evidence. People who live near rail transit stops in the US have much higher rates of transit use than the typical resident of a rail-served region. In California, surveys show that residents who live near a transit station use transit for their commutes at a rate four to five times higher than residents of the same region who don’t live near stations. This pattern has held steady over time. In the case of the Pleasant Hill BART station, for instance, 47 percent of station-area residents took transit to work in 1993. Ten years later, in 2003, the share was 44 percent.

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SELF-SELECTION

The higher transit use among station-area residents is largely a product of what economists call “self selection.” People who prefer to take a train to work—whether to avoid the stress of fighting traffic or to have time to read a newspaper en route to work—purposely choose to live near a rail stop. That is, they are predisposed to transit commuting; they are not “converted” to transit use simply because of where they live. A recent study I led estimated that around 40 percent of the ridership bonus attributed to TOD is due to self selection.

TOD AND TRAFFIC

TOD has increased transit ridership, but this has had little influence on how TOD projects are seen and judged by municipal traffic engineers and local planners. Traditionally, engineers and planners evaluate new developments in terms of their impact on automobile traffic, not on how much they might increase transit ridership. That is, practitioners pass judgment on the transportation impact of any new development project, whether near a rail station or not, based on roadway level-of-service rather than on modal splits (the distribution of trips across different modes: car, rail, bike, etc.). In a society where over 90 percent of all trips are by car, planners and engineers who are accountable to local constituents for keeping streets running smoothly care more about traffic congestion than about transit use.

Herein lies a dilemma. Invariably, because not all TOD residents take transit, and many of them drive, dense development will congest the nearby road intersections during peak periods. In the near term, even if it is well served by transit, dense development translates into more congestion.

NIMBY opposition to higher density has stopped TOD plans around a number of middle-income neighborhoods served by BART in the San Francisco East Bay—Rockridge, North Berkeley, Orinda, Lafayette—mainly through building height restrictions. For example, some 2,400 new households have located within a 5-minute walk to the Pleasant Hill BART station over the past twenty years. But TOD dwellers are no more immune to NIMBYism than anyone else. Once a critical mass of TOD residents forms, they create neighborhood associations which, among other things, stop efforts to add more development. In Pleasant Hill, plans to build a massive entertainment complex, with a 20-screen IMAX movie theater, were scuttled due to neighborhood backlash. The lesson is clear: don’t expect to transform middle-income, stable neighborhoods with large-scale infill projects, because residents have the political might to stop such proposals every step of the way. More acceptable are TOD proposals for transitional neighborhoods, redevelopment districts, or greenfields with few people around to oppose new development. Also, forget about large-scale, regional trip generators that bring outsiders to neighborhoods made up of professional-class residents. Only local- and neighborhood-serving land uses will be welcomed in such settings.

The downside of preventing new growth around transit stations is that the development will end up elsewhere and most likely increase vehicle miles traveled (VMT)—the strongest single correlate of greenhouse gas emissions (GHG), air pollution, and energy consumption in the transport sector. Like toothpaste in a tube, if development is squeezed from one area, it simply gets redistributed elsewhere. Shifting growth from TOD to AOD (automobile oriented development) can reduce local traffic congestion at the cost of environmental degradation for a region at large.

There is good and bad congestion, just like good and bad cholesterol. I would argue that congestion caused by TOD is, for the most part, good. There is no avoiding the fact that

denser areas have denser traffic. Dense cities with world-class rail systems, like Paris and London, are often more traffic-choked than sprawling cities. Yet these dense cities are also attractive places to live, work, and visit. Congestion is part of the territory of being an active, vibrant place. TOD, moreover, offers a relief valve to congestion. In a TOD, it is easier to predict when and where congestion will occur, and it is easier to avoid that congestion—e.g., one can hop on a train or ride a bike.

TOD AND THE DE-GENERATION OF TRIPS AND PARKING

I recently led a study that probed the traffic implications of TOD. Specifically, the study measured vehicle trip generation rates for 17 TOD projects in five US metropolitan areas (Philadelphia, Northeast New Jersey, Washington, DC, Portland, and the San Francisco Bay Area). Over a typical weekday period, the TOD housing projects averaged 44 percent fewer vehicle trips than that estimated by the *Trip Generation* manual of the Institute of Transportation Engineers (ITE), which is widely used as the reference manual for gauging traffic impacts. As Donald Shoup and others have noted, the predictions of the ITE manual are based largely on observing suburban settings with meager transit service. Unsurprisingly, these settings exhibit high levels of car travel. During peak periods, our study showed even higher levels of trip de-generation for TODs—nearly 50 percent fewer vehicle trips than ITE predictions (see figure below).

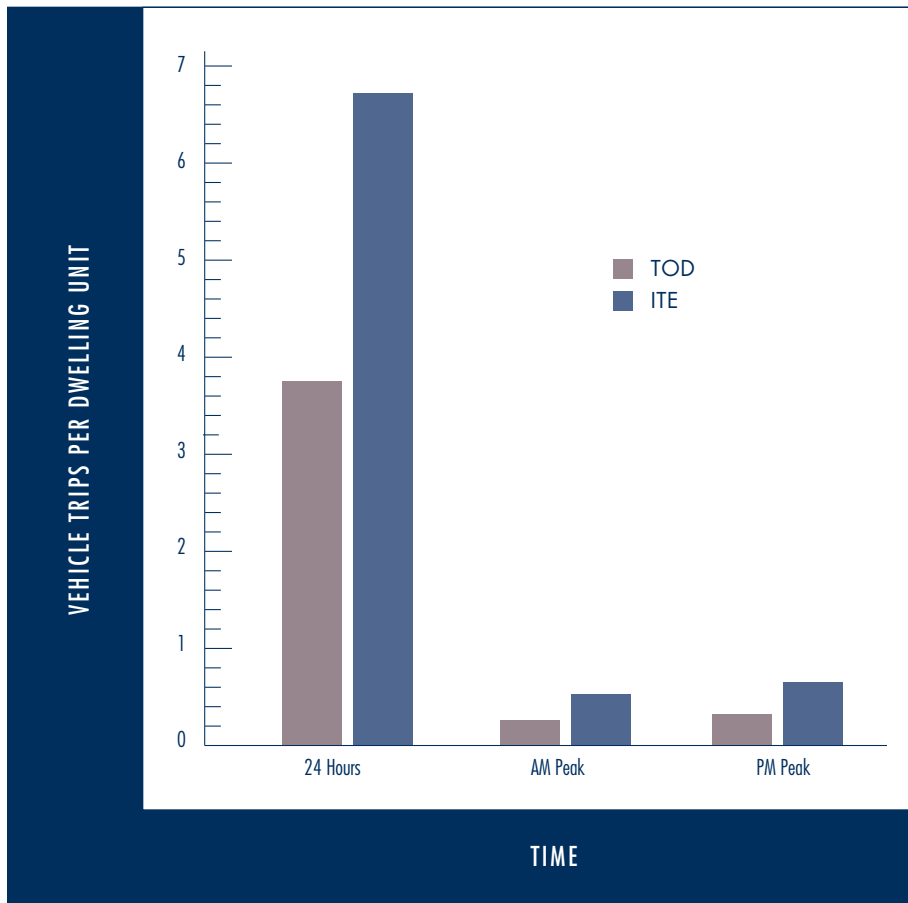


FIGURE 1

Comparison of vehicle trip rates: weighted averages of TOD housing and ITE estimates

COMPARISON OF VEHICLE TRIP RATES: WEIGHTED AVERAGES OF TOD HOUSING AND ITE ESTIMATES

A more recent analysis I led extended the study to analyze parking generation for 15 TOD projects in Portland and 16 in the Bay Area. While average vehicle trip generation rates in Portland were 41 percent below the ITE rates for TOD projects, the average use of parking spaces was only 11 percent less. The parking occupancy at three of the 15 surveyed TOD projects in Portland was actually higher than that predicted by the ITE manual. In the Bay Area, owning and parking a car seemed to be even more of a necessity for TOD residents. There, TOD parking rates were equivalent to ITE's standard of 1.2 spaces per unit. For all seven TOD housing projects surveyed near the Fremont BART station, parking levels were actually higher than the ITE rates—as much as 40 percent above.

What's going on? One factor may be that most cities do not reduce the parking requirements for TODs. One survey of TODs in California found no reduction in cities' parking requirements at seven of the 11 sites studied. Planners appear to assume that more transit will not reduce parking demand, and they may be right. In most suburban TODs, residents still need access to a car. They just don't use them as much. But like most suburbanites, they still need a car to get to most non-work destinations—the vast majority of which are away from rail stops. While transit-oriented housing might mean that more trip *origins* are near rail stops, as long as most *destinations* are not, TOD residents will still own cars and use them for shopping, going out to eat, and the like.

TOD AND CARSHARING

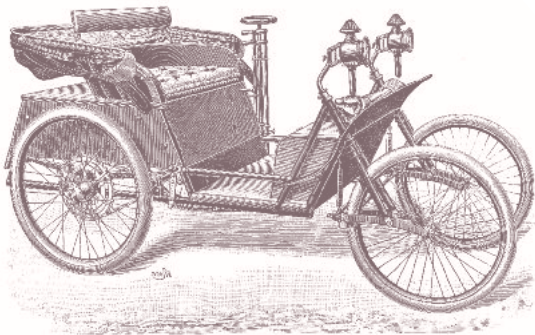
My guess is that a significant share of TOD residents would shed a car if they had carsharing options. My graduate students and I recently completed a four-year study of the impacts of carsharing on travel and car ownership based on experiences with the City CarShare program in San Francisco. From a panel survey, we found that four years into the City CarShare program, 29 percent of carshare members had gotten rid of one or more of their cars. Fully 63 percent of City CarShare members lived in zero-vehicle households.

A predictive model showed that living close to a carshare pick-up spot was strongly associated with car-shedding. By extension, putting shared cars in and around TODs could relieve many households from owning a second car or a vehicle altogether. TOD and carsharing, I contend, are a perfect marriage. Through a combination of proximity advantages and lifestyle predispositions, living near transit can *de-generate* vehicle trips. And with the option of carsharing, it can likely reduce parking demands as well.

Strangely, as of now, there are few TODs in the US with carsharing options.

Perhaps carsharing companies fear the competition of transit. Or maybe transit agencies fear that carsharing will take away customers. In truth, carsharing and transit are more likely complements than competitors. Experiences from Switzerland suggest this is the case. Zurich, for example, has the second highest per capita transit use in the world (over 600 transit trips per capita per year) and the highest per capita carsharing participation anywhere (7 percent of households are members of Mobility Carsharing Switzerland). And in spite of having one of the world's highest per capita incomes (on a purchasing power parity basis), only one out of three households has an off-street parking space. Zurich, I might add, has the highest commercial real estate prices in Europe (along Bahnhofstrasse) and according to the management consulting firm Arthur D. Little, ranks number one in

*There is good
and bad
congestion,
just like good
and bad
cholesterol.*





quality-of-life among global cities. In Zurich, world-class transit, carsharing, parking limits, and prosperity go hand-in-hand.

One project in the works that aims to mimic the success of places like Zurich is Greenprint, a TOD pilot project in Richmond, California. Designed by new urbanists with state funding support, the Greenprint housing project aims to cut the carbon emissions of residents 50 percent below that of a traditional apartment building. Besides proximity to transit, a combination of carsharing using electric and hybrid vehicles, on-site childcare, and a state-of-the-art telecommuting center will be introduced. Forward-thinking public policies like carbon-trading credits for projects like Greenprint would go a long way toward ushering along progressive initiatives that marry TOD with demand-management initiatives like carsharing.

Another way for cities to play the role of matchmaker between TOD and carsharing is to allow developers to provide a shared-car parking space instead of several private parking spaces. A convenient carshare option may convince some residents to skip buying a second (or even first) car, and thus reduce the demand for parking in the building. Suppose that making one shared car available for an apartment building leads residents to buy 10 fewer personal cars. In this case, the city's parking requirements can allow one shared-car parking space to substitute for ten private parking spaces. This arrangement would save money for both the developer (who provides fewer parking spaces) and residents (who own fewer cars) without eliminating anyone's ability to use a car when needed. The carshare organization would also gain members and would be able to locate its cars in more locations, making membership in the club even more beneficial. Unbundling the cost of a private parking space from the cost of renting an apartment in the building would further reduce car ownership and increase the demand for shared cars. Offering developers the option to provide one shared-car parking space in lieu of several private parking spaces can thus increase the demand for carsharing, reduce development costs, increase transit ridership, and reduce the demand for driving. The arranged marriage between TOD and carsharing can be consummated in a garage. ♦

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PAVED WITH GOOD INTENTIONS

FISCAL POLITICS, FREEWAYS, AND THE 20TH CENTURY AMERICAN CITY

BY JEFFREY R. BROWN, ERIC A. MORRIS, AND BRIAN D. TAYLOR

STUCK IN TRAFFIC IN WASHINGTON, DC IN 1959, PRESIDENT EISENHOWER was shocked to learn that the delay was being caused by Interstate Highway construction. Surely the Interstates were being built between cities, not *in* them. The President demanded to know who was responsible for this state of affairs, only to be told that *he* was; it was the result of legislation he had signed three years earlier. Aghast, Eisenhower attempted to get the federal government out of the urban freeway business. But it was too late: the program had built up momentum that not even he could halt.

Fifty years later, many planners and urbanists are still asking Eisenhower's question: Why did the United States, unlike every other developed country, choose to mass-produce freeways in cities? What caused the *Interstate* Highway program to urbanize, decisively shaping both *intracity* travel and American cities?

Other questions about America's unique urban freeway systems abound. Why did the Interstate program shift control over crucial metropolitan transportation decisions from city halls to statehouses and Washington? Why are urban freeways not nimble, context-sensitive facilities but the large, ungainly ones we have today? Why did poor, predominantly minority communities in the inner city, and newer low-density communities on the suburban fringe, bear the brunt of freeway construction, while established, better-heeled neighborhoods were spared? And why did freeway-building explode onto the scene so dramatically, only to flame out just as spectacularly such a short time later?

The answers to these questions involve planning, engineering, and politics. But more importantly, they involve a force as prosaic as it is powerful: money. The development of metropolitan freeways is a powerful testament to the ways that money—the constraints caused by the lack of it, the means of raising it, the politics of dividing it, and the policies for spending it—can powerfully, even decisively, shape transportation outcomes. To a surprising—and perhaps disturbing—extent, the urban freeways' capacity, routing, geometrics, safety provisions, and much else were significantly shaped by the internal logic of the transportation finance system. To understand the development of metropolitan freeways, and thus the American city, it is necessary to “follow the money.”

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PLANNING FOR CARS IN CITIES

In the early years of the 20th century, urban transportation was funded at the municipal level. Property taxes and special assessments paid for street networks. Since these taxes were levied and collected locally, local officials had authority over the transportation system.

Thus it was municipalities, armed with locally-generated revenue streams, that struggled to cope with the tidal wave of automobiles that flooded city streets as the car became a mass market good. Auto registrations rose from 8,000 in 1900, to half a million in 1910, to over 8 million in 1920, to over 22 million in 1930—a more than 2,700-fold increase in just 30 years. In an effort to deal with the congestion that resulted, cities hired consultants from among a small coterie of planners and engineers to map out plans to accommodate the car. These consultants, who included planning pioneers like Harland Bartholomew, Charles Cheney, and John Nolen, usually recommended operational fixes like widening and standardizing streets, eliminating jogs and dead ends, installing traffic signals, funneling traffic onto main thoroughfares, and segregating different types of traffic (i.e. streetcars, autos, trucks, and pedestrians). For a time these measures provided congestion relief, but the ever-increasing number of autos meant that more radical approaches were soon needed.

Planners proposed one such approach: a new type of road that adapted design principles from facilities intended for recreational motoring. In the late 1800s, real estate developers discovered that access to parks could boost property values. To capitalize on this they built “parkways,” roads that scenically linked their developments to nearby open space. The builders of parkways took advantage of two crucial design features. *Limited access* to the roads prevented slow-moving vehicles from unpredictably entering and exiting the traffic stream. This meant less disruption to traffic, a reduced risk of collisions, and less cluttering of streets. *Grade separation* at intersections eliminated the need to stop at cross streets, increasing speeds on both roads and effectively doubling the parkways’ vehicular capacity. Transportation planners incorporated these features into plans for a type of facility that, it was thought, would be the permanent solution to urban traffic woes. The relatively free movement of vehicles on these proposed roads led to their eventual name: “freeways.”

Where parkways were recreational facilities, early plans for freeways were utilitarian, designed to untangle the jams of autos, streetcars, trucks, buses, and pedestrians that cluttered American cities. They envisioned roads far different from those we know today. These freeways would have had fewer lanes (typically four), lower design speeds (usually 45 mph, though by the 1930s most new cars were capable of going much faster), and smaller, simpler interchanges. Building them would have required displacing some homes and businesses, but far fewer than were eventually displaced to accommodate the much larger freeways eventually constructed. The early freeway plans also called for dense networks of highways, with an eye towards dispersing traffic, not concentrating it on a few large facilities. And land use was integral to many of the early plans; the freeways were designed to cut with the urban grain, not against it. Proposed joint highway/real estate developments were not uncommon, and in some cases freeways were to be multi-modal, with transit vehicles traveling in the medians. Finally, some early plans called for gridiron as opposed to radial layouts to disperse traffic across rapidly decentralizing cities.



SHOW ME THE MONEY: FINANCE DRIVES PLANNING

Most cities had the technical and financial means to widen their streets, install traffic signals, and carry out other operational fixes. But they lacked the means to shoehorn extensive freeway systems into dense urban areas. One problem was that the tax instruments available to local governments were not appropriate for the task. Local governments had the authority to levy taxes and special assessments on property and businesses, but not, for example, on fuel. The property tax is a sensible mechanism for financing local streets and roads, because these streets link individual land parcels to the world and help give them value. It is thus logical for property owners to help pay for local street construction. Freeways, however, affect the value of property across the entire metropolitan area, not just of nearby parcels. This makes it hard to justify special assessments on freeway-adjacent properties, since the majority of a freeway's benefits accrue to travelers and landowners over much larger areas. (Indeed, being too close to a freeway can *lower* land values, particularly for residential property.) And in any case, property tax revenues were inadequate for building even relatively modest freeway facilities, much less networks of them.

A potential solution to these problems emerged in the 1920s with the development of the gas tax. As a way to finance freeways, gas taxes had much to recommend them: they placed the tax burden on users of the system, they were relatively easy to administer and collect, and they were robust. Property tax revenues nationwide plummeted 72 percent during the Depression years of 1930 to 1939, but fuel consumption and its associated tax revenues proved surprisingly resilient. Except for a small dip at the beginning of the Depression, fuel consumption rose every year until World War II.



But the gas tax had one key drawback for cities: the revenues were collected at the state and later the federal levels. Accepting outside funding would mean accepting outside control. City officials thus faced the Hobson's choice of giving authority over metropolitan freeways to the states, or foregoing most of their ambitious plans. With congestion worsening, city officials had to act. So in the dozen years following the Second World War most cities ceded authority over the planning, development, and operation of urban freeways to state highway departments and the engineers who staffed them.

Transferring control from municipal to state (and later federal) authority needn't have meant abandoning the locally-developed metropolitan freeway plans. But with state money and state authority came state ideas. State highway departments had a rural orientation; they were primarily responsible for rural roads and their engineers were disproportionately from rural areas. The state highway engineers typically focused on high-speed farm-to-market and intercity access, increasing access to remote areas, rural economic development, and reducing rural road accidents. They also sought to maximize traffic flows on new high-speed facilities; in the eyes of state highway engineers, the challenge facing rural roads was not that they attracted too much traffic but that they often attracted insufficient traffic to justify the investment.

For the most part state highway engineers lacked a holistic view of freeways' place within the larger urban organism. Context, land use, and multi-modalism were largely absent from their plans. For example, many early freeway plans called for frequent interchanges in order to alleviate the burden of traffic spillover on nearby streets, but state highway engineers sought to minimize the number of interchanges in order to speed traffic, discourage short trips, and reduce costs. This rural-centered focus on high-speed superhighways, even in cities, was gradually etched in stone and would become—for better or worse—a hallmark of the Interstate system.

RAMPING UP THE PROGRAM: THE GENESIS OF THE INTERSTATES

Though the state departments of transportation took over most metropolitan highway planning in the late 1940s and early 1950s, during World War II and the years that followed little progress was made in building freeways either within or outside of cities. The national Interstate Highway System was adopted in 1944, but the program lay nearly dormant for over a decade. The dearth of freeway building at either the state or federal levels was largely due to a lack of funds. Only California surged ahead with state construction of metropolitan freeways, which is one reason its model of state-directed urban freeway development would later be copied nationwide. California's pioneering role can be traced to finance: to pay for its freeways the state passed steep tax increases on fuel and trucks in 1947.

In contrast to California's decisive action, it took a dozen years of false starts and dead ends before the financing system for the massive national network could be crafted. That schema required the cobbling together of a diverse coalition of interests to support the substantial tax increases needed to fund the system. In political terms, the creation of this coalition was a triumph. But in transportation terms the outcome was decidedly mixed. The final, landmark legislation that turned the beliefs of state highway engineers into "facts on the ground" also sounded the death knell for the vision of the early metropolitan transportation planners, and introduced financial incentives that would have important unintended consequences for urban freeway development.

In 1955, Congress soundly defeated yet another piece of legislation to fund the Interstates. A year later, similar legislation easily passed both houses and was signed into law. Why did Congress have such a sudden change of heart? First, the 1955 bill faced opposition from the rubber, petroleum, trucking, and intercity bus industries, as well as the Teamsters and the American Automobile Association. The former organizations objected to proposed tax increases on fuel and tires. The trucking industry protested that taxes on diesel fuel and other levies on heavy vehicles were too onerous; the AAA protested they were too light.

In addition, urban members of Congress were generally uninterested in what was widely perceived as a rural intercity highway bill. The original Interstate highway plan adopted in 1944 had explicitly left the urban portions of the system unplanned, with the routes to be located and designated later. While this deference represented an enormous tip of the hat to urban transportation planners, it also meant urban legislators failed to grasp the implications of the proposed freeways for their districts. In order to capture the imagination (and support) of urban congressmen, in 1956 federal highway officials hastily sketched out the urban segments of the system. In a planning process lasting only eight months, deference to local transportation planning and urban concerns was cast aside and routes were hurriedly laid out for one-size-fits-all superhighways through cities large and small around the country.

To overcome opposition to the tax increases, the congressmen, federal highway officials, and interest group members (particularly from the construction industry) who formed the core of the interstate lobby created the Highway Trust Fund. The Trust Fund guaranteed that all new revenues from fuel and other taxes would be dedicated only to highways. Dedicating the revenue secured widespread political support, even from the interests being taxed, and at the same time conjured an up avalanche of money. But it also narrowed the possibilities for freeway building. Dedication of money to the Trust Fund, for example, meant that plans including transit were jettisoned in favor of highway-only facilities.





The rules governing the financing of the system had other important effects. Prior to the Interstate program, the federal government had matched states' expenditures on federal-aid highways on a 1:1 basis. Beginning in the early 1950s this ratio began to rise, reflecting bipartisan enthusiasm for highway development and a fear that states might not prioritize Interstate construction. Finally, the 1956 legislation settled on a terrifically generous 9:1 match. This meant that states could best leverage their transportation dollars on Interstate spending. Predictably, to maximize the buying power of their revenues, states all but dropped plans for smaller, less invasive complementary facilities and concentrated their resources on new Interstates.

To create a limited system of superhighways, the federal legislation capped the center-line mileage of Interstate highway each state was permitted to build. While this was perhaps a sensible way to manage the extent of the system, the limit encouraged states to concentrate traffic onto sparse networks of freeways, in a sharp contrast to what was proposed by early metropolitan freeway plans. Moreover, while capping mileage, the federal government did not cap expenditures; this encouraged the building of roads with as many lanes and bells and whistles (weaving sections, elaborate interchanges) as possible. The resulting sparse networks of very high-capacity urban freeways disrupted cities more than the planners' original vision of denser, smaller, often multi-modal networks would have.

Financial considerations also dictated that during the early years of the program the Interstates were built with terrific haste. The increases in fuel and other taxes brought in so much money in the decade after 1956 that state highway engineers literally couldn't build planned freeways fast enough; states were forced to quicken the pace of Interstate construction for fear that unused funds might be reallocated. This decade of rushed freeway construction offered planners and engineers limited opportunity to learn from their mistakes.

Financial incentives also helped to ensure that the burden of freeway construction fell disproportionately on lower-income neighborhoods. While freeway builders had lavish funding at their disposal in the early years, their desire to quickly complete as much mileage as possible drove them to start with the inexpensive low-hanging fruit: suburban segments (which required minimal displacement of existing homes and businesses) and routes through lower-income central city neighborhoods (where land costs were lower and organized political opposition was weaker). Higher-cost routes, by contrast, were often moved down in the queue. But by the time these more expensive (and often controversial) segments were ready for construction, money had begun to run short and the freeway-building program was winding down. Thus many of these routes (like a planned freeway through Beverly Hills) were shelved and never built.

END OF THE ROAD

The rapid ascent of freeway-building was matched by an equally rapid demise. By the mid-1970s, only 20 years after the program commenced, urban freeway construction had slowed to a trickle, even though the system remained well short of completion.

In part the urban freeways were stopped due to "freeway revolts." Spearheaded by the nascent environmental and social justice movements, agitation against freeways took place in cities like Baltimore, Boston, Los Angeles, New Orleans, New York, Reno, and San Francisco. In some cases the anti-freeway movement scored spectacular successes, using popular and political pressure to block highway projects. Environmental legislation like the National Environmental Policy Act (NEPA), which was signed into law in 1970, shapes transportation planning to this day thanks in part to popular discontent with freeway-building.

But the more significant cause of the freeway program's premature sunset was simpler: it ran out of money. Stagnant real revenues and escalating costs for labor, materials, and rights-of-way (all of which rose considerably faster than inflation) doomed the program, which was waning well before most freeway revolts began. Chronic fiscal shortfalls resulted not so much from a conscious effort to terminate the freeway program as from benign neglect and political inertia, as public officials turned their collective attention elsewhere. Moreover, freeway building ironically carried some of the seeds of its own demise. With the exception of immediately adjacent residential parcels, freeways generally increase surrounding land values, especially in new, outlying suburbs. Thus when new freeways were proposed, speculators often rushed to purchase land in the proposed corridor, thereby raising property values and driving up right-of-way costs for the departments of transportation.

By the 1970s, the fiscal shortfalls were so dramatic that dozens of locally popular routes to which there was little opposition were shelved—evidence that dollars, and not dissent, were the primary force behind the withering of the freeway-building program.

CHANGING LANES

Today, we have in many ways come full circle and returned to the outlook of the early 20th century urban planners. The current highway planning process is a well-intentioned if sometimes quixotic effort to ensure that the mistakes of the Interstate-building era will never be repeated.

Cities and regions now have much more input into and control over their transportation destinies. To a large extent we have moved from embracing to tolerating autos, from circumventing stakeholder objections to facilitating stakeholder input, from fostering auto-oriented suburban expansion to encouraging less auto-dependent forms of development, from constructing major new highways to mitigating the effects of transportation facilities, and from focusing on metropolitan freeway networks to multimodal planning with an emphasis on transit in larger cities. Regional transportation plans and proposals today—like those crafted before the freeway-building era—reflect a wide array of urban concerns, including reducing congestion, preserving central business districts, improving public transit, and reviving depressed communities.

And yet it is possible the pendulum may have swung too far. An era of comprehensive, centrally-directed planning has given way to an era of piecemeal, atomized planning that often lacks coordination, direction, vision, or, importantly, a sustainable stream of revenue. The freeway era of fantastic financial largesse has given way to one of comparative penury, as cities and regions scramble to cobble together funds for popular individual projects—another way in which the modern planning paradigm resembles that of the first half of the 20th century. Instead of fuel taxes, general sales taxes and public debt increasingly fund projects, a change that abandons the user-fee logic of the past and brings a very different set of constraints and incentives.

President Obama's 2009 stimulus package momentarily changed this calculus; once again boom replaced bust in transportation finance. In the haste with which the funds were allocated, the stimulus harkened back to the Interstate era. Thus it is wise to remember the unintended consequences this kind of spending can have. Interstate backers wanted to build freeways, and were willing to make many financial compromises to do so. Freeways were built, in spectacular fashion, but the unforeseen and sometimes harmful results of their achievements reverberate to the present day. ♦



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