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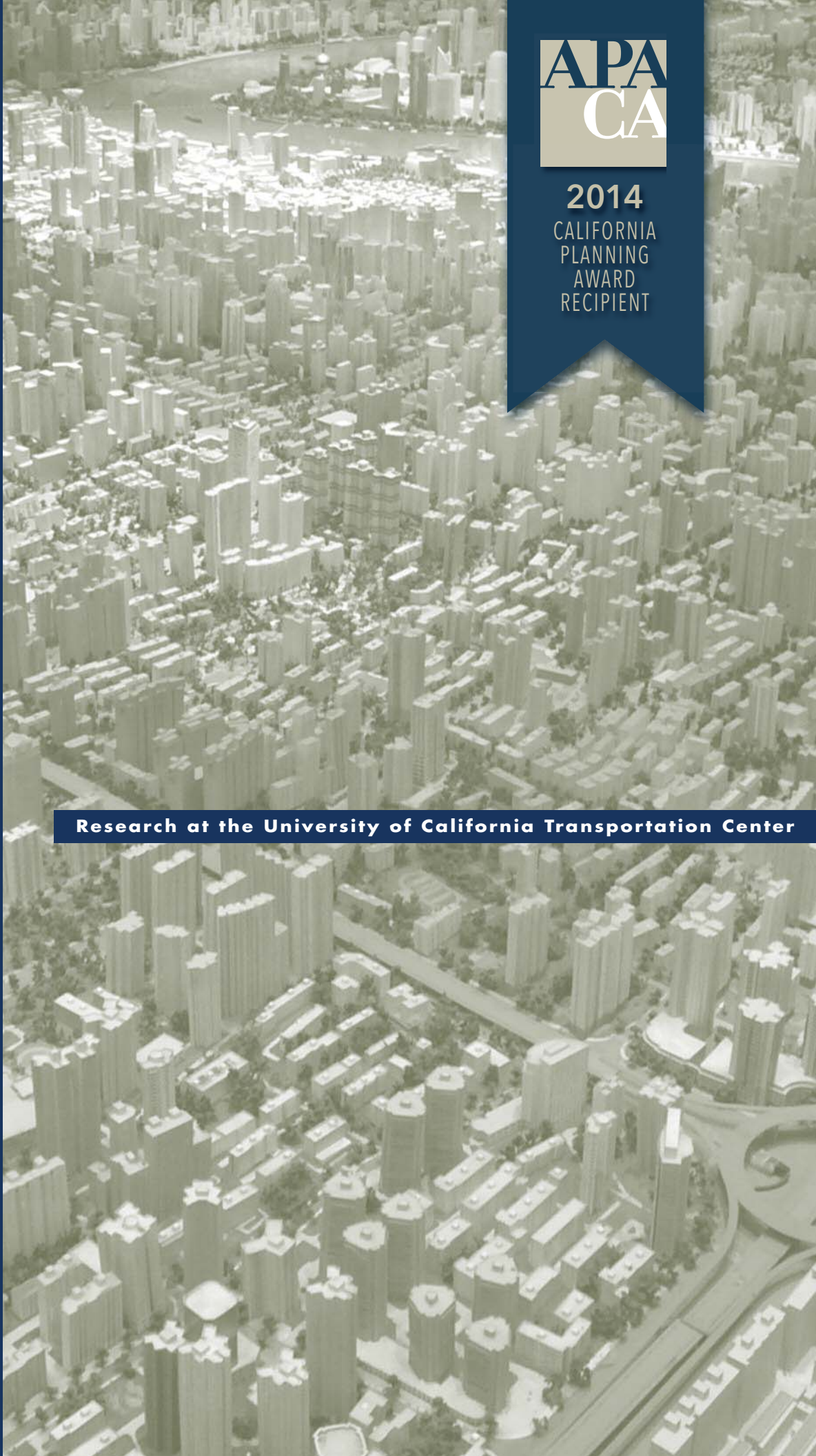


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ACCESS Magazine reports on research at the University of California Transportation Center and the University of California Center on Economic Competitiveness in Transportation. The goal is to translate academic research into readable prose that is useful for policymakers and practitioners. Articles in ACCESS are intended to catapult academic research into debates about public policy, and convert knowledge into action.

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Passing the Baton

For over two decades *ACCESS Magazine* has published short, engaging summaries of transportation research conducted at the University of California. We ask our authors to write for lay readers rather than solely for professional peers, without overestimating the readers' familiarity with the subject or underestimating their intelligence. We also ask authors to explain the practical significance of the problems they have studied, and to show how their research can affect current thinking and public policy.

Professor Melvin Webber founded *ACCESS* in 1992 to showcase the research funded by the University of California Transportation Center (UCTC). The 240 articles in our archive of first 44 issues testify to the long and productive association between UCTC and *ACCESS*, and chronicle the impressive range of research that UCTC has sponsored.

During the past year, *ACCESS* won two awards from the American Planning Association for excellence in communication. Many readers wrote letters to recommend these awards, showing that *ACCESS* is achieving its goal. Here is an example: "The hard work that academics put into scholarship rarely makes the leap into practice. Even in a professional field like planning, all too often policy makers, neighborhood activists, and community residents seldom get much benefit from academic research. The problem is not that academics are doing useless things. Instead, most academics are either unable or unwilling to explain their good work in plain and helpful ways. *ACCESS* is a rare example of doing just that; it translates sophisticated ideas into tight, punchy, and concise messages that appeal to a wide audience."

Beginning with this Fall 2014 issue, *ACCESS* will be sponsored by the new University of California Center on Economic Competitiveness in Transportation (UCCONNECT), which succeeds UCTC as the University Transportation Center for Region 9 of the US Department of Transportation. The transition may bring modest changes in the magazine's focus to reflect UCCONNECT's emphasis on economic competitiveness in transportation. Perhaps the future will also see greater efforts to report on research in California's neighboring states. But whatever changes may come, the high standard of readability that has become the hallmark of *ACCESS* will remain. We have a responsibility to honor the past and influence the future. We eagerly look forward to showcasing the new research sponsored by UCCONNECT.

ACCESS is dedicated to the vital last step in transportation research: making information accessible to a broad audience. By connecting scholars with transportation planners and elected officials, *ACCESS* aims to catapult academic research into public debate and translate knowledge into action.

Michael Cassidy
Director, UCCONNECT

Robert Cervero
Director, UCTC

Donald Shoup
Editor of ACCESS



Phantom Trips

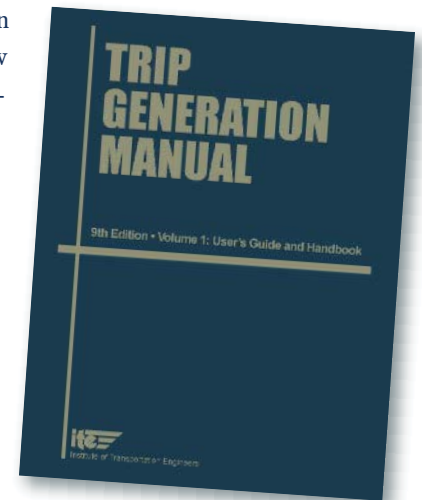
ADAM MILLARD-BALL

Traffic lies at the heart of many fears about new urban development. In some cases, cities require developers to scale back housing or retail proposals to alleviate concerns about congestion. In other cases, cities widen roadways, add turn lanes, or lengthen signal cycles to accommodate projected traffic volumes.

In both instances, planners and engineers wield considerable influence through their predictions of the number of vehicle trips that a proposed development will generate. This seemingly mundane process—trip generation analysis—profoundly shapes the physical form and financial feasibility of urban development. Estimates of trip generation help shape the road infrastructure, determine the amount that developers must pay for new roads and greenhouse gas mitigation, and sway local support or opposition to proposed development. Trip generation practices also help determine how much urban space cities dedicate to cars; the viability and character of transit-oriented and infill development; and whether a project proceeds at all.

How do we predict how much more traffic there will be? In the United States, the Institute for Transportation Engineers' (ITE) *Trip Generation Manual*, now in its 9th edition, is the standard reference. It provides data on the number of trips generated by 172 different land uses, from “Baby Superstore” to “Cemetery.” Some of the land-use categories are remarkably specific, such as “Batting Cage” or even “Coffee/Donut Shop with Drive-Through Window and No Indoor Seating.”

Given the ubiquitous influence of the *Trip Generation Manual* on the built environment, it is important to understand the validity of its data and ITE's recommended practices. Rather than accurately forecasting the impacts of new developments, I show in this article that ITE substantially overestimates trip generation rates. Moreover, I explain why ITE's core premise, that development always *generates* new trips, is misleading in many circumstances. Because ITE rates do not fully consider how trips are reshuffled among destinations, they are often inappropriate for evaluating traffic, fiscal, and environmental impacts. In short, we are planning for “phantom trips” that never appear in reality. >



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TESTING THE VALIDITY OF ITE RATES

Transportation professionals have long recognized that ITE rates are not suitable for mixed-use centers, transit-oriented developments, or similar projects where many trips will be made by public transit, cycling, or walking. The ITE manual stresses this limitation, and agencies often allow developers to adjust down their trip generation rates in certain contexts.

But what about the wider validity of ITE's trip generation rates? To date, these have gone unchallenged. Here, I compare national-level estimates of vehicle trips based on ITE rates with those from the 2009 National Household Travel Survey (NHTS)—the most comprehensive travel behavior survey in the US.

Comparing the two estimates of total trips in the US for a single year (2009) shows that the ITE-based method produces an estimate that is 55 percent higher than the NHTS. As shown in Table 1, this overestimate is present across all but one of the land-use types. Given the rigor and methodological transparency of the NHTS, coupled with an adjustment to match the totals in the Federal Highway Administration's *Highway Statistics*, the NHTS-based method is likely to be more accurate than the ITE-based one. The results thus suggest that ITE substantially overestimates trip generation rates.

TABLE 1
ITE-Based Estimates vs.
NHTS-Based Estimates

LAND USE	Trips in 2009 (millions)		ITE Overestimate
	ITE-Based Estimate	NHTS-Based Estimate	
RESIDENTIAL			
Single-Family Detached	253,844	170,778	49%
Other Owner-Occupied	30,055	21,948	37%
Other Rental	64,176	30,903	108%
All Residential	348,075	223,629	56%
COMMERCIAL			
Education	41,024	13,748	198%
Food	60,832	42,243	44%
Medical	16,024	18,427	-13%
Office	42,047	33,134	27%
Religion	21,113	9,228	129%
Retail	214,303	125,989	70%
Other	61,706	54,096	14%
All Commercial	457,049	296,866	54%
All Residential and Commercial	805,124	520,495	55%

EXPLAINING THE DISCREPANCY

Lower trip generation rates from mixed-use and transit-oriented development, as discussed by Schneider and his colleagues in this issue, provide one possible explanation for the discrepancy between the ITE- and NHTS-based estimates. The data, however, suggest that this is not the primary problem with ITE's rates. There is no indication that the ITE-based method is more accurate in more sprawling regions with less transit use, less walking, higher vehicle ownership, or lower residential density. Transit-oriented and mixed-use development, while undoubtedly inflating ITE's trip generation rates, does not appear to be the primary reason for the overestimates.

A more compelling possibility is that the ITE trip generation rates are not based on a representative sample. The ITE data are compiled mostly from voluntary submissions of traffic counts from specific developments, making it likely that such data are biased towards more traffic-intensive sites. Such traffic counts are not conducted as a matter of course; some specific reason must exist to collect the data. Perhaps a large and controversial development required a traffic-monitoring plan as a condition of approval, or perhaps trip generation studies tend to be commissioned by cities or states where traffic is a particular concern.

These explanations remain somewhat speculative, as the *Trip Generation Manual* says almost nothing about the characteristics of the developments surveyed beyond their size, and ITE refuses to release further specifics, citing confidentiality constraints. Nonetheless, it seems likely that the data published in the *Trip Generation Manual* are far from a random sample of new developments.

ITE's guidance on selecting sites for trip generation studies reinforces the idea that the data are biased. ITE recommends that developments where traffic counts are conducted should have "reasonably full occupancy," "appear to be economically healthy," be "mature," and represent "the ultimate characteristics of a 'successful' development." Using only data from well-patronized, *successful* developments to forecast the impacts of *all* new developments will naturally inflate trip generation rates. While developers do not intend to build unsuccessful projects with high vacancy rates and few customers, inevitably, not every development succeeds.

MARGINAL OR AVERAGE TRIPS?

The comparison presented earlier was for a single year, 2009. However, the magnitude of the ITE overestimate appears to be increasing over time. From 1990 to 2009, the number of annual trips (or more precisely, trip ends) in the US increased by 89 million, according to the NHTS. But according to the ITE-based method, annual trips should have increased by 189 million—an estimate more than double that of the NHTS. The contrast is even starker in more recent years: an increase of 2 million trips between 2001 and 2009 according to NHTS, but 90 million by the ITE-based method.

These comparisons over time reveal a core problem with ITE's approach. In recent years, household travel has plateaued or may even be falling, and several studies have concluded that we have reached "peak travel" in the US. Even if the pace of development has slowed since the last recession, however, residential and non-residential projects continue to be built. By ITE's logic, each new house, apartment, office, and factory should be generating additional trips, thus leading to significant travel growth throughout the country. But in reality, total trip-making in the US has been relatively flat since 1995. >

By ITE's logic, each new house, apartment, office, and factory should be generating additional trips. But in reality, total trip-making in the US has been relatively flat since 1995.



The fundamental issue is ITE's core premise that new development always generates *new* trips. The implicit assumption in this model is that new destination opportunities spur households to make new trips, rather than merely substituting new destinations for old ones. In practice, new development has much more complex effects on total trip making. Some trips will be completely new, as households take advantage of new employment or recreational opportunities. But most trips substitute for existing ones—they are diverted from existing locations as people change where they live, work, and shop in the light of new travel options.

In other words, ITE's data reflect the *average* trip generation rate, not the *marginal* trip generation rate. The average rate is simply the number of trips that could be expected at a development of a particular type. The marginal rate is the *increase* in total trips as a result of that same development. The marginal rate will typically be less than the average rate, because some new trips merely substitute for old ones. Engineers, planners and policy makers, however, often care more about the marginal trip generation rate, which tells us the *net* impact of a new development on traffic or greenhouse gas emissions.

Scale matters in this analysis. At the micro level—the newly constructed driveway or street that serves a new development—the projected trips are supplementary to what would have been there otherwise. In this case, the average rate will equal the marginal rate, so the distinction is of little import. But when we consider the macro level—trips on arterials and freeways—substitution becomes more important, and the marginal rate becomes less than the average rate. The larger the area of analysis, the greater the likelihood that the previous origin or destination lies within that area of analysis, and the more the marginal rate will diverge from the average rate.

Take, for example, the construction of a new courthouse. Presumably, the number of murders, divorces, and other legal matters—and thus the total number of trips to court—has little to do with the number of courthouses in a county. Courts do not cause crime. Nevertheless, the new courthouse will cause trips to be relocated from other facilities, and its location, transit access, and parking cost will influence the marginal number of trips. If the courthouse is located in a more transit-rich, denser center than before, the marginal impact may well be negative. None of this would be considered by simply looking up the average trip generation rate in the ITE manual.

ITE's recommended practice in the *Trip Generation Handbook* partially recognizes issues of scale and, implicitly, the difference between average and marginal rates, by distinguishing between three types of trips: primary trips; pass-by trips to intermediate destinations, where the driver simply stops along the way; and diverted linked trips, which are similar to pass-by trips but involve a diversion. This framework, however, only partially captures the trip substitutions that cause the average rate to exceed the marginal rate, because even primary trips do not necessarily increase travel at the macroscopic scale. For instance, a primary trip to a new grocery store may substitute for a primary trip to the household's previous store of choice.

In the case of local intersections, it might be justifiable to disregard the distinction between average and marginal trips. In the case of regional freeways, though, it is dubious to ignore trip substitutions. When considering entirely non-local effects like greenhouse gas emissions, the substitution component is almost completely dominant, and it is wrong to base an analysis on average trip generation rates. In this case, almost all trips are substituted from other origins and destinations, and marginal trips are negligible. New development projects do not normally generate trips—or greenhouse gas emissions—at the regional or national scale, but simply reshuffle existing ones around.

CONCLUSION

ITE's *Trip Generation Manual* represents standard practice when analyzing the traffic and environmental impacts of new development. Most criticism has focused on the inapplicability of ITE trip generation rates to mixed-use and transit-oriented development. However, I find that the problems with ITE trip generation rates run far deeper.

First, the rates appear to greatly overestimate the number of vehicle trips that can be attributed to any development project, most likely because ITE's data are based on a biased sample. Engineers and planners who use ITE rates are likely designing streets to cater for phantom trips that will never materialize.

Second, trip generation rates published by ITE must be interpreted as the average rate, not the marginal rate, and the marginal rate depends on the scale of the analysis. This is largely a criticism of standard practices in traffic engineering and air quality >

Scale matters
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New development
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or national scale,
but simply reshuffle
existing ones
around.

FURTHER READING

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analysis, rather than the quality of ITE's data. Indeed, at scales beyond the immediate vicinity of a particular development, it makes little sense to think in terms of trip generation. By calling this process "generation," we mislead people into thinking new trips are created as a direct result of development activities. But new land uses do not generate trips in a mechanistic way. Instead, *people* generate trips, in response to the characteristics of the built environment rather than the amount of development.

What, then, is the practicing planner or engineer to do? Regional travel demand models provide an option for large projects, but are likely to be too costly for smaller developments. For analysis of traffic movements at intersections adjoining a new development—the bread and butter of traffic engineering practice—it would be wise to bear in mind that ITE trip generation rates are likely to lead to large overestimates. Preferably, the analyst would seek sources of trip generation data that are tailored to the local characteristics of a particular development.

An altogether different approach is needed for analysis of traffic, air quality, or greenhouse gas emissions at a scale beyond the immediate vicinity of a development project. Instead of conceptualizing new housing, offices, or retail centers as generating traffic or emissions, it seems more useful to judge them against the baseline of existing development.

In a sprawling metropolitan region, new high-density, transit-oriented housing will probably reduce total vehicle travel. Adjusting down the number of trips generated for developments of this nature is certainly a step in the right direction, but fundamentally it is misleading to think that such transit-oriented housing generates *any* additional vehicle trips at a regional scale. A more reasonable starting point is to consider that new development is just as likely to reduce traffic, air pollution, and greenhouse gas emissions as it is to increase them.

Traffic levels in the US have plateaued while development is rebounding following the economic downturn. When considered together, these two trends are incompatible with the idea that new development "generates" traffic at any scale beyond the very local. But current planning practices demand that roadway infrastructure be designed, and developers assessed fees, to accommodate both actual and phantom trips. Rethinking the assumptions behind trip generation studies may not only avoid wasting resources on over-sized roadways, but can also support efforts to promote transit-oriented, livable communities. ♦

This article is adapted from "Phantom Trips: Overestimating the Traffic Impacts of New Development," originally published in the *Journal of Transport and Land Use*.

Trip Generation for Smart Growth Projects

ROBERT J. SCHNEIDER, SUSAN L. HANDY, AND KEVAN SHAFIZADEH

California encourages developers to pursue urban infill projects in order to achieve a variety of infrastructure efficiency and environmental goals. Since they are already surrounded by established developments, infill projects provide better opportunities for walking, bicycling, and public transit, and they encourage fewer automobile trips than new suburban developments. Nevertheless, developers often meet resistance when proposing infill projects. Neighbors worry, “The development will increase traffic and make it difficult to park.” Public officials warn, “The developer must pay a fair share of the roadway improvements that are needed to serve the additional cars and trucks.” >



Since smart growth developments increase travel by modes other than automobiles, the ITE rates likely over-estimate vehicle trips for these projects.

To address these concerns, developers must complete a transportation impact assessment (TIA), required by federal, state, and local laws. If an assessment predicts that an infill project will generate more automobile trips than local streets can handle, local officials may require the developer to build or pay for wider roads, additional turning lanes, or larger parking lots. By accommodating more cars and trucks, these requirements counteract potential reductions in auto travel. In addition, the added costs make some infill projects financially infeasible, causing developers to scrap infill proposals in favor of suburban greenfield development.

Why isn't this process working? The answer is related to the traditional TIA approach. The California Department of Transportation (Caltrans) asked our UC Davis research team to delve into TIA trip generation practices, and in response we created an adjustment tool that improves the accuracy of estimating automobile trips in urban areas and should make it easier for developers to get infill projects approved.

THE HEART OF THE PROBLEM

At the heart of the TIA process is the Institute of Transportation Engineers (ITE) *Trip Generation Manual*, used throughout the US for decades. This manual provides automobile trip generation rates—the number of cars and trucks expected to enter and exit a site per hour—for land uses ranging from apartments and offices to coffee shops and bowling alleys. As the industry standard for many years, ITE trip generation rates have rarely been challenged. Local governments use them to evaluate developments in vastly different geographic areas, from the suburban fringe to the city center. The rates are typically derived using the simple relationship between the size of a development and the predicted number of trips generated by that development during a particular time of day (e.g., the number of trips per 1,000 gross square feet of retail, during the afternoon peak hour).

ITE estimates trip generation rates using data collected by practitioners and researchers at development sites throughout the United States. To control for external influences on automobile trip generation rates, ITE requires data be collected at isolated, single-use sites that are neither served by transit nor typically accessed on foot or by bicycle. In other words, most urban infill sites, transit-oriented developments (TODs), mixed-use sites, and other types of “smart growth” developments are not incorporated into ITE calculations; the sites represented in the manual are primarily suburban. Since smart growth developments increase travel by modes other than automobiles, the ITE rates likely over-estimate vehicle trips for these projects.

Recognizing this possibility, the ITE *Trip Generation Handbook* provides clear guidance that the ITE trip generation rates do not apply in smart growth areas. But this leaves several critical gaps for practice. How inaccurate are ITE-based trip generation estimates in smart growth areas? If ITE rates aren't appropriate, what trip generation rates *should* be used for smart growth developments?

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HOW BIG IS THE PROBLEM?

Recent studies suggest that ITE rates overestimate automobile trips in smart growth areas. For example, one study found that at a sample of 17 residential TODs, trip estimates based on ITE rates were, on average, 80 percent higher than the number of documented vehicle trips. Another study of mixed-use urban infill sites found that ITE-based estimates were up to double the number of actual vehicle trips. Our own analysis of 22 smart growth sites in California found that ITE-based estimates of evening peak-hour vehicle trips were on average 50 percent higher than observed rates at mixed-use developments, and 90 percent higher than at infill sites. Though these studies are based on data from a limited number of sites, they provide convincing evidence of overestimation.

So what is the alternative? A few innovative communities have developed their own local trip generation rates, while others have worked with consultants to adjust ITE rates. These adjustments account for characteristics such as population and employment density, transit service, and pedestrian and bicycle facilities. We reviewed these methods and found that, while substantially better than the ITE rates, they still had flaws: data collection and analysis remained burdensome, few methods could be transferred to other communities, and some methods were insensitive to smart growth variables. Also, some of the methods were based on data from travel diary surveys rather than observed trip-generation data. Because of these limitations, we collaborated with Caltrans and our project review panel to develop a new, easy-to-use method to adjust trip generation for smart growth sites. ➤



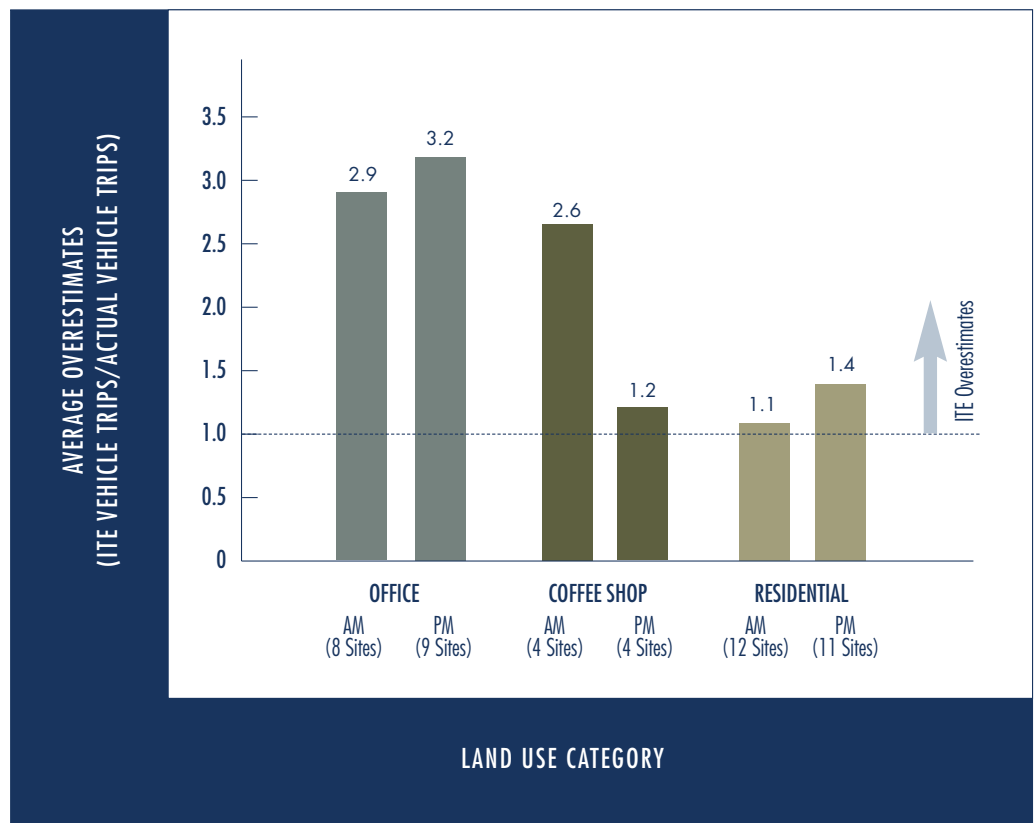
NEW DATA REVEAL MORE INSIGHTS

We developed a rigorous data collection method to count vehicle trips as accurately as possible at sites in smart growth areas. Many characteristics of smart growth sites present challenges for data collection, including mixed-use buildings (e.g., a coffee shop on the first floor of an office building), on-street parking, parking lots shared by multiple land uses, and internal doorways connecting to parking garages. To address these challenges, we combined door counts and intercept surveys at 30 targeted land uses in central areas of Los Angeles, Oakland, Sacramento, and San Francisco. The results showed more evidence of the discrepancies mentioned earlier: ITE rates overestimated vehicle trips by an average of 2.3 times in the morning peak-hour period and by 2.4 times in the evening peak-hour period.

If the ITE rates overestimated vehicle trip generation by these ratios at all smart growth sites, it would be simple to adjust a rate by dividing it by 2.3 or 2.4 to get the correct vehicle trip estimate. However, the accuracy of the ITE rates varied substantially among the study sites (Figure 1). For example, on average, ITE rates overestimated vehicle trip generation at office buildings by 2.9 times in the morning and 3.2 times in the evening peak hour. They overestimated trip generation at mid- and high-density residential buildings by 1.1 times in the morning and 1.4 times in the evening peak hours. We suspected that, in addition to land use, the site itself and surrounding built environment characteristics also affected the magnitude of ITE overestimates. Therefore, to adjust ITE estimates correctly, our smart growth adjustment method must account for a variety of influences on travel behavior that may be operating at a given site.

FIGURE 1

ITE Rate vs. Actual
Vehicle Trips at Smart
Growth Sites





A NEW SMART GROWTH ADJUSTMENT METHOD

We chose a statistical modeling approach to account for a variety of influences on vehicle trip generation, such as the characteristics of the site, adjacent streets, and surrounding neighborhood. To maximize the data available for the new method, we supplemented our initial 30 study sites with trip-generation data collected by other researchers and consultants from more than 30 additional California smart growth sites.

We followed a two-step process to adjust ITE estimates for smart growth developments:

Step 1: Calculate a smart growth factor (SGF) to quantify how well the site represents smart growth characteristics. The SGF expresses the cumulative impact of variables such as distance from the site to the central business district, population density, job density, metered on-street parking, transit service near the site, building setback from the sidewalk and surface parking coverage at the site. All of the SGF components can be easily measured from available data sources.

Step 2: Apply a morning or evening peak-period equation to calculate ITE adjustments. Both the morning and evening equations include the SGF from Step 1, indicator variables for office and coffee shop land uses, and an indicator variable for sites located within one mile of a university campus. ➤

The equations adjust the number of trips estimated by ITE rates to provide a more accurate estimate of vehicle trip generation at a smart growth site. We built these equations into a free, user-friendly spreadsheet that can be downloaded and applied by practitioners during the TIA process (Figure 2).

THE FUTURE OF TRIP GENERATION

This research provides practitioners with the tools to improve TIA practice in California. Planners and developers now have an easy-to-use tool at their disposal to adjust ITE estimates. This more realistic assessment of automobile trip generation should make it easier for developers to get urban infill sites approved. Still, we can improve accuracy by expanding the sample of sites and by examining additional land uses listed in the *ITE Trip Generation Manual*. Furthermore, since the SGF simply adjusts the ITE method, it does

FIGURE 2
Spreadsheet Tool for
Smart Growth Trip
Generation

California Smart Growth Trip Generation Adjustment Tool, Version 1.0
SHEET 2: APPLY TOOL
Developed by UC Davis for the California Department of Transportation

Instructions: If your study site meets the smart-growth criteria in the first sheet ("1_CheckSmartGrowthCriteria"), enter values into the white cells in Column D of the "Site Characteristics & ITE-Estimated Trips" and "Model Inputs" tables (values in the grey cells are transferred automatically from the first sheet). This spreadsheet will calculate values in Column D of the "Model Outputs" table automatically. The key outputs are the estimated number of motor-vehicle trips generated at a study site located in a smart-growth area during the weekday AM and weekday PM peak hours. For more information about the model, see the California Smart-Growth Trip Generation Final Report at the project website: <http://ultrans.its.ucdavis.edu/projects/smart-growth-trip-generation>.

Site Characteristics & ITE-Estimated Trips	
Name	Central City Association of LA
Address	826 Wilshire Boulevard
City	Los Angeles, CA
ITE Land Use Code	710
Dwelling Units (Residential) ¹	138452
Gross Square Feet (Retail, Office) ²	0.98
Proportion Occupied (0.00 to 1.00) ³	210
ITE-Estimated AM Peak-Hour Vehicle-Trips (from ITE Trip Generation Manual) ⁴	202
ITE-Estimated PM Peak-Hour Vehicle-Trips (from ITE Trip Generation Manual) ⁴	

Model Inputs	
Residential population within a 0.5-mile, straight-line radius	13072
Jobs within a 0.5-mile, straight-line radius	74881
Straight-line distance to center of central business district (CBD) (miles) ⁵	0.09
Average building setback distance from sidewalk (feet) ⁶	0
Metered on-street parking within a 0.1-mile, straight-line radius (1=yes, 0=no) ⁷	1
Individual PM peak-hour bus line stops within a 0.25-mile, straight-line radius	208
Individual PM peak-hour train line stops within a 0.5-mile, straight-line radius	4
Proportion of site area covered by surface parking lots (0.00 to 1.00) ⁸	0.00
Study land use is an office (1=yes, 0=no)	1
Study land use is a coffee/donut shop (1=yes, 0=no)	0
Site is within 1 mile (straight-line distance) of a college campus (1=yes, 0=no) ⁹	0

Model Outputs ¹⁰	
Smart Growth Factor	1.72
Actual/ITE-Estimated AM Peak Hour Vehicle Trips	0.30
Actual/ITE-Estimated PM Peak Hour Vehicle Trips	0.28
Estimated AM Peak Hour Vehicle Trips	63
Estimated PM Peak Hour Vehicle Trips	56

Source: <http://ultrans.its.ucdavis.edu/projects/smart-growth-trip-generation>

not address the method's existing limitations, such as basing trip generation rates for some land uses on small samples and distinguishing between average and marginal trip generation (see Millard-Ball's article in this issue).

This initial smart growth trip-generation adjustment tool is part of a broad movement to improve trip generation practice. The ITE *Trip Generation Handbook* is currently being updated, opening up possibilities to improve the most widely accepted approach for TIAs. For example, researchers are expanding trip generation estimation tools to include walking, bicycling, and public transit. Our data collection method helps quantify trips made by these other modes, providing the foundation for a future multimodal trip generation database.

It is particularly important for planners and developers to be able to estimate multimodal trip generation in smart growth areas, since it can guide them to better allocate available right-of-way among different modes based on anticipated demand. Trip generation models can also influence the resources allocated to projects that upgrade sidewalks, bicycle lanes, safe roadway crossings, and public transit service.

This new smart growth trip generation tool is a significant step forward. In response to proposed development, neighbors may now say, "This project will create more life on our streets without having a big impact on traffic." Public officials can proclaim, "The development is bringing more jobs and residents to the core of our city while improving the sidewalks, bicycle lanes, and transit systems that serve them." By supporting urban infill development, this new tool can make our cities more sustainable and better places to live. ♦

This article is adapted from "Method to Adjust Institute of Transportation Engineers Vehicle Trip-Generation Estimates in Smart-Growth Areas," originally published in *Journal of Transport and Land Use*.

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By supporting infill development, this new tool can make our cities more sustainable and better places to live.



POUNDS THAT KILL

MICHAEL L. ANDERSON AND MAXIMILIAN AUFFHAMMER

Buying a car can be a stressful process, requiring choices based on quality, fit, and cost. When making this choice, we focus mainly on our own well-being and often ignore the negative effects our purchases may have on others. This illustrates the problem of *externalities*—public costs and benefits not reflected in the cost of a private choice. Classic examples of externalities include air pollution and traffic congestion. In our study, we focus on the externality imposed by the weight of a vehicle. If you drive a heavier car and collide with a lighter vehicle, the occupants of the vehicle you hit are more likely to be injured or killed. The occupants of the struck vehicle thus bear an external cost of your heavier vehicle.

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Many consumers like bigger vehicles because they provide more space and are perceived to be safer in crashes. These heavier vehicles are generally less fuel efficient and are therefore both costlier to operate and more harmful to the environment. Some studies argue that fuel-economy standards encourage people to purchase lighter and potentially less safe vehicles, resulting in an increase in traffic fatalities. We show that these studies ignore the external safety costs imposed by heavier vehicles.

When you buy a car, you choose the amount of protection by selecting a vehicle of a given size and weight. You internalize the higher purchase price and higher operating costs of a heavier vehicle in order to obtain safety benefits. At the same time, your choice imposes a cost on all drivers sharing the road with you, since heavier vehicles are more dangerous to other roadway users. Ideally, your choice of vehicle would reflect these significant external costs, but currently there is little or no incentive for you to consider them. The safety benefits of your heavy vehicle thus come at the cost of greater risk to other roadway users. This causes consumers to overinvest in vehicle weight, which has costs in terms of fuel economy and manufacturing expense.

Our research quantifies the external costs of choosing heavier vehicles. These external costs are an important policy topic: traffic accidents claim about the same number of life-years lost in the United States to lung cancer. Under current laws, consumers have the right to shift risk to others with little recourse for compensation. We do not evaluate the ethics of risk shifting; rather we quantify whether it produces inefficient outcomes. We conclude by discussing several potential policies for regulating these external costs in order to increase social welfare.

THE RELATIONSHIP BETWEEN VEHICLE WEIGHT AND FATALITIES

Police departments across the country record a tremendous amount of information on reported accidents. We obtained permission from eight state police chiefs to examine over ten million state accident reports between 1989 and 2008. While police officers do not weigh vehicles at the scene of an accident, they often record the Vehicle Identification Number (VIN). This number allows us to determine the weight of each vehicle involved in a crash. We are also able to observe whether anyone in a given vehicle was severely injured or killed in the accident, along with a rich data set of driver, vehicle, and accident characteristics. We use regression models to estimate the probability of a fatality or serious injury in the struck vehicle as a function of the weights of both the striking and struck vehicles, driver characteristics, accident characteristics, and other vehicle attributes.

Our model indicates that when the striking vehicle is 1,000 pounds heavier than a baseline vehicle, the probability of a fatality in the struck vehicle increases by 40 to 50 percent. Additionally, the probability of a serious injury in the struck vehicle increases by 17 to 20 percent. This effect is both economically and statistically significant. While 1,000 pounds may sound like a lot, it is not. In fact, it is equivalent to the weight gain of the Honda Civic between 1981 and today, and close to the average US light-vehicle fleet weight gain since the early 1980s. ➤



Excess vehicle weight
imposes an external
safety cost on other
drivers of \$79 billion
per year.

We estimate that the private safety benefit of driving a heavier striking vehicle is roughly equivalent in magnitude to the external cost estimates above. In other words, adding weight to vehicles is a “zero sum game” from a safety perspective. Every pound in a heavy vehicle that brings extra safety for the driver comes at the cost of a roughly equivalent reduction in safety for those in lighter vehicles. Furthermore, our data show that collisions between two heavy vehicles are not, on average, safer than collisions between two light vehicles.

We conducted a number of sensitivity checks to see whether our estimates might have been biased. One potential bias is that heavier vehicles may be concentrated in rural areas with longer distances to hospitals, which increases the time to receive critical medical care. To make sure our regressions did not wrongly attribute this distance-to-hospital effect to vehicle weight, we controlled for crash location and found no evidence supporting the rural hypothesis.

A second potential bias is that more aggressive drivers may select heavier cars to drive. We tested for this bias using single-car accidents from our dataset and National Highway Traffic Safety Administration crash test results, but found no supporting evidence.

Finally, we used a number of different sources to identify variation in vehicle weight (e.g., variation in the number of occupants in the vehicle, which generates variation in the vehicle’s net weight, and the changes in weight in a specific vehicle model over time). We determined that the estimated effects are quantitatively similar in all cases.

HOW BIG ARE THESE EXTERNAL COSTS?

We calculate that excess vehicle weight imposes an external safety cost on other drivers of \$79 billion per year. Our data allow us to estimate causal effects of vehicle weight on accident fatalities and then convert them into annual dollar figures. To do this, we assume that the lightest car that provides basic transportation services weighs 1,850 pounds, which is roughly the weight of a Toyota iQ subcompact hatchback. We then take the weight of the *average* vehicle sold in the most recent year of our sample and calculate the increase in external fatalities due to vehicle weight (relative to the 1,850 pound benchmark vehicle). When we multiply these additional fatalities by the value of a statistical life (\$5.8 million in 2008), we arrive at an external cost to other drivers of \$79 billion per year. Once we account for fatalities of bicyclists, motorcycle riders, pedestrians, and collisions involving more than two vehicles, we arrive at a total external cost of vehicle weight of \$136 billion dollars *per year* (or an average of \$586 per vehicle per year). This represents the additional external costs that consumers do not consider when purchasing their vehicles, and is a guide for the size of the appropriate corrective tax or fee. For comparison, this number is \$12 billion more than the estimated social cost of total US carbon emissions.

If we divide the total external safety cost of vehicle weight by the number of gallons of gasoline consumed in the US annually, we arrive at an external cost of 97 cents per gallon. Thus, per gallon, the external cost of vehicle weight is larger than the estimated external costs of air pollution (21 cents per gallon) and congestion (29 cents per gallon). This estimate does not even incorporate the fact that heavier vehicles may be more likely to crash due to longer braking distances and poorer maneuverability. Furthermore, 97 cents does not include the additional likelihood of a fatality if the striking vehicle is an SUV or light truck. A back-of-the-envelope calculation suggests that incorporating these costs could raise the total external cost to be as high as \$1.89 per gallon of gasoline.

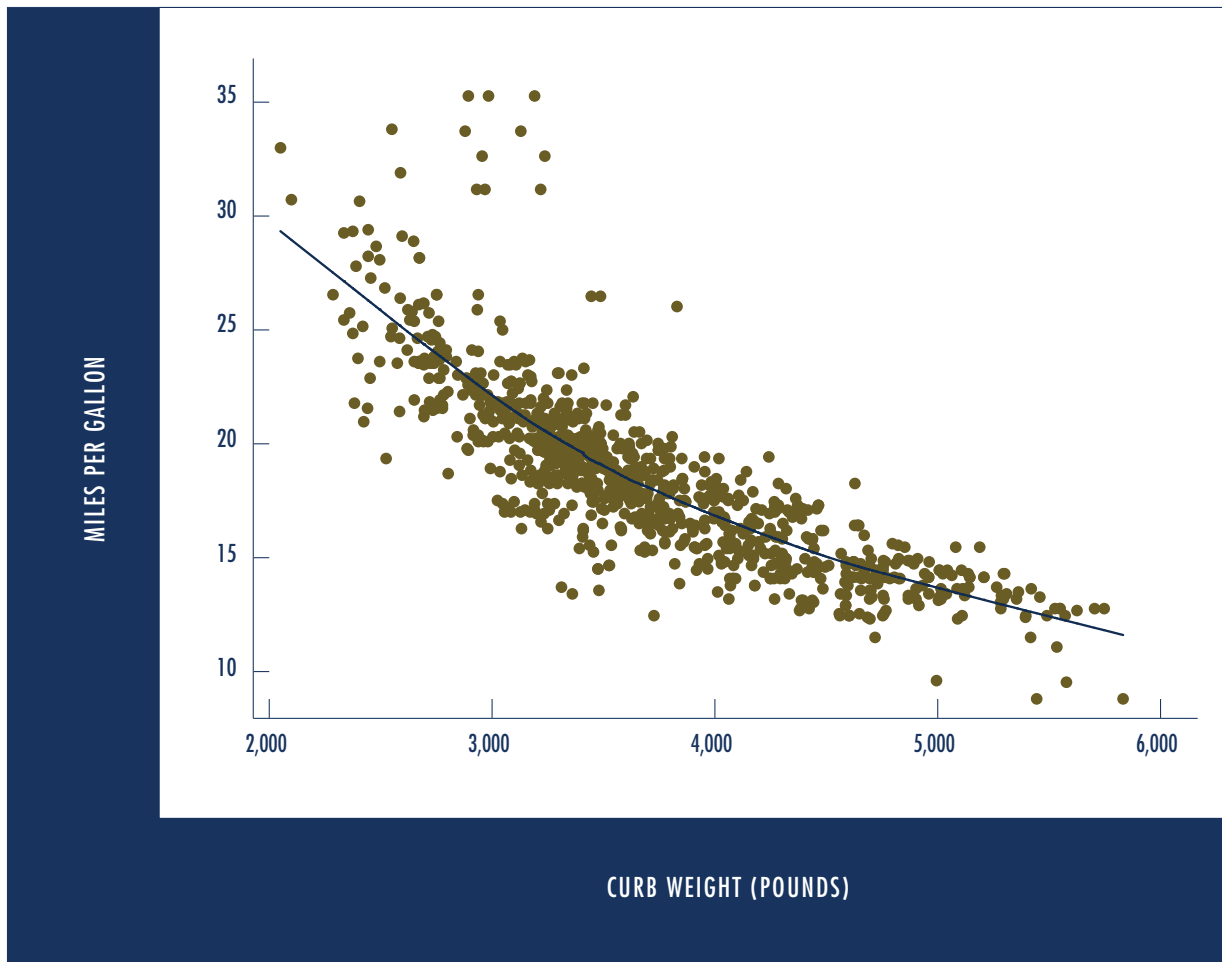
HOW CAN WE REGULATE?

These results suggest that, if heavier vehicles impose safety externalities on other vehicles, governing bodies should regulate vehicle weight. There are several policy options that could achieve this goal. The first is the economist's least favored approach: a Corporate Average Fuel Economy standard. This regulation, which has been in effect in the US since the 1980s, reduces vehicle weight indirectly by prescribing higher fuel efficiency, but it does not regulate the problem directly. While these regulations limit consumers' vehicle choices, they do not involve an explicit tax. A more efficient strategy would be to charge an excise tax linked to weight, but this would likely be politically unpopular.

Another way to control vehicle weight, which economists prefer, would be to pass the external safety cost on to consumers in the form of a gasoline tax. Higher gasoline prices encourage consumers to choose more fuel-efficient vehicles, which are lighter by design. Figure 1 displays the relationship between fuel economy and curb weight for model year 2005 vehicles. While the correlation between fuel economy and weight is strong, it is not perfect, so a gas tax does not price additional weight in an exact manner.

The optimal regulation would be similar to a pay-as-you-drive (PAYD) scheme, where drivers pay a per-mile fee proportional to vehicle weight. In this scheme, heavier cars >

FIGURE 1
Fuel Economy vs. Weight for
2005 Light Vehicles



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would pay a higher per-mile fee than lighter cars, and people who drive more would bear more of the costs associated with the risks they impose. An attractive feature of this policy is that the tax would also vary with driver behavior; since the insurance rates are higher for risky drivers, they would face a higher weight tax than safe drivers. This is desirable because the weight externality is ultimately proportional to the number of accidents drivers have rather than the number of miles they drive. While this policy is economically preferable, it currently imposes logistical challenges.

A gas tax, however, is a reasonable proxy for the optimal PAYD scheme. For 96 percent of vehicle models, the difference between the two fees is less than two cents per mile. Thus, a gas tax is very close to the optimal mileage fee that is proportional to vehicle weight. For reference, a consumer who chooses a mid-size SUV over a mid-size sedan might expect to pay approximately \$200 more over the course of a year.

THE PUZZLE

So should we regulate vehicle weight? We say yes. From an economist's perspective, an externality should be corrected by a tax that enhances social welfare. To understand why the current vehicle fleet is inefficiently heavy, consider a situation in which a tax uniformly reduces fleet curb weight by 1,000 pounds. Our research suggests that this weight loss will not increase the number of fatalities or serious injuries. We can thus achieve a lighter fleet that costs less to operate and causes less damage to the environment without compromising safety. This solution is similar to that of nuclear disarmament. If both sides cut their arsenals uniformly, the probability of a conflict is likely to remain unchanged and both sides save money on weapons expenditures. Policies to diminish our own highway arms race can improve welfare while keeping us safe. ♦

This research was funded by the University of California Energy Institute and the Robert Wood Johnson Foundation. The article is adapted from "Pounds That Kill: The External Costs of Vehicle Weight," originally published in the *Review of Economic Studies*.

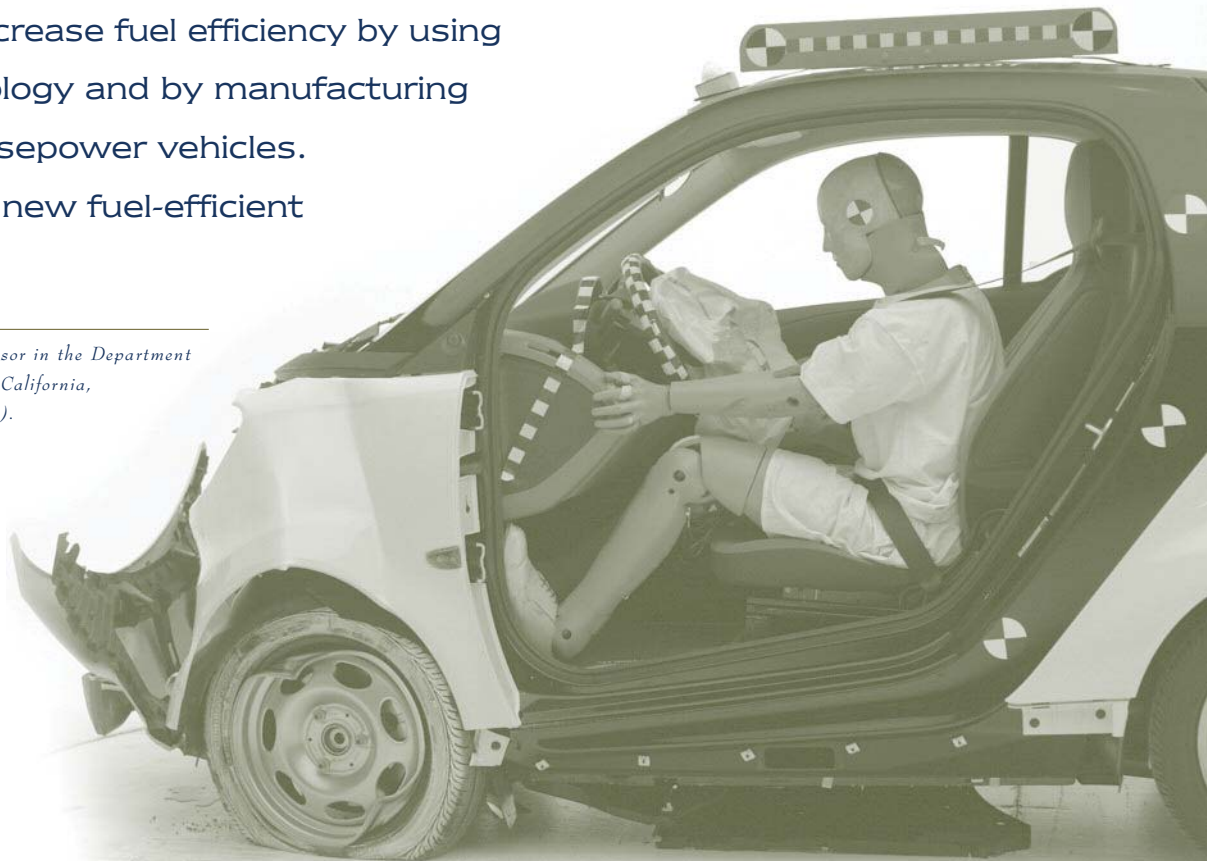
FUEL-EFFICIENCY STANDARDS: ARE GREENER CARS SAFER?

MARK JACOBSEN

The United States has strengthened its fuel efficiency regulations several times in recent years in an effort to reduce the environmental, economic, and energy security costs associated with gasoline. These standards encourage automakers to increase fuel efficiency by using advanced technology and by manufacturing lighter, lower-horsepower vehicles.

But are these new fuel-efficient vehicles safe? >

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Traffic accidents killed more than 32,000 Americans in 2011, representing the leading cause of death for those under 40. They also caused two million non-fatal injuries.

Traffic accidents killed more than 32,000 Americans in 2011, representing the leading cause of death for those under 40. They also caused two million non-fatal injuries. Given the large scale of traffic deaths and injuries, fuel efficiency regulations that produce even small percentage changes in safety, in either direction, can have a dramatic effect. I find that even subtle changes in the policy, for example the way pickup trucks or vehicles with larger footprints are treated, can importantly influence safety.

To measure the safety of the increasingly fuel-efficient US fleet, I studied the link between fleet composition and accidents, examining safety implications for both car occupants and occupants of other vehicles. In my research, two key patterns emerged: 1) in single-car crashes (which make up more than half of fatalities), smaller and lighter cars are more vulnerable to damage than larger vehicles, and 2) smaller and lighter cars involved in multiple-car crashes are much less likely to cause a fatality in other vehicles.

I examined the safety effects of an increase in the gasoline tax as well as three different types of fuel economy policy: a simple average fuel efficiency requirement, the historical Corporate Average Fuel Economy (CAFE) standards, and the recent “footprint-based” policy that is being phased in through 2025.

US FUEL ECONOMY POLICY

The US has embarked on the most ambitious reduction of gasoline use since the 1978 CAFE standards, with a target for 2025 that nearly doubles the average fuel efficiency of new vehicles sold relative to 2010. These rules place an upper limit on the average fuel consumed per mile driven in the mix of new vehicles sold or, equivalently, a lower limit on miles per gallon (MPG).

Figure 1 plots fuel use per 100 miles (this measure is proportional to overall gasoline use in the country controlling for the number of drivers and distance traveled) among new vehicles sold in the US since 1955. This figure shows both the historical effects of the 1978 CAFE standards as well as the requirements of new standards through 2025. Corresponding changes in the more familiar MPG measure are shown on the right-hand scale. Notice that MPG improvements save more fuel when MPG is low to start with. For example, Figure 1 shows that when the initial fuel efficiency was 14 MPG, an increase of 3 MPG to 17 MPG saved one gallon of gasoline per 100 miles traveled. When the initial fuel efficiency is 33 MPG, however, it will take a further increase of 17 MPG to 50 MPG to save another one gallon per 100 miles traveled.

Most notably, there is a sharp decline in fuel consumption following oil price increases during the 1970s supply crisis. Average fuel use fell from over seven gallons for a 100-mile trip to fewer than four gallons in the late 1980s. This drop was followed by a slow rebound in fuel use, which ended with the 2005 spike in gasoline prices.

Economists largely agree that without CAFE standards gasoline use would have risen much faster during the 1990s and early 2000s. CAFE regulations held the fuel use of two broad categories—passenger cars and light trucks—almost constant. The small increase in fuel use between 1987 and 2004 reflects a shift in the fleet from passenger cars to light trucks, a category that includes SUVs, pickups, and minivans.

Figure 1 also displays the ambitious fuel economy standards that will be phased in by 2025. These standards extend the gasoline-saving trend that began in 2005 and will eventually reduce fuel consumption to only two gallons for a hundred-mile trip, or around 50 miles per gallon. Additionally, a new feature of the rules—measuring average fuel

economy based on the size of each vehicle—will significantly change the way fuel economy standards influence fleet composition.

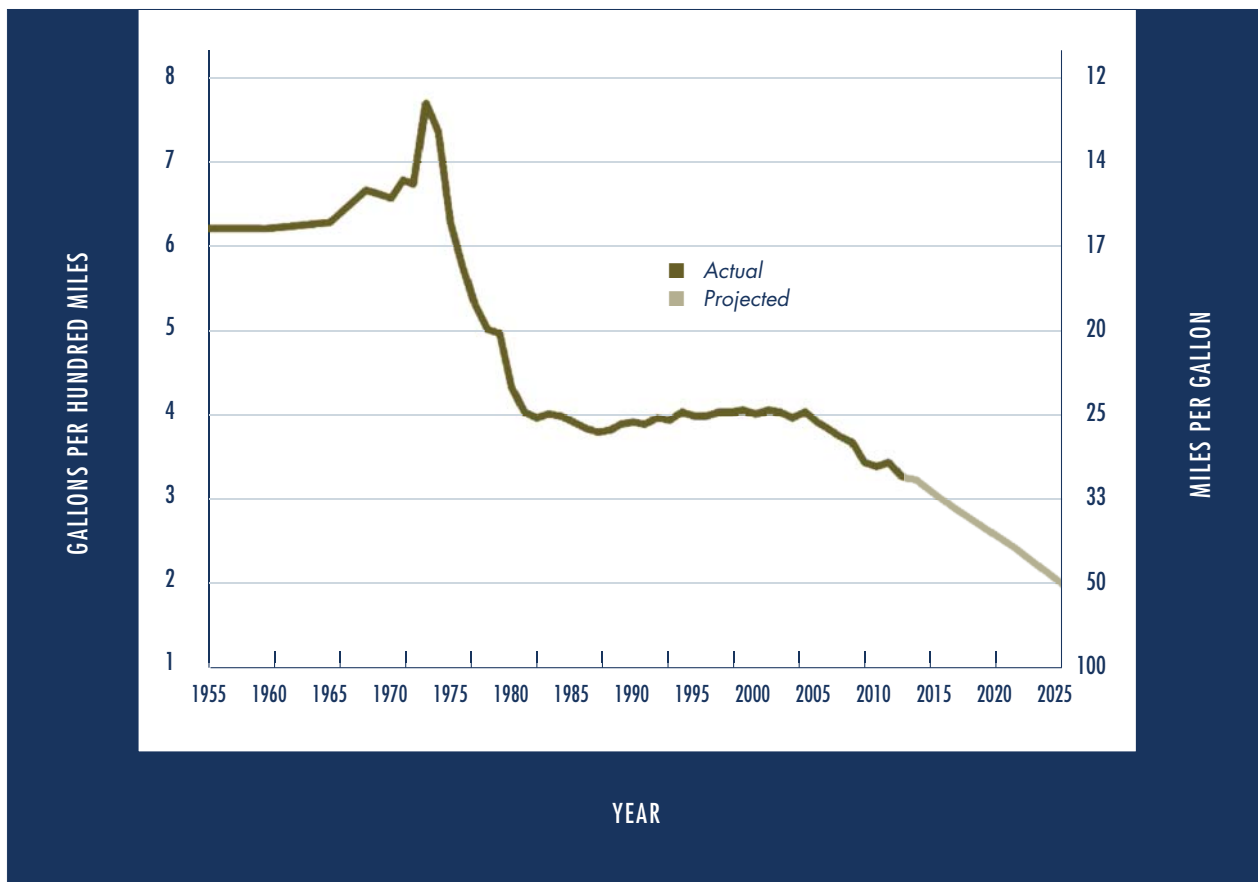
ACCIDENT SAFETY AND FLEET COMPOSITION

Through the 1980s and 1990s, American consumers bought larger vehicles in part as a defense against other large vehicles. As a result, a slow but costly arms race has taken place in the US vehicle fleet. The fleet we have today is composed of vehicles that are, on average, about 1,000 pounds heavier than they were in 1980.

Gasoline-saving policies, however, encourage the purchase of smaller and lighter vehicles. At first glance, this would seem to worsen safety, as crash tests highlight the risks of small vehicles. On the other hand, economists Michael Anderson and Maximilian Auffhammer, who also have an article in this issue, estimate that making a car 1,000 pounds lighter reduces the risk of causing a fatality in another car by 50 percent. Thus, fuel economy policies, by promoting smaller and lighter vehicles, have the potential to reduce this arms race and increase overall safety.

Smaller cars may offer less protection to their own occupants but they also greatly reduce fatalities for people in other vehicles. To assess the effect of fuel economy policy on vehicle safety, I measure the following three key factors: 1) how well each type of vehicle protects its own occupants, 2) the risk each vehicle type imposes on others, and >

FIGURE 1
Gasoline Use by New Vehicles:
Actual and Projected to 2025





3) the risks posed by individual drivers when they select different vehicle types. This last consideration is essential when working with real-world accident data because drivers who choose different vehicle types often have very different risk factors due to different driving behavior.

Using a comprehensive dataset of fatal traffic accidents in the US, I considered the safety impacts of consumers' switching among car types, such as from larger sedans to compact cars.

The key challenge in using accident data comes from the risks imposed by drivers themselves. For example, a large fraction of fatal accidents occur on rural roads. Therefore, safety data for the large pickups and SUVs often chosen by rural drivers will partially reflect the dangers of rural driving rather than the vehicles' inherent safety. A host of other confounding factors also exist, such as the vehicle choices and driving behavior of younger

drivers, night drivers, drunk drivers, or distracted drivers. These important factors are often unobserved in the data. My technique to isolate them involves a statistical comparison of fatal accident rates across all pairs of vehicles (for example pickups vs. compacts and pickups vs. minivans) with rates of single-vehicle accidents.

The results of my analysis of driver risk confirm the intuition many already have. For example, minivan drivers appear the safest among all classes, with accident risks that are approximately one third of the average. This captures unobserved attributes of minivan drivers such as the locations and times of day that they tend to drive. Likewise, small SUV drivers have very low risk for fatal accidents—about half of the average—perhaps because they tend to locate in urban areas. Drivers of different types of sedans are generally more similar to one another, with slightly more risk coming from drivers of larger, higher horsepower sedans.

After controlling for driver risk, I consider the risk each vehicle type imposes on others in the fleet. The results here are also intuitive: the accidents most likely to be fatal are those involving poorly matched vehicles. For instance, a pickup truck imposes about twice as much risk on a compact-car driver as a heavy luxury sedan does, and both luxury cars and pickups impose many times more risk than another compact car would. In single-car accidents, the largest sedans are safest (their heavy weight combines with low rollover risk), while small pickups have the greatest rate of fatal accidents even after controlling for the risk of drivers who choose them.

I combine these safety results with an economic model of US fuel economy rules. I then assess the safety effects of each type of policy, correcting for the changing distribution of people selecting different vehicle classes. For example, a policy might encourage some minivan drivers (with their safe driving habits) to switch to large sedans. The newly combined group of sedan drivers will then have lower average risk, reducing the overall rate at which large sedans appear in fatal accidents. I account for similar changes (for both better and worse) across all vehicle classes in my results. Table 1 summarizes these findings for four gasoline-saving policies, arranged from most to least efficient (before considering safety). ➤

	GASOLINE TAX	SINGLE FUEL ECONOMY STANDARD	ORIGINAL CAFE STANDARDS	NEW FOOTPRINT-BASED CAFE
EFFICIENCY IN CAR MARKETS				
EFFECT ON ACCIDENT FATALITIES	Decrease (neutral on composition, plus benefits through reduction in miles driven)	Zero Change (cars become smaller, but several effects on risk cancel each other out)	Increase (mismatched and single-car accident risks are worsened)	Zero Change (new standards intentionally keep all vehicle sizes about the same)

TABLE 1
Accident Fatalities and Gasoline Policy

An increase in the gasoline tax is the most efficient policy since it encourages gasoline saving at multiple decision points: consumers will drive less and also choose more fuel-efficient cars.

POLICIES

Gasoline Tax

An increase in the gasoline tax is the most efficient policy since it encourages gasoline saving at multiple decision points: consumers will drive less and also choose more fuel-efficient cars. An increased gasoline tax will increase demand for cars that are smaller, lighter, and that contain efficient engine technologies, while reducing the demand for SUVs, pickups, and minivans. Although it is the most economically efficient, an increase in the gasoline tax faces considerable political opposition. US policy therefore focuses on fuel economy standards.

Single Fuel Economy Standard

The most flexible and efficient standard is a single rule that simply requires a higher average fuel economy among all vehicles sold. This policy is the second most efficient of the options and would encourage fuel saving technology, smaller vehicle sizes, and fewer trucks and SUVs. In spite of this flexibility, a single average standard is less efficient than a gasoline tax since it changes car choice but fails to encourage people to drive less.

Original CAFE Standards

Unlike a single average fuel economy standard, the original CAFE standards separate light trucks (pickups and SUVs) from sedans. This additional complexity means that the CAFE standards are less efficient than imposing a single average rule. Manufacturers can no longer switch away from pickups and SUVs in order to improve their fuel economy rating so they must be stricter along other dimensions, such as size changes and new technologies.

New Footprint-Based CAFE Standards

Finally, the new footprint rules that are in place in the US until 2025 are the least efficient in terms of the flexibility they allow in meeting the goal. The required fuel economy for each vehicle is based on its physical dimensions, meaning that smaller cars are held to higher standards. This removes the incentive for manufacturers to change fleet composition toward smaller vehicles, instead leading them to focus almost exclusively on technological advances and weight and horsepower reductions.

Why move to a footprint-based policy that doesn't encourage reducing vehicle size as a way to save gas? According to the National Highway Traffic Safety Administration, the footprint-based policy was created to mitigate "the potential negative effects on safety." Without incentives to move to smaller cars, however, the main changes under the new rules will be features like engine technology and aerodynamics. The sizes and shapes of vehicles, and also accident outcomes, will be held roughly constant.

SAFETY IMPLICATIONS

Table 1 also shows safety outcomes for each of the four policies. Perhaps the most encouraging result is that a simple, average fuel economy standard involves almost no change in the total number of fatalities. The average standard encourages smaller and lighter vehicles, which worsens single-car accident outcomes, but it also slows down the

vehicle arms race. When there are fewer large vehicles, there are also fewer accidents between large and small vehicles. Since large-small vehicle accidents are by far the most dangerous accident type, reducing their frequency via the fuel economy policy creates a dramatic safety improvement.

The original CAFE standard is less flexible and more costly than a single standard or gasoline tax, and it creates the worst accident outcomes among all four policies. This policy maintains the dangerous mismatches in two-vehicle accidents while still worsening risks in single-vehicle accidents because of lower weights within each vehicle category.

CONCLUSION

Several policy options, including new footprint-based standards now going into effect, can reduce gasoline use while maintaining or even enhancing safety. More important, there also appears to be no clear tradeoff between the economic cost of a policy and safety. This result is striking as we might expect that economically “cheap” policies for saving gasoline (involving lots of people moving to smaller cars) would also require us to sacrifice safety. In fact, the opposite is true. The most efficient ways for the US to save gasoline—a simple tax increase or an average fuel economy standard—also provide the best outcomes in terms of safety. ♦

This article is adapted from “Fuel Economy and Safety: The Influences of Vehicle Class and Driver Behavior,” originally published in *American Economic Journal: Applied Economics*.

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An Innovative Path to Sustainable Transportation

DANIEL SPERLING

“The Stone Age came to an end not because we had a lack of stones, and the oil age will come to an end not because we have a lack of oil.”

—Sheik Zaki Yamani, Oil Minister for Saudi Arabia (1962–1986)

Contrary to popular belief, the world is awash in fossil energy, much of which can be readily converted into fuels for our cars, trucks, and planes. We are not running out of fossil fuels.

The abundance of fossil fuels means we are unlikely to see high fuel prices due to scarcity. Indeed, most analysts predict that future oil prices will not be much higher than today’s, apart from occasional peaks due, for example, to conflicts in the Middle East. Prices might even end up lower as new exploration and extraction technologies for shale oil, heavy oils, deep-sea oil, and oil sands make it cheaper and easier to extract fossil energy. Thus, we cannot depend on high oil prices to reduce transport energy use and greenhouse gas (GHG) emissions.

There are already 1.2 billion vehicles on the world’s roads, most of which are in the rich countries of Europe, North America, and Japan. Billions more people will buy vehicles over the next century, especially in developing countries such as China and India. This raises the question: can wealthy countries not only curb their appetite for fossil energy, but also lead in developing and adopting new low-carbon lifestyles? How can mobility and accessibility be increased without disrupting ecosystems, altering the climate, depleting water supplies and extinguishing species?

We need to wean ourselves off fossil fuels—and the GHG emissions they produce—and rebuild our cities and transportation systems to be far more energy efficient. We need to shift to a world that relies on sun, water, wind, and plants for energy. We need visions, strategies, and action.

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We are not running out
of fossil fuels.

Crafting visions to reduce GHG emissions can focus public attention on what is possible and what transformations are needed. But far more important and far more challenging is the question of how we build pathways to get from here to there, with specific incremental steps to achieve desirable long-term outcomes. These pathways require a mix of strategies and technologies, which can be sorted into three legs of the transportation stool: mobility, fuel type, and vehicle efficiency. These categories are represented by a simple formula:

$$\begin{aligned} & \text{Mobility (vehicle miles traveled)} \\ \times & \text{ Carbon Intensity of Energy (GHG emissions/unit of energy)} \\ & \times \text{ Vehicle Energy Efficiency (energy use/vehicle mile)} \\ \hline & = \text{GHG Emissions} \end{aligned}$$

MOBILITY: BEYOND CAR-CENTRIC CITIES

The first leg of the transportation stool is mobility, which includes vehicle use and the infrastructure and land use that support it. In many rich countries, and increasingly in emerging economies, personal cars dominate metropolitan travel. In the US, for example, personal vehicles account for 85 percent of passenger miles traveled, air travel for about 10 percent, public transportation for less than 3 percent, and bicycles and walking less than 2 percent. In Europe, where cities are more compact and fuel prices much higher, public transport has shrunk to only about 16 percent of passenger miles traveled. Walking accounts for about 20 percent of trips in much of Europe and Japan, though the trips are short and thus account for only a small share of total travel.

Reliance on personal vehicles makes transforming our cities and transportation systems a daunting challenge. In the US, passenger transport has changed little in over 60 years. While cars are safer, more reliable, and more energy efficient, they continue to perform at similar speeds and capacities and continue to be powered by internal combustion engines and petroleum. Highways, too, have changed little over the last 60 years, and for the most part remain toll-free, serve all vehicle types, and provide roughly the same performance.

Transit, too, has seen little innovation since the 1950s. The concept of bus rapid transit (BRT), where buses operate in platoons over dedicated rights-of-way, is one of the few significant innovations in intervening decades. Aside from BRT, transit operates with nearly identical service, capacity, and performance. US rail transit technology has improved, but rail ridership has decreased; heavy and light rail systems together carry less than one percent of passenger travel. Even in Europe, where ridership is more robust, rail transit carries only seven percent of overall passenger travel.

We need much more innovation. We need a new model of mobility and accessibility, especially in rapidly expanding economies such as Brazil, China, and India. Rich countries are now largely locked into car-centric development, but even car-centric cities still have the opportunity to reduce car use by expanding innovative mobility services, improving communication technologies, and charging full-cost prices for vehicles, fuels, roads, and parking. Better land use policies, too, will reduce vehicle use.

One promising legislative initiative is California's "Sustainable Communities Act of 2008," known as SB375. SB375 imposes on cities a greenhouse gas target for passenger travel and provides a framework to transform the mix of mobility services, land use, institutions, and behaviors that underlie our cities.

The information and communication revolution is bringing efficient, cost effective mobility services that can fill the gap between single-occupant cars and bus and rail transit. Vans and small buses can respond to real-time trip requests through demand-responsive transit services. Travelers located near each other self-organize carpools in real time using smart carpooling. And smart car and bike sharing facilitate one-way trips through shared vehicle use. Proliferating start-up companies are beginning to offer all these services, but they still account for only a tiny share of urban travel.

Additional benefits can come from enhanced data gathering and road pricing to improve traffic management. Innovations such as high occupancy toll lanes are a step toward more rational use of roads, and collection of "big data" from sensors and smart phones will lead to better design and management of roads, public transit, and new mobility services. Another innovation—automated vehicle technology—provides more

Car-centric cities still have the opportunity to reduce car use by expanding innovative mobility services, improving communication technologies, and charging full-cost prices for vehicles, fuels, roads, and parking.



potential for greater access at lower cost (but also runs the risk of encouraging more driving).

These strategies are not original ideas, and many have not yet been vetted or embraced. Concerns about privacy, opposition from taxi companies, and liability concerns all threaten the spread of innovative mobility services. But changes are afoot. Many new companies provide real-time mobility services, and some are preparing to market small neighborhood cars. Some cities use pricing to manage traffic flows and parking. Other cities are establishing bus rapid transit systems.

Unfortunately, these initiatives are fragmented in scattered cities. Therein lies the real challenge. No one technology, service, or land use change will substantially reduce car dependency by itself. Travelers will use more sustainable modes in large numbers only if they gain access to a suite of mobility services, reinforced with pricing and better non-car infrastructure.

REDUCING THE CARBON INTENSITY OF FUELS

Vehicle fuel, the second leg of the transportation stool, adds carbon and other greenhouse gases to our atmosphere and threatens our climate. Oil companies are investing hundreds of billions of dollars in unconventional oil production such as shale oil, heavy oils, deep-sea oil, and oil sands. They focus on carbon-intense unconventional oil production, rather than renewable energy, for two reasons: 1) OPEC countries have nationalized their oil supplies, thereby reducing access by large investor-owned western oil companies to the most abundant conventional oil reserves; and 2) oil companies' >



core competencies are best suited to building large (fossil) projects rather than small renewable energy projects.

To invest in a sustainable future, we must shift investment from fossil sources to renewable sources, but replacing petroleum will be difficult and slow. The hegemony of petroleum creates multiple barriers for new fuels including liability, public skepticism, and sunk investment in supportive infrastructure like refineries, pipelines, and fuel stations. Politicians and the media are quick to embrace new transportation fuels—methanol in the 1980s, electric vehicles in the early 1990s, and hydrogen in the early 2000s—but the barriers and the inertia inevitably hamper newer fuels' potential. This *fuel du jour* phenomenon, whereby new fuels are hyped and then quickly abandoned, describes the recurring failures of alternative fuels over the past few decades.

Looking forward, there are three sets of promising energy options. The first is electricity for vehicles, which provide large environmental benefits, and battery technology is steadily improving. But will the short attention span of politicians and media again kill off this attractive alternative before it has time to gain consumer acceptance, achieve scale economies, benefit from learning-by-doing, and fully realize the benefits of supportive policies?

The combination of efficiency improvements and electrification could lead to an 80 percent reduction in greenhouse-gas emissions for light duty vehicles by 2050.

Hydrogen is a second promising option. Hydrogen may have the greatest potential to replace petroleum across transportation, but it faces even greater start-up and fuel-distribution challenges. Not only must the vehicle industry transform from combustion engines to fuel cells, but the fuel industry must also shift from supplying gasoline and diesel fuel to supplying hydrogen.

Biofuels are the third major contender to reduce oil dependency. A downside to biofuels is that they require ample land. Diverting land to energy production is problematic because it reduces farming areas and releases huge amounts of carbon embedded in soils and plants. Biofuels are most promising if made from urban, forestry, and crop wastes, which do not require additional land.

Policies should reward and support options that are most likely to reduce oil dependency and carbon intensity. Performance-based policies that reward carbon reduction, such as the low carbon fuel standard in California, are promising, especially when accompanied by incentives that help boost initial investments in hydrogen stations and advanced biofuel technologies. Without strong policies, high-GHG petroleum fuels will sweep aside all alternatives, including electric vehicles.

ROLLING OUT EFFICIENT VEHICLES

Improving vehicle efficiency is the third and most promising strategy for reducing GHG emissions for the next few decades. Aggressive policies in most large car markets, including Europe, the US, China, and Japan, aim to cut fuel consumption per vehicle roughly in half in the next 15 years. Importantly, the international auto industry has made energy efficiency a top priority. Car manufacturers are using more lightweight materials, more efficient transmissions, better combustion technology, improved aerodynamics, and hybrid engines. They are also developing pure battery-electric vehicles, plug-in electric hybrids, and hydrogen-powered fuel cell electric vehicles. By 2035, a large proportion of new vehicle sales around the world are likely to be plug-in and fuel cell vehicles. The combination of efficiency improvements and electrification could lead to an 80 percent reduction in greenhouse-gas emissions for light duty vehicles (per vehicle-mile) by 2050.

Vehicle electrification is key to the long-term sustainability of vehicles. Electrification includes a spectrum of technologies, from those operating on gasoline or diesel fuel but assisted by batteries and electric motors, to those operating solely on electricity and/or hydrogen.

Today, every major car company is actively pursuing zero-emission technologies, and most have such vehicles in production. The challenge is to sustain the momentum. Costs of new technology are always high. Strong, durable policies are needed to keep automakers and consumers engaged, including the following:

- Incentives and mandates for early vehicle production,
- Government support of charging and hydrogen supply infrastructure,
- Market-based policies that internalize the cost of climate change and provide incentives to consumers and automakers to buy and sell low-carbon vehicles and fuels, and
- Performance-based standards to provide a regulatory framework for automakers as they plan for the future. >

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While cars are a big success story, trucks are not. Truck efficiency improvements are much slower and early regulations in Europe, the US, and Japan are much weaker than those for light duty vehicles. More stringent performance standards are likely to be developed in the future. The bigger obstacle, though, is that most current low-carbon energy alternatives are unsuitable for trucks. Trucks are heavy and tend to travel long distances each day. Most trucks cannot be easily powered by electricity because the batteries needed to provide sufficient energy are very heavy and bulky. Fuel cells may be a more feasible option for trucks, since they are far lighter and smaller than batteries. The best long-term energy option for trucks, however, will probably be low-carbon biofuels.

CONCLUSION

We need to change how we harness and use energy for transport. All of us need to confront the reality that transportation as we know it is incredibly expensive, resource-intensive, and socially unjust. We need to improve our technologies and learn new behaviors. But new technologies and new behaviors do not appear spontaneously; they take time. Climate change, a compelling reason for these new technologies and behaviors, is not directly experienced, unlike the more observable problems of smog, polluted water, and marred landscapes. With no direct, observable consequences to increased greenhouse gas emissions, it is difficult to pursue new transportation and energy pathways that are initially more expensive and less convenient.

And yet, sweeping changes are needed. If we don't make those tough economic choices and major lifestyle changes, then we condemn our grandchildren and great-grandchildren to an environmentally compromised world. Who has the courage to step forward and lead? It is morally and economically irresponsible to leave this looming disaster as our legacy. We need to muster the necessary courage and channel our innovative spirit if we hope to create a better world. ♦

This article is adapted from the Commemorative Lecture that Daniel Sperling delivered in Tokyo when he was awarded the Blue Planet Prize in 2013.
<http://www.af-info.or.jp/en/blueplanet/doc/prof/2013profile-eng.pdf>

Making Parking Meters Popular

DONALD SHOUP

Most people view parking meters as a necessary evil, or perhaps just evil. Meters can manage curb parking efficiently and provide public revenue, but they are a tough sell to voters. To change the politics of parking, cities can give price discounts at parking meters for their own residents.

PARKING DISCOUNTS FOR RESIDENTS

In [Miami Beach](#), residents pay only \$1 an hour at meters where nonresidents pay \$1.75 an hour. Some British cities give the first half hour at meters free to residents. [Annapolis](#) and [Monterey](#) give residents the first two hours free in municipal parking lots and garages.

Pay-by-license-plate technology enables the resident discounts. Drivers pay either by cell phone by entering their license plate number at a parking kiosk and paying with cash or credit card. Both the cell phones and the meters can automatically give discounts to all cars with license plates registered in a city. Cities link payment information to license plate numbers to show enforcement officers which cars have paid or not paid. Pay-by-plate is common in Europe, and several US cities, including [Pittsburgh](#), now use it.

Like hotel taxes, parking meters with resident discounts can generate substantial local revenue without unduly burdening local voters. The price break for city plates should also please merchants because it will give residents a new incentive to shop locally. In big cities, the discounts can be limited to each neighborhood's residents. More shopping closer to home can then reduce total vehicle travel in the region.

Resident parking discounts are justified because residents already pay taxes to maintain the streets and municipal garages in their city. The discounts are also justified because they can increase voter support for meters that are needed to manage the parking supply. Parking meters with resident discounts come close to the most popular way to raise public revenue: tax foreigners living abroad. >



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PARKING DISCOUNTS FOR SMALLER AND CLEANER CARS

Cities can also use parking discounts to achieve economic and environmental goals. If a city classifies license plates by car length, it can give discounts for smaller cars that take up less curb space. Because smaller cars tend to be more fuel efficient, discounts for smaller cars will also reduce fuel consumption and CO₂ emissions. Parking discounts based on car size will therefore produce local economic benefits and reduce global environmental costs.

Table 1 illustrates parking discounts based on car lengths. Column 1 shows a selection of cars, and Column 2 shows their lengths, ranging from 20 feet for a Rolls Royce down to 8.8 feet for a Smart car. The typical length of a marked on-street parking space is 20 feet, but pay-by-plate systems do not require marked spaces, so more small cars can fit on a block with unmarked curb parking. Column 3 illustrates the discount for each car based on its length. Because the Rolls Royce is 20 feet long, it pays the full price, while the 10-foot Scion receives a 50 percent discount. Two Scions pay the same as one Rolls, so the payment per foot of curb space is the same for both cars.

Parking discounts for shorter cars also favor higher fuel efficiency and lower CO₂ emissions. Column 4 shows each car’s fuel efficiency, ranging from 14 miles per gallon for the Rolls up to 37 miles per gallon for the Scion. Finally, Column 5 shows each car’s CO₂ emissions per mile. For example, the Ford emits less than half as much CO₂ as the Rolls. If cities want to reduce CO₂ emissions, they don’t have to wait for state or federal action before offering discounts for small cars. Each city can choose its own parking discounts according to its own priorities.

Will parking discounts for small cars be fair? The manufacturer’s suggested retail price starts at \$474,990 for a 20-foot Rolls Royce Phantom and \$13,270 for an 8.8-foot Smart car. In this case, it seems unfair *not* to offer parking discounts for smaller cars. Most people who can afford to buy a longer car can probably afford to pay more to park it.

TABLE 1
Parking Discounts Based on Car Length

MAKE AND MODEL (in 2014) <i>1</i>	LENGTH (feet) <i>2</i>	DISCOUNT (percent) <i>3</i>	FUEL EFFICIENCY (miles/gallon) <i>4</i>	CO ₂ EMISSIONS (grams/mile) <i>5</i>
Rolls Royce Phantom	20.0	0%	14	637
Lincoln MKS	17.2	14%	22	400
Buick Regal	15.8	21%	24	371
Ford Fiesta	14.5	28%	29	301
Chevrolet Spark	12.1	40%	34	258
Scion iQ	10.0	50%	37	238
Smart	8.8	56%	36	243

Cities with serious air pollution can also give parking discounts for cars with low hydrocarbon or nitrogen oxide emissions. Parking meters in [Madrid](#), for example, charge 20 percent less for clean cars and 20 percent more for dirty cars. Cities can give these discounts by linking license plate records to emissions data from car manufacturers or smog tests. According to the head of Madrid's sustainability division, "We thought it would be fair if the cars that pollute more pay more, and compensate those who use more efficient vehicles."

Cities may have to raise their pre-discount meter prices to prevent overcrowding the curb, but only nonresidents with the biggest and dirtiest cars will pay the pre-discount prices. To manage curb parking efficiently, cities should charge the lowest meter price that will leave one or two open spaces on every block. Residents will then gain two great advantages. First, they will easily find an open curb space wherever they want to park, and second, they will pay a discounted price when they do park.

Parking discounts may seem complicated, but few residents will be confused by or object to discounts automatically given at meters. The meters can even print the discounts on parking receipts to reinforce the rewards of shopping close to home and driving small, clean cars. The resident discounts will appeal to local voters and the other discounts will achieve public goals.

Prices are the most reliable way for cities to send signals about the behavior they want to encourage, and parking discounts can easily send these price signals. If meters give discounts for smaller and cleaner cars, more people will drive them.

USING THE METER MONEY

Cities can also increase political support for parking meters by using the meter revenue to improve local public services. [Pasadena](#), for example, offers neighborhoods a package that includes both parking meters *and* additional public services financed by the meters. The meters not only manage curb parking but also provide a steady stream of revenue to pay for cleaning and repairing the sidewalks. The parking meters in Galveston and [Ventura](#) provide free public WiFi on the metered streets. People who live, work, shop, and own property in the metered neighborhoods can then see their meter money at work. With discounts for residents, locals will see that parking meters are working for them rather than against them.

A WORLD OF GOOD

Many cities suffer from congested curb parking, polluted air, poor public services, and political opposition to parking meters. To solve these problems cities can charge fair market prices for curb parking, spend the revenue to improve public services on the metered streets, and give price discounts for residents, small cars, and clean cars. By changing the politics of parking, cities can meter more of their valuable curb space, producing more money, less traffic, cleaner air, and a cooler planet. Parking meters can then do a world of good. ♦

This article is adapted from "Change the politics of parking - offer resident discounts," originally published in the *San Francisco Chronicle*.



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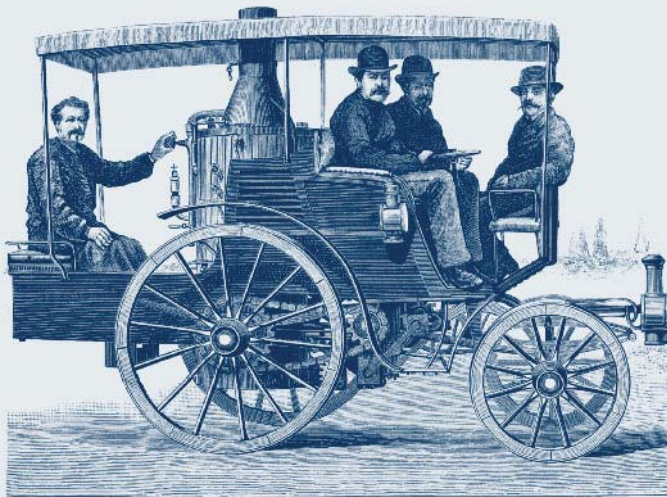
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