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University of California Transportation Center
Berkeley, CA 94720–1782
Phone: 510-642-5624
Fax: 510-643-5456
www.uctc.net

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Transportation and the Environment

TALK ABOUT transportation and the environment, and most engineers and planners will tick off a long list of concerns: air pollution, water pollution, noise, petroleum consumption, community disruption, habitat loss. Since the 1970s, a variety of federal and state laws has aimed to minimize harm done to the environment by transportation programs. The benefits have been significant.

Probably the greatest success has been the reduction of air pollutants. Today's cars produce only a small fraction of the pollutants their predecessors emitted. Almost all the reduction is due to legally mandated emissions control technologies on new cars. Even with massive growth in auto ownership and vehicle-miles traveled, most cities exceed pollution limits only a few days a year.

Fuel economy has also improved since the '70s, when US autos averaged about fourteen miles per gallon. Pushed by CAFE standards and pulled by consumer preferences, today the average is over twenty mpg, even with large numbers of light trucks and sport utility vehicles in the mix.

We are discovering, however, that these gains are not enough. Recent evidence points to adverse health consequences for children and the elderly at lower pollution levels than we previously recognized. Truck use is growing, and the small particles emitted from burning diesel fuel are particularly bad for human health. With low fuel prices, consumers are again buying less efficient cars and trucks. We are learning, sometimes the hard way, that we must watch out for unanticipated system effects—as when the fuel additive MBTE, introduced to reduce air pollution, turned out to be a dangerous water pollutant.

We also are discovering new cause for environmental concern. Emissions of the naturally occurring gas, carbon dioxide, a by-product of burning fossil fuels, are now proving troublesome. CO_2 is building up in the atmosphere, causing the Earth's average temperature to rise. Forecasted temperature increases could produce marked changes in precipitation patterns, rising sea levels, and altered ranges for plants and animals. The changes could be so rapid that neither natural systems nor social systems will be able to adapt easily. The issue comes back to transportation choices: a quarter of CO_2 emissions come from the US, and our surface transportation produces a quarter of that.

The longstanding debates about land use and transportation in turn have environmental dimensions. People and firms deal with traffic congestion by relocating. Relocation further allows many to secure affordable housing, find better schools, and escape crime or the fear of it. Still, development at the suburban fringe, supported by transportation investments, often comes at an environmental cost. Formerly open lands are consumed, wetlands filled, and habitats fragmented. Outward movement also has consequences, some good but others negative, for those who remain behind.

Research has important roles to play in improving transportation's environmental performance. Current research on new vehicles and fuels aims to produce environmentally benign automobiles. Trucks, our main mode of freight transport, are especially in need of researchers' attention. Likewise, more research remains to be done on land use options. Researchers tell us that alternative approaches promoted so far produce modest results at best, but most have looked only at direct and short-term transportation effects, not at the broader range of environmental concerns. Development strategies that protect habitat and preserve important farm and forest lands are being tried out, as are strategies that aim to improve the distribution of environmental costs and benefits. We don't know yet how well they work, or what they will cost, or where transportation fits into these strategies. Nor do we know what price consumers are willing to pay for environmental protection and enhancement.

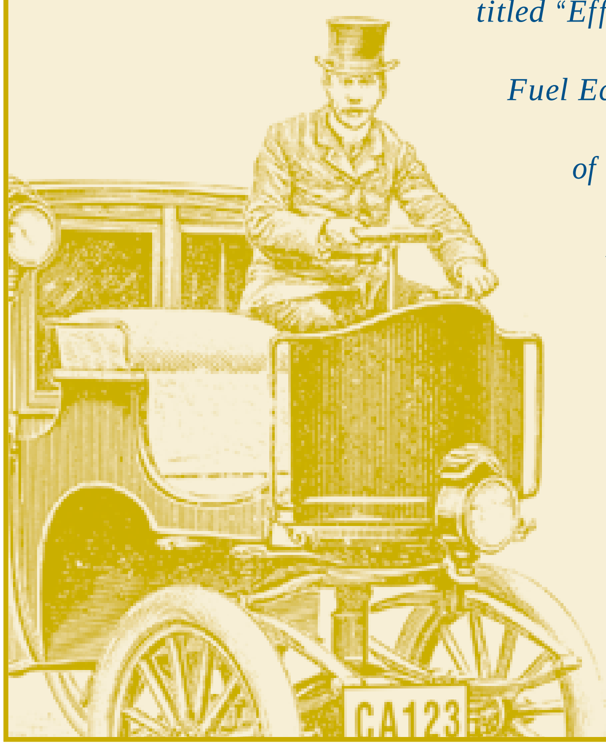
So researchers have much yet to do on transportation and the environment. The agenda should cover both the natural and the built environments and should consider direct and indirect effects and their distributions. Research topics must range from vehicles and fuels, land use and transportation, air pollution and energy, to planning and institutions.

Elizabeth Deakin

A New CAFE

BY CHARLES LAVE

Over the past six months, a National Academy of Sciences panel has been working intensively on a congressionally mandated evaluation of federal regulations on fuel economy in cars. The panel concluded that significant, cost-effective, safety-enhancing improvements were possible. Its report received extensive peer review and was published under the aegis of the National Research Council in a report titled "Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards." I was a member of that panel and in the following two essays, I want to review of some of the issues raised in its deliberations. The analytic material comes from the panel's report; the opinions are my own.

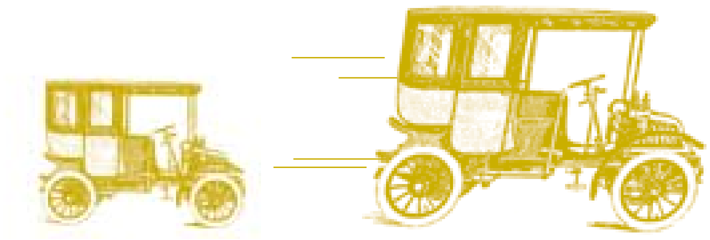


Charles Lave is professor emeritus of economics at the University of California, Irvine (calave@uci.edu)

PART I

SIZE AND SPEED:

Two Races Society Can't Win



OVER THE LAST FIFTEEN YEARS, the cars and trucks we use for personal transportation have become bigger and faster. Is that good or bad? Consider an analogy: suppose I'm in a sports stadium, and I stand up to get a better view. This blocks your view, so you have to stand up too. Pretty soon everyone is standing, everyone is uncomfortable, and no one has a better view.

Back to the highway. I can't see around the tall vehicles I encounter on the road, so I decide to get a taller vehicle myself. The idea spreads broadly. We all need to defend our ability to see down the road, but we don't end up any better off.

We play out a similar race with vehicle speed: I want to peel out from the stop light faster than you, so I get a more powerful car; you respond by getting a more powerful car, too. Eventually all cars are more powerful, but there is still only one winner per stop light.

Some of these competitions have serious side effects. I can buy a big SUV to protect myself against other people in big SUVs. But all those who decline this competition are in danger of being crushed like eggshells in an unexpected meeting with my SUV. It's a losing proposition for society as a whole: the extra danger for those who drive normal cars is greater than the extra safety for those who buy SUVs. And conversely, reducing the weight of SUVs would have only a small safety effect on SUV drivers, but would save a lot of lives among other drivers—not to mention pedestrians and cyclists.

Sometimes society intervenes in these kind of races. Most beach communities, for example, have enacted building height limits to control the futile competition for views. And although I could make my house somewhat safer if I were to install an electrified fence, most communities have laws that prevent me from doing this because the danger to society as a whole is greater than the benefit to me.

The point is this: there is precedent for regulations that limit consumer choice in these sorts of races and it might be reasonable for Congress to pass regulations that rein in the size and power race. The existing fuel-economy regulations (called Corporate Average Fuel Economy, or CAFE) did so indirectly by demanding that each company's vehicle fleet achieve a certain average fuel economy level. During its first ten years, CAFE acted as an indirect regulation on weight and size. But eventually technology improved enough to make the CAFE regulations easy to meet, freeing the automakers to increase size and power. Thus one possible way of dealing with the size/power race is to revise the fuel economy standards. (Part II of this essay, "A Safety-Enhanced CAFE Standard," suggests one possible revision that would accomplish this.)

THE BROAD PICTURE: HOW WE GOT HERE

Some instructive lessons can be learned from the period before the first oil embargo in 1973–74. There was a size and horsepower competition then too: satirists poked fun at the race, speculating about "the new Belchfire V-16"; Terry Southern, in *The Magic Christian*, described wondrous new car models as big as yachts, so big they had trouble navigating corners in New York.

That oil embargo forced a bit of global perspective on us. Congress reacted by mandating CAFE regulations that required auto companies to radically improve the fuel economy of their cars and trucks. Fortunately, engineers were able to meet the challenge by making technological improvements in the efficiency of vehicle aerodynamics and drivetrains.

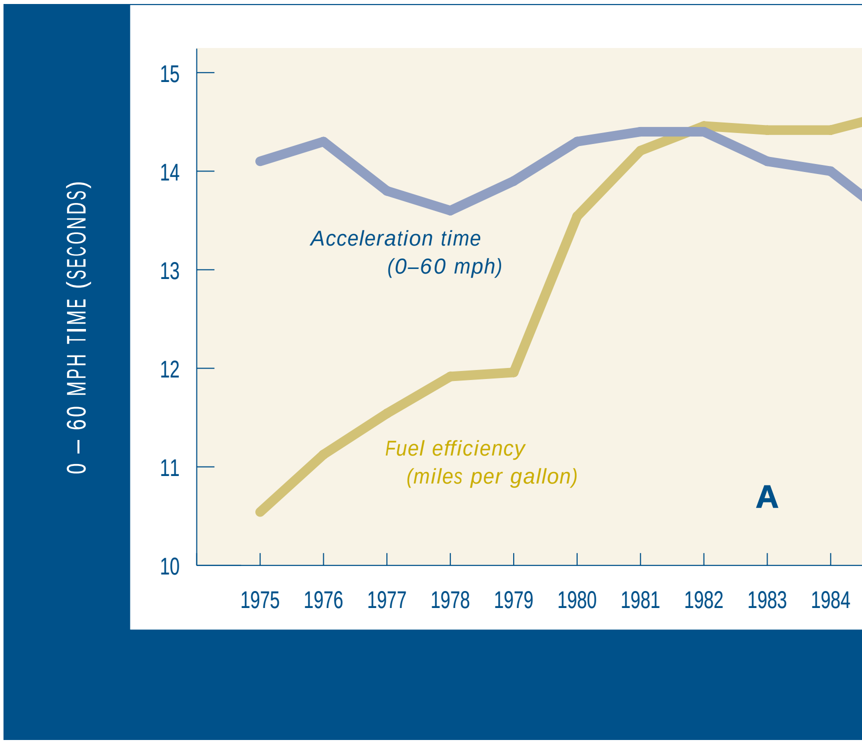
Automotive technology continues to improve—consider it a dividend from the large expenditure society makes in science and engineering. This technological dividend can be spent on three kinds of vehicle changes: better fuel economy, bigger size, or faster acceleration.

During its first ten years, CAFE directed the technology dividend toward fuel economy. During the last fifteen it has permitted the competition for speed and size. The big question is: How shall we spend this technology dividend in the future? Consider the past first. ➢

FIGURE 1

A) The 1st era: a large jump in mpg, while 0–60 mph acceleration time is essentially unchanged

B) The 2nd era: mpg is essentially unchanged, while 0–60 mph acceleration time becomes substantially faster



THE 1ST POST-OPEC ERA: TECHNOLOGY TO THE RESCUE

How did the auto companies react to the CAFE regulations? Between 1975 and 1984 the fleetwide average over all cars and light-duty trucks rose from 15.3 mpg to 24.6 mpg, a 61 percent improvement. Most people think this was accomplished by reducing performance, making vehicles more anemic. Figure 1A shows what happened to mpg and to performance, as measured by the time required for a vehicle to accelerate from zero to sixty mph. The curves show that acceleration ability remained essentially constant while fuel economy took a big upward leap.

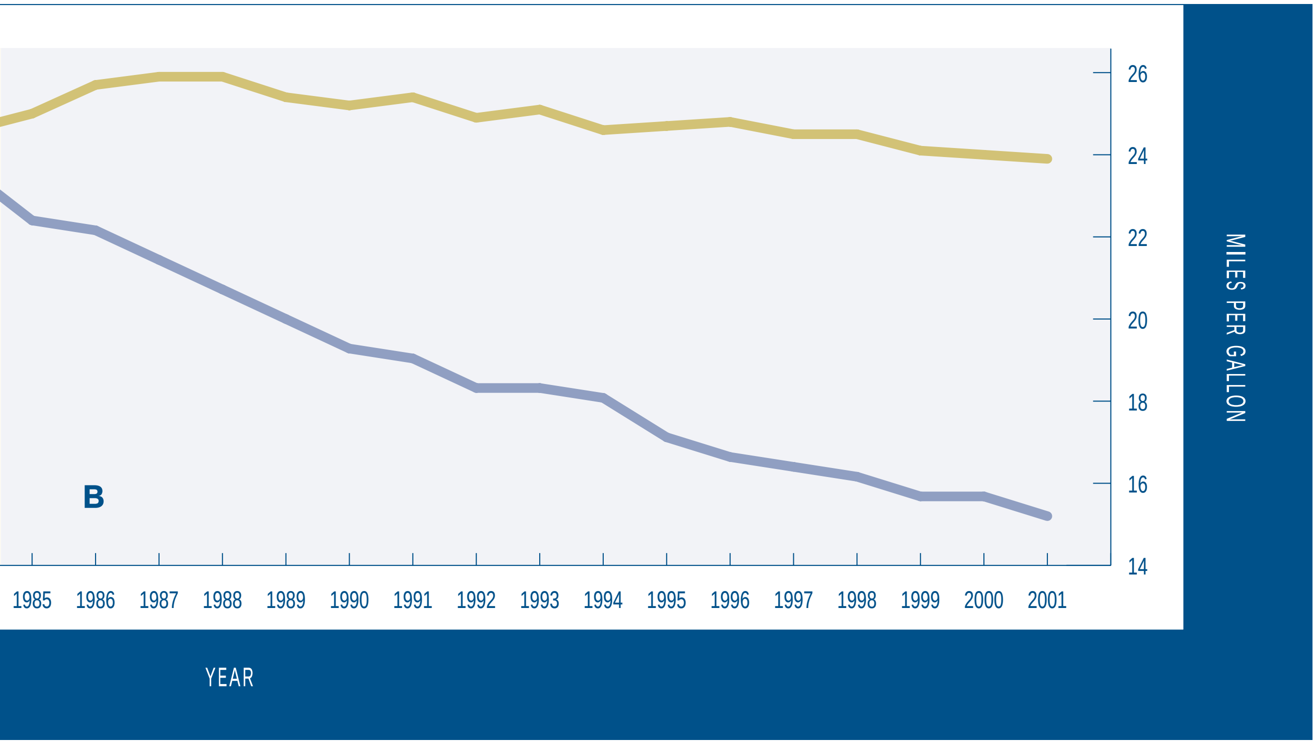
How was this possible? The major source of the increase, the hero of our story, was new technology—engineering improvements like front wheel drive, more efficient engines, and improved aerodynamics. And this was done with no sacrifice in performance. (The zero-to-sixty-mph acceleration time of the average vehicle actually improved slightly, from 14.1 to 14 seconds.)

Some of the mpg increase came about through downweighting, but not much. Between 1975 and 1984, the average vehicle became twenty percent lighter. A reasonable rule of thumb is that each one percent reduction in weight produces a 0.66 percent improvement in fuel economy. Thus we can partition the 61 percent overall mpg improvement: 13 percent was due to weight reduction, 48 percent to improved technology.

THE 2ND POST-OPEC ERA: THE ENGINEERS GIVETH AND THE MARKETEERS TAKETH AWAY

Technology continued to improve after 1984. Drivetrains and aerodynamics became even more efficient. How were these efficiency improvements used? Having essentially achieved the mandated fuel consumption targets at this point, and hence no longer constrained by CAFE, the auto industry resumed the race for size and power.

Figure 1B shows mpg and performance trends during this second era. Between 1985 and 2000, the average mpg of the new vehicle fleet was essentially constant, but acceleration times became 33 percent faster. That is, the improvements in technological efficiency were devoted to increased size and performance. They could have been used to improve mpg, but they



weren't. We have no way to know motives, but some critics have speculated that the marketing staff at one company decided it could increase vehicle sales by telling consumers that they needed more "zoom, zoom." Of course, such success is temporary at best. It's ironic that auto companies, themselves, ended up in a race for relative position.

THE 3RD POST-OPEC ERA: IT'S UP TO US—WHAT WILL WE CHOOSE?

What happens next? In July 2001, the National Academy of Sciences mapped out one possible technological path, projecting future fuel economy based on the following somewhat conservative restrictions. The report considered only those technologies that:

- were already proven;
- could pay for themselves over the lifetime of the vehicle; and
- would not reduce either weight or acceleration.

The NAS panel found that, even given these restrictions, the mpg of cars could be improved by 16 to 37 percent, and the mpg of SUVs and light trucks could be improved by 26 to 45 percent.

Things might happen that way. We know that automotive technology will continue to improve. But we don't know how this improvement will be applied: better fuel economy, bigger size, or faster acceleration? The CAFE law can act like a traffic cop, directing the technology dividend among these three possibilities.

We will continue to enjoy improvements in technology. How shall we put them to work? Do we continue the inherently futile race for relative acceleration, relative view-blocking ability, and relative car-crushing ability? Or do we agree in advance that we would be better off, collectively, if we got out of this unwinnable race, and spent the technology dividend to improve fuel economy?

PART II

PART II

A SAFETY-ENHANCED CAFE STANDARD:

Better Things for Better Living Through Measurement

MEASUREMENT SYSTEMS create incentives. When the results of a measurement determine eligibility for some special status or reward, you can bet that people will alter behavior to move their measurement toward eligibility. For example, about a decade ago, medical schools began making part of their admissions decision based on evidence of students' public-spirited activities outside the classroom. Soon I was seeing student resumes that would have made Mother Teresa proud. That is, the act of measurement causes changes in the behavior being measured. It's the Heisenberg Uncertainty Principle applied to people.

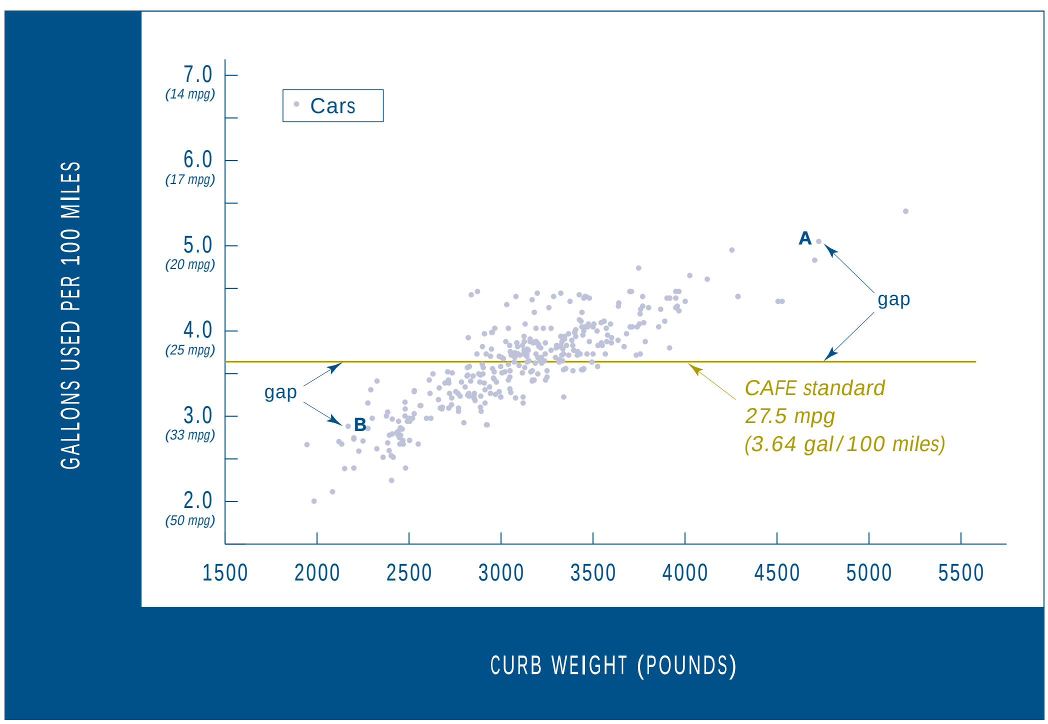
Twenty-six years ago the federal government decided to regulate the fuel economy of cars and trucks. The measurement system it created, the Corporate Average Fuel Economy standards, or CAFE, produced a lot of good results—and some undesirable ones too. Now, with Congress thinking about changing the standards, it's important to take the opportunity to change the measurement system as well.

I want first to describe the current measurement system and its perverse outcomes, and then to suggest a replacement for it that could reduce fuel consumption and make a major improvement in the vehicle fleet's overall safety.

For the moment, leave aside the question of whether or not there should be fuel consumption targets. Take that as a given and ask: "Can we do a better job of it? Can we improve CAFE?" A recent panel of the National Academy of Sciences took up these questions and came up with a number of significant improvements; this article is excerpted from Chapter 5 of the NAS report. But before we talk about improvements, let's try to understand the problems with the current CAFE system by examining how it operates.

FIGURE 2

The CAFE standard for cars



THE CURRENT CAFE SYSTEM

Figure 2 shows how CAFE works now. Each dot is a specific passenger car model—for example, the four-cylinder Accord and the six-cylinder Accord are separate marks. The horizontal axis shows car weight; cars on the right-hand side weigh more and use more fuel than those on the left.

The vertical axis shows fuel consumption. Instead of measuring in miles per gallon, it measures the amount of gasoline each car needs to travel 100 miles, e.g., a car that gets 25 mpg needs 4 gallons to drive 100 miles. The horizontal line shows the current CAFE standard, which is 27.5 mpg, or 3.64 gallons per 100 miles on the vertical axis. It applies to the average car a company makes, so a manufacturer producing gas-guzzlers can balance them by also selling very fuel-efficient models.

Vehicle A uses more fuel than is allowed by the CAFE standard. The gap between A and the CAFE line is the amount of excess fuel use. Vehicle B uses less fuel than the CAFE standard. The gap between B and the CAFE line is not as large, so the manufacturer who makes both As and Bs will have to sell approximately two Bs to offset the high fuel consumption of one A.

There are also differences among manufacturers. Some have a product mix that emphasizes light- and medium-weight cars—these manufacturers found it cheap and easy to meet the CAFE standards. Other manufacturers were producing a mix that was more toward the right side of the curve, and they had to spend a considerable amount of money to develop and sell lighter cars so they could create enough CAFE credits to bring their total fleet into compliance.

These problems arise in part because the CAFE standards hold all cars to the same fuel economy target regardless of their weight, size, or load-carrying capacity. We could avoid them by developing a new measure that responds to differences in vehicle attributes, such as weight, for example.

The blue, upward sloping line in Figure 3 shows the average relationship between vehicle weight and fuel consumption. It is obviously a very good fit. A weight-based CAFE system would use such a line for fuel economy targets, rather than the current horizontal line stuck at 27.5 mpg, or any other measure.

Unfortunately, weight-based targets have three major disadvantages. First, because they are weight-neutral, a principal lever for influencing fuel economy is lost. Second, they remove most of the incentive behind current research programs pursuing the use of lightweight materials as substitutes for steel—research that has potentially important safety benefits, because new materials allow vehicles to be lighter while maintaining current crush-space.

Third, and most important, weight-based standards could result in higher fuel consumption. Unlike CAFE, there would be no cap on the fleet average, so the average vehicle could move to the right on the curve (that is, get heavier). Is this likely? ➢

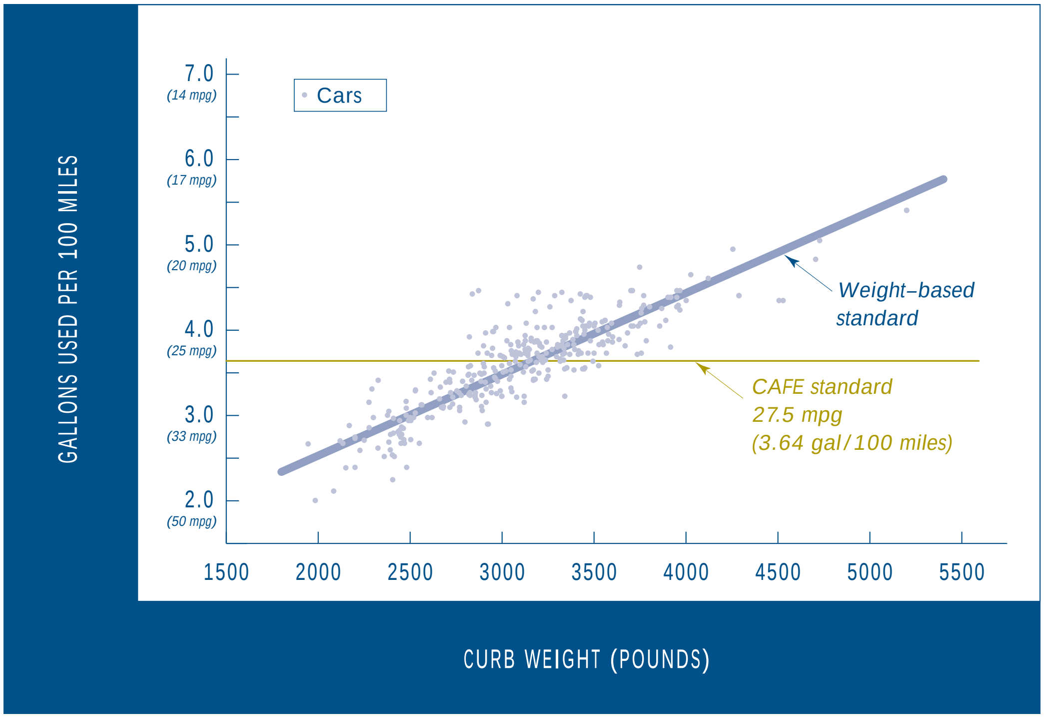
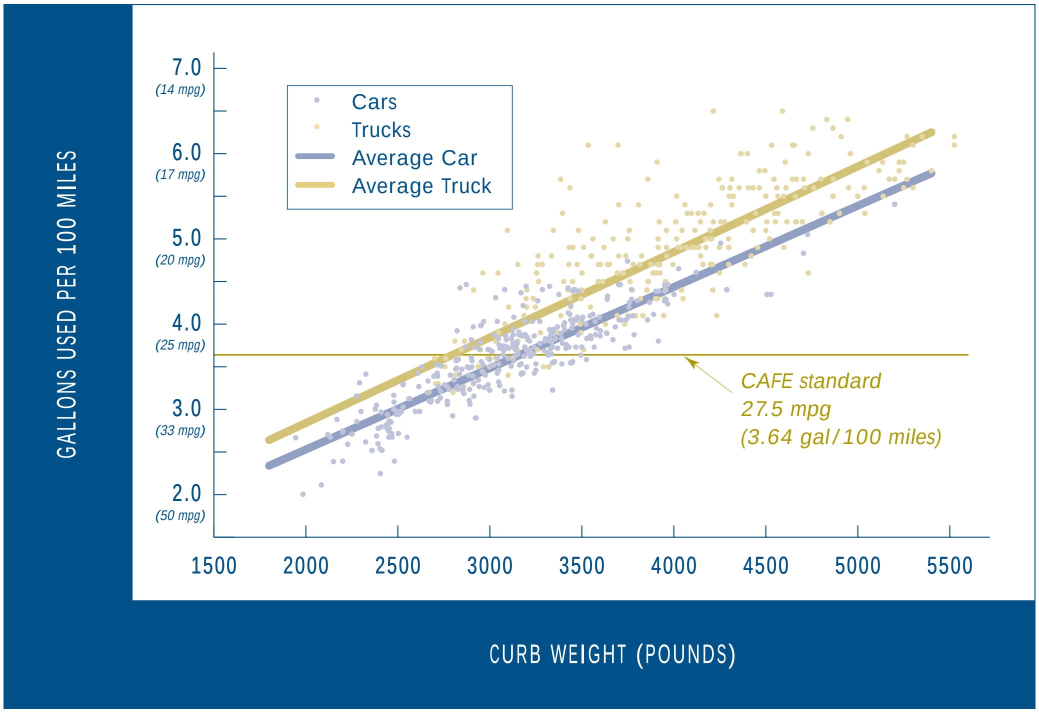


FIGURE 3

CAFE vs. weight-based standard for cars

FIGURE 4

Weight vs mpg — cars and trucks



Note that car weights and truck weights have been increasing over the past decade despite strong counteracting pressure from CAFE. Furthermore, the profit margin associated with large vehicles has traditionally been much higher than that associated with small ones. Thus there are substantial market incentives for manufacturers to increase vehicle weights and no restraints on them doing so once CAFE is removed.

Figure 4 adds data for light-duty trucks. Again there is a strong relationship between weight and fuel consumption, though with somewhat more outliers than in the car graphs. The average truck data are shown as a gold line, which is nearly parallel to the average car line, and only 2.5 mpg higher.

THE SAFETY-ENHANCED CAFE STANDARD

It is possible to combine the current CAFE system with weight-based targets to preserve most advantages of each while eliminating most disadvantages. In particular, the combined measure should improve safety; hence it is called the "Safety-Enhanced CAFE" (SE-CAFE) standard. The Safety-Enhanced CAFE system creates a different kind of baseline for measuring compliance, and hence different incentives for manufacturers—incentives that move us toward some highly desirable goals.

The line in Figure 5 shows the SE-CAFE fuel consumption target: a single baseline used to measure performance deviations for both cars and trucks. For vehicles that weigh less than 4,000 pounds, the target is sloped upward like the weight-based targets. For those that weigh more than 4,000 pounds, the target is a horizontal line like the current CAFE standard.

In particular, SE-CAFE creates a strong set of incentives to improve the fuel economy of the heaviest vehicles. Under the current CAFE law, if a manufacturer wishes to offset the excess fuel consumption of a large vehicle, it can do so easily by selling a light vehicle: the vertical gap of the large vehicle (A) in Figure 2 is offset by the vertical gap of the small vehicle (B). But if the baseline is changed to SE-CAFE (Figure 5), the small vehicle does not generate a large credit because it is on the sloped portion of the baseline and its gap is measured with respect to the slope, not with respect to the horizontal line.

SOME IMPLICATIONS

How would this proposal affect the different manufacturers? I computed a fleetwide compliance measure for each of the Big 3 manufacturers plus Honda and Toyota. How do they measure up to the SE-CAFE targets? Compliance ranged from three percent below the targets to six percent above. None of the

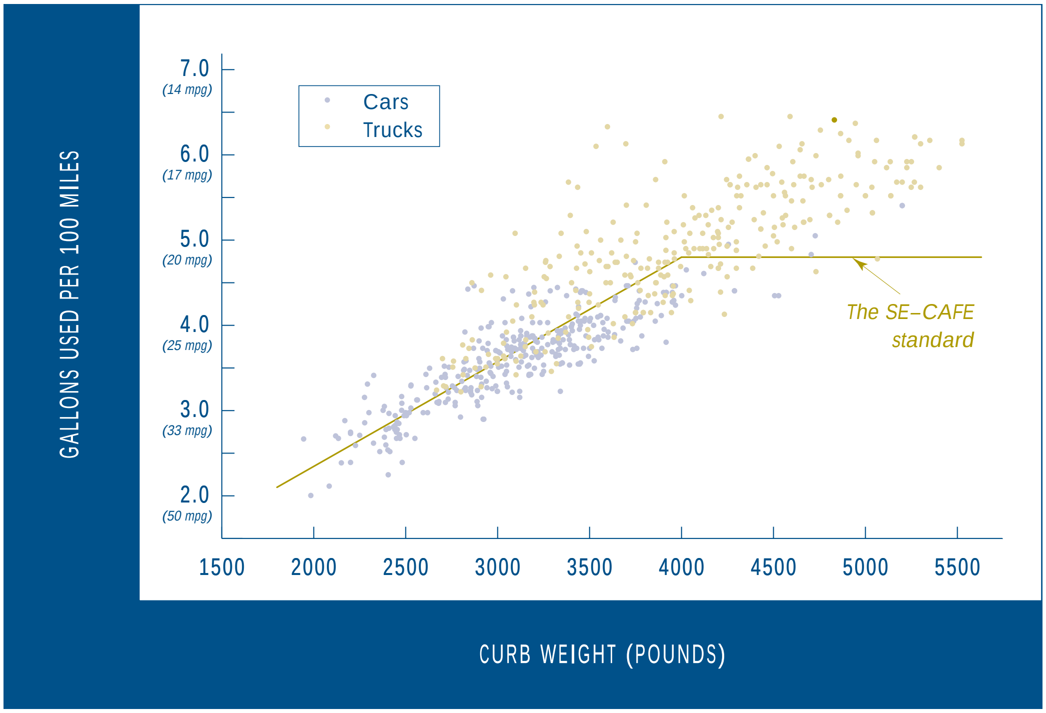


FIGURE 5

A "Safety-Enhanced" CAFE standard for cars and light-duty trucks

major manufacturers begins with a large compliance deviation; it's a relatively fair starting point.

SE-CAFE has a single set of targets for all vehicles, eliminating concerns about arbitrary truck/car distinctions and their possible manipulation. For example, the popular PT Cruiser made minor design changes so it could be classified as a truck, which means it need meet only a 20.7 mpg standard, instead of the 27.5 mpg standard for cars. SE-CAFE eliminates the problem by eliminating distinctions between cars and trucks; all vehicles are treated the same.

There would be a small incentive for lightweight vehicles to be made heavier, and a large incentive for vehicles weighing more than the cutoff weight to be made lighter. Thus the variance in weight across the combined fleet should be lower, which would improve safety in car-to-car collisions.

The present position of the lines could serve as the initial baseline under the SE-CAFE system. It produces a combined car and truck fuel economy of 24.6 mpg (which is the overall car/truck fleet average for the model year 2000 fleet). To improve overall fuel economy in subsequent years, the horizontal portion of the baseline would be lowered while simultaneously reducing the slope of the lower portion of the baseline; the slope of the lower portion could also be adjusted to reflect the most cost-effective use of technology. Of course there should be a transition period to allow phase-in of the SE-CAFE system: manufacturers have already made plans based on existing CAFE standards, and they must be given time to redo their product plans.

SUMMARY

The Safety-Enhanced CAFE Standard has several important advantages. While it is "only" a change in the measurement system, it creates incentives that will reduce fuel consumption and increase safety of the overall vehicle fleet. ◆

FURTHER READING

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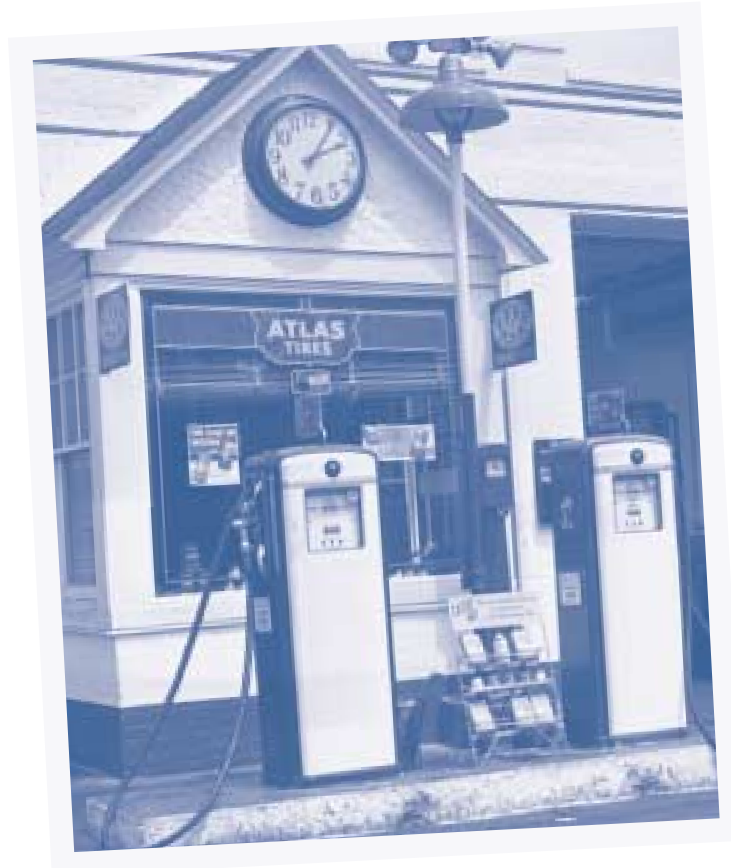
Reconsider the Gas Tax: Paying for What You Get



BY JEFFREY BROWN

SUPPOSE WE COULD design the ideal transportation system from scratch and could pay for it with the most efficient, equitable, flexible, and predictable finance instrument. What kind of finance instrument should we choose? Economists say we should rely principally on user fees. User fees encourage efficient use of the transportation system by making clear the relationship between transportation costs and transportation benefits, which allows users to make informed decisions. Other instruments, by contrast, remove price signals from a traveler's decision-making, which can lead to inefficient mismatches between supply and demand for transportation. Furthermore, finance instruments not based on user fees may be unfair because individuals who don't use the transportation system are required to subsidize those who do.

As a matter of fact, we already have a user fee that fares pretty well against these criteria. We've been using it for more than eighty years—it's the gasoline tax. But, despite its many merits, this tax has few friends.

The gasoline tax is the centerpiece of our transportation finance system, but we have recently been moving away from it. Some academics charge the tax is flawed. They note that fuel consumption is only partially related to the costs a vehicle imposes on the transportation system. They call for theoretically more ideal—but currently politically unacceptable—user fees, such as congestion pricing.

Jeffrey Brown is a Ph.D. student in urban planning at the University of California, Los Angeles (jrbgeog@ucla.edu)

Politicians appear to be abandoning the gasoline tax precisely because it *is* a user fee. They shy away from increasing gas tax rates except in rare periods of extreme fiscal crisis. Instead, they embrace nonuser taxes, such as sales taxes, that hide the cost of maintaining the transportation system in the prices of a wide array of goods and services, in an attempt to minimize political opposition to any tax increase. The voters approve sales tax increases because they seem small, whereas even modest gas tax increases seem quite large. Most voters have yet to recognize that a one-half percent sales tax increase—the most frequently requested tax increase—is the same as an increase of more than fifteen cents per gallon in the gasoline tax. Politicians give the voters what they seem to prefer. And when gasoline prices soar, many politicians call for reducing the gas tax—a politically popular move that reveals ignorance of or disdain for the tax's original purpose.

We seem to be moving towards a less ideal transportation finance system than the one we already have, so this may be a good time to recall why we have the gasoline tax. By reviewing its origins, perhaps we can see the way to develop an equitable and efficient successor.

Why the US adopted a gasoline tax

Before the gasoline tax, property taxes and bonds formed the cornerstones of American transportation finance. These instruments performed reasonably well in the pre-automobile era, but they proved unable to cope with the explosion in automobile use during the 1910s and the inevitable demands of motorists for better roads. Property tax revenues, used for many government purposes, were stretched too thin, and property owners balked at raising tax rates to finance road upgrades. The heavy debt loads and large interest payments associated with bonds limited their use, and states were loath to issue more forty-year bonds for roads that would require major reconstruction only a few years after they were built. Highway-related expenses put a major strain on state budgets. In 1922, 44 percent of California state government expenditures went to highway construction and maintenance or the repayment of highway bonds. The imposition of a user fee to help finance roads was a logical response to the crisis.

The gasoline tax was chosen, *first* because it was an effective means of assessing motorists for their use of highways. Gasoline consumption correlates with miles traveled, vehicle weight, and vehicle speed, and the cost of roads was known at the time to be a function of these factors. Alternatives, such as fees for vehicle-miles traveled or ton-miles traveled—more direct measures of road use—were not feasible because of technological and administrative limitations at the time. The gasoline tax also applied to everyone who bought gasoline in an area, including out-of-state motorists. In the Rocky Mountain region, out-of-state motorists accounted for as much as half of all automobile travel.

Second, the gasoline tax raised a lot of money. In 1932, in the depths of the Great Depression, the gasoline tax produced just over $513 million ($6.3 billion in 2001 dollars) for the 48 states and the District of Columbia. ➢

Third, because it was collected from gasoline distributors rather than from retail outlets or individual motorists, the cost of administering the tax was quite low. In California, the early administrative cost averaged less than 0.4 percent of tax proceeds.

Fourth, the gasoline tax provided political cover for nervous legislators. Distributors who paid the tax knew how much it cost but retailers and motorists often did not, because it was hidden in the price of gasoline. Legislators thus enjoyed a degree of protection from consumers. Motorists paid the tax a few pennies at a time. While the cost added up over time, this feature reduced motorists' hostility towards the tax.

Finally, the gasoline tax was politically popular. The petroleum industry, construction industry, automobile industry, and motorists embraced the tax because of its direct link to better roads. The tax brought motorists direct benefit for their taxpaying pain. Oregon adopted the first American gasoline tax in 1919, followed within two months by New Mexico and Colorado. California adopted its own gasoline tax in 1923 after a long campaign by the automobile clubs and legislators. Between 1919 and 1929, all 48 states and the District of Columbia adopted gasoline taxes. Rarely has a tax been universally accepted in so short a time.

Interest group reaction to the gasoline tax

Automobile clubs were major advocates for gasoline taxes. They led the drive for a tax in Oregon and California, and the national Good Roads Convention championed a variety of gasoline tax proposals during the early 1920s. The automobile industry supported the tax because industry leaders knew that better roads would lead to increased automobile sales.

The petroleum industry was directly affected by the gasoline tax, and it was divided over it. Most companies supported moderate gasoline taxes, because better roads meant more cars and a larger market for industry products. But the industry was concerned that the trend was toward ever higher tax rates. During the 1920s, there were more than eighty successful efforts to impose or raise gasoline taxes and only twelve successful efforts to reduce them. Industry leaders believed that every one-cent increase in the tax reduced gasoline consumption by five percent, and they foresaw a day in the future when a twenty-cent-per-gallon gasoline tax might mean an end to the use of gasoline as a motor fuel. Still, as late as 1928, *The Filling Station*, a leading industry publication, observed that the use of gasoline-tax revenues for new roads produced net benefits for the industry as a whole.

In contrast, the editors of *Petroleum World* claimed the gasoline tax was nothing short of a socialist attempt to strangle American capitalism. A few industry executives persuaded business groups to join them in an attempt to stop gasoline-tax proposals. But their efforts were undercut by public skepticism in the wake of the Teapot Dome scandal and congressional investigations into industry price-fixing schemes. Politicians like Huey P. Long of Louisiana became household names exploiting popular hostility toward the petroleum industry.

Standard Oil of California's opposition to the gasoline tax emerged much earlier than in the petroleum industry as a whole. The company first began to complain in late 1923 when it objected to the supposedly high administrative cost of paying the tax. When the California Legislature considered raising the tax from two cents to three cents per gallon in 1924, the company's hostility became much more public; it waged a very public campaign against further gasoline tax increases. As John Burnham recounts, "Standard distributed hundreds of thousands of handbills to motorists warning of 'More Taxes for You.' The campaign was in part inspired by a proposal in Oregon to raise the tax there to six cents, which was cited as an indication of the 'dangerous lengths' to which the idea could be carried. Company officials vigorously denied they had raised the price of gasoline two cents to head off the measure."

Standard Oil also pioneered the soon universal practice of prominently posting the tax rate on pumps in its service stations. Throughout the middle and late 1920s, Standard Oil officials were highly visible in Sacramento and other state capitals pressing upon legislators the dangers of higher gasoline taxes. The rest of the petroleum industry was not as concerned until the onset of the Depression, when rough financial times made industry officials view the ever increasing gasoline taxes with genuine alarm. Some officials began to feel that gasoline tax advocates had taken advantage of them.

Why the gasoline tax lost its early appeal

The gasoline tax remained a popular user fee as long as the proceeds funded highway construction and maintenance. But then legislators and interest groups began to covet gasoline tax revenues for other uses. In 1922, the Oregon Legislature proposed using a one-cent-per-gallon increase in the gasoline tax to finance a world's fair. The Oregon State Motor Association rallied its members to defeat this proposal by one vote in the legislature. In 1924, the California Legislature attempted to raise the gasoline tax to increase county highway aid and reduce county property taxes. Standard Oil helped to defeat this proposal (although a similar proposal succeeded in 1927).

Throughout the 1920s, the share of gasoline tax revenues diverted to nonhighway purposes rarely exceeded two percent. Diversion increased rapidly during the Depression, reaching over ten percent by 1932. Most states diverted gasoline tax revenues to provide relief funds for the unemployed. In 1933, the American Petroleum Industries ➢

Committee complained that unemployment relief "was a paramount issue in many state legislatures in 1932 and 1933. Almost invariably, the gasoline tax was suggested as a fruitful source of revenue. Even school authorities, threatened by shrinking budgets and appropriations, gave it their enlightened attention. The original purpose of the levy was forgotten."

Other projects also sought to divert revenues from the gas tax. In 1929 Maryland diverted $75,000 to fund an oyster-propagation program. In 1931 Oklahoma diverted $900,000 to fund a free-seed program. Petroleum industry officials complained that "the American petroleum industry has been, and is being, victimized in a manner and to a degree probably unparalleled in recent history."

The petroleum industry mounted major public relations offensives against future gas tax increases, and it sought alliances with the automobile clubs. Auto clubs were fuming because all gasoline tax proceeds were not being used to build more roads; hence, they argued the tax had ceased to be a fair highway user levy. The clubs not only opposed future tax hikes but also began to fight for tax decreases and for adoption of state constitutional amendments to prohibit diversion. The first such amendments were enacted in Minnesota (1923), Kansas (1927), and Missouri (1928). The anti-diversion campaign achieved notable success everywhere except in southern states—Georgia, Texas, and Louisiana—where diversion became an accepted practice. Both Georgia and Louisiana diverted gas tax revenues for general-revenue purposes, while Texas was constitutionally required to use 25 percent of all excise tax revenues, including those from gasoline taxes, to support public education.

The first notable successes in the campaign against higher gasoline taxes came in 1932 when voters in Arizona, Maine, New York, and North Dakota defeated proposed tax increases. That same year, automobile clubs and the petroleum industry blocked efforts in Pennsylvania, California, and New Jersey to divert gasoline tax revenues to the states' general funds. Gasoline tax increases were fewer in number in the 1930s than in the 1920s, but the proliferation of anti-diversion amendments reflected widespread public support for tying gasoline tax revenues to road construction and maintenance. Implicit linkage between the tax and highways became explicit with the creation of state highway trust funds. And even the federal gasoline tax, originally enacted in 1932 for simple revenue-producing reasons, became linked to the size of the federal-aid highway program by the 1940s.

Lessons of the story

The gasoline tax was invented as a user fee whose purpose is to raise money for roads. Many politicians and the general public seem to have lost sight of these facts. The gasoline tax is now lumped together with all the other unpopular taxes. The challenge for policy makers is to restore the connection in the public's mind between the tax and the roads they provide, and to reassert the gasoline tax's original rationale as a user fee.

Transportation academics recognize the strengths of user fees as being fair and efficient, but they also emphasize that some user fees are better than others. All else being equal, direct user charges, such as tolls, are preferable to indirect charges, such as gasoline taxes. The gasoline tax is not perfect, and its imperfections have been chronicled in hundreds of articles and reports. But it also has strengths. Albeit crudely, it relates taxes paid to costs imposed on the highway. We might complain that the tax rates are too low or too high, but this is a weakness of policy and not of the instrument itself. The gasoline tax also raises a lot of money and requires tiny expenditures for administration and collection. There are no technological or administrative impediments to its use, and it has a history of acceptance and success. The gasoline tax was a brilliant innovation eighty years ago, and it still works today.

The development of alternative-fuel vehicles poses a challenge to transportation finance, and we will eventually need to develop a successor to the gasoline tax. We will then face a choice between user fees or taxes based on something else. Nonuser-based taxes like sales taxes seem an easy way out of this dilemma, because the public seems to have accepted them; but they do not relate directly to highway use and are therefore not necessarily paid by those who use the roads. Political acceptability and revenue-raising ability, while important considerations, are their sole strengths.

User fees, in contrast, are fair and efficient, they are paid only by their direct beneficiaries, and they have a proven track record. The gasoline tax's successor should be some kind of user fee, perhaps even a direct road charge of some kind. Eventually we will develop this successor; meanwhile let's not bury the gasoline tax prematurely in our haste to do so. ◆

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Clean Diesel: Overcoming Noxious Fumes

Are diesel engines part of the problem or part of the solution?

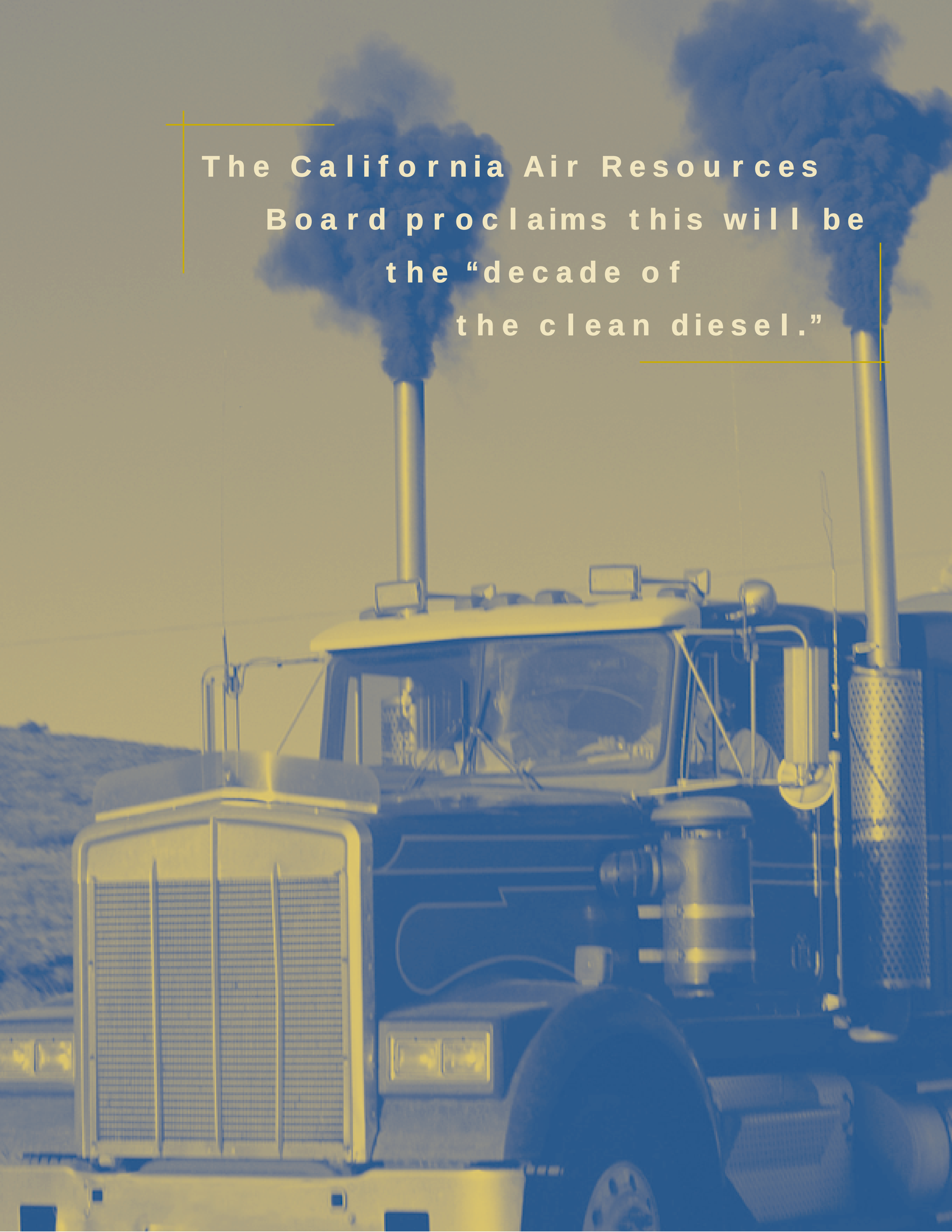
BY CHRISTIE-JOY BRODRICK, DANIEL SPERLING, AND HARRY A. DWYER

WHAT IS THE TRUTH about diesel engines? Are they inherently dirty? Do they belch clouds of black soot? Are they unsuited to cars, as evidenced by 1980s class-action suits against GM's diesel "lemons?" Do they make an unnecessary racket when idling and accelerating? Are their emissions toxic and a threat to human health? Many ask, in this age of ultra-clean transport, why do we still have diesel engines? The governor of Tokyo and air quality regulators in southern California have both launched campaigns to ban them.

But there's another side to the story of diesel engines. European regulators assert they are an answer to climate-change threats. Many automotive companies claim that new diesel engines are dramatically improved and as clean and quiet as gasoline engines. And freight companies rely almost exclusively on diesel engines for their trucks because they are durable and efficient. Indeed, diesel engines continue to increase their market share worldwide, now accounting for about forty percent of all roadway fuel consumed.

Because government plays a central role in determining diesel's destiny, a broad and sound understanding of diesel engines is especially important. Here, we offer a synthesis of the issues and conflicts surrounding diesel technology. We look at technical, regulatory, and economic issues addressing trucks, buses, and cars. We note that diesel engine technology is evolving rapidly. While we find their future attributes and health impacts are still uncertain and that a definitive assessment is not yet possible, we find ourselves cautiously optimistic. ➢

Christie-Joy Brodrick is research manager of several heavy-duty vehicle research projects at the Institute of Transportation Studies at the University of California, Davis (cjbrodrick@ucdavis.edu). Daniel Sperling is director of the Institute of Transportation Studies and professor of Environmental Science and Policy and civil and environmental engineering at the University of California, Davis (dsperling@ucdavis.edu). Harry A. Dwyer is professor of mechanical and aeronautical engineering at the University of California, Davis (hadwyer@ucdavis.edu).


The California Air Resources Board proclaims this will be the "decade of the clean diesel."

DIESEL HISTORY AND STATUS

Diesel engines have come to play major roles in our freight transport system. They have powered almost all heavy-duty trucks and most transit buses for decades, for good reasons. They are more fuel efficient, durable, and reliable than gasoline engines; they require less maintenance, provide high torque for moving heavy loads, and, in high-mileage vehicles, tend to have lower lifecycle costs. The cost advantage is especially crucial to the freight industry. Indeed, until the tightening of heavy-duty engine emission standards in the late 1980s, diesel engine use in trucks and buses was accepted as unquestionably positive. Even now, despite growing controversy about their health effects, diesel engines continue to gain prominence. They doubled their share of total roadway fuel use in the world in the past 25 years, and the percentage continues to increase.

Diesel engine use has been most controversial in the United States. Mercedes had been producing diesel cars for many years, but in the mid-1970s, in response to skyrocketing fuel prices and newly imposed fuel-economy standards, a number of other manufacturers began producing diesel cars. Market penetration increased to 6.1 percent of light-duty vehicle sales by 1981. But one manufacturer was too quick getting to market. One of the GM diesel car engines, a 5.7-liter engine converted from truck use, turned out to have many widely reported problems (though it is instructive that other diesel engines in GM cars performed well). GM spent large amounts of money vainly trying to fix the engine, settling class-action lawsuits, and dealing with complaints to the Federal Trade Commission.

Because of that bad experience, and also because diesel fuel prices in the US increased around that time to rough parity with gasoline prices and have remained at that level, no automaker has aggressively promoted diesel cars since. A recent resurgence of interest in light-duty diesels reflects steady improvements in noise and emissions and automakers' difficulty meeting the national 20.7 mpg fuel economy standard for gasoline-fueled light-duty trucks (applicable to vans, pickups, and sport utility vehicles). Diesel engines are now being introduced in small numbers in pickups and other light-duty trucks. Diesels account for 0.1 percent of automobile sales (with VW the only supplier) and approximately 4 percent of light-truck sales in the US.

The contrast with Europe is striking. There, diesel cars now account for over thirty percent of sales—over fifty percent in some countries—and the percentage continues to climb. Aided by low diesel-fuel prices, relatively gentle regulatory treatment of diesel car emissions, and aggressive CO_2 emission goals, diesel cars are likely to exceed forty percent of European vehicle sales within a decade.

TRUCK AND BUS EMISSIONS—PAST AND PRESENT

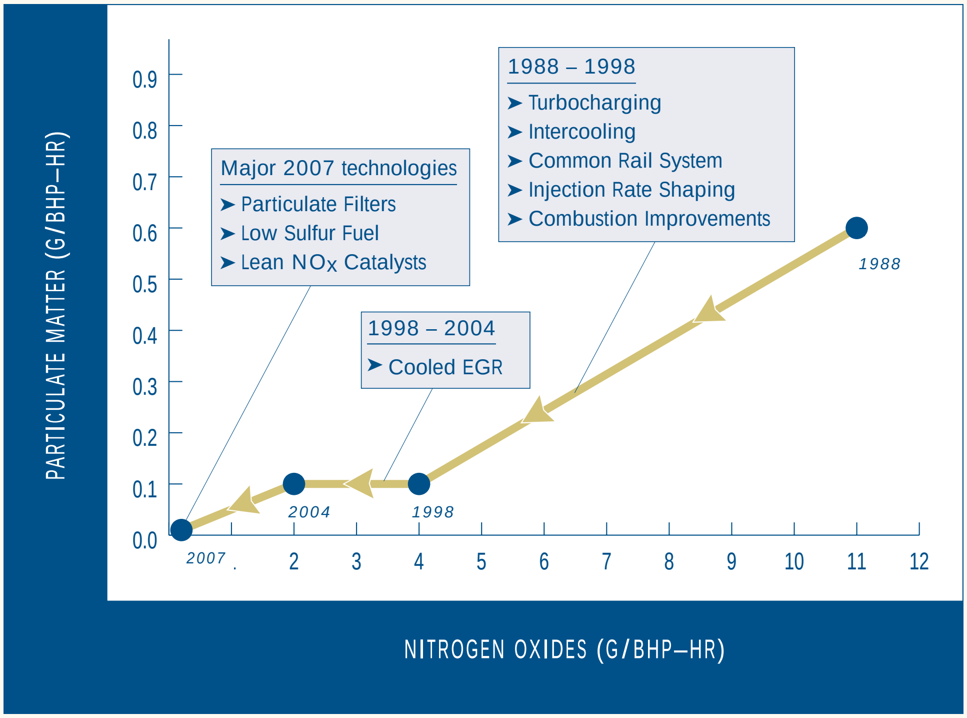
Diesel engines produce much lower levels of carbon monoxide (CO) and hydrocarbons (HC) than do gasoline engines, but much higher levels of nitrogen oxides (NO_x) and particulate matter. Unfortunately for diesels, their low emissions of CO and HC are no longer a strong attraction in the US. As a result of aggressive controls placed on gasoline engines (and other stationary sources), total carbon monoxide and hydrocarbon emissions have already been greatly reduced in the US and are no longer of principal concern. The most problematic air pollutants are now considered to be NO_x, which combine with hydrocarbons to produce smog (ozone), and particulate matter—small carbon particles that contribute to respiratory problems and cancer.

In the US, diesel engines contribute about a third of the nitrogen oxides produced by vehicles (vehicular emissions account for about half of all urban NO_x). They contribute a smaller share of particulate matter, but because vehicles tend to emit fumes closer to humans than other sources, and to produce relatively more of the dangerous nano-scale size particles, they are subjected to more intense regulatory scrutiny. NO_x emission rates from modern diesel engines are about five to ten times greater than from comparable gasoline engines, and particulate emissions are ten to three hundred times greater. Diesel engines are now a principal focus among air quality regulators. The California Air Resources Board proclaims this will be the "decade of the clean diesel."

Vehicular emission controls were first imposed in the 1960s on gasoline engines, with increasingly stringent standards since. Diesel truck and bus emissions, in contrast, were essentially unregulated until the early 1990s. Lax treatment was due to the difficulty of creating standardized rules for trucks operating with varying loads and in widely disparate applications. Regulators recognized that the relatively small diesel engine manufacturers had limited resources, and that the trucking lobby was politically powerful. As indicated in Figure 1, the first set of stringent heavy-duty diesel particulate matter standards took effect in 1994, and more stringent NO_x standards followed in 1998. As with gasoline engines, initial emission improvements were easy and inexpensive. New 1998 diesel engines produced over eighty percent less particulate emissions and sixty percent less NO_x than older engines (largely using

FIGURE 1

Diesel emissions reduction trends (G / BHP–HR = grams per brake horsepower per hour)



technology from Europe). Future emission reductions will be far more difficult, in part because catalysts and other emissions-control devices developed for gasoline engines are not transferable to diesels. Considerable effort is now being devoted to developing new diesel-specific technologies.

Diesel emission reduction is hindered by the "diesel dilemma." Changes to reduce NO_x emissions increase particulate emissions, and vice versa: high temperatures and additional oxygen reduce particulate levels, but increase NO_x formation. A similar trade-off exists between NO_x and fuel economy: adjusting the engine for greater economy results in higher NO_x. The challenge for engine manufacturers is to reduce both NO_x and particulates, *and* retain diesel's superior fuel efficiency.

Regulators in California, US, Europe, and Japan all continue to tighten heavy-duty truck emission standards. US regulators are requiring that emissions of both pollutants be 98 percent below 1988 levels by 2007. In parallel, European regulators are about to require use of particle filters by 2005 and NO_x catalysts by 2008. Manufacturers are on track to achieve the huge reductions in particulates being called for. Large reductions are also being made in NO_x emissions, but not nearly as fast nor as easily. NO_x control on diesel engines continues to lag behind gasoline engines by over a decade.

CAR EMISSIONS

The steep learning curve also applies to light-duty diesel emissions, though circumstances are quite different. In the US, diesel cars must meet the same stringent pollutant emission standards as gasoline cars. A few companies have technology that gets them close to the national standard (which is good enough since they are allowed limited averaging to meet an overall fleet average). But none qualify for even the least stringent category in California, where standards are somewhat more rigorous, and thus no light-duty diesels are being sold in that state. It is uncertain whether any manufacturer will be able to meet federal standards in 2004, when they are next tightened.

The European situation is quite different. Europe treats diesel car emissions more leniently. While Europe has been closing the gap in gasoline emission standards with the US and California over the past decade, this has not been so with diesel cars. Europe continues to impose considerably weaker NO_x and particulate-matter standards on light-duty diesel vehicles. The test cycles are different, so exact comparisons are not possible, but the European standards are less stringent by at least a factor of six (i.e., the US Tier II and California ULEV standard in 2004 will be 0.043 grams / km for NO_x and the California SULEV standard will be 0.012, while the comparable European standard ➢

for diesel cars will be 0.25 grams/km). Moreover, the European standard covers only the first 100,000 km of a vehicle's life, while the US and California standards are for 193,000 km. Similar differences exist for particulate standards.

Japan also treats diesel cars more lightly than the US. But diesel cars in Japan have not enjoyed the same market success as in Europe. Diesels slowly increased to ten percent of total cars on the road in the 1990s, but then began to recede at the end of the decade. The principal reason for this slower diesel growth in Japan appears to be a sense that diesels are a principal source of persistent air pollution. In 1999, the Governor of Tokyo proposed to ban the sale and use of diesel vehicles in the entire city. While that will not happen, a retrofit program may emerge instead. In any case, it indicates the extent of antagonism to diesels. In addition there have been court cases where the public has sued the government and toll-road authorities, claiming that vehicle pollution, especially from diesels, is damaging health. The effect seems to be a chilling of diesel car sales.

THE FUTURE OF DIESEL EMISSIONS

Black clouds of soot are about to recede into history, certainly with new vehicles. Today's diesel engines burn far cleaner. Emission improvements to date have mostly involved improved engine design and operation, including electronic engine controls, fuel injection, and the shaping of the fuel pulse as it enters the cylinder—as opposed to after-treatment technologies, such as catalysts and filters, that reduce emissions after they leave the engine.

But even with those improvements, diesel NO_x emissions remain a large share of total national emissions of NO_x, and particulate emissions continue to be a serious health hazard. After-treatment technology, widely used on gasoline engines for over two decades, will soon be applied to diesel engines. The 2004 heavy-duty standard for NO_x will be largely met with a new after-treatment technology called cooled exhaust gas recirculation (EGR), which has also been extensively used for gasoline engines. EGR lowers the temperature of the combusting fuel by recirculating oxygen-depleted exhaust gases back to the cylinders, thereby reducing the oxygen content of air involved in the burn. Cooled EGR will need to be supplemented or replaced by other technologies to meet the stringent heavy-duty NO_x standards of 2007.

To meet the 2007 standards, a sophisticated multi-pronged systems approach will be needed, encompassing three technologies: fuel changes, engine controls, and after-treatment. Likely changes include the use of low-sulfur fuel, oxidation catalysts, selective catalytic reduction (SCR) techniques, and particulate filters.

Dramatic emission improvements are likely to continue. But improvements may not be as fast or as large as required by the standards. Some of the challenges and questions that underlie anticipated improvements include the following:

Sulfur removal from fuel. Sulfur, which occurs naturally in petroleum, poisons catalysts and particulate filters and produces particulates. It must be removed, but doing so is costly and difficult. The oil industry prefers a slow phase-down. Only one control technology, selective catalytic reaction (SCR), can function with high sulfur fuel, but SCR has other drawbacks. Many European countries, such as Sweden, already require fuels to be low in sulfur, and some refiners already supply very low sulfur fuels. The US EPA has proposed a ninety percent reduction in sulfur content of diesel fuel, to less than 15 ppm, by 2006, but it is being contested.

Emission Control Performance. It took more than a decade for reliable two-way gasoline catalysts to evolve into effective and durable vehicle components. Many didn't perform effectively as they aged, and others degraded engine performance. Tampering, malfunctions, and poor maintenance were parts of the problem. The same will hold for new diesel control technologies and engine designs. Particle filters are of some concern because they cause increased backpressure, which limits the flow of fuel, reducing fuel economy and possibly damaging the engine. Catalytic systems are of uncertain and unproven durability and reliability. SCR systems are problematic because drivers must load another fuel (urea); without urea, emissions will not be reduced, and with an incorrect fuel, the catalyst is ruined.

As with gasoline cars, the net effect of tampering, malfunctions, and poor maintenance is much higher emissions. One study estimated that over its life, a 1995 truck's average emissions increase by 34 percent for HC, 7 percent for NO_x, and 44 percent for particulates. Another (Northern Front Range Air Quality Study) found actual in-use particulate emissions from heavy-duty trucks to be 20 to 170 percent higher than predicted by EPA models, and NO_x emissions to be 20 to 100 percent higher. Inspection and maintenance programs and onboard diagnostic technology are possible solutions, but they have not yet proven to be highly effective (with either gasoline *or* diesel engines).

Particle mass versus number. The design of current regulations may be misguided. Current regulations address the mass of emissions. Thus, emission control strategies are aimed at reducing the total mass of particles. But to accomplish that goal, they tend to produce many more very tiny particles. New health research suggests that nanoscale-size particles are far more dangerous than larger, heavier particles, since the tiny particles navigate past the body's normal barriers and penetrate deep into the lungs and bloodstream. It may be that modern diesel engines, while producing lower mass emissions (cleaner to the eye), are more dangerous to health. There is evidence that natural gas engines, which regulators are promoting as a substitute for diesels (and sometimes mandating, as with buses in Delhi, India), produce even more very fine particles than next-generation diesel engines. Regulators are exploring new standards that are based on particle size, as a complement or substitute for mass-based standards. The health effects research is not definitive, however, and standards take many years to be altered. The relative importance of particle number versus particle characteristics will influence the type of technologies and strategies adopted. These considerations will be very important for particulate filter retrofit programs, especially since diesel engines typically have a significantly longer life than gasoline engines.

Even if health research were definitive, measurement of small particles is difficult. The size and chemical composition of emissions particles are highly sensitive to a variety of factors—including temperature, sampling technique, and time lags between formation and sampling—making it difficult to characterize and measure these particles. Measurement techniques need refinement to ensure accurate representation of the emissions and to understand their effects on human health.

In summary, dramatic improvements are being made, and the sophistication and effectiveness of diesel emission control is on a steep upward curve. Attainment of heavy-duty 2007 standards is not assured, at least by 2007; but regulators in Europe, the US, and Japan continue to press for major improvements. Industrial R&D investment is scaling up in response to increasingly stringent standards.

ENERGY EFFICIENCY AND CO_2 EMISSIONS

Diesel engines are more energy efficient than other internal combustion engines. Advanced direct-injection diesel engines are up to 45 percent more efficient than current gasoline engines, and about 20 percent more efficient than advanced gasoline engines.

The higher energy efficiency is a strong attraction where diesel fuel prices are lower than gasoline prices, and where

vehicle manufacturers are subject to fuel economy or CO_2 restrictions. No country imposes fuel economy standards on large trucks, nor plans to. Light-duty vehicles are a different story. The US and Japan impose fuel economy standards on cars and light trucks, and the European Union has a voluntary agreement with automakers to reduce CO_2 emissions by 25 percent (per vehicle kilometer) between 1995 and 2008. The effect of these policy instruments is to encourage diesel over gasoline. In the US, the effect is muted by lingering memories of the GM diesel car experience and the absence of diesel fuel price advantages. In Europe, however, diesel's strong price advantage and the aggressive CO_2 targets have been highly effective at stimulating diesel car sales.

ECONOMIC CONSEQUENCES

Regulator decisions about air pollutant emissions, greenhouse gases, and fuel economy play an instrumental role in the future of diesel engines and fuels and the success and even survival of many car, truck, and oil companies. Those policy decisions are seldom based on solid scientific evidence. The problem is the proprietary nature of engine and catalyst design and the adversarial nature of many regulator-industry relations. It is difficult to determine the actual state of diesel technologies or to know what levels of regulation are appropriate. Without performance and cost projections, regulators cannot determine how their policies will affect industry. Thus, they engage in a game of chicken, enacting technology-forcing regulations that they hope will not impose undue economic burdens on manufacturers. ➢

In the US, proposed light-duty diesel vehicle standards are so strict that the economic consequences of meeting the standards could prove prohibitive. Anticipating these new and more stringent standards, most automakers have withheld the introduction of diesel engines in cars and light trucks.

The heavy-duty vehicle market will remain loyal to diesel fuels in almost any scenario, but major changes are possible. Some heavy-duty diesel vehicles, including many buses, have switched to natural gas. But even natural-gas trucks and buses will have to reduce their particulate and NO_x emissions by a factor of five or ten to meet the very stringent 2007 standards. In the US, where more than 90 percent of all freight is moved by diesel power and where diesel fuel accounts for 25 percent of fuel sold, the economic repercussions of stringent diesel emissions standards could be large and far-reaching.

HEALTH RISKS

Central to the debate over diesels is the unresolved question of health effects of particulate emissions. It's unresolved for several reasons: it's difficult to tease out the effects of diesel emissions from those of tobacco, other fossil fuels, and other sources; few humans are exposed for an extended time to diesel fumes; and extrapolation of findings from animals to humans is dubious, partly due to species-specific responses. For example, prolonged diesel exposure does not produce lung tumors in hamsters, whereas it clearly does in rats.

Despite these uncertainties, some conclusions can be drawn from the large numbers of studies that have been conducted:

- Fine particles are associated with increased hospital admissions and emergency room visits, asthma, chronic bronchitis, decreased lung function, and premature death.
- Diesel particles have many chemicals adsorbed onto their surfaces, including some known or suspected mutagens and carcinogens. The risk of lung cancer among workers with high exposure to diesel exhaust is approximately 1.2 to 1.5 times the risk in those unexposed.
- Exact biological mechanisms are poorly understood, but small particles (those in the submicron range) are believed to pose the most severe health risks. By number, the vast majority of diesel particulates (92 percent) are less than one micron in diameter. Particles this size can be inhaled and trapped into the bronchial and alveolar regions of the lung.

The overall impact on human health is less clear. Effects range from increased rate of death from cardiovascular and respiratory illnesses (asthma, chronic bronchitis) to cancer. In California, the Multiple Air Toxics Exposure Study found that approximately seventy percent of all cancer risk in the South Coast Air Basin related to outdoor air pollution is attributable to diesel particles—but it also estimates that outdoor toxic air pollution overall accounts for less than one percent of cancer when all risk factors are considered.

The regulatory communities' interpretations of these results differ. Diesel exhaust includes over forty substances listed by the EPA as hazardous air pollutants, and by the California Air Resources Board (CARB) as toxic air contaminants. In 1998, CARB classified diesel particulate matter itself as a toxic air contaminant. However, the EPA recently acknowledged the uncertainty inherent in the existing studies and recommended not adopting a cancer risk estimate. CARB, on the other hand, has established risk estimates for cancer from diesel exhaust particles.

Complicating the interpretation of health-effects research is the fact that current data do not apply to future vehicles. Because of improvements in engine design and emissions control technology and the use of reformulated diesel fuels, future human exposure will differ from past and current exposures. Secondly, as indicated in Figure 1, future technologies will produce substantially lower emissions, with different characteristics, both chemical and physical. Third, diesel emissions are chemically transformed over time as they move through the air—altering the toxic, mutagenic, and carcinogenic properties of the original emissions. Consequently, the new pollutants from diesels will likely lead to new end products with undetermined levels of hazard.

Based on the above evidence, the Health Effects Institute, a respected independent center jointly funded by car companies and the US Environmental Protection Agency, concludes, "The characterization of modern-day diesel exhaust can not be…used reliably to project future emissions profiles."

THE LONG-TERM FUTURE OF THE DIESEL ENGINE

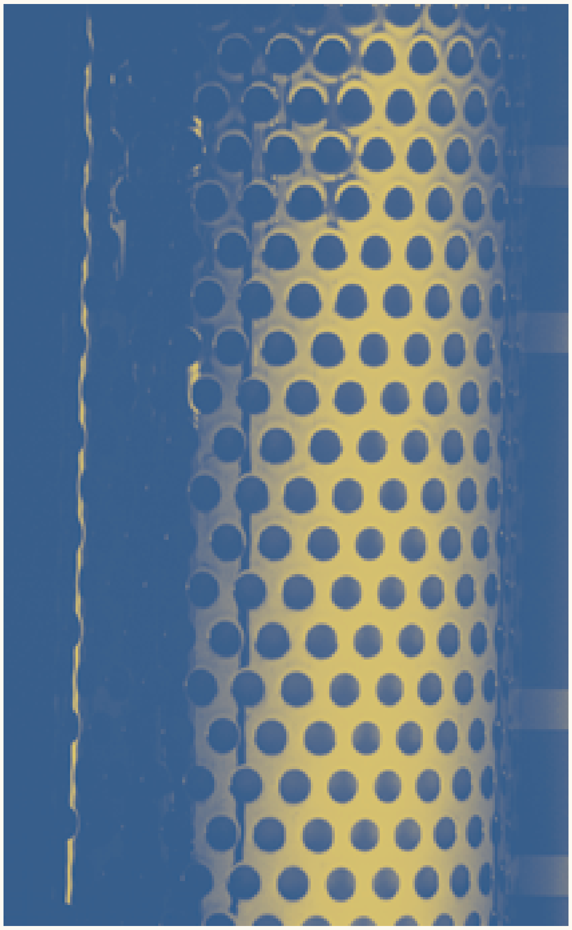
Emissions control strategies have evolved from engine design and management to use of after-treatment devices. The goal is to reduce emissions without degrading fuel economy and engine performance. Beyond 2007, the focus will broaden beyond narrow emission control strategies into broader strategies that reduce emissions *and* enhance other vehicle attributes, including performance and energy efficiency. This broader approach is motivated initially by opportunities to reduce losses and costs associated with idling and stop-and-go operations—not only emissions, but also the large consumption of energy and accelerated wear and tear on the engine. Two strategies already being examined are auxiliary power sources and hybrid drive-trains. As indicated below, these two strategies have the potential to provide not only environmental benefits, but also economic and performance benefits; and they could provide a path toward fundamentally superior designs.

AUXILIARY POWER UNITS (APU)

Long-haul heavy-duty trucks in the US idle up to ten hours each day, and as much as fifty percent of total engine run time. Idling consumes significant amounts of diesel fuel and generates large amounts of noise, vibration, and air pollution. Up to a third of NO_x emissions is produced by these trucks during idle. Energy consumption is also large, and engine efficiency is very poor. At idle, heavy-duty diesel engines operate at only one to eleven percent energy efficiency, compared with forty percent efficiency when the engine is operating on the road. Conservative estimates are that a diesel engine in an average late-model truck, idling six hours per day 303 days per year, consumes 1818 gallons of fuel per year. The annual cost of this idling is over $3,000 for fuel, plus more for additional preventative maintenance and engine overhauls. The DOE's Office of Heavy-Duty Technologies estimates that the total cost of idling heavy-duty trucks in the US is $1.17 billion for fuel and $1 billion for extra maintenance.

Drivers idle their engines to power sleeper-compartment heaters and air conditioners, to power "hotel" accessories such as TVs, refrigerators, computers, tools, and fleet communications devices during nondriving operations, to avoid start-up problems in cold weather, to maintain air-system pressure, and simply as general practice during many delivery operations. Use of large diesel engines for idling is not only expensive and polluting; it also vibrates the cabin and is noisy, thereby disrupting driver sleep and creating a safety and performance concern.

An attractive auxiliary power unit that could replace the main engine is a diesel-fueled fuel cell. Two types of fuel cells could run on diesel fuel: a proton-exchange membrane fuel cell of the type being developed for cars, with a device to convert the diesel fuel to hydrogen, or a solid-oxide fuel cell that can operate directly on diesel fuel. As batteries and small alternative-fuel engines advance, they may also become appropriate. The use of fuel cells and other devices as auxiliary power units in long-haul trucks might lead to a migration of these clean, efficient devices to other trucks (and even cars), and also accelerate electrification of ➢



Black clouds of soot are about to recede into history. Today's diesel engines burn far cleaner.

the truck's drive train, steering, braking and other accessories—leading to even further efficiency and environmental benefits. It should also be pointed out that there is a need for APU devices in recreational vehicles (RVs), which spend a large amount of time in national parks and other wilderness locations. An analogy may be computers in cars, which initially were used to control emissions, but soon gained much wider applications.

HYBRID VEHICLES

The stop-and-go drive cycle of many delivery trucks and buses is highly inefficient for both diesel and gasoline engines. Often these trucks are driven less than a hundred miles per day, and their average trip length may be only a few blocks. Not only is such a cycle very energy inefficient, it is also demanding on the engine and propulsion system.

Hybrid vehicles, in which a battery and electric motor are coupled with the existing internal combustion engine system, are far more efficient for these types of applications. Hybrid designs are beginning to be widely used in cars, light trucks, and buses; but they can also be used in intermediate-size trucks, perhaps with even greater benefit. Hybrid trucks are attractive in stop-and-go applications for a variety of reasons. One benefit is elimination of many engine starts. The vehicle could start with a battery, with the diesel engine turned on only when the vehicle's computer determines that extra power is necessary; or, in other hybrid configurations, the engine turns on only to maintain the battery at a specified state of charge. A second benefit would be downsizing of the engine, whereby it operates near the most efficient load point at all times. The result is elimination of idling, elimination of hard accelerations that cause puffs of soot, and the ability to use regenerative braking to capture energy otherwise lost as heat during braking. Hybridization thus provides the potential for much greater energy efficiency and much lower emissions.

CONCLUSIONS AND RECOMMENDATIONS

Diesel technology is evolving rapidly. It is not a mature technology. Earlier uncontrolled engines were highly polluting, noisy, and dirty; current engines are much cleaner and quieter, and future engines will be even cleaner. Improvements in energy efficiency and emissions are producing the "new" diesel—modern machines that are much less damaging to the environment than previous versions. How much cleaner, however, is still uncertain, and so are future health effects. What is known is that diesel engines will tend to produce higher NO_x and particulate emissions than gasoline engines if they lack particulate filters, but better fuel economy and lower CO_2 emissions. With filters, particulate emissions of all sizes can be dramatically reduced.

Opinions about the future role of diesel engines differ depending upon how one weights pollution and climate change. Many, especially in the US, believe air pollution from diesels is so serious that even new, cleaner diesel engines should not be used in light-duty vehicles and should be phased out of heavy-duty vehicles. In Europe, the prevailing view toward diesel is more benign, premised on a greater commitment to greenhouse gas reduction. These differences are reflected in Europe's more gentle treatment of light-duty diesel emissions.

However, characterizing the future of diesel engines as a trade-off between air pollution and greenhouse gases is a gross oversimplification. The environmental, health, and economic effects of using diesel engines are unclear and difficult to measure, and much of what we do know is based on data from older technology.

Diesel technology is here to stay for a very long time. It has compelling advantages that are difficult to replicate with other propulsion technologies and fuels. The massive R&D investment now being directed at mitigating the inherently high NO_x and particulate emissions is bearing fruit, much as happened with gasoline engines. Diesel engines may not come as close to zero emissions as gasoline engines seem destined to, but it appears that they will eventually come close.

For now the focus of diesel improvements is on after-treatment devices, improved engine design and operation, low-sulfur fuels, and retrofit devices. At the same time, increasing emphasis will be placed on strategies for fundamentally cleaner and more efficient engines. These include hybrid electric drivetrains, especially in medium-sized trucks used for deliveries, and fuel-cell auxiliary power units for long-haul heavy-duty trucks. Over time, hybrid electric and fuel-cell electric drivetrains are likely to migrate to other truck types and other applications.

The challenge for public policy is to acknowledge but not be paralyzed by uncertainties—about health effects, climate change, and cost and performance of future technologies. Simplistic policies banning diesel or forcing particular technologies are inappropriate. Given the dramatic progress being made in reducing emissions, and the late start in doing so, polices aimed at mitigating the downsides of diesel engines are clearly desirable. These initiatives might include inspection and maintenance of vehicles, combined with random on-road testing—though difficulties with gasoline vehicle inspection and maintenance programs give pause. A less controversial and probably cheaper approach would be incentive funding. New

Hampshire is considering economic incentives such as truck registration fees based on engine type and estimated emissions. Vehicle retirement programs should also be considered in cases where it is not economical to repair or retrofit a vehicle.

Public action and funding appear most justified for the following purposes and applications:

- Accelerated replacement of older polluting diesel transit and school buses. Transit operators have limited funds, the bus market is small, and manufacturer commitment to this market segment is weak. Importantly, those exposed tend to be the most vulnerable (they are young, old, or poor).
- Public R&D funds to leverage industry investments in key technology areas and to support basic R&D at universities and other independent research centers.
- Incentives to buyers of next generation clean technologies, including fuel cell auxiliary power units and hybrid diesel-electric trucks.

Regulatory reform is also needed to reflect the mixed energy and environmental impacts of diesel engines, and the rapid progress being made with emission reduction. As previously noted, California and the US have adopted new particulate and NO_x standards that are so stringent that they could eliminate the use of diesel in light-duty vehicles. This seems problematic.

It is important to note that light-duty emission standards were structured for gasoline cars. They are not based on a scientific formula; rather, they are based in part on how much reduction is needed to bring polluted areas into compliance with air quality standards and in part on determinations of what is deemed economically viable. For instance, standards for CO and HC have been more aggressively tightened than for NO_x over the years in large part because it was judged easier and cheaper to accomplish. To maintain the spirit of the rules and goals, but recognizing diesel's superior efficiency (and lower CO_2 emissions), it would seem appropriate to explore ways of making the standards more flexible. This should not be done in a way that compromises air quality, but that provides more options for companies to expand their suite of products. And perhaps some means could be created to link the Corporate Average Fuel Economy (CAFE) program with emissions regulations. The ultimate goal should be design of a regulatory approach that allows manufactures to supply a mix of vehicles, fuels, and technologies that attain social goals at less overall cost. ◆

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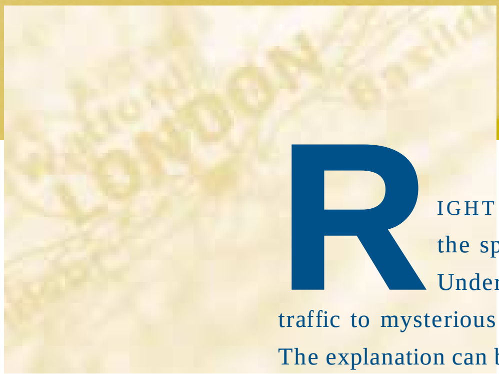
HIGH-SPEED RAIL COMES TO LONDON

BY SIR PETER HALL



RIGHT NOW, monster traffic jams surround London's St. Pancras station as they dig up the space in front of the great neo-Gothic Victorian pile to build an extension to the Underground station. As drivers sit motionless, they see mysterious red signs directing traffic to mysterious destinations: "CTRL WORKS TRAFFIC 1J," "CTRL WORKS TRAFFIC 2J-4J." The explanation can be found not far away, at the back of the station: behind security fences, Victorian coal gas tanks are being demolished or (because some are landmark structures) moved, while giant tunnel-boring machines are eating into the London clay. All this frenetic activity has one purpose: construction of the Channel Tunnel Rail Link, Stage Two—the UK's new link to the continent of Europe, and one of the largest civil engineering projects since Victorian times—at last happening.

It's the cumulation of a long-drawn-out story that has had many false starts and some premature near-endings. Some of us, who've been associated with it over the years, had almost given up all hope that we'd live to see this day. We see it as some kind of miracle. At a time when California and the United States are in the throes of a debate about high-speed rail transportation, spurred by the huge disruption to the airlines following the September 11 disaster, it's a tale worth recounting.

It began long ago: in 1986, UK Prime Minister Margaret Thatcher and France's President François Mitterrand signed the Treaty of Canterbury, the legal instrument that allowed the two countries to cooperate in building the Channel Tunnel. The tunnel itself started construction the following year and opened to traffic in 1994: a rail-only tunnel, carrying a mixture of freight trains, flat-bed wagons that carry roll-on roll-off cars and trucks in a constant shuttle, and high-speed Eurostar trains connecting

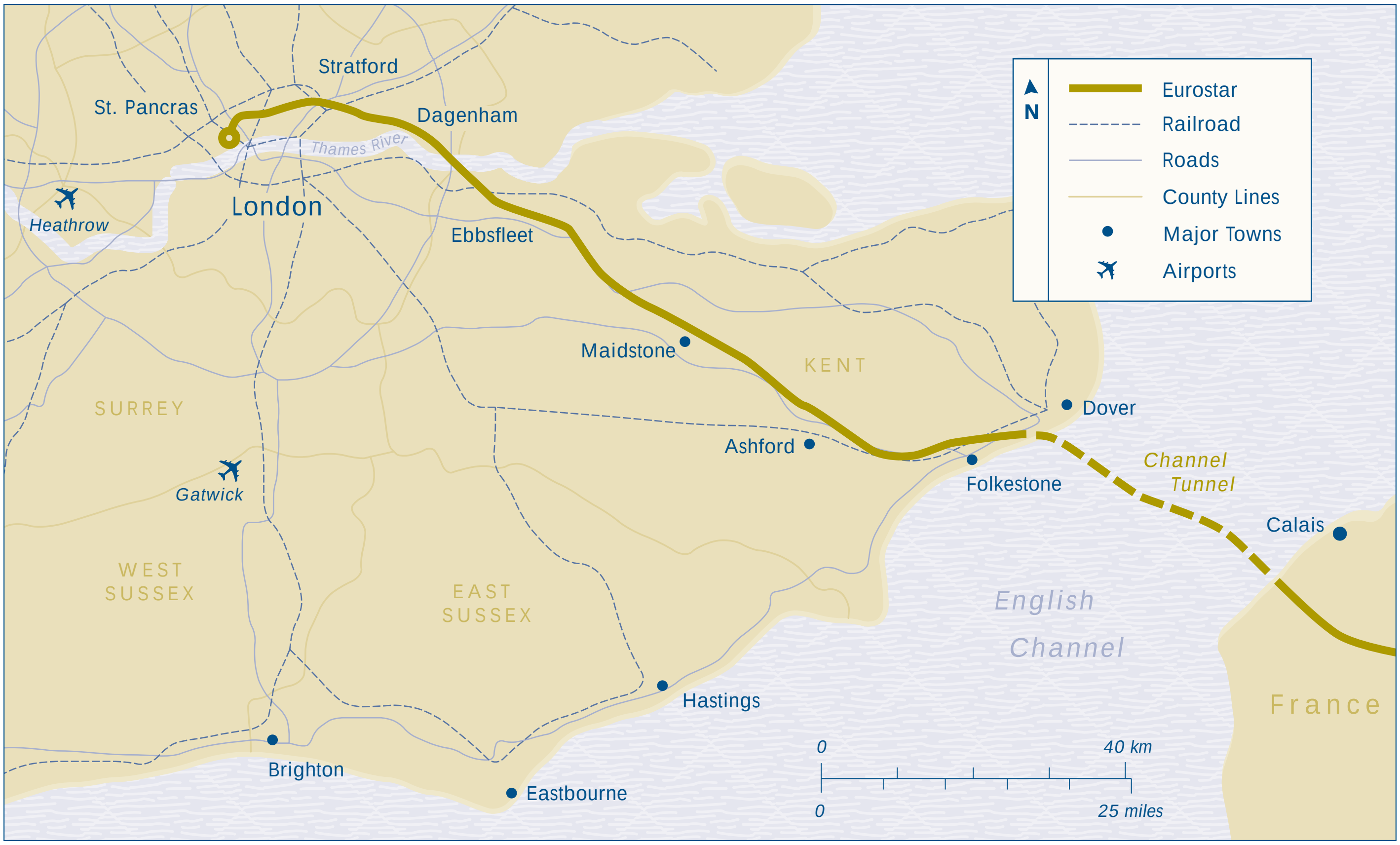
Sir Peter Hall is professor emeritus of city and regional planning at the University of California, Berkeley, and professor of planning at University College London (p.hall@ucl.ac.uk)

London with Paris and Brussels. At the French end, the Eurostars continue on to a brand-new high-speed railway completed just before the tunnel opened, carrying TGVs (*Trains à Grande Vitesse*, High-Speed Trains) at 186 mph all the way to the outskirts of Paris, and now extended from Lille through Belgium to Brussels. But on the UK side, the twenty-car Eurostars trundle at a slower pace—maximum 90 mph—mixed in with London commuter trains. As Mitterrand jested when the tunnel opened, it gives plenty of time to enjoy the beauties of the English countryside.

The reason was that the treaty contained a clause saying that no state money could be used to build the tunnel or any associated works. The French, in their inimitable way, got around that by saying that their TGV Nord was built to carry domestic traffic. No such hope with the parsimonious UK Treasury in charge. They insisted that a high-speed link from the Chunnel to London, like the tunnel itself, had to be a strictly private job in which investors carried the entire risk. Since the Chunnel had been a commercial disaster, with cost overruns that bankrupted the investors—mainly French, as it turned out—that didn't seem particularly good news.

Nonetheless, British Railways—then still a nationalized undertaking—pressed on with a project for a high-speed line. By 1990, it had defined a seventy-mile route running through the county of Kent and the south-east London suburbs to a vast new underground station built between the two major central London termini of King's Cross and St. Pancras, from where trains could continue to the north of England. But then the whole project became entangled with an emerging great debate about urban regeneration and city planning.

Three years earlier, a planner then with the Kent County Council, Martin Simmons, had published an article in a professional planners' magazine. In it, he argued that London's Heathrow airport, built west of the capital for military reasons in 1943, had played an important role in the subsequent growth of the so-called western sector, ➢



the UK's main high-tech cluster. Thus, it had helped reinforce the traditional imbalance in London between a prosperous west and an impoverished east. With a new rail link from the Chunnel, Simmons argued, there was an opportunity to reverse this historic imbalance.

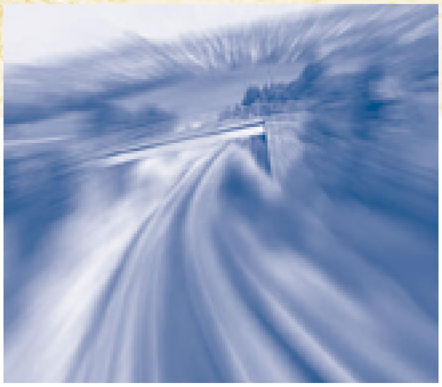
His argument was widely noticed and widely discussed. But then there was a further twist. A major civil engineering and planning consultancy, Ove Arup, decided to take a chance. Led by an economist, Mark Bostock, they began at their own expense to prepare an alternative route for the new line. Instead of entering London through the solidly middle-class southeastern suburbs, their line would tunnel under the Thames to go north of the river, past the giant Ford works at Dagenham and through undeveloped marshland. It could have a station at Stratford in east London, one of the capital's most deprived areas. Thus it could serve the deprived and underdeveloped eastern side of London, and stations along it could play the same role in the following half-century that Heathrow had played since 1945. Some of us began to argue strongly for the alternative route for precisely that reason.

Thus began a huge national debate. In 1990 Michael Heseltine, a brilliant politician who led the regeneration of the London Docklands and then resigned from Margaret Thatcher's cabinet on a point of principle, campaigned to become party leader—and thus Prime Minister—in her place. He lost to John Major, who gave him back his old job at the Department of the Environment. In March 1991 he summoned the media for a startling press conference: the Docklands project, then grinding its way to completion, was to be followed by a much larger one: the East Thames Corridor. Running thirty miles downstream through East London and Kent, it was to consist of a whole series of regeneration schemes and new developments—and they could all be strung along the line of the new railway.

Now the debate intensified. The British Railways line, the Arup line, and yet another private alternative were closely evaluated. The Arup line could cost more money, but it was less disruptive to existing communities and it would bring big regeneration benefits—how big was hard to say, and the experts disagreed. Finally, after a summer of frantic activity, the government announced in October 1991 that the Arup line would be adopted.

It took two more years to fix the line in detail. One key decision placed intermediate stations at Stratford in east London, six miles from the St. Pancras terminus, and at Ebbsfleet just over the Kent boundary. Meanwhile the government had decided it should be built and operated by a private consortium. It was busy preparing for the privatization of British Railways, so this was logical. On the rest of the network, impelled in part by a recommendation from the European Commission in Brussels, it split the tracks from the trains: the tracks would be maintained by a monopoly company, Railtrack, while operations would be franchised out to a score of regional and local companies. But, oddly, for the new link the government departed from its own logic. On the high-speed line it decided to maintain integration. There would be a competition to build and operate the new line. The new Eurostar trains, just starting to operate over the old tracks, would be passed to the winning consortium. And on top, the consortium would get some potentially valuable development land around the new stations.

The winner of the competition, announced late in 1995, was London & Continental Railways. L&C was a consortium that included Arup, Bechtel, a division of the French National Railways (SNCF), and Virgin, Richard Branson's legendary company that had started selling music records and now sold almost everything; it was just completing a successful bid to operate one of the main rail lines in Britain, from London to Birmingham, Manchester, Liverpool, and Glasgow. A key element in the L&C bid, reached only after intense internal debate, was to build a direct link outside St. Pancras so that trains from the Virgin line could run directly on to the new link without entering and reversing in the station. This neatly provided for direct services from British provincial cities to the European mainland, and also ensured that their London stop would be at Stratford. It may have proved the clinching element. But in any event it was of great strategic importance, because these two elements—connection to other British cities and stop in eastern London—were being called for by the European Commission to complete the Trans European Network (TEN) of highways and high-speed railways that would connect the major cities of Europe. ➢



But, three years after winning the competition and on the eve of the start of construction, L&C made a momentous announcement: it could not afford to go ahead. The reason was that traffic growth on the existing Eurostar trains was well below the level that had been forecast. Even now, in 2001, total traffic is still only eight million passengers a year, against a forecast thirteen to fourteen million. Though the new trains have captured as much of the air traffic as was expected—nearly two thirds of the combined air-rail traffic to Paris, nearly half to Brussels—newly generated traffic has grown far more slowly. One factor could be the deregulation of European airways, which has grown apace through the entrepreneurship of low-cost operations like Ryanair, Easyjet, Go, and Buzz. They may have captured much of the traffic that planners predicted would divert from cross-Channel ferries onto the trains. Or maybe the real growth in traffic will come only after completion of the new line.

After L&C was bailed out by the government in a complicated financial deal that effectively meant takeover by Railtrack—which, ironically, itself went bankrupt in October, 2001—the project was split into two stages. Stage One, from the Chunnel to a point near the Thames crossing, just short of Ebbsfleet, will open in 2003, cutting twenty minutes off the journey—currently three hours to Paris, two hours forty minutes to Brussels. Stage Two, in 2007, will cut Paris times to two hours and twenty minutes, Brussels times to two hours.

But that is not the end, because when Stage Two opens in 2007, it will be one year behind some major new links which will have opened on the continental side of the Channel, in the form of new lines from Brussels to Rotterdam and Amsterdam in the Netherlands, and to Cologne and Düsseldorf in Germany. Effectively, all the major capitals and commercial cities of this most densely populated central region of Europe—London, Brussels, Paris, Amsterdam, Cologne, Frankfurt—will be directly linked by high-speed trains traveling at up to three miles a minute.

This will happen not a moment too soon, because the airports of this region have been suffering from rising traffic and increasing congestion—at least up to September 11, and doubtless again. London awaits a government decision on Terminal 5 at Heathrow, a dedicated British Airways terminal which would almost double the airport's capacity; Paris expects a final decision among eight alternative sites for a third airport; Amsterdam still debates how to provide additional capacity at Schiphol. The new rail network will relieve these airports, because at critical points—Paris Charles de Gaulle, Amsterdam Schiphol, Frankfurt International—it will directly serve them, allowing passengers to make a seamless connection from long-haul flight to high-speed rail feeder. Lufthansa already operates its own dedicated trains from Stuttgart to the Frankfurt airport, carrying passengers who have already checked in. Air France similarly allows train check-in to the TGVs from Lille to Charles de Gaulle. Despite the huge security complications arising from September 11, which can be resolved—Eurostar already employs European-level airline-style security—such rail-air integration must be the way of the future, and is likely to develop hugely after completion of the rail network in this, Europe's Central Capitals region, in 2006–7.

So, not only the UK but Europe is constructing a largely new transportation system. That's remarkable because it is an international enterprise: state-owned railways and private companies are cooperating to build and operate it, overcoming major technical problems such as different signaling and electrical systems.

Is what Europe does today a likely prelude to what America will be doing tomorrow? The current confusion in the American airline system—fear of flying, massive loss of passengers, threatened corporate collapses—is symptomatic of basic security problems that high-speed rail travel might help resolve. On the East Coast many air passengers are switching to Amtrak's moderately high-speed Boston-New York-Washington service, reflecting a pattern that has become common in Europe. Might that experience encourage Congress to release federal funds for high-speed rail connections that, like those in Europe, would link many of America's major cities? Might America's airlines revive their fortunes as restructured air-rail corporations, buying into Amtrak as some European airlines have invested in rail? ◆

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Prepaid Transit at Universities

JEFFREY BROWN, DANIEL BALDWIN HESS, AND DONALD SHOUP

IMAGINE A transportation program that increases transit ridership, reduces traffic congestion, saves energy, cleans the air, and costs very little. Many American colleges offer such a program, and they have given it a variety of names—such as BruinGO, UPass, ClassPass, and SuperTicket. We refer collectively to these programs as Unlimited Access.

Unlimited Access turns student identification cards into public transit passes. The university pays the transit agency an annual lump sum based on expected student ridership, and the transit agency accepts student identification cards as transit passes. For every student on any day, a bus ride to campus (or anywhere else) is free. Unlimited Access is not free transit, but is instead a new way to pay for transit.

To learn how Unlimited Access works, we surveyed 35 universities that offered it during the 1997–1998 school year. We found that the average cost of Unlimited Access was $30 per student per year, and that 825,000 students at the 35 universities were eligible to ride free. Unlimited Access encouraged some students to shift from cars to public transit for their trips to campus, and student transit ridership increased between 71 percent and 200 percent at different universities. At one school the number of vehicle trips to campus decreased by 26 percent. The reduction in vehicle trips reduced parking demand by 400 to 1,000 spaces. Because Unlimited Access allows students to get around without a car, the university financial aid budgets suggest that it can reduce the cost of attending college by up to $2,000 a year.

UNLIMITED ACCESS AT 35 UNIVERSITIES	
Average cost of Unlimited Access	$30 per student per year
Number of students eligible to ride free	825,000
Increase in student transit ridership	71% – 200%
Reduction in parking demand	400 – 1,000 spaces
Reduction in cost of attending college	Up to $2,000 per year
Approval rates in student referenda	54% – 94%

If student fees are increased to pay for Unlimited Access, the students must approve this arrangement in a referendum. The approval rates in these referenda ranged from 54 percent to 94 percent, and the yes votes typically increase in subsequent referenda as students get to know the programs.

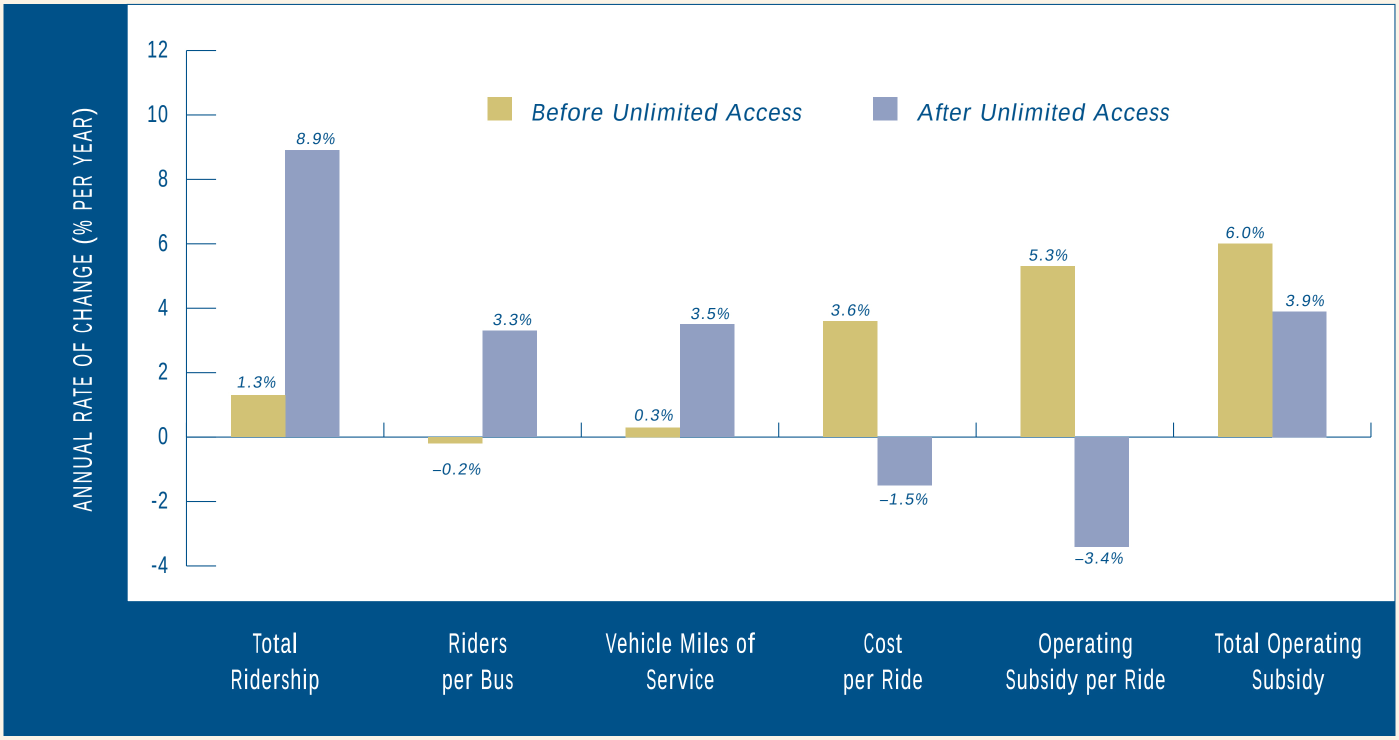
Unlimited Access is a good bargain for universities and students, but is it also a good bargain for transit agencies? To answer this question, we examined the transit agencies' rates of change in total ridership, riders per bus, cost per rider, vehicle miles of service, operating subsidy per rider, and total operating subsidy before and after Unlimited Access began. The first three panels of the bar chart suggest that Unlimited Access improves transit performance: it increases total transit ridership, fills empty seats, and improves transit service. The last three panels suggest that Unlimited Access reduces transit cost: it reduces the operating cost per ride, reduces the operating subsidy per ride, and reduces total operating subsidies.

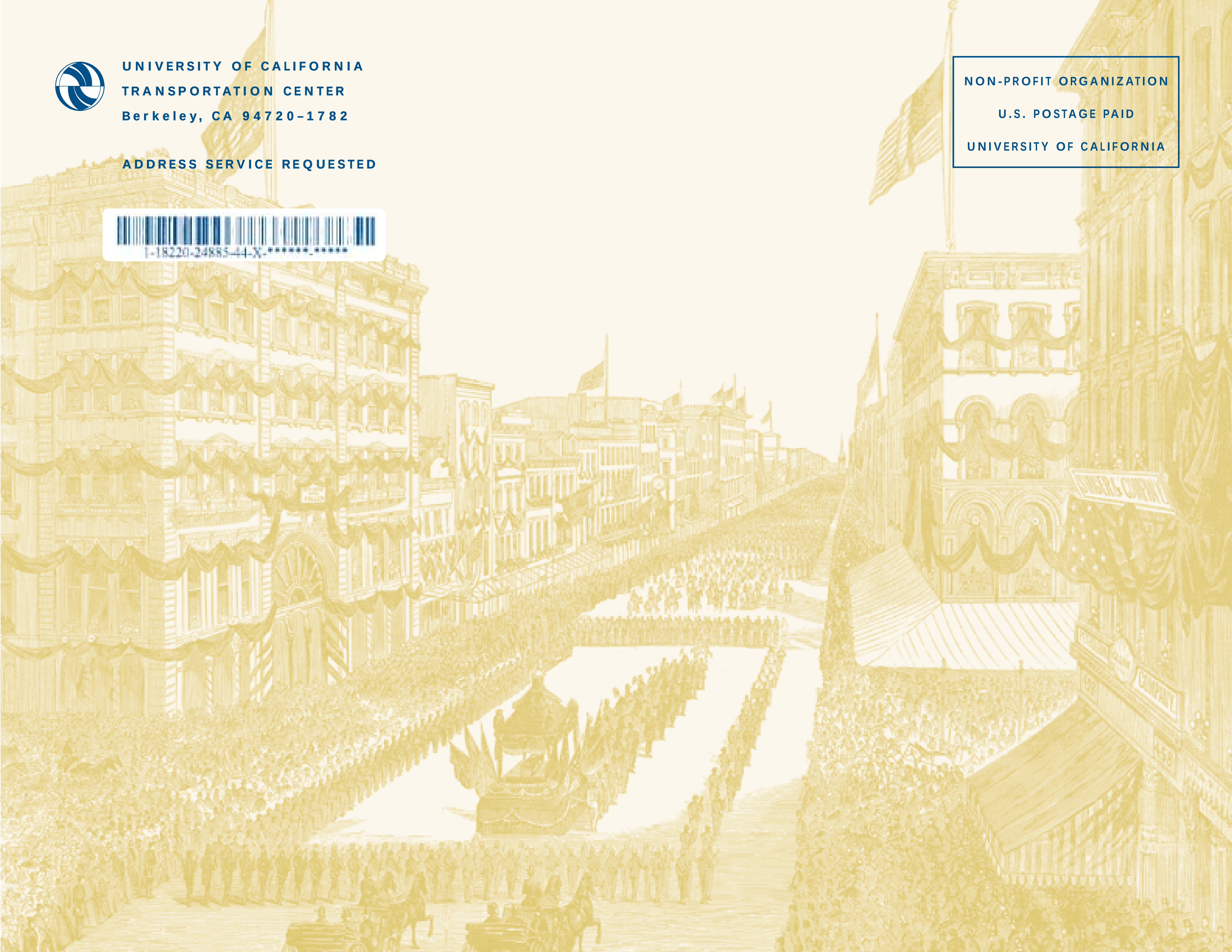
Few transportation reforms increase mobility *and* reduce vehicle trips. Unlimited Access increases mobility by giving students free access to public transportation, and it reduces vehicle trips by shifting some travelers from cars to public transportation. Unlimited Access is a creative, inexpensive way to take advantage of the excess capacity on public transit. Nearly three-fourths of all seats on American public transit are now empty, and transit agencies have found a group eager to buy this excess capacity—university students. Unlimited Access programs serve less than 6 percent of the 14 million students enrolled in American universities, so the opportunity for growth is enormous. Unlimited Access is a promising innovation with great potential. ◆

FURTHER READING

Jeffrey Brown, Daniel Baldwin Hess, and Donald Shoup. 2001. "Unlimited Access." *Transportation* 28(3): 233–267. Available on-line at http://www.sppsr.ucla.edu/its/UA

Average annual rate of change in transit agency performance indicators in the two years before and the two years after Unlimited Access began





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