ACCESS

ACCESS NUMBER 16 SPRING 2000

CONTENTS

The University of California Transportation Center, founded in 1988, facilitates research, education, and public service for the entire UC system. Activities have centered on the Berkeley, Davis, Irvine, Los Angeles, Riverside, and Santa Barbara campuses.

University of California Transportation Center
Berkeley, CA 94720–1782
Fax: 510-643-5456
access@uclink4.berkeley.edu
http://socrates.berkeley.edu/~uctc

Surprises

TRANSPORTATION is a field in which everyone is an expert. If we're bus riders, we know where to catch the bus, which one to take, and what's wrong with the service. Motorists know how to start the car, how to fill it up, and maybe even how to fix it. And there's one topic on which everybody is an authority: traffic.

Everyone knows traffic congestion has been increasing. More: we all know it has become horrendous. A recent public opinion poll where I live says it's the most serious public policy issue of our time. It's no wonder so may university researchers, the "real" experts, are trying to understand its causes and possible remedies. But it's surprising that so many of their findings have been turning out to be counter-intuitive, if not, well, surprising.

In contrast to contract research for which the results can be specified ahead of time, the outcomes of academic research are often wholly unpredictable. University researchers are encouraged to pose their own research questions and then to follow the logic of their inquiries wherever it may lead them. When the system works as it should, the investigators' biases are irrelevant. Whatever their beliefs and hence their preferred findings might be, they bear no influence on the conclusions. The results are frequently surprising, even to the researchers themselves.

In a recent issue of ACCESS, Patricia Mokhtarian and Ilan Solomon told us that most people, in spite of what we may think, actually like to commute. Their studies suggest that policies aimed at lowering traffic peaks are hindered by commuters' preferences for about sixteen minutes' worth of travel.

In an earlier issue Robert Cervero reported on his study into the effects of the spatial mismatch of jobs and housing. He had already written extensively on the subject, and so began his work expecting to find little difference in joblessness among racial groups. But, to his surprise and ours, his new findings showed that race is more important than space in explaining joblessness, at least among African Americans. And so it has commonly gone—surprising research findings and surprising outcomes.

Congestion pricing has gained considerable support in recent years and may stand today as the preferred remedy for traffic congestion, at least among academics. But now along comes Mark Delucchi arguing that, even if we tried to apply marginal social costs pricing, it wouldn't work. He contends that it's too hard to calculate the right prices, and that even if we could do so we'd generate undesired effects such as converting transit riders into car drivers. And besides, he says, there are other things more important than transportation efficiency.

But transportation efficiency is very important to researchers who've been developing plans for automated highways. As Steven Shladover reports here, PATH has successfully demonstrated its design for a new transportation system in which cars can drive themselves, running at very close headways and very high speeds, thus promising a doubling or tripling of freeway capacity and dramatic reductions in congestion. The big surprise to each of us is that a car can drive better than we can.

Perhaps this issue's greatest surprise comes from Timothy Lipman's projections about the future of transportation energy. What might happen, he asks, if the preferred cars of the future turn out to be electrics, powered by fuel cells? They'll be recognized as having such tremendous capacity for generating electricity that they'll be tied in to supplement the electric-power grid. And then, he suggests, instead of plugging our new electric car into the house to recharge it, we might plug the house into the car.

Melanie Curry
Managing Editor

What If Cars Could Drive Themselves?

BY STEVEN E. SHLADOVER

EVEN WHEN cars were still young, futurists began thinking about vehicles that could drive themselves, without human help. Perhaps the best known of these conjectures was the General Motors Futurama, the hit of the 1939 New York World's Fair. During the following decades interest in automated vehicles rose and fell several times. Now, at the start of the new century, it's worth taking a fresh look at this concept and asking how automation might change transportation and the quality of our lives.

Consider some of the implications of cars that could drive themselves.

- We might eliminate the more than ninety percent of traffic crashes that are caused by human errors such as misjudgments and inattention.
- We might reduce antisocial driving behavior such as road rage, rubbernecking delays, and unsafe speeds, thereby significantly reducing the stress of driving.
- The entire population, including the young, the old, and the infirm, might enjoy a higher level of mobility without requiring advanced driving skills.
- The luxury of being chauffeured to your destination might be enjoyed by the general populace, not just the wealthiest individuals, so we might all do whatever we like, at work or leisure, while traveling in safety.
- Fuel consumption and polluting emissions might be reduced by smoothing traffic flow and running vehicles close enough to each other to benefit from aerodynamic drafting.
- Traffic-management decisions might be based on firm knowledge of vehicle responses to instructions, rather than on guesses about the choices that drivers might make.
- The capacity of a freeway lane might be doubled or tripled, making it possible to accommodate growing demands for travel without major new construction, or, equivalently, today's level of congestion might be reduced, enabling travelers to save a lot of time.

IS IT FEASIBLE?

But is this a realistic prospect? Or is it some Buck Rogers fantasy? Based on more than a decade's research at California PATH and other institutions, it is most certainly a genuine prospect for operations on controlled-access freeway lanes. This research has addressed issues ranging from operational concepts to technology development, from societal and institutional issues to the effects on transportation system capacity and safety. The National Automated Highway System Consortium's Demo '97 in San Diego provided an opportunity for visitors from around the world to experience automated vehicles in operation under controlled conditions. The reactions of those visitors were overwhelmingly positive.

Automating the process of driving is a complex endeavor. Advancements in information technology of the past decade have contributed greatly, and research specifically devoted to the design of automated highway systems has made many specific contributions. This progress makes it possible for us to formulate operational concepts and prove out the technologies that can implement them.

AN AUTOMATED DRIVE

We can now readily visualize your trip on an automated highway system:

Imagine leaving work at the end of the day and needing to drive only as far as the nearest on-ramp to the local automated

Steven Shladover is deputy director of PATH (Partners for Advanced Transit and Highways), Institute of Transportation Studies, University of California, Berkeley, Richmond Field Station, 1357 S. 46th St., Building 452, Richmond, CA 94804-4698 (sess@uclink4.berkeley.edu)

highway. At the on-ramp, you press a button on your dashboard to select the off-ramp closest to your home and then relax as your car's electronic systems, in cooperation with roadside electronics and similar systems on other cars, guide your car smoothly, safely, and effortlessly toward your destination. En route you save time by maintaining full speed even at rush-hour traffic volumes. At the end of the off-ramp you resume normal control and drive the remaining distance to your home, better rested and less stressed than if you had driven the entire way. The same capability can also be used over longer distances, e.g. for family vacations that leave everybody, including the "driver," relaxed and well-rested even after a lengthy trip in adverse weather.

Although many different technical developments are necessary to turn this image into reality, none requires exotic technologies, and all can be based on systems and components that are already being actively developed in the international motor vehicle industry. These could be viewed as replacements for the diverse functions that drivers perform every day: observing the road, observing the preceding vehicles, steering, accelerating, braking, and deciding when and where to change course.

OBSERVING THE ROAD

PATH researchers have developed a road-reference and sensing system that makes it possible to determine accurately a vehicle's position and orientation relative to the lane's center. Cheap permanent magnets are buried at four-foot intervals along the lane centerline and detected by magnetometers mounted under the vehicle's bumpers. The magnetic-field measurements are decoded to determine the lateral position and height of each bumper at accuracies of less than a centimeter. In addition, the magnets' orientations (either north pole or south pole up) represent a binary code (either 0 or 1), and indicate precise milepost locations along the road, as well as road geometry features such as curvature and grade. The software in the vehicle's control computer uses this information to determine the absolute position of the vehicle, as well as to anticipate upcoming changes in the roadway.

Other researchers have used computer vision systems to observe the road. These are vulnerable to weather problems and provide less accurate measurements, but they do not require special roadway installations, other than well-maintained lane markings.

OBSERVING PRECEDING VEHICLES

The distances and closing rates to preceding vehicles can be measured by a millimeter-wave radar or a laser rangefinder. Both technologies have already been implemented in commercially available adaptive cruise control systems in Japan and Europe. The laser systems are currently less expensive, but the radar systems are more effective at detecting dirty vehicles and operating in adverse weather conditions. As production volumes increase and unit costs decrease, the radars are likely to find increasing favor.

STEERING, ACCELERATING AND BRAKING

The equivalents of these driver muscle functions are electro-mechanical actuators installed in the automated vehicle. They receive electronic commands from the onboard control computer and then apply the appropriate steering angle, throttle angle, and brake pressure by means of small electric motors. Early versions of these actuators are already being introduced into production vehicles, where they receive their commands directly from the driver's inputs to the steering wheel and pedals. These decisions are being made for reasons largely unrelated to automation. Rather they are associated with reduced energy consumption, simplification of vehicle design, enhanced ease of vehicle assembly, improved ability to adjust performance to match driver preferences, and cost savings compared to traditional direct mechanical control devices.

DECIDING WHEN AND WHERE TO CHANGE COURSE

Computers in the vehicles and those at the roadside have different functions. Roadside computers are better suited for traffic management, setting the target speed for each segment and lane of roadway, and allocating vehicles to different lanes of a multilane automated facility. The aim is to maintain balanced flow among the lanes and to avoid obstacles or incidents that might block a lane. The vehicle's onboard computers are better suited to handling decisions about exactly when and where to change lanes to avoid interference with other vehicles.

NEW FUNCTIONS

Some additional functions have no direct counterpart in today's driving. Most important, wireless communication technology makes it possible for each automated vehicle's computer to talk continuously to its counterparts in adjoining vehicles. This capability enables vehicles to follow each other with high accuracy and safety, even at very close spacings, and to negotiate cooperative maneuvers such as lane changes to increase system efficiency and safety. Any failure on a vehicle can be instantly known to its neighbors, so that they can respond appropriately to avoid possible collisions.

In addition, there should be electronic "check-in" and "check-out" stations at the entry and exit points of the automated lane, somewhat analogous to the toll booths on closed toll roads, where you get a ticket at the entrance and then pay a toll at the exit, based on how far you traveled on the road. At check-in stations, wireless communication between vehicles and roadside would verify that the vehicle is in proper operating condition prior to its entry to the automated lane. Similarly, the check-out system would seek assurance of the driver's readiness to resume control at the exit. The traffic management system for an automated highway would also have broader scope than today's traffic management systems, because it would select an optimal route for every vehicle in the system, continuously balancing travel demand with system capacity, and directing vehicles to follow those routes precisely.

Most of these functions have already been implemented and tested in experimental vehicles. All except for check-in, check-out, and traffic management were implemented in the platoon-scenario demonstration vehicles of Demo '97. A single 166 MHz Pentium computer (obsolete by standards of today's normal desktop PCs) handled all the necessary in-vehicle computations for vehicle sensing, control, and communications.

REMAINING TECHNICAL CHALLENGES

The key technical challenges that remain to be mastered involve software safety, fault detection, and malfunction management. The state of the art of software design is not yet sufficiently advanced to support the development of software that can be *guaranteed* to perform correctly in safety-critical applications as complex as road-vehicle automation. Excellent performance of automated vehicle control systems (high accuracy with superb ride comfort) has been proven under normal operating conditions, in the absence of failures. Elementary fault detection and malfunction management systems have already been implemented to address the most frequently encountered fault conditions, for use by well-trained test drivers. However, commercially viable implementations will need to address *all* realistic failure scenarios and provide safe responses even when the driver is a completely untrained member of the general public. Significant efforts are still needed to develop system hardware and software designs that can satisfy these requirements.

NONTECHNICAL CHALLENGES

The nontechnical challenges involve issues of liability, costs, and perceptions.

Automated control of vehicles shifts liability for most crashes from the individual driver (and his or her insurance company) to the designer, developer, and vendor of the vehicle and roadway control systems. Provided the system is indeed safer than today's driver-vehicle-highway system, overall liability exposure should be reduced. But its costs will be shifted from automobile insurance premiums to the purchase or lease price of the automated vehicle and toll for use of the automated highway facility.

All new technologies tend to be costly when they first become available in small quantities, then their costs decline as production volumes increase and the technologies mature. We should expect vehicle automation technologies to follow the same pattern. They may initially be economically viable only for heavy vehicles (transit buses, commercial trucks) and high-end passenger cars. However, it should not take long for the costs to become affordable to a wide range of vehicle owners and operators, especially with many of the enabling technologies already being commercialized for volume production today.

The largest impediment to introduction of electronic chauffeuring may turn out to be the general perception that it's more difficult and expensive to implement than it really is. If political and industrial decision makers perceive automated driving to be too futuristic, they will not pay it the attention it deserves and will not invest their resources toward accelerating its deployment. The perception could thus become a self-fulfilling prophecy.

It is important to recognize that automated vehicles are already carrying millions of passengers every day. Most major airports have automated people movers that transfer passengers among terminal buildings. Urban transit lines in Paris, London, Vancouver, Lyon, and Lille, among others, are operating with completely automated, driverless vehicles; some have been doing so for more than a decade. Modern commercial aircraft operate on autopilot for much of the time, and they also land under automatic control at suitably equipped airports on a regular basis.

Given all of this experience in implementing safety-critical automated transportation systems, it is not such a large leap to develop road vehicles that can operate under automatic control on their own segregated and protected lanes. That should be a realistic goal for the next decade. The transportation system will thus gain substantial benefits from the revolution in information technology. ◆

FURTHER READING

Steven E. Shladover, "Why We Should Develop a Truly Automated Highway System," *Transportation Research Record,* No. 1651, pp. 66–73, 1998.

Steven E. Shladover, "Progressive Deployment of Vehicle-Highway Automation Systems," Sixth World Congress on Intelligent Transport Systems, Toronto, Nov. 1999.

Steven E. Shladover, "Progressive Deployment Steps Leading Toward an Automated Highway System," 79th TRB Annual Meeting, Washington, DC, January 2000, Paper No. 00-0835.

Power from the Fuel Cell

BY TIMOTHY E. LIPMAN

Automobiles are often criticized for consuming so much petroleum. While much has been done in the past twenty years to make vehicles pollute less, the growing popularity of larger vehicles is making vehicles consume more energy. However, emerging technologies suggest that new generations of vehicles can be built that will be much more efficient than those on the roads today. Furthermore, the prospect of future vehicles incorporating electric drive systems means they may be able to integrate with the electricity grid in a novel way: they may be able to supply electricity *to* the grid, thereby eliminating the need to build new power plants in some areas.

Ever since the 1920s, people have been predicting that the following twenty years would see the end of world oil supplies. More recently, the energy crises of the 1970s led many of us to believe that gasoline was already becoming scarce. But we now find there are huge amounts of crude oil still left in the earth's crust. Experts debate how much of the remaining oil can be extracted, but the US Geological Survey's 1993 review estimated that proven and as-yet-undiscovered reserves amount to 1.6 trillion barrels of oil. Compare that with the approximately 800 billion or so barrels consumed so far in all human history.

If all of the estimated remaining oil were used up at the present global consumption rate of seventy million barrels per day, the supply would last about sixty years. Forecasted increases in demand, anticipating huge expansion in developing countries, make it reasonable to predict that crude oil will become scarce sometime in the middle of this century. However, even when crude oil does become scarce, it is possible that billions or even trillions of gallons of synthesized gasoline could be produced from the abundant global supplies of natural gas and coal. It's not certain at this time how much those fuels might cost, but the implication is clear: If demand for petroleum-based fuels remains strong, the oil industry will be able to match it for many years beyond the middle of the 21st century.

Even so, an increasing proportion of the oil and natural gas consumed in the US will be imported. Prior to about 1950, we produced nearly all the oil and natural gas we needed. But imports grew steadily in the period since then, and by 1992 oil imports exceeded domestic production. In 1998, the US imported a record 9.5 million barrels of oil per day—over 55% of total consumption. Increasing reliance on imports contributes to the nation's negative balance of trade and exposes us to potential adverse economic effects from oil price and supply shocks. When OPEC embargoed sales to the US in the '70s, the imposed "oil shortage" caused high gasoline prices and long lines at gas stations because we had become dependent on petroleum for transportation. With imports on the rise, the US remains vulnerable to future political instability in the Middle East and other oil-producing regions.

Despite this abundant supply of fossil fuels, the climactic implications of burning the remaining vast stores of oil, natural gas, and coal, though uncertain, are potentially dire. Recent analysis of the potential social costs of climate change have shown that when carbon dioxide concentrations reach double their 1990 levels (predicted to happen in about the middle of the 21st century), damages to the economies of both developed and developing nations could be in the range of 1.4% to 1.9% of gross domestic product each year.

THE FUTURE OF ENERGY USE

In any case, oil supplies are finite. Eventually we'll have to find substitutes, either in response to scarcity or to stabilize emissions of greenhouse gases. But the future is not entirely bleak.

Global supplies of natural gas are huge. Existing reserves are estimated at over five quadrillion cubic feet, or almost one million cubic feet for each person on the planet. Already thousands of cars, taxis, buses, and trucks around the world are running on natural gas stored in tanks on board. Natural gas burns cleanly, and thousands of hours of real-world experience have proven it safe. Natural gas is particularly advantageous when used in urban

Timothy Lipman is associate director of the Fuel Cell Vehicle Center at the Institute of Transportation Studies, University of California, Davis, CA 95616 (telipman@ucdavis.edu)

buses and short-haul trucks because, unlike diesel fuel, it produces very low levels of unhealthy particulate matter.

The next likely source of energy for vehicles is electricity. Recent technological innovations—including better batteries and ultracapacitors, better electric motors and motor-control systems, and lightweight materials—are leading to the prospect of vehicles that carry stored electricity, rather than petroleum products, on board. The electric energy can be drawn from many sources, such as renewable solar, wind, geothermal, and hydroelectric as well as conventional fossil-fuel and nuclear sources. Initially it is being stored in batteries that act like gas tanks, carried along in the vehicle as it makes its way.

Many analysts expect that the technological successor to the electric vehicle with on-board electricity storage is most likely to be the fuel-cell vehicle. Fuel cells are fundamentally different from batteries. Instead of merely storing and releasing electricity, they generate it by converting hydrogen gas and oxygen into water via processes that force electrons to flow. Hydrogen can be drawn from an array of different feedstocks—natural gas, methanol, biomass, and even water converted into hydrogen and oxygen by electrolysis. These several options promise that motor vehicles will become less and less reliant on petroleum-based fuels, while also potentially reducing air pollution and greenhouse gases.

MOTOR VEHICLES AS GENERATORS?

But the possibilities presented by widespread use of fuel-cell vehicles are enormous, going far beyond reductions in petroleum use and pollution. Once the national vehicle fleet has been converted to fuel cells, it will become obvious that it represents a tremendous latent electric-power resource. A few bold analysts—including Amory Lovins, Willett Kempton, and Kelly Kissock—suggest that electricity generated by fuel-cell vehicles could be routed directly into homes or into the electric-power grid and used to provide peak power (or even base-load power) for nontransport uses. Cars parked in residential garages could be used to cook dinner or heat the house. When not needed at home, the car's electricity could be sold to managers of the grid.

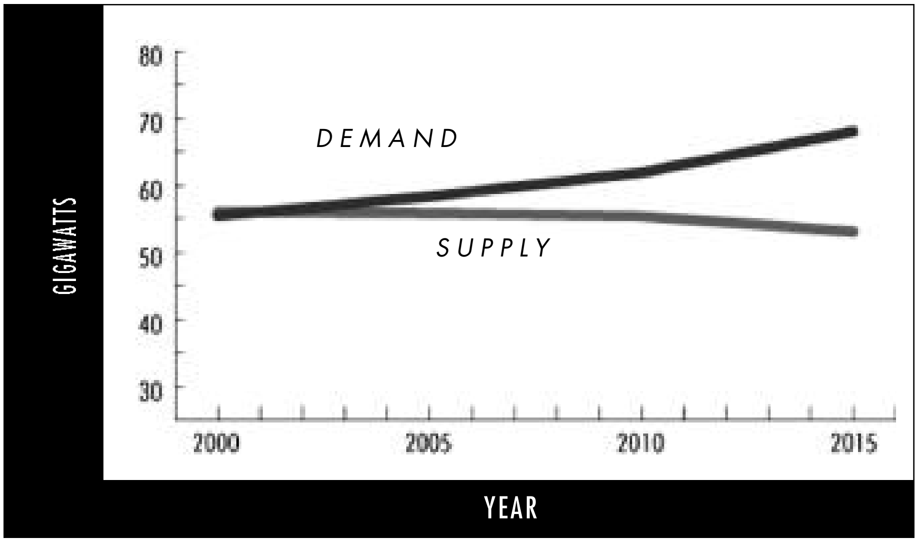
The current motor-vehicle fleet in the US (about 146 million vehicles) has a total power-generating capacity equivalent to about 14 terawatts (trillion watts). If used as generators, they could produce about 12 terawatts of electric power (generators are about 85% efficient). That's approximately sixteen times the entire present stationary electric-generating capacity in the US!

Motor vehicles are driven an average of about one hour a day, so the generating capacity of the vehicle fleet would be idle approximately 95% of the time. A fleet of 100,000 fuel-cell electric vehicles would be capable of producing about 4.8 gigawatts (billion watts) of power for the grid, assuming 50 kilowatts net fuel-cell output of power per vehicle and 95% vehicle availability. Even if the vehicles were available for generating power only 50% of the time, those 100,000 vehicles could still contribute about 2.5 gigawatts. So, if we suppose that half the vehicles in California's South Coast Air Basin were fuel-cell powered (say by about 2020 or so), with each vehicle able to supply 50 kW of power to the grid half the time, the total generating capacity of these vehicles would be nearly double the present level of installed generating capacity in the entire state.

Using fuel-cell vehicles in this way could help reduce the need for additional power-generating capacity to meet California's expected 1.8% annual growth in demand for electricity (and 1.7% annual growth in peak-period demand) over the next decade. In the shorter term it could make up at least some of the expected electricity-supply deficit of 2.8 gigawatts in 2003 and 6.7 gigawatts by 2007. Figure 1 shows the forecasted electricity supply gap in California from 2000 to 2015.

FIGURE 1

Forecasted annual peak electric power supply and demand for California



Source: California Energy Commission, 1997

This arrangement would require some additional equipment where the electricity produced by the vehicle interfaces with the electrical grid. However, if "smart meters" could monitor the spot price of electricity and activate the system when the price is right, electricity generated by the fuel cell could be sold to the grid at a profit. Imagine getting a check from the utility company instead of a bill! Particularly with early fuel-cell vehicles, which will be expensive, this arrangement could help to offset some of the vehicle's cost. For example, a 50 kW automotive fuel-cell system producing electricity an average of twelve hours per day could see a profit of $0.02 per kWh, which would net approximately $4,380 per year for the vehicle's owner.

FUTURE DEVELOPMENT POSSIBILITIES

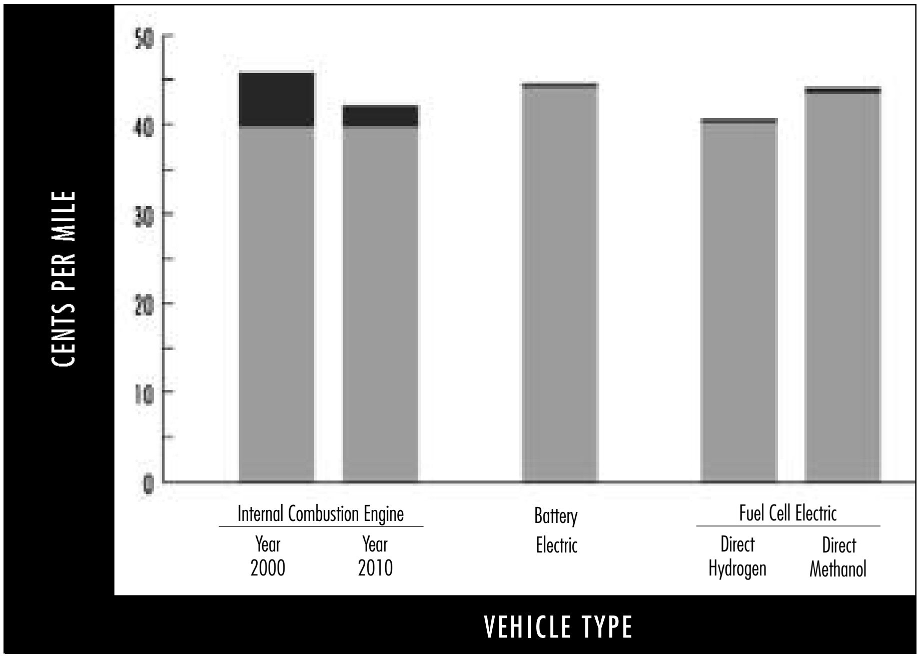
Emerging technologies hold out prospects for both new types of vehicles and new synergies in energy production and consumption. However, these emerging vehicle types still face several important obstacles, and these hurdles must be overcome if they are to succeed in the marketplace. Some new vehicles, especially battery-powered ones, have attributes that may be unattractive to consumers, such as relatively short driving ranges and long recharging times. Consumers accustomed to the performance of conventional vehicles may be discouraged from buying and using battery-powered cars. Further, new technologies inevitably carry high initial costs because production volumes are low and designs are perfected only incrementally over time. As production volumes increase for such components as batteries, electric motors, and fuel cells, manufacturing costs will decline. However, manufacturing costs for new vehicle types may exceed those of conventional vehicles for some time, resulting in another market hurdle. Our studies at UC Davis conclude that, even in mature, high-volume production, the retail prices for some of these new vehicle types may exceed those for conventional vehicles by at least a few thousand dollars per car.

On lifecycle bases, however, costs of battery and fuel-cell vehicles may become quite competitive with conventional vehicles, even if their initial costs are higher. This is owing to greater fuel efficiency, as well as greater longevity of components and reduced maintenance requirements. So, if battery and fuel-cell cars are to make it in the marketplace, consumers must learn to account for vehicle lifecycle costs in addition to initial purchase prices.

When social costs are included—accounting for damages from air pollutants and greenhouse gases, for example—relative lifecycle costs of electric vehicles look more attractive. Figure 2 shows total vehicle-lifecycle plus emission-cost estimates for battery-powered vehicles, direct-hydrogen fuel-cell cars (i.e., fuel-cell vehicles that store hydrogen on-board, rather than generating it from a liquid fuel with a fuel reformer), and direct-methanol fuel-cell vehicles (an emerging technology whereby liquid methanol and air are converted directly into electricity, water, and carbon dioxide, without the methanol being first reformed into hydrogen). The table assumes high-volume component production and vehicle operation in the Los Angeles area. The figure suggests that hydrogen fuel-cell vehicles

FIGURE 2

Vehicle lifecycle costs and emission costs: high-volume production, middle-range case (in 1997 cents per mile)



may be particularly attractive, with possible total lifecycle and externality costs below even those of low-emission internal combustion engine vehicles. There are, of course, significant uncertainties in estimates of this sort, and Figure 2 shows only one estimate—the middle-range case—from among many other plausible ones.

To be sure, these optimistic projections may prove too rosy. The developmental paths of technologies are seldom either straight or smooth, especially when they run into unanticipated financial and environmental entanglements. Certainly the next research and development tasks are to find a path to economical and safe supplies of hydrogen, as well as to drive down fuel-cell system costs through product and process innovations. The industry must develop the equipment needed to produce hydrogen with low demand on carbon-based fuels and with low environmental damage. And then it must find ways of handling this explosive gas safely. No doubt numerous other troublesome problems will arise along the way. But the potential advantages of fuel cells as clean and reliable sources of power suggest that they are likely to attract the attention they deserve.

CONCLUSIONS

Because oil resources are finite, they will run out—not soon, but eventually. As supplies decline, prices will rise, creating incentives for alternative supplies of energy, especially natural gas and renewable sources such as solar and biomass. Electric-powered vehicles are already becoming plausible substitutes for today's internal combustion vehicles. Fuel-cell vehicles are an increasingly promising idea, and they appear to be the likely long-run successors to the petroleum-powered cars, buses, and trucks that dominate our cities today. In the future, integration of fuel-cell vehicles with our electric power generating systems could help to reduce the need for further investments in large-scale power generators, as well as helping to achieve the environmental and social goals of better air quality, reduced emissions of greenhouse gases, and eased dependence on imported fossil fuels. ◆

FURTHER READING

Willett Kempton and Steven E. Letendre, "Electric Vehicles as a New Power Source for Electric Utilities," *Transportation Research–D,* v. 2, no. 3, pp. 157–175, 1997.

J. Kelly Kissock, "Combined Heat and Power for Buildings Using Fuel-Cell Cars," *Proceedings of the ASME International Solar Energy Conference,* Albuquerque, NM, pp. 121–132, June 13–18, 1998.

Timothy E. Lipman, *Zero-Emission Vehicle Scenario Cost Analysis Using a Fuzzy Set-Based Framework,* Ph.D. Dissertation (University of California, Davis: Institute of Transportation Studies, 1999). UCD-ITS-RR-99-18.

Amory B. Lovins and Brett D. Williams, *A Strategy for the Hydrogen Transition,* Rocky Mountain Institute, Snowmass, Colorado (presented at the Meeting of the National Hydrogen Association, Vienna, Virginia, April 7–9, 1999).

Should We Try To Get The Prices Right?

BY MARK DELUCCHI

THERE IS considerable interest these days in "getting the prices right" in transportation. Some environmentalists and supporters of mass transit believe the "right" prices will induce a lot of people to switch from cars to public transit. So they advocate a variety of additional charges on vehicles, fuel, road use, emissions, and so on. Some economists believe that the "right" prices will lead to an economically efficient and socially desirable use of transportation modes and fuels.

In a society seeming to become ever more leery of government regulations, and concomitantly more enamored of "market" solutions to difficult social problems, there can be strong appeal to getting the prices right in transportation. Arguably, if we can estimate and implement transportation prices intelligently, without slighting efforts towards important social objectives that are not well addressed by pricing, then perhaps we ought to try to "get the prices right." But that's a big "if." For three reasons, I believe we should be wary of embracing pricing as a solution to transportation problems:

Poor pricing schemes might do more harm than good. Pricing is difficult. It's difficult to estimate the "right" prices, and harder still to implement "right" pricing. So-called "second-best" solutions can leave us worse off than we'd be with no change in our current pricing system at all.

Pricing might surprise and disappoint some of its advocates. Contrary to expectations, the use of pricing to "level the playing field" will induce people to shift from transit to autos, because presently the field is tilted in favor of public transit. Those who feel it important to get people out of their cars should focus on improving the quality and reducing the cost of alternatives.

Pricing might detract from important noneconomic concerns. In matters as complex and socially important as transportation, we care about a good deal more than economically efficient pricing, even broadly defined. We care about distributive fairness, equal opportunity, uncertainty and risk, ecological stability, future generations, quality of life, and so on. We should not subordinate or abandon these concerns to efficient pricing.

In short, pricing might turn out to be counterproductive, ineffective, or irrelevant. If we are unable to estimate and implement transportation prices intelligently, without slighting efforts towards other important social objectives, then we should continue to rely on other tools. To deal with our multidimensional transportation problems, we can turn to performance standards, education, and market incentives designed with more than just economic efficiency in mind.

In the following sections, I develop these cautions in more detail. I conclude with a discussion of alternatives to pricing. First, though, we must define "right prices" more carefully.

WHAT IS A RIGHT PRICE?

The "right" transportation prices are generally considered to be *efficient* prices—the prices that arise in a properly functioning competitive market and result in an economically efficient use of transportation resources. Economists have developed an elaborate theory of efficient pricing. Generally, the efficient price of a resource is its *marginal social cost* (MSC). The *social* cost is the cost to society as a whole, which may or may not be the same as the "private" cost that an individual pays. The *marginal* cost is the cost of an incremental unit of a resource, as distinguished from the average cost of a great many units.

Users of cars, buses, and trains already pay at least some of the social cost: they pay for vehicles, fuel, insurance, repairs, transit fare, and so on. If all these transportation markets were perfect, then users would face efficient prices. But, of course, we know that transportation markets are not perfect—that trans-

Mark Delucchi is a research scientist at the Institute of Transportation Studies, University of California, Davis, CA 95616 (madelucchi@ucdavis.edu)

AN EXAMPLE OF MSC PRICING

An individual is thinking about making a particular trip. Suppose the value of the trip to him is $10.75. If he goes by bus, the trip will cost him, by his own reckoning: $0.75 in fare, $8 in time, and $0.25 in potential accident costs—$9 total cost. From his point of view, cost is less than his valuation, so he takes the trip. But suppose further that the total social cost of the trip is $11, including $2 in subsidies. From society's point of view, the $11 total social cost will exceed the benefit. If society decides to raise bus fares enough to "get the prices right," the cost to the potential bus rider will exceed the benefit, and he won't take the trip.

Now, let's introduce another mode of transportation. Suppose the person can also make the trip by car, for a cost of $7 in time, $0.50 in potential accident cost to himself, and $2 in fuel, operating, and depreciation costs—$9.50 total. Without MSC pricing, the traveler will choose the $9 bus trip over the $9.50 car trip. But suppose now that the external accident and pollution costs of the car trip are a relatively high $1. The total MSC of the car trip then is $10.50, which is less than the $11 MSC of the bus trip, and less than the benefit. Thus, if the traveler faces MSC prices for all modes, he will in this example switch from the bus to the car, and save society $0.50.

portation gives rise to a variety of social costs that are not properly priced: air pollution, noise, congestion, some accident costs, costs related to importing oil, and some public infrastructure and service costs. These unpriced costs may be called, loosely, "externalities," or, even more loosely, "subsidies." These externalities, or subsidies, can create an unhappy situation in which the cost to individuals is less than, but the cost to society greater than, the benefit to society (see sidebar). Some individuals win, but society loses.

We may say, then, that to "get the prices right," we should make transportation users pay their external costs, or subsidies. To do this, we first must identify and estimate the subsidies.

THE DIFFICULTY OF PROPERLY ESTIMATING AND IMPLEMENTING MSC PRICING

With good reason, many people are skeptical about estimated external costs of transportation. The best estimates of virtually all important external costs—air pollution, noise, accidents, congestion, and oil importing—vary by about an order of magnitude. (Estimates of infrastructure, service, capital, and operating subsidies are less uncertain.) Although further research and analysis can in principle reduce this uncertainty, they might not reduce it enough for us to pick the "right" price with confidence, especially for environmental externalities. Some issues, such as valuing mortality related to air pollution, may be intractable. Presently, researchers raise as many issues as they resolve.

Even if we could estimate the right prices precisely, it would be difficult to install efficient pricing. Ideally, prices would not be fixed for a vehicle-mile of travel or gallon of fuel. Rather they would vary with the factors that determine the external costs being priced: ambient conditions, road attributes, traffic characteristics, exposed population, and so on. But it would be difficult to measure these in real time.

The real-world technical and political difficulties of measuring and pricing each external cost precisely at the margin suggest that a practical pricing scheme would seriously compromise theoretical purity—perhaps so much that we couldn't be sure how much benefit, if any, we would gain. Suppose, for example, that the best we can do in the name of MSC pricing is to raise the gasoline tax. Although this might be practical and might on its face seem to promise improvement, in effect it would be so far from theoretically correct MSC pricing that, without sophisticated and comprehensive analyses, we couldn't be sure we've done any good at all. There are two general reasons for this:

1. *The gasoline tax does not match well with the external costs of gasoline use.* External costs vary from place to place and time to time, but within each state the gasoline tax does not. At some times or places, the tax might exceed the actual external cost, hence deterring people from making trips that are socially beneficial. At other times or places, the tax might not be high enough to deter socially harmful trips. These real-world shortcomings easily could erode most of the theoretical benefit of proper MSC pricing. And when the actual cost of setting up and running the tax system is considered, we might be no better off than with no tax at all.

2. *We would have failed to apply social-cost pricing to all transportation options.* Even if we were able to apply exact marginal-cost prices to, say, gasoline use, we still could have perverse outcomes if we don't apply MSC pricing to *all* transportation

options. Turn again to the example in the sidebar, but suppose now that the personal time cost of the bus trip is $9 instead of $8. Without MSC pricing, the traveler will choose the $9.50 car trip over the $10 bus trip. This is the best choice for society, because the $10.50 MSC of the car trip is less than the $12 MSC of the bus trip. However, if we apply MSC pricing to motor-vehicle use but not bus use, then the traveler will choose the bus (still $10 private cost but $12 social cost) over the car (now $10.50 private and social cost, including the $1.00 externality charge), and society will be worse off than with no MSC pricing at all.

I emphasize that these are problems not with the ideal theory of MSC pricing, but rather with *any* imperfect application (including, for example, charges per vehicle mile of travel), especially to environmental externalities such as air pollution. Although it is possible, in principle, to analyze these issues carefully and lessen problems, such "second-best" analyses are as complicated and uncertain as analyses of external costs. One might reasonably be skeptical of building policy on such compounded uncertainty.

MARGINAL SOCIAL COST PRICING WOULD FAVOR PASSENGER GASOLINE VEHICLES

Some people advocate "getting the prices right" in the belief that it will encourage the use of public transit or new transportation technologies, such as electric vehicles. But if the "right" prices are supposed to be *efficient* prices, then, as mentioned above, all transportation modes must be priced at MSC. As we shall see, the subsidies to public transit generally are much greater than the external costs of automobile use, per passenger mile; as a result, MSC pricing generally would favor auto use over transit use. Similarly, MSC pricing probably would favor conventional gasoline vehicles over new vehicle technologies.

The table below compares external costs and subsidies of gasoline passenger vehicles with those of electric vehicles, buses, and trains. Each entry in the table is the estimated cost of the externality created by use of a particular transportation mode, expressed as cents per mile. I show what I think is the most likely value, and, in some cases, a range indicative of the uncertainty discussed above. The estimates are derived from my work on the social cost of motor-vehicle use, analyses by the Federal Highway Administration of the appropriate allocation of social costs to different modes, and reported capital and operating costs and fare revenues of transit operators.

The first row of the table estimates the air pollution externality (health, physical damage, etc.). For gasoline-powered autos, the most likely cost is 2 cents per vehicle mile, and the range of possible estimates goes from 0.8 to 13 cents per mile. Electric

External costs and subsidies for different passenger-transport modes (cents per vehicle mile, except last row is cents per passenger mile)
[Numbers in brackets are my best estimates]

COST ITEM	GASOLINE AUTO	ELECTRIC AUTO	TRANSIT BUS	LIGHT RAIL	HEAVY RAIL
Air pollution	0.8 to 13 [2.0]	1.5	5.4 to 123 [20.0]	5*	5*
Oil use, water pollution	0.3 to 1.5 [0.8]	0.4	1.5 to 8.7 [4.0]	1*	1*
Noise	0.01 to 2.0 [0.2]	0.15	0.5 to 10.0 [2.0]	1*	1*
Congestion	4.0	4.0	8.0	not estimated	not estimated
Accidents	2.5	2.6	3.5	2*	2*
Marginal highway and service costs	0.1	0.1	1.5	0	0
Unpriced parking	0 to 8 [0]	0 to 8 [0]	0	0	0
Inefficient highway user taxes and fees, meant to cover highway costs	–2.7	0	0 (exempt from fuel taxes)	0	0
Government subsidy:					
Operating costs minus fares	0	0	339	685	372
Operating + rolling-stock costs minus fares	0	0	[398]	1,137	797
Total operating + capital costs minus fares**	0	0	465	2,800	1,177
Extra private costs relative to gas auto	0	0 to 16 [8]	see subsidy	see subsidy	see subsidy
Total cents per vehicle-mile	5 to 28.4 [6.9]	8.8 to 24.8 [16.8]	359 to 620 [437]	694 to 2,809	381 to 1,186
Passengers per vehicle	assume 1.0	assume 1.0	10.9 (avg.)	25.7 (avg.)	22.3 (avg.)
Total cents per passenger-mile	5 to 28.4 [6.9]	8.8 to 24.8 [16.8]	33 to 57 [40]	27 to 109	17 to 53

* Data are not available for these numbers, which are estimated based on my studied judgment.

** Note that, because the official statistics do not report passenger fare payments by individual transit mode, it is not possible to calculate the actual government subsidy for each mode. I have assumed that ratio of fare payments to operating expenses is the same for all modes.

autos are nearly as high, 1.5 cents per vehicle mile, because of emissions from power plants. The externality from transit buses is 20 cents per vehicle mile—ten times higher than the air pollution externality of autos, so a bus must carry ten times more passengers, averaged over the day, to have a lower air pollution cost per passenger-mile. The "Government Subsidy" row gives three estimates for each public transit mode, depending on the three possible definitions of cost.

These costs are added up for each mode: for example, autos cost 6.9 cents per vehicle mile, transit buses cost $3.59 to $6.20 per vehicle mile. Then these figures are divided by an average load factor to compute the cost per passenger mile for each mode: 6.9 cents per mile for autos, 33 to 57 cents per mile for transit buses. (The load factor for buses and trains varies widely, from close to zero during off-peak hours in some suburban areas, to several times the average in some cities during periods. However, the average gives a good picture of the overall status.)

For electric and gasoline vehicles, I compare private ownership and operating costs and relevant external costs for advanced technology vehicles in high-volume production. We see that a gasoline vehicle does indeed generate greater external costs, but this difference is smaller than the difference in private costs of ownership and operation. The private cost per mile of a technologically mature electric vehicle (EV) will be greater than that of a clean and efficient modern gasoline car. As a result, it's unlikely that MSC pricing would induce many people to buy and use EVs instead of gasoline vehicles. Other researchers have reached broadly similar conclusions regarding EVs and other alternative-fuel vehicles.

The comparison of auto with public-transit use is dominated by the enormous direct government subsidies to buses and trains. These subsidies are the differences between the cost and the fares received from users. In official transit statistics, the subsidy is estimated against *operating* costs only. In these official statistics, the operating subsidy alone is about $1.40 per passenger, or nearly 30 cents per passenger mile, averaged over all transit modes.

However, one can argue that an efficient price for transit would cover some or all of the capital costs. (Unsubsidized providers of transit, such as taxi and van companies, presumably price to cover capital costs). In the table, I show the subsidy estimated with respect to operating costs, operating costs plus the cost of rolling stock, and operating costs plus all capital costs.

On the auto side of the ledger, there is some question as to whether "free" parking is a subsidy. I believe it is not, at least not entirely, because in perfect markets some (and perhaps most) parking would remain unpriced. Nevertheless, I have shown a high-end estimate that counts the cost of all unpriced parking as a subsidy.

It turns out, though, that it really doesn't matter how one does the accounting. In virtually every case, the total subsidy to transit greatly exceeds the total subsidy to auto use, per passenger mile, in both absolute terms and relative to the prices users currently pay. *Thus, the elimination of subsidies in accordance with a plan for MSC pricing (and optimal investment) would, on average, reduce, not increase, the use of public transit.*

I do not mean to imply by this that MSC pricing would have no effect on automobile use. Motor-vehicle users are not insensitive to price. If they face road tolls, higher fuel or vehicle taxes, mileage charges, and so on, they might drive less, carpool more, drive at different times, buy and use different vehicles, use different fuels, or switch modes. In certain places, at certain times, these changes might add up to noticeable reductions in congestion, air pollution, accidents, or energy use. But it is almost inconceivable that social-cost pricing, *by itself,* would dramatically reverse the heretofore ineluctable, long-term, world-wide increase in ownership and use of motor vehicles. The private benefits of motor-vehicle use are too great, and the costs of alternatives too high, for MSC pricing to have anything more than marginal effects. Recent studies of the effects of pricing on mode choice and travel, along with evidence of growing auto ownership and use in countries with much higher vehicle and fuel taxes than in the US, support this conclusion. The wealthier a society gets, the more cars it buys and the more miles it drives. To price modes at MSC will not reverse this trend. (Of course, it is possible to manipulate prices so that many people will switch to public transit, but the price differentials required to achieve this would far exceed what could be justified on the grounds of economic efficiency.)

Some advocates of MSC pricing might reply: "So be it. If that's all that MSC pricing accomplishes, then that's all that *should* be accomplished." But most folks do not believe that social cost-benefit analysis reflects everything that society cares about, or that all problems can or should be addressed by pricing. Many analysts believe that the present state of practice in cost-benefit analysis does not satisfactorily accommodate social concerns about distributive fairness, equal opportunity, uncertainty and risk, ecological stability, future generations, quality of life, and so on. They believe that these concerns still need to be worked out in messy political processes, not subordinated to or eviscerated in analyses of efficient pricing. To allow for these concerns, we must continue to use and develop politically open policies that are informed, *but not determined,* by technical economic analyses.

OTHER POLICIES

Emission standards. It is unarguable that emission standards on automobiles have greatly reduced air pollution and measurably improved urban air quality. And it is inconceivable that, had we started with emission taxes rather than standards almost thirty years ago, we would have ended up with the near-zero-emission vehicles that we have today. What is arguable is whether any particularly stringent standard or technology mandate (such as the zero-emission vehicle mandate of the California Air Resources Board) is in some sense "worth it." Social-cost/benefit analysis can and should inform—but not *decide*—these arguments.

Economic tools in a broader social context. Transportation markets can be manipulated to help achieve broad social goals. For example, society can decide on appropriate environmental or social constraints on transportation. It could then control relevant transportation "quantities"—numbers of vehicles in a particular area at a particular time, for example—rather than prices, in order to more directly satisfy the constraints. Something akin to tradeable permits could be used to allocate the politically determined total quantities efficiently among all users. (This is done now in the electricity sector, to reduce emissions of sulfur dioxide.)

Research and development. The best way to get people to buy and use inherently clean alternative transportation technologies, such as fuel-cell electric vehicles, is to make them attractive on the basis of private cost. This requires aggressive long-term research and development to improve performance and lower sales prices.

Fuel-economy standards. There are good arguments that fuel-economy standards, not fuel prices, caused the development of more fuel-efficient vehicles, and that the standards, moreover, did not have pernicious side effects. Of course, this does not mean that fuel-economy standards should be raised indefinitely (or even at all), or that standards should be set without regard to costs. The point, once again, is that social-cost/benefit analysis should inform, but not decide, energy policy.

Focused transit and land-use planning. Although transit and land-use policies may never have a significant effect on total urban pollution, congestion, energy use, or accidents, they can focus successfully on certain problems. For example, a small auto-free zone in a city center will have essentially no effect on global climate, but it may make the city center a decidedly nicer place. Similarly, innovative urban transit programs for the poor will not affect oil imports, but they can be important components of programs for the urban underclass. These require innovative transit and land-use policies focused on improving the quality and reducing the cost of alternatives to private automobile use—not MSC pricing.

Admittedly, all these tools have serious shortcomings: they can restrict producers too much, coerce consumers too much, inappropriately exclude important effects, be too unfocused (or too constrained) to be productive, too liable to political manipulation, and so on. Moreover, MSC pricing and these other tools are not, in principle, mutually exclusive. Indeed, as I emphasized at the outset, *if* we can estimate and implement MSC pricing intelligently, without abandoning or subordinating tools that address transportation problems more broadly and directly, then perhaps we ought to "get the prices right." After all, the theory is appealing, and already some applications (such as road pricing to reduce congestion) are becoming technically and even politically feasible. For those who believe that our main objective should be to improve economic efficiency—to maximize net social benefits of transportation—and that we are equipped analytically to attain that objective, MSC pricing may be the logical approach. But one can conclude that MSC might not be feasible and that economic efficiency, even broadly defined to incorporate external costs, is just one of several social goals. Then the appropriate policy is to conduct systematic social-cost/benefit analysis, along with other forms of analysis and argument, to inform open political decision-making processes.

THE ROLE OF SOCIAL-COST ANALYSIS

Even though we should we be wary of embracing MSC pricing unreservedly, we still should employ social-cost analysis to understand the relative importance of transportation problems, illuminate tradeoffs, and evaluate transportation alternatives. For example, even if we have no intention of pricing every gram of particulate matter according to its size, composition, and time and place of emission, it still may be helpful to know whether particulate emissions are more costly than emissions of ozone precursors, or how much particulate emissions from diesel vehicles must be reduced to retain the benefits of higher fuel economy. It may help us set standards, invest in new vehicle technology, plan cities, and so on.

Of course we care about more than just economic efficiency; and, because MSC pricing as the primary means of achieving efficiency is difficult to implement and has limited and uncertain benefits, we ought to think twice before applying MSC pricing to transportation. Rather than address most transportation problems by MSC pricing, we should use the analyses that underlie it to inform political debate. Political decision making may be clumsy, messy, irrational, and aggravating, but it surely will be more inclusive, more nuanced, and more equitable than the best social-cost/benefit analysis. ◆

FURTHER READING

Mark A. Delucchi, *The Annualized Social Cost of Motor-Vehicle Use, 1990-1991: Summary of Theory, Methods, Data, and Results* (University of California, Davis: Institute of Transportation Studies, 1997). UCD-ITS-RR-96-3 (1).

Robert A. Johnston and Caroline J. Rodier, "Synergisms Among Land Use, Transit, and Travel Pricing Policies," *Transportation Research Record,* forthcoming (2000).

A. Scheffer Lang, "A New Transportation Paradigm," *Transportation Quarterly,* v. 53, no. 4, pp. 14–22, 1999.

Susan Owens, "From 'Predict and Provide' to 'Predict and Prevent'?: Pricing and Planning in Transport Policy," *Transport Policy,* v. 2, pp. 43–49, 1995.

Kenneth A. Small, "Economics and Urban Transportation Policy in the United States," *Regional Science and Urban Economics,* v. 27, pp. 671–691, 1997.

An Eye on the Fast Lane: Making Freeways Work

BY PRAVIN VARAIYA

BEFORE LEAVING for work you can check the weather from the newspaper, radio, or TV report. You can just look at the sky and make your own guess. But you can't determine much about current traffic conditions. TV and radio traffic reports provide only a summary ("traffic is running smoothly this morning") and spotty coverage of incidents ("an accident in the second lane has been cleared"). If you are unexpectedly stalled in traffic, your frustration and anxiety mount. You don't know how long you'll be stuck or whether you should use your cell phone to cancel your appointment.

You need a service that tells how long you can expect your journey to take if you leave right now or wait for fifteen minutes. You'd love to have this information available on the web, where you could collect if from your computer at home or work or even from your car phone. The service is not available for you today; but it will be very soon. A Berkeley group, in cooperation with Caltrans and the California PATH program, has developed a prototype computer system that provides this service for Orange County; the plan is to extend coverage to all freeways in California within the year. And the system, called PeMS (Performance Management System), can do much more than just calculate your trip time.

Until now, there has been no way of knowing how efficiently the freeway system is operating. But with PeMS, traffic engineers can analyze whether control equipment (such as ramp metering) is being used effectively and can then adjust settings accordingly. They can track the most frequently congested freeway segments. They can quickly determine the effects of lane closures. Using PeMS, these analyses can be done in minutes or hours. Without PeMS, such studies would take months, and so they aren't undertaken.

For the first time the director of a Caltrans district can, at the click of a mouse, obtain an objective, quantitative comparison of the daily performance of different parts of the freeway system. Poor performance can be diagnosed and corrected. Analyses can identify freeway bottlenecks, so resources can be allocated to clear incidents quickly and thus prevent congestion from choking them again.

Transportation planners can use PeMS to observe traffic and determine whether performance can be improved by making adjustments, or whether new capacity has to be built.

Policy makers and the public can use PeMS to get a quantitative grip on "the transportation problem." They can see where congestion is frequent; how much it costs in terms of delay; whether HOV lanes are effective; where traffic growth is greatest. PeMS is also designed to incorporate data from local roads and transit. If such data become available, PeMS would be able to provide objective appraisals of different transportation systems and modes within a metropolitan area.

HOW DOES IT WORK?

PeMS relies on data feeds from traffic surveillance equipment maintained in the field by Caltrans and other transportation agencies. Buried under freeways in every state, including California, are copper loop detectors. The loops are located in most urban areas at approximately a third of a mile apart in every lane and at entrance ramps and exits. There are lots of these detectors. Orange County has 4,000 loops, and the largest district, Los Angeles, has several times as many. You can spot a loop in the freeway by a six-foot rectangular, diamond-shaped or circular outline in each lane across the freeway which seals a cut in the pavement made to bury the loop. Sometimes loops are deployed in pairs separated a few feet apart, in which case they're called double loops.

Electric current in a loop changes when a vehicle is directly above it. An electronic circuit detects and records the time when these changes occur. These basic data are then processed to calculate two numbers, called count and occupancy, every thirty seconds. Count is the number of vehicles that cross the detector in a thirty-second period; occupancy is the fraction of time during those thirty seconds that a vehicle is present above the detector. Where there is a double loop, two additional numbers can be calculated: the average speed of the vehicles crossing the loop in

---

Pravin Varaiya is professor of electrical engineering and computer science, University of California, Berkeley, CA 94720 (varaiya@eecs.berkeley.edu)

thirty seconds, and the average length of those vehicles. All these calculations are routinely carried out in equipment located in a cabinet on the side of the freeway close to the loops.

Every thirty seconds, these data are sent over telephone lines to the district's Transportation Management Center (TMC). Large volumes of data are generated each day: 100 MB in Orange County, about ten times as much in Los Angeles, twenty times as much in the entire state. No district mines these data for the large amount of useful information they contain—but PeMS does.

As the data are fed from the detectors to the Caltrans Orange County TMC, a copy is shipped over a telephone line to the PeMS computer on the UC Berkeley campus. Software developed at Berkeley works on the data as soon as they arrive. These real-time calculations produce information of use to travelers, traffic engineers, and managers. Additional software works on historical data to record trends, and researchers are continuously developing new software to extract other useful information. Researchers are also developing and improving other traffic monitoring technologies such as video image processing and laser-based systems.

The PeMS computer is called *transacct.* Its website (http://transacct.eecs.berkeley.edu) provides some general information about PeMS, and it also displays PeMS's current speed estimate for different parts of the freeway network on a color-coded map of Orange County. (There are no double-loop detectors in Orange County, but an ingenious algorithm can calculate speed from single-loop detectors.) You can also request an account, which allows you to access a great deal of information about the performance of the Orange County freeways. Some of this information is described below.

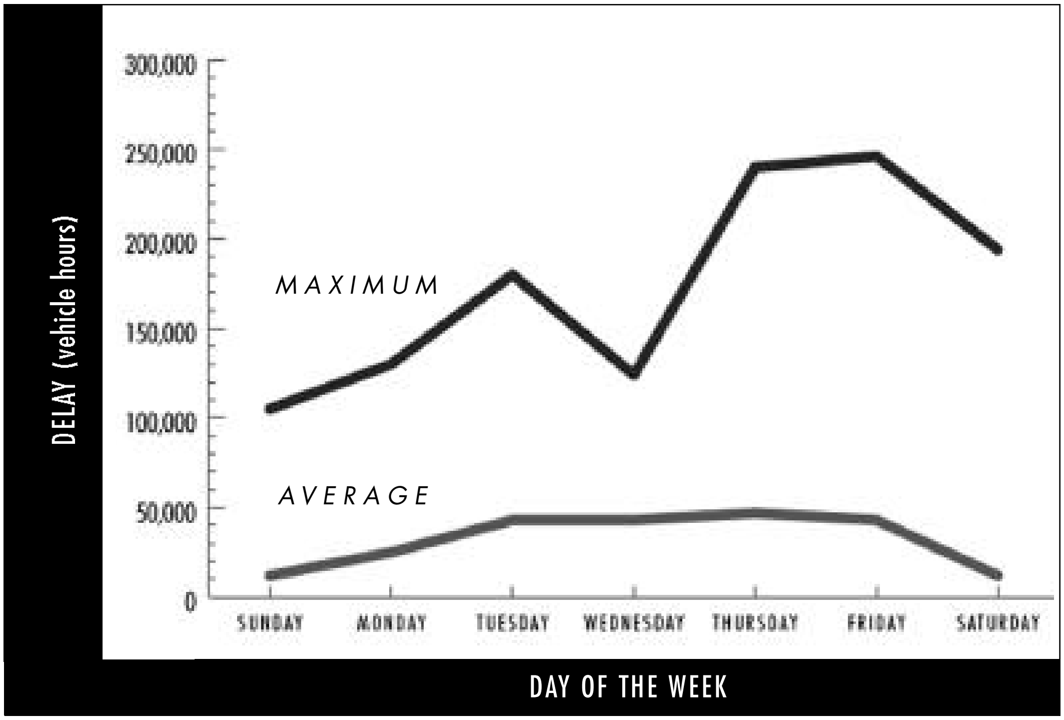
FOR THE MANAGER

As manager, you may wish to see aggregate performance measures, either daily or averaged over a long duration. Several measures are available. Caltrans publishes an annual congestion measure of daily vehicle-hours of delay. To estimate this delay, cars equipped with computers that record speed and distance are driven along each section of congested freeways during commute periods twice a year. Aside from being expensive, this is not a statistically sound estimate, because daily variation is very large. In contrast, PeMS calculates this delay over any portion of the freeway network, averaged over any number of days or for each day.

Figure 1 shows the average and maximum delay over a 23-mile stretch of the 405 freeway for each day of the week, averaged over all of 1998. Congestion is lowest on Saturdays and Sundays. On the year's worst Friday, delay on this freeway was five times longer than the average. As manager, you might insist on finding an explanation whenever the delay reaches a certain point, say when it exceeds the delay during 75 percent of the days in the previous year.

FIGURE 1

The average and maximum delay on a 23-mile stretch of I-405 North during 1998.



PeMS also calculates a more revealing performance measure than delay, a measure based on the premise that the freeway network produces a service—namely, movement of people and goods. By comparing a freeway's "output"—vehicle miles traveled (VMT)—and "input"—vehicle hours traveled (VHT)—we can measure its productivity, that is, the speed at which vehicles can travel. ($Q = VMT/VHT$, with Q being average speed weighted by number of vehicles. The larger Q is, the better the operation of that freeway).

An even better measure of output and input is PMT and PHT, where P stands for persons. We can convert VMT to PMT if we know the average number of people per vehicle. PMT and PHT are good measures for evaluating transit operations and comparing them with freeway operations.

Data show that during rush hour, as the number of cars increases, speed remains constant until some saturation point is reached, at which time speed quickly drops and stays slow for a long time. Every commuter knows this. More interesting is the fact that the saturation point (or capacity), measured by number of vehicles per hour, is different every day and varies by as much as twenty percent, even in the absence of any accident. It is not known why capacity varies so much—researchers are testing various hypotheses using PeMS data. The manager's goal should be to achieve the higher capacity. Note that a twenty percent increase is equal to the capacity of one lane on a five-lane highway, so this represents a significant difference.

FOR THE ENGINEER

When traffic on a freeway link reaches a saturation level, people are stuck in their vehicles (VHT increases and VMT drops). The result is a waste of people's time, increased frustration, and a large increase in pollution. The ultimate objective of traffic engineering is to increase utilization and capacity and to prevent congestion.

We know that in principle the freeway system can be operated to meet these objectives by the proper control of ramp metering and advisory messages. There is considerable international know-how about good control strategies. These strategies are all in "feedback" form: they specify, say, ramp metering rates as a function of the current state of the network. Thus an essential element in implementing a good strategy is a good estimate of the network's state. PeMS provides such estimates in real time. Traffic engineers can use PeMS to design strategies, measure their effectiveness, and improve them. PeMS thus has the potential to significantly improve freeway operations.

Considerable effort has gone into producing freeway simulation models. These computer models of traffic take into consideration many parameters representing driver behavior, freeway geometry, trip characteristics, etc. Large amounts of data are needed to calibrate these models with enough accuracy to make them useful for prediction. PeMS makes these data available in a very convenient form. Simulation models can now be calibrated and tested, which will make them invaluable to traffic engineers. For example, the models could be used to predict the effects of lane closures or of a major event such as a football game; and as shown in recent work at UC Irvine, support advanced, real-time traffic management strategies.

FOR THE TRAVELER

If you have an account and click the button labeled "Travel time calculation" on the transacct home page, a map of Orange County is displayed. You can then indicate the origin and destination of your trip either by selecting the freeway and cross street from a pull-down menu, or simply by clicking those locations directly on the map. Transacct then computes the shortest time and route for two cases, depending on whether you can use the HOV lanes. If data were available, transacct could also display travel options for transit alternatives.

Algorithms are being developed to predict future trip times ("Tell me the best route if I start fifteen minutes from now"), which combine current estimates with historical trends. It is likely that, if such a service were available, travelers would change their departure times or routes to reduce their trip times. The result would be a "spreading" of the commute peak and a reduction in total delay.

CONCLUSION

Imagine a company that produces a service for a large market, but does not keep track of how much it produces, or what it costs, or how satisfied its customers are. Such a company would soon go out of business, unless it is a monopoly whose behavior does not arouse the public's wrath. A transportation agency is like this company: it does not measure the quantity or quality of its product, or how much time and money it costs people to travel over its freeways. It responds when the public or political leaders are particularly agitated. But the public does not have the means to judge how well it performs.

The PeMS project is based on the common sense beliefs that you cannot manage a transportation system today if you don't know how it performed yesterday, and that the best way to improve the system is to enable everyone to easily figure out how the system is performing every day. ◆

FURTHER READING

Caltrans, District 4, Office of Highway Operations. 1998 Highway Congestion Monitoring Report. Available at: http://www.caltrans.gov

CORSIM, FHWA's microscopic traffic corridor simulation. See http://www.fhwa-tsis.com

On Bus-Stop Crime

BY ANASTASIA LOUKAITOU-SIDERIS AND ROBIN LIGGETT

IT'S EARLY MORNING at the bus stop on Central and 7th in downtown Los Angeles. A middle-aged Latino woman is waiting for the bus, nervously clutching a big plastic bag close to her body. There are no pedestrians on the street, just a few parked cars behind a barbed-wire fence. The nearby corner is occupied by a cheap, run-down motel called the Square Deal with a liquor store on the ground floor. A man in ragged clothes appears to be sleeping (or is he dead?), curled up on the sidewalk outside the store, not far from the woman. Broken glass, empty cans, and other trash litter the bus stop where the woman is standing. She nervously surveys the street for the bus. From time to time she throws a fleeting look at the sleeping man. At last the bus arrives, and the woman disappears behind its protective doors.

Fear is a fact of life for hundreds of thousands of inner-city residents who are captive bus riders. They describe bus stops as common settings for crime, providing cover for criminals who hang out waiting for potential victims without arousing suspicion. Inner-city riders are constantly wondering how safe it is to wait for the bus. They say they're always leery of individuals who stand behind them at bus stops. They're afraid of strangers, some of them gulping from bottles hidden in shabby brown bags. They're intimidated by homeless people who hang out at bus stops mumbling obscenities. They're often overcome by eerie feelings while waiting alone for the bus, surrounded by vacant buildings or fenced lots, with no other human being in sight.

Most of us don't know such fears because we commute in private cars. The metal cocoons of our automobiles protect us from exposure to the dangers of the public realm. Maybe this is why the plight of bus riders at the inner-city bus stops has not attracted much attention from the media, nor generated response from transit authorities. Or maybe it's because many of the victims are poor, immigrants, or nonvoters. Some are even afraid to report a crime to the authorities lest they expose their illegal-resident status.

Typically, transit authorities do not perceive the bus-stop environment as their responsibility and instead concentrate their security measures on the buses and trains. After all, bus stops are on the city's streets, and they're no more unsafe than other parts of the urban environment. Approximately 1.2 million people ride Los Angeles buses every year, and only 3,111 bus-stop crime incidents were reported to the transit police in the two-year period 1994–1995. Incidence of serious crime (rape, robbery, and assault) was even lower. Fewer than five violent crimes were reported per 100,000 passengers. However, this offers little comfort to inner-city bus passengers who are victimized at bus stops.

We find a significant spatial concentration of crime incidence at specific places. About half of all reported crimes in Los Angeles are committed within a thirteen-square-mile area that includes downtown and adjacent neighborhoods to the west. There, downtown and inner-city bus lines pass through some of the most neglected, poor, and crime-ridden neighborhoods of the city. So it's no surprise that these bus stops suffer most from crime. It's astonishing, however, that within the same overall area, even along the same bus line, bus stops near each other have very different crime rates. Some bus stops seem to be immune to crime, while others are described as "hot spots" of criminal activity. If we take ridership data into account and normalize crime incidence per capita, we still find that some bus stops are much more dangerous than others even though they're close together and along the same bus routes. Based on criminological research and our own observations, it seems that environmental attributes in the vicinity of a bus stop can play a major role in the safety of the setting and its susceptibility to crime.

ENVIRONMENT AND CRIME

During the last few decades there's been a resurgence of interest in the locations of violent behavior and in the importance of

Anastasia Loukaitou-Sideris is associate professor of urban planning at the University of California, Los Angeles, CA 90095 (sideris@ucla.edu). Robin Liggett is professor of architecture and urban planning in the School of Arts and Architecture and the School of Public Policy and Social Research, University of California, Los Angeles, CA 90095 (rliggett@ucla.edu)

space and place as settings for crime. The roots of this emphasis on place are not new. They can be traced to the ecologic studies of the Chicago School in the 1920s and 1930s, when Louis Wirth suspected that physical characteristics of cities significantly affect crime. Chicago sociologists Clifford Shaw and Henry McKay were the first to identify and study crime variations within the same city. But these findings were later disputed and forgotten.

The importance of environmental attributes for crime prevention was revisited in the 1960s and 1970s. Jane Jacobs argued that crime and the physical environment are related in a systematic, observable, and controllable manner. Jacobs viewed natural surveillance—"eyes on the street," as she put it—as an effective deterrent to criminal activity. Oscar Newman's studies of crime in public housing elaborated the idea of *defensible space*—an environmental layout whose physical characteristics can deter criminal activities. He argued that such environments are characterized by location within "safe zones," surveillance opportunities by residents, and a sense of ownership on the part of neighbors, who are likely to protect "their" space against criminals.

The ideas of Jacobs and Newman prompted a series of public programs on crime prevention through environmental design in the 1970s. But interest in environmental crime prevention languished again in the 1980s, when critics condemned such efforts as pure environmental determinism. In recent years, however, new criminological theories once again emphasized the importance of place and the relationship between built environment and crime. Criminologists spoke persuasively about the "broken windows effect"—signs of disrepair, dereliction, and dilapidation as catalysts for crime. Unrepaired broken windows, uncollected trash, and unkempt streets send messages to potential criminals that no one is in control and that their actions will go unnoticed.

Criminologists also introduced the idea of an *environmental backcloth* that can influence criminal behavior. This refers to the physical infrastructure and the buildings, roads, transit systems, land uses, and people located within this infrastructure—constellations of certain environmental attributes that seem to be associated with criminal behavior. Criminologists call these high-crime spots "crime generators" or "hot spots."

HOT SPOTS AT BUS STOPS

High-crime bus stops are hot spots. But *why* do these particular bus stops attract so much crime while other bus stops nearby are much safer? What makes some bus stops so dangerous?

To address these basic questions, we examined the physical and social environments of the ten most dangerous bus stops in the city of Los Angeles. These bus stops were identified from crime data obtained by the transit police for the period of January 1994 through December 1995. Consistent with hot-spot theory, each of these ten bus stops had much more crime than any of the thousands of other bus stops in L.A. More specifically, crime incidents at these ten bus stops during the study period accounted for eighteen percent of the total reported crime incidents at all bus stops. Even after normalizing for crime incidents per capita, a rider was twenty to thirty times more likely to be victimized at these bus stops than at others in Los Angeles.

A survey of 212 bus riders whom we found waiting at these high-crime bus stops revealed an even higher incidence of crime than was reported to the police. We found that almost *one third* of our respondents had been victimized on the bus or at the bus stop during the past five years. "It felt like I was drowning," said a young African-American woman who described how a thief had grabbed and cut a golden chain from her neck. "You always have to keep your eyes wide open here," exclaimed a Latino man. Half the respondents reported feeling unsafe and "always on guard" while waiting for the bus. Those feelings were more prominent among women passengers, who said they felt tense and under siege, wishing they could see behind themselves, as their anxiety levels rose until the bus finally arrived.

We found these ten high-crime bus stops have none of the elements that might mark their space as "defensible." All are situated in seedy and litter-filled commercial areas. Their surrounding environment is derelict and forbidding. Most are not visible from surrounding shops and lack adequate lighting. Empty lots and vacant, dilapidated buildings adjoin many of them. Desolate settings lacking either formal or informal surveillance make them attractive to criminals bent on committing crimes unnoticed.

Our data indicate that most serious crimes take place in isolated situations. A close examination of the immediate environment reveals a number of possible hiding places where potential criminals can easily hide to prey on their victims. Nearby alleys and empty lots offer perpetrators easy and varied escape routes. "These people are smart," a police officer told us, referring to criminals who prey at bus stops. "They wear two shirts; they wear another pair of sweats over their pants. They'll run into the alley, tear off their first layer, and walk out of the alley like nothing happened."

While bus stops plagued by serious crime are desolate, stops with a high incidence of pickpockets and petty thefts are overcrowded. Overcrowding tends to happen at busy street corners, where multiple bus lines converge. In such situations many "eyes on the street" do not seem particularly helpful, as criminals easily blend into the crowd.

Criminologists argue that specific land uses are more likely to generate, or at least allow, crime than others; this has led them to identify certain negative land uses. This may be a controversial view, but we found evidence to support it. For example, bars and liquor stores are located close to eight of the ten most dangerous

FIGURE 2

Crime rates and the bus-stop environment

bus stops. While some of these liquor stores provide the only outlet for groceries in inner-city neighborhoods, we can't ignore studies showing that consumption of alcohol can induce aggression and increase one's willingness to take risks. Check-cashing facilities and pawn shops are also near high-crime bus stops. These businesses often substitute for banks and, because they deal in large cash transactions, their customers offer likely targets for criminals. "Hot-sheet" motels, adult bookstores, and porn movie theaters are also common near high-crime bus stops. High concentrations of these businesses, combined with dilapidated buildings and other signs of neglect, increase the perception of seediness.

MEASURING THE EFFECTS OF ENVIRONMENT

Qualitative and ethnographic data help portray the social traits of residents and riders who use high-crime bus stops. But we also need to understand how particular features of the physical environment relate to crime. So we also studied sixty high- and low-crime bus stops downtown in an effort to measure the effects of specific environmental variables. The map in Figure 1 displays the crime and ridership levels at the bus stops we chose for study.

Environmental indicators that we looked at include 1) urban-form characteristics of the surrounding area; 2) bus-stop characteristics; and 3) street characteristics. As we suspected, our analysis revealed that certain urban-form and bus-stop characteristics seem compatible with crime. For example, crime rates are higher at bus stops in areas with alleys and mid-block passages (corroborating the idea that crime is high where there are avenues for escape) and near multi-family housing, liquor stores, check-cashing establishments, vacant buildings, and buildings marked by graffiti and litter. When we narrowed the field to violent crimes only, we found that check-cashing establishments at bus stops have the strongest correlation with crime rates, followed by the presence of alleys.

Positive environmental factors include good visibility from surrounding establishments and the presence of bus shelters. Street characteristics such as on-street parking and vehicle traffic seem to affect crime rates. Intersections with on-street parking tend to have high rates, while heavy vehicular traffic is associated with lower crime rates.

More research is needed to expose the effects of variables that we've been unable to measure adequately. For example, counting light poles near bus stops during daylight hours has not allowed us to consider illumination levels from surrounding establishments, and our reluctance to conduct fieldwork at night in these unsafe locations has kept us from checking to see whether streetlights were working properly. We measured pedestrian traffic at only one time during the day for each bus stop, even though this is likely to be an important variable.

WHAT CAN BE DONE TO MAKE BUS STOPS SAFER?

Our data are clear evidence that environmental settings affect crime at bus stops. Because stops in close proximity, along the same bus routes, and presumably with passengers having the same socio-demographic characteristics are marked by different crime rates, we conclude it's the microenvironments that matter. In turn, that implies an array of policy and design options, some very simple, that can complement policing and thus improve safety.

Unlike railway stations, bus stops are not permanently fixed in the urban landscape. They can be moved up or down the street as prudence requires. Moving bus stops away from undesirable establishments, multiple escape routes, and desolately empty spaces is imperative for passengers' safety. Opportunities for crime can be reduced by eliminating niches where individuals wait in hiding and where isolated alleys offer escape routes. The general upkeep and cleanliness of the immediate public environment of the bus stop sends the signal that "someone cares." Appropriate shelter design and good siting of a bus stop near open-front retail establishments can increase surveillance. In situations of extreme crowding, widening or extending sidewalks at the bus stop can decrease pedestrian congestion and reduce opportunities for purse and jewelry snatching. The retrofit of bus stops with shelters and lighting can make waiting for the bus more comfortable, less anxious, and safer.

For all these to happen, however, transit companies have to admit that the bus stop wait is a significant part of the overall transit system. They should target resources for the safety of their patrons by improving and maintaining the public environment at places where their buses stop. ◆

FURTHER READING

Patricia L. Brantingham and Paul J. Brantingham, "Nodes, Paths, and Edges: Considerations on the Complexity of Crime and Physical Environment," *Journal of Environmental Psychology,* v. 13, pp. 3–28, 1993.

Ned Levine, Martin Wachs, and Elham Shirazi, "Crime at Bus Stops: A Study of Environmental Factors," *Journal of Architectural and Planning Research,* v. 3:4, pp. 339–361, 1986.

Anastasia Loukaitou-Sideris, "Hot Spots of Bus Stop Crime: The Importance of Environmental Attributes," *Journal of the American Planning Association,* v. 65, no.4, 1999.

Anastasia Loukaitou-Sideris, Robin Liggett, Hiro Iseki, and William Thurlow, "Measuring the Effects of Built Environment on Bus Stop Crime," Working Paper, 1999. UCTC No. 419

Adele Pearlstein and Martin Wachs, "Crime in Public Transit Systems: An Environmental Design Perspective," *Transportation,* v. 11, pp. 277–297, 1982.

Gerda Wekerle and Carolyn Whitzman, *Safe Cities: Guidelines for Planning, Design and Management* (New York: Van Nostrand Reinhold, 1995).

James Q. Wilson and George L. Kellig, "Broken Windows: The Police and Neighborhood Safety," *Atlantic Monthly,* no. 249 (3), pp. 29–38, 1982.

RECENT PAPERS IN PRINT

Ⓦ **Anas, Alex, Richard Arnott, and Kenneth A. Small**
"Urban Spatial Structure"
1997 UCTC 357

Bagley, Michael N. and Patricia L. Mokhtarian
"Analyzing the Preference for Non-Exclusive Forms of Telecommuting: Modeling and Policy Implications"
1997 UCTC 370

Barth, Matthew J. and Ramakrishna R. Tadi
"An Automobile/Transit Emissions Evaluation of Southern California's Metrolink"
1995 UCTC 279

Ⓦ **Blumenberg, Evelyn, Steven Moga, and Paul M. Ong**
"Getting Welfare Recipients to Work: Transportation and Welfare Reform"
1998 UCTC 389

Ⓦ **Boarnet, Marlon G.**
"Business Losses, Transportation Damage, and the Northridge Earthquake"
1997 UCTC 341

Boarnet, Marlon G.
"Geography and Public Infrastructure"
1996 UCTC 305

Boarnet, Marlon G.
"Highways and Economic Productivity: Interpreting Recent Evidence"
1995 UCTC 291

Ⓦ **Boarnet, Marlon G.**
"The Direct and Indirect Economic Effects of Transportation Infrastructure"
1997 UCTC 340

Boarnet, Marlon G.
"The Economic Effects of Highway Congestion"
1995 UCTC 292

Boarnet, Marlon G.
"Transportation Infrastructure, Economic Productivity, and Geographic Scale: Aggregate Growth versus Spatial Redistribution"
1995 UCTC 255

Boarnet, Marlon G. and Nicholas S. Compin
"Transit-Oriented Development in San Diego County: Incrementally Implementing a Comprehensive Idea"
1997 UCTC 343

Boarnet, Marlon G. and Randall Crane
"L.A. Story: A Reality Check for Transit-Based Housing"
1995 UCTC 250

Boarnet, Marlon G. and Randall Crane
"Public Finance and Transit-Oriented Planning: New Evidence from Southern California"
1995 UCTC 304

Ⓦ **Boarnet, Marlon G. and Sharon Sarmiento**
"Can Land Use Policy Really Affect Travel Behavior? A Study of the Link Between Non-Work Travel and Land Use Characteristics"
1997 UCTC 342

Bosselmann, Peter and Elizabeth Macdonald
"Environmental Quality of Multiple Roadway Boulevards"
1997 UCTC 354

Burke, Andrew F. and Marshall Miller
"Assessment of the Greenhouse Gas Emission Reduction Potential of Ultra-Clean Hybrid-Electric Vehicles"
1997 UCTC 376

Burns, Elizabeth K.
"Involuntary Mobility, Gender, and Travel Demand Management in Metropolitan Phoenix"
1995 UCTC 332

Cervero, Robert
"Commercial Paratransit in the United States: Service Options, Markets and Performance"
1996 UCTC 299

Cervero, Robert
"Subcentering and Commuting: Evidence from the San Francisco Bay Area, 1980-1990"
1996 UCTC 331

Cervero, Robert, Alfred Round, Todd Goldman, and Kang-Li Wu
"BART @ 20: Rail Access Modes and Catchment Areas for the BART System"
1995 UCTC 307

Cervero, Robert and Alfred Round
"Future Ride: Adapting New Technologies to Paratransit in the United States"
1996 UCTC 306

Cervero, Robert and Carolyn Radisch
"Travel Choices in Pedestrian Versus Automobile Oriented Neighborhoods"
1995 UCTC 281

Cervero, Robert and Jonathan Mason
"Transportation in Developing Countries: Conference Proceedings"
1998 UCTC 387

Cervero, Robert, Carlos Castellanos, Wicaksono Sarosa, and Kenneth Rich
"BART @ 20: Land Use and Development Impacts"
1995 UCTC 308

Cervero, Robert, Thomas Kirk, Douglas Mount, and Carma Reed
"Paratransit in the San Francisco Bay Area: Providing Feeder Connections to Rail"
1995 UCTC 252

Ⓦ **Cervero, Robert, Timothy Rood, and Bruce Appleyard**
"Job Accessibility as a Performance Indicator: An Analysis of Trends and their Social Policy Implications in the San Francisco Bay Area"
1997 UCTC 366

Ⓦ **Chan, Evelyn, Adib Kanafani, and Thomas Canetti**
"Transportation in the Balance: A Comparative Analysis of Costs, User Revenues, and Subsidies for Highway, Air, and High Speed Rail Systems"
1997 UCTC 363

Chan, Shirley, Matthew Malchow, and Adib Kanafani
"An Exploration of the Market for Traffic Information"
1997 UCTC 390

Crane, Randall
"On Form Versus Function: Will the 'New Urbanism' Reduce Traffic, or Increase It?"
1995 UCTC 266

Ⓦ **Crane, Randall and Richard Crepeau**
"Does Neighborhood Design Influence Travel? A Behavioral Analysis of Travel Diary and GIS Data"
1998 UCTC 374

Delucchi, Mark A.
"Emissions of Criteria Pollutants, Toxic Air Pollutants, and Greenhouse Gases, from the Use of Alternative Transportation Modes and Fuels"
1996 UCTC 344

Delucchi, Mark A.
"Monetary Externalities of Motor-Vehicle Use"
1996 UCTC 318

Delucchi, Mark A.
"Motor-Vehicle Goods and Services Priced in the Private Sector"
1996 UCTC 315

Delucchi, Mark A.
"Payments by Motor-Vehicle Users for the Use of Highways, Fuels, and Vehicles"
1996 UCTC 327

Delucchi, Mark A.
"Personal Nonmonetary Costs of Motor-Vehicle Use"
1996 UCTC 314

Delucchi, Mark A.
"Some Comments on the Benefits of Motor-Vehicle Use"
1996 UCTC 329

Delucchi, Mark A.
"Some Conceptual and Methodological Issues in the Analysis of the Social Cost of Motor-Vehicle Use"
1996 UCTC 312

Delucchi, Mark A.
"Summary of the Nonmonetary Externalities of Motor-Vehicle Use"
1996 UCTC 319

✷ *Not previously listed*

Ⓦ *Available at UCTC website*

Delucchi, Mark A.
"The Allocation of the Social Costs of Motor-Vehicle Use to Six Classes of Motor Vehicles"
1996 UCTC 320

Ⓦ **Delucchi, Mark A.**
"The Annualized Social Cost of Motor-Vehicle Use in the U.S., 1990-1991: Summary of Theory, Methods, Data, and Results"
1996 UCTC 311

Delucchi, Mark A. and Don McCubbin
"The Contribution of Motor Vehicles to Ambient Air Pollution"
1996 UCTC 326

Delucchi, Mark A. and James Murphy
"General Taxes Paid by Producers and Consumers of Motor Vehicles, Motor Fuels, and Other Motor-Vehicle Goods and Services"
1996 UCTC 328

Delucchi, Mark A. and James Murphy
"Motor-Vehicle Goods and Services Bundled in the Private Sector"
1996 UCTC 316

Delucchi, Mark A. and James Murphy
"Motor-Vehicle Infrastructure and Services Provided by the Public Sector"
1996 UCTC 317

Delucchi, Mark A. and James Murphy
"U.S. Military Expenditures to Protect the Use of Persian-Gulf Oil for Motor Vehicles"
1996 UCTC 325

Delucchi, Mark A. and Shi-Ling Hsu
"The External Cost of Noise from Motor Vehicles"
1996 UCTC 324

Delucchi, Mark A., James Murphy, Jin Kim, and Don McCubbin
"The Cost of Reduced Visibility Due to Air Pollution from Motor Vehicles"
1996 UCTC 323

Delucchi, Mark A., Jin Kim, James Murphy, and Don McCubbin
"The Cost of Crop Losses Caused by Ozone Air Pollution from Motor Vehicles"
1996 UCTC 322

Dill, Jennifer, Todd Goldman, and Martin Wachs
"The Incidence of the California Vehicle License Fee"
1999 UCTC 414

Dreher, David B. and Robert A. Harley
"A Fuel-Based Inventory for Heavy-Duty Diesel Truck Emissions"
1997 UCTC 367

Fielding, Gordon J.
"Congestion Pricing and the Future of Transit"
1995 UCTC 330

Gillen, David W., Mark Hansen, and Robson Ramos
"Free Trade in Airline Services: Accessing the Proposals to Liberalize the Canada - U.S. Air Transport Bilateral"
1990 UCTC 407

Glazer, Amihai and Charles Lave
"Regulation by Prices and by Command"
1995 UCTC 276

Glazer, Amihai, Daniel B. Klein and Charles Lave
"Clean on Paper, Dirty on the Road: Troubles with California's Smog Check"
1995 UCTC 275

Golledge, Reginald D.
"Defining the Criteria Used in Path Selection"
1995 UCTC 278

Golledge, Reginald G.
"Object-Oriented Dynamic GIS for Transportation Planning"
1996 UCTC 337

Golledge, Reginald G.
"Path Selection and Route Preference in Human Navigation: A Progress Report"
1995 UCTC 277

Ⓦ **Golob, Thomas F.**
"A Model of Household Demand for Activity Participation and Mobility"
1996 UCTC 335

Golob, Thomas F. and Michael G. McNally
"A Model of Household Interactions in Activity Participation and the Derived Demand for Travel"
1997 UCTC 287

Ⓦ **Golob, Thomas F., Mark A. Bradley and John W. Polak**
"Travel and Activity Participation as Influenced by Car Availability and Use"
1995 UCTC 286

Golob, Thomas F., Seyoung Kim, and Weiping Ren
"How Households Use Different Types of Vehicles: A Structural Driver Allocation and Usage Model"
1996 UCTC 361

Gottlieb, Robert, et al.
"Homeward Bound: Food-Related Transportation Strategies in Low-Income and Transit-Dependent Communities"
1996 UCTC 336

Gould, Jane and Thomas F. Golob
"Shopping Without Travel or Travel Without Shopping? An Investigation of Electronic Home Shopping"
1997 UCTC 369

Hårsman, Björn
"Worker and Workplace Heterogeneity, Transport Access, and Residential Location: A Historical Perspective on Stockholm"
1995 UCTC 289

Hårsman, Björn and John M. Quigley
"Education, Job Requirements, and Commuting: An Analysis of Network Flows"
1998 UCTC 378

Henderson, Dennis K. and Patricia L. Mokhtarian
"Impacts of Center-Based Telecommuting on Travel and Emissions: Analysis of the Puget Sound Demonstration Project"
1996 UCTC 349

Henderson, Dennis K., Brett E. Koenig and Patricia L. Mokhtarian
"Using Travel Diary Data to Estimate the Emissions Impacts of Transportation Strategies: The Puget Sound Telecommuting Demonstration Project"
1996 UCTC 265

Hestermann, Dean W., Joseph F. DiMento, Drusilla van Hengel, and Brenda J. Nordenstam
"Public Works, the Courts, and the Consent Decree: Environmental and Social Effects of the 'Freeway With a Heart'"
1997 UCTC 348

Huang, William S.
"BART @ 20: Transit and Regional Economic Growth: A Review of the Literature"
1995 UCTC 310

Jacobs, Allan B., Elizabeth S. Macdonald, Diana Marsh, and Clark Wilson
"The Uses and Re-uses of Major Urban Arterials: A Study of Recycling, Revitalizing, and Restructuring 'Gray Area' Transportation Corridors"
1997 UCTC 371

Jacobs, Allan B., Yodan Y. Rofé and Elizabeth S. Macdonald
"Multiple Roadway Boulevards: Case Studies, Designs, and Design Guidelines"
1995 UCTC 300

Ⓦ **Jia, Wenyu and Martin Wachs**
"Parking Requirements and Housing Affordability: A Case Study of San Francisco"
1998 UCTC 380

Johnston, Brian, et al.
"The Design and Development of the University of California, Davis Future Car"
1997 UCTC 375

Johnston, Robert A.
"The Evaluation of Transportation and Land Use Plans Using Linked Economic and GIS Models"
1995 UCTC 268

✸ *Not previously listed*

Ⓦ *Available at UCTC website*

Johnston, Robert A. and
Raju Ceerla
"Effects of Land Use Intensification and Auto Pricing Policies on Regional Travel, Emissions, and Fuel Use"
1995 UCTC 269

Johnston, Robert A., Jay R. Lund
and Paul P. Craig
"Capacity-Allocation Methods for Reducing Urban Traffic Congestion"
1995 UCTC 270

Kirchstetter, Thomas, Brett Singer
and Robert Harley
"Impact of California Reformulated Gasoline On Motor Vehicle Emissions. 1. Mass Emission Rates"
1999 UCTC 411

Kirchstetter, Thomas, Brett Singer
and Robert Harley
"Impact of California Reformulated Gasoline on Motor Vehicle Emissions. 2. Volatile Organic Compound Speciation and Reactivity"
1999 UCTC 413

Kirchstetter, Thomas, Brett Singer
and Robert Harley
"Impacts of Oxygenated Gasoline Use on California Light-Duty Vehicle Emissions"
1996 UCTC 280

Klein, Daniel B., Adrian Moore,
and Binyam Reja
"Property Rights Transit: The Emerging Paradigm for Urban Transportation"
1996 UCTC 382

Klein, Daniel B. and
Adrian T. Moore
"A Property Rights Framework for Transit Services"
1995 UCTC 303

Klein, Daniel B. and
Adrian T. Moore
"Schedule Jockeying and Route Swamping: A Property Right Interpretation of British Bus Deregulation"
1995 UCTC 302

Klein, Daniel B. and
Pia Maria Koskenoja
"The Smog-Reduction Road: Remote Sensing Versus the Clean Air Act"
1996 UCTC 301

Kwan, Mei-Po and
Reginald G. Golledge
"Computational Process Modeling of Disaggregate Travel Behavior"
1996 UCTC 334

Kwan, Mei-Po and
Reginald G. Golledge
"Integration of GIS with Activity-based Model in ATIS"
1995 UCTC 254

Kwan, Mei-Po, Jon M. Speigle,
and Reginald G. Colledge
"Developing an Object-Oriented Testbed for Modeling Transportation Networks"
1997 UCTC 409

Kwan, Mei-Po,
Reginald G. Golledge, and
Jon M. Speigle
"A Review of Object-Oriented Approaches in Geographical Information Systems for Transportation Modeling"
1996 UCTC 412

Kwan, Mei-Po, Reginald G.
Golledge and Jon Speigle
"Informational Representation for Driver Decision Support Systems"
1996 UCTC 333

Landis, John D. and
David Loutzenheiser
"BART @ 20: BART Access and Office Building Performance"
1995 UCTC 309

Landis, John D.,
Subhrajit Guhathakurta,
William Huang, and Ming Zhang
"Rail Transit Investments, Real Estate Values, and Land Use Change: A Comparative Analysis of Five California Rail Transit Systems"
1995 UCTC 285

Levine, Ned and Martin Wachs
"Factors Affecting Vehicle Occupancy Measurement"
1996 UCTC 350

Loukaitou-Sideris, Anastasia
"Hot Spots of Bus Stop Crime: The Importance of Environmental Attributes"
1998 UCTC 384

Loukaitou-Sideris, Anastasia
"Inner-City Commercial Strips: Evolution, Decay—Retrofit?"
1997 UCTC 353

✷ **Loukaitou-Sideris, Anastasia,**
Robin Liggett, Hiro Iseki, and
William Thurlow
"Measuring the Effects of Built Environment on Bus Stop Crime"
1999 UCTC 419

Malchow, Matthew, Adib Kanafani
and Pravin Varaiya
"Modeling the Behavior of Traffic Information Providers"
1997 UCTC 396

Malchow, Matthew, Adib Kanafani
and Pravin Varaiya
"The Economics of Traffic Information: A State-of-the-Art Report"
1996 UCTC 393

Mannering, Jill S. and
Patricia L. Mokhtarian
"Modeling the Choice of Telecommuting Frequency in California: An Exploratory Analysis"
1995 UCTC 282

McCubbin, Don and
Mark A. Delucchi
"The Cost of the Health Effects of Air Pollution from Motor Vehicles"
1996 UCTC 321

Ⓦ **McCullough, William Shelton III,**
Brian D. Taylor, and
Martin Wachs
"Transit Service Contracting and Cost Efficiency"
1997 UCTC 365

Mokhtarian, Patricia L. and
Ilan Salomon
"Modeling the Choice of Telecommuting 2: A Case of the Preferred Impossible Alternative"
1995 UCTC 263

Mokhtarian, Patricia L. and
Ilan Salomon
"Modeling the Choice of Telecommuting 3: Identifying the Choice Set and Estimating Binary Choice Models for Technology-Based Alternatives"
1995 UCTC 264

Mokhtarian, Patricia L. and
Ilan Salomon
"Modeling the Desire to Telecommute: The Importance of Attitudinal Factors in Behavioral Models"
1994 UCTC 284

Mokhtarian, Patricia L. and
Ilan Salomon
"Modeling the Preference for Telecommuting: Measuring Attitudes and Other Variables"
1995 UCTC 293

Mokhtarian, Patricia L.,
Elizabeth A. Raney and
Ilan Salomon
"Behavioral Response to Congestion: Identifying Patterns and Socio-Economic Differences in Adoption"
1997 UCTC 373

Ⓦ **Mokhtarian, Patricia L., et al.**
"Adoption of Telecommuting in Two California State Agencies"
1996 UCTC 338

Mokhtarian, Patricia L.,
Michael N. Bagley, and
Ilan Salomon
"The Impact of Gender, Occupation, and Presence of Children on Telecommuting Motivations and Constraints"
1998 UCTC 383

Mokhtarian, Patricia L.
and Dennis Henderson
"Analyzing the Travel Behavior of Home-Based Workers in the 1991 CALTRANS Statewide Travel Survey"
1998 UCTC 415

Murphy, James and
Mark A. Delucchi
"Review of Some of the Literature on the Social Cost of Motor-Vehicle Use"
1996 UCTC 313

✷ *Not previously listed*

Ⓦ *Available at UCTC website*

RECENT PAPERS IN PRINT

Ⓦ **Noland, Robert B. and Kenneth A. Small**
"Simulating Travel Reliability"
1997 UCTC 372

O'Regan, Katherine M. and John M. Quigley
"Accessibility and Economic Opportunity"
1997 UCTC 362

O'Regan, Katherine M. and John M. Quigley
"Spatial Effect upon Employment Outcomes: The Case of New Jersey Teenagers"
1996 UCTC 359

O'Regan, Katherine M. and John M. Quigley
"Teenage Employment and the Spatial Isolation of Minority and Poverty Households"
1996 UCTC 290

Ⓦ **O'Regan, Katherine M. and John M. Quigley**
"Where Youth Live: Economic Effects of Urban Space on Employment Prospects"
1997 UCTC 358

Rodier, Caroline J. and Robert A. Johnston
"Incentives for Local Governments to Implement Travel Demand Management Measures"
1995 UCTC 251

Rosenbloom, Sandra and Elizabeth Burns
"Gender Differences in Commuter Travel in Tucson: Implications for Travel Demand Management Programs"
1993 UCTC 273

Rubin, Jonathan D. and Catherine Kling
"An Emission Saved is an Emission Earned: An Empirical Study of Emission Banking for Light Duty Vehicle Manufacturers"
1993 UCTC 253

Ruud, Paul A.
"Restricted Least Squares Subject to Monotonicity and Concavity Constraints"
1995 UCTC 288

Salomon, Ilan and Patricia L. Mokhtarian
"Coping with Congestion: Understanding the Gap Between Policy Assumptions and Behavior"
1997 UCTC 360

Shoup, Donald C.
"Evaluating the Effects of Cashing Out Employer-Paid Parking: Eight Case Studies"
1997 UCTC 352

Shoup, Donald C.
"Evaluating the Effects of Parking Cash Out: Eight Case Studies"
1997 UCTC 377

Shoup, Donald C.
"The High Cost of Free Parking"
1996 UCTC 351

Singer, Brett C. and Robert A. Harley
"A Fuel-Based Motor Vehicle Emission Inventory"
1996 UCTC 296

Ⓦ **Small, Kenneth A.**
"Economies of Scale and Self-Financing Rules with Noncompetitive Factor Markets"
1996 UCTC 339

Ⓦ **Small, Kenneth A.**
"Project Evaluation"
1998 UCTC 379

Small, Kenneth A. and Camilla Kazimi
"On the Costs of Air Pollution from Motor Vehicles"
1995 UCTC 237

Small, Kenneth A. and Xuehao Chu
"Hypercongestion"
1997 UCTC 356

Small, Kenneth and José A. Gómez-Ibáñez
"Road Pricing for Congestion Management: The Transition from Theory to Policy"
1998 UCTC 391

Taylor, Brian D.
"Public Perceptions, Fiscal Realities, and Freeway Planning: The California Case"
1995 UCTC 385

Taylor, Brian D. and Paul M. Ong
"Spatial Mismatch or Automobile Mismatch? An Examination of Race, Residence and Commuting in US Metropolitan Areas"
1995 UCTC 386

Ⓦ **Wachs, Martin**
"Critical Issues in Transportation in California"
1997 UCTC 347

Ⓦ **Wachs, Martin and Brian D. Taylor**
"Can Transportation Strategies Help Meet the Welfare Challenge?"
1997 UCTC 364

Ⓦ **Wachs, Martin and Jennifer Dill**
"Regionalism in Transportation and Air Quality: History, Interpretation, and Insights for Regional Governance"
1997 UCTC 355

Ⓦ **Washington, Simon P. and Troy M. Young**
"'Modal' Activity Models for Predicting Carbon Monoxide Emissions from Motor Vehicles"
1995 UCTC 295

Washington, Simon P., Randall Guensler, and Daniel Sperling
"Assessing the Emission Impacts of IVHS in an Uncertain Future"
1993 UCTC 298

Youssef, Waleed and Mark Hansen
"The Consequences of Strategic Alliances Between International Airlines: The Case of Swissair and SAS"
1993 UCTC 405

VIDEOS

Jacobs, Allan B., Yodan Y. Rofé and Elizabeth S. Macdonald
"Boulevards: Good Streets for Good Cities" (20 min.)
1995 Video 1

Quirós, Gabriela
"Tango 73: A Bus Rider's Diary" (28 min.) 1999
Please contact New Day Films for purchase information (888-367-9154, orders@newday.com)

BOOKS

Cervero, Robert
Paratransit in America: Redefining Mass Transportation (Westport, CT: Praeger Press, 1997)

Cervero, Robert and Michael Bernick
Transit Villages for the 21st Century (New York: McGraw Hill, 1996)

Daganzo, Carlos F., ed.
Transportation and Traffic Theory (Amsterdam: Elsevier Science Publishers, 1993)

DeCicco, John and Mark Delucchi, ed.
Transportation, Energy, and Environment: How Far Can Technology Take Us? (Washington, D.C.: American Council for an Energy-Efficient Economy, 1997)

Garrett, Mark and Martin Wachs
Transportation Planning on Trial: The Clean Air Act and Travel Forecasting (Beverly Hills: Sage Publications, 1996)

Garrison, William L. and Jerry D. Ward
Tomorrow's Transportation: Changing Cities, Economies, and Lives (Boston: Artech House, 2000)

Jacobs, Allan B.
Great Streets (Cambridge: MIT Press, 1993)

Klein, Daniel B., Adrian T. Moore, and Binyam Reja
Curb Rights: A Foundation for Free Enterprise in Urban Transit (Washington, DC: The Brookings Institution, 1997)

Sperling, Daniel
Future Drive: Electric Vehicles and Sustainable Transportation (Washington, DC: Island Press, 1995)

Sperling, Daniel and Susan Shaheen, ed.
Transportation and Energy: Strategies for a Sustainable Transportation System (American Council for an Energy Efficient Economy, 1995)

✷ *Not previously listed*

Ⓦ *Available at UCTC website*

RECENT DISSERTATIONS AND THESES

Abdel-Aty, Mohamed Ahmed
"Investigating the Factors Influencing Route Choice: New Approaches in Data Collection and Modeling"
1995 Diss 27

Adler, Jeffrey L.
"An Interactive Simulation Approach to Systematically Evaluate the Impacts of Real-Time Traffic Condition Information on Driver Behavioral Choice"
1993 Diss 18

Ben-Joseph, Eran
"Subdivision Guidelines and Standards for Residential Streets and their Impact on Suburban Neighborhoods"
1995 Diss 29

Brown, Jeffrey Richard
"Trapped in the Past: The Gas Tax and Highway Finance"
1998 Thesis 38

Chatti, Karim
"Dynamic Analysis of Jointed Concrete Pavements Subjected to Moving Transient Loads"
1992 Diss 9

Chen, Wan-Hui
"Contributing Factors in Traffic Crashes: A Method for Variable Identification and Selection in Statistical Models"
1998 Diss 40

Chu, Xuehao
"Trip Scheduling and Economic Analysis of Transportation Policies"
1993 Diss 16

Dahlgren, Joy W.
"An Analysis of the Effectiveness of High Occupancy Vehicle Lanes"
1994 Diss 25

Delucchi, Mark A.
"Emissions of Greenhouse Gases from the Use of Transportation Fuels and Electricity"
1991 Diss 6

Du, Yafeng
"Fleet Sizing and Empty Equipment Redistribution for Transportation Networks"
1993 Diss 11

Garcia, Reinaldo C.
"A Pareto Improving Strategy for the Time-Dependent Morning Commute Problem"
1999 Diss 45

Goulias, Konstadinos G.
"Long Term Forecasting with Dynamic Microsimulation"
1991 Diss 21

Guensler, Randall
"Vehicle Emission Rates and Average Vehicle Operating Speeds"
1994 Diss 19

Handy, Susan L.
"Regional versus Local Accessibility: Variations in Suburban Form and the Effects on Non-Work Travel"
1992 Diss 5

Kim, Seyoung
"Commuting Behavior of Two-Worker Households in the Los Angeles Metropolitan Area"
1993 Diss 22

Kockelman, Kara Maria
"A Utility-Theory-Consistent System-of-Demand-Equations Approach to Household Travel Choice"
1998 Diss 41

Kurani, Kenneth Stuart
"Application of a Behavioral Market Segmentation Theory to New Transportation Fuels in New Zealand"
1992 Diss 15

Kwan, Mei-Po
"GISICAS: A GIS-Interfaced Computational-Process Model for Activity Scheduling in Advanced Traveler Information Systems"
1994 Diss 24

Lee, Richard W.
"Travel Demand and Transportation Policy Beyond the Edge: An Inquiry into the Nature of Long-Distance Interregional Commuting"
1995 Diss 30

Lem, Lewison Lee
"Fairness or Favoritism? Geographic Redistribution and Fiscal Equalization Resulting From Transportation Funding Formulas"
1996 Diss 34

Levine, Jonathan Charles
"Employment Suburbanization and the Journey to Work"
1990 Diss 12

Levinson, David Matthew
"On Whom the Toll Falls: A Model of Network Financing"
1998 Diss 39

Li, Jianling
"Inter-Modal Transit Performance Indicators"
1997 Diss 35

Macdonald, Elizabeth Suzanne
"Enduring Complexity: A History of Brooklyn's Parkways"
1999 Diss 46

Mannering, Jill S.
"Determinants of the Decision to Telecommute: An Empirical Analysis"
1994 Thesis 43

McCullough, William Shelton III
"Transit Service Contracting and Cost Efficiency"
1997 Thesis 36

Nesbitt, Kevin Abolt
"An Organizational Approach to Understanding the Incorporation of Innovative Technologies into the Fleet Vehicle Market with Direct Application to Alternative Fuel Vehicles"
1996 Diss 33

Newman, Alexandra Mary
"Optimizing Intermodal Rail Operations"
1998 Diss 42

Pendyala, Ram Mohan
"Causal Modeling of Travel Behavior Using Simultaneous Equations Systems: A Critical Examination"
1993 Diss 14

Picado, Rosella
"Non-Work Activity Scheduling Effects in the Timing of Work Trips"
1999 Diss 47

Raphael, Steven Paul
"An Analysis of the Spatial Determinants and Long-Term Consequences of Youth Joblessness"
1996 Diss 32

Rubin, Jonathan D.
"Marketable Emission Permit Trading and Banking for Light-Duty Vehicle Manufacturers and Fuel Suppliers"
1993 Diss 13

Shaw, John
"Transit, Density, and Residential Satisfaction"
1994 Diss 28

Smith, James E.
"A Comparative Study of Entrepreneurial Strategies among African-American and Latino Truckers in the Los Angeles and Long Beach Ports"
1993 Diss 23

Song, Shunfeng
"Spatial Structure and Urban Commuting"
1992 Diss 8

Souleyrette, Reginald R. II
"Transportation Services and Innovation in the Housing Industry: A Study of the Relations Between Transportation and Production"
1989 Diss 7

Steiner, Ruth Lorraine
"Traditional Neighborhood Shopping Districts: Patterns of Use and Modes of Access"
1996 Diss 37

Turrentine, Thomas
"Lifestyle and Life Politics: Towards a Green Car Market"
1995 Diss 26

van Hengel, Drusilla
"Citizens Near the Path of Least Resistance: Travel Behavior of Century Freeway Corridor Residents"
1996 Diss 31

Walls, W. David
"Open Access Transportation, Network Competition, and Market Integration in the Natural Gas Pipeline Industry"
1992 Diss 17

Yim, Youngbin
"The Relationship between Transportation Services and Urban Activities: The Food Retail Distribution Case"
1990 Diss 20

ACCESS BACK ISSUES

ACCESS NO. 1, FALL 1992

Cars and Demographics, *Charles Lave*

Compulsory Ridesharing in Los Angeles, *Martin Wachs and Genevieve Giuliano*

Redundancy: The Lesson from the Loma Prieta Earthquake, *Melvin M. Webber*

Environmentally Benign Automobiles, *Daniel Sperling, et al.*

Pavement Friendly Buses and Trucks, *J. Karl Hedrick, et al.*

Commuter Stress, *Raymond W. Novaco*

ACCESS NO. 2, SPRING 1993 (OUT OF PRINT)*

Cashing Out Employer-Paid Parking, *Donald C. Shoup*

Congestion Pricing: New Life for an Old Idea? *Kenneth A. Small*

Private Toll Roads in America— The First Time Around, *Daniel B. Klein*

Investigating Toll Roads in California *Gordon J. Fielding*

Telecommuting: What's the Payoff? *Patricia L. Mokhtarian*

Surviving in the Suburbs: Transit's Untapped Frontier, *Robert Cervero*

ACCESS NO. 3, FALL 1993

Clean for a Day: California Versus the EPA's Smog Check Mandate, *Charles Lave*

Southern California: The Detroit of Electric Cars? *Allen J. Scott*

The Promise of Fuel-Cell Vehicles *Mark Delucchi and David Swan*

Great Streets: Monument Avenue, Richmond, Virginia, *Allan B. Jacobs*

Why California Stopped Building Freeways *Brian D. Taylor*

THE ACCESS ALMANAC: Trends in Our Times *Charles Lave*

***Photocopies of ACCESS No. 2 can be obtained for $10, payable to UC Regents.**

ACCESS NO. 4, SPRING 1994

Time Again for Rail? *Peter Hall*

No Rush To Catch the Train, *Adib Kanafani*

Will Congestion Pricing Ever Be Adopted? *Martin Wachs*

Cashing in on Curb Parking, *Donald C. Shoup*

Reviving Transit Corridors and Transit Riding *Anastasia Loukaitou-Sideris*

THE ACCESS ALMANAC: Love, Lies, and Transportation in LA, *Charles Lave*

ACCESS NO. 5, FALL 1994

Highway Blues: Nothing a Little Accessibility Can't Cure, *Susan Handy*

Transit Villages: From Idea to Implementation *Robert Cervero*

A New Tool for Land Use and Transportation Planning, *John D. Landis*

It Wasn't Supposed to Turn Out Like This: Federal Subsidies and Declining Transit Productivity *Charles Lave*

The Marriage of Autos and Transit: How To Make Transit Popular Again, *Melvin M. Webber*

THE ACCESS ALMANAC: The CAFE Standards Worked *Amihai Glazer*

ACCESS NO. 6, SPRING 1995

The Weakening Transportation–Land Use Connection, *Genevieve Giuliano*

Bringing Electric Cars to Market, *Daniel Sperling*

Who Will Buy Electric Cars? *Thomas Turrentine*

Are HOV Lanes Really Better? *Joy Dahlgren*

THE ACCESS ALMANAC: Slowdown Ahead for the Domestic Auto Industry, *Charles Lave*

ACCESS NO. 7, FALL 1995

The Transportation–Land Use Connection Still Matters, *Robert Cervero and John Landis*

New Highways and Economic Growth: Rethinking the Link, *Marlon G. Boarnet*

Do New Highways Generate Traffic? *Mark Hansen*

Higher Speed Limits May Save Lives, *Charles Lave*

Is Oxygen Enough? *Robert Harley*

ACCESS NO. 8, SPRING 1996

Free To Cruise: Creating Curb Space For Jitneys *Daniel B. Klein, Adrian T. Moore, and Binyam Reja*

Total Cost Of Motor-Vehicle Use, *Mark A. Delucchi*

Are Americans Really Driving So Much More? *Charles Lave*

SmartMaps for Public Transit, *Michael Southworth*

Decision-Making After Disasters: Responding to the Northridge Earthquake *Martin Wachs and Nabil Kamel*

THE ACCESS ALMANAC: Autos Save Energy *Sharon Sarmiento*

ACCESS NO. 9, FALL 1996

There's No There There: Or Why Neighborhoods Don't Readily Develop Near Light-Rail Transit Stations *Anastasia Loukaitou-Sideris and Tridib Banerjee*

The Century Freeway: Design by Court Decree *Joseph DiMento, Drusilla van Hengel, and Sherry Ryan*

Transit Villages: Tools For Revitalizing the Inner City *Michael Bernick*

Food Access For the Transit-Dependent *Robert Gottlieb and Andrew Fisher*

The Full Cost of Intercity Travel *David Levinson*

The Freeway's Guardian Angels *Robert L. Bertini*

THE ACCESS ALMANAC: Travel by Carless Households *Richard Crepeau and Charles Lave*

ACCESS NO. 10, SPRING 1997

The High Cost of Free Parking, *Donald C. Shoup*

Dividing the Federal Pie, *Lewison Lee Lem*

Can Welfare Recipients Afford to Work Far From Home?, *Evelyn Blumenberg*

Telecommunication Vs. Transportation
Pnina Ohanna Plaut

Why Don't You Telecommute?
Ilan Salomon and Patricia L. Mokhtarian

THE ACCESS ALMANAC: Speed Limits Raised, Fatalities Fall, *Charles Lave*

ACCESS NO. 11, FALL 1997

A New Agenda, *Daniel Sperling*

Hot Lanes: Introducing Congestion-Pricing One Lane at a Time
Gordon J. Fielding and Daniel B. Klein

Balancing Act: Traveling in the California Corridor
Adib Kanafani

Does Contracting Transit Service Save Money?
William S. McCullough, Brian D. Taylor, and Martin Wachs

Tracking Accessibility
Robert Cervero

THE ACCESS ALMANAC: The Pedigree of a Statistic
Donald C. Shoup

ACCESS NO. 12, SPRING 1998

Travel by Design? *Randall Crane*

Traditional Shopping Centers
Ruth L. Steiner

Simulating Highway and Transit Effects
John D. Landis

Cars for the Poor
Katherine M. O'Regan and John M. Quigley

Will Electronic Home Shopping Reduce Travel?
Jane Gould and Thomas F. Golob

ACCESS NO. 13, FALL 1998

Congress Okays Cash Out
Donald C. Shoup

Global Transportation
Wilfred Owen

Taxing Foreigners Living Abroad
David Levinson

Parking and Affordable Housing
Wenyu Jia and Martin Wachs

Lost Riders
Brian D. Taylor and William S. McCullough

ACCESS NO. 14, SPRING 1999

Middle Age Sprawl: BART and Urban Development
John Landis and Robert Cervero

Access to Choice
Jonathan Levine

Splitting the Ties: The Privatization of British Rail
José A. Gómez-Ibáñez

Objects In Mirror Are Closer Than They Appear
Theodore E. Cohn

THE ACCESS ALMANAC: Gas Tax Dilemma
Mary Hill, Brian Taylor, and Martin Wachs

ACCESS NO. 15, FALL 1999

Requiem for Potholes
Carl Monismith as told to Melanie Curry

Instead of Free Parking
Donald Shoup

Partners in Transit
Eugene Bardach, Timothy Deal, and Mary Walther

Pooled Cars
Susan Shaheen

Travel for the Fun of It
Patricia L. Mokhtarian and Ilan Salomon

ORDER FORM

UCTC #	AUTHOR	TITLE	QUANTITY

Papers also available at our website http://socrates.berkeley.edu/~uctc

Papers and ACCESS back issues: free, but please
limit your request to subjects of genuine interest to you

Dissertations and theses: $15, payable to UC Regents

To receive future issues of ACCESS, please check here ☐

NAME ____________________

AFFILIATION ____________________

ADDRESS ____________________

____

PHONE ____________________

Send to:
Publications, University of California Transportation Center
University of California, Berkeley, CA 94720–1782
Fax (510) 643-5456
access@uclink4.berkeley.edu

ADDRESS CORRECTION

Attach incorrect mailing label here

☐ **Delete name from ACCESS mailing list**

☐ **New address provided on order form above**

ACCESS NUMBER 16, SPRING 2000

Center Director
Elizabeth E. Deakin

Editor
Melvin M. Webber

Associate Editor
Charles Lave

Managing Editor
Melanie Curry

Design
Mitche Manitou

Managers
Briggs Nisbet
Chow Saephanh

University of California
Transportation Center

VISIT OUR WEBSITE AT
http://socrates.berkeley.edu/~uctc