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TRUCKS



Research at the University of California Transportation Center



FALL 1992
NUMBER 1

C O N T E N T S

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Front Cover, from left to right

Courtesy of CSAA

Courtesy of CSAA

*Courtesy of U.S. Department
of Transportation, Federal
Highway Administration.*



Courtesy of CSAA

I N T R O D U C T I O N

With this first issue of Access, we at the University of California Transportation Center seek to introduce our research to a diverse community of readers. By presenting our findings in a nontechnical format, we hope to make them accessible to professionals in various fields and to citizens who might find them useful or perhaps merely interesting.

Most of our research reflects the importance of improving accessibility in metropolitan areas — and without worsening the transport system's environmental effects. Because metropolitan development patterns shape travel choices on roads and transitways, we conduct research on those underlying urban forces that make for movement of people and goods. Because public policy so fundamentally affects both the shape of the modern metropolis and the functioning of its transportation system, we are primarily oriented to exposing policy options that might improve both. Because remedies for deficient accessibility cannot be found by attacking mere symptoms of systemic problems, we seek to explore alternative long-term, whole-system strategies that might inform officials in both the public and the private sectors.

The University of California Transportation Center (UCTC) was founded in Fall 1988, sponsored by the U.S. Department of Transportation (USDOT) and the California State Department of Transportation (Caltrans). Our research, education, and public service activities are primarily conducted on the University's campuses at Berkeley, Davis, Irvine, and Los Angeles. Some additional work is based at the University of Southern California; at California State University, Long Beach; and at Arizona State University, Tempe. UCTC's participants are drawn from many disciplines and professions, joined by the shared goal of enhancing accessibility for everyone. We look forward to continuing expansion of our research and to growing collaboration with USDOT, Caltrans, the many agencies within our region, and colleagues at other universities.

Selected articles on other research will appear in future issues of Access. UCTC's technical research papers currently in print are listed, along with an order form, at the back of the magazine. We encourage you to write for those you'd like to read.

If you have critical responses to articles appearing here or suggestions for future editions of Access, we shall be pleased to receive them. With the wish that Access will become an effective medium for exchanging information and ideas, we offer these essays hoping they'll entice open conversations on topics of mutual interest.

Melvin M. Webber
Center Director



Cars and Demographics

BY CHARLES LAVE

Imagine that it's January 1993.

Our environmentalist coalition has swept all the national elections and is ready to declare war on the automobile. We shall make urban life in America as civilized as urban life in Europe. Our major legislative program is put forth, and passed:

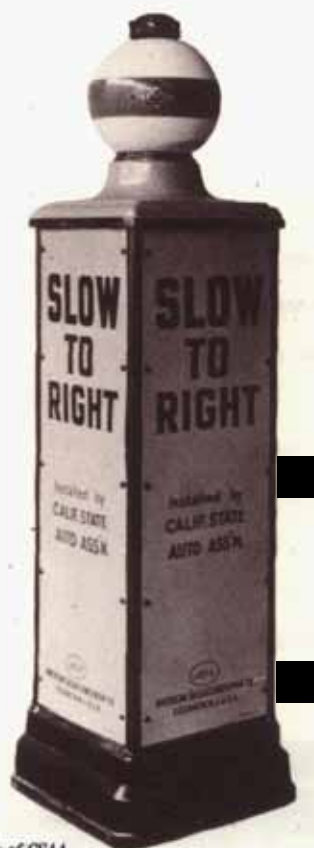
- We triple the price of gasoline — to \$4 per gallon.
- We build thousands of miles of rail transit.
- We radically increase the cost of downtown parking.
- We effectively restrict land use so that most of the suburban population moves back into the cities.

Tough measures? Yes, but worth it. We are serious about driving a stake through the heart of the automobile demon. To validate the efficacy of these new policies all we need to do is look abroad. Most Western European nations implemented such legislation years ago. Let's look at their success. Figure 1 compares the growth of the automobile population in the U.S. and in Western Europe.

Notice, over the period 1965-87, the 3-to-1 ratio in the growth of automobiles per capita. An impressive difference. And how much of that difference can we attribute to the pro-transit, anti-auto, anti-suburbanization policies in Western Europe? Unfortunately, at least in terms of this graph, the answer is: None. The fast growth curve in Figure 1 is Western Europe; the slow growth curve is the United States.

There are no statistical gimmicks in Figure 1; the number of automobiles in Western Europe has risen about three times as fast as the number in this country. To understand why, consider a very simple explanation.

First of all, people have a strong desire for convenient, fast, private transportation. As personal income rises, people are increasingly able to afford these desires. Most people seem to view public transportation as a barely tolerable substitute for the real things — their own cars. But they will quickly buy cars once they have enough money to do so. The tough anti-auto policies in Western Europe have been overwhelmed by a far stronger force: the growth of personal income. Let's begin by examining data from the United States.



Courtesy of CSAA

DEMOGRAPHICS OF AUTO GROWTH IN THE UNITED STATES

From 1950 to 1970, the number of vehicles in the United States grew 3.8 times faster than the human population. One reason for the disproportionate growth rate was the country's changing age structure: the large baby-boom cohort got older and began to get driver's licenses. Although the total U.S. population grew slowly, the portion eligible to drive grew quite rapidly. But now the transition in age structure is over. The baby boom ended in 1964; the youngest are now 28 years old. The number of new driving-age Americans is not what it once was.

Traditional sex roles related to driving and working have also changed, and so the numbers of women with driver's licenses grew much faster than the population as a whole. Figure 2 shows the pattern of licensing among women in 1969 and 1989. The 1969 data show a sharp decline in the proportion of women driving after age 40: these older women grew up in a time when it was not customary for women to drive. But this drop-off is not evident in the 1989 data. To see this more clearly, mentally shift the 1969 curve to the right 20 years, add in a small secular increase and the result is close to the observed 1989 data. The essentially flat profile in 1989 shows that this demographic transition is almost completed.

One of the forces behind the change in licensing patterns was overall income growth. Also important was the growth in women's participation in the job market. Jobs increase financial clout and let a higher proportion of women demand the kind of independence that auto travel provides. The number of women working in the United States has risen steadily, and by 1988, 56.6 percent of all working-age women were in the labor force. Can it rise much higher? The 56.6 percent figure seems to allow plenty of room.

It doesn't work that way, however. We should not expect that all women will ultimately choose to compete in the job market, especially since we know that all working-age men don't. Using labor force figures as a baseline, Figure 3 shows the relevant ratio and its growth over time. Women's labor force participation is now 82 percent of men's, and it is obvious that the growth is slowing. In fact, the Bureau of Labor Statistics projects only 5 percent growth during the 1990s.¹ →

¹ Fullerton, p. 4.

FIG. 1
Growth of Autos per Person:
U.S. vs. Western Europe

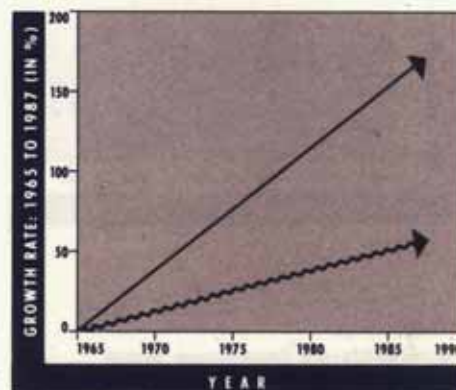
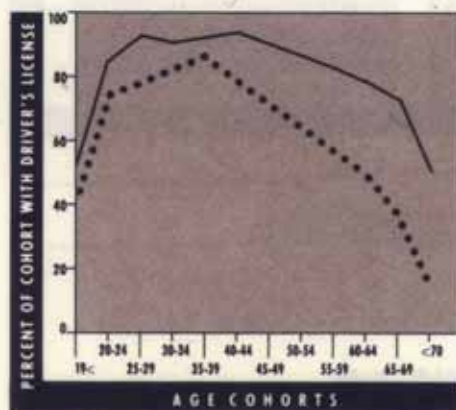


FIG. 2
Transition of
Non-Driving Older-Women
Out of the Population



1989 —————
1969

FIG. 3
Women Workers as
a Proportion of the
Total Labor Force

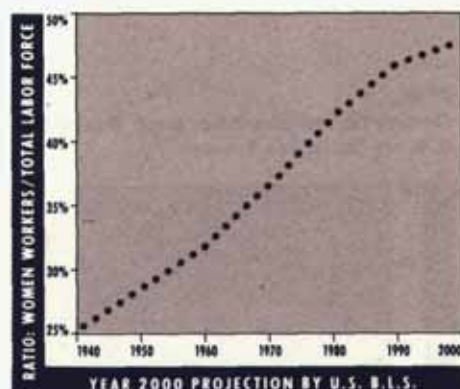
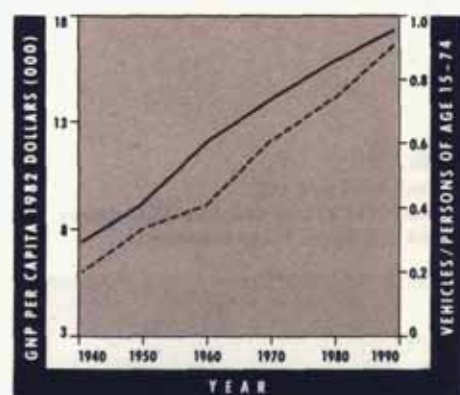


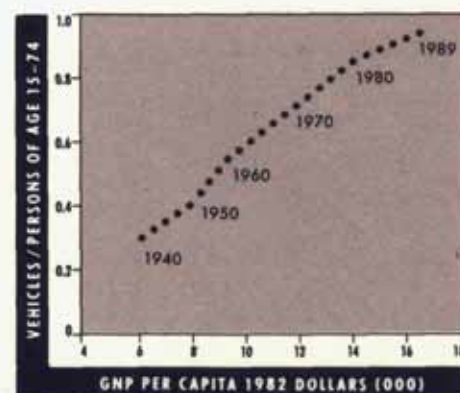
FIG. 4-A
Growth of Income and
of Vehicles/Person



GNP PER CAPITA

PERSONAL-USE VEHICLES
 PER PERSON OF AGE 15-74

FIG. 4-B
Personal-Use Vehicles
vs. Income



Research also suggests a strong relationship between income and vehicle ownership. So it seems reasonable to suspect that the enormous growth in U.S. per capita income during the 1950-70 period led to an equally explosive growth in numbers of vehicles. Figure 4-A shows the data: the top line shows growth in income per person; the lower line shows growth in vehicles per person.² Figure 4-B plots the relationship between these ratios. The horizontal axis is per capita income in constant 1982 dollars. The curve starts at about 0.3 vehicles per person in 1940 and grows to almost one vehicle per person today.

SATURATION OF AUTO DEMAND

Casual observers attribute the increase in the number of automobiles to population growth (more people means more cars), while more sophisticated observers know that income and licensing are important factors. But what many have missed altogether is the slowdown in growth resulting from saturation of auto demand. The shifts in demographics that produced the increases have run their course. The growth in vehicle population will be much slower in the future.

Trends in auto sales can be understood through comparison to the videocassette recorder (VCR) market. When VCRs were first introduced, no households had them. As consumers began buying VCRs, yearly sales rose much faster than the annual population growth. But manufacturers eventually reached a saturation point: nearly every household had a VCR. Since few consumers felt they needed more than one, VCR growth rates declined. Future sales will primarily be to first-time buyers, or to replace existing recorders. (This analogy also explains the over-capacity in auto manufacturing, and suggests that the current round of plant closings will be permanent, not temporary.)

We now have about 1.1 vehicles per licensed driver, but this is not a good measure of saturation. This ratio has always been high (it was .8 vehicles per licensed driver in 1950). To measure vehicle saturation, we must look at the ratio of cars to potential drivers — that is, all persons of driving age. The United States had .95 vehicles per person of driving age in 1989; essentially one car per person capable of being licensed. Absent distribution effects, such a ratio seems a good indication of vehicle saturation.

² Throughout this section, the term "vehicles" or "autos" refers to personal-use vehicles, i.e., the sum of cars plus those light trucks used for personal transportation. (This was 67 percent of light trucks in 1987 and 57 percent in 1982.) The term "population" means the driving-age population, those in the 15-74 age-cohort — the relevant group for measuring demand saturation.

Figure 5-A shows the disproportionate growth rate of vehicles compared to the driving-age population. Figure 5-B shows the same data in a different perspective: the growth of vehicles per person. In the 1950s, the ratio of vehicles to people jumped 40 percent, followed by a 27 percent jump in the 1960s, a 19 percent rise in the 1970s, and only a 12 percent increase during the 1980s. The era of disproportionate vehicle growth is over.

DISTRIBUTIONAL ISSUES

Does this country's average of 0.95 vehicles per person of driving age indicate vehicle saturation? What might be hiding behind this average?

REGIONAL EFFECTS: Perhaps the high average reflects a few "car crazy" states (like California) being combined with more environmentally conscious states. I compiled data for 13 states distributed randomly across the United States. All regions show essentially similar patterns of vehicle growth and saturation. (Nor is California abnormal: in the West, Colorado and Washington have significantly higher vehicle/population ratios; Florida and Georgia are higher in the South.)

HOUSEHOLD EFFECTS: Perhaps the high statewide averages conceal big differences among households: some households have many more vehicles than drivers, while others have none. I cannot make a direct evaluation of this possibility with the available published data. I can, however, show that the unequal distribution effect is not large. In 1980, 82-90 percent of all households had at least as many vehicles as workers. Researcher Alan Pisarski comments: "Zero-vehicle households tend to be very small households located in larger central cities. In fact, the New York area alone has 20 percent of the nation's households having no vehicles."³ Accordingly, I do not expect any additional vehicle growth to come from purchases made by members of zero-vehicle households.

SUMMARY FOR THE UNITED STATES

The United States has undergone a period of disproportionately rapid growth in numbers of autos. The increased desire for auto transportation was sparked by changes in the composition of the work force, and in the age structure of the population. The increase in per capita income gave people the means to implement their desires.

These changes have run their course. Although the era of rapid growth is over, its psychological effects are not. Much of our pessimism about congestion comes from living during that rapid growth period. Planners say there's no point in building more roads, they always fill up immediately. But sometimes we place too much weight on experience. Generals prepare to fight the last war; urban planners prepare to fight the last trend. It's time to think seriously about expanding the U.S. highway network. ➔

³ Pisarski, pp. 6-7.

FIG. 5-A
USA: Driving-Age
Population (15-74) and
Personal-Use Vehicles

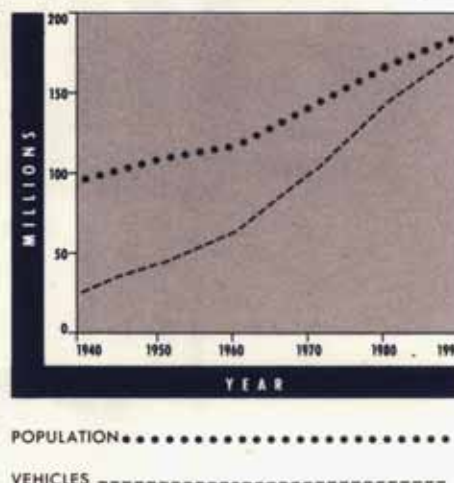
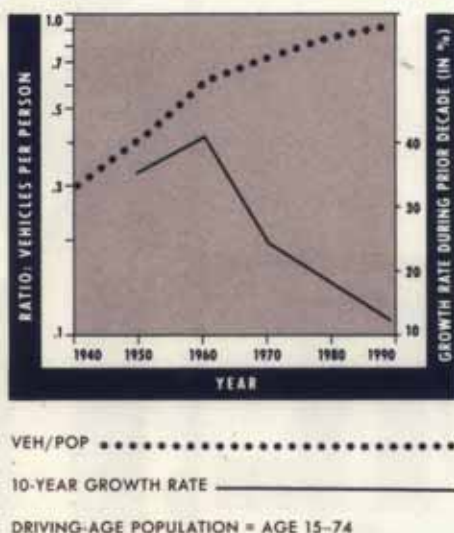


FIG. 5-B
USA: Vehicles/Driving-Age
Person and its Growth Rate



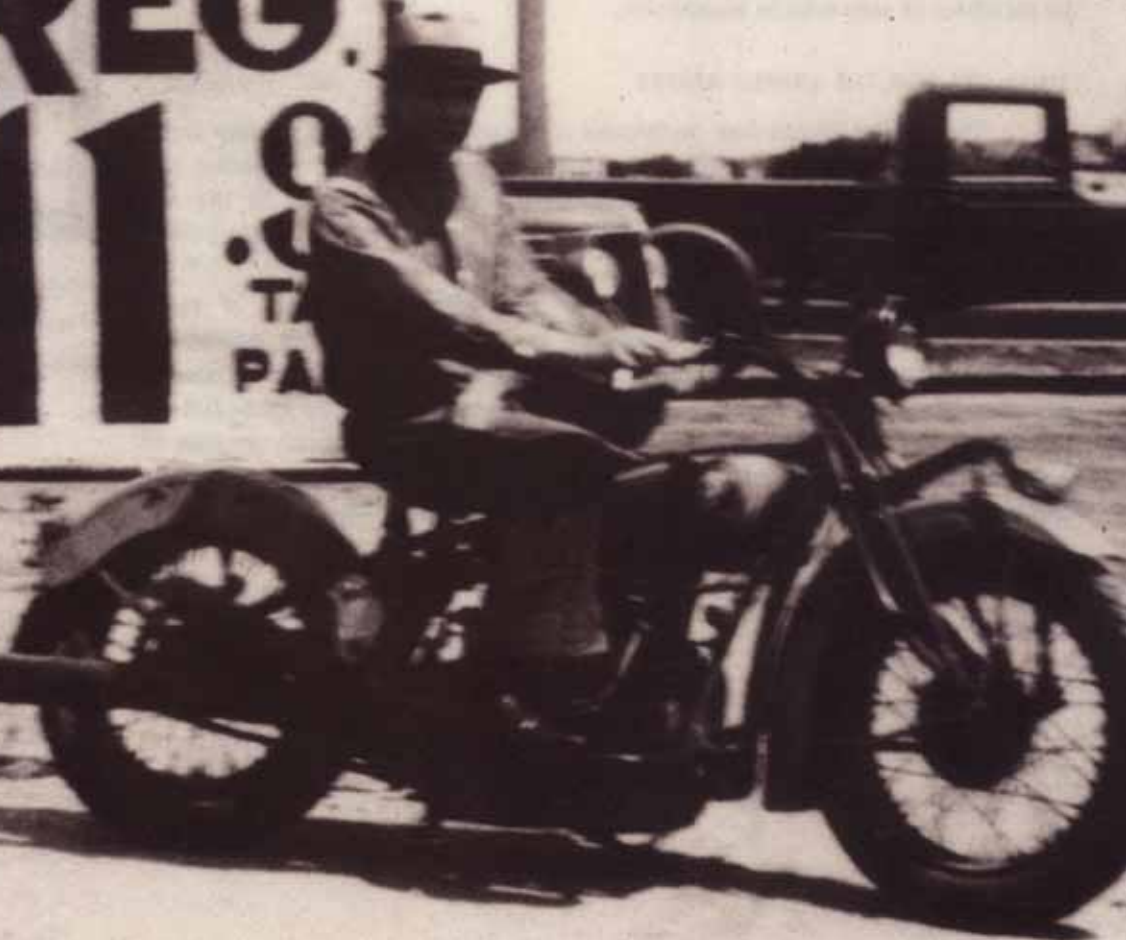
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AUTO GROWTH AND USE IN WESTERN EUROPE

Figures 6-A and 6-B show the curves of vehicle growth in 10 Western European countries. The difference in growth rates between the United States and Europe is clear: the United States has reached the saturation point while Europe is still growing fast.

I noted earlier that even Europe's tough anti-auto policies have not been sufficient to stifle growth in numbers of autos. But where will it end? At current growth rates, these 10 countries will reach the vehicle saturation point in 19 years. Will they get that far? Perhaps those anti-auto policies will stop growth before that point. Perhaps not. Vehicle growth has already increased much further than planners expected.

Vehicle ownership is just part of the story. Intensity of use matters as well. Europe's high gasoline prices, expensive parking, and inadequate roads must surely discourage driving. But not by much, apparently. In 1987 the average European car was driven 8,149 miles per year, compared with 9,928 in the United States.

Finally, we might compare growth trends in auto travel. For the period 1965-87, vehicle miles traveled (VMT) per person increased 154 percent in Europe, but only 69 percent in the United States. Consider again Europe's anti-auto regulations. They include every item that has been on this country's environmental wish list for the past 30 years. These are strong policies. The degree of governmental restriction upon personal freedom would be unprecedented in this country. But even this set of policies has not been sufficient to exorcise the demons of auto use in Europe.

We know that public transportation has lost the battle against the auto in the United States. Figure 7 shows it is losing the battle in Europe too. The fraction of total travel made on public transit is steadily declining. Surely, this is discouraging, for the quality of European transit systems is far better than anything we might hope to achieve in the United States.

ENVIRONMENTAL IMPACT OF PUBLIC TRANSIT

But, suppose we could reverse the trend. Might increased use of public transit then have an important effect on our consumption of energy or on emissions of greenhouse gases? The answer is: no.

The difference in energy efficiency between transit and autos was never very large to begin with, and federal policy over the past twenty years has reduced it. First, federal CAFE standards have almost doubled auto fuel efficiency since 1973. Second, as an unintended consequence of federal

FIG. 6-A
Vehicles/Total Population

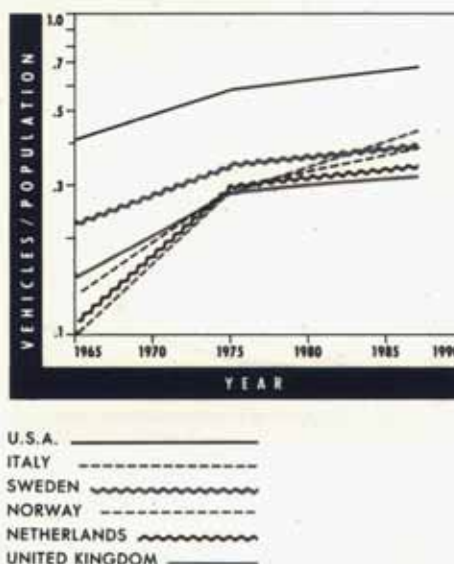


FIG. 6-B
Vehicles/Total Population

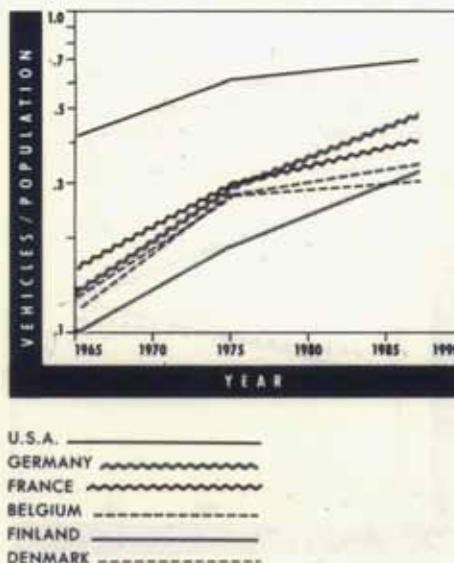
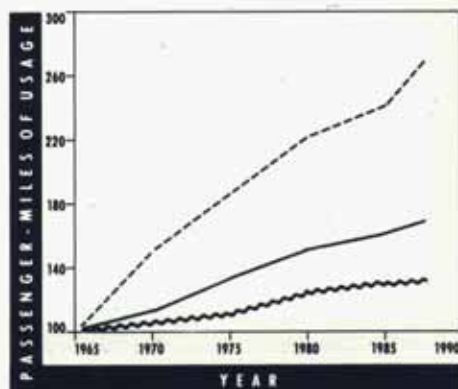
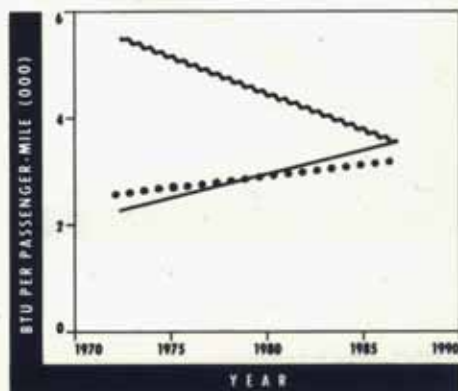


FIG. 7
OECD Countries:
Shift in Modal-Share
 Passenger-Miles of Usage (1965 = 100)



CAR & TAXI -----
 BUS & TROLLEY _____
 RAIL ~~~~~
MODAL SHARES (1987):
 CAR & TAXI = 82%
 BUS & TROLLEY = 11%
 RAIL = 7%

FIG. 8
Energy Efficiency
of Passenger Modes
 Autos vs. Rail Transit vs. Buses



AUTOS ~~~~~
 RAIL
 BUS _____

actions to increase transit patronage, the average transit vehicle's energy efficiency has fallen by about 50%. (Buses and rail transit cars became air conditioned and heavier.) Figure 8 shows the surprising result. Autos, transit buses, and rail transit are now nearly equivalent.

However, we must read these data with caution, for they reflect vehicles operating with average load factors. Autos used for the journey to work have lower than average load factors, so auto energy efficiency would be decreased about 50% for that portion of auto travel. (Commute trips are about 30% of total auto miles of travel.) But the rail data record the average between energy-efficient old rail systems such as the New York subways, and inefficient rail systems such as BART and Washington Metro.

PROSPECTS FOR INCREASING TRANSIT PATRONAGE

Since 1964 the federal mass transit agency has spent about \$100 billion trying to find some way to lure people out of cars. Money was easily available to pay for almost any conceivable experiment: subsidized fares (even free fares), more comfortable vehicles, increased schedule frequency, express schedules, free refreshments, timed transfer systems, extended operating hours, special fares for special groups, free parking at transit stations, advertising, image-improvement campaigns, etc. None of these experiments produced significant gains in transit patronage. The federal money managed to halt the long-term decline in patronage, but could not reverse it.

Radical new policy measures such as substantial parking fees would increase transit use for the tiny proportion of travel involved in commuting to large central business districts. But the effect on overall travel volumes would be barely measurable.

So we must conclude that it's very, very hard to lure people out of automobiles and into transit. Even if it were possible (and there is no evidence in the literature to support this hope), we would still not save much energy because the energy efficiency of transit and autos are roughly the same.

SUMMARY AND CONCLUSION

In worldwide perspective, rapid growth of automobiles began in the United States because we were richer than other nations. But other nations soon headed down the same path as their incomes increased, and their stock of autos is rapidly approaching ours. Europe's anti-auto policies may ultimately stop the growth of auto use before it reaches U.S. levels, but that is only a guess.

The desire for personal mobility seems to be unstoppable — it is, perhaps, the Irresistible Force. The role for U.S. policy is clear: if we cannot suppress that desire we should certainly channel it toward a more civilized automobile — one that is smaller, more fuel-efficient, and less polluting. Instead of continuing our ineffective crusade against auto use, we should try to provide environmentally sound automobiles. It's not so noble a goal as suppression, but it does have the advantage of feasibility. □

U.S. TRANSPORTATION ENERGY SUMMARY

The Importance of Oil

Transportation sector's energy from oil:	97.1%
Proportion of total oil consumption used by transportation:	63.2%
Proportion of total energy produced from oil	41.9%
Proportion of total US energy used by transportation	27.3%

Proportions of All U.S. Transportation Energy Used, by

Cars	50%
Light trucks	18%
Other trucks	14%
Off-highway vehicles	3%
Airlines	9%
Transit buses	0.7%
Rail transit	0.3%
Water freight	6%
Pipelines	4%
Rail freight	2%

Proportion of Vehicle Miles Traveled, by

Autos and personal light trucks	84%
Commercial trucks	16%

Proportions of Person-Miles Traveled, by

Autos	71%
Personal light trucks	14%
Commercial vehicles	15%

Total Freight Ton-Miles: 3,114 billion, by

Truck	22%
Water	28%
Pipeline	19%
Rail	31%

WORLD TRANSPORTATION ENERGY COMPARISONS

Proportion of All Oil Used in Transportation, in

Japan	38%
Europe	45%
United States	63%

Proportion of Passengers Carried in Public Transit, in

Japan	22%
Europe	8%
United States	1%

Prices of Unleaded Regular Gasoline per gallon, in

Japan	\$3.41
Europe	\$3.00
United States	\$0.92

New Car Fuel Economy in Japan, Europe, and United States

same

Annual Miles Traveled per Vehicle

Japan as percent of U.S.	65%
Europe as percent of U.S.	85%

Sources: Page xxxi, and pages xxiv, 1-20, *Transportation Energy Data Book*, 11th Edition, Oak Ridge National Laboratory, 1991.

R E F E R E N C E S

S. Davis and P. Hu, *Transportation Energy Data Book: Edition 11*. (Oak Ridge, Tennessee: Oak Ridge National Laboratory for the U.S. Department of Energy, January 1991).

Federal Highway Administration, *America's Challenge for Highway Transportation in the 21st Century*, Interim report of the Future National Highway Program Task Force. (Washington, D.C.: U.S. Department of Transportation, November 1988).

Federal Highway Administration, "The Future National Highway Program: 1991 and Beyond." Working Paper No. 2, "Trends and Forecasts of Highway Passenger Travel," (Washington, D.C.: U.S. Department of Transportation, December 1987).

Howard N. Fullerton, Jr., "New Labor Force Projections, Spanning 1988-2000," *Monthly Labor Review*, Vol. 112, No. 11, pp. 3-12, (Washington, D.C.: November 1989).

Steven D. McLoughlin et al, *The Changing Lives of American Women*, (Chapel Hill: The University of North Carolina Press, 1988).

Gary Moring, *Highway Travel Forecasts*, (Washington, D.C.: Office of Highway Planning, FHWA, U.S. Department of Transportation, November 1974).

Alan E. Pisarski, *Commuting in America: A National Report on Commuting Patterns and Trends*, (Westport, Conn.: The Eno Foundation for Transportation, Inc., 1987).

Alan E. Pisarski, "The External Environment for Public Transit to the Year 2020: A Speculative Assessment." Unpublished paper prepared for the APTA 2000 Task Force. (Washington, D.C.: January 1988).

J. C. Tanner, "International Comparisons of Cars and Car Usage," TRRL Report LR1070. (Crowthorne, Berkshire: Department of Transport, Transport and Road Research Laboratory, 1983).

U.S. Department of Transportation, *Survey Data Tabulations, 1983-84 Nationwide Personal Transportation Study*, (Washington, D.C.: November 1985).

U.S. Department of Transportation, *Personal Travel in the U.S., 1983-84 Nationwide Personal Transportation Study, Volumes I and II*, (Washington, D.C.: November 1986).



American Stock Photography

COMPULSORY RIDESHARING IN LOS ANGELES

BY MARTIN WACHS AND GENEVIEVE GIULIANO

Americans often look to Southern California as a place where lifestyle trends are born. Now, ironically, the land that has long glorified the car culture is galvanizing commuting behavior and encouraging abstinence from the once-respectable custom of solo driving. The catalyst for this behavioral change is Regulation XV, adopted by the South Coast Air Quality Management District in 1987. Also known as "The Commuter Program," Regulation XV requires all public and private employers (firms, government agencies, schools, hospitals, etc.) with at least 100 employees at any work site to devise commute alternatives for employees and to reduce the numbers of people driving alone to work.

Regulation XV is part of the regional plan for meeting federal and state air quality standards in the auto-dependent Los Angeles area (Los Angeles, Orange, Riverside, and part of San Bernardino counties) where topography, prevailing winds, and extended daylight hours all contribute to its infamous smog. Soon, nearly a dozen American cities will adopt their own versions of Southern California's ridesharing ordinance. The Clean Air Act Amendments of 1991 require that other "non-attainment areas," (regions with air quality rated severe or extreme), enforce mandatory ridesharing programs at all work sites with 100 or more employees. The overall effectiveness of Regulation XV will be of national interest since it will serve as a prototype for other cities. We have monitored the program since its inception, and preliminary results of the regulation's impact on ridesharing behavior are quite encouraging.

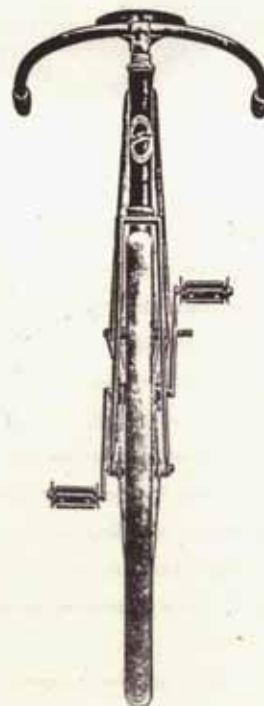
Companies falling within the Regulation XV guidelines must submit an implementation plan within 90 days of notification and must designate and train an on-site Employee Transportation Coordinator. In the plan, which must also be approved by the district office, the employer outlines a strategy for increasing Average Vehicle Ridership (AVR) to a specified level over the first year. AVR is the ratio of peak morning commuters to the total number of cars driven by these employees. One year after the plan's implementation, the employer must recalculate the AVR of its workforce. If the company fails to meet its target AVR, it is then required to revise the plan and implement the revisions during the second year. Failing to reach the AVR goal is not a violation of the regulation; failing to implement the plan, though, is punishable by fine. So far, fines as high as \$150,000 (a major retailing chain was the guilty party) have been levied against companies that failed to fulfill their obligations under the regulation. ➔

Changes in Mode Shares After One Year of Regulation XV Sample of 1110 Work Sites

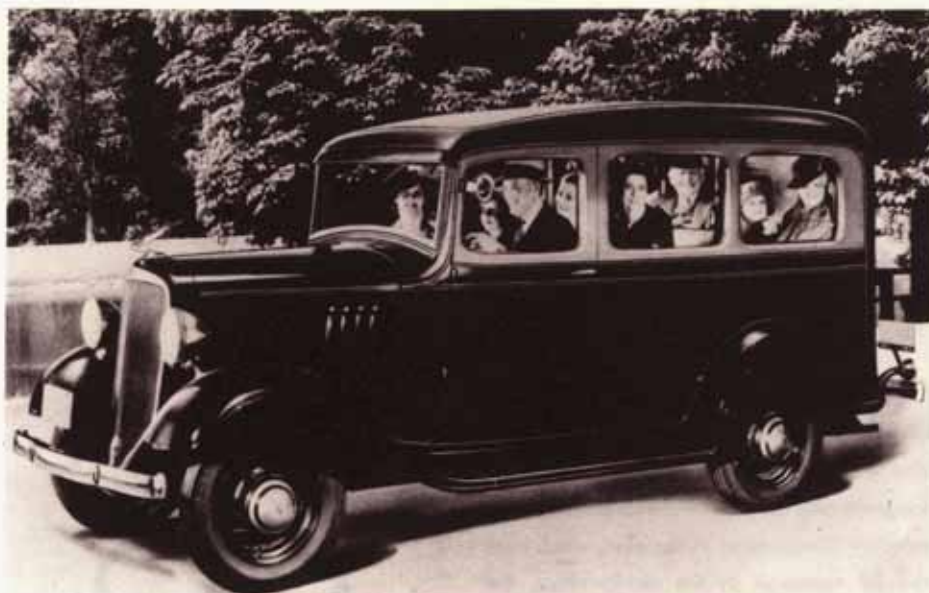
CHANGES IN MODE SHARE

Mode	Year One	Year Two	% Change
Drive Alone	.757	.709	-6.3*
Carpool	.138	.184	33.3*
Vanpool	.021	.021	14.2
Bus	.032	.032	0.0
Walk/Bike	.029	.028	-3.4
Telecommuting	.006	.005	16.7
Compressed Hours	.016	.019	18.8

* significant at $p \leq .01$



Martin Wachs is professor of urban planning at the University of California, Los Angeles, CA 90024. Genevieve Giuliano is associate professor of urban planning at the University of Southern California, Los Angeles, CA 90089.



Courtesy of MVMA

Employees who abandon solo driving for alternative commute methods such as public transit, carpooling, vanpooling, walking, telecommuting, and cycling — often enjoy benefits like gas reimbursement, discounted transit tickets, and preferential parking. Enterprising companies have developed promotions such as posters and prizes to encourage ridesharing. On-site amenities including automatic teller machines, health clubs, and restaurants are implemented to reduce employees' need to make daytime car trips.

We monitored the progress of some 1,110 job sites subjected to the regulation for at least one year. Data collected by the district office helped evaluate whether AVR targets were being met. We also examined the role of the Employee Transportation Coordinator.

Preliminary analysis shows the level of solo commuting has diminished. Average vehicle ridership figures rose from 1.21 to 1.25, a statistically significant improvement. Of the job sites monitored, more than two thirds experienced AVR increases during the first year, and one fifth of the job sites had AVR growth of more than 10 percent. Carpooling was the

most popular commute option, and vanpooling also increased significantly. As a transportation method, sharing rides makes sense: it is the alternative least disruptive to existing organizational patterns, and there are many ridesharing agencies and consultants able to provide matching services. However, the numbers of employees walking, cycling, and using public transit did not increase.

Generally, the greatest improvement in AVR was among employers whose initial AVRs were quite low. We also found that numbers of workers at different job sites had little to do with levels of AVR improvement.

Among the firms sampled, more than two thirds offered preferential parking for carpool and vanpool commuters, while only a fraction of employers introduced parking pricing as a strategy to encourage ridesharing. The most widely adopted incentives included financial reimbursement to users of public transit, a guaranteed ride-home program, and promotional prize drawings.

Regulation XV has created thousands of new positions for Employee Transportation Coordinators. Some coordinators have participat-

ed in formal training programs; still others have formed professional organizations. A telephone survey of 200 coordinators found that more than 90 percent were employees of their firms prior to adoption of Regulation XV.

Despite the rigid requirements, the amount of effort devoted to ridesharing by most employers has been modest. One third of coordinators surveyed estimated that their employers spent less than \$10,000 per year on the alternative commuting program. Almost half said they devoted less than 10 percent of their time to ridesharing duties.

Our research also includes in-depth case studies of five companies, aimed at examining the organizational and institutional benefits and costs of Regulation XV, as well as ways to estimate the impacts of the regulation on vehicle miles traveled. These components of the study are still underway. □

R E F E R E N C E S

- South Coast Air Quality Management District, *Air Quality Management Plan*, 1989.
- South Coast Air Quality Management District, Transportation Program Management Division, *Regulation XV Status Report Summary*, February 10, 1992.
- Genevieve Giuliano, Keith Hwang, and Martin Wachs, "Mandatory Trip Reduction in Southern California: First Year Results," UCTC Working Paper, No. 98, 1992.
- Martin Wachs, "Transportation Demand Management: Policy Implications of Recent Behavioral Research," *Journal of Planning Literature*, Vol. 5, No. 4, May 1991. UCTC Reprint, No. 81.
- Martin Wachs and Genevieve Giuliano, "Employee Transportation Coordinators: A New Profession in Southern California," UCTC Working Paper, No. 99, 1992.

REDUNDANCY:

THE LESSON FROM THE LOMA PRIETA EARTHQUAKE

BY MELVIN M. WEBBER

The big news from the Bay Area's 1989 earthquake was that the transportation disruptions were only inconvenient, not dreadful. Structural failures on the Bay Bridge and several elevated concrete freeways cut major metropolitan commuting routes. Nevertheless, the regional transportation system didn't crash at the time. It was resilient because it was redundant — the parallel links took up the burden. Commuters got to work without intolerable hardship. Trucks got their freight delivered, nearly on time. Some businesses suffered in the short-term, but only a few failed.

Estimates place direct losses from the Loma Prieta quake at over \$8 billion dollars, making it the costliest natural disaster in American history at the time. In addition, some costs must be assigned to the secondary losses resulting from the breakdown in accessibility. The surprise is that the losses were so low. Our studies into the effects of breaks in the metropolitan transportation network reveal three major reasons why traffic disaster did not follow the earthquake disaster:

ONE: THE BAY AREA HAS A REDUNDANT TRANSPORTATION SYSTEM

There is no more important feature of the Bay Area's system than its substantial redundancy — and no more important lesson from the 1989 quake. Because we had other bridges that could substitute for the Bay Bridge, motorists had several options to choose among. Because we had an alternative channel with large and underused capacity in BART's underwater tube parallel to the Bridge alignment, many transbay commuters and others could get to their destinations on time simply by changing modes.

Fortunately, the Bay Area has a network of freeways (including parallel freeways) and a ubiquitous network of wide streets and urban highways — virtually everywhere. We have a great many transit systems, some directly competing with one another. There are more than twenty local diesel bus operations, plus electric buses, electric trolleys, light rail in subway and light-rail above ground, heavy-rail rapid transit, a suburban railroad, ferries, jitneys, shuttle buses, and taxis, not to mention cable cars. In addition there are more than five million cars and trucks, mainline railways, major seaports, three major commercial airports, and numerous small general-aviation airports.

So when the quake struck down several big highway structures, individual travelers and shippers still had many options. As independent and autonomous consumers of transport services, they exploited those options, and pretty effectively. For some it took a little experimentation among unfamiliar possibilities during the first week or so. But then, most soon settled into one medium or another, and virtually everyone got to work without catastrophic delay or cost. ➔

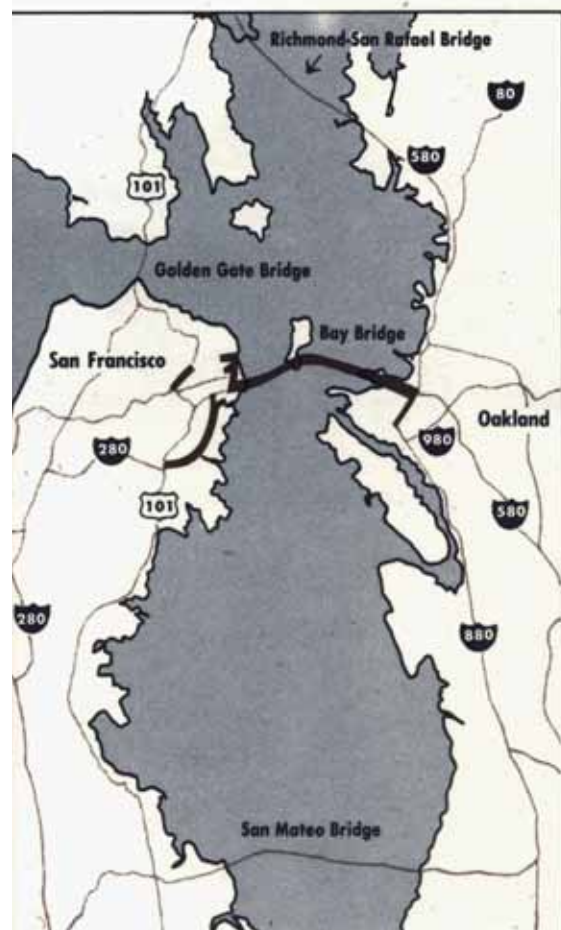
Courtesy of EERC Library, UCB



Damaged section of
Oakland Cypress
structure.

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Central Bay Area Closed Sections of Transport Network



ROADS CLOSED BY THE QUAKE

Central Bay Area
Road Network. Some
damaged sections have
been torn down. Three
years later, some sections
are still closed.

As a result of those millions of individual choices, the overall regional transportation system also adapted to the broken links in the networks. Even though some routes were severely overloaded and subjected to their most severe tests ever, self-adjustments of route-timing-and-mode by individual motorists kept even those roads from clogging up entirely. Congestion was bad in some places, but even there we never did suffer the dreaded "gridlock."

Contrast this with the earthquake's effects on the city of Santa Cruz. Lying behind mountains that are crossed by only one major road, it was nearly isolated when the road was cut by slides and cracks. Emergency equipment couldn't get in, and economic disruption was severe.

True, Santa Cruz was closer to the epicenter, but the comparative transportation access at Santa Cruz and the Bay Area was a major factor in their comparative losses. Transport redundancy protected the Bay Area from severe disaster. It's in part because Santa Cruz lacked such transport redundancy that it suffered unduly.

I wish we could say that the genius of the Bay Area's transport-system lies in the redundancy built into it by design. But it's not true that it was deliberately planned — that we built parallel routes as an intentional hedge against breakdown in the system. Instead, our standard design criterion calls for just-enough capacity to meet expected traffic loads and no more. Standard planning doctrine calls for least means — for minimum inputs in pursuit of maximum efficiency. It does not aim for maximum effectiveness.

Indeed, standard public administration dogma holds that redundancy — duplication or overcapacity — is equivalent to waste. However, it was redundancy that saved us in this instance, as in so many others. In other fields where system-wide failure is intolerable, designers require duplication (or triplication or quadruplication) of component parts. Computers, aircraft, space vehicles, telephones, missiles, and other complex systems, including complex institutions, are built that way. Their designers guard against system-wide collapse by installing standby components, seemingly superfluous parts that stand by, ready to take over in an emergency or whenever a component subsystem fails.

Urban infrastructural systems are analogous to those less-complex examples, but the costs of urban breakdown can be enormous as compared to even complete failure of one of those. Loss of life from an 8-point earthquake in places like San Francisco or Los Angeles or Tokyo may be thousands of times greater than loss of life in an airliner crash. Financial losses may be millions of times greater than loss from a bank's computer crash. Standby infrastructural components may prove by far the most effective — and least-expensive — means for protecting ourselves from natural disaster, despite heavy expenditures for additional physical plant in the short run.

So, I suggest that a first principle of system design should be to install redundant subsystems from the start — purposefully. We should do so recognizing the probability, if not certainty, that unanticipated breakdowns will occur, no matter how hard we try to prevent them.

TWO: TRANSPORT AND URBAN SYSTEMS ARE HIGHLY ADAPTIVE

The second reason the metropolitan transportation system failed to fail is that traffic systems, like market systems, have self-adjusting and self-correcting processes built into them. Urban travelers are remarkably adaptive. In the short-run, given the chance and given adequate information, they're

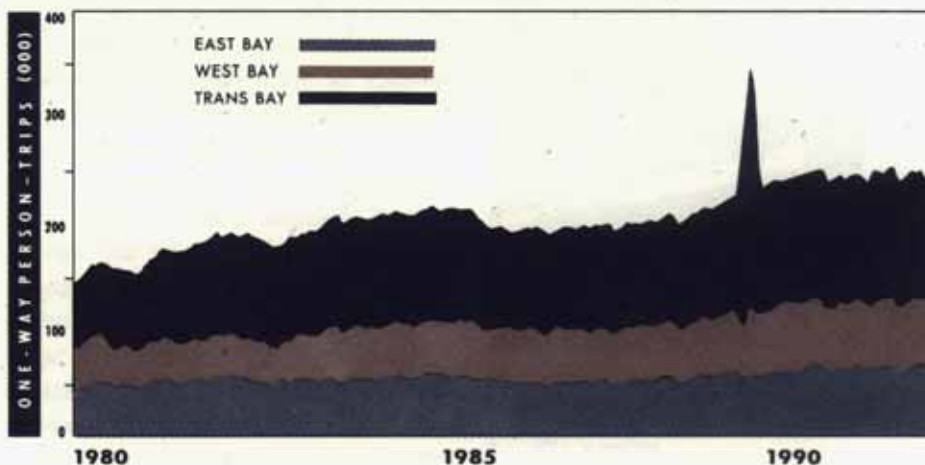
quick to find ways around bottlenecks by adjusting their travel routes, times, and modes. In the long-run, through the workings of labor markets and land markets, both job locations and residential locations get readjusted to accommodate traffic congestion and other constraints in the transportation system.

Those short-run adjustments were clearly evident during the Los Angeles Olympic Games when dire predictions of horrendous traffic jams proved wrong, mostly because travelers anticipated the congestion and took counter measures to avoid it. The adjustments are observed every day of the year when a road gets clogged and alert motorists find ways of avoiding the tie-up. So it was no surprise when transbay motorists quickly adapted to the closed freeways and the break in the Bay Bridge. They just moved over to the other roads and other bridges, and many became first-time BART riders or ferry passengers.

Long-term adjustments are evident in the huge expansion of houses and jobs in suburbs everywhere — the visible outcomes of individuals' and corporations' decisions to relocate in response to changing levels of accessibility. Where costs of traffic congestion exceed perceived tolerance levels, many employees look for work closer to home or try to find houses closer to their jobs. Always alert to the availability of an adequate labor force, employers respond to changing costs of congestion and to employee reactions to it. The relative decline of older central business districts and the rise of suburban job markets directly reflect long-term adaptations to crowded radial transportation corridors.

San Francisco city held over 50 percent of the metropolitan area's jobs in 1930, 31 percent in 1960, and only 18 percent today. Among other forces shaping the regional economy,

BART Average Weekday Patronage



BART absorbed large numbers of motorists and bus riders after the Bay Bridge broke.

that decline reflects the adaptation of land use patterns to traffic patterns, including patterns of congestion. Over recent decades, the old star-shaped radial travel pattern which focused on the central city has been transformed into a multidirectional network. Today most trips go from dispersed suburban origins to dispersed suburban destinations. The transportation system is thus much more flexible than it used to be when a few radial corridors were the dominant commuter routes. So, when the quake struck even large radial corridors, commuters were less cut-off than they would have been in an earlier time.

Right after the quake struck it also became clear that transportation agencies are themselves highly adaptive. Despite all we hear about bureaucratic rigidity, when there was need for quick response after the quake, they sprang into action with sophisticated diagnoses and damage repair, with effective traffic controls, with supplemental transit and ferry services, and with informative media campaigns that advised travelers about alternative routes and modes.

Furthermore, employers proved adaptive too. Some accommodated by adopting flex-time work schedules.

Others shortened the work week, relocated work places close to employees' homes, permitted telecommuting from home, and in other ways tried to adjust to the truncated transportation system. Transit agencies responded quickly to keep undamaged facilities operating and to expand or install mass transit services where roads were closed. Truckers found ways around the blocks. As a consequence, the effects of the transportation system's failures were not nearly as bad as you might have expected. →



The double-decked section of I-880 in Oakland collapsed, crushing motorists on the lower deck.



Courtesy of CalTrans

The section of the Bay Bridge upper deck fell when a bridge footing slipped out of place.

We are thus led to conclude that, to a large degree, we can rely on the autonomous and adaptive responses of the many components of the metropolitan system and that we are not dependent upon central command-and-control management when natural disaster strikes. Individuals, employers, suppliers, and the various private and governmental organizations can be trusted to accommodate spontaneously. If supplied with sufficient resources, including sufficient infrastructural resources, the metropolitan system seems to be remarkably resilient.

THREE: THIS WAS NOT THE BIG ONE

Although the transport system survived the 1989 quake, it will not prove so hardy when The Big One comes, as we're assured it will. The Iron Law of Seismic Events holds that the further we are from the last quake, the closer we are to the next one and the greater will be its severity. We're now 86 years from the last big break on the Bay Area sector of the San Andreas Fault in the West Bay and 124 years from the last one on the Hayward Fault in the East Bay. Recent forecasts now set the probabilities of a magnitude 7 or larger earthquake in the San Francisco Bay Area at 67 percent before the year 2020. Next time, the present system may be unable to adapt.

THE LESSON FOR INFRASTRUCTURE PLANNING IN EARTHQUAKE COUNTRY

So the message from the Loma Prieta quake is clear: we were rescued by redundancy. We should plan now to build-in more redundancy and more flexibility, even as we accelerate efforts to retrofit existing facilities to withstand the major temblors that will come.

Of course the first and major effort must be to strengthen existing bridges, overpasses, roadbeds, buildings, and other structures that will be endangered by severe earth shaking. But, despite the most valiant efforts, there will inevitably be structural failures even then. Smart planning requires that we recognize the inevitability of failure and plan accordingly.

Parallel systems provide options, permitting the overall transport system to continue to function effectively, even when parts get broken. Next time, we should be prepared by deliberately installing parallel routes — and the more the better. For the Bay Area, I suggest that means more parallel bridges, more freeways, and more transit routes.

Despite its many transport subsystems, the Bay Area's transport capacity is already deficient. That's especially so in the suburbs where growth was earlier spurred by congestion in the metropolitan center and where we've been slow to install capacity sufficient to meet present and coming demand. But I suggest we need more than just-enough additional capacity to relieve congestion. We also need to install safeguards in the form of excess capacity.

Public officials will think it wasteful and inefficient to build a lot of capacity in excess of short-term traffic volumes. But the Bay Area's future viability may well hang on the region's ability to continue functioning after The Big One hits — after the region has been shaken by 8 or more Richter points.

The ability to move emergency equipment freely can spell the difference between life and death for tens of thousands of persons and mean the preservation or loss of tens of thousands of buildings. The ability to sustain the metropolitan system — distribute foods and medicines; to supply water; to rejoin families; to the

keep the economy in working order; to maintain the critical telecommunications, fire-fighting, and policing services — all depend on a functioning metropolitan-wide transportation system.

Prolonged dislocation of passenger and freight movements that would follow severe damage to the transport system could, in turn, inflict severe and long-term damage to the local economy and to the public health. By averting some of the horrendous costs that will follow The Big One, investment *now* in future options and additional capacity will surely yield tremendous returns *then*.

The conclusions concerning transportation must be equally applicable to other public services. Sections of San Francisco were without electricity for about a week after the Loma Prieta shock, because several large transformers and circuit breakers were damaged; it then took time to find and install replacement parts. Future redundancy in power lines, telephone and other communication channels, water mains, hospitals, and the diverse arrays of emergency equipment will all surely increase the chances of surviving a large quake in the future.

Are the costs of these additional facilities warranted? It depends on the time horizon we assign to our estimates and the discount rates we apply. We have a notorious habit of heavily discounting future benefits that are further away than the next quarterly report or the next election. However, when the next quake strikes, whenever it comes, everyone will be grateful for the foresight that averted disaster.

And for survivors of The Big One — for those who live to tell about it — redundant public facilities systems could well prove to have been the major reason they survived. □

REFERENCES

Immediately following the earthquake, several researchers at the University of California in collaboration with researchers in several governmental transportation agencies undertook a series of quick-response studies. Their aim was to assess the consequences of damage to the metropolitan transportation network. Findings from some of these studies are reported in the following papers, available from the University of California Transportation Center.

Mark Hansen and Jakob Sutter, *The Shake With Freight: The Impact of the Loma Prieta Earthquake on Bay Area Truckers*. Earthquake Series No. 1, 1991.

Anna K. Bennett and David D. Little, *Earthquake Effects on Employee Transportation*. Earthquake Series No. 2, 1991.

Cynthia A. Kroll, John D. Landis, Qing Shen, and Sean Stryker, *Economic Impacts of the Loma Prieta Earthquake: A Focus on Small Business*. Earthquake Series No. 3, 1991.

Pamela Tsuchida and Linda Wilshusen, *Commute Behavior in Santa Cruz County*. Earthquake Series No. 4, 1991.

Mark Hansen and Sharon Weinstein, *East Bay Ferry Service and the Loma Prieta Earthquake*. Earthquake Series No. 5, 1992.

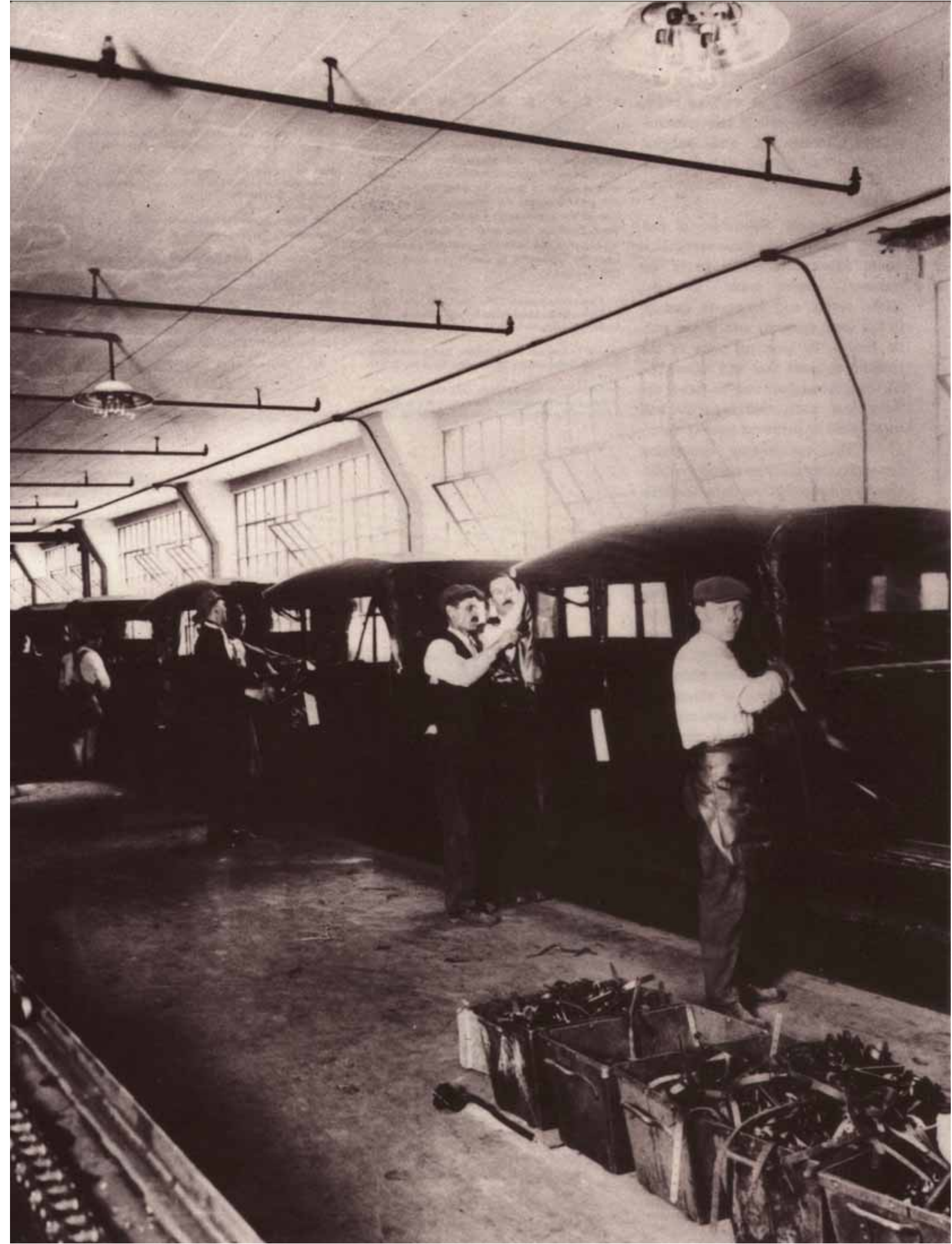
David Reinke, *Effects of the Loma Prieta Quake on BART Patronage*. Earthquake Series No. 6, 1992.

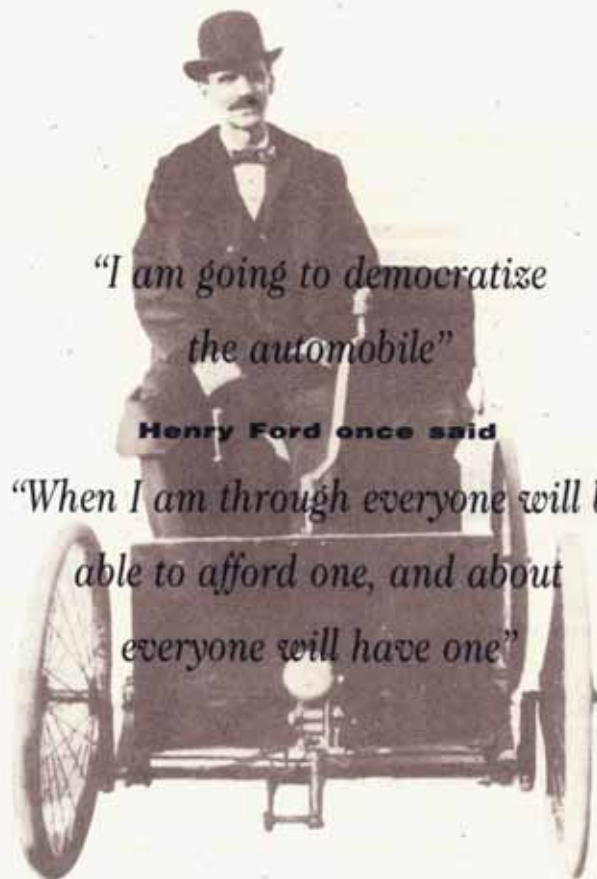
In addition to the above-listed authors, the core research group included Bruck Couchman and Ace Forsen (California State Department of Transportation), Joel Markowitz (Metropolitan Transportation Commission), Wolf Homburger and Melvin M. Webber (University of California, Berkeley).



The replacement deck of the Bay Bridge being lowered into place, less than one month after the quake.

Courtesy of EERC Library, UCB





*"I am going to democratize
the automobile"*

Henry Ford once said

*"When I am through everyone will be
able to afford one, and about
everyone will have one"*

Courtesy of CSAA

Environmentally Benign Automobiles

BY DANIEL SPERLING, LEE SCHIPPER, MARK DELUCHI, AND QUANLU WANG

His dream has come true. There's now more than one vehicle for every licensed driver in the United States, and other developed countries are not far behind.

But has the car's success created the conditions for its own demise? Conventional wisdom of market researchers, consultants, and other experts is that the automobile and its petroleum-powered internal combustion engine will be with us for a long time and that any energy and environmental problems can be readily solved.

The automotive industry would very much like to believe that cheery prognosis — and perhaps it's correct. But suppose it's not. What if global warming and climate change accelerate? What if people and governments begin to demand and expect even higher environmental quality? And how will the United States and other developed nations respond to growing oil imports?

The truth of the matter is that the automotive and energy industries are not prepared — neither in terms of technology nor corporate thinking — for the major changes that are imminent. Just as the American auto

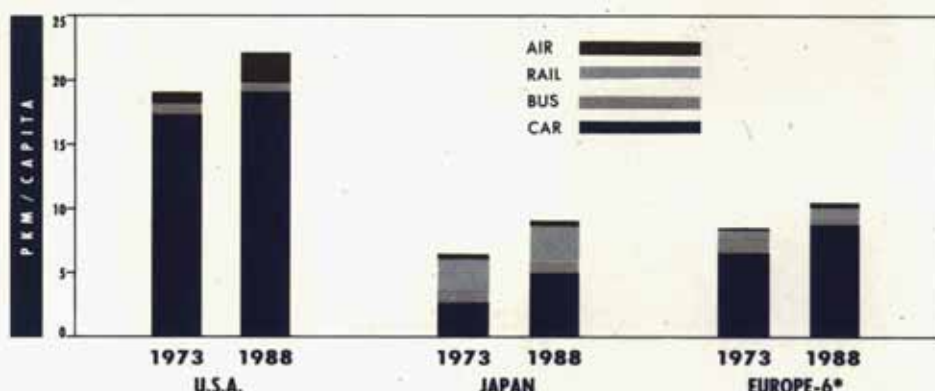
industry underestimated the market threat of Japanese imports 20 years ago, the industry may now be underestimating demands for "greener" and more socially responsible vehicles and fuels. If the industry itself is not responsive, government will undoubtedly intervene, as it has in California. And it boils down not to the survival of the automobile itself, but of the automobile manufacturers.

TRENDS

Increased car usage has already created tremendous environmental stresses, along with parallel economic and political problems. Passenger travel, expressed as passenger miles per capita, is rising virtually everywhere, especially in the United States where cars are readily available. As shown in Figure 1, auto travel accounts for 75-85 percent of all domestic travel in virtually every developed country except Japan. But even in Japan, where distances are short, congestion nightmarish, and rail transit accessible, autos still account for almost 60 percent of



DOMESTIC TRAVEL BY MODE, OECD COUNTRIES: 1973 and 1988



Source: U.C. Davis/LBL study of "The Future of Motor Vehicles."
• Europe-6: France, W. Germany, Italy, Norway, Sweden and United Kingdom.

total travel — a figure that continues to rise. It is simply a myth that public transit is the principal passenger transportation mode in Europe and Japan; in developed countries, auto use is far more prevalent than transit.

The auto industry benefits from the high value that most people place on the mobility and accessibility offered by motor vehicles, and those people will likely sacrifice much to maintain freedom of movement. But those same people are becoming less tolerant of the growing energy and environmental stresses created by the current transportation system. Tensions are increasing between continuing demand for mobility and the adverse effects of automobile use.

Increasing use of gasoline and diesel vehicles will exacerbate problems of petroleum supply. The predicament is not one of inadequate world supply: all signs indicate plentiful amounts of oil will be available at reasonable prices for years to come. The hitch is that for the United States, Europe, and Japan, those plentiful resources lie elsewhere. Virtually all forecasts anticipate a large drop in oil production in the United States and other countries outside the Per-

sian Gulf region in the 1990s and beyond. So automotive energy use in our country is increasing at the same time that petroleum production is declining, indicating potential political and economic problems domestically and internationally.

More use of petroleum-powered autos leads to increased emissions of greenhouse gases. Although there has been no definitive proof of global warming, scientists do know that emissions and atmospheric concentrations of greenhouse gases, especially CO₂, are rising at a rapid rate. It would be unwise to proceed as if climate change is not a potential problem. We would be grossly irresponsible, not to mention disrespectful of future generations, if we did not attempt to reduce these emissions now. As the Rio conference made clear, civic leaders around the world are demanding policies and actions to forestall further environmental damage, and governments are responding in turn.

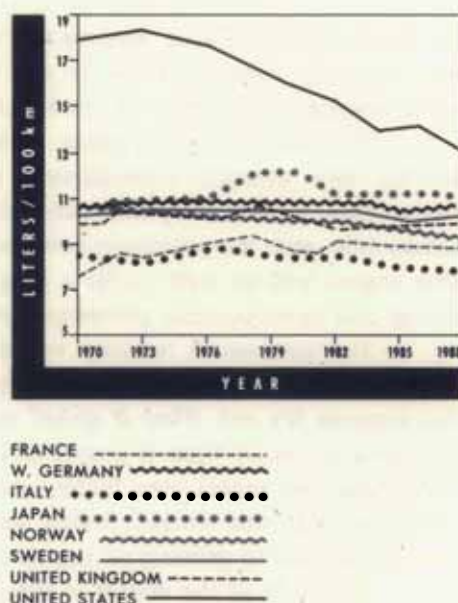
OPTIONS

So what are the remedies? Several possible options for reducing petroleum use and vehicle emissions

are at hand — some that involve behavioral changes and some that require technological developments.

Behavioral changes range from rethinking government policy to modifying individuals' conduct. For individuals it means switching from single-occupant autos to carpool and transit, and also rearranging job-residence locations. For government it means improving land-use management and regional transportation systems with the aim of reducing numbers and lengths of single-occupant car trips. Of course, substantive behavioral changes are hard to influence and slow to occur. Current research shows that politically palatable strategies aimed at behavioral change are likely to achieve vehicle travel reductions of only a few percent. More sweeping changes may be possible over the long term, but they would require aggressive road pricing and land use management initiatives.

FIG. 2
Automobile Fuel Economy
On Road (Actual)
Fleet Averages



Source: UC Davis/LBL Study of "The Future of Motor Vehicles."

Technological fixes appear to be more effective at reducing emissions and petroleum use, in part because they are politically more acceptable. One technological approach to the problems of increased petroleum use and greenhouse gas emissions that promises modest improvement is improved fuel efficiency in automobiles. In fact, the fuel efficiency of new cars soared in the United States between the 1973-74 energy crisis and the late 1980s and improved slightly elsewhere. But, as shown in Figure 2, when a country's entire vehicle fleet is taken together, one finds virtually no improvement over time, except in the U.S. where vehicles were previously huge and heavy.

Can fuel efficiency be improved further, and at what cost? The auto industry says new car efficiency could rise by 10-15 percent in the next 15 years, but many environmentalists insist that 40-50 percent improvements are necessary. Studies show that improvements in the range of 15 percent will provide a net economic gain. Upping efficiency beyond that may be socially desirable, but will likely require higher prices and down-sizing.

In any case, since the late 1980s, fuel economy has been falling, while per capita car ownership and use continue to rise. The result is increasing use of petroleum by passenger cars, as measured on both per capita and per country bases. Adding in expanding truck and air travel means that total transportation energy use is on a steady upswing. All this tells us that market forces alone won't result in improved efficiency and reduced oil consumption and that, even with substantial government intervention, it will be difficult to reduce total petroleum consumption.

The most promising long-term technical fix for reducing petroleum consumption and environmental threats is to substitute alternatively fueled vehicles, especially electric vehicles. Unfortunately, methanol (made from natural gas) is no better than gasoline in reducing greenhouse gases, and natural gas vehicles are only slightly better, as shown in Table 1. Nevertheless, both offer modest air quality benefits along with replacing petroleum imports. The only way to obtain large reductions in greenhouse gases is to shift to non-fossil fuels — which means creating alcohol fuels from cellulosic biomass, and producing electricity and hydrogen from solar and nuclear sources.

The biomass option is promising. The U.S. Department of Energy is now targeting biomass production and conversion as a primary strategy for reducing greenhouse gases from transportation. However, because biomass plantations require large tracts of land, biomass fuels are unlikely ever to be the dominant source of transportation energy in any developed country (except perhaps in sparsely populated Scandinavia and New Zealand).

In the long run — which may not be far off — there loom two promising large-scale options. The first is electricity, produced from solar (and perhaps nuclear) sources and used to drive electric cars. The second is hydrogen, separated from water, using solar energy via photovoltaic cells, then burned directly in internal combustion engines or, more likely, in fuel cells.

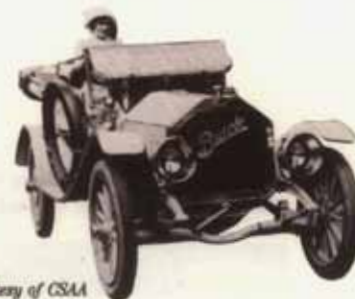
Fuel-cell and solar technologies are immature and expensive. Ultimately, though, as the technologies are improved and the costs are reduced, electricity and hydrogen will likely become the dominant transportation energy sources. If climate change proves to pose a real threat and energy security becomes a high priority, we'll likely see accelerated development and use of solar-based hydrogen and electricity. ➔



Courtesy of CSAA



Courtesy of CSAA



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Courtesy, The Bancroft Library



Courtesy of CSAA

Table 1. Greenhouse Gas Emissions of Motor Vehicles, Full Fuel Cycle, Relative to Gasoline Vehicles

FUEL/FEEDSTOCK	PERCENT CHANGE
Fuel cells using hydrogen made from water with solar power	-90 to -85
Ethanol made from wood	-75 to -40
Hydrogen from water using nuclear energy	-70 to -10
EVs, electricity from natural gas powerplants	-50 to -25
Compressed natural gas	-20 to 0
Methanol made from natural gas	-10 to +8
EVs, current U.S. powerplant mix	-20 to 0
Gasoline	—
EVs, electricity from new coal powerplants	0 to +10
Methanol made from coal	+30 to +70

Source: M.A. DeLuchi, *Emissions of Greenhouse Gases from the Use of Transportation Fuels and Electricity*, Argonne National Laboratory, ANL/ESD/TM-22. NTIS: Springfield, VA, 1991.

Note: Emissions of all relevant greenhouse gases (CH_4 , N_2O , NO_x , CO_2 and NMHC) were calculated and weighted according to their "global warming" effect. Calculations include emissions from the entire fuel cycle, including production, transportation, end use, and vehicle manufacturing.

Table 2. Emission Impacts of Electric Vehicles, Full Fuel Cycle, Year 2010

	REACTIVE HYDROCARBONS	CARBON MONOXIDE	NITROGEN OXIDES	SULFUR OXIDES	PARTICULATE MATTER
Belgium	-99	-99	-70	322	130
Canada	-99	-99	-65	-38	26
France	-99	-99	-83	110	12
Germany	-99	-99	-90	4	212
Greece	-99	-99	-21	1046	493
Italy	-99	-99	-68	-16	242
Japan	-99	-99	-73	-75	71
Netherlands	-99	-99	-82	-17	149
Norway	-99	-99	-89	-96	-92
Spain	-99	-99	-59	463	258
Sweden	-99	-99	-95	-95	-18
United Kingdom	-99	-99	-37	31	378
United States	-95	-99	-67	204	122

Source: D. Sperling and M.A. DeLuchi (1992), *Alternative Transportation Fuels and Air Pollution*, Prepared for the Organisation for Economic Cooperation and Development (OECD), Paris, France. Forthcoming.

As for now, continuing development of electric vehicle (EV) technology, along with modest improvements in vehicle efficiency, are the most sensible options. EVs provide a "least-regrets" and least-cost strategy in preparing for the hydrogen and electricity future. While it's true that present generation EVs are more expensive, require longer refueling periods, and have limited driving ranges, they also have positive attributes — less maintenance, convenience of home recharging, and quiet operation. More important from a policy perspective, they provide modest greenhouse and huge air-quality benefits in most regions of the world. (See Table 2.) In general, the less coal used for electricity generation, the greater the benefits. But even in the U.S., where 55 percent of electricity is made from coal, electrification of the entire automobile fleet would still result in up to 20 percent reduction in greenhouse gas emissions and substantial reductions in ozone pollution.

In most countries, EVs will be a boon to air quality. They eliminate hydrocarbon and carbon monoxide emissions and substantially reduce nitrogen oxides. They do tend to increase sulfur oxide and particulate emissions, but these increases are generally unimportant because cars generate less than 2 percent of those pollutants. Thus even a tripling of sulfur oxide emissions from cars would cause a relatively small overall impact. If introduced on a large scale, EVs would provide much larger air quality benefits than would any other serious option, including any liquid or gaseous fuels. In the long term, as electricity supply shifts to renewable sources, electric vehicles promise almost complete elimination of air pollution and greenhouse gases, as well as almost complete reliance on domestic resources.

THE FUTURE

Throughout industrialized countries, then, cars play an increasingly dominant role in passenger transportation, placing great stress on cities, the environment, and political institutions. Politicians and voters will continue to push for stricter environmental and social policing of the auto's effects. Not a single auto manufacturer has persuasively marketed itself and its vehicles as being socially responsible. Even if one had, who would have noticed? Most car owners — most people — would probably continue to behave as free riders, unwilling to pay extra for environmentally sound cars and fuels even if they do have strong environmental ideals. These same people will, however, vote to force car and fuel suppliers to act more responsibly, to subsidize the expenses associated with reduced environmental pollution. And politicians sense that.

That's what happened in California, where, in late 1990 and 1991, voters adopted strict regulations on vehicle emissions and the quality of gasolines. The new standards require vehicle manufacturers to reduce emissions by up to 80 percent over the next 12 years and require gasoline to be reformulated to reduce hydrocarbon and other emissions by 20-30 percent, at an estimated cost to consumers of about 15 cents per gallon.

The state also mandated that all major automakers must begin selling electric or other zero-emission vehicles by 1998. In that year, 2 percent of the cars sold in the state by each manufacturer must be zero-emitting. The percentage increases to 5 percent in 2001 and to 10 percent in 2003 — accounting for about 200,000 cars per year in 2003.

The facts regarding automobile use are unambiguous: cars provide accessibility and mobility, and they will likely dominate passenger transportation into the foreseeable future. The challenge is to commercialize a car that is environmentally benign. But that's not likely to happen without increased governmentally sponsored research aimed at such energy sources as fuel cells, biomass, and solar-hydrogen. Nor is it likely to happen without high taxes on high-impact fuels and on gas-guzzling cars — taxes high enough to motivate consumers and industry to turn to those fuels and vehicles. Government must also redesign anti-pollution regulations, making them more flexible and incentive-based. Current regulatory systems are economically inefficient, inappropriate for promoting alternative fuels, and lacking incentives for improvement and innovation. More appropriate incentives and effective regulations will spur the adoption of fuels and vehicles that are sensitive to regional differences and that provide major air quality, greenhouse, and energy-security benefits. □



Courtesy of MVMA

Prototypical
electric car
of another year.

R E F E R E N C E S

- Genevieve Giuliano, Keith Hwang, and Martin Wachs, "Mandating Trip Reductions in Southern California," UCTC Working Paper, No. 98, 1992.
- David Greene and Daniel Sperling, *Transportation and Energy*, (Westport, Conn.: ENO Foundation for Transportation, 1992.)
- National Research Council, *Automotive Fuel Economy*, (Washington, D.C.: National Academy Press, 1992.)
- Office of Technology Assessment, U.S. Congress, *Replacing Gasoline*, (Washington, D.C.: Government Printing Office, 1991).
- Quanlu Wang, Mark Deluchi, and Daniel Sperling, "Emission Impacts of Electric Vehicles," *Journal of Air and Waste Management Association*, Vol. 40, pp. 1275-1284. UCTC Reprint, No. 41, 1990.
- Daniel Sperling, Mark Deluchi, and Quanlu Wang, *Toward Alternative Transportation Fuels and Incentive-Based Regulation of Vehicle Fuels and Emissions*, (Berkeley: California Policy Seminar, 1991).
- M. A. Deluchi, *Emissions of Greenhouse Gases from the Use of Transportation Fuels and Electricity*, Argonne National Laboratory, ANL/ESD/TM-22. (Springfield, VA.: NTIS, 1991).
- Thomas Turrentine and Daniel Sperling, "Is there a Market for a Vehicle With 100 Mile Range?" *Proceedings, Urban Electric Vehicle*, (Paris: OECD/IEA, 1992).

Pavement-Friendly Buses and Trucks

BY J. KARL HEDRICK, KYONGSU YI,

AND MARGARET WARGELIN

Our roads are crumbling under the weight of buses and heavy truck loads. Although early researchers attributed the pavement damage to a fixed, "static" factor — the vehicle's weight and design — we now know that much of the blame is owed to "dynamic" variables — the interaction between the vehicle's suspension and the road surface. Recent studies show that dynamic force can double, even quadruple, pavement damage. But by equipping trucks and buses with advanced, "semi-active" suspensions, the problem of road wear can be effectively addressed. We are anticipating an up to 20 percent reduction in tire force on pavement surfaces.

Advanced suspensions have for years been available on high-performance cars, designed to improve performance. Semi-active suspensions — outfitted with a "smart" shock absorber, having a variable damping rate, a sensor, and a microprocessor that provides the smarts — afford a better ride than passive suspensions, which use a conventional spring and shock absorber system and can only temporarily store energy. Likewise, fully active suspensions, which include actuators to generate force, provide improved performance over their semi-active counterparts.

Still, active suspensions do have drawbacks, such as the need for a large external power source, increased complexity, and higher cost. Semi-active suspensions are the perfect compromise: they're better performers than passives and are safer, more economical, and more practical than the actives. Our research investigated the effectiveness of semi-active truck and bus suspensions on reducing pavement damage.

Among the research methods we used were computer simulations to estimate dynamic tire force. The vehicle simulation package, known as VESYM, and the flexible pavement simulation programs, VESYS and PMARP, allowed us to compare alternative suspensions such as walking beam, leaf spring/short rocker, air spring, and, of course, semi-active suspensions. Figure 1 symbolizes the interaction between a truck or a bus subjected to a rough road surface and the road, which has previously been exposed to heavy loads. Figure 2 shows the interaction of the computer simulation programs developed and modified at the Massachusetts Institute of Technology and the University of California at Berkeley. VESYM figures the dynamic tire loads of trucks or buses once the road surface is specified. VESYS and PMARP compute pavement stress and also predict ultimate road life once the dynamic factors have been determined.

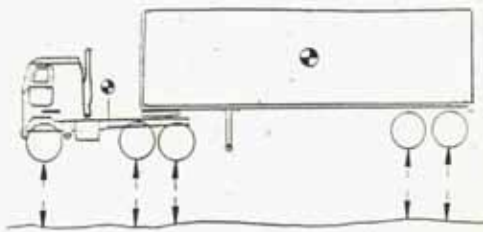


Fig. 1
Vehicle/Pavement
Interaction

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The research also includes laboratory experiments with a half-car test rig, shown in Figure 3. These tests showed how semi-active suspensions could reduce dynamic force and checked the feasibility of the suspensions from a real-time perspective. Although, obviously, the half-car, which was equipped with the semi-active system, is much lighter than a truck or bus, the experimental performance could prove helpful in the future, when actual vehicles are used.

Although the semi-active suspension provided large reductions in dynamic tire force both in the computer simulation and on the half-car rig, we needed to try experiments in actual field conditions. We conducted a two-week series of tests at the PACCAR test facility in Mt. Vernon, Washington, with help from PACCAR and the LORD Corporation, which provided the semi-active dampers. Besides confirming that semi-active suspensions would reduce dynamic force, and thereby reduce pavement damage, we also hoped to show that the suspensions would operate with limited computing speed and memory and be compatible with existing high-tech parts.

Figure 4 shows the experimental research vehicle, a Peterbilt 359 truck with a four-leaf driving axle suspension. The truck had been disassembled at the University of Michigan Transportation Research Institute in order to measure its physical and dynamic properties. We equipped the fully loaded truck with strain-gauged axles to measure the actual tire force on the road. Accelerometers showed how the semi-active suspension affected the cargo and driver. We put variable shock absorbers — with 13 possible damping rates, from very stiff to very soft — on each end of the two drive axles. It took two milliseconds to switch from one setting to an adjacent one, or 20 milliseconds to change from soft to

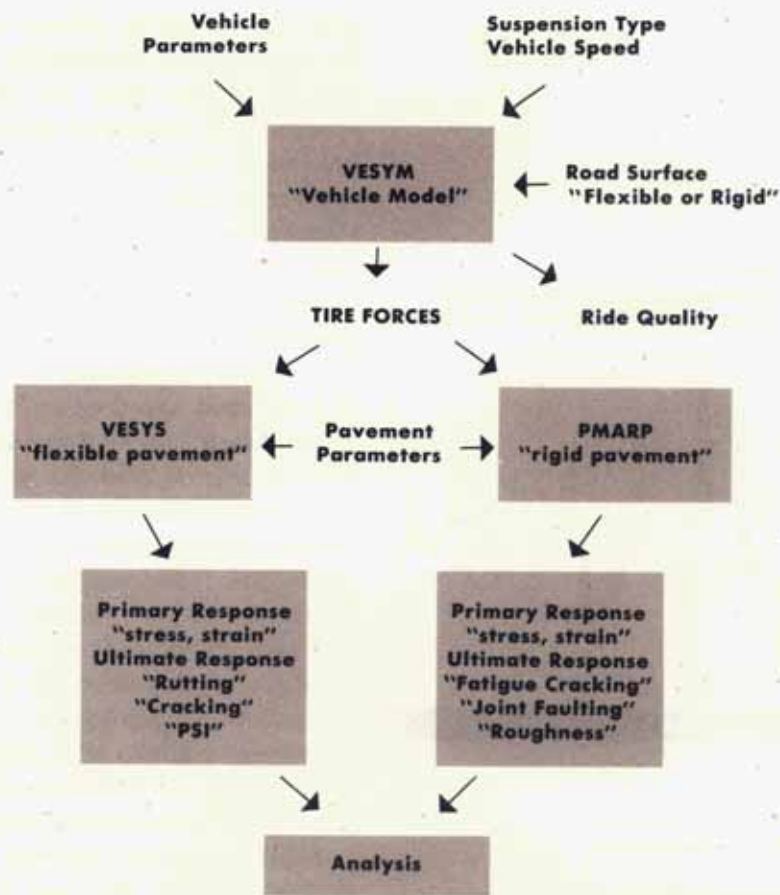
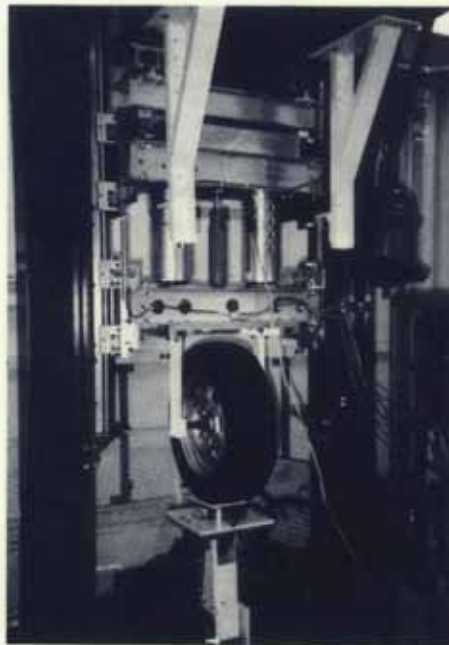


Fig. 2 Flow Chart for Vehicle Study

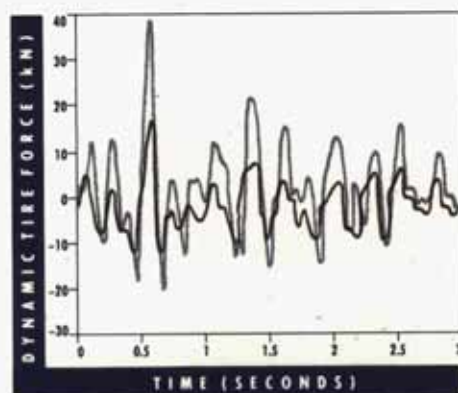


**Fig. 3
Berkeley Half Car
Suspension Test Laboratory**



**Fig. 4
Experimental Vehicle,
a Peterbilt 359 truck**

FIG. 5
Comparison of Estimated
Tire Forces (Vehicle Test)



PASSIVE _____
SEMI-ACTIVE _____

Vehicle Test: Broken concrete, 5 mph, driving wheel

hard. A semi-active clipped controller, when fed information about vehicle motion from an IBM PC, automatically switched the damper. Processing the cargo and axle accelerations in real time allowed for the elimination of the effects of noise on these values, which were then used to find desired settings for the shock absorbers.

The experiments took place at a constant speed on two sections of test track and on two three-mile sections of real road. We affixed 36 surface strain gauges at one-foot intervals along the track to determine the effects of the suspension on the pavement. Another section of track was made up of rough or broken concrete designed to simulate at 5 mph the results of driving on a moderately rough highway at 55 mph. Tests on a section of Interstate 5 North showed how semi-actives operate on a rough concrete highway, while another section of rural highway showed performance on asphalt.

We expected peak tire force reductions of up to 20 percent, which was the range computed during the computer-simulation experiments. (Figure 5) The data from the pavement sensors and strain gauges in the field are not yet available to be analyzed, but we have verified that the computer memory and speed requirements were within reason. The motors which set the shock absorber position did give us some trouble, but the absorbers themselves met all specifications.

The simulations and tests show a wide range in the pavement-damaging effects of existing suspensions and reveal that semi-active suspensions have the potential to reduce road wear dramatically. As for the future, the research done here is bound to be useful in other suspension experiments: for instance, the control algorithm could be optimized to improve vehicle handling and ride

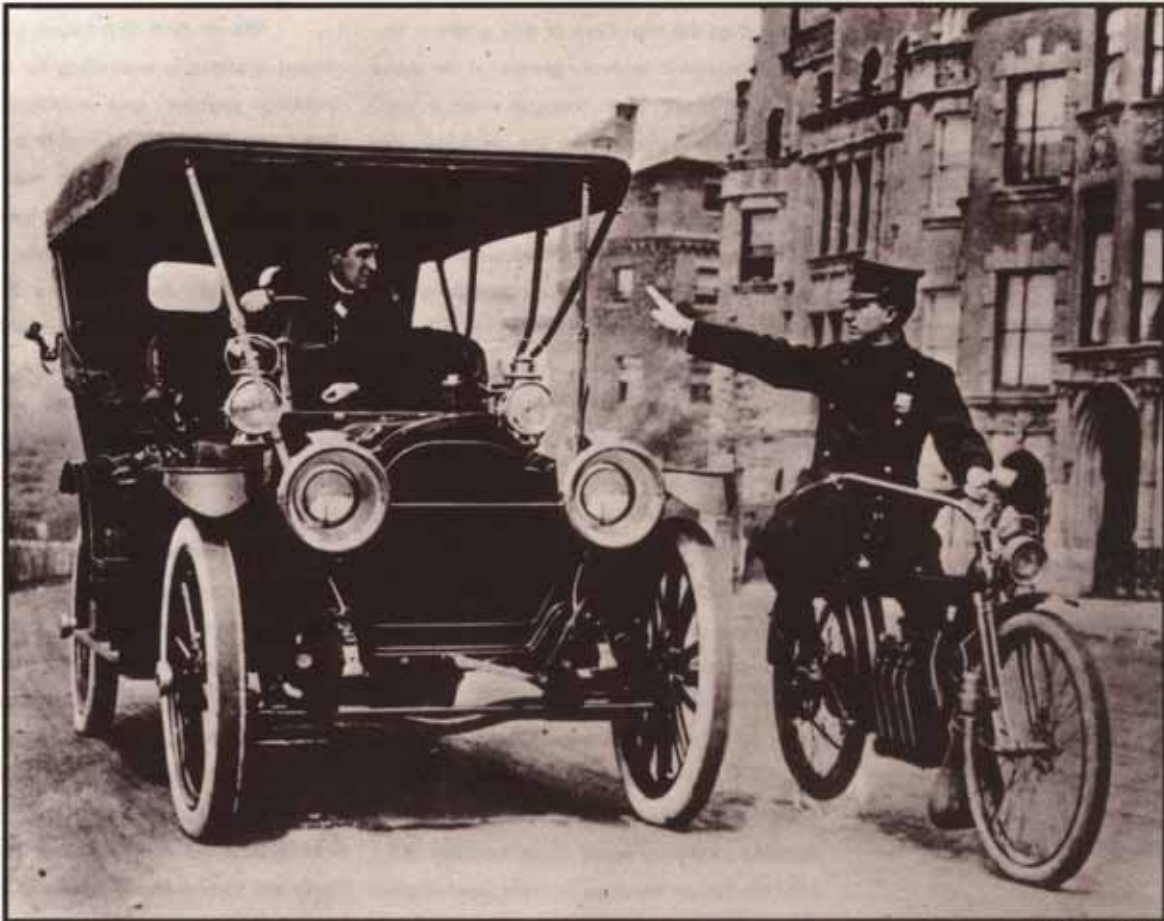
quality. New research could focus on the development of adaptive control algorithms to estimate vehicle loading. Other directions include figuring sensor, microprocessor, and damper requirements and developing a prototype of the microprocessor controller. Since the preliminary tests conducted at the PACCAR Technical Center reveal that semi-active suspensions are feasible from a real-time perspective, future studies are necessary to be sure about the cost/benefit tradeoff of such a system. □

REFERENCES

- F.H. Besinger, D. Cebon, and D.J. Cole, "An Experimental Investigation into the Use of Semi-active Dampers on Heavy Lorries," Proceedings, 12th IAVSD Symposium, Lyon, France, August 26-30, 1991, pp. 57-71.
- D. Cebon, "Road Damaging Effects of Dynamic Axle Loads," Proceedings, International Symposium on Heavy Vehicle Weights and Dimensions, Kelowna, British Columbia, Canada, June 1986.
- J.K. Hedrick and K. Yi, "The Effect of Heavy Truck Suspensions on Flexible Pavement Response," UCTC Working Paper, No. 46, 1991.
- P.F. Sweatman, "A Study of Dynamic Wheel Forces in Axle Group Suspensions of Heavy Vehicles," Australian Road Research Board, Special Report No. 27, 1983.
- Kyongsu Yi and J.K. Hedrick, "Active and Semi-Active Heavy Truck Suspensions to Reduce Pavement Damage," SAE Technical Paper Series, November 1989. UCTC Reprint, No. 27.
- Kyongsu Yi, Margaret Wargelin, and J.K. Hedrick, "Dynamic Tire Force Control by Semi-Active Suspensions," prepared for the 1992 ASME Winter Annual Meeting, Anaheim, California, November 1992. UCTC Working Paper, No. 97.

COMMUTER STRESS

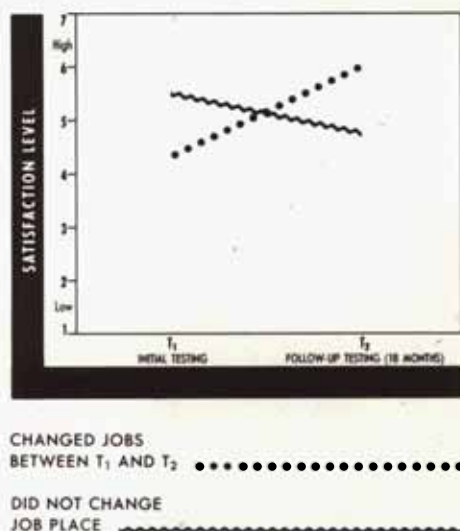
BY RAYMOND W. NOVACO



Courtesy of CSAA

Everyone knows that being stuck in traffic is stressful, and few look forward to long commutes on congested roadways. But the negative effects of traffic congestion go beyond frustration and fatigue. Our research at UC Irvine since the late 1970s has discovered adverse health impacts of what we call "high impedance" commuting. ➔

FIG. 1
Commuting Satisfaction Shifts
as a Function of Change in Place of
Employment Between Initial Testing
and Follow-up



Our studies have been aimed at determining whether commuting really does lead to stress, and then to identify the exact causes of stress. We find that traffic congestion is indeed stress-inducing by virtue of the physical and perceptual dimensions of travel impedance. Physical impedance is objectively measured, reflecting the distance and time spent on the journey, along with the number of roads and freeways traveled on the trip. Time of day is also a factor: congestion is normally greater in the evening peak hours, when induced stress is compounded by fatigue from the workday. We find that commuting distance is directly related to blood pressure — the longer the distance, the higher the commuter's blood pressure. High levels of physical impedance are also related to lower tolerance for frustration, to negative mood at the workplace, and to illness. For example, the more roads traveled by commuters, the more times they will call in sick at work.

Recently we have begun to pay greater attention to the perceived dimension of commuting constraints — what we call subjective impedance. It is measured by clusters of questionnaire items in various formats. We find subjective impedance is related to illness, chest pain, job choice, and residential satisfaction. Among the strongest findings are its effect on negative mood at home in the evening. Our ongoing research seeks to understand more fully the factors involved in these psychological effects of traffic congestion.

Documenting the social costs of traffic congestion involves moving beyond simple intuitions. While it may seem obvious that chronic exposure to traffic congestion is stressful, the specific psychological and physiological effects are far from obvious. It is quite a puzzle to determine which conditions will lead to significant differences in observable stress among which people. Furthermore, before we can say that the observed stress is due to commuting, we must scientifically control for many other factors, such as the person's physical characteristics, income, education, home life, and work environment.

For example, you might think that long distance commuting (driving 20 miles or more) would lead to increased heart rates or to decreased positive mood at work. You might also think that people with Type-A personalities who have long commutes on congested roads would be the most stressed. While these seem to be reasonable intuitions, we do not find any of them to be true.

We do find that blood pressure is affected (statistically controlling for age, weight, smoking, exercise, and medication), but not heart rate. Similarly we find that a congested commute increases negative moods (tension, nervousness, impatience, and irritability), but we have never found significant decreases in positive moods. And while we first hypothesized that Type-A personalities with long commutes would be the most stressed, our studies show that Type-B individuals (more relaxed, easy-going personalities) are most negatively affected. It turns out that the personality factor is a dynamic variable affecting residential choice, job involvement, and what one does in the car. Long-distance Type-A commuters exercise more control in selecting their residences, are more involved in their jobs, and tend to think about work during the commute instead of paying attention to the traffic.

The demographic group with the most commuting stress is that of female solo drivers having long-distance commutes. Although they have the highest family income of all groups in our studies and are most involved in their jobs, they report less choice among residential locations and feel rushed in getting to work each morning. Because we find no differences between males and females in the objective characteristics of their commutes (distance traveled, time of commute, roads used, and intermediary stops), we are now studying whether the higher stress rate among women is due to role strain (an overload of demands at home and at work) or to other factors.

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Our most recent study examined the potential stress-mitigating effects of ridesharing. We studied solo drivers, carpoolers, and vanpoolers — all with commute distances of more than 15 miles. Based on multiple testings at work sites, we find that female ridesharers have lower stress than do female solo drivers. Of the ridesharing groups, passengers consistently have lower blood pressure than drivers. Male passengers and female rideshare drivers not only have significantly lower blood pressure than solo drivers, but they also perform better on mental tests — digit copying, digit recall, and proofreading.

Our studies of commuting stress reveal substantial hidden costs associated with commuting. Figure 1 illustrates these hidden costs of commuting, both to the worker and to the business organization, pertaining to job change and commuting satisfaction. The commuters in this study worked at companies in the Irvine Industrial Area, and they participated in a two-phased project that had an initial testing phase and a follow-up 18 months later. During this interval, 14 percent of the participants changed jobs to new locations.

Those who moved to different companies had lower commuting satisfaction at the initial testing than those who did not change job locations. At the time of the follow-up, those who changed jobs had increased commuting satisfaction, while those who continued to work at the same place had decreased commuting satisfaction. All these differences in commuting satisfaction are statistically significant. Importantly, when we conducted these same analyses for job satisfaction and for residential satisfaction, we found no significant differences. This suggests that the job change was primarily a function of dissatisfaction with the commute, rather than with job or residential conditions.

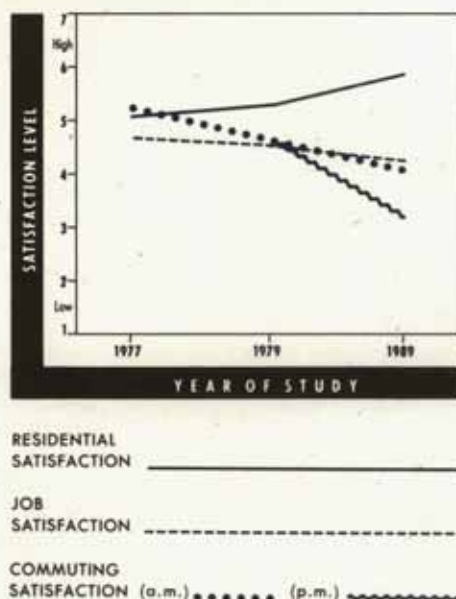
Intensification in commuting dissatisfaction over time can be seen in a comparison of these three satisfaction measures (commute, job, and residence) in 1977, 1979, and 1989 when employees of the same two Irvine companies participated in our research. Figure 2

shows that, while the level of residential satisfaction reported in 1989 was somewhat higher than in previous years and job satisfaction was slightly lower (neither to a statistically significant degree), the level of commuting satisfaction dropped quite significantly, especially for the evening commute. Thus, for these samples of commuters from the same two companies, dissatisfaction with commuting intensified, but not with the job or residence.

Dissatisfaction with the commute is a cost the employee absorbs, often with delayed effects on health and well-being. Our research found there are strong spillover effects of this aspect of subjective impedance on home life. Employee turnover negatively affects the work organization as well. People will change jobs to cope with traffic congestion, but commuting stress is more often manifested in illness-related absence from work, employee turnover, and reduced levels of productivity and morale.

The findings from this program of research on commuting stress should alert businesses and social institutions to adverse consequences of commuting, providing another incentive for organizations to encourage workers to try alternative modes of transportation. Our preliminary results suggest that ridesharing has benefits for well-being, but these findings require corroboration and a larger investigation. We find that commuter interest in company-sponsored vanpools has increased significantly over the period of our research. We are now beginning a study on the psychological effects of commuting by that mode. □

FIG. 2
Changes in Satisfaction Measures
Across Years of Study at the Same
Two Companies



REFERENCES

- Raymond W. Novaco, "Commuting, Stress, and Well-being," *ITS Review*, Institute of Transportation Studies, University of California, Berkeley, Vol. 12, No. 2, 1989, pp. 4-8.
- Raymond W. Novaco, Wendy Kliever, and Alexander Broquet, "Home Environment Consequences of Commute Travel Impedance," *American Journal of Community Psychology*, Vol. 19, pp. 881-909, 1991. UCTC Reprint, No. 77.
- Raymond W. Novaco, Daniel Stokols, and Louis Milanesi, "Objective and Subjective Dimensions of Travel Impedance as Determinants of Commuting Stress," *American Journal of Community Psychology*, Vol. 18, No. 2, pp. 231-257, 1990. UCTC Reprint, No. 30.
- Raymond W. Novaco, Daniel Stokols, J. Campbell, and J. Stokols, "Transportation Stress and Community Psychology," *American Journal of Community Psychology*, Vol. 7, pp. 361-380, 1979.
- Daniel Stokols and Raymond W. Novaco, "Transportation and Well-Being" in I. Altman, J. F. Wohlwill, and P. Everett (eds.), *Transportation and Behavior*, (New York: Plenum Press, 1981).
- Daniel Stokols, Raymond W. Novaco, J. Stokols, and J. Campbell, "Traffic Congestion, Type A Behavior, and Stress," *Journal of Applied Psychology*, Vol. 63, pp. 467-480, 1978.

- Adler, Jeffrey L., Wilfred W. Recker and Michael G. McNally, "Using Interactive Simulation to Model Driver Behavior Under ATIS." Working Paper, 1992. UCTC No. 126.
- Adler, Jeffrey L., Wilfred W. Recker and Michael G. McNally, "A Conflict Model and Interactive Simulator (FASTCARS) for Predicting Enroute Driver Behavior in Response to Real-Time Traffic Condition Information." Presented to the Transportation Research Board, 71st Annual Meeting, Washington, D.C., January 1992. Working Paper, 1992. UCTC No. 127.
- Boer, Christopher T., Daniel B. Klein and John Majewski, "From Trunk to Branch: Toll Roads in New York, 1800-1860." Working Paper, 1992. UCTC No. 121.
- Barnett, Roger, "Tilting Trains: The Italian ETR and the Swedish X-2000." Working Paper, 1992. UCTC CalSpeed Series No. 113.
- Bennett, Anna K. and David D. Little, "Earthquake Effects on Employee Transportation." Working Paper, 1991. UCTC Earthquake Series, No. 2.
- Berechman, J. and Kenneth A. Small, "Modeling Land Use and Transportation: An Interpretive Review for Growth Areas." *Environment and Planning*, Vol. 20, pp. 1285-1309, 1988. Reprint, 1990. UCTC No. 1.
- Blankson, Charles and Martin Wachs, "Preliminary Evaluation of the Coastal Transportation Corridor Ordinance in Los Angeles." *Transportation Research Record*, No. 1280, pp. 39-45, 1990. Reprint, 1990. UCTC No. 32.
- Brownstone, David, "Multiple Imputations for Panel Studies." Working Paper, 1991. UCTC No. 37.
- Brownstone, David and Thomas F. Golob, "The Effectiveness of Ridesharing Incentives: Discrete-Choice Models of Commuting in S. California." Working Paper, 1992. UCTC No. 93.
- Bunch, David S. and Ryuichi Kitamura, "Probit Model Estimation Revisited: Trinomial Models of Household Car Ownership." Working Paper, 1991. UCTC No. 70.
- Bunch, David S., "Estimability in the Multinomial Probit Model." *Transportation Research*, Vol. 25B, No. 1, pp. 1-12, 1991. Reprint, 1991. UCTC No. 71.
- Burns, Elizabeth K., "Improving Traffic Congestion by Regulating Employee Travel: A Phoenix Survey." Working Paper, 1991. UCTC No. 22.
- Burns, Elizabeth K., "Arizona's Metropolitan Travel Reduction Programs." Working Paper, 1992. UCTC No. 81.
- Burns, Elizabeth K., "Vance's Commuting Analysis Extended to the Suburban Southwest: Tempe, Arizona." *Yearbook of the Association of Pacific Coast Geographers*, December 1991. Reprint, 1992. UCTC No. 67.
- Cervero, Robert, "Land-Use Mixing and Suburban Mobility." *Transportation Quarterly*, Vol. 42, No. 3, pp. 429-446, July 1988. Reprint, 1990. UCTC No. 3.
- Cervero, Robert, "Land Market Impacts of Urban Rail Transit and Joint Development: an Empirical Study of Rail Transit in Washington, D.C. and Atlanta." *Sixth World Conference on Transport Research*, Lyon, France, 1992. UCTC No. 135.
- Cervero, Robert, "Congestion, Growth, and Public Choices." *Berkeley Planning Journal*, 1990. Reprint, 1991. UCTC No. 51.
- Cervero, Robert, "Suburban Employment Centers: Probing the Influence of Site Features on the Journey-to-Work." *Journal of Planning Education and Research*, Vol. 8, No. 2, 1991. Reprint, 1991. UCTC No. 49.
- Cervero, Robert, "Jobs-Housing Balancing and Regional Mobility." *APA Journal*, Spring 1989. Reprint, 1991. UCTC No. 50.
- Cervero, Robert, "Profiling Profitable Bus Routes." *Transportation Quarterly*, Vol. 44, No. 2, 1990. Reprint, 1992. UCTC No. 92.
- Cervero, Robert, "Land Uses and Travel at Suburban Activity Centers." *Transportation Quarterly*, Vol. 45, No. 4, 1991. Reprint, 1992. UCTC No. 91.
- Cervero, Robert, "Paratransit in Southeast Asia: A Market Response to Poor Roads?" *Review of Urban and Regional Development Studies*, Vol. 3, pp. 3-27, 1991. Reprint, 1992. UCTC No. 90.
- Cervero, Robert, "Accessibility and Third World Rural Development: A Case Study of Sumatra." Reprint, 1990. UCTC No. 108.
- Cervero, Robert and John Landis, "Suburbanization of Jobs and the Journey to Work." Working Paper, 1991. UCTC No. 83.
- Deakin, Elizabeth, "Transportation and Air Quality in California: A Policy Analysis." Working Paper, 1991. UCTC No. 55.
- Deakin, Elizabeth, "Toll Roads: A New Direction for U.S. Highways?" *Built Environment*, Vol. 15, Nos. 3/4, pp. 185-194, 1989. Reprint, 1990. UCTC No. 56.
- Deakin, Elizabeth, "Suburban Traffic Congestion, Land Use and Transportation Planning Issues: Public Policy Options." *Transportation Research Circular*, 1990. Reprint, 1991. UCTC No. 57.
- Deakin, Elizabeth, "Transportation and Land Use Planning in California: Problems and Opportunities for Improved Performance." Working Paper, 1991. UCTC No. 53.
- Deakin, Elizabeth, "Land Use and Transportation Planning in Response to Congestion: The California Experience." Working Paper, 1991. UCTC No. 54.
- Deakin, Elizabeth, "The United States." *Transport Policy and the Environment: Six Case Studies*, Earthscan Publications, Ltd., 1990. Reprint, 1991. UCTC No. 66.
- Deluchi, Mark, Quanlu Wang, and Daniel Sperling, "Electric Vehicles: Performance, Life-Cycle Costs, Emissions, and Recharging Requirements." *Transportation Research*, Vol. 23A, No. 3, pp. 255-278, 1989. Reprint, 1990. UCTC No. 7.
- De Vany, Arthur and W. David Walls, "When Barriers to Markets Fall: Pipeline Deregulation, Spot Markets, and the Topology of the Natural Gas Market." Working Paper, 1992. UCTC No. 123.
- Fielding, Gordon J. and Daniel B. Klein, "How to Franchise Highways." Working Paper, 1992. UCTC No. 134.
- Garrison, William L. and Reginald E. Souleyrette II, "Relations Between Transportation and Production." *Transportation Research Record*, October 1990. Reprint, 1990. UCTC No. 45.
- Giuliano, Genevieve, "New Directions for Understanding Transportation and Land Use." *Environment and Planning*, Vol. 21, pp. 145-159, 1989. Reprint, 1990. UCTC No. 2.
- Giuliano, Genevieve and Thomas F. Golob, "Using Longitudinal Methods for Analysis of a Short-Term Transportation Demonstration Project." *Transportation*, Vol. 17, pp. 1-28, 1990. Reprint, 1990. UCTC No. 28.
- Giuliano, Genevieve and Kenneth A. Small, "Subcenters in the Los Angeles Region." Working Paper, 1990. UCTC No. 39. Since published in *Regional Science and Urban Economics*, Vol. 21, pp. 163-182, 1991.
- Giuliano, Genevieve, "Is Jobs-Housing Balance a Transportation Issue?" *Transportation Research Record*, No. 1305, pp. 305-312, 1991. UCTC No. 133.
- Giuliano, Genevieve and Martin Wachs, "Responding to Congestion and Traffic Growth: Transportation Demand Management." *Growth Management and Sustainable Development*, Sage Publications, 1992. Reprint, 1991. UCTC No. 86.
- Giuliano, Genevieve, Keith Hwang, Diane Perrino, and Martin Wachs, "Preliminary Evaluation of Regulation XV of the South Coast Air Quality Management District." Working Paper, 1991. UCTC No. 60.
- Giuliano, Genevieve, Keith Hwang and Martin Wachs, "Mandatory Trip Reduction in Southern California: First Year Results." Working Paper, 1992. UCTC No. 98.
- Giuliano, Genevieve and Kenneth A. Small, "Is the Journey to Work Explained By Urban Structure?" Working Paper, 1992. UCTC No. 107.
- Glazer, Amihai and Eska Niskanen, "Parking Fees, Congestion, and Consumer Welfare." Working Paper, 1991. UCTC No. 24.
- Golob, Thomas F., "The Dynamics of Household Travel Time Expenditures and Car Ownership Decisions." *Transportation Research*, Vol. 24A, No. 6, pp. 443-463, 1990. Reprint, 1991. UCTC No. 26.
- Golob, Thomas F. and Jacqueline M. Golob, "Practical Considerations in the Development of a Transit User Panel." Working Paper, 1990. UCTC No. 17.
- Golob, Thomas F., "Structural Equation Modeling of Travel Choice Dynamics." Working Paper, 1990. UCTC No. 4. Since published in *New Developments in Dynamic and Activity-Based Approaches to Travel Analysis*, pp. 343-370. Aldershot, Hants, England.
- Golob, Thomas F. and Lee Van Wissen, "A Joint Household Travel Distance Generation and Car Ownership Model." *Transportation Research*, Vol. 23B, No. 6, pp. 471-491, 1989. Reprint, 1990. UCTC No. 8.
- Goulias, Konstadinos G., "Forecasting the Impact of Sociodemographic Travel Demand." Presented at the Sixth World Conference on Transport Research, Lyon, France, June/July 1992. Working Paper, 1992. UCTC No. 94.
- Goulias, Konstadinos G., "A Dynamic Micro-simulator for Travel Demand Forecasting." Working Paper, 1992. UCTC No. 95.

- Goulias, Konstadinos G., "Analysis of Binary Choice Frequencies With Limit Cases." *Transportation Research, Part B*. Reprint, 1992. UCTC No. 96.
- Goulias, Konstadinos G., Ram M. Pendyala, and Ryuichi Kitamura, "Updating a Panel Survey Questionnaire." Working Paper, 1991. UCTC No. 61.
- Goulias, Konstadinos G., Ram M. Pendyala, and Ryuichi Kitamura, "A Practical Method for the Estimation of Trip Generation and Trip Chaining." *Transportation Research Record*, No. 1285, 1991. Reprint, 1991. UCTC No. 62.
- Goulias, Konstadinos G. and Ram Pendyala, "Innovations in Transportation: The Case of Telecommuting." Working Paper, 1991. UCTC No. 72.
- Goulias, Konstadinos and Ryuichi Kitamura, "Recursive Model System for Trip Generation and Trip Chaining." *Transportation Research Record*, Vol. 1236, pp. 59-66, 1991. Reprint, 1991. UCTC No. 40.
- Hall, Peter, Daniel Leavitt and Erin Vaca, "High-Speed Trains for California. Strategic Choice: Comparisons of Technologies and Choice of Route." Working Paper, 1992. UCTC CalSpeed Series No. 104.
- Hall, Peter, Daniel Leavitt and Erin Vaca, "High-Speed Trains for California. Volume II: Detailed Segment Descriptions, Cost Estimates, and Travel Time Calculations." Working Paper, 1992. UCTC CalSpeed Series No. 105.
- Hall, Randolph W., "Design for Local Area Freight Networks." Working Paper, 1991. UCTC No. 63.
- Hall, Randolph W., "Pickup and Delivery Systems for Overnight Carriers." Working Paper, 1992. UCTC No. 106.
- Hall, Randolph W. and Wei Hua Lin, "LTL Trucking in Los Angeles: Congestion Relief Through Terminal Siting." Working Paper, 1990. UCTC No. 43.
- Hansen, Mark and Jacob Sutter, "The Shake With Freight: The Impact of the Loma Prieta Earthquake on Bay Area Truckers." Working Paper, 1991. UCTC Earthquake Series No. 1.
- Hansen, Mark and Sharon Weinstein, "East Bay Ferry Service and the Loma Prieta Earthquake." Working Paper, 1992. UCTC Earthquake Series No. 5.
- Hedrick, J.K. and K. Yi, "The Effect of Alternative Heavy Truck Suspensions on Flexible Pavement Response." Working Paper, 1991. UCTC No. 46.
- Hwang, Keith and Genevieve Giuliano, "Review of the Literature on the Determinants of Ridesharing." Working Paper, 1991. UCTC No. 38.
- Jovanis, Paul P., Tetsuya Kaneko, and Tsuoa-Din Lin, "Exploratory Analysis of Motor Carrier Accident Risk and Daily Driving Patterns." Working Paper, 1991. UCTC No. 73.
- Kaneko, Tetsuya and Paul P. Jovanis, "Multiday Driving Patterns and Motor Carrier Accident Risk: A Disaggregate Analysis." Working Paper, 1991. UCTC No. 59.
- Keeler, Theodore E., "Highway Safety, Economic Behavior, and Driving Enforcement." Working Paper, 1991. UCTC No. 65.
- Kitamura, Ryuichi and David S. Bunch, "Heterogeneity and State Dependence in Household Car Ownership: A Panel Analysis Using Ordered-Response Probit Models with Error Components." *Transportation and Traffic Theory*, pp. 477-496, 1990. Reprint, 1990. UCTC No. 52.
- Kitamura, Ryuichi, "Panel Analysis in Transportation Planning: An Overview." *Transportation Research*, Vol. 24A, No. 6, pp. 401-415, 1990. Reprint, 1991. UCTC No. 68.
- Kitamura, Ryuichi, Patricia L. Mokhtarian, Ram M. Pendyala, and Konstadinos G. Goulias, "An Evaluation of Telecommuting as a Trip Reduction Measure." Working Paper, 1991. UCTC No. 5.
- Kitamura, Ryuichi, Jack M. Nilles, Patrick Connery, and David M. Fleming, "Telecommuting as a Transportation Planning Measure: Initial Results of California Pilot Project." *Transportation Research Record*, No. 1285, 1991. Reprint, 1991. UCTC No. 58.
- Kitamura, Ryuichi, Konstadinos Goulias, and Ram M. Pendyala, "An Impact Assessment for State of California Telecommute Pilot Project Participants." Working Paper, 1991. UCTC No. 85.
- Klein, Daniel, "The Voluntary Provision of Public Goods? The Turnpike Companies of Early America." *Economic Inquiry*, March 1990. Reprint, 1990. UCTC No. 18.
- Klein, Daniel and John Majewski, "Promoters and Investors in Antebellum America: The Spread of Plank Road Fever." Working Paper, 1991. UCTC No. 75.
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- Majewski, John, Christopher Boer, and Daniel B. Klein, "Market and Community in Antebellum America: The Plank Roads of New York." Working Paper, 1991. UCTC No. 47.
- Meurs, Hank, Leo Van Wissen, and Jacqueline Visser, "Measurement Biases in Panel Data." *Transportation*, Vol. 16, pp. 175-194, 1989. Reprint, 1990. UCTC No. 9.
- Miller, Vincent P. and John M. Quigley, "Segregation by Racial and Demographic Group: Evidence from the San Francisco Bay Area." *Urban Studies*, Vol. 27, No. 1, pp. 3-21, 1990. Reprint, 1991. UCTC No. 14.
- Mokhtarian, Patricia L., "Telecommuting and Travel: State of the Practice, State of the Art." *Transportation*, Vol. 18, No. 4, 1991. Reprint, 1991. UCTC No. 79.
- Mokhtarian, Patricia L., "Defining Telecommuting." *Transportation Research Record*, 1991. Reprint, 1991. UCTC No. 80.
- Mokhtarian, Patricia L., "A Typology of Relationships Between Telecommunications and Transportation." *Transportation Research*, Vol. 24A, No.3, pp. 231-242, 1990. Reprint, 1991. UCTC No. 82.
- Mokhtarian, Patricia L., "An Empirical Analysis of the Transportation Impacts of Telecommuting." *Proceedings, Sixth International Conference on Travel Behavior*, Quebec, Canada, May 1991. UCTC No. 131.
- Mokhtarian, Patricia L., "An Empirical Evaluation of the Travel Impacts of Telecommuting." *Transportation Research*, Vol. 22A, No. 4, pp. 283-239, 1988. UCTC No. 132.
- Menismith, C.L., J. Lysmer, J. Sesus, and J.K. Hedrick, "Truck Pavement Interactions: Requisite Research." *SAE Technical Paper Series*, SP-765, November 1988. Reprint, 1990. UCTC No. 48.
- Munshi, Kaivan and Edward C. Sullivan, "A Freight Network Model for Mode and Route Choice." Working Paper, 1990. UCTC No. 25.
- Novaco, Raymond, "Aggression on Roadways." *Targets of Violence and Aggression*, Elsevier Science Publications, 1989. Reprint, 1991. UCTC No. 16.
- Novaco, Raymond W., Wendy Kliever, and Alexander Boaguet, "Home Environment Consequences of Commute Travel Impedance." *American Journal of Community Psychology*, Vol. 19, pp. 881-909. Reprint, 1991. UCTC No. 77.
- Novaco, Raymond W., Daniel Stokols, and Louis Milanese, "Objective and Subjective Dimensions of Travel Impedance as Determinants of Commuting Stress." *American Journal of Community Psychology*, Vol. 18, No. 2, 1990. Reprint, 1990. UCTC No. 30.
- Novaco, Raymond W., "Automobile Driving and Aggressive Behavior." *The Car and the City*, Martin Wachs and Margaret Crawford, eds., 1991. Reprint, 1991. UCTC No. 42.
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Willson, Richard W. and Donald Shoup, "Parking Subsidies and Travel Choices: Assessing the Evidence." *Transportation*, Vol. 17, pp. 141-157, 1990. Reprint, 1990. UCTC No. 34.

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