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Introduction

We've previously dubbed this the century of the automobile, and to some degree it has been. It's also been the century of the telephone, the airplane, the movies, the radio, the high-rise office building, and a lot of other wonders. But among the technologies that have marked these 100 years, the automobile has surely been one of the most visible and most consequential.

Many commentators have written of the car's glories, its nasty byproducts, and its effects on cities and lifestyles. Quite a few of our colleagues have joined the discussion, both in the pages of ACCESS and elsewhere. This time, we find ourselves preoccupied with the car once again—its past repercussions and its future.

With so much research on the car and the city already completed, we thought we understood the transportation–land use connection. Years ago Sam Bass Warner taught us that streetcars opened the suburbs and automobiles spread them out. Back in 1954 Robert Mitchell and Chester Rapkin wrote the book that spilled the beans, titling it *Urban Traffic: a Function of Land Use*. Travel patterns derive from land use patterns; simultaneously, land use derives from patterns of roads and transit lines, they said. Hmmmm? During the 1960s, location theorists explained how each of us trades-off the costs of travel and the costs of land rent when deciding where to live and where to conduct business. The explanations all came in tidy packages.

Now along comes Genevieve Giuliano and her partners to disassemble those packages. She says that we've now installed so much accessibility throughout each metropolitan area that changes in the transportation system no longer have much influence on urban form. That's in part why the new rail transit systems have scarcely affected metropolitan spatial structure, quite unlike Warner's trolley cars. She tells us to address our environmental and social concerns directly, rather than attempt to use transportation or land use policies to achieve some idealized urban form.

For instance, if we want cleaner air, we should directly reduce harmful emissions from automobiles. Dan Sperling and Tom Turrentine ask us to consider what might happen if the California zero-emission mandate holds up and American automakers begin to produce electric cars. Will they really come through with a viable machine? Will the federal government reinforce state efforts to push zero-emission vehicles? Even if so, given that electric cars will be high priced and their driving ranges limited, will American consumers buy them, after all?

We could also achieve cleaner air, not to mention relieve congestion, by reducing the number of cars on the road. One current strategy involves high-occupancy-vehicle (HOV) lanes, which reward commuters who rideshare with a faster trip. Joy Dahlgren examines the effectiveness of HOV lanes and finds them wanting. In her most telling observation, she notes that HOV lanes are most attractive only if they're relatively empty. She concludes that, in most cases, the space they occupy would best be used for additional general-purpose lanes instead.

And then, with his eye characteristically fixed on the empirical data, Charles Lave asks whether there's still room for growth in the automobile market. With apparent distress for the macro-economic consequences of a stable or declining auto industry, he glumly predicts a flat growth curve.

If all these non-commonsense interpretations are right, isn't it best that we know now, before we spend too many additional dollars on projects with little or no payoff? Isn't it so that, in the research enterprise, unexpected findings are sometimes the most valuable and most useful ones?

Lydia Chen
Editor


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The Weakening Transportation–Land Use Connection

BY GENEVIEVE GIULIANO

The precise relationship between transportation and land use continues to elude us. It seems self-evident that transportation facilities and services have enormous effects on land use patterns. We've all observed developments occur around freeway interchanges, and we all know the history of automobile-oriented suburban development. However, when we look beyond broad generalizations, we see far more complex and uncertain relationships, as well as a cluster of unsubstantiated beliefs.

A large body of formal theory contends that the basic factor underlying these relationships is accessibility—the ease of connection between places. As contact between two places becomes cheaper in time and money, accessibility increases. The propensity for people to interact with others at a distance increases as the cost of access decreases.

Urban theory tells us that people locate their houses and their workplaces by trading off housing and commute costs. Commuters choose residential locations that satisfy both housing needs and workplace access, and employers choose work sites that are accessible to employees at tolerable time and dollar costs. ➢

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TABLE 1

Studies of Commuting as a Test of the Standard Model of Residential Location (Unconstrained and Constrained Model Results)

AUTHOR	AREA	CONSTRAINT	PREDICTED COMMUTE	ACTUAL COMMUTE	PERCENT EXCESS
White (1988)	25 US metro areas	None	20.0 min	22.5 min	11.1
Hamilton (1989)	Boston metro area	None	4.82 miles	9.11 miles	47.1
Cropper & Gordon (1991)	Baltimore metro area	None	4.39 miles (owners) 3.65 miles (renters)	~10.2 miles	~57–64
		Housing Utility	5.04 miles (owners) 4.17 miles (renters)	~10.2 miles	~51–59
Giuliano & Small (1993)	Los Angeles metro area	None	8.42 min	23.0 min.	63.4
		Occupation	10.27 min	23.0 min.	55.3

Source: Giuliano and Small, 1993

The simplest version of the standard urban economic theory assumes that:

- All employment is fixed and located at the city center;
- All households have only one worker, and each considers only work travel;
- Housing depends on available capital and land, and therefore location and lot size are the distinguishing factors; and
- Unit transportation cost includes both time and monetary costs, and it is constant and uniform in all directions.

This residential-location theory predicts a city form with greatest population density and highest land value at the center (even though we know that many subcenters may surround the metropolitan center). Since the theory assumes that jobs are located at the major center, it predicts that average commute trip length will correspond to the mean distance of the total population from that center.

Several recent studies have tested these propositions empirically. Table 1 gives some results. Note that, with one exception, observed average commute distance, whether measured in minutes or miles, far exceeds the model's prediction. *Why do people have much longer commutes than the standard theory predicts?*

Is It Jobs-Housing Balance?

First, there may be imbalances or mismatches between workers and jobs. Imbalances occur when the number of workers who can be housed in an area differs from the number of jobs there. Mismatches occur when prices or other characteristics make housing in the area unsuitable for workers who hold jobs there.

Kenneth Small and I examined the effect of the jobs-housing balance on average commute distance. We found that only extreme imbalance has a noticeable effect on average commute length because the difference between the observed commute and the predicted commute diminishes as the average distance between workers and jobs increases. In other words, there is more "excess" commuting close to the city center, where jobs and housing are balanced, than farther away, where they are not.

What about mismatches? Researchers have cited exclusionary zoning practices, growth controls, rising development costs, and rapid economic growth to explain a shrinking supply of affordable housing in many metropolitan areas. If affordable housing were available near their jobs, the theory goes, these workers would have shorter commutes. We can test this idea by incorporating housing and household characteristics into our model's predictions.

Two studies applied such constraints: Cropper and Gordon's Baltimore study used housing characteristics as the constraint, and our Los Angeles study used worker occupation as the constraint. The shaded portions of Table 1 show the strikingly similar results. The predicted average commute increases by about 20 percent in both cases, but it leaves a large portion of actual commuting still unexplained. I conclude that imbalances or mismatches between jobs and workers do not account for a substantial part of observed commuting patterns.

Is It Low Transportation Costs?

Second, observed average commutes may be longer than predicted because transportation costs are low relative to housing costs. Over time, the real cost of commuting has dropped dramatically. Turn-of-the-century streetcar commuters spent about 20 percent of their daily wages on the work trip; urban auto commuters today spend about 7 percent. It therefore seems reasonable that workers would incur longer commutes in order to obtain more preferred housing and neighborhood surroundings.

Changing Lifestyles

A survey conducted in Orange County, California, illustrates the changing factors affecting where people choose to live. In February 1994, the metropolitan newspaper sponsored a random telephone survey of 600 residents to examine attitudes about living in several planned communities at the southeast edge of the county. Known as the Southern Foothills, the area is surrounded on the east by a national forest and on the south by a large military installation. Only two major roads connect this "urban fringe" with the rest of the county.

One of the questions asked was, "what do you like best about your community?" Table 2 shows that the most frequent choice was "remote area." The residents enjoy living *far from* the metropolitan core. Convenience, the only measure of accessibility on the list, ranks sixth. Affordable housing is at the bottom of the list, although the survey included respondents from moderately priced housing in the area, as well as from a variety of housing developments.

The survey also provides evidence of what these residents are willing to give up in order to live in a remote, semi-rural environment. Table 3 shows that Southern Foothills community residents display greater satisfaction with outdoor amenities, housing, and public schools than do Orange County residents as a whole. They display less satisfaction with entertainment, shopping, and job opportunities, suggesting they are willing to give up access to jobs and other urban activities to obtain preferred housing ➢

TABLE 2

What Do You Like Best About Living in Your Community? Southern Foothills Residents

ITEM	PERCENT
Remote area	23
New homes	21
Neighbors	17
Outdoors	14
Safe from crime	10
Convenient	4
Things to do	4
Schools	2
Prestige address	1
Affordable housing	1
Nothing, don't know	3

Source: Los Angeles Times, 1994

TABLE 3

Satisfaction with Amenities: Southern Foothills vs Orange County (percent saying they are very satisfied)

AMENITY	SOUTHERN FOOTHILLS	ALL ORANGE COUNTY
Outdoors, parks	82	51
Housing	68	56
Public schools	67	41
Movies, restaurants, entertainment	34	57
Shopping malls and stores	32	62
Traffic and transportation	22	8
Job opportunities	18	50

Source: Los Angeles Times, 1994

and neighborhood amenities. Limited accessibility is also reflected in average commute length: 36 minutes for Southern Foothills residents compared to the countywide average of 25 minutes.

This evidence indicates that commuting considerations play a limited role in residential-location choices for these folks. It suggests that attempts to alter the structure of urban land use patterns via policy intervention may not have much effect on commuting patterns, even if they are successful in changing the degree of jobs-housing balance or in reducing mismatches.

Transportation Investments' Effect on Land Use

If transport costs do play an important role in location choice, then transportation improvements should influence land use patterns. Any significant improvement in accessibility should be capitalized in land values, which should spur shifts in land use. That's why planners advocate investment in transportation facilities as a means to direct urban development.

However, today's metropolitan areas are marked by well-developed transportation systems. Even a large investment (such as a new freeway segment) will have only an incremental effect on accessibility. For example, the $2 billion, 17-mile Century Freeway (I-105) in Los Angeles, which opened in 1993, serves only 0.6 percent of the region's total daily vehicle trips, based on 1994 average daily traffic volumes. Moreover, the decentralized land use pattern of today's metropolitan areas has reduced differences in accessibility among locations.

Despite what I consider rather overwhelming evidence that transit investment is not an efficient means for affecting land use patterns, rail transit continues to have strong public support. The most extreme example of a public commitment is perhaps Los Angeles County's. Traffic congestion and air pollution problems there have prompted a transportation vision involving a $78.3 billion rail-transit investment plan (currently being scaled back because of funding problems). Planners expect this massive program to increase the proportion of commuters who use transit from 4.5 percent to 19 percent by the year 2010. They also expect to generate high-density and mixed-use development along transit lines and to reduce the spread of suburban development in outlying areas.

To test whether their expectations were reasonable, the regional planning agency sponsored a study using a transportation forecasting model to determine the effect of various land use scenarios on transit use. Results show that by relocating 75 percent of all forecast employment growth and 65 percent of population growth in the region (Los Angeles and four other counties) to transit-station capture areas and local activity centers, 7 to 10 percent of commuters would use transit—much below the goal of 19 percent. Study authors conclude that even if anticipated land use changes were to occur, *travel patterns would not change very much, because the overall regional pattern of land use would not change very much.*

The Oregon Example

A study in Washington County, Oregon—a suburban area west of central Portland—also finds that both land use policies and major transit investments have little effect on regional travel patterns. Regional forecasts to 2010 predict a 60 percent population increase (from its 1988 level of 287,000) and a 70 percent increase in the number of jobs. To accommodate this anticipated growth, the Oregon Department of Transportation planned a freeway extension called the Western Bypass.

Community activists persuaded the transportation department to sponsor a study called LUTRAQ (Land Use Transportation Air Quality Connection), which proposes development of higher-density, mixed-use communities oriented to pedestrian and transit travel. To serve the more clustered land use pattern, the LUTRAQ alternative employs an expanded light-rail system, expanded local and express bus services, transit shuttle service, and bicycle and pedestrian facilities. It also eliminates the Bypass highway improvements.

A second alternative, LUTRAQ-II, promotes further transit use by incorporating an additional transportation-demand-management (TDM) element. All workers in the study area would enjoy free transit; but if they drove to work they would pay a parking charge equivalent to one-third of prevailing fees in downtown Portland.

Table 4 shows that the Bypass and LUTRAQ-I alternatives would have similar transit mode shares. With the LUTRAQ-II alternative, the transit and carpool mode shares for home-based work trips would each be 45 percent higher than with the Bypass alternative. Changes in the transit mode share are minor in other categories.

Another objective of LUTRAQ is to reduce vehicular travel. The last column in Table 5 compares the LUTRAQ-II and Bypass alternatives. With LUTRAQ-II, vehicle use would be reduced 7.7 percent for afternoon peak vehicle hours of travel and 13.6 percent for vehicle miles traveled. Note also the increase in vehicle hours of delay for the LUTRAQ alternative, an expected result of reducing investments in road facilities. ➢

TABLE 4

Travel Outcomes of LUTRAQ Study: Mode Share

Source: Cambridge Systematics, Inc., 1992, and data provided by Parsons-Brinkerhoff

ITEM	BYPASS MODE SHARE (percent)	LUTRAQ-I MODE SHARE (percent)	LUTRAQ-II MODE SHARE (percent)
Home-based work:			
Walk	2.5	3.5	3.5
Drive alone	75.1	72.7	63.9
Carpool	13.6	13.8	19.7
Transit	8.8	10.0	12.8
Total home-based:			
Walk	4.9	5.7	5.7
Auto	85.4	84.2	83.4
Transit	9.7	10.2	10.9
Total non-home based:			
Walk	0.3	0.5	0.5
Auto	99.0	98.8	98.8
Transit	0.7	0.8	0.8
Total all trips:			
Walk	3.7	4.5	4.5
Auto	89.0	87.6	87.0
Transit	7.3	8.0	8.6

What can we conclude from these results? Land use policies appear to have little impact on travel outcomes; most of the observed change is due to the TDM policies, rather than to the land use and transit policies. Without TDM, travel impacts of the LUTRAQ alternative are minor.

Although changes in travel outcomes are small, the magnitude of change in land-use patterns for the LUTRAQ alternative is large. It seems development density must increase dramatically if we want to induce significant change in mode shares and trip lengths. That implies more stringent land use controls than have historically been possible in the United States.

Can Transportation Policy Shape Urban Form?

Regional scientists and others predict continued decentralization and reliance on personal modes of transportation. Increasing affluence of the population and structural economic shifts to information-based activities will engender decentralization. Rising incomes will generate demand for more housing (at lower densities) and will increase the value of one's time (with more demand for private vehicles). We expect structural shifts in the economy to be accompanied by more flexible work arrangements and less clustering among firms, implying more spatial dispersion. We expect more leisure activities and an increased emphasis on environmental quality in choosing household's and firm's locations, again suggesting more decentralization.

Thus, scholars view transportation as an ineffective means for shaping urban form for three reasons:

- The transportation system in most U.S. metropolitan areas is highly developed, and therefore the relative impact of even major investments will be minor.

- The built environment has a very long life; most structures survive 50 years or more. Even in rapidly growing metropolitan areas, the vast proportion of buildings that will exist 10 or 20 years from now are already built.
- Transportation is of declining importance in the locational decisions of households and firms. Transport costs make up a relatively small proportion of household expenditures, and increasingly flexible work arrangements (including telecommuing) are likely to make access to workplaces even less important in the future. Information-based firms are "footloose," meaning that physical access is no longer a key locational consideration; and these firms make up an increasingly large share of total economic activity.

Given these trends, transportation policy efforts would have to be truly extreme to have a significant impact on urban form.

These old city buildings remain viable today…

just as these suburban houses are likely to survive 100 years from now. Stability of the built environment limits how much urban form can change.

Getting the Prices Right

Transportation's declining influence on locational choices reflects the way transportation services are priced. The price of private vehicle travel in the United States is very low. Private vehicle users do not pay directly for the pollution they generate or the congestion they impose on other travelers. Police and other emergency services, maintenance of local roads, and many other parts of the transportation system are supported indirectly by property and other taxes. Gasoline taxes, vehicle-registration fees, drivers license fees, and automobile taxes are lower here than anywhere in the developed world. Parking is offered free to most workers and shoppers. Given the extent of subsidies to private vehicle use, we should not be surprised that other forms of transportation cannot compete, and that people take advantage of the many personal benefits of private auto-mobility.

We should not be surprised that efforts to shift travel to other modes, either by promoting higher-density land use patterns or building massive rail systems, are doomed to fail if current automobile pricing policies are maintained. In Los Angeles, for example, it costs a lot to use rail transit as a lure to get commuters out of their cars. According to the transit operating agency's data, full cost (capital plus operating) per passenger is $1.17 for bus; $11.34 for the Blue Line, a light-rail system operating between the downtowns of Los Angeles and Long Beach; and $21.02 for MetroLink, the commuter rail service. Budget shortfalls, partly resulting from the high subsidy cost of rail system expansion, have been met by reducing bus service; ironically thus reducing total transit riding. ➢

TABLE 5

Travel Outcomes of LUTRAQ Study: Vehicle Use

ITEM	BYPASS	LUTRAQ II	DIFFERENCE (percent)
Average autos/household	1.90	1.83	–3.7
Total daily vehicle trips/household	7.68	7.09	–8.1
PM peak vehicle miles traveled	679,390	586,660	–13.6
PM peak vehicle hours traveled	19,920	18,380	–7.7
PM peak vehicle hours of delay	1,670	1,950	16.8

Source: Cambridge Systematics, Inc., 1992, and data provided by Parsons-Brinkerhoff

TABLE 6

Commuting Distance and Population Density

Source: Downs, 1992

ITEM	POPULATION DENSITY VERY LOW	LOW	MEDIUM	HIGH
Average exurban residents/sq. mile	886	2800	4363	9075
Percent increase from lowest density case	—	216	392	924
Average commute in miles, all workers	13.02	12.57	9.49	9.38
Percent decrease from lowest density case	—	−3.45	−27.11	−27.96
Average commute in miles, exurban workers	16.44	15.11	14.09	13.56
Percent decrease from lowest density case	—	−8.09	−14.29	−17.52

Because land use development involves many factors besides transit investment, such as local land use policies, general economic climate, land availability, and local preferences for economic development, we must recognize the limited potential of transportation policies to affect land use, even if we were to "get the prices right."

Aiming for Efficiency

Why should we attempt to guide land use patterns anyway? There are at least two possible rationales. The first holds that existing land use patterns are inefficient: low-density suburbs necessitate long trips and reliance on private autos, thus wasting energy, generating air pollution, requiring more public infrastructure, and consuming open space. This is the familiar anti–urban-sprawl argument. Newman and Kenworthy make a distinction between fuel-efficient transportation and fuel-efficient cities. They argue that while investing in highway facilities can make travel more efficient by reducing congestion, the added highway capacity will ultimately lead to more travel and thus more total energy consumption. They therefore advocate the promotion of "compact cities": high-density, pedestrian- and transit-oriented cities.

Anthony Downs calculated changes in commuting distance resulting from changes in residential density. He assumed that densities can be increased only for new development because urban redevelopment is costly, has a limited market, and is typically opposed by residents. Table 6 shows some results. Average densities increase much faster than average trip lengths decrease, meaning that very large increases in density are required to realize significant travel savings. Interestingly, the greatest percentage reduction in trip length occurs when moving from low to medium density, while going from medium to high density yields only a small additional reduction.

Downs's calculations, together with the results of the Los Angeles and Oregon planning studies, suggest that the compact city alternative would have at best a moderate effect on travel. A seemingly more effective strategy for reducing travel would promote moderate densities. If we were to restructure our transportation pricing policy, we might realize this objective.

Aiming for Social Equity

A second rationale for attempting to change land use and transportation patterns is to increase social equity. Peter Mieskowski and Ed Mills describe two contrasting theories of suburbanization. The first, called the "natural evolution theory," explains suburbanization basically as the result of economic forces. City expansion occurs in conjunction with rising incomes. Thus, we find older, smaller housing near the city center and larger, newer housing at the periphery. If this theory holds, there is little justification for attempting to change land use patterns: low-density, suburban environments are simply the result of household preferences associated with rising incomes.

The second theory explains suburbanization as the result of the affluent population escaping the fiscal and social problems of central cities. Higher-income households, able to pay the higher transportation costs involved, move to the suburbs to form homogeneous communities that are fiscally independent of the central city. Once they establish such communities, they can exercise land use controls to exclude households with different housing needs or preferences. This process results in spatial segmentation of the population on the basis of income, ethnicity, and race; people most in need of public services concentrate in the central city; and the central-city tax base declines.

If the second theory holds, intervention is justified because suburban residents are actively preventing a spontaneous mixing of population, thus denying less affluent and minority populations access to suburban jobs and suburban amenities. Evidence of exclusionary land use practices is extensive, and consequently policies to end such practices are surely worthwhile. I therefore propose that land use policy should focus on eliminating distortions in the land market. We should aim to eliminate barriers to more diverse land use patterns. Essentially, this is the complement of "getting the prices right" in transportation policy.

The roots of our transportation and land use policy dilemmas lie in the absence of consensus on which environmental and social conditions are truly problematic. In turn, they reflect our confusion about how changes in either transportation systems or land use policies might work to ameliorate those environmental and social problems.

If the aim is to reduce environmental damage generated by automobiles, the effective remedy is to directly price and regulate autos and their use, not land use. If the aim is to reduce metropolitan spatial segmentation, the effective remedy is to expand the range of housing and employment choices, not travel choice. As urban areas continue to evolve, the link between land use and transportation will likely continue to weaken. Thus only direct policy interventions can solve the social and environmental problems associated with existing travel and land use patterns. ◆

Denver, CO, 1874

FURTHER READING

M. Cropper and P. Gordon, "Wasteful Commuting: A Re-Examination," *Journal of Urban Economics*, Vol. 29, No. 1, 1991, pp. 2-13.

Anthony Downs, *Stuck in Traffic: Coping with Peak Hour Congestion* (Washington, D.C.: Brookings Institution, 1992).

Genevieve Giuliano, "New Directions for Understanding Transportation and Land Use," *Environment and Planning A*, Vol. 21, 1989, pp. 145-159. UCTC No. 2.

Genevieve Giuliano and Kenneth A. Small, "Is the Journey to Work Explained by Urban Structure?" *Urban Studies*, Vol. 30, No. 9, 1993, pp. 1485-1500. UCTC No. 107.

B. Hamilton, "Wasteful Commuting Again," Journal of Political Economy, Vol. 97, 1989, pp. 1498-1504.

Peter Mieskowski and Ed Mills, "The Causes of Metropolitan Suburbanization," *Journal of Economic Perspectives*, Vol. 7, No. 3, 1933, pp. 135-147.

Peter Newman and J. Kenworthy, "The Transport Energy Trade-Off: Fuel Efficient Traffic versus Fuel Efficient Cities," *Transportation Research A*, Vol. 22A, No. 3, 1988, pp. 163-174.

M. White, "Urban Commuting Journeys Are Not 'Wasteful' ," *Journal of Political Economy*, Vol. 96, 1988, pp. 1097-1110.

Bringing Electric Cars to Market

BY DANIEL SPERLING

Over the past five years, electric vehicles (EVs) have emerged as promising alternatives to cars driven by internal combustion engines (ICEs). A wave of technological innovations in electronics, lightweight materials, and electrochemistry, and a variety of energy-saving improvements have made the imminent commercialization of EVs possible. These include not only battery-powered cars, whose ultimate role may be modest, but also vehicles powered by electric fuel cells or by hybridized combinations of ICEs and electric motors.

EVs are particularly suited to countries where pollution is severe, petroleum imports are spiraling upward, cheap electricity is available in off-peak hours, or vehicle acceleration and range is secondary to reliability and low maintenance. Whoever pioneers large-scale production of low-cost electric-drive vehicles will find inviting and profitable markets around the world.

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In response to these opportunities, the Clinton administration has pointed to the EV as one of 22 critical technologies for the nation's economic revitalization. Battelle Technology Management Group, a private consulting firm, listed fuel cells, batteries, and hybrid vehicles as three of the ten hottest technologies for 2005. Because their principal advantages—improved air quality, reduced emissions of greenhouse gases, and energy savings—initally will be outside the marketplace, only strong government action can give EV technologies a chance in the near term. But public policy must be formulated carefully so that it is flexible enough to permit midcourse corrections and to let the market, rather than government, pick the winners.

Lots of batteries...

A COMPELLING ALTERNATIVE

Policymakers have long debated the environmental and economic effects of air pollution, global warming, and dependence on foreign oil. Although there is no consensus, it is clear that each of these problems carries some potentially serious risks. Electric-drive vehicles are the most promising option for significantly reducing all three.

A compelling feature of electric-drive vehicles are their low or nonexistent emissions and hence their air quality benefits. These benefits will be greatest in regions where air pollution remains severe, where fuel cells are used, or where the electricity comes from largely clean sources—tightly controlled natural gas electric-power plants or zero-emitting hydroelectric and nuclear plants.

and a drive system consisting of a power-electronics unit and an AC induction motor...

Electric-drive vehicles are also more energy-efficient (on a full-energy-cycle basis) than conventional automobiles. Conversion of chemical energy into mechanical energy—by burning fuel—is simply less efficient than using electricity. Electric motors are about 90 percent efficient, compared to less than 25 percent for ICEs. In addition, an EV can recapture as much as half the energy lost during braking (through regenerative braking); it does not need a transmission, which reduces energy use by another 6 percent or so; and it does not consume energy while idling and coasting, saving still another 10 percent. These efficiency gains are partly offset by the low efficiencies of electric-power plants. Oil refineries are about 90 percent efficient, compared to efficiencies of about 33 percent achieved by today's electric power plants fired with oil, natural gas, and coal. But oil refineries are not expected to become more efficient, whereas power plants' efficiency rates are expected to rise by as much as 50 percent.

make this a zero-emission vehicle.

During the past few years, considerable progress has been made with electric-drive technologies with relatively little expenditure. Total investment in EVs and EV batteries by all U.S. manufacturers and governments in the first four years of this decade probably fell short of a billion dollars. Ford and General Motors reported spending a total of $450 million during the first few years of the decade. (For perspective, consider that the U.S. auto industry generated more than $14 billion in profits in 1994 alone, that GM spent $6 billion to develop their Saturn model, and that the oil industry is spending about $10 billion this decade to produce reformulated gasoline.) Achieving the refinements necessary for commercializing EV technologies will, in auto industry terms, require modest investments in research and development. The more daunting barrier is market uncertainty and risk, which can be reduced only by firm federal and state commitments to the development and use of EV technology. ➢

A flywheel stores energy and can be used as a substitute for or complement to batteries.

THE ZEV MANDATE

The zero-emission-vehicle (ZEV) mandate issued by the California Air Resources Board in 1990 (and later adopted by New York and Massachusetts) has spurred more progress in electric propulsion technology than was accomplished during the previous 20 years by the automobile industry and the Department of Energy combined. Mostly because of the mandate, every major automaker in the world, as well as hundreds of technology companies, have invested in EV development; and dozens of companies have sprouted to develop batteries, ultracapacitors, flywheels, and fuel cells.

The mandate requires that by 1998, at least 2 percent of vehicles sold in California by major automakers must have zero emissions; the requirement will rise to 5 percent in 2001 and 10 percent in 2003. Major automakers are defined as those with sales of 35,000 vehicles or more per year in California. They are, in descending order, General Motors, Ford, Toyota, Chrysler, Honda, Nissan, and Mazda. In 2003, the mandate will be expanded to include manufacturers with as few as 3,000 vehicle sales per year. Companies will be fined $5,000 per car for the number of sales by which they fall below the quota.

The mandate also permits manufacturers to trade EV credits. That is, a company can satisfy the mandate's requirements by buying credits from other companies that have sold more than their quota of ZEVs. This provision is important because it gives mainstream manufacturers the flexibility to buy credits rather than build ZEVs, while providing cash for industry outsiders, such as small and nontraditional manufacturers of EVs whose ZEV quota is zero.

PARTNERSHIP WITH THE GOVERNMENT

The ZEV mandate will spur the transition to electric-drive vehicles despite a caution that borders on ambivalence within the Clinton administration. Although the auto industry and the administration have launched several high-profile initiatives favoring environmentally benign vehicles, these are providing little funding and making little progress.

Perhaps the most widely publicized initiative is the Partnership for a New Generation of Vehicles (PNGV), formed in 1993. Its stated purpose is to build a prototype midsize sedan that triples the fuel economy of today's cars by 2004. Portrayed as a modern counterpart to the Apollo moon program and initially known as the Clean Car Initiative by government and the Supercar Initiative by the automotive industry, PNGV is a public-private partnership. It is intended to accelerate development of electric propulsion, lightweight materials, and advanced manufacturing processes.

The government devised the program in part to transfer some of the technological resources developed during the Cold War to the civilian sector. The plans provide virtually no new funding; instead, the government will divert personnel and resources at the national laboratories, especially the weapons labs, to work with the Big Three auto companies and their suppliers to develop advanced transportation technologies. In theory, everyone benefits. The labs would have a renewed mission; thousands of highly trained scientists and engineers would be productively employed; and automakers would receive a much-needed infusion of technical know-how.

However, the PNGV initiative has a fundamental weakness: there are no built-in incentives (or rules) to encourage commercialization of the technologies developed. The initiative contains timetables for creating concept prototypes (2000) and production prototypes (2004) but none for actually manufacturing and marketing EVs.

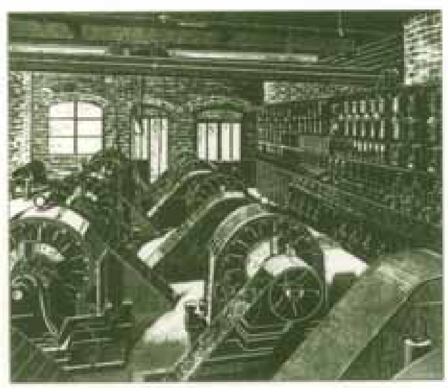
The absence of incentives and regulations undermines the credibility of the PNGV initiative. If one could elicit a promise from auto manufacturers to swiftly transfer laboratory knowledge to the marketplace, perhaps regulatory pressure would be unnecessary. But such promises might not be honored. We know that automakers resisted adopting safety and environmental features, from airbags to catalytic converters, until government action required them. Once deadlines were set, however, industry found ways to adopt these technologies cheaply and effectively.

EXTENDING THE MANDATE

The ZEV mandate is not, theoretically, the most efficient mechanism for initating the transition to more benign propulsion technologies, but it may be the most politically palatable and the most effective at overcoming large start-up barriers.

On the basis of many discussions with auto industry executives, I sense that opposition to the mandate goes far beyond quarterly profit statements. Commercialization of EVs may spell major structural changes within individual automobile companies and in the industry as a whole. Electric-propulsion technology requires a fundamental shift in many aspects of car manufacturing. More than one-third of an EV's value will be composed of entirely new components. Another one-third of the components will need to be redesigned. Manufacturers will have to adopt new materials, new manufacturing processes, and new marketing and distribution practices, and collaborate with unfamiliar companies. For example, the use of lightweight composite materials in EVs will raise the vehicles' efficiency. But, because manufacturing with these materials, unlike steel and aluminum, offers fewer economies of scale, they are suited to small-scale decentralized assembly rather than mass production on the level usually found in Detroit.

Similarly, a company's success in marketing EVs may require new ways to sell and service them. Vehicles may be more specialized, giving consumers incentives to trade vehicles more frequently. More consumers might lease vehicles rather than own them, with marketers bearing responsibility for insuring and maintaining them. The high reliability of EVs, compared to gasoline-fueled cars, enhance the attractiveness of such arrangements.



Faraday's high-voltage power station, 1896

The ZEV mandate is proving a blunt but effective instrument for overcoming market uncertainty, contrary corporate cultures, and technological barriers. Although there is considerable political pressure to weaken or revise it, and although it will initially impose substantial costs on automakers, to tinker with it at this time would be costly to the many companies making substantial investments based on the mandate's terms. Any indication that it might be changed or abandoned would freeze investments in hundreds of companies, especially in small companies dependent on outside financing. Given the large risk faced by automakers, perhaps the most sensible strategy might be to encourage other states to lag one or more years behind California, allowing California to be the experiment.

ACCELERATING EV RESEARCH

The federal govenment plays a critical role in developing advanced vehicles. A research partnership between government and industry could accelerate investment in advanced EV technologies and speed the transition to an environmentally benign ➢

transportation system. The PNGV initiative offers a framework for this kind of research, despite its reliance on the national laboratories and the Big Three.

The weapons labs have a store of potentially valuable knowledge and technology—in particular, expertise in basic science relevant to electric propulsion and energy storage. However, the labs are not oriented to products destined for the marketplace. The principal need over the next 10 to 15 years is not new science or new technology but cheap technology. That is primarily a challenge of engineering and manufacturing, not basic science.

Relying on the major automakers may brake rather than accelerate progress. Certainly they need to be intimately involved in any federally led research partnership, but not necessarily as the dominant players. They are best suited to directing the research agenda for incremental technologies—refining some materials and manufacturing processes—especially because they and their suppliers are likely to be the principal users of these technologies. However, their history of resisting innovations in energy conservation, environmental protection, and safety suggests that they may not be enthusiastic developers of new propulsion technologies whose principal benefits are a cleaner environment and reduced energy-use.

If the government were to seek out and forge closer links with companies whose expertise, investments, and corporate culture are not tied to ICE technology, the entire process would undoubtedly be accelerated. For example, a broader array of companies should be encouraged to participate in the cooperative research and development agreements (CRADAs) used to transfer technology from the national labs. CRADAs give a company exclusive rights for five years to any technology developed with the lab. Most of the automotive technology agreements are with the Big Three and their primary suppliers. It will take substantial effort to create collaborative links between smaller companies and the national laboratories, but the result may be quicker commercialization of the research.

Electric vehicles in New York, depicted in *The Automobile Review and Automobile News*, 1902

FORGING MARKET SOLUTIONS

All things being equal, sustained change is most effectively achieved by harnessing market forces. The ZEV mandate cannot stand alone. Once startup barriers have been overcome (when EV sales reach 5 to 10 percent of the market), we will need measures that rely on market forces to guide transportation choices toward reduced social and environmental costs.

With this goal in mind, the federal government will need to overhaul the regulatory structure that shapes the nation's transportation strategy. The oil and auto industries are shackled by rigid and fragmented regulations. Automakers, for example, must meet every single standard for every single tailpipe pollutant—which discourages innovations that accelerate emission reduction and preclude those that allow even one pollutant to increase. For instance, even incremental innovations such as lean-burn and two-stroke engines, which cut energy use and greenhouse gas, hydrocarbon, and carbon monoxide emissions, but slightly increase nitrous oxide emissions, are essentially precluded from the market.

The government could use instruments such as taxes, tax credits, fees, and marketable credits to complement technology initiatives aimed at reducing or eliminating emissions. For example, if automobile companies were allowed to average emissions across their fleet of vehicles to meet emissions standards, just as with fuel-economy requirements, the public's clean-air goals might be more readily attained. (Average emissions would have to be set at a level that permits total emissions reduction to match or exceed the unaveraged standard.) "Emissions trading" (for both air pollutants and greenhouse gases) might prove to be even more economically efficient, creating a side market in which manufacturers sell credits for emission reductions from very low-emitting vehicles, such as zero-emission vehicles, to manufacturers who produce higher-emitting vehicles. Allowing banking of emissions-reduction credits from year to year would provide an additional bonus, giving manufacturers an incentive to invest sooner in technologies that will outperform today's standards. California has taken tentative steps in this direction; EPA has not.

Initiatives like the ZEV mandate will be more effective if combined with price signals that reward consumers' use of clean and efficient fuels and vehicles. For instance, the government could offer a revenue-neutral "feebate" by which consumers who purchase energy-efficient vehicles receive a rebate, whereas those who purchase gas guzzlers pay a fee. Combining technology initiatives with incentives is not only effective, it is also politically more appealing. Only a flexible, incentive-based regulatory approach will create the framework needed to guide business and consumer decisions in an efficient manner toward a sustainable future.

Although the technological basis for a transition to electric drive is falling into place, progress will remain slow and inefficient until some way is found to reduce the risk for automotive manufacturers and to create a firm but flexible regulatory structure. The goal should be to encourage technological and institutional innovation by new and established firms and to promote early commercialization of their new products. Thanks in large part to the ZEV mandate, our society can choose from a menu of transportation opportunities that did not exist only a few years ago. To backslide and ignore those opportunities would be poor policy and bad business. ◆

FURTHER READING

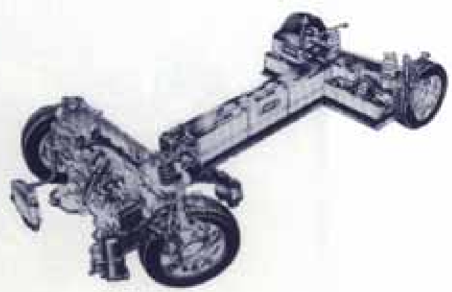
International Energy Agency, *Electric Vehicles: Technology, Performance, and Potential* (Paris: Organization of Economic and Cooperative Development, 1993).

Scott Kronk, ed., Building the E-Motive Industry (Warrendale, Penn.: Society of Automotive Engineers, 1995).

James MacKenzie, *The Keys to the Car* (Washington, D.C.: World Resources Institute, 1994).

Michael Brian Schiffer, *Taking Charge: The Electric Automobile in America* (Washington, D.C.: Smithsonian Institution Press, 1994).

Daniel Sperling, *Future Drive: Electric Vehicles and Sustainable Transportation* (Washington, D.C.: Island Press, 1995).



An advertisement in *The Outlook*, 1909

Who Will Buy Electric Cars?

BY THOMAS TURRENTINE

1998 will be a big year for both automakers and clean-air advocates. In less than three years, the seven largest car sellers in California must sell zero-emission vehicles (ZEVs)—2 percent of their sales of vehicles under 3750 lbs loaded weight. Given the size of the current market, that's about 20,000 vehicles and they most likely will be electric cars. By 2003, 10 percent must be zero-emitters.

The crux is that the government requires the auto industry to put ZEVs on the market without requiring consumers to buy them. The big manufacturers say electric cars cost too much to make and consumers won't choose them, even if prices were to match those of gasoline vehicles. The automakers have threatened to raise the price of gasoline vehicles to offset their losses. Much of the debate hinges on just how many Californians—or other car buyers throughout the world—will want an electric vehicle (EV). ➢

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An early electric delivery fleet

If the market were big enough, car makers and battery makers could lower prices. Few EVs have been sold so far, and they bear little resemblance to cars expected in showrooms in 1998, or especially 2003. With so little to go on, it's tough to forecast sales.

Old Doubts, New Concerns

Skeptics like to point out that electrics lost their consumers eighty years ago, when Model Ts first came rolling off assembly lines. Early electric cars had the same disadvantages as modern ones: limited daily driving ranges and batteries that need recharging and replacement.

Back then, most Americans still lived on farms, the electric grid was incomplete, and many new car buyers were rural dwellers who needed a vehicle to get to town. Most households had only one vehicle until after World War II. The electric car's zero-emission advantage had little meaning for rural, small-town America, and its limited driving range posed a major disadvantage.

But that America is gone. Americans who buy new cars today are primarily suburban. Virtually everyone has electricity at home, and probably half of new car buyers already have 220-volt circuits in their garages with up to 30-amp circuit breakers. Most new-car buyers already have two, or three, or more vehicles in the garage. When they go touring, at least one car is left at home. Additionally, healthy living and clean air have become major national concerns. Even though tailpipe exhaust is much cleaner today than two decades ago, it's still not clean enough.

A New Generation of Electrics

If you wanted to buy an EV today, you'd have difficulty finding one. You'd have to make your own, buy a used one, bring a gas car to a conversion shop, or buy from a very expensive "batch" converter (someone who buys new gas cars, converts them, and sells them for twice the price of the original). There are several conversion shops in California, garage-sized operations where enthusiasts tear the gasoline power system out of cars or trucks, refit an electric motor and controller into the cavity, and fill the leftover spaces with batteries—lots of batteries that fill the trunk and sometimes the back seat. With the big companies reluctant to put an EV on the market with today's technology, shops like these are doing a small part of the job.

AC Propulsion is a small electric-vehicle conversion shop operating out of a single bay in an inconspicuous industrial park off of I-10 in San Dimas, California. Its owner, Alan Cocconi, is often called the whiz kid of EVs. His latest design shows what's possible. He has taken a Honda CRX, fitted it with a 200 hp AC air-cooled electric motor and a battery pack of newly designed lead-acid batteries that fit in a channel down the center of the underbody. The vehicle goes 0-60 mph in 6.2 seconds, has a governed top speed of 85 mph, gets 110 miles per charge at 60 mph, and can be 80 percent recharged on a 220-volt charger in about one hour. (A top-of-the-line 1995 Ford Taurus goes from 0-60 mph in 7.5 seconds, tops out at 130 mph, and can travel 400 miles on a tank of gasoline.) The electric CRX has full traction control, cruise control, regenerative braking, and batteries that last about 20,000 miles. About 22 of these conversions have sold for around $75,000 each. All this done in a small shop with no subsidies.

The AC Propulsion vehicle illustrates much about the EVs that will hit the market in a few years. They won't be golf carts by any means. They will have sophisticated electronics, have plenty of power, and will look like other cars on the road. General Motors and Ford Motor Company have also been testing some limited-production vehicles across the United States in some select markets. The reports are good so far. People seem to like the way the vehicles perform, and affluent consumers are quite interested in the General Motors Impact, a small sports coupe with lots of power and speed. These limited markets are critical to manufacturers who wish to charge luxury prices for initial sales and to build their products' reputation as premium goods.

Once the price of electrics approaches that of gasoline vehicles, say in 2005, and consumers can get electrics in many models, styles, and body types, the market question will be determined by consumer response to three important attributes: *range, recharging, and zero emissions.*

Battery Woes

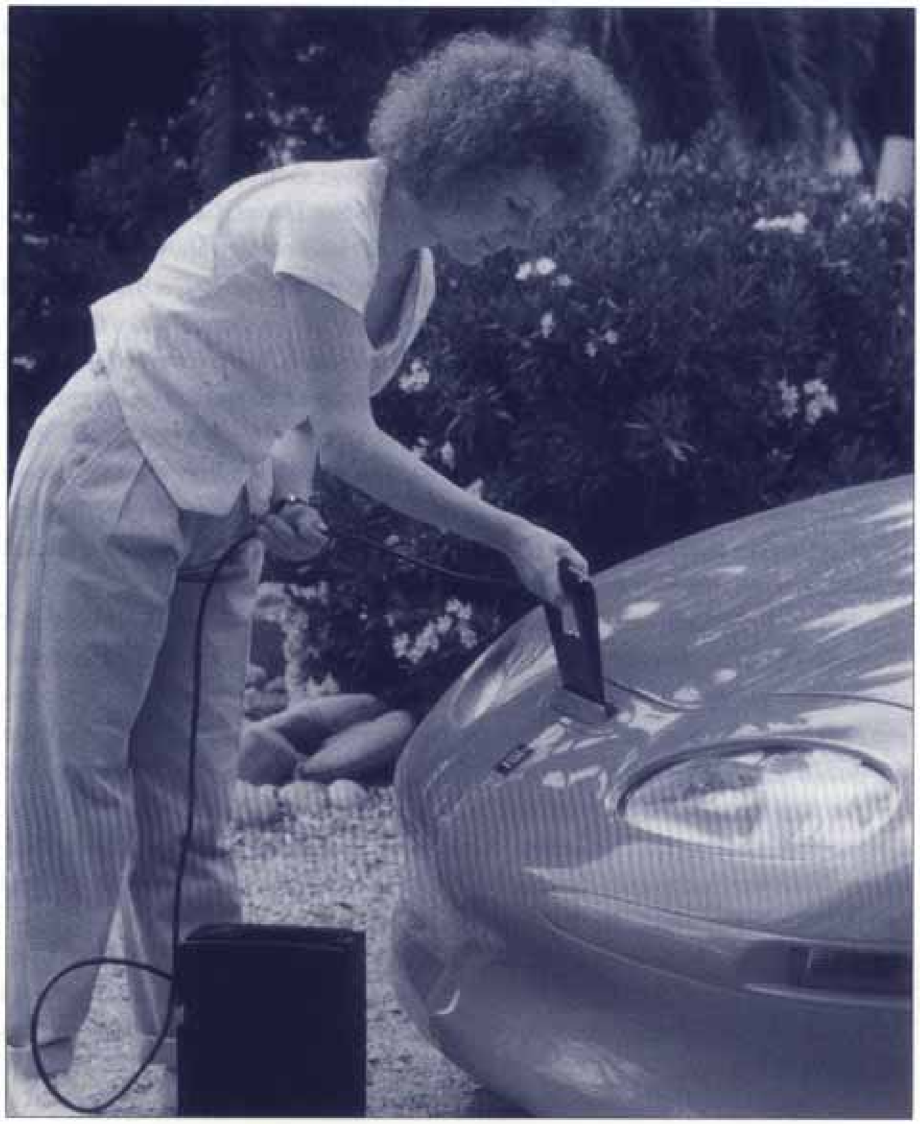
Just as it was eighty years ago, we still do not have the battery technology to allow EVs to drive as far as gasoline vehicles without recharging or refueling. The ZEV mandate has encouraged development of a wide range of new batteries which promise to double the capacity of current traction batteries and hopefully extend their life to five or even ten years. Most of these are prototypes with high prices, and we have yet to develop manufacturing methods. What we need is a cheap, durable, and environment-friendly battery—not an expensive super battery.

A variety of EV models already exist, but their luxury prices could discourage the ordinary consumer.

Range and Recharging

Many market studies have tried to assess how far consumers want their cars to go before needing to refuel, based on their stated preferences, using hypothetical ranges and prices. Several studies conducted from the 1970s to the present conclude that preferred driving ranges make EVs unmarketable.

However, our studies find that consumers' preferences for travel range are highly volatile. Small increments of information push respondents' estimates back and forth ➢



New habits: recharging the car with a portable inductive charger.

radically. Most people we interviewed had never thought about how much range they want or need, until we posed the question. It wasn't an issue when they purchased their gasoline car. Some don't know the range of their current vehicle; they fill up once a week on Friday and never drive out of town. Most simply think more range is better than less.

Consumers of EVs must consider range together with recharging time, and they must develop a new set of habits. The EV might have only 100 to 150 miles of range, but you won't need to go to a gas station. You can have a freshly charged car every morning. To recharge an "empty" vehicle will take two or three hours on a 220-volt, 30-amp circuit. You'll probably plug the car in every night and use a timer to get the best rates from the power company. Most days you'll drive only 40 miles or less, so recharging will take only one hour.

Because electricity will cost much less than gasoline, you'll prefer the electric for most of your running around. Precise instruments will tell you how much range you have left. So as long as you're near home, you can run the battery low and get all your errands done. Actually, you'll like using the electric because it's already heated and defrosted when you get in, and some communities will offer preferential parking for EVs. On the other hand, you won't think of taking the electric on long trips—that's why you have the gasoline car.

Imagining Hybrid Households

Our research investigates a central hypothesis: "a sizable percentage of multi-car households will find it reasonable—even attractive—to have vehicles with different refueling characteristics." We call this the hybrid-household hypothesis. To test it, we conducted a series of consumer studies in which—unlike other related studies—we first helped respondents think about the capabilities of EVs—providing questions, maps, reading material, videos, and even test drives of new electric vehicles. Shortly afterward, we asked them whether they would want to buy an EV. Critics accuse us of tampering with the thoughts of our participants, giving them too many hints, too much information. The alternative would be to ask what choices consumers would make without knowledge. We argue that would be worse.

Preferences develop over time, and they become meaningful only when accompanied by experience and knowledge. My little girl, for example, will say with some conviction that she "hates" salmon without having tasted it—then, one bite from my fork reverses her "preference." So it is with EVs. In a test drive we held at the Pasadena Rose Bowl, many participants reversed their stated preferences after driving electric cars. Most thought the cars would be slow, like golf carts, but even modest electrics changed their opinions. On the other hand, some who had said they wanted an electric reversed their preference to a larger vehicle in the interest of safety (the test vehicles were all sub-compacts).

In one survey, using a method we dubbed PIREG (Purchase Intentions and Range Evaluation Games), we first collected diaries for a week of driving for all vehicles in 51 two-car California households. Then we interviewed each household at home, using the diaries to see just how a limited-range vehicle would have worked for the recorded week, as well as for expected future travel. We wanted to know whether household members would swap cars, the radius of their routine activity space, the critical locations they needed to reach, the amount of cargo or hauling they did, and the frequency of their vacations. We wanted to see if participants who emphatically claimed they wanted to buy an electric car were realistic candidates. We found that 29 of the 51 households could immediately use an EV with a 100-mile range, without having to make any adjustments; 15 households needed to make small adjustments, such as swapping cars with another family member one day a month; and 7 households were unwilling or unable to adapt to EVs with limited ranges.

Recently, we mailed surveys to 454 California households with two or more cars, who had bought a new car in the last five years in size categories similar to future EVs. We provided households with a wide range of information about EVs, including a video and magazine articles, in order to stimulate their thinking about the subject. The households also kept driving diaries and marked important household destinations on a local map. At the end of the week, they made vehicle choices. ➢

How about a clean spin around the neighborhood?

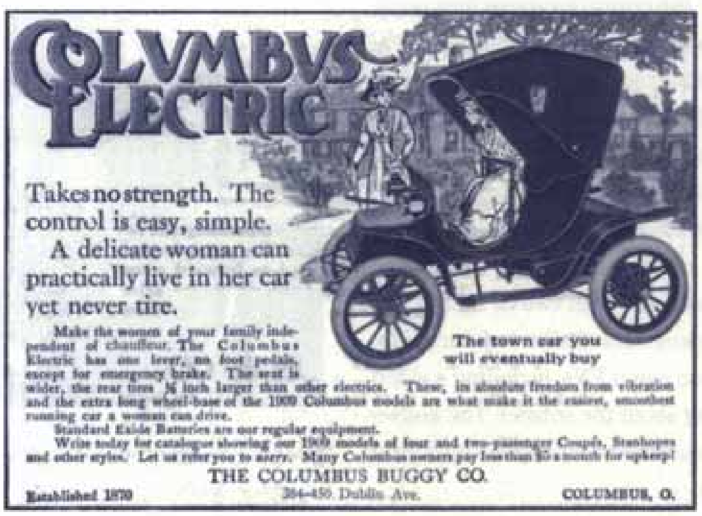
In the most simple test of our participants' response to limited range, recharging, and zero emissions, 46 percent said they would be interested in purchasing an EV with about 100 miles of range if the price were equivalent to gasoline vehicles. We think these are highly probable sales, if manufacturers can meet the price condition. Such two-vehicle households (with one midsize or smaller vehicle) account for about 40 percent of California's new-car annual sales, in a car market that is now about 1.4 million new vehicles per year. If half of the 46 percent who showed interest in electrics actually bought one, that would mean about 10 percent of the annual market, or about 140,000 buyers annually. That would meet the mandate in 2003 and doesn't include fleet sales.

We expect sales among commercial and public fleets, which account for 20 to 25 percent of current annual sales. With scattered sales among the remaining 35 percent of the market, including one-car households, it's not hard to imagine EV sales reaching 20 percent of annual vehicle sales. At that rate, electrics could become 20 percent of the vehicle stocks in California within a ten-year period. That would be 4 to 5 million vehicles—according to some studies, that might be about the right number of electrics given California's electric-power-generating capabilities.

The Green Machine

A bigger question is whether electrics will lead us to environmental improvement. Once zero-emission vehicles are on the road, gasoline cars and gas stations will seem a lot smellier and dirtier than they do now. Cleaning up the air will be like cleaning the walls in your kitchen: you start with that greasy place above the stove and, once that leaves an obvious clean spot, you suddenly notice just how dirty the kitchen has become. The next thing you know, you end up repainting the entire kitchen.

Electric vehicles could allow us to enjoy our suburban lifestyles while preserving the environment, too. And that's how they'll succeed. As Michael Schiffer notes in his history of electric cars, what often attracts new buyers are a product's *extreme* capabilities. Early car buyers admired the touring capabilities of gasoline vehicles, and so, they turned down the electrics. Today, the zero-emission standard makes EVs look attractive. ◆



An advertisement in *The Literary Digest*, 1910

FURTHER READING

S.D. Beggs and N.S. Cardell, "Choice of Smallest Car by Multi-Vehicle Households and the Demand for EVs," *Transportation Research A*, Vol. 14A , 1980, pp. 380-404.

D.S. Bunch, M. Bradley, T.F. Golob, R. Kitamura, and G.P. Occhiuzzo, "Demand for Clean Fueled Vehicles in California: A Discrete-Choice, Stated Preference Survey," *Transportation Research A*, Vol. 27A, 1993, pp. 237-53.

J.E. Calfee, "Estimating the Demand for Electric Automobiles Using Fully Disaggregated Probabilistic Choice Analysis," *Transportation Research B*, Vol. 19B, 1985, pp. 287-301.

K. Kurani, T. Turrentine, and D. Sperling, "Demand for EVs in Hybrid Households: An Exploratory Analysis," *Transport Policy* , Vol. 1, No. 4, 1994, pp. 244-256. UCTC No. 232.

M. Schiffer, *Taking Charge: The Electric Automobile in American History* (Washington D.C.: Smithsonian Institution Press, 1994).

T. Turrentine,"Lifestyles and Life Politics: Towards a Green Car Market", Ph.D. dissertation, University of California, Davis, 1995. UCTC Diss No. 26.

T. Turrentine, K. Kurani, and D. Sperling, "Market Potential Study of Zero Emissions Vehicles: A Reflexive, Diary-based Survey of New Car Buyers in California," ITS Davis report available May 1995.

Are HOV Lanes Really Better?

BY JOY DAHLGREN

Public policy currently promotes high-occupancy-vehicle (HOV) lanes and discourages construction of general-purpose lanes. HOV lanes supposedly reduce congestion and harmful emissions because they encourage ridesharing and transit use. Just add a few passengers, and you can be rewarded with a fast, pleasant drive to work. That's the ideal behind HOV lanes. But the reality is not so simple.

A curious thing about an HOV lane is that people want to use it only if it's less congested than the other freeway lanes—so, congestion must *persist* on the other freeway lanes. But HOV lanes are supposed to reduce congestion. Another curious thing is that, as people shift to high-occupancy vehicles to travel faster, they increase traffic on the HOV lane while decreasing traffic on the general lanes. The time savings offered by the HOV lane then shrinks, and so does the incentive to shift to high-occupancy-vehicles. Thus we face a paradox: the more effective an HOV lane is, the less effective it is.

If policymakers want only to encourage ridesharing and transit use—that is, increase vehicle occupancy—then, constructing HOV lanes will certainly work better than constructing general-purpose lanes. But more densely populated vehicles are not necessarily benefits in themselves. Rather, they allow us to achieve greater objectives: reduced person-delay, reduced emissions of pollutants, and reduced fuel consumption. ➢

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THE STUDY

My research compares the effectiveness of HOV lanes to general-purpose lanes in reducing person-delay and harmful emissions. Because adding a new highway lane,whether for HOVs or not, generates many effects that are difficult to measure—such as route shifts, start-time shifts, induced trips, and new bottlenecks—I combined queueing theory and mode-choice theory to develop a simulation model that requires but little observed data. The model does not predict what actually will happen when a lane is added because it assumes away route and start-time shifts and makes other simplifying assumptions. However, because these assumptions either favor an HOV lane or do not alter the ranking of the two alternatives, the model can be used to compare their benefits. Whenever the model shows less delay with a general-purpose lane, this really is the case. But when the model shows less delay with an HOV lane, this is not necessarily true—there actually may be less delay with a general-purpose lane.

The model calculates the number of vehicle- and person-trips and total vehicle- and person-delay, along with the final proportion of high-occupancy vehicles. The proportion of people who will use high-occupancy vehicles during any time increment is estimated with a logit discrete-choice model.

REDUCING PERSON-DELAY

HOV lanes are supposed to help people travel faster by relieving freeway bottlenecks. In theory, this happens in three ways:

- People shift from low- to high-occupancy vehicles, thus reducing the overall number of vehicles on the road.
- High-occupancy vehicles have priority, thus vehicles with more passengers suffer less delay than do vehicles with only one person.
- An added HOV lane increases road capacity, thus reducing overall congestion.

In practice, however, the first two benefits are limited. Several studies report that a person's decision to use a high-occupancy vehicle rather than drive alone is not very sensitive to in-vehicle travel time. Kenneth Small found that people placed an equal value on one minute of pre-trip waiting time and 10 minutes of in-vehicle travel time. That is, they would just as soon drive 10 more minutes as wait one minute for a ride. People may be discouraged from shifting to high-occupancy vehicles because carpooling requires advance arrangements and restricts one's choice of travel times. And transit involves waiting, circuitous routing, stops en route, and sometimes transfers. Furthermore, many trips discourage group travel: trips with uncommon origins or destinations, trips at uncommon times, or trips for transporting heavy or bulky things. So, even if riding in a high-occupancy vehicle would save them 5, 15, or even 25 minutes on the freeway, many solo drivers would not make the switch.

The benefits of giving high-occupancy vehicles priority is limited by the fact that "high occupancy" often means just two people. Such priority is most beneficial when there are large numbers of people in buses.

Giving priority to high-occupancy vehicles works best when lots of people share one vehicle.

Increased road capacity is the primary factor in reducing person-delay. When existing high-occupancy vehicles move to the HOV lane, congestion decreases on the general-purpose lanes. At some point where the proportion of high-occupancy vehicles approaches the proportion of capacity set aside for them, person-delay is minimized. For example, if about 20 percent of vehicles on a three-lane highway already have high occupancy when an HOV lane is added, then the HOV lane will be well used and still offer a slight advantage to ridesharers. It turns out that the proportion of *preexisting* high-occupancy vehicles on a highway critically affects an additional HOV lane's advantages compared to a general-purpose lane.

REDUCING EMISSIONS

Policymakers often just presume that constructing an HOV lane is more effective in reducing pollution than constructing another general-purpose lane. However, it does not necessarily work out that way. The main source of reduced emissions is reduced congestion, not reduced trips. For example, if reduced congestion allowed an average vehicle to increase its average speed from 20 mph to 50 mph over ten miles, that vehicle's emissions of reactive organic gases (ROG) and carbon monoxide (CO) would be reduced by 5 and 39 grams, respectively. Multiplied by the thousands of vehicle trips that benefit from congestion reduction, these harmful emissions could be reduced by hundreds of thousands of grams per day.

In comparison, a light passenger vehicle traveling at 20 mph emits 21 grams of ROG and 211 grams of CO on a 20-mile trip. Eliminating one such trip certainly provides greater environmental benefit than reducing congestion for that one vehicle. But, if overall benefits of trip reduction are to exceed overall effects of reduced congestion, thousands of trips would have to be eliminated. But the evidence shows that the addition of an HOV lane does not greatly motivate solo drivers to rideshare, so it is difficult to eliminate trips.

When freeway expansion is considered, clearly the strategy that best reduces congestion will also best reduce harmful emissions. The question, then, is whether adding an HOV lane will reduce congestion more effectively than adding a general-purpose lane.

WHEN WOULD AN HOV LANE BE BETTER?

The advantage of adding an HOV lane is that, as long as some delay remains on the other lanes, it does reduce some vehicle trips. The disadvantage is that the freeway is only partially used. My research shows that HOV lanes perform better than general-purpose lanes only when there is initially long delay, thus motivating solo drivers to rideshare, and the initial proportion of HOVs is fairly high, resulting in greater use of HOV lane capacity.

Figures 1-3 compare the effectiveness of adding an HOV lane to adding a general-purpose lane on a three-lane highway, with average peak-period person-delay as the indicator. An average high-occupancy vehicle is assumed to have 2.15 persons. The vertical axis represents the difference in average person-delay between the added HOV lane and the added general-purpose lane. When the value is positive, it means more person-delay would occur on an added HOV lane than on an added general-purpose lane (so a general-purpose lane would be more effective in reducing congestion). The right horizontal axis represents the proportion of preexisting high-occupancy vehicles on the highway before a new lane was added. The left horizontal axis is a coefficient that estimates the likelihood of solo drivers shifting to high-occupancy vehicles, depending on how much travel-time they save by using the HOV lane. The higher the number (–0.01), the more resistant solo drivers would be to switching modes. The lower the number (–0.05), the more likely they would shift to high-occupancy vehicles, even for a small savings in travel time.

Figures 1 and 2 show results for highways with initial maximum delays of 15 minutes and 25 minutes, respectively. Nowhere do the graphs drop below zero on the vertical axis. That is, in all cases an added general-purpose lane would cause either the same amount of person-delay or less person-delay than an added HOV lane, even if the initial proportion of high-occupancy vehicles were high, and even if solo drivers shifted to high-occupancy vehicles easily.

Figure 3 shows results for highways with initial maximum delays of 35 minutes. Only when the initial proportion of high-occupancy vehicles is 20 percent or more does the graph drop below zero. That is, only then would an additional HOV lane offer less person-delay than an additional general-purpose lane. ➢

Difference in Average Peak-Period Person-Delay Between an HOV Lane and a General-Purpose Lane (when added to a three-lane highway)

FIGURE 1

15-Minute Initial Maximum Delay

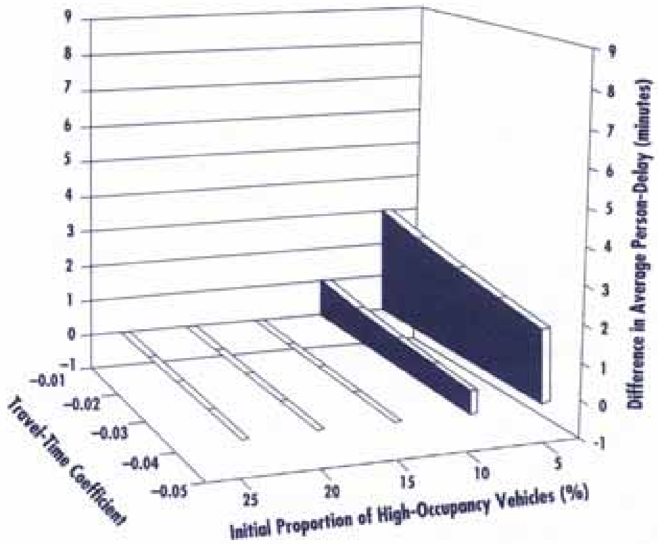


FIGURE 2

25-Minute Initial Maximum Delay

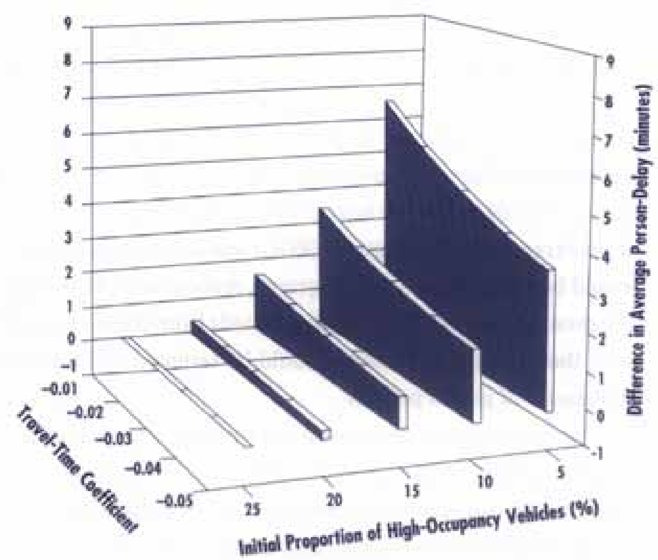
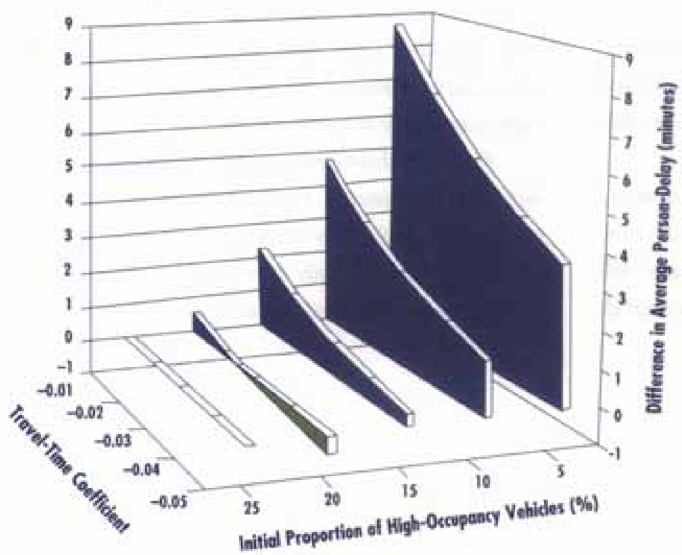


FIGURE 3

35-Minute Initial Maximum Delay



WHAT ABOUT GROWTH?

Advocates of HOV lanes might argue that expected population and economic growth will make a new HOV lane a better choice, in ten years, than would an additional general-purpose lane. However, if an HOV lane is added prematurely, the greater person-delay and emissions reductions of an added general-purpose lane will be lost. Besides, the expected growth may not occur. Why not first construct a general-purpose lane and convert it to an HOV lane if and when growth requires it?

However, when converting a general-purpose lane to an HOV lane, planners must carefully evaluate whether a limited-use lane is really a better choice in terms of person-delay and emissions. The proportion of high-occupancy vehicles should be less than, but approaching, the proportion of capacity provided by the converted HOV lane, to assure good use of the lane. There must also be considerable delay to induce solo drivers to shift to high-occupancy vehicles. Finally, the proportion of *people* in high-occupancy vehicles must also be high so that the number of winners is comparable to the number of losers.

When one of the four existing lanes on the Santa Monica Freeway was converted to an HOV lane in 1976, the number of carpools increased by 65 percent, bus ridership increased by 250 percent, and peak-period vehicle-trips decreased by 10 percent. Carpools required three or more occupants. But initially carpools accounted for only 3 percent of vehicles and bus passengers accounted for 0.8 percent of travelers. Therefore, 25 percent of freeway capacity became dedicated to about 6 percent of vehicles that were carpools and 3 percent of travelers who rode buses—far too few winners. Overall person-delay increased. There was a public outcry and, shortly afterward, the lane was returned to general use.

Another interesting question merits further research: in cases where adding an HOV lane has much greater benefits than adding a general-purpose lane, might it be more cost-effective to add *two* general purpose lanes? Given that many HOV-lane projects include auxiliary lanes, flyover ramps, or enforcement areas, the cost and space required for two general-purpose lanes might not be a lot more than that required for an HOV-lane project.

If the goal of transportation policy were to minimize vehicle travel, then *no* capacity should be added. The fact that policymakers ignore that option may reflect the understanding that society benefits when people travel. We could even consider congestion a measure of the system's success. Therefore, we should aim not to reduce person-trips but to reduce the costs that these trips impose. One solution is to increase highway capacity, and new general-purpose lanes may serve that goal better than constructing HOV lanes. ◆

FURTHER READING

F. Crain, *The Rapid Bus Concept* (Menlo Park: Stanford Research Institute, 1963).

J. W. Dahlgren, *An Analysis of the Effectiveness of High Occupancy Vehicle Lanes*, Ph.D. dissertation, University of California, Berkeley, 1994. UCTC Diss No. 25.

R.H. Henk, D.E. Morris, and D.L. Christiansen, *An Evaluation of High-Occupancy Vehicle Lanes in Texas* (College Station: Texas Transportation Institute, 1993).

T.J. Lomax and D.E. Morris, *Guidelines for Estimating the Cost Effectiveness of High-Occupancy Vehicle Lanes* (College Station: Texas Transportation Institute, 1985).

K. Small, "Predicting Car-Pool Demand—Priority Lanes on Urban Radial Freeways: An Economic-Simulation Model," *Transportation Research Record* No. 637, 1977, pp. 8-13.

K. F. Turnbull, *An Assessment of High-Occupancy Vehicle Facilities in North America: Executive Report* (College Station: Texas Transportation Institute, 1992).

U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, *National Air Pollutant Emission Estimates 1990-1991* (Washington D.C.: U.S. Environmental Protection Agency, 1992).

Adler, Jeffrey L. and Michael G. McNally
"In-Laboratory Experiments to Investigate Driver Behavior Under Advanced Traveler Information Systems (ATIS)
1993 UCTC 184

Adler, Jeffrey L., Michael G. McNally and Wilfred W. Recker
"Interactive Simulation for Modeling Dynamic Driver Behavior in Response to ATIS"
1993 UCTC 171

Adler, Jeffrey L., Thomas F. Golob and Michael G. McNally
"A Structural Model with Discrete-Choice Variables for Predicting Enroute Behavior Under ATIS"
1993 UCTC 174

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"
1992 UCTC 127

Adler, Jeffrey L., Wilfred W. Recker and Michael G. McNally
"In-Laboratory Experiments to Analyze Enroute Driver Behavior Under ATIS"
1993 UCTC 148

Adler, Jeffrey L. Wilfred W. Recker and Michael G. McNally
"Using Interactive Simulation to Model Driver Behavior Under ATIS"
1992 UCTC 126

Baer, Christopher T., Daniel B. Klein and John Majewski
"From Trunk to Branch: Toll Roads in New York, 1800-1860"
1992 UCTC 121

Barnett, Roger
"British Rail's InterCity 125 and 225," CalSpeed Series
1992 UCTC 114

Barnett, Roger
"Tilting Trains: The Italian ETR and the Swedish X-2000," CalSpeed Series
1992 UCTC 113

Bennett, Anna K. and David D. Little
"Earthquake Effects on Employee Transportation,"Studies on the Loma Prieta Earthquake, No. 2
1990 UCTC 152

Bennett, Anna K. and David D. Little
"Earthquake Effects on Employee Transportation," Studies on the Loma Prieta Earthquake, No. 2 Executive Summary
1990 UCTC 153

Berechman, J. and Kenneth A. Small
"Modeling Land Use and Transportation: An Interpretive Review for Growth Areas"
1988 UCTC 1

Blankson, Charles and Martin Wachs
"Preliminary Evaluation of the Coastal Transportation Corridor Ordinance in Los Angeles"
1990 UCTC 32

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

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

Brownstone, David
"Multiple Imputations for Linear Regression Models"
1991 UCTC 37

Brownstone, David and Thomas F. Golob
"The Effectiveness of Ridesharing Incentives: Discrete-Choice Models of Commuting in Southern California"
1991 UCTC 93

Brownstone, David, David S. Bunch and Thomas F. Golob
"A Demand Forecasting System for Clean-Fuel Vehicles"
1994 UCTC 221

Bunch, David S.
"Estimability in the Multinomial Probit Model"
1991 UCTC 71

Bunch, David S. and Ryuichi Kitamura
"Probit Model Estimation Revisited: Trinomial Models of Household Car Ownership"
1991 UCTC 70

Burns, Elizabeth
"Arizona's Metropolitan Travel Reduction Programs"
1992 UCTC 81

Burns, Elizabeth
"Improving Traffic Congestion by Regulating Employee Travel: A Phoenix Survey"
1991 UCTC 22

Burns, Elizabeth
"Linking Geographic Information Systems and Trip Reduction: Success and Failure in a Pilot Application"
1993 UCTC 143

Burns, Elizabeth
"Vance's Commuting Analysis Extended to the Suburban Southwest: Tempe Arizona"
1992 UCTC 67

Burns, Elizabeth K.
"Employee and Student Trip Reduction: First Year Results from Metropolitan Phoenix"
1994 UCTC 226

Burns, Elizabeth K.
"Linking Geographic Information Systems and Trip Reduction: Limitations in a Pilot Application"
1994 UCTC 241

Cervero, Robert
"Accessibility and Third World Rural Development: A Case Study of Sumatra"
1990 UCTC 108

Cervero, Robert
"Congestion, Growth and Public Choices"
1991 UCTC 51

Cervero, Robert
"Jobs-Housing Balancing and Regional Mobility"
1989 UCTC 50

Cervero, Robert
"Land Market Impacts of Urban Rail Transit and Joint Development: An Empirical Study of Rail Transit in Washington, D.C. and Atlanta"
1992 UCTC 135

Cervero, Robert
"Land Uses and Travel at Suburban Activity Centers"
1991 UCTC 91

Cervero, Robert
"Land-Use Mixing and Suburban Mobility"
1988 UCTC 3

Cervero, Robert
"Paratransit in Southeast Asia: A Market Reponse to Poor Roads?"
1991 UCTC 90

Cervero, Robert
"Profiling Profitable Bus Routes"
1990 UCTC 92

Cervero, Robert
"Ridership Impacts of Transit-Focused Development in California"
1993 UCTC 176

Cervero, Robert
"Suburban Employment Centers: Probing the Influence of Site Features on the Journey-to-Work"
1991 UCTC 49

Cervero, Robert
"Surviving in the Suburbs: Transit's Ultimate Challenge"
1993 UCTC 169

* **Cervero, Robert, Alfred Round, Carma Reed, and Brian Clark**
"The All-Electric Commute: An Assessment of the Market Potential for Station Cars in the San Francisco Bay Area"
1994 UCTC 249

Cervero, Robert and John Landis
"Suburbanization of Jobs and the Journey to Work"
1991 UCTC 83

Cervero, Robert and Mark Dunzo
"An Assessment of Suburban-Targeted Transit Service Strategies in the United States"
1993 UCTC 178

Cervero, Robert and Peter Bosselmann
"An Evaluation of the Market Potential for Transit-Oriented Development Using Visual Simulation Techniques"
1994 UCTC 247

* not previously listed

Cervero, Robert and Val Menotti
"Market Profiles of Rail-Based Housing Projects in California"
1994 UCTC 242

Cervero, Robert, Michael Bernick and Jill Gilbert
"Market Opportunities and Barriers to Transit-Based Development in California"
1994 UCTC 223

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

Choy, Manhoi, Mei-Po Kwan and Hong Va Leong
"On Real-Time Distributed Geographical Database Systems"
1994 UCTC 216

Chu, Xuehao
"Endogenous Trip Scheduling: The Henderson Approach Reformulated and Compared with the Vickrey Approach"
1993 UCTC 199

Chu, Xuehao and Gordon J. Fielding
"Electronic Road Pricing in Southern California: Policy Obstacles to Congestion Pricing"
1994 UCTC 189

Cohn, Theodore E.
"Integration by the Human Eye: Implications for Warning Signal Design"
1993 UCTC 207

Cohn, Theodore E. and David J. Lasley
"Wallpaper Illusion: Cause of Disorientation and Falls on Escalators"
1990 UCTC 160

Crane, Randall
"Cars and Drivers in the New Suburbs: Linking Access to Travel in Neotraditional Planning"
1994 UCTC 239

Crane, Randall
"The Influence of Expected Suburbanization on Urban Form and the Journey to Work"
1994 UCTC 240

De Vany, Arthur and W. David Walls
"Network Connectivity and Price Convergence: Gas Pipeline Deregulation"
1993 UCTC 202

De Vany, Arthur and W. David Walls
"Pipeline Access and Market Integration in the Natural Gas Industry: Evidence from Cointegration Tests"
1993 UCTC 200

De Vany, Arthur and W. David Walls
"When Barriers to Markets Fall: Pipeline Deregulation, Spot Markets, and the Topology of the Natural Gas Market"
1992 UCTC 123

Deakin, Elizabeth
"Land Use and Transportation Planning in Response to Congestion: The California Experience"
1989 UCTC 54

Deakin, Elizabeth
"Suburban Traffic Congestion, Land Use and Transportation Planning Issues: Public Policy Options"
1990 UCTC 57

Deakin, Elizabeth
"The United States" (from *Transport Policy and the Environment: Six Case Studies*)
1990 UCTC 66

Deakin, Elizabeth
"Toll Roads: A New Direction for U.S. Highways?"
1990 UCTC 56

Deakin, Elizabeth
"Transportation and Air Quality in California: A Policy Analysis"
1989 UCTC 55

Deakin, Elizabeth
"Transportation and Land Use Planning in California: Problems and Opportunities for Improved Performance"
1988 UCTC 53

DeLuchi, Mark A. and J.M. Ogden
"Solar-Hydrogen Fuel-Cell Vehicles"
1993 UCTC 158

DeLuchi, Mark A., Quanlu Wang and Daniel Sperling
"Electric Vehicles: Performance, Life-Cycle Costs, Emissions, and Recharging Requirements"
1989 UCTC 7

Fielding, Gordon J. and Daniel B. Klein
"High Occupancy / Toll Lanes: Phasing in Congestion Pricing a Lane at a Time"
1993 UCTC 179

Fielding Gordon J. and Daniel B. Klein
"How to Franchise Highways"
1992 UCTC 134

Gärling, Tommy, Mei-Po Kwan and Reginald G. Golledge
"Computational-Process Modelling of Household Activity Scheduling"
1993 UCTC 217

Gärling, Tommy, Mei-Po Kwan and Reginald G. Golledge
"Computational-Process Modelling of Travel Decisions: Review and Conceptual Analysis"
1991 UCTC 209

Garrison, William L. and Reginald R. Souleyrette II
"Relations between Transportation and Production"
1990 UCTC 45

Garrison, William L. and Reginald R. Souleyrette II
"The Relationship between Transportation and Innovation"
1994 UCTC 230

Giuliano, Genevieve
"Is Jobs-Housing Balance a Transportation Issue?"
1991 UCTC 133

Giuliano, Genevieve
"New Directions for Understanding Transportation and Land Use"
1989 UCTC 2

Giuliano, Genevieve and Kenneth A. Small
"Alternative Strategies for Coping with Traffic Congestion"
1994 UCTC 188

Giuliano, Genevieve and Kenneth A. Small
"Is the Journey to Work Explained by Urban Structure?"
1992 UCTC 107

Giuliano, Genevieve and Kenneth A. Small
"Subcenters in the Los Angeles Region"
1990 UCTC 39

Giuliano, Genevieve and Kenneth A. Small
"The Determinants of Growth of Employment Subcenters"
1994 UCTC 220

Giuliano, Genevieve and Martin Wachs
"Responding to Congestion and Traffic Growth: Transportation Demand Management"
1991 UCTC 86

Giuliano, Genevieve and Thomas F. Golob
"Using Longitudinal Methods for Analysis of a Short-Term Transportation Demonstration Project"
1990 UCTC 28

Giuliano, Genevieve, Keith Hwang and Martin Wachs
"Employee Trip Reduction in Southern California: First Year Results"
1993 UCTC 164

Giuliano, Genevieve, Keith Hwang, Diane Perrine, and Martin Wachs
"Preliminary Evaluation of Regulation XV of the South Coast Air Quality Management District"
1991 UCTC 60

Glazer, Amihai and Esko Niskanen
"Parking Fees, Congestion, and Consumer Welfare"
1991 UCTC 24

Glazer, Amihai and Esko Niskanen
"When Do Consumers Favor Price Increases: With Applications to Congestion and to Regulation"
1992 UCTC 193

Glazer, Amihai and Esko Niskanen
"Why Voters May Prefer Congested Public Clubs"
1992 UCTC 195

Glazer, Amihai and Kai A. Konrad
"Ameliorating Congestion by Income Redistribution"
1993 UCTC 192

Glazer, Amihai and Refael Hassin
"Governmental Failures in Evaluating Programs"
1994 UCTC 194

Glazer, Amihai, Daniel Klein and Charles Lave
"Clean for a Day: Troubles with California's Smog Check"
1993 UCTC 163

Golledge, Reginald G.
"Do People Understand Spatial Concepts: The Case of First-Order Primitives"
1992 UCTC 211

Golledge, Reginald G.
"Place Recognition and Wayfinding: Making Sense of Space"
1992 UCTC 212

Golledge, Reginald G.
"Time and Space in Route Preference"
1993 UCTC 213

Golledge, Reginald G., Mei-Po Kwan and Tommy Gärling
"Computational Process Modelling of Travel Decisions: Empirical Tests"
1991 UCTC 210

Golledge, Reginald G., Mei-Po Kwan and Tommy Gärling
"Computational-Process Modelling of Household Travel Decisions Using a Geographical Information System"
1994 UCTC 218

Golledge, Reginald G., Valerie Dougherty and Scott Bell
"Survey Versus Route-Based Wayfinding in Unfamiliar Environments"
1993 UCTC 214

Golob, Thomas F.
"Structural Equation Modeling of Travel Choice Dynamics"
1988 UCTC 4

Golob, Thomas F.
"The Dynamics of Household Travel Time Expenditures and Car Ownership Decisions"
1990 UCTC 26

Golob, Thomas F. and Jacqueline M. Golob
"Practical Considerations in the Development of a Transit Users Panel"
1989 UCTC 17

Golob, Thomas F. and Leo van Wissen
"A Joint Household Travel Distance Generation and Car Ownership Model"
1989 UCTC 8

Golob, Thomas F., Seyoung Kim and Weiping Ren
"A Structural Model of Vehicle Use in Two-Vehicle Households"
1994 UCTC 224

Goulias, Konstadinos G.
"A Dynamic Microsimulator for Travel Demand Forecasting"
1992 UCTC 95

Goulias, Konstadinos G.
"Forecasting the Impact of Sociodemographic Changes on Travel Demand: Experiments with a Dynamic Microsimulation Model System"
1992 UCTC 94

Goulias, Konstadinos G. and Ram Pendyala
"Innovations in Transportation: The Case of Telecommuting"
1991 UCTC 72

Goulias, Konstadinos G. and Ryuichi Kitamura
"Analysis of Binary Choice Frequencies with Limit Cases: Comparison of Alternative Estimation Methods and Application to Weekly Household Mode Choice"
1991 UCTC 96

Goulias, Konstadinos G. and Ryuichi Kitamura
"Recursive Model System for Trip Generation and Trip Chaining"
1991 UCTC 40

Goulias, Konstadinos G., Ram M. Pendyala and Ryuichi Kitamura
"A Practical Method for the Estimation of Trip Generation and Trip Chaining"
1991 UCTC 62

Goulias, Konstadinos G., Ram M. Pendyala and Ryuichi Kitamura
"Updating a Panel Survey Questionnaire"
1991 UCTC 61

Guensler, Randall and Daniel Sperling
"Congestion Pricing and Motor Vehicle Emissions: An Initial Review"
1993 UCTC 229

Hall, Peter, Brian Sands and Walter Streeter
"Managing the Suburban Commute: A Cross-National Comparison of Three Metropolitan Areas"
1993 UCTC 177

Hall, Peter, Daniel Leavitt and Erin Vaca
"High-Speed Trains for California. Strategic Choice: Comparisons of Technologies and Choice of Route," CalSpeed Series
1992 UCTC 104

Hall, Peter, Daniel Leavitt and Erin Vaca
"High-Speed Trains for California. Volume II: Detailed Segment Descriptions, Cost Estimates, and Travel Time Calculations," CalSpeed Series
1992 UCTC 105

Hall, Randolph W.
"Design for Local Area Freight Networks"
1991 UCTC 63

Hall, Randolph W.
"Pickup and Delivery Systems for Overnight Carriers"
1992 UCTC 106

Hall, Randolph W. and Wei Hua Lin
"LTL Trucking in Los Angeles: Congestion Relief through Terminal Siting"
1990 UCTC 43

Handy, Susan
"A Cycle of Dependence: Automobiles, Accessibility, and the Evolution of the Transportation and Retail Hierarchies"
1993 UCTC 233

Handy, Susan
"Regional versus Local Accessibility: Implications for Nonwork Travel"
1993 UCTC 234

Handy, Susan L.
"Regional versus Local Accessibility: Neo-Traditional Development and Its Implications for Non-Work Travel"
1993 UCTC 235

Hansen, Mark and Jacob Sutter
"The Shake with Freight: The Impact of the Loma Prieta Earthquake on Bay Area Truckers," Studies on the Loma Prieta Earthquake, No. 1
1990 UCTC 151

Hansen, Mark and Sharon Weinstein
"East Bay Ferry Service and the Loma Prieta Earthquake," Studies on the Loma Prieta Earthquake, No. 5
1991 UCTC 162

Harsman, Bjorn and John M. Quigley
"The Spatial Segregation of Ethnic and Demographic Groups: Comparative Evidence from Stockholm and San Francisco"
1993 UCTC 149

Hedrick, J.K. and Kyongsu Yi
"The Effect of Alternative Heavy Truck Suspensions on Flexible Pavement Response"
1991 UCTC 46

Hwang, Keith and Genevieve Giuliano
"The Determinants of Ridesharing: Literature Review"
1990 UCTC 38

* **Jacobs, Allan B., Yodan Y. Rofé and Elizabeth S. Macdonald**
"Boulevards: A Study of Safety, Behavior, and Usefulness"
1994 UCTC 248

Jayakrishnan, R., Michael G. McNally and Michael I. Cohen
"Simulation of Advanced Traveller Information Systems (ATIS) Strategies to Reduce Non-Recurring Congestion from Special Events"
1993 UCTC 173

Jayakrishnan, R., Wei T. Tsai, Joseph N. Prashker, and Subodh Rajadhyaksha
"A Faster Path-Based Algorithm for Traffic Assignment"
1994 UCTC 191

Jovanis, Paul P., Tetsuya Kaneko and Tzuoo-Din Lin
"Exploratory Analysis of Motor Carrier Accident Risk and Daily Driving Patterns"
1991 UCTC 73

Kaneko, Tetsuya and Paul P. Jovanis
"Multiday Driving Patterns and Motor Carrier Accident Risk: A Disaggregate Analysis"
1991 UCTC 59

Keeler, Theodore E.
"Highway Safety, Economic Behavior, and Driving Environment"
1993 UCTC 65

* not previously listed

Kim, Seyoung
"After the Resolution: Excess Commuting for Two-Worker Households in the Los Angeles Metropolitan Area"
1993 UCTC 144

Kim, Seyoung
"Gender Differences in Commuting: An Empirical Study of the Greater Los Angeles Metropolitan Area"
1994 UCTC 190

Kitamura, Ryuichi
"Panel Analysis in Transportation Planning: An Overview"
1990 UCTC 68

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"
1990 UCTC 52

Kitamura, Ryuichi, Jack M. Nilles, Patrick Conroy, and David M. Fleming
"Telecommuting as a Transportation Planning Measure: Initial Results of California Pilot Project"
1991 UCTC 58

Kitamura, Ryuichi, Patricia L. Mokhtarian, Ram M. Pendyala, and Konstadinos G. Goulias
"An Evaluation of Telecommuting as a Trip Reduction Measure"
1991 UCTC 5

Klein, Daniel B.
"The Voluntary Provision of Public Goods? The Turnpike Companies of Early America"
1990 UCTC 18

Klein, Daniel B. and Chi Yin
"The Private Provision of Frontier Infrastructure: Toll Roads in California, 1850-1902"
1994 UCTC 238

Klein, Daniel B. and Gordon J. Fielding
"Private Toll Roads: Learning from the 19th Century"
1992 UCTC 118

Klein, Daniel B. and John Majewski
"Economy, Community and Law: The Turnpike Movement in New York, 1797-1845"
1991 UCTC 76

Klein, Daniel B. and John Majewski
"Plank Road Fever in Antebellum America: New York State Origins"
1994 UCTC 243

Klein, Daniel B. and John Majewski
"Promoters and Investors in Antebellum America: The Spread of Plank Road Fever"
1991 UCTC 75

Kroll, Cynthia A., John D. Landis, Qing Shen, and Sean Stryker
"Economic Impacts of the Loma Prieta Earthquake: A Focus on Small Business," Studies on the Loma Prieta Earthquake, No. 3
1991 UCTC 154

Kurani, Kenneth S., Thomas Turrentine and Daniel Sperling
"Demand for Electric Vehicles in Hybrid Households: An Exploratory Analysis"
1994 UCTC 232

Kwan, Mei-Po and Reginald G. Golledge
"Contributions of GIS to ATIS"
1994 UCTC 215

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

Landis, John D.
"The California Urban Futures Model: A New Generation of Metropolitan Simulation Models"
1994 UCTC 244

Landis, John D. and Ming Zhao
"Pilot Study of Solano and Sonoma Land Use and Development Policy Alternatives"
1994 UCTC 245

Landis, John D., Subhrajit Guhathakurta and Ming Zhang
"Capitalization of Transportation Investments into Single Family Home Prices: A Comparative Analysis of California Transit Systems and Highways"
1994 UCTC 246

Lasley, David J., Russell D. Hamer, Robert Dister, and Theodore E. Cohn
"Postural Stability and Stereo-Ambiguity in Man-Designed Visual Environments"
1991 UCTC 157

Lave, Charles
"Measuring the Decline in Transit Productivity in the U.S."
1991 UCTC 159

Lave, Charles
"State and National VMT Estimates: It Ain't Necessarily So"
1994 UCTC 231

Lave, Charles
"The Demand Curve Under Road-Pricing and the Problem of Political Feasibility"
1992 UCTC 136

Lave, Charles
"Things Won't Get a Lot Worse: The Future of U.S. Traffic Congestion"
1990 UCTC 33

Lave, Charles and Patrick Elias
"Did the 65 Mph Speed Limit Save Lives?" (revised)
1993 UCTC 69

Leavitt, Dan, Sean Ennis and Pat McGovern
"The Cost Escalation of Rail Projects: Using Previous Experience to Re-Evaluate the CalSpeed Estimates," CalSpeed Series
1993 UCTC 156

Leavitt, Daniel, Erin Vaca and Peter Hall
"Revenue and Ridership Potential for a High-Speed Rail Service in the San Francisco / Sacramento - Los Angeles Corridor" Calspeed Series
1994 UCTC 185

Leavitt, Daniel, Peter Cheng, Erin Vaca, and Peter Hall
"Potential for Improved Intercity Passenger Rail Service in California: Study of Corridors," Calspeed Series
1994 UCTC 222

Lem, Lewison Lee, Jian-Ling Li and Martin Wachs
"Comprehensive Transit Performance Indicators"
1994 UCTC 225

• **Lipman, Timothy E., Kenneth S. Kurani and Daniel Sperling (editors)**
"Proceedings of the Neighborhood Electric Vehicle Workshop: A Policy, Technology, and Research Conference"
1994 UCTC 258

Loukaitou-Sideris, Anastasia
"Retrofit of Urban Corridors: Land Use Policies and Design Guidelines for Transit-Friendly Environments"
1993 UCTC 180

Majewksi, John, Christopher T. Baer and Daniel B. Klein
"Market and Community in Antebellum America: The Plank Roads of New York"
1991 UCTC 47

McNally, Michael G.
"Regional Impacts of Neotraditional Neighborhood Development"
1993 UCTC 172

McNally, Michael G. and Sherry Ryan
"A Comparative Assessment of Travel Characteristics for Neotraditional Developments"
1992 UCTC 142

McNally, Michael G. and Sherry Ryan
"Accessibility of Neotraditional Neighborhoods: A Review of Design Concepts, Policies, and Recent Literature"
1992 UCTC 141

Meurs, Henk, Leo van Wissen and Jacqueline Visser
"Measurement Biases in Panel Data"
1989 UCTC 9

Miller, Vincent P. and John M. Quigley
"Segregation by Racial and Demographic Group: Evidence from the San Francisco Bay Area"
1989 UCTC 14

Mokhtarian, Patricia L.
"A Typology of Relationships Between Telecommunications and Transportation"
1990 UCTC 82

Mokhtarian, Patricia L.
"An Empirical Analysis of the Transportation Impacts of Telecommuting"
1991 UCTC 131

Mokhtarian, Patricia L.
"An Empirical Evaluation of the Travel Impacts of Teleconferencing"
1988 UCTC 132

Mokhtarian, Patricia L.
"Defining Telecommuting"
1992 UCTC 80

Mokhtarian, Patricia L.
"Telecommuting and Travel: State of the Practice, State of the Art"
1991 UCTC 79

Mokhtarian, Patricia L. and Ilan Salomon
"Modeling the Choice of Telecommuting: Setting the Context"
1993 UCTC 147

Monismith, C.L., J. Lysmer, J. Sousa, and J.K. Hedrick
"Truck Pavement Interactions: Requisite Research"
1988 UCTC 48

Munshi, Kaivan and Edward C. Sullivan
"A Freight Network Model for Mode and Route Choice"
1989 UCTC 25

Novaco, Raymond W.
"Aggression on Roadways"
1989 UCTC 16

Novaco, Raymond W.
"Automobile Driving and Aggressive Behavior"
1990 UCTC 42

Novaco, Raymond W. and Cheryl Collier
"Commuting Stress, Ridesharing, and Gender: Analyses from the 1993 State of the Commute Study in Southern California"
1994 UCTC 208

Novaco, Raymond W., Daniel Stokols and Louis Milanesi
"Objective and Subjective Dimensions of Travel Impedance as Determinants of Commuting Stress"
1990 UCTC 30

Novaco, Raymond W., Wendy Kliewer and Alexander Broquet
"Home Environment Consequences of Commute Travel Impedance"
1991 UCTC 77

O'Regan, Katherine M.
"Space and Poverty: The Effect of Concentrated Poverty"
1992 UCTC 150

O'Regan, Katherine M. and John M. Quigley
"Family Networks and Youth Access to Jobs"
1992 UCTC 128

O'Regan, Katherine M. and John M. Quigley
"Labor Market Access and Labor Market Outcomes for Urban Youth"
1991 UCTC 84

Parker, John K.
"Meeting Land Transportation Needs of the Ports of Long Beach and Los Angeles"
1990 UCTC 35

Parker, John K.
"The Consolidated Transportation Corridor: Surface Access to the Ports of Long Beach and Los Angeles" Final Report
1990 UCTC 137

Pendyala, Ram M., Konstadinos G. Goulias and Ryuichi Kitamura
"Impact of Telecommuting on Spatial and Temporal Patterns of Household Travel"
1992 UCTC 111

Prosser, Neil A. and Stephen G. Ritchie
"Real-Time Knowledge-Based Integration of Freeway Surveillance Data"
1990 UCTC 89

Ritchie, Stephen G.
"A Knowledge-Based Decision Support Architecture for Advanced Traffic Management"
1990 UCTC 31

Ritchie, Stephen G. and Neil A. Prosser
"A Real-Time Expert System Approach to Freeway Incident Management"
1990 UCTC 88

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

Sampath, Srikanth, Somitra Saxena and Patricia L. Mokhtarian
"The Effectiveness of Telecommuting as a Transportation Control Measure"
1991 UCTC 78

Sands, Brian D.
"InterCity Express: A Technical and Commercial Assessment," CalSpeed Series
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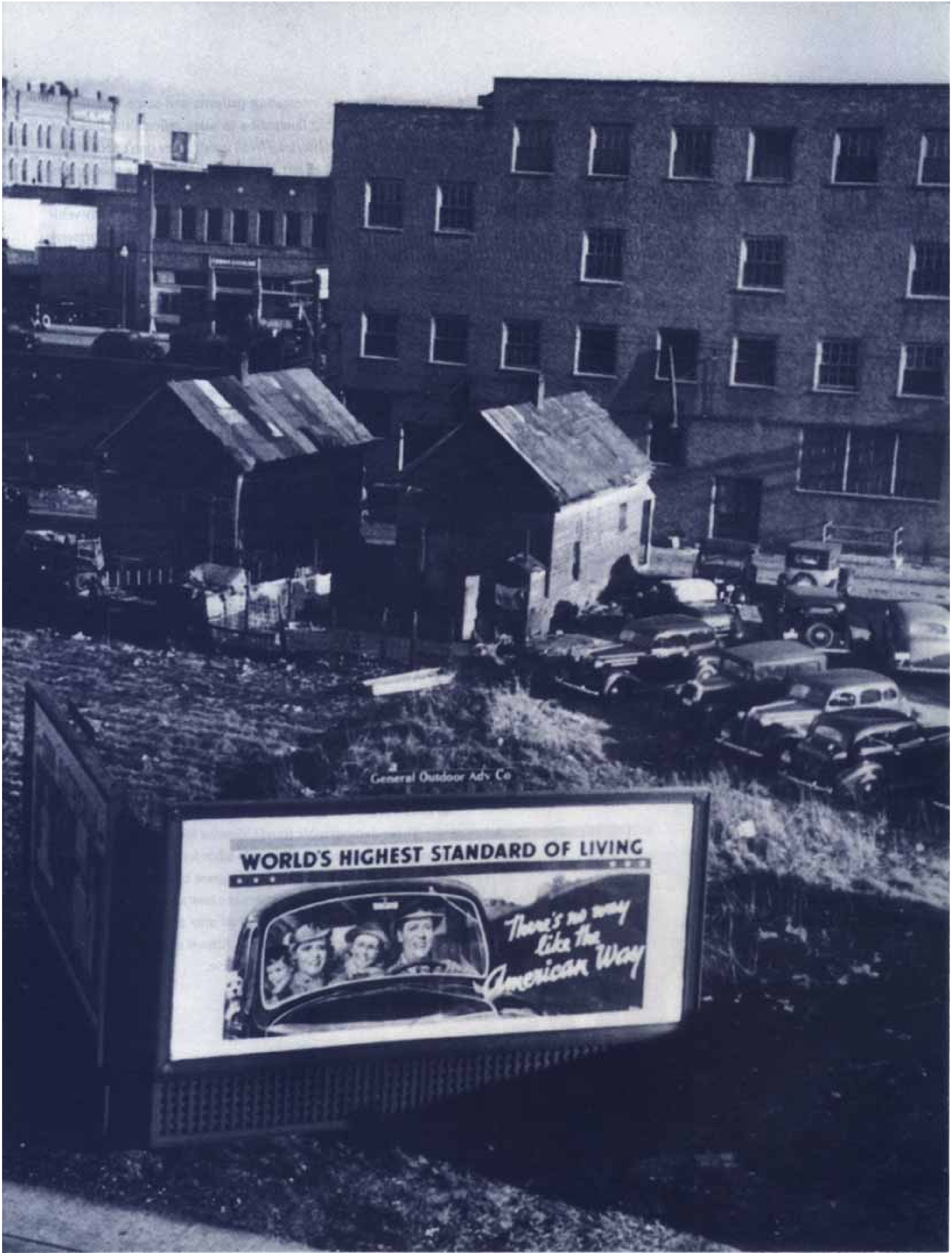
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The ACCESS Almanac:

SLOWDOWN AHEAD FOR THE DOMESTIC AUTO INDUSTRY

Figure 1 has some interesting patterns and some disquieting implications. The big fluctuation in sales reflects the business cycle. Cars are durable, long-lived goods; they don't necessarily have to be replaced in any given year. So when the economy is down, people can postpone new-car purchases.

Growth is another obvious pattern in the graph. Yearly vehicle sales doubled between 1960 and 1973. Given the enormous size and widespread influence of the auto industry, this boom was a major force behind the growth of the U.S. economy.

Another pattern, one that most analysts have missed is that the growth has nearly flattened out. Split the graph in two at 1973, then draw a mental line through the fluctuations in the early years, and another line through the post-1973 fluctuations. Recent sales growth is virtually flat compared to the earlier years.

Will the slowdown continue? You can bet on it. Not as an exercise in simple curve projection, but because of changes in the fundamental demographic factors that shape auto sales. Long-term lethargy in auto sales may be good news for the environment, but it's bad news for the economy.

What lies behind the change in auto sales? Consider Figure 2. The lower line shows vehicle-fleet growth; the upper line shows population growth. At the outset, there were many potential drivers but few vehicles. Incomes grew, giving more potential drivers the *means* to buy cars, and they did so with enthusiasm. From 1950 to 1970, the vehicle population grew 2.9 times faster than the human population.

The explosive demand for automobiles also resulted, in part, from women entering the work force and baby-boomers reaching adulthood. Forty years ago, few women worked. Now most do, thus expanding the proportion of the population desiring cars to get to work. Thirty years ago, most baby-boomers were too young to drive. Now they comprise a disproportionate share of all drivers.

These demographic trends likewise foretell the end of rapid growth in auto demand. Women's labor-force participation, now 82 percent of men's, is projected to grow by only 5 percent during the 1990s. And baby-boomers are now all older than sixteen. In the future, auto demand can grow only at the population rate because we are nearing saturation. Almost everyone old enough to drive already has access to a vehicle.

To measure saturation, we must compare potential drivers to vehicles available. Figure 2 maps the number of potential drivers (population aged 15 to 74) against the number of personal-use vehicles (cars plus the proportion of light trucks used for personal travel). The rapid growth of the vehicle stock and the near convergence of the two lines are apparent.

Figure 1 shows further evidence of vehicle saturation: the size of sales fluctuations is increasing over time. A typical household thirty years ago had only one vehicle. When that vehicle wore out, it had to be replaced soon. A typical household today has two vehicles, giving it more flexibility in postponing a replacement.

The auto industry, sized to accommodate disproportionate vehicle growth, must now confront the implications of ownership saturation. Manufacturing capacity is excessive, and the "temporary" layoffs and plant closings of the last few years are likely to become permanent.

Would any policies put auto sales back onto a high growth path? Strict import quotas would produce some short-term sales growth; but, in the medium term, sales would still run up against the same saturation ceiling. Future expansion of geographic markets is limited: although Europe is still in its high-growth phase (autos per capita has been growing about three times faster there than here) demand for U.S.-built cars is low, and Japanese automakers have a strong headstart there. Finally, the domestic industry might try to persuade each household to expand its portfolio of vehicles. For example, a household with two drivers and two cars might be persuaded to buy an off-road vehicle, or an electric vehicle for local travel.

None of these strategies will be easy to implement, and none promises large, long-term gains. It's not going to be easy for the auto industry to restore significant growth.

—Charles Lave

FIGURE 1

U.S. Yearly Total Sales of Cars and Trucks

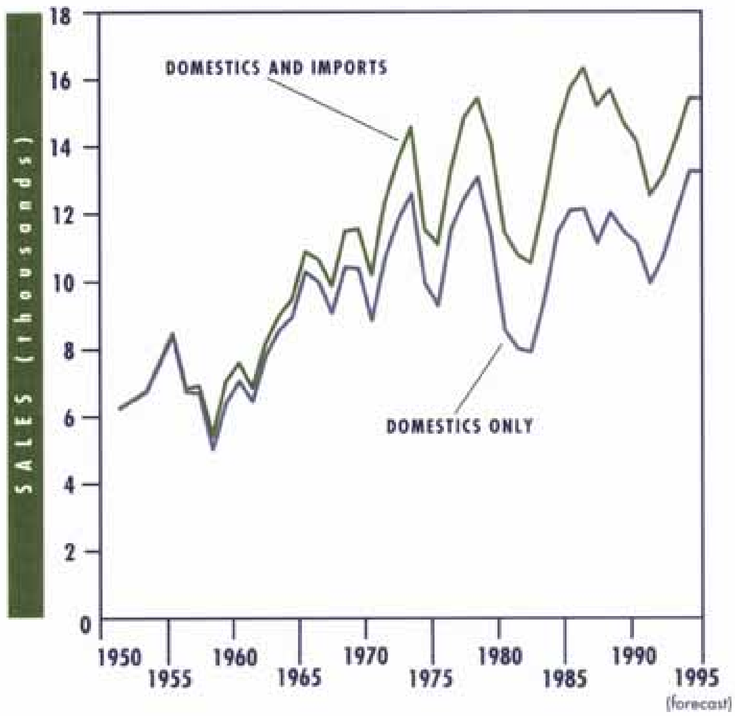
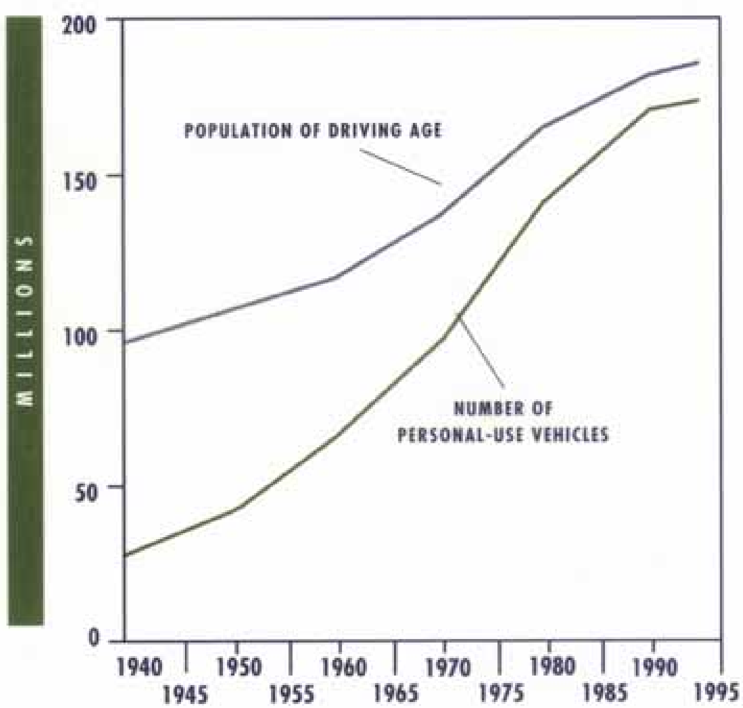


FIGURE 2

Growth of Vehicles vs. Population



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