Policy Options for Transportation Energy Conservation

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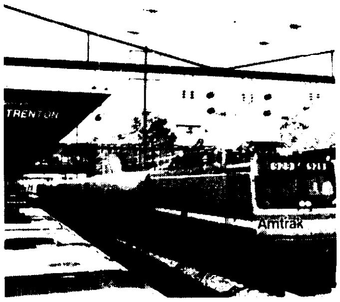
Policymakers interested in transportation energy conservation-whether for reducing oil use, lowering emissions of greenhouse gases, or generally reducing energy use and its environmental and economic consequences--are faced with a complex array of conservation activities and a variety of policy options or tools that will promote the activities. The key categories of conservation activities are:

- improving the technical efficiency of existing vehicles, or introducing new, more efficient replacement vehicles;
- increasing vehicle load factors:
- using more efficient travel modes:
- reducing the number and length of trips made; and
- shifting to non-oil-based fuels.

The policy options available to policymakers to pursue the various conservation activities include:

1. *economic incentives--direct* taxes, granting or eliminating tax breaks, subsidies, granting of regulatory exemptions, making pricing more efficient:
2. *public investment---in* research and development (R&D), new infrastructure (including new types of systems and service), maintenance and rehabilitation of old mass transit infrastructure. and expansion of service; also includes withholding investment and investing in urban development, and
3. *regulatory incentives--efficiency* standards, zoning, fuel use requirements, speed limits, inspection and maintenance requirements, and travel restrictions.

In most cases, each of the basic categories of policy options is applicable to each activity, forming a matrix of government actions that can be used to pursue increased efficiency. For exam-



pie, the option of getting travelers to shift to more efficient modes can be pursued with economic incentives in the form of taxes on gasoline and parking, elimination of the treatment of free employee parking as a normal business expense, and higher operating subsidies for transit; public investments in busways and rail transit (also *withholding* of investment from expansion of road capacity); and regulatory incentives in the form of zoning changes designed to increase urban density (increasing the ability of transit systems to achieve high modal shares). Table 5-1 lists each of the

TABLE 5-1: Transportation Conservation Options

Improve the Technical Efficiency of Vehicles

1 Higher fuel economy requirements—CAFE standards (R)
2 Reducing congestion smart highways (E,l), flextime (E, R), better signaling (l), Improved maintenance of roadways (1), time of day charges (E), Improved air traffic controls (1, R), plus options that reduce vehicular traffic
3 Higher fuel taxes (E)
4 Gas guzzler taxes, or feebate schemes (E)
5 Support for increased R&D (El)
6 Inspection and maintenance programs (R)

Increase Load Factor

1 HOV lanes (1)
2 Forgiven tolls (E), free parking for carpools (E)
3 Higher fuel taxes (E)
4 Higher charges on other vmt trip-dependent factors (E) parking (taxes, restrictions, end of tax treatment as business cost). tolls etc

Change to More Efficient Modes

1 Improvements in transit service
  a New technologies—maglev, high speed trains (E,l)
  b Rehabilitation of older systems (1)
  c Expansion of service—more routes, higher frequency (1)
  d Other service improvements (1)—dedicated busways, better security, more bus stop shelters, more comfortable vehicles
2 Higher fuel taxes (E)
3 Reduced transit fares through higher U S transit subsidies (E) [a]
4 Higher charges on other vmt/trip-dependent factors for less efficient modes (E)—tolls, parking
5 Shifting urban form to higher density, more mixed use, greater concentration through zoning changes (R), encouragement of "infill " development (E, R, I), public Investment in Infrastructure (l), etc

Reduce Number or Length of Trips

1 Shifting urban form to higher density, more mixed use, greater concentration (E,R,I)
2 **Promoting** working at home or at decentralized facilities (El)
3 Higher fuel taxes (E)
4 Higher charges on other vmt/trip-dependent factors (E)

Shift to *Alternative Fuels*

1 Fleet requirements for alternate fuel-capable vehicles and actual use of alternative fuels (R).
2 Low-emission/zero emission vehicle (LEV/ZEV) requirements (R)
3 Various promotions (E) CAFE credits, emission credits, tax credits, etc
4 Higher fuel taxes that do not apply to alternate fuels (E), or subsidies for the alternatives (E)
5 Support for Increased R&D (E,l)
6 Public Investment—government fleet Investments (1)

Freight Opt/ens

1 RD&D of technology improvements (E,l)

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[a] U S transit subsidies already among the highest in the developed world may merely promote inefficiencies

KEY CAFE - corporate average fuel economy E - economic incentive; HOV - high-occupancyvehlcle, I = public investment, maglev = trams supported by magnetic levitation R - regulatory action RD&D - research, development, and demonstration, vmt = vehicle-miles traveled

SOURCE Office of Technology Assessment 1994 conservation activities and the policy options available to stimulate that activity. Each of the options listed in table 5-1 is tagged with an indicator: *E* for economic incentive, *R* for regulatory incentive, and *I* for public investment.

As discussed throughout this report, policymakers do not have the freedom to pick and choose freely among conservation activities and individual policy actions, even if budgetary limits and potential damage to the private economy were not constraints. The constraint on freedom of choice occurs because there is negative synergy among certain sets of policy actions. For example, policy actions that promote the freer flow of automobile traffic will generally sabotage measures to effect shifts to mass transit, reductions in trip length and frequency, and increased load factors in automobiles.

In choosing transportation energy conservation policy opt ions, therefore, policymakers must consider how implementation of these options will fit into an overall (multioption) transportation strategy, as well as how—individually—the options satisfy a number of performance criteria. Table 5-2 lists relevant criteria for option selection.

The first criterion, examining the extent to which the option requires a major lifestyle shift for transportation system users, is ignored at a policymaker's peril. Some lifestyle shifts are conceptually very attractive—for example, large increases in urban residential density and firm restrictions on development of outer areas can yield strong environmental and energy advantages that go well beyond transportation energy reductions. However, the types of intrusive policy actions required to implement such changes are socially and politically acceptable only if an uncommon consensus can be created among all segments of an urban area's residents and business interests. This is likely to be feasible only in isolated cases or in cases of widespread perceptions of an emergency. Such perceptions may well emerge in the future as more becomes known about global warming and other potential environmental or social problems, but at present there is little likelihood of achieving such a consensus.

The last criterion, which inquires whether the option has relevance to the needs of developing nations, may not apply to most options but recognizes that the largest future growth in energy and

TABLE 5-2: Selection Criteria for Transportation Energy Conservation Options

- Degree of lifestyle/social changes required
- Cost-effectiveness measured by using market benefits and costs *or* full social benefits and costs
- Effectiveness at resolving individual energy problems
  1 oil use reduction
  2 greenhouse gas reduction and
  3 energy security Improvement
- Effectiveness at resolving other transportation-related problems
  1 air emissions reduction, and
  2 reduced congestion
- Potential risks
  1 technical risks,
  2 uncertainty in consumer reaction, and
  3 management difficulty
- Time scale
- Potential interaction with other goals—does it foreclose or aid future projects?
- Distribution of costs and benefits—which segments of society absorb costs or gain benefits?
- Integration with International needs-–does it yield benefits for other nations, particularly developing nations?

SOURCE Office of Technology Assessment 1994

BOX 5-1: Measuring Costs and Be

Measuring the costs and benefits of adding a new transportation service or changing the nature of an existing one is complicated by the Interdependence between the supply of and demand for transportation services In general. because much of the U.S. transportation network is near capacity during parts of the day, adding to the supply of transportation can reduce congestion, improve travel times, and thus Increase demand on the affected segments Highway analysts often comment on the long-term futility of continuously expanding highway capacity, because continued travel growth overtakes the new capacity until it, too, is congested Similarly, addition of travel capacity on competing modes (e g , competition between high-speed rail and air or highway travel for trips of a few hundred miles) may relieve congestion at airports and on highways, but add to overall travel demand by encouraging more trips

Also, the options for adding new capacity may not be clear although an intensive assessment of new travel capacity may spell out a range of options, in actual planning it is not always clear what will happen if an option under consideration, such as a new railway, is not built. Will airports, many already close to capacity and experiencing substantial congestion delays, be expanded, or will new airports be built? Will lack of capacity force changes in aircraft design and operations that allow greater capacity without physical expansion? Will growth in air travel be constrained by lack of capacity, with excess demand either stifled entirely or forced into other modes (such as highways or existing train service)? Will the lack of physical capacity force early development of advanced telecommunication services that, for a segment of the travel market, can substitute for physical travel?

Each of these alternatives has radically different energy implications, as well as radically different implications for the whole range of societal Impacts Because in many cases it is impossible to predict which option--or which set of options—will be pursued, analysis of the energy implications of adding new systems is made much more uncertain

SOURCE Office of Technology Assessment 1994

oil use and in greenhouse gas emissions will occur in the developing world, not in the industrial nations. Developing nations often cannot afford technological options that are considered cost-effective in the industrialized world, and so apply more weight in their decisionmaking than industrialized nations would to criteria such as low infrastructure requirements, and ease of maintenance.

A critical and difficult aspect of measuring costs and benefits is to measure losses and gains that occur because lifestyle decisions and investments made under the current set of economic and regulatory rules will lose (or gain) value under the new set of rules. For example, restrictions on automobile travel, or large increases in gasoline taxes, will have effects that go far beyond simple increases in travel costs and convenience: they will reshape real estate values and the distribution of prices in the used-car market, as fringe housing loses value and fuel-efficient used cars increase in price.

Another problem encountered in measuring costs and benefits, discussed in box 5-1, is the set of complex interdependencies among alternative transport systems.

This chapter discusses some of the conservation activities and policy options available for the transportation sector. Given the very large number of activities and options available, no attempt is made to be comprehensive; instead, the focus is on a range of potential government actions. The chapter begins with a discussion of how the U.S. transportation future is likely to look if the Federal

Government makes *no* major changes to transportation and urban planning policy.

WHAT IF THE FEDERAL GOVERNMENT INITIATES NO NEW POLICY MEASURES?

If the baseline case in the Energy Information Administration's (EIA's) *Annual Energy Outlook 1993,*[1] Baseline Case is an accurate guide, oil use in the transportation sector will grow from about 11 million barrels per day (mmbd) in 1990 to 12.5 mmbd by 2000 and 13.9 mmbd by 2010-a 20-year growth rate of 1.2 percent per year, for a total growth of 29 percent over the period. The growth of *travel,* however, is substantially higher in this forecast: for 1990-2010, light-duty vehicle-miles traveled (vmt) increases 41 percent, freight truck vmt 45 percent, and air travel (in seat-miles) 128 percent. Thus, even without new efficiency standards, EIA expects moderate rates of efficiency growth to continue: over the 20 years, it projects new car fuel economy to grow from 28.0 to 34.6 miles per gallon (mpg)[2] and light-truck fuel economy to grow from 20.7 to 25.4 mpg, though the total fleet of light-duty vehicles is projected to grow in efficiency only from 18.6 to about 21.3 mpg;[3] and aircraft efficiency is expected to increase 36 percent.

What does this mean in more physical and policy-oriented terms? First, the transportation sector projected addition of nearly 3 mmbd of oil use is a source of substantial concern, particularly since industrial use of petroleum is also expected to increase more than 1 mmbd during the period, and domestic *production* is expected to decline by more than 1 mmbd. This means that oil imports, already at 7 mmbd, or 42 percent of consumption, in 1990, will rise to more than 12 mmbd, or 58 percent of consumption, by 2010. Although the import situation would look considerably better in EIA's high oil price case—10.3 mmbd, or 52 percent of consumption—recent price trends and patterns of reserve additions make this case (assumed oil price of $38 per barrel in 2010, in 1991 dollars) appear to be a low probability one.

The 29-percent increase in energy use also translates into an approximately 29-percent increase in emissions of carbon dioxide (CO_2),[4] in contrast to international goals of maintaining greenhouse gas emissions at or below 1990 levels.

Although EIA's *expected* increases in oil imports and CO_2 emissions are of substantial concern, the Office of Technology Assessment (OTA) believes the EIA projections of energy growth and its consequences to be understated. As discussed in chapter 2, EIA's projections of travel growth appear consistently at the low end, and its projections of efficiency improvements consistently at the high end, of the plausible range. Without new regulations or economic incentives, there is little reason to be optimistic about future increases in new car and light truck fuel economy, nor are changing demographics likely to reduce growth in vehicle-miles traveled (vmt) nearly as much as EIA projects.

Second, the 41-percent increase in light-duty vmt and 45-percent increase in freight truck vmt projected by EIA--or the still higher travel increases that OTA believes are more likely—imply a substantial increase in highway congestion, since road miles will not increase nearly as fast. Available forecasts of congestion, when translated into specific examples, often are alarming:

> A one-way 30-mile commute on U.S. Route 1 from New Brunswick, New Jersey to Trenton could easily turn into a five-hour ordeal by 2005, "

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[1] U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook* 1993, DOE/EIA-0383(93) (Washington, DC January 1993), app. A.

[2] U.S. Environmental Protection Agency test values.

[3] On-road values.

[4] There will be some small variation from 29 percent because the composition of liquid fuels will change due to reformulation of gasoline and moderate amounts of alternative fuels entering the marketplace.

> as traffic inches along at an average speed of six miles per hour, slower than a trotting horse.[5]

If Federal Highway Administration (FHWA) forecasts were realized, congestion levels in the year 2010 would create enormous costs in terms of time lost, gasoline wasted, and emissions increased. However, as discussed in chapter 4, the forecasts overstate likely congestion growth. Also, it is quite possible that much of the growth in vmt will occur in areas where congestion problems are limited. Although congestion is expected to grow, this growth will probably not be as severe as feared.

Third, EIA did not model transit explicitly in the forecasts, so energy use estimates are not directly translatable into mass transit's modal share or ridership estimates. However, transit share of total trips is likely to decline during the period, although total ridership may increase. Increased ridership will result primarily from the attempts of hundreds of urban areas to deal with Clean Air Act requirements. A great diversity in transit solutions is expected, with a few planned heavy and light rail systems and system additions, many different types of paratransit[6] operations, and expansions of conventional bus systems. In some areas, such as Portland, Oregon, planned solutions to both air quality and congestion problems will include attempts to shift land use toward greater density and better mixes of uses. It is difficult to predict the outcome of this kind of program, because there is little precedent to forecast the effects of the strategies used---changes in zoning laws, an urban growth boundary, implementation of light rail, etc.—in the face of the U.S. auto-oriented market trends and incentives.

NEW FUEL ECONOMY STANDARDS

Introducing new, more stringent standards for the corporate average fuel economy (CAFE) of each automaker is one option for reducing the fuel consumption of the U.S. light-duty highway fleet. In 1991-92, Members of Congress responded to recent growth in gasoline demand and sagging new car fuel economy by introducing a number of legislative proposals designed to boost the current CAFE standard of 27.5 miles per gallon (mpg) for each corporate domestic and import fleet. One of the first of the 102d Congress, Senator Richard Bryan's bill (S. 279), called for a 20-percent improvement in each company's new car fleet average (over a 1988 baseline) by 1996 and a 40-percent improvement by 2001 (yielding an overall new car fleet average of about 34 and 40 mpg, respectively). Other bills were introduced that offered different standards and approaches.

S. 279 and the other bills generated substantial controversy, with the key issue (aside from the obvious question of whether setting *any* new fuel economy standards is sensible national policy) being disagreement about the level of fuel economy increase that is technically and economically feasible. The debate also brought out significant concerns about potential negative impacts of new standards on vehicle safety and auto industry jobs, as well as substantial disagreement about how much oil would be saved by new standards. Other issues that deserve careful attention are the relative merits of alternative regulatory *structures (e.g.,* level standard, uniform percentage increase, or standards based on vehicle interior volumes) and the appropriate scheduling of any new stan-

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[5] Harvey Gantt, American Institute of Architects, testimony at hearings before the House Committee on Interior and Insular Affairs, Subcommittee on Energy and Environment, June 27, 1991, cited in J.J. MacKenzie et al., *The Go@ Rate: What It Really Costs To Drive* (Washington, DC: World Resources Institute, 1992).

[6] Paratransit is public transportation that is more flexible than regular transit operations in route and schedule, and often privately operated.

dards. OTA's findings regarding most of these issues, published in a recent report, are summarized below.'

Are Fuel Economy Standards an Efficient and Effective Approach to Fuel Conservation?

Arguments about whether or not standards are a sound approach to conservation in the transportation sector revolve around the effectiveness of the 27.5-mpg standard set in 1975[8] and the relative merits of a regulatory approach versus the use of economic incentives such as gasoline taxes and/or taxes and rebates on vehicles depending on their efficiency.

Arguments have raged for years about the effectiveness of the 1975 standards. The only area of agreement is that the years in which the standards took effect coincided with a large increase in the fuel economy of the U.S. new car fleet, from 17.2 mpg in 1976 to 27.9 mpg in 1986.[9] Although advocates of new regulations seize upon this efficiency increase as an indicator of the success of the standards, opponents point out that real gasoline prices tripled between 1973 and 1980, affecting both industry planning and consumer purchasing decisions about car size and efficiency. Thus, some industry analysts conclude that the CAFE standards increased fuel economy only about 1.0 to 1.5 mpg beyond the level that would have been achieved without them,[10] whereas other analysts conclude that the standards had an impact of 4 to 5 mpg or more.[11] Further, analysts argue about whether or not the standards affected the rate and composition of new car sales, since any slowdown in sales (leaving older and less efficient vehicles on the road) or shift from automobiles to light trucks (vans, pickups. and utility vehicles) would adversely affect the fuel economy of the entire fleet.[12] During the last two decades, light truck sales rose significantly as a percentage of total light-duty sales, and the median age of registered automobiles increased from 4.9 to 6.5 years.[13] The most likely reasons for the rise in median age were the improvements made in rust prevention and auto reliability, and a gradual increase in the value embedded in vehicles (sophisticated sound systems, air conditioning, automatic transmission. etc.). If the trends in light-truck sales and fleet median age were somehow abetted by the CAFE standards, however, the real effectiveness of the standards would be less than it appeared.

To gauge the impact of the CAFE standards, analysts must be able to estimate how automakers would have reacted in the *absence* of standards. Unfortunately, these estimates are suspect because, prior to the 1972 oil shock, oil prices had been low and stable for many years, so no historical model is available. Thus, analysts must rely on other clues about whether or not similar fuel economy gains would have been attained even without standards. Some analysts have focused on the degree to which the standards appear to have constrained automakers; that is, they assume that automakers who easily exceeded the standards probably were not affected by them and would

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[7] U.S. Congress, Office of Technology Assessment, *Improving Automobile Fuel Economy: New Standards, New Approaches*, OTA-E-504 (Washington, DC: U.S. Government Printing Office, October 1991).

[8] That is, demonstrating that the old standard worked (did not work) would serve as evidence that a new standard would be likely (unlikely) to work.

[9] S.C. Davis and M.D. Morris, *Transportation Energy Data Book*, ed. 12, ORNL-6710 (Oak Ridge, TN: Oak Ridge National Laboratory, March 1992), table 3.15.

[10] R.A. Leone and T.W. Parkinson, "Conserving Energy: Is There a Better Way? A Study of Corporate Average Fuel Economy," paper prepared for the Association of International Automobile Manufacturers, May 1990.

[11] Ibid.

[12] Light trucks are less efficient than automobiles, and on the average, old cars are less efficient than new ones.

[13] Davis and Morris, op. cit., footnote 9.

have reached their recorded fuel economy levels with or without standards.[14] OTA's examination of some analyses claiming to demonstrate a minor impact of CAFE standards on fuel economy levels found these analyses to be unconvincing.[15] Probably the most convincing evidence of the effectiveness of CAFE standards is the family of graphs of actual versus required levels of corporate fuel economy.[16] These show that Ford. General Motors, and (to a lesser extent) Chrysler—companies likely to be most affected by the standard because their fleets had relatively low economy—increased their fleet fuel economy in virtual lockstep with the levels required. On the other hand, the levels of Japanese and other manufacturers producing small, high-fuel-economy cars-companies little affected by the standard but affected by rising gasoline prices—meandered (and sometimes fell) during the same period. Although this does not "prove" that the standards played a critical role, it places the burden of proof squarely on the shoulders of doubters.

The role of CAFE standards in the increased sales of light trucks and greater age of the auto fleet is unclear, but no impact on new car sales was obvious, and the success of light trucks seems due primarily to their market attractiveness, not to any artificial advantage conferred by fuel economy requirements.

If the previous CAFE standards "worked" in the sense that they played a major role in driving up industrywide fuel economy levels and had no significant side effects that might have slowed vehicle turnover, policy makers still need to be concerned about the efficiency of standards: Do the gains in reduced fuel use and lower oil imports justify the costs, and are standards preferable to alternative ways of reducing auto fuel use?

Because regulations generally are justified by the claimed existence of market failures (usually the market failure to incorporate social costs into its prices), determination of a favorable cost-benefit ratio for CAFE demands an evaluation of the environmental, energy security, and other social costs of gasoline use. This type of evaluation is discussed in chapter 4. However, policy makers must judge for themselves whether reducing these extramarket costs justifies adding the costs of a CAFE standard.

Opponents of CAFE standards argue that alternatives, especially taxes on gasoline or oil, are a more attractive, efficient means of reducing automobile fuel consumption. Gasoline taxes (discussed later in this chapter) reduce oil use by reducing the demand for travel *in addition to* increasing new car fuel economy. The demand effect applies to the entire fleet, not just new cars, so much of the oil use impact occurs immediately without requiring an extensive period for the fleet to turn over.

Unfortunately, comparative estimates of the costs and benefits of gasoline taxes and fuel economy standards depend on a number of highly uncertain assumptions about the cost of fuel economy increases, manufacturer responses to standards, the gasoline price elasticity of demand for travel, and so forth. One recent comparison concluded that a gasoline tax beginning at 3 cents per gallon in 1996 and rising to 25 cents per gallon by 2006 would save as much gasoline as a CAFE increase to 34 mpg in 1996 and to 40 mpg in 2001, at much lower (43 to 83 percent less) welfare costs than the CAFE standards.[17] However, the as-

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[14] See e.g., Leone and Parkinson, op. cit., footnote 10; and D.L. Greene, *CAFE or Price?: An Analysis of the Effects of Fuel Economy Regulations and Gasoline Price on New Car MPG, 1978-89* (Oak Ridge, TN: Oak Ridge National Laboratory, revised Nov. 30, 1989).

[15] For example, Leone and Parkinson (op. cit., footnote 10) appear to award an "unconstrained" status to some automakers in an unusually generous fashion; and to underestimate the role of technological advances in improving fuel economy.

[16] Greene, op. cit., footnote 14.

[17] Charles River Associates, "Policy Alternatives for Reducing Petroleum Use and Greenhouse Gas Emissions," paper prepared for the Motor Vehicle Manufacturers Association, September 1991.

sumptions used appear to overly favor gasoline taxes over CAFE standards in terms of cost-effectiveness. On the other hand, because it is possible to structure gasoline taxes so that they have few or no net negative impacts on the economy,[18] it should be possible to gain energy savings from a well-designed tax at lower total social costs than from CAFE standards.

The above perspective reflects an "either/or " view of taxes and standards. However, policymakers may not view taxes as a viable option because of political considerations, or they may be willing to consider taxes and standards as complementary policies. Although taxes alone can save much energy by reducing travel demand, they are unlikely to yield very high fuel economy levels at the rates (perhaps up to $1 per gallon) likely to be the outer limit of political feasibility;[19] consumers typically exhibit very high discount rates in their purchasing decisions for energy conserving technologies.

Further, although automakers may complain about the market risk associated with new fuel economy standards, new standards may work to *reduce* some of the market risk of introducing new fuel-efficient technologies. In the current market, consumer devaluation of fuel economy tends either to keep new technologies out of the marketplace or to dictate their use in a form that maximizes performance. For example, the higher specific horsepower of multi valve engines can be used primarily to gain acceleration performance. but this sacrifices a significant component of their fuel economy potential by foregoing the engine downsizing that could be accomplished. Automakers choosing to gain maximum fuel economy from such engines might lose market share to others that stressed performance, a more highly valued commodity in the current marketplace, and in fact multivalves have generally been designed and advertised as performance boosters, A new fuel economy standard, if properly designed to put near equal technological pressure on each automaker, would limit the ability of competing makers to grab market share by focusing on performance, thus limiting the market risk of stressing fuel economy.

What Is the Fuel Economy Potential of the U.S. New Car Fleet?**

Congress has been bombarded with a range of estimates of the “technological potential” of the fleet. Many of the variations among these estimates result not from technical disagreement about the efficiency improvement from specific technologies--although such disagreements clearly exist—but from differences in the following assumptions:

- the time frame of the higher fuel economy levels, that is, the lead time available to the industry for making technical and marketing changes;
- the nature of regulations accomplishing the efficiency change;
- future shifts in the size mix of the fleet;
- changes in acceleration capabilities or other measures of vehicle performance;
- passage of new safety and emission regulations;
- the time required to develop, perfect, certify, and bring to market new technologies;
- judgments about what should be considered an acceptable level of economic disruption to the industry in responding to new fuel economy regulations; and

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[18] By "recycling" the revenues into reductions in other taxes, especially taxes that have distorting effects on the economy. See the discussion of gasoline taxes elsewhere in this chapter.

[19] It is worth remembering how difficult it has been to pass gasoline taxes on the order of a few *cents* per gallon.

[20] The evaluation presented here is based on an earlier analysis by Energy and Environmental Analysis, Inc., for the Office of Technology Assessment, for inclusion in its report, *Increasing Automobile Fuel Economy: New Standards, New Approaches*, published in October 1991. Ideally, this analysis should be recomputed using more timely data; in the absence of such an updated analysis, this earlier analysis is presented with comments about revised target dates for new legislative initiatives.

- judgments about the response of consumers to changes in vehicle costs and capabilities (which is, in turn, a function of oil prices and supply expectations).

Assumptions about these factors must be made to calculate "technological potential]," since each factor will affect the ultimate fuel economy achieved by the fleet.

OTA has examined various estimates of technological fuel economy potential, which range from conservative estimates prepared by domestic automakers to optimistic estimates prepared by energy conservation advocates. The technical arguments surrounding the many technologies available to improve the fuel economy of the U.S. auto fleet are not discussed here; the interested reader is urged to examine the 1991 OTA report[21] as well as a report of the National Research Council, especially its appendix B.[22] The range of views about fuel economy potential can, however, be characterized as follows: at the conservative extreme, further increases in fleet fuel economy are characterized as likely to be quite small-—less than 3 mpg within 10 years[23]—because the major gains have already been achieved, consumer tastes are heading toward vehicle characteristics that conflict with greater fuel economy, and government safety and emissions standards will tend to degrade fuel economy. At the optimistic extreme, large increases in fleet fuel economy, to 45 mpg and higher, are portrayed as readily obtainable by existing or soon-to-be-available technology, possibly as early as the year 2000.[24]

OTA's contractor, Energy and Environmental Analysis, Inc. (EEA), prepared a set of estimates of future fleet fuel economy potential for the earlier OTA report. These must be used in context: each individual estimate of the fuel economy potential for a certain "scenario"--a concept of a particular future, with defined characteristics—is associated with a set of critical assumptions that is a powerful determinant of the magnitude of reported fuel economy values. In some regards, EEA estimates may be viewed as somewhat conservative for the 2001 time frame, because they do not consider the possibility that new technologies, not yet available commercially, may begin penetrating the market by that date; they do not allow for improvements in the fuel economy performance of already-installed technologies;[25] nor do they consider the potential for diesel engines to overcome their current negative market perceptions and their problems in meeting emission requirements. On the other hand, the scenarios all assume that, *at worst,* vehicle performance, use of luxury equipment, and size will not increase indefinitely, but instead level off after 1995; other scenarios assume a policy-driven rollback in these characteristics to 1990 or 1987 levels. These assumptions could prove too optimistic. Further, the EEA values assumed passage of fuel economy legislation by the end of calendar year 1991. The passing of this date with no legislative action, the intervening 2 years and the failure of fleet fuel economy to improve during that time, and the high probability that at least an additional year

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[21] **office** of Technology Assessment, op. cit., footnote **7**

[22] National Research Council, Committee on Fuel Economy of Automobiles and Light Trucks, *Automotive Fuel Economy: How Far Should We Go?* (Washington, DC: National Academy Press, 1992).

[23] SRI International, "Potential for Improved Fuel Economy in Passenger Cars and Light Trucks," paper prepared for the Motor Vehicle Manufacturers Association, July 1991. This paper concludes that an additional 2.6 mpg (over a 1990 baseline) can be added by 2001, with a 10-year payback for gasoline savings.

[24] E.g., see M. Ross et al., *Options for Reducing Oil Use by Light Vehicles: An Analysis of Technologies and Policy* (Washington, DC: American Council for an Energy-Efficient Economy, December 1991), which concludes that by using only current technology, 42 mpg can be achieved cost-effectively by 2000, with higher values available at some technological risk. Because these and other claims of environmental and conservation organizations were made a few years ago, the "year 2000" target date may no longer be applicable.

[25] That is, where fuel economy technologies have already been incorporated into a number of car models, EEA allows no possibility that when models are redesigned, the technologies will be upgraded to yield better fuel economy performance.

will pass before new standards might be set imply that the times specified in the original analysis should be reset by adding a few years.

Table 5-3 provides OTA estimates for a variety of fuel economy scenarios, ranging from a "product plan" meant to represent a projection of likely fleet fuel economy in a "business-as-usual" scenario (no new fuel economy regulations, no major shifts in market factors), to a "maximum-technology" scenario that postulates what could be achieved if regulations forced maximum use of fuel economy technologies and accelerated model retirement rates, to a longer-term projection postulating the success of several new technologies

[redacted]

		Fuel economy[a] levels achieved (mpg)
1995	*Product plan*	
	Cost-effective technology, continuation of current trends, no new policy initiatives	283 domestic[b] 31 1 imports 292 fleet
	Regulatory pressure	
	Fuel economy potential with added pressure of new efficiency regulations but without size-class shifts	300 fleet
2001[c]	*Product plan at rising oil prices*	
	No new policy iniatives and no radical changes in market, but higher oil prices ($1 50 per gallon of gasoline in 1991 dollars); size/performance/luxury stable after 1995, tier 2 emissions standards not considered	32.0 domestic 34.6 imports 32.9 fleet
	Maximum current technology	
	Feasible technology added regardless of cost, size/performance/luxury rolled back to 1987 levels, normal life cycle requirements not allowed to limit technology penetration rates, no advanced technologies.	37.3 domestic 39.9 imports 38.2 fleet
	Regulatory pressure	
	Technology added that is cost-effective at $2 per gallon of gasoline (higher than expected price levels) Ten-year payback, size/performance/luxury rolled back to 1990 levels technology penetration limited by normal life cycle requirements, no advanced technologies	34.5 domestic 37.4 imports 35.5 fleet
2005	*Regulatory pressure*	
	As above	365 domestic 374 Imports 371 fleet (38 1, mpg with 2-stroke)
2010	*Advanced technologies*	
	Size/performance/luxury rolled back to 1987 levels, no new emissions standards post-2000	
	▪ Addition of technologies that most automotive engineers agree would be commercialized by 2000.	45 fleet
	▪ Addition of technologies without general agreement about benefitsl and commercia prospects.	55 fleet

[a] U S Environmental Protect Ion Agency test values, combined city-highway, potential credits for alternate fuel vehicles not considered

[b] Domestic refers to vehicles made and sold in the United States by the three U S automakers, imports refer to vehicles sold in the United States by the lop five Japanese automakers

[c] Note that these dates reflect the assumption that any **new** standards would be set by the end of 1991

SOURCE U S Congress Off Ice of Technology Assessment *Improving Automobile Fuel Economy OTA-E-504* (Washington, DC U S Government Printing Off Ice October 1991) based on analysis by Energy and Environmental Analysis, Inc such as two-stroke engines. The “regulatory pressure” scenario yields a result that may be viewed by some as a “middle-of-the-road” fuel economy target, although it does assume a rollback in vehicle size and performance to 1990 levels in defiance of current upward trends. OTA does not, however, believe that there is any “best” fuel economy target, since any selected target value involves both a degree of market and technological uncertainty and a balancing of many values.

As illustrated by these scenarios, neither end of the range of claimed fuel economy potential—"little change” to better than 45 mpg by 2000 or soon thereafter—appears credible for the time frame in question. OTA analysis shows that the application of multiple existing technologies can lead to fleet fuel economy gains of several, and up to about 10 mpg by 2001 (or 2004 when the passing of the date by which fuel economy standards were assumed to have been passed is taken into account) if consumers are willing to accept some rollback in vehicle size and performance, and to pay more for improvements in fuel economy than will likely be repaid in fuel savings. Such an acceptance, however, is not a foregone conclusion, given the existing market trends discussed above. A few additional miles per gallon may be available in this time frame from incremental improvements in technology performance and upgrading of existing applications of fuel-efficient technologies. On the other hand, buyer resistance to limits on vehicle acceleration or increased purchases of light trucks could either reduce the potential for increases in fleet fuel economy or partially defeat the purposes of higher auto standards.

The National Research Council (NRC) is somewhat more pessimistic than OTA about achievable levels of fuel economy. NRC projects that a “practically achievable” level of fuel economy for 2006 is 34 to 37 mpg, with the higher value representing a low-technical-confidence, high-cost level.[26] Its practically achievable level for 2001, which may be somewhat comparable to OTA’s regulatory pressure scenario (35.5 mpg), is 31 to 33 mpg.[27] In OTA’s view, NRC’s projections of fuel economy are not consistent with its assessment of the likely technological performance of individual technologies.[28]

Greater fuel economy gains than those discussed above, to 45 mpg or even higher, *may be* available by 2010 when new technologies could make major inroads into the marketplace, although the success of these technologies is by no means guaranteed. The longer schedule is required because of the time needed to develop and adequately test new technologies.

As noted above, changes in consumer preferences for fuel economy, vehicle size, and vehicle performance or, in the extreme, the imposition of limits in the choice of these attributes, offers an alternative to a strictly technological approach to improving new car fleet fuel economy. Moderate changes in purchaser selection of vehicles within size or weight classes toward more efficient models, and shifts in size or weight class to smaller vehicles, can substantially increase fleet fuel economy. For example, in the 1990 U.S. new car fleet, if consumers had purchased only the dozen most fuel-efficient models in each weight class and shifted their purchases towards lighter-weight classes so that average weight was reduced by 6.2 percent, fleet fuel economy would have improved from 27.8 to 33.2 mpg, or 20 percent.[29] About two-thirds of the fuel economy improvement would have been due to consumers selecting the more efficient vehicles in each weight class, with the remainder due to the actual shift in weight class market shares. The “cost” of the improve-

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[26] Committee on Fuel Economy of Automobiles and Light Trucks, op. cit., footnote 22.

[27] ibid.

[28] The individual technologies are assessed in ibid., app. B.

[29] R. M. Heavenrich et al., *Light-Duty Automotive Technology and Fuel Economy Trends Through 1991*, EPA/AA/CTAB/91-02 (Washington, DC U.S. Environmental Protection Agency, May 1991).

ment (in terms of loss of consumer attributes) would have been a 7-percent decrease in the average interior volume of the fleet (from 107 to 99 cubic feet), an 11-percent increase in 0 to 60 miles per hour (mph) acceleration time (12. 1 to 13.4 seconds), and a major shift from automatic to manual transmissions (about 40 percent of the fuel economy benefit would be lost if drivers refused to change transmission types). The "average car"—the car that attains the average fuel economy of the fleet and is representative of its average characteristics—-would have been a Toyota Camry rather than a Dodge Dynasty.[30]

What, then, should be the targets for a new generation of fuel economy standards? If Congress wishes to set a fleet target for 1998 that pushes the industry further than it would otherwise be likely to go, a realistic target would be 30 mpg, if no significant changes occur in current trends in vehicle size and performance. With full use of available alternative fuel credits, a *reported fleet* average[31] of 31 mpg should be feasible. The fleet average could be considerable y higher if consumers change their relative preferences for efficiency, performance, and size; legislators will have to weigh the benefits of attaining this higher level against the risks—particularly potential customer dissatisfaction with smaller, lower-powered cars and the resulting lower vehicle sales. Congress could reduce these risks by coupling higher fuel economy standards with economic incentives-gasoline taxes, or rebates and penalties tied to fuel economy--designed to push the market toward higher efficiency.

For the longer term, the choice becomes more difficult because there are more options and more uncertainties. The maximum-technology value of 38 mpg in 2001 (2004 given delayed passage) assumes a rollback in size and performance to 1987 levels, an increase in vehicle costs that will *not* be offset entirely by fuel savings (unless gasoline prices rise substantially), and early retirement of several model lines. which could be costly to the industry. The compression of vehicle life cycles embodied in the maximum- technology scenario is not unprecedented, however, and legislators may feel that growing oil imports and the need to reduce greenhouse emissions warrant such measures. Further. a high fuel economy standard may accelerate the entry of new technologies, such as the two-stroke engine, into the fleet (although not without market and technical risks). And, as noted. the maximum technology target may be attainable with less performance rollback or at lower cost than projected; the projections do not consider potential improvements in the fuel economy performance of these technologies. or the likely upgrading of pre-1990 applications of fuel economy technologies when the models in which they are installed are redesigned.

For legislators who believe that the market should better reflect the societal costs of oil, but who wish neither to demand that the industry abandon product lines before their initial costs can be recovered nor to risk requiring major changes in vehicle size and performance, a fleet target of 35 mpg should be feasible by 2004. Alternatively, a maximum-technology scenario that assumed a rollback in size and performance only to 1990 levels would yield a fleet average fuel economy of about 37 mpg by 2004. The change in size and performance between 1987 and 1990 cost more than 1 mpg in new car fuel economy. Because of the importance of lead time, these targets assume passage of new fuel economy legislation by calendar year 1994. Substantial delays in passing new rules would lower the fuel economy values attainable in the target year.

For the still longer term (i.e.. 2010 and beyond), as noted above, there is real potential for

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[30] Note that the 1990 Camry was a compact, not the larger car it is today.

[31] That is, the tested value plus any available credits.

very high fleet fuel economy values, 45 or even 55 mpg,[32] but considerable uncertainty as well because attainment requires introduction of still-untested technologies. For this time period, Congress might consider mechanisms to ensure continued technological pressure while maintaining enough administrative discretion to reduce fuel economy goals if optimistic forecasts of technology potential turn out to be incorrect.

Which Type of Standard Is Best?

Recent proposals for new fuel economy legislation have moved away from the format of current law, which imposes a uniform 27.5-mpg standard on all automakers. With the current format, automakers that produce a variety of vehicle sizes, or primarily large vehicles, are subject to a more demanding technological challenge than those who concentrate on small vehicles. This gives the latter more flexibility to capture markets for larger cars and to introduce features (high-performance engines, 4-wheel drive, etc.) that are both attractive to consumers and fuel-inefficient, which puts full line and "high-end" manufacturers at substantial market disadvantage.

Many legislators would not approve a new fuel economy standard unless domestic automakers could comply with it without a drastic shift in their fleets toward small cars. However, a new "uniform-mpg" standard set under a restriction of this sort would be unlikely to force makers of primarily small cars to improve very much. As a result, the maximum fuel economy the fleet could be expected to attain from a uniform standard will be lower than that from a format that would challenge *all* automakers, even those making only small cars, to substantially improve their CAFES.

New legislative proposals ask that automakers raise their CAFES by a uniform percentage over that attained in a baseline year—1 988 in Senator Bryan's proposal (S. 279). Because these 1988 CAFES reflect in some measure the size makeup of each company's fleet, they will take account of the differences in size among various companies in assigning fuel economy requirements—but only to the extent that these differences do not change from the baseline year to the compliance year. If companies seek to gain share in market segments different from their traditional market (e.g., by marketing large luxury cars), the uniform-percentage approach could prevent them from doing so and thus be viewed as anticompetitive. Furthermore, to the extent that some of the differences for the baseline year were due to differences in fuel economy technology and design, a uniform-percentage increase places the most severe new demands on those companies who have tried hardest to improve their fuel economy. There *have* been differences in fuel economy technology and design among different automakers, and several companies—through deliberate marketing strategy or loss of market shares—have changed their size mix over time; both factors compromise the internal logic of the uniform-percentage approach to CAFE regulation.

An alternative approach is to base company standards on the attributes of each company fleet at the time the standards are to be met. If based on interior volume, for example, a new standard would place the highest numerical fuel economy target on the company making vehicles with the lowest interior volumes. Such a volume average fuel economy (VAFE) standard could be designed to place as equal as possible a technological (or financial) burden on each automaker. This type of standard would put no pressure on automakers to build small (low-interior volume) cars[33]—a minus with some conservationists who believe that

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[32] Even higher values could be achieved, but only with major changes in the basic character of cars (e.g., large numbers of diesel-electric hybrid vehicles).

[33] Because smaller cars will have higher fuel economy targets and selling more of them will not make it easier for an automaker to achieve its company standard-unless the size-based targets are deliberately set to give smaller cars a less difficult target fuel economy than large cars would have.

most cars are too large, but a plus with others who believe that consumers should have an unrestricted choice of car size and may also believe that large cars are safer. Instead, a VAFE standard demands that automakers focus on technology, design, and performance to improve fuel economy, thereby removing the contentious issue of car size from the policy debate. A perceived disadvantage of a VAFE standard is that any increase in market share of cars in the larger size classes could reduce the overall fleet fuel economy target, a potential outcome that disturbs some policymakers. This disadvantage is not unique to VAFE standards, however; a uniform-percentage increase standard could also have its total fleet target reduced with market changes .[34]

Another potential problem with VAFE standards—and with the original uniform 27.5-mpg standard—is that they are difficult to apply to manufacturers who fall outside the envelope of automakers competing in the mass market. Companies such as Mercedes-Benz and BMW sell products that stress high performance, luxury, and safety at a high price. Traditionally, their vehicles are substantially heavier than other vehicles in their size class, more powerful, and rear-wheel drive to achieve the handling characteristics they seek), all of which compromise fuel economy. These companies cannot match the fuel economies of mass-market automakers in their size classes at similar levels of technology.

Basing fuel economy standards on a wider group of vehicle attributes could provide more of a move to a “pure”' technology standard, that is, a standard that can be met only by improving technology (rather than by reducing size or power). Mercedes-Benz, BMW, and Porsche have proposed a standard based on a group of variables--curb weight, the ratio of curb weight to interior volume, and the ratio of curb weight to torque--that would allow companies in a wide range of market niches to comply with a reasonable standard by improving technology. without being forced to move into other markets to "balance” their production of niche vehicles. The standard is formulated by performing a regression analysis,[35] using U.S. Environmental Protection Agency (EPA) data for the 1990 fleet, that defines current vehicle fuel consumption as a function of the above three variables. A standard requiring 1995 fleet fuel economy to be at least 20 percent higher than the 1990 level would simply reduce the 1990-based fuel consumption function by 20 percent and apply this new function to each automaker's fleet. As with the uniform percentage increase and VAFE standards, this system will not guarantee attainment of an exact fuel economy level (because the market can change), but it will force technology improvement and provide positive incentives for weight and performance reduction.[36]

What Is the Best Schedule for New Standards?

Legislation proposed during the 1991-92 debate focussed on setting new fuel economy standards for 1996 and 2001. If the debate resumes this year, these dates may be changed to 1998 and 2003, (o reflect the loss of 2 years of "lead time" for the automakers. Are these the best years for a set of new standards?

Generally, the design and product development lead time for new models and major components is about 4 to 5 years, indicating that products for the 1998 model year are now being finalized,

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[34] For example, if an automaker with a relatively low mile-per-gallon target gained market share, the overall fleet fuel economy target would be reduced.

[35] Regression analysis involves a statistical examination of data that seeks to determine functional relationships among variables the analyst believes to be related, for example, between fuel economy and variables that should affect fuel economy, such as weight and horsepower.

[36] Although this type of standard does adjust the mile-per-gallon target inversely with weight and performance, the technical and economic difficulty of achieving the (lower) target will increase with higher weight and performance. In other words, the form of the standard provides a positive incentive for the automaker to reduce weight and performance.

whereas products for 1997 have moved to a stage at which tooling orders are being placed. The models of domestic automakers will have a life cycle of at least 7 to 8 years prior to redesign, during which their large development costs must be recovered. Japanese models tend to have shorter life cycles, as low as 4 years.[37]

These time horizons imply, first, that 1998 is very early to demand significant improvements in fuel economy beyond those already built into product plans, and second, that 2003, although enough time for major adjustments to be made, is early for a standard that might seek fleetwide redesign *unless Congress believes that energy concerns warrant an accelerated redesign schedule that would induce accelerated retirement of several model lines.* Although OTA has reached no conclusion about what an optimal schedule might be, a set of dual dates that would allow an interim fuel economy adjustment followed by a full redesign of all model lines *without forced early retirements* would be 2000 followed by 2006 or 2007. If desired, a 2003 standard could also be included, predicated on redesign of only a portion of company model lines.

Any decision to design a schedule for new fuel economy standards should include a careful examination of changes in new model lead times being pursued by the major automakers. For example, Chrysler's new LH models apparently were brought to market in less time than the 4 to 5 years noted above, and other domestic manufacturers are striving to reduce their lead times as well.

New Fuel Economy Standards and Safety

Arguments about safety have been at the center of the debate about new fuel economy standards. Industry and Administration opposition to new standards has included arguments that more stringent standards, such as those proposed by S. 279, would force consumers into a new fleet of smaller cars that would be significantly less safe than a new fleet with an unchanged size mix—perhaps even less safe than the current fleet.[38] Although some safety advocates argue correctly that small cars need not be unsafe, the bulk of statistical evidence argues that, *given current design,* the car fleet would be less safe if all its vehicles were somewhat smaller than they are today.

In OTA's view, new CAFE standards of the magnitude discussed here would be unlikely to cause *absolute* levels of safety to decrease because automakers should be able to achieve such standards without downsizing and because safety improvements will continue to be introduced to the fleet. There is evidence, however, that reduced *weight--a* likely consequence of new fuel economy standards--could cause some decrease in *relative* fleet safety, although changing safety equipment and design should lessen this decrease. Also, there is no guarantee that automakers will not choose downsizing as a method of meeting new standards (unless standards are specifically designed to avoid this). Further downsizing of the fleet (especially a reduction in exterior dimensions) would likely make the fleet less safe than it would otherwise be. However, much of the rhetoric about safety used by both sides in past debates about new standards has been overstated,[39] and some of the arguments purporting to demonstrate the magnitude of the risk are flawed or misleading.

Car size can be characterized by weight, interior volume, or exterior dimensions. Each has a different relationship to safety. Added weight may help the heavier car in a vehicle-to-vehicle collision, because the laws of momentum dictate that a

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[37] Light trucks may have somewhat longer life cycles.

[38] E.g., see Jerry Ralph Curry, administrator, National Highway Traffic Safety Administration, statement at hearings before the House Committee on Energy and Commerce, Subcommittee on Energy and Power, Oct. 1, 1990.

[39] The level of rhetoric has escalated to the point that administration representatives have nicknamed Senator Bryan's fuel economy proposal "The Highway Death Act of 1991." And, some in favor of standards have argued that there is *no* connection between vehicle size and safely.

heavier car will experience less deceleration in a crash, but the weight and safety advantage afforded the first car represents a disadvantage to the second, increasing the forces on it. Although studies of accident records have demonstrated a positive *statistical* relationship between *overall* fleet safety and average weight of vehicles in the fleet, the strong collinearity between weight and various measures of vehicle size, especially exterior dimensions, makes it difficult to separate the effects of weight and size. Many safety experts think size is more important than weight to overall fleet safety, even though weight may be important to consumers making individual purchase decisions. However, some experienced safety analysts do believe that weight plays a role in fleet safety independent of size.[40]

Interior volume may affect safety somewhat because a larger interior makes it easier for vehicle designers to manage the "second crash''—when passengers are flung about the passenger compartment. The average interior volume of the U.S. automobile fleet has been remarkably stable over the past decade, but there is concern that this may change if fuel economy standards are set at levels that cannot be attained with technology alone. However, the increased use of air bags may make differences in interior space of less importance to overall vehicle crashworthiness, because air bags should reduce the movement-and the likelihood of secondary collisions-of front-seat passengers in a crash.

Exterior dimensions may be particularly important to a car's crashworthiness, since these will affect available crush space, and narrower vehicle tracks and shorter wheelbases appear to increase rollover frequency (rollover accidents are often associated with fatalities). Accident studies have shown that some of the largest vehicles in the fleet consistently have the lowest fatality rates, even when the data are corrected for driver characteristics (especially age).[41] Further, studies by the National Highway Traffic Safety Administration (NHTSA) indicate that small vehicles experience more rollover accidents, and more traffic fatalities in such accidents, than large vehicles,[42] and the Insurance Institute for Highway Safety claims that downsizing has driven up death rates in several redesigned General Motors models.[43]

Will new fuel economy standards yield a decrease in automobile safety? The risks are less than characterized by some. First, substantial increases in fuel economy can be achieved with little or no downsizing, although automakers might conceivably choose downsizing over other measures to satisfy new fuel economy standards. Vehicle *weight* would likely be reduced, however. If careful attention is paid to vehicle structural integrity, this may not have negative safety consequences, although some statistical evidence points to a distinct role for weight in fleet safety.

Second, even if further downsizing were to cause a decrease in safety relative to that without new standards, this need not mean an *absolute* safety decrease. Since CAFE standards have been in effect, when the median weight of new automobiles decreased by about 1,000 pounds, wheelbase by 10 inches, and track width by 2 to 3 inches, the safety record of the U.S. fleet improved substantially: between 1975 and 1989, death rates for passenger cars *declined* from 2.43 per 10,000 registered cars (2.5 per 100 million miles) to 1.75 per

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[40] See e.g., L. Evans and M.C. Frick, General Motors Research Laboratories, "Car Size or Car Mass—Which Has Greater Influence on Fatality Risk?" unpublished document, Aug. 30, 1991.

[41] National Highway Traffic Safety Administration, "The Effect of Car Size on Fatality and injury Risk." unpublished paper, 1990.

[42] C.J. Kahane, National Highway Traffic Safety Administration, "Effect of Car Size on the Frequency and Severity of Rollover Crashes," unpublished paper, May 1990.

[43] Insurance Institute for Highway Safety, "Downsizing Cars Means More Deaths," *Status Report*, vol. 25, No. 8, Sept. 8, 1990.

10,000 registered cars (1.7 per 100 million miles).[44] In other words, *at worst* the reductions in vehicle size and weight reduced somewhat the fleet's overall improvement in safety during this period, and new standards might well do the same. Not surprisingly, this outcome can be interpreted in radically different ways: to proponents of more stringent standards, it indicates that better fuel economy was achieved without compromising safety—in fact with substantially improved safety—and that this can be the case in the future; to opponents, it indicates that nearly 2,000 lives per year, which *could have been saved,* were lost because of forced downsizing of the fleet,[45] and that new standards will similarly reduce our ability to improve safety in the future. Both viewpoints may be correct.

Improvements in vehicle design have not been the sole cause of the noted improvements in the fleet's safety record. Improvements to highway design, a crackdown on drunk driving, reductions in highway speed limits, and other nonvehicle factors played a critical role. Some analysts question whether further improvements in these factors of similar magnitude are available; if they are not, this would call into question the conclusion that absolute levels of highway safety will continue to improve even if there is some decrease in the average size of the fleet.

Third, some of the differences in safety between small and large cars do not seem irrevocable, as stated by some officials, but maybe amenable to correction. The safety technologies now entering the fleet, including air bags and antilock brakes, should work at least as well on small cars as on large ones and should tend to decrease any safety "gap," measured in fatalities per 100 million miles, between the two.[46] Also, some safety features may focus on problems rather specific to small cars. A major cause of increased fatalities in small cars appears to have been their high propensity to roll over.[47] NHTSA is preparing regulations to deal specifically with this problem, and OTA expects design improvements to be available to reduce rollover danger and thus further reduce the safety gap between large and small vehicles.

Fourth, in estimating the likely safety outcome of further downsizing of the fleet, it may be incorrect to assume that all of the safety features incorporated into a downsized fleet would be incorporated even if no downsizing occurred. Under this assumption, new safety features do not really compensate for downsizing, since even more lives would be saved with the same features added to a fleet of larger vehicles. In the past, however, government rulemaking, consumer pressure, and automaker design decisions have not been made in isolation from changes in the actual safety situation. All responded to perceived safety problems, not to some absolute safety standard. In other words, had the problems been less severe, fewer safety measures may have been taken. To the extent that future safety responses are driven by problems emerging from downsizing, the argument that safety would have been still greater

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[44] National Highway Traffic Safety Administration, *Fatal Accident Reporting System 1989* (Washington, DC: 1989), table 1-2B. For all motor vehicles, death rates declined from 3.23 per 10,000 vehicles (3.4 per 100 million miles) to 2.38 per 10,000 vehicles (2.2 per 100 million vehicles), table 1-1.

[45] National Highway Traffic Safety Administration, op. cit., footnote 41

[46] However, early statistics on air bag effectiveness in preventing occupant fatalities show that for 1987-92, the addition of air bags reduced fatalities per 10,000 registered cars virtually identically in small, midsize, and large cars. Contrary to OTA expectations, the *percentage* decline in fatalities was greater for large cars than for small cars. Thus far, the use of air bags has not decreased the safety gap between large and small cars. Insurance Institute for Highway Safety, *Status Report*, vol. 28, No. 11, Oct. 9. 1993.

[47] Kahane, op. cit., footnote 42.

without such downsizing may become, at least in part, disingenuous.[48]

Opportunities to counteract any adverse impacts of new fuel economy standards maybe foregone by lack of resources. According to the Transportation Research Board, federal funding for highway safety research has been cut 40 percent since 1981—to only $35 million per year-despite the enormous cost of traffic accidents in both dollars and tragedy ($70 billion, 45,000 deaths, 4 million injuries per year).[49] Additions to Safety R&D resources could go a long way toward mitigating any future negative consequences of further fleet downsizing.

In conclusion, potential safety effects of fuel economy regulation will most likely be a concern if increases in fleet fuel economy are required over a period too short to allow substantial vehicle redesign, thereby forcing manufacturers to try to sell a higher percentage of small cars of current design, *or* if requirements exceed the technological capability of the automakers, thus forcing significant downsizing. Significant improvements in fuel economy (on the order of 30 percent) should be possible over the longer term (e.g., by 2004) without compromising safety. Over this time, there are opportunities to improve fuel economy without downsizing, and there are also opportunities to redesign smaller cars so as to avoid some of the safety problems currently associated with them. However, the *potential* for safety problems will still exist if automakers choose to emphasize downsizing over technological options for achieving higher fuel economy, and if they do not focus on solving problems such as the increased rollover propensity of small cars of current design. If auto fatality rates would be lower without new fuel economy standards than with them (even if overall rates decline), then a real tradeoff between new standards and safety *does* exist and must be addressed explicitly during the fuel economy debate.

Employment Impacts

The potential impacts of more stringent standards on both auto industry and national employment have also been a source of controversy in the debate over fuel economy. Focusing on the impact of a 40-mpg standard by 2001, the industry has claimed that new standards would cost hundreds of thousands of auto industry jobs;[50] in rebuttal, analysts in the conservation community have claimed that standards would not claim industry jobs and would increase overall domestic employment by hundreds of thousands of jobs. with many of these being in the auto industry.[51] The basic assumptions and conclusions of two key and opposing positions are described in table 5-4.

Whether new fuel economy standards will be net job creators or destroyers depends on rather uncertain assumptions or conclusions about the capability of automakers to increase fuel economy by technological means; the costs of new fuel economy technologies; and the tradeoff consumers make among added costs, improved fuel economy, and any necessary changes in other vehicle attributes (such as size). These factors will, in turn, affect both total auto sales and the likely share of those sales captured by U.S. manufacturers. For example, the American Automobile

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[48] It should be noted, somewhat counter to this argument, that automakers tend to introduce new technologies first in the luxury portion of their fleet, and this tendency applies to safety equipment as well, despite the fact that larger luxury models tend to have good safety records and "need" the new equipment less than smaller models. The most recent examples of this tendency are the introductions of airbags and antilock brakes.

[49] Transportation Research Board, *Safety Research for a Changing Highway Environment*, Special Report 229 (Washington, DC National Academy Press, 1991).

[50] Motor Vehicle Manufacturers Association, "U.S. Employment Effect of Higher Fuel Economy Standards, " unpublished paper, Jan. 30, 1990.

[51] H Geller et al. *Energy Efficiency and Job Creation: The Employment and Income Benefits From Investing in Energy Conservation Technologies* (Washington, DC. American Council for an Energy-Efficient Economy, October l W?).

TABLE 5-4: Assumptions and Results of Two Analyses of the Effects of 40-mpg Fuel Economy Standards on Employment

Motor Vehicle Manufacturers Association

1 Technically achievable fuel economy level:
29 mpg by 1995
33 mpg by 2000

2 Decline in sales of larger car sizes,

Large and luxury cars	87 percent
Midsized cars	72 percent

3 Higher sales of small cars at 80 percent of the labor of larger sizes

4 Overall sales decline of 10 percent by 2001 (increased fuel economy is not cost-effective)

5 Domestic Industry retains current share of small car market segment

6 Half of the Increases in foreign sales of small and midsize cars are produced in transplants

7 Transplant labor productivity is twice the domestic automaker average

Results
- **200,000 jobs lost by 1995, 210,000 by 2001, base case**
- **173,000 jobs lost by 2001 without 10-percent sales decrease**
- **159,000 jobs lost if Big 3 gets 53 percent of small-car market**
- **315,000** jobs lost if sales decline 20 percent

American Council for an Energy-Efficient Economy

1 Technically achievable fuel economy level 34 mpg by 1995, 40 mpg **by** 2000

2 No decline in car sales, no change in domestic-import market share

3 40-mpg increase in fuel economy is cost-effective for 2000

Results By 2010, fuel savings are $53,8 billion per year, fuel economy investment is $17.3 billion per year
- 25,000-job increase nationally by 1995
- 72,000-job increase nationally by 2000
- 244,000-job Increase by 2010
- 47,000-job increase in auto industry by 2010

SOURCE Off Ice of Technology Assessment, 1994.

Manufacturers Association (AAMA)[52] assumes that new fuel economy standards will not be cost-effective.[53] It further assumes that industry jobs will be lost by a combination of lower sales (because of higher auto prices with inadequate compensation in fuel savings); shifts to smaller cars requiring less labor to build (AAMA believes that technology alone cannot achieve 40-mpg standards); losses of domestic manufacturers' market share due to Asian manufacturers' relatively greater strength in the small-car segment of the market; and the greater labor productivity y of transplant factories, which will win part of the Asians' larger market share.

On the other hand, the American Council for an Energy-Efficient Economy (ACEEE) assumes that stringent new CAFE standards are cost-effective; that customers will value the increased fuel economy of new cars well enough to maintain sales levels; and that no shifts to smaller cars are necessary, because new standards can be met by improved technology alone.[54] Under these cir-

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[52] Formerly the Motor Vehicle Manufacturers Association of the United States, or MVMA.

[53] Motor Vehicle Manufacturers Association, op. cit., footnote 50.

[54] Geller et al., op. cit., footnote 51.

cumstances, any impacts on jobs are caused by the balance of job losses from lower gasoline sales and job gains from both the added dollars spent on new cars (because of the added unit costs associated with the new fuel economy technologies) and resending by consumers of any net fuel savings (ACEEE estimates that, by 2010, fuel savings will outweigh auto investment costs by $37.5 billion per year[55]). ACEEE also concludes that jobs lost in oil production, refining, and so forth, are more than counterbalanced by jobs created elsewhere in the economy, because the labor intensity of the oil industry is very low compared with the rest of the economy. In other words, even if the money saved in reduced oil expenditures is exactly balanced by the costs of fuel economy technologies. net jobs will increase.

Some elements of each analysis appear firmly grounded, and others do not. For example, achieving a 40-mpg standard by 2001 would be unlikely by using improved technology alone (even assuming that passage of new CAFE standards had taken place when they were first proposed). Automakers would probably have to reduce both average vehicle size and performance, with a likely drop in sales as a result. (Note that, if OTA's fuel economy analysis is correct, automakers could comply with a 35- or 36-mpg standard without reducing car size, although probably with some small reductions in performance.[56]) Thus, ACEEE's "no loss in sales" assumption seems optimistic. On the other hand, AAMA's conclusions about a large sales loss are based on relatively pessimistic assumptions about technology and cost, and appear overstated.[57] ACEEE's premise that losses in oil jobs (from the loss in gasoline sales due to greater efficiency) will be more than counterbalanced by job gains elsewhere in the economy appears to be on firm analytical ground, as discussed above. In fact, this argument applies to an y oil conservation measure, not just automobile-oriented measures. This source of job gain was not considered by AA MA. However, there is substantial controversy about the magnitude of fuel savings—and thus about the extent of the effect on jobs (see discussion below). ACEEE's estimated oil savings are on the high side of the potential range. The oil savings, dollar benefits, and thus new jobs created as a result of new standards appear likely to be lower than the ACEEE estimate.

A new fuel economy standard. if set at a level that does not demand wrenching shifts in the composition of the fleet and does not require the introduction of technologies whose oil savings are greatly outweighed by their costs, might have a positive job impact at the national level, primarily by shifting investment from the low-labor-intensity oil importing segment of the economy[58] to higher-labor-intensity segments: however, new standards may well have some negative impact on auto industry jobs if consumers remain relatively indifferent to fuel economy as a positive factor in new car purchase decisions. This type of negative impact might be reduced or eliminated if policymakers were to couple new standards with economic incentives—feebate-rebate programs, or gasoline taxes—that make high fuel economy more desirable to potential auto purchasers.

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[55] Ibid.

[56] Office of Technology Assessment, op. cit., footnote 7. Of course, there is no guarantee they will do so; instead, they could adopt only part of the necessary technology, or fail to restrain performance increases, and opt instead to attempt a sales shift to smaller cars. Given the realities of the marketplace, however, this strategy seems unlikely.

[57] As part of a sensitivity analysis, ACEEE did examine the impact on employment of a 2- and 4-percent drop in vehicle sales resulting from adverse consumer reaction to more efficient (but more expensive) vehicles. With a 2-percent drop, net job gains drop from 244,000 to 171,000. With a 4-percent drop, net job gains drop to 98,000. A larger drop in sales could mean a net job loss. Geller et al., op. cit., footnote 51.

[58] Especially because virtually all of the oil displaced, and much of the gasoline, will be imported, with the number of *domestic* jobs lost being quite small and concentrated in fuel handling, distribution, and to some extent, refining.

Fuel Savings From an Aggressive Fuel Economy Standard (S. 279)

The magnitude of fuel savings likely from a new fuel economy standard is both a critical component of the decision calculus for the policy debate about standards and a source of great controversy because of large differences in estimates prepared by opposing interests. The source of these differences is the set of assumptions associated with each estimate. Critical assumptions affecting the magnitude of estimated savings include:

1. *Fuel economy values without new standards.* Alternative assumptions about the fuel economy of the new car fleet in the absence of new standards will play a critical role in estimating fuel savings associated with new standards. Factors affecting future fleet fuel economy include future oil prices and price expectations, fuel availability, consumer preferences for vehicle size and power, new safety and emission standards, and progress in technology development. The span of credible assumptions about future fuel economy is likely to be quite wide, especially for the late 1990s and beyond.
2. *Use of alternative fuel credits.* Manufacturers can claim up to 1.2 mpg in CAFE credits by producing vehicles capable of using either gasoline or alternative fuels, and can gain additional credits by producing vehicles dedicated to alternative fuels. If the automakers produce large numbers of alternative fuel vehicles and use the credits to help them to comply with new CAFE standards, the actual fuel savings associated with new standards would be reduced.
3. *Magnitude of a "rebound" in driving.* An increase in fuel economy, by reducing per-mile costs, may stimulate more driving and thus reduce the associated fuel savings. The magnitude of such a rebound effect is controversial, with estimates ranging up to 30 percent of potential fuel savings lost to increased driving. In OTA's opinion, estimates on the low side of the range— 10 percent or less—are more realistic, implying greater fuel savings.
4. *Magnitude of vmt growth.* Small differences in the growth rate of vehicle miles traveled can make a significant difference in the fuel savings estimated to occur from a new standard. The credible range of future rates is fairly broad, perhaps from 1.5 percent per year to 3.0 percent per year, which translates into a variance of about 1 mmbd in estimated fuel savings for S. 279 in the year 2010.
5. *Effects of new standards on vehicle sales.* Some opponents of new fuel economy standards have argued that stringent standards will have the effect of slowing vehicle sales (because of higher vehicle prices and reduced customer satisfaction with smaller, slower, less luxurious cars), thereby reducing vehicle turnover and its positive effect on fleet fuel economy. Others consider the likelihood of a sales slowdown that is large enough to affect fleet fuel economy significantly to be very small. Clearly, however, such an effect is theoretically possible, and would be like] y if policy makers were to miscalculate and set a standard beyond automakers' technical capabilities.[59]

Different estimates of the likely fuel savings from S. 279, which requires improvements in each automaker's fleet fuel economy levels of 20 percent by 1996 and 40 percent by 2001, include:

- American Council for an Energy-Efficient Economy, for the Senate Commerce Committee: 2.5 mmbd by 2005;
- Department of Energy (DOE): 0.5 mmbd in 2001, 1 mmbd by 2010; and
- Congressional Budget Office (CBO): 0.88 mmbd by 2006 and.21 mmbd by 2010 (base case); range of 0.45 to 1.42 mmbd by 2006 and 0.59 to 1.82 mmbd by 2010.

The differences among the above estimates can be readily understood by examining their assumptions. For example, ACEEE assumes that fuel

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[59] This assumes that policymakers refuse to reconsider the standard when the industry 'S difficulties become clear.

economy levels will remain unchanged from today in the absence of new standards (i.e., about 28.5 mpg for cars and 21 mpg for light trucks). DOE assumes that without new standards, new vehicle fleet fuel economy will rise to about 33 mpg for cars and 24 mpg for light trucks by 2001, and remain at that level thereafter. CBO has chosen baseline values of 30 mpg (range 28.5 to 33.0 mpg) for 2001. This difference in baseline mpg asresumptions is the most important factor in accounting for differences among estimates.

Similarly, DOE has chosen assumptions about alternative fuel credits, rebound effect, and vmt growth rate that tend to yield lower estimated fuel savings than ACEEE, with CBO choosing assumptions somewhat in between. Much of the difference stems from DOE's assumptions of rising oil prices—$29 per barrel in 2000 and $39 per barrel in 2010 (1990 dollars).

The DOE baseline estimate of 1-mmbd fuel savings from S. 279 by 2010 appears analytically correct but very conservative. Although none of its assumptions are extreme, virtually *all* push the final result toward a low value. The likelihood of such uniformity is small, although much less improbable if oil prices follow their assumed (upward) path.

In contrast to the DOE estimate, the ACEEE estimate of 2.5 mmbd by 2005 appears overly optimistic because it discounts entirely the potential for a driving "rebound"; ignores the role that CAFE credits for alternative fuel vehicles could play in allowing automakers to boost their official CAFE levels without actually improving efficiency; and accepts pessimistic assumptions about likely fuel economy improvements in the absence of new standards. However, if oil prices remain low for the next decade or so and no major new gasoline taxes are enacted, the assumption of no improvement in fuel economy may turn out to be correct.

Although the range of potential fuel savings from S. 279 is wide, OTA believes that the "most likely" value for savings in the year2010 lies between 1.5 and 2.2 mmbd *as long as compliance with S. 279 does not significantly hurt new car sales.* For a 10-percent rebound effect, a 2-percent vmt growth rate per year. baseline fuel economy of 32.9 mpg in *2001* (frozen for the next decade), and no accounting for alternative fuel vehicles. the fuel savings would be 1.64 mmbd in 2010. Although the 32.9-mpg baseline (no new standards) value is optimistic unless oil prices rise substantially, it is also likely that automakers will use alternative fuel credits to achieve at least part of the fuel economy increase required by new standards. These two factors will tend to cancel one another: an overly optimistic baseline fuel economy will tend to yield an underestimate of fuel savings. and ignoring the likely use of CAFE credits will tend to yield an overestimate.

■ Regulation of Light-Truck Fuel Economy

Because light trucks make up a rapidly growing proportion of the passenger vehicle fleet, and consumers can readily find transportation alternatives to new cars in the light-duty truck fleet. fuel economy regulations must address light truck fuel economy to ensure an effective reduction in total fuel use. Proposed legislation generally recognizes this necessity and sets fuel economy standards for trucks that are similar to those for automobiles. For example, S. 279 proposes that light trucks attain the same 20- and W-percent fuel economy increases (by 1996 and 2001, respectively) as automobiles.

Currently available technology will not allow automakers to improve light-truck fuel economy to the same extent that they improve passenger automobiles. Sources of fuel economy limitations include:

- load carrying requirements that impose structural and power needs that are more a function of the payload weight than the body weight of the truck—yielding fewer flowthrough benefits from initial weight reduction;

- open cargo beds for pickups and large ground clearance that limit potential for aerodynamic improvements;
- need for low-end torque, limiting benefits from four-valve engines; and
- likelihood of additional safety and emission requirements, with associated fuel economy penalties.

Projecting future light-truck fuel economy and determining the potential for regulation-driven improvements are made difficult by the large differences among types of vehicles—pickups, vans, utility vehicles—all of which are made in varying size and weight classes. Changes in sales mixes among the classes have been a major cause of previous fluctuations in the fuel economy of the fleet; for example, about two-thirds of General Motors' 3.05-mpg light-truck fleet increase between 1980 and 1985 was caused by changes in sales mix, and much of the decline in 1985-90 was caused by mix shifts.[60] During the same periods, there were substantial improvements in fuel economy technology, but these improvements were offset somewhat by increases in performance, weight, and level of options (four-wheel drive, automatic transmissions, air conditioning, etc.). For example, during 1980-90, the fuel economy of GM's standard trucks increased 12 to 14 percent from technology improvements, but decreased 5 to 8 percent from performance, weight, and option increases.[61]

Energy and Environmental Analysis, Inc. has made projections of year 2005 domestic light-truck fuel economy for two scenarios—a product plan scenario that assumes no regulatory pressure on fuel economy, and a maximum-technology scenario that assumes maximum practical adoption of fuel economy technologies and restraints on size and performance levels. In the product plan scenario, domestic manufacturers' light truck fleets average about 23 mpg in 2005; for the maximum technology scenario, the fleets average about 26 mpg. The product plan scenario is optimistic in that it assumes no further size increases past 1998 and holds performance increases to an average of 1 percent per year in horsepower/weight ratios; the maximum-technology scenario holds size and performance constant at 1995 levels, but restricts technology penetration somewhat because of the long product cycles normally associated with light trucks.[62]

A "uniform-percentage increase" approach to regulating light-truck fuel economy is particular y problematic because of the extreme differences in truck fleet composition among different automakers. A format based on truck attributes, similar in concept but not in detail to automobile standards based on interior volume, might be preferable. Such standards would have to be individually tailored to truck types—undoubted] y an opportunity for a considerable degree of argument about which type each model falls into. As a point of departure for further study, appropriate standards might look as follows:

- *passenger vans--standards* based on interior volume, probably measured somewhat differently from automobiles;
- *utility vehicles--standards* based on passenger interior volume. with miles-per-gallon credit for rough terrain capability; and
- *pickup trucks and cargo vans—standards* based on both volume and tonnage[63] of load carrying capacity (e.g., square or cubic foot-tons).

Given the growing importance of light trucks to overall fuel consumption, more attention needs to

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[60] Energy and Environmental Analysis, Inc., "Domestic Manufacturers Light Duty Truck Fuel Economy Potential to 2005," paper prepared for Oak Ridge National Laboratory, July 1993.

[61] Ibid.

[62] Ibid.

[63] However, measures of load carrying capacity would have to be carefully developed and monitored to avoid manipulation.

be paid to the problems associated with regulating these vehicles.

Conclusions

Using new fuel economy standards to promote improved light-duty fleet fuel efficiency is a viable conservation option, but one that involves difficult tradeoffs and demands careful program design to avoid problems encountered by the previous CAFE program. Aside from the decision about whether or not to set new standards, policymakers who favor standards must make careful decisions about the stringency of fuel economy requirements. the schedule for compliance, and the format of any new standards.

Critics of previous CAFE standards have claimed they accomplished little in the way of improving fuel economy and caused severe market distortions. Available evidence implies, however, that the standards did force fuel economy improvements significantly above the levels that would otherwise have been achieved, especially with U.S. automakers, and that much of the market distortion was due to the design of the standards and should be avoidable in the future. OTA's analysis implies that a set of standards that would be technically achievable, would not force early retirements of car lines that would hurt cost recovery, would avoid the most severe market distortions, and would reflect a societal valuation of gasoline savings somewhat above market prices (to account for environmental and other societal costs) might look like the following:

- Required achievement of a fleetwide average fuel economy of about 35 or 36 mpg by 2004 or so for automobiles, and about 25 or 26 mpg by 2005 for light trucks.
- Assignment of individual company fuel economy targets by accounting for differences in the actual makeup of company fleets, by vehicle size or other physical attributes. The assignment formula for autos and light trucks should be different, to reflect differences in use for these vehicles.

Major congressional concerns about new standards include safety and impacts on employment. Some concern about safety is justified, but past debate about likely safety impacts has tended to be highly polarized and characterized by overstated positions. Achievement of the above standards could be accomplished without downsizing vehicles, and this would minimize adverse safety consequences. Also, design and equipment improvements should be available to mitigate problems. Setting unrealistically high standards or designing schedules with too little lead time would pose substantial safety concerns, however.

Employment concerns should also be allayed by setting standards at realistic levels. Policymakers should recognize, however, that it is difficult to forecast employment impacts with accuracy: previous estimates were driven more by their starting assumptions than by data and analytical structure.

FEEBATE PROGRAMS: AN ALTERNATIVE OR COMPLEMENT TO CAFE STANDARDS

As noted earlier, gasoline taxes maybe viewed either as a substitute for new fuel economy standards or as a supplement to them: they could serve to move market forces in the same direction as regulatory pressure, reducing market risk by raising the value of fuel economy in purchaser decisions and thus making the higher vehicle costs required to obtain greater fuel economy seem less onerous. Gasoline taxes clearly are a major policy option for saving transportation fuel and are treated later in this chapter.

"Feebate" plans offer another market substitute for, or supplement to, new fuel economy standards. Feebate plans involve charging fees to purchasers of new cars that obtain low-fuel economy[64] and awarding rebates to purchasers of new

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[64] Measured against the average for all cars, cars in that class, or some other value.

cars that obtain high-fuel economy. The plans can be designed to be revenue neutral or revenue generating, but their general purpose is to provide a strong incentive to consumers to purchase efficient vehicles and to manufacturers to produce them.

Price incentives tied to fuel economy have some precedents. The gas guzzler tax in the United States is a primary example. It has been successful in encouraging U.S. automakers to improve the fuel economy of their larger vehicles to avoid the tax (and to avoid having their vehicles branded as "gas guzzlers"), but there is little evidence available to gauge consumer response to the higher prices of those models below the efficiency cutoff (because only a few luxury vehicles have been forced to pay the tax). Austria allows cars averaging less than 3 liters per 100 kilometers (km) (more than 78 mpg) of fuel consumption to escape any excise tax, and applies a sliding-scale tax of up to 14 percent on less efficient vehicles.[65] Other related programs exist in Denmark, Germany, and Sweden, and Ontario (Canada) has a four-tier gas guzzler tax.[66] The State of Maryland has proposed a feebate program, but the program has been blocked by the U.S. Department of Transportation. And a number of such programs have been considered at both the State (e. g., California, Arizona, Connecticut) and the Federal levels.[67]

Feebates can be structured in a variety of ways. They can be scaled on fuel economy or fuel consumption,[68] or a measure of one or the other normalized to a measure of size (interior volume, wheelbase, wheelbase times track width, and so forth).[69] The purpose of normalizing is to focus the incentive on choosing vehicles with good technology and design rather than on small vehicles, which may present safety problems. Light trucks can be treated separately or combined with the auto fleet.

A critical issue associated with feebates is the possibility that U.S. domestic manufacturers would fare poorly compared with their Japanese counterparts, because the Japanese fleets have higher CAFES than the U.S. fleets. However, most of the Japanese advantage is due to the smaller average size of the vehicles they sell. Analyses of hypothetical feebate programs by the American Council for an Energy-Efficient Economy show that a feebate program that separated light trucks from autos and normalized according to size measures-either interior volume or "footprint" (wheel base times track width)—-largely eliminated the disadvantages to domestic automakers.[70]

Estimates of the effectiveness of feebate programs are uncertain because of doubts about the likely response of manufacturers to the incentives for increasing fuel economy that such programs provide. Although calculations of potential consumer response can be made, this response is complicated by the existence of different configurations of each vehicle model (e.g., different engine and transmission choices, levels of power equipment), the interaction between (unknown) manufacturer actions and consumer actions, and

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[65] J.M. DeCicco et al., *Feebates for Fuel Economy: Market Incentives for Encouraging Production and Sales of Efficient Vehicles* (Washington, DC: American Council for an Energy-Efficient Economy, May 1993).

[66] Ibid.

[67] Ibid.

[68] That is, for a program scaled to fuel economy, if the target was 30 mpg, a 40-mpg vehicle would receive half the feebate of a 50-mpg vehicle; if the program was scaled to fuel consumption, the 40-mpg vehicle would receive about 62 percent of the feebate rewarded to the 50-mpg vehicle, because the 10 mpg between 40 and 50 mpg saves less fuel than the 10 mpg between 30 and 40 mpg.

[69] An alternative to normalizing is to subdivide the fleet into groups (e.g., according to EPA size classes), and to have separate feebates for each group. A limitation of using groups is that it provides a very strong incentive for vehicles at the upper range of a group to grow into the next group (e.g., in a size class group, to increase interior volume to the point where it reaches the next class), which presumably would have a lower average fuel economy.

[70] DeCicco et al., op. cit., footnote 65.

the large number of factors that affect vehicle purchase decisions. ACEEE quotes a rough estimate for the consumer response of 1 -mpg fleet improvement for a $300/mpg feebate, ignoring multiple vehicle configurations and assuming a one-time only response.[71] Such a response would save 0.3 million barrels of oil per day in 10 to 12 years;[72] coupled with good manufacturer response, the likely total response would be substantially larger.

A recent study by Lawrence Berkeley Laboratory (LBL) accounts for both consumer and manufacturer response to feebates.[73] LBL estimates manufacturer response by using EEA's model, which contains estimates for both the costs and the effect on fuel economy of a large number of automotive technologies, and by assuming that manufacturers will introduce any technologies costing less than the fuel saved plus the increase in feebate that they will capture (by improving the fuel economy of the vehicle),

LBL estimated the impacts of six different feebate schemes on fleet fuel economy, fuel use, CO_2 emissions, and consumer surplus.[74] Key (draft) conclusions are:

1. A relatively moderate feebate (e.g., one that awarded a $500 differential between a 20- and a 25-mpg car) can achieve substantial fuel economy improvements (e.g., a 15 percent improvement in new car fuel economy by 2010 over levels expected without feebates).
2. Virtually all of the fuel economy improvement comes from manufacturers' adding more fuel economy technologies to their vehicles. Because vechicles of about the same size and performance tend to have similar fuel economies to begin with, and because the fuel economy upgradings they would receive in response to a feebate system should not be dissimilar, such vehicles will tend to have similar fuel economies and feebates after a feebate system is instituted; the major differences in fees and rebates will arise between vehicles with very different size and performance characteristics, and consumers are rarely willing to switch to very different vehicles in response to rewards of a few hundred dollars.
3. For feebates that group all autos (or all light trucks and autos) together, domestic manufacturers on average will pay a fee on their vehicles, and foreign manufacturers will receive a rebate. The net fees and rebates will decline over time.
4. Feebates that account for vehicle size[75] can reduce the disparity between domestic and foreign manufacturers, but at a substantial cost in the improvement of total fleet fuel economy.
5. There is a rapidly diminishing response to increases in the size of feebates, because manufacturers "use up" most available technology at relatively moderate feebate rates. Although higher rates will increase consumer response, this response is small and will remain that way.
6. The precise form of the fuel economy performance indicator used in a feebate program (i.e., either miles per gallon, gallons per mile, or some nonlinear function of one or the other) does not make a great deal of difference in the results.

It is difficult to know how reliable these conclusions are. The key uncertainty involves the assumption that manufacturers will add technologies on the basis of their cost-effectiveness. In fact, the presence in the marketplace of technologies that are not cost-effective, such as four-speed automatic transmissions, indicates that manufac-

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[71] Ibid.

[72] Ibid.

[73] W.B. Davis et al., *Feebates: Estimated Impacts on Vehicle Fuel Economy, Fuel Consumption, CO_2 Emissions, and Consumer Surplus,* LBL-34408 (Berkeley, CA Lawrence Berkeley Laboratory, August 1993), draft.

[74] Ibid.

[75] That is, small vehicles would have to achieve a higher fuel economy than large vehicles to receive the same rebate.

turers' decisions about technology introduction involve more complex decision making processes. Another important source of uncertainty is the tradeoff between performance and fuel economy. The technologies can be used to achieve either higher fuel economy, improved acceleration performance, or both, with more of one usually meaning less of the other. The likely choices of manufacturers, in their design tradeoffs, and of consumers, in their purchase decisions, are not well understood. Other potential problems with the calculations include treatment of the auto manufacturers as one large entity rather than as multiple companies with a variety of design and marketing strategies; and the inability of the model to account for manufacturers' desire to optimize their investment decisions *over time*, rather than to immediately capture as many of the available feebate dollars as they can regardless of the potential near-term availability of less expensive technologies.[76] Finally, part of the very high benefits and low costs may be due to the model's assumption that two-stroke engines, a very inexpensive way to gain large fuel economy benefits, will be fully successful in a short time.

In conclusion, feebates appear to be a potentially attractive option to improve fleet fuel economy while maintaining market flexibility. According to LBL, most of the improvement in fuel economy is likely to come from manufacturers' attempts to maintain or gain market share by reducing the net costs of their vehicles (by adding technologies whose costs are less than the gains in rebates plus fuel savings). If the consumer response is as small as LBL concludes, this implies that a small feebate program (e.g., the program proposed by Maryland), will have little impact because it will likely have little or no effect on manufacturers' design decisions. Only a national or multistate program is likely to affect manufacturers; thus only this large a program is likely to have a significant impact on fleet fuel economy.

The uncertainty associated with manufacturer response implies that policy makers should be prepared for the possibility that feebates, by themselves, might not improve fleet fuel economy nearly as much as hoped. LBL suggests that feebates might be used to complement CAFE standards, to add certainty that the desired fuel economy improvements will be achieved.[77] Since virtually all of feebates fuel economy improvements are expected to come from manufacturer response, feebates would do little to help achieve the standards. Their purpose would be to ensure continued incentives to boost fuel economy *above* mandated levels; if new, relatively inexpensive fuel economy technologies became available in the future, feebates would give the manufacturers an added incentive to incorporate these technologies *in addition to,* rather than instead of, the technologies already in use.

MOVING TO THE SUPEREFFICIENT AUTOMOBILE

Conventional improvements to automobile fuel efficiency-particularly at the optimistic end of the spectrum (e.g., a 40- to 45-mpg new car fleet)--have the potential to stabilize oil use and

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[76] All of these uncertainties also apply to analyses of the costs and benefits of fuel economy regulations, discussed previously. However, the analysis of feebates attempts to understand how manufacturers will behave in a free market situation. In the absence of regulatory constrains, manufacturer behavior different from what the model predicts might sharply reduce or increase the fuel savings benefits being sought with feebates. The previous analysis, on the other hard sought to understand what the manufacturers could do in response to a regulation. Presumably, if they could behave differently to save themselves money or reduce risk while complying with the regulation, this would reduce only the costs of the regulation while maintaining: the fuel savings benefits of compliance. In other words, uncertainty is much less of a concern with the analysis of a fuel economy regulation, at least in terms of projecting the impact on fuel savings. On the other hand, cost and performance uncertainties become a very great concern in computing CAFE standards' *economic impact on producers,* because standards based on overoptimistic assumptions could create large negative impacts; with feebates, the effect would be simply to reduce the magnitude of the manufacturer response.

[77] Davis et al., op. cit., footnote 73.

carbon dioxide emissions, at least for a decade or two. To “outrun” rising travel demand and achieve absolute reductions in oil use, however, will require *either* a successful effort to suppress travel through economic incentives. radical shifts in urban form (which would take many decades to have significant impacts), and other means, or else a much larger change in automobile design than required to reach 40 mpg. Whatever the technical and economic benefits and costs of each approach, a major change in design should most easily gain public acceptance if the new designs do not significant] y degrade the basic amenities offered by current designs—space, performance, safety, reliability, convenience in refueling—and can be made available at competitive prices. Reducing the overall cost of key technologies--batteries or fuel cells, lightweight materials, and so forth--will be a critical challenge to any effort to “reinvent” the automobile.

For purposes of this discussion, a “major change” in automobile design would entail a major shift in materials and drivetrain technology built around either the internal combustion engine (ICE), fueled by reformulated gasoline or by one of a variety of alternative, nonpetroleum fuels, or an electric or electric hybrid drivetrain.[78]

The option of moving quickly to superefficient automobiles raises a number of generic issues that deserve careful evaluation. These include:

- the appropriate role of government in researching, designing, and commercializing superefficient vehicles, given the government’s ability to focus on longer-term goals, the expertise of the national laboratories, the need to avoid stifling innovation. and so forth;
- the importance of financial and personnel resource constraints on the auto industry, given requirements for continued evolutionary updates[79] and satisfaction of new safety and emission standards:
- the potential for important shifts in market power away from the traditional vehicle manufacturers, especially if the new vehicles are electric, and the large changes in employment patterns and other national economic factors that would follow:
- the vulnerability of radically new vehicle designs to product liability challenges; and
- the potential need for substantial new investment in infrastructure (e.g., new electric capacity, charging stations).

On September 29. 1993, the White House announced the signing of an agreement between the Federal Government and the three domestic automakers designed to create a Federal-industry partnership to develop a new generation of vehicles up to three times more fuel efficient than current vehicles. Box 5-2 describes the proposed effort.

Designs Based on the Internal Combustion Engine

The basic features that would have to be included in a major redesign of an ICE vehicle are reasonably well known:

- a shift in body materials, probably to carbon-fiber or other composite materials;
- a total dedication to streamlining, bringing the vehicle drag coefficient[80] down to 0.2 or lower, compared with the current commercial state of the art of about 0.3;
- high-pressure, low-rolling resistance tires, perhaps similar to those in General Motors” Impact electric vehicle:
- an advanced engine, probably either a superefficient four-stroke design with four or more valves per cylinder, adjustable valve lift and

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[78] See A.B. Lovins et al., Rocky Mountain Institute, “Supercars: The Coming Light-Vehicle Revolution,” unpublished paper, Mar. 31, 1993. This paper contends that advanced vehicles with an electric hybrid configuration can achieve fuel economies well in excess of 100 mpg.

[79] It is unlikely that the auto industry would discontinue its current evolutionary approach to model updating while developing the alternative “revolutionary” vehicles, given the substantial risk that the revolutionary approach will not succeed.

[80] Defined as aerodynamic drag divided by (vehicle frontal area) x (velocity squared).

BOX 5-2: The Clinton Administration's Clean Car Initiative

On September 29, 1993, the Clinton Administration, together with the chief executive officers of Ford, General Motors, and Chrysler, announced the formation of a research and development (R&D) partnership to develop a new generation of vehicles that would be up to three times as fuel efficient as today's models. Broadly, this Clean Car Initiative is intended to restore U.S. leadership in automotive technologies, reduce the environmental impact of automobiles, and reduce U.S. dependence on imported oil The specific goal is to develop a manufacturable prototype within 10 years that achieves a threefold increase in fuel efficiency while maintaining the affordability, safety standards, performance, and comfort available in today's cars

Achieving this goal is expected to require technological innovations in both the vehicle power plant and the vehicle structure. These innovations might include replacing the internal combustion engine with fuel cells or a gas turbine-electric hybrid power plant, and making the car body with advanced polymer composites instead of steel. Accordingly, the R&D partnership will also develop supporting technologies, such as advanced manufacturing techniques and lightweight, high-strength materials.

The Clean Car Initiative is intended not just to pioneer technical frontiers, but also to serve as a model for a more cooperative relationship between government and industry in the future On the government side, many agencies will contribute, including the Departments of Energy, Defense, Commerce, and Transportation, the Environmental Protection Agency, the National Aeronautics and Space Administration, and the National Science Foundation They will be coordinated by Mary Good, Undersecretary of Commerce for Technology. On the industry side, the effort will be coordinated by USCAR, a partnership of Ford, General Motors, and Chrysler that also includes other ongoing automotive research consortia (such as the Advanced Battery Consortium, the Automotive Composites Consortium, and the Vehicle Recycling Partnership)

The research agenda of the Clean Car Initiative will be set jointly by a team of officials from both government agencies and industry No new money is expected to be earmarked for this effort, rather, the goals are to be achieved through reprogramming existing funds so as to mesh ongoing research efforts more closely Projects will be funded jointly by government and industry, with the proportion of industry funding greater for those projects having near-term commercial applications, and the proportion of government funding greater for riskier projects with longer term payoffs. The Administration sees the initiative as an opportunity to realize a "peace dividend, " with defense researchers and weapons laboratories contributing their expertise to expand the envelope of available technologies. Indeed, the Administration compares the level of effort required to that of the Apollo and Manhattan Projects.

SOURCE Office of Technology Assessment, 1994

timing, and other low-friction measures; a two-stroke engine; or an advanced diesel;

- extensive use of aluminum and other lightweight materials in suspension and other components (e.g., brake rotors and calipers, sway bars, wheels);
- major redesigns of seats, bumpers, and other components to reduce weight; and
- advanced transmissions, probably a five or six-speed automatic.

Another possibility might be an automatic engine turnoff at stops coupled with a flywheel for accessory power.

The ultimate capabilities of such a vehicle are somewhat controversial. Although some advocates of advanced designs use 100 mpg as a target and hold up existing prototype vehicles[81] as demonstrations of this potential, most of these prototypes are small two- or four-passenger vehicles

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[81] For example, Renault's VESTA2, which claims a fuel economy of 78 mpg city and 107 mpg highway, or Toyota's AXV, with 89 mpg city and 110 mpg highway. See D.L. Bleviss, *The New Oil Crisis and Fuel Economy Technologies* (Westport, CT: Quorum Books, 1988).

with limited performance and few if any power accessories. Maintaining the performance and other basic vehicle attributes now common to the U.S. market presents a substantial challenge to attempts to attain very high levels of fuel economy. Similarly, existing and new safety and emission standards may create additional constraints on the achievable efficiency levels.

General Motors' new Ultralite prototype demonstrates both some of the potential and some of the limitations of a major redesign. The vehicle weighs just 1,400 pounds despite being comparable in interior volume to a Chevrolet Corsica, which weighs over 3,000 pounds; is powered by a 1.5-liter, three-cylinder, two-stroke engine that weighs only 173 pounds yet generates 111 horsepower at 5,000 revolutions per minute (rpm); has a drag coefficient of only O.192: and rolls on high-pressure, low-rolling resistance tires that need no spare because they are self-sealing. Although its fuel economy at 50 mph is 100 mpg, the Ultralite's EPA fuel economy is only 56 mpg, or about 48 mpg when adjusted for on-road conditions.[82] This value, although superb, still falls far short of the levels often touted as readily available to the far-sighted vehicle designer. Perhaps backing off vehicle performance (the Ultralite can reach from O to 60 mph in 7.8 seconds, which is sports-car performance and far better than the fleet average) and improving on the conventional four-speed automatic transmission (from Saturn) will help, but reaching 70-mpg levels and higher clearly will require even more radical redesigns.

▮ Electric Vehicles

Electric vehicles, or EVs, use either batteries. fuel cells, or a combustion engine-generator combination to provide electricity to power electric drive motors. An advanced EV would use small, efficient, variable speed alternating-current (AC) motors mounted at the wheels, rather than the larger. heavier direct-current (DC) motors used on most current EV designs: recent advances in electronics have greatly reduced the size and weight of equipment to convert DC power (provided by fuel cells or batteries) to AC power for the motors. This setup provides very high drivetrain efficiencies, since AC motors can readily attain efficiencies well above 90 percent, no transmission is required, and the engine need not run when the vehicle is stopped. Further, regenerative braking—using the motors as generators to provide braking force and storing the electricity thus generated in the batteries—further enhances system efficiency by capturing a portion of the otherwise-wasted braking energy. The key roadblock to EVs is the difficulty of storing enough energy on-board; the energy density of battery storage is a small fraction of that of gasoline;[83] and hydrogen (for fuel cells) is also lacking in energy density.

Cost analyses of advanced EVs are quite speculative, and projections by advocates that EVs can have life-cycle costs fairly competitive with gasoline-powered vehicles clearly must be viewed with some skepticism. Optimistic estimates depend on a number of factors:

- *Vehicle lifetimes.* Although advocates assert that electric drivetrains will outlast ICE-based drivetrains severalfold, this must be proven in actual automotive service, and other components of the vehicle may determine scrappage times anyway. Many analysts assume EVs will last longer than ICE vehicles. Although this may be likely, the uncertainty associated with any estimates of the difference in lifetimes is high. Similarly, most analysts assume that the electric drive train will require significantly less maintenance than the ICE vehicle drivetrain;

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[82] General Motors Corp. brochure, n.d.

[83] Gasoline stores over 300 (80) times the energy of the same weight (volume) of conventional lead-acid battery, assuming 40 watt-hour/kg for the battery (J.M. Ogden and R.H. Williams, *Solar Hydrogen: Moving Beyond Fossil Fuels* (Washington, DC: World Resources Institute, October 1989), table 14. Gasoline's energy density advantage is reduced by a factor of perhaps 4 or 5 when the higher efficiency of an electric drivetrain over a gasoline-based drivetrain is accounted for.

this appears likely, as well, but the magnitude of savings is essentially a guess.

- *Overall vehicle design and performance.* Designs for EVs may well stress efficiency more than competing ICE vehicles, and may downplay high performance, because the EVs will have to maximize range to be competitive. Cost comparisons will depend critically on whether the competing vehicles are assumed to achieve similar levels of design efficiency and performance, or whether the EVs are assumed to be more efficient in design and poorer performers. Similarly, demanding longer ranges for EVs will raise costs, so the range assumption will be important in the cost comparison.
- *Technology cost.* An advanced EV will have critical technologies that are not currently commercial and thus cannot be costed firmly. The battery system will generally be the critical cost element, although hybrids will have a complex power control system and other elements that, in some configurations, may exceed the battery in cost.

Fuel-Cell Vehicles

A fuel-cell-powered vehicle is essentially an electric car, with the fuel cell[84] and storage tank (for hydrogen or for a hydrogen-carrying substance such as methanol) substituting for the battery. If the fuel is not hydrogen but a "hydrogen carrier" (methanol or natural gas), an onboard reformer is required to release hydrogen from the carrier fuel. Because any excess electricity from the fuel cell, as well as electricity obtained from regenerative braking, can be shunted to battery storage, the vehicle can use a high-power-density battery (or other storage device such as an ultracapacitor or flywheel[85]) to provide the necessary power boost for rapid acceleration; the fuel cell then does not have to be sized for the vehicle's maximum power needs.

All advanced EVs have important opportunities for reduction in energy use and greenhouse gas emissions. A fuel-cell-powered electric vehicle (FCEV) is especially intriguing because fuel cells are extremely efficient energy converters and would be coupled to an EV efficient drivetrain; in addition, they generate no harmful emissions (although the total system will generate emissions if the vehicle fuel is a hydrogen carrier such as methanol and must be converted into hydrogen on board). And they can be refueled quickly, so that range constraints are far less of a problem once sufficient refueling infrastructure is put into place. This is important because, like battery storage, hydrogen is not an energy-dense fuel: its energy density is about one-third that of natural gas, which at 3,000 pounds per square inch (psi) has only about one-quarter the energy density of gasoline.

Three types of fuel cells may be suitable for light-duty vehicles. Proton-exchange membrane (PEM) fuel cells, also known as solid-polymer-electrolyte (SPE) cells, generally are considered closest to commercialization of the three candidates, although policy makers should be skeptical of any claims that practical fuel cells for vehicles are only a few years away from fleet entry. The recent patenting of a method to achieve an 80-fold reduction in the amount of platinum needed in the cell—to levels not a great deal higher than those used in three-way catalytic converters-has greatly enhanced the commercial possibilities of PEM

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[84] A fuel cell converts the chemical energy in its hydrogen fuel into electricity in a manner similar to that of a battery. Hydrogen is fed into the cell at the negative anode and gives up its electrons to the anode, becoming hydrogen ions in the process; the electrons then flow through a circuit to the cathode, where they combine with atmospheric oxygen to form oxygen ions. The hydrogen ions then move through the electrolyte, which will allow them to pass but will block hydrogen or oxygen in gaseous form, to the anode where they combine With the oxygen to form water.

[85] An ultracapacitor is an energy storage device that stores electricity directly, rather than transforming it into chemical energy and reconverting it to electricity when demanded, as a battery does. A flywheel stores electricity as mechanical energy in the form of a rotating mass.

fuel cells.[86] Alkaline fuel cells should have low material cost and high performance, but CO_2 will poison the electrolyte so that a CO_2-free air supply is required; this type of fuel cell will depend for success in light-duty vehicles on a breakthrough in CO_2 removal or identification of a CO_2-tolerant alkaline electrolyte.[87] Solid-oxide fuel cells also should have high performance, but are far from commercialization.[88]

Aside from differences in engineering design details and choice of fuel cell, an FCEV system has a range of major design options. In addition to the choice of hydrogen or hydrogen carrier as a fuel, multiple storage technologies can be used (hydrogen can be carried as a highly compressed gas; a low-temperature, or cryogenic, liquid; a metal hydride; or in water, to be released in reaction with sponge iron[89]) and multiple ways to produce the hydrogen or hydrogen carrier (e.g., hydrogen can be produced from natural gas, by gasifying biomass or coal, or by electrolysis of water with any source of electricity). Some of the choices will be made because of the different stages of development of the technologies (e.g., initial production of hydrogen would likely be from natural gas, with water electrolysis from solar electricity following if costs of photovoltaic cells are reduced sufficiently). Others might be made because of variances in impacts among the choices (e.g., although biomass hydrogen costs may be considerably lower than solar power-based costs, hydrogen production from solar electricity would use about one-fiftieth the land area required by a system obtaining hydrogen from biomass gasification because of the inefficiency of photosynthesis and of the gasification process[90]).

Technological (and cost) uncertainty, high with any advanced EV, should be highest with an FCEV. Sources of uncertainty include the fuel cell itself, the reformer (if necessary), and the fuel storage system (storage at very high pressure—e.g., 8,000 psi—is desirable, and this requires carbon-wrapped aluminum canisters, which have been very expensive but apparently are coming down in price,[91] and powerful compressors that may have high initial and operating costs), as well as high-tech materials and other efficiency technologies needed to maximize system efficiency and thus ensure adequate range. Also, hydrogen supply costs are highly uncertain, especially if nonhydrocarbon sources are used.

Battery Electric Vehicles and Electric Hybrids

The alternative to a fuel-cell-powered vehicle is one powered either by a high-energy-density battery or by a hybrid system combining two power sources, with at least one powering an electric motor. The range of potential power sources includes batteries, flywheels, ultracapacitors, heat engines, and others,

Hybrid systems generally are advanced as a means to obtain most of the gains of an EV with greater range. They come in a variety of configurations. One would use a small, constant-speed ICE as a generator to power high-efficiency electric motors at the wheels, with a high-power-density battery or ultracapacitor used to provide a cur-

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[86] U.S. Congress, Office of Technology Assessment, *Defense Conversion: Redirecting R&D*, OTA-ITE-552 (Washington, DC: U.S. Government Printing Office, May 1993).

[87] M. DeLuchi, Institute of Transportation Studies, University of California-Davis, "Hydrogen Fuel-Cell Vehicles," unpublished paper, Sept. 1, 1992.

[88] Ibid.

[89] In this system, steam reacts with sponge iron to create rust and release hydrogen; after the iron is completely oxidized, the fuel storage canister is removed, and in a special facility, the rust is regenerated to iron through reduction. This system has been newly patented by J. Werth, H-Power, Inc.

[90] DeLuchi, op. cit., footnote 87.

[91] Ibid.

rent boost to the motors for acceleration or hill climbing. The ICE in this case would be sized for average power needs, can be quite small, and can be very efficient and clean because it runs at one design speed.[92] Alternative systems could rely exclusively on batteries for most trips, with the engine-generator for extended range only, or they could use both electric motors and a small ICE to drive the wheels, perhaps with the electric motors providing higher power only when necessary.

For the simpler, all-battery alternative, the crucial element for successful commercialization is development of a battery that combines high energy density for range, high power density to allow competitive acceleration performance, long lifetime under relatively adverse conditions, and moderate cost. A variety of battery types are under development, including lithium-aluminum-iron disulfide, a variety of lithium-based batteries including lithium polymer, nickel-metal hydride, and others. Also, a number of variants of lead-acid batteries are being developed that seek higher energy density and longer life through design alterations and use of new materials. Although a variety of claims about performance and cost have been made for all battery types, virtually all of the advanced batteries are far from commercialization, with numerous design decisions that affect performance yet to be made and crucial problems yet to be solved. In other words, it is too early to know whether the batteries currently under development will perform (and cost) as claimed under mass production and use conditions.

Optimistic estimates for conventional and hybrid EVs depend on the factors noted above. Further, analyses of all of these vehicle types may assume superefficient characteristics throughout the vehicle, with relatively low power and fuel storage requirements because of the extreme light weight of the vehicles, the very high efficiency of the power train, the recovery of most of the braking energy through regenerative braking systems (for the electric systems), the advanced aerodynamics, and extremely low-friction tires. These characteristics do create some difficult questions for designers, however. For example, safety may become a critical issue for these vehicles, especially if they aim for weights around 1,000 pounds, which the Ultralite demonstrates is possible. Although the new materials used may be extremely strong, and the vehicles presumably would incorporate extensive safety equipment and design, the basic problem of protecting passengers in such a light structure is a difficult one—especially if the vehicle shares the road with much heavier vehicles. Another concern is the *robustness* of the vehicle's performance, It is not clear that optimistic design concepts for extremely light, aerodynamic vehicles have taken fully into account the variety of tasks for which automobiles are sometimes used. For example, with a 1,000-pound vehicle, four heavy passengers plus luggage will more than double the total vehicle weight; hauling cargo on the roof of such a vehicle could make a huge difference in its total aerodynamic drag; and so forth. Although challenges of this nature may well be met, either through design or through changes in the way consumers use automobiles, they add more uncertainty to fuel economy projections.

Finally, key uncertainties remain about crucial design and manufacturing details. In particular, the production of vehicle bodies with strong, lightweight composite materials is still accomplished largely by hand, at great cost. Unless manufacturing processes can be heavily automated, costs will remain prohibitive. And component efficiencies, especially for regenerative braking, remain unclear, although they are critical to overall efficiency and cost.

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[92] Lovins et al., op. cit., footnote 78, discusses this configuration. At idle or other times when power needs are low, the excess electricity generated by the ICE recharges the battery or ultracapacitor; at times when power requirements are high, the battery adds power to the electric motors.

Which Technology Will Win?

A combination of varying State and Federal requirements, the existence of various niche markets. and likely preferences for their "own"' fuel by electric and natural gas utilities guarantees that a variety of power-train types will be represented in the U.S. fleet during the process of moving to a super-efficient auto. It is far from clear which types of vehicles will endure and gain significant market shares over the long term. However, it is worth noting that the development of many of the efficiency technologies that apply to all power-trains (lightweight materials, low-friction tires, advanced aerodynamic designs, etc.) will yield a gasoline-fueled auto of considerable attractiveness, with a built infrastructure and built-in public acceptance, probably capable of attaining emission reductions that might reduce some of the critical environmental arguments against it.

ALTERNATIVE FUELS AND CONSERVATION

The use of alternative, nonpetroleum-based fuels in vehicles, though generally viewed as a fuel substitution measure, also offers opportunities to reduce overall energy use and greenhouse emissions; in other words, alternative fuels can play a role in energy conservation. The shift from gasoline and diesel fuel has effects that reverberate throughout the entire fuel cycle. Feedstock materials for alternative fuels are different from those in the oil-based system, with different energy use required to find, collect, and transport the materials, different processes to transform them into fuel, (sometimes) different means of distributing the fuel, and different fuel efficiencies and possibly even different engine and storage technologies on (he vehicle. These differences in energy use, coupled with the alternative fuels differences in carbon content and general chemical makeup, yield fuel cycle emissions of both carbon dioxide and non-CO_2 greenhouse gases (carbon monoxide (CO), nonmethane organic compounds (NMOC), nitrogen oxides (NO_x), nitrous oxide (N_2O), methane (CH_4), and possibly chlorofluorocarbons) that maybe significantly different from the greenhouse emissions produced by using petroleum fuels (see box 5-3).

Background

During the 1970s, programs aimed at developing and commercializing alternative transportation fuels were a centerpiece of U.S. efforts at combatting perceived problems of national security; the aim was to reduce U.S. oil use and import dependency. Today, the primary impetus for alternative fuels programs has shifted toward reducing urban air quality problems, especially in State programs such as California's. At the national level, however, national security still plays a strong complementary role in driving legislative initiatives for increasing alternative fuel use.

Both Federal and State governments have taken a number of policy steps to introduce alternatives to petroleum-based fuels into the transportation sector. The alternative fuels of primary interest for the light-duty fleet of automobiles and light trucks are the alcohols methanol and ethanol, either "neat" (alone) or as blends with gasoline; compressed or liquefied natural gas (CNG or LNG); liquefied petroleum gas (LPG) and propane; hydrogen; and electricity. The fuels and their basic characteristics are described in table 5-5.

Several important policy measures for promoting alternative fuels development have already been undertaken. These are:

1. CAFE credits[93] available to automakers who produce alternatively fueled vehicles, allowing them to treat the vehicles as very high mileage cars that can be averaged into their fleets, allowing fuel economy standards to be met more easily. These credits are unlikely to provide

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[93] Under the Alternative Motor Fuel Use Act of 1988.

BOX 5-3: Why Does Alternative Fuel Use Affect Greenhouse Emissions?

Efficiency

Because many of the fuel-cycle stages of alternative fuels differ significantly from their gasoline fuel-cycle counterparts, the overall energy efficiency of alternative fuel vehicles can differ substantially from that of gasoline or diesel vehicles Important sources of differential energy use Include

1 *Feedstock recovery.* Alternative fuel feedstocks include wood and other biomass materials (including intensively grown row crops), natural gas, coal, and all feedstocks used to generate electric power. The energy use for obtaining feedstocks such as coal and row crops will be significantly higher than for oil; natural gas production may have energy consumption similar to that for oil, except for pumping energy. (In most cases, natural gas flows freely from the wellhead and requires no pumping; an exception is the pumping energy required to remove water from coalbed methane wells.)

2 *Fuel processing.* Processing energy for alternative fuels made from coal and biomass may be much larger than that for gasoline, and larger still than that for natural gas. However, natural gas as well as hydrogen may incur large energy penalties for compression and, possibly, liquefaction.

3 *Transportation.* Locally made fuels, such as biomass-based methanol or domestic natural gas, may incur less transportation energy costs than gasoline made with imported oil or imported directly from abroad.

4 *Fuel characteristics.* Differences in the basic characteristics of the fuels can greatly affect energy usage at the vehicle, even if the fuels are used in internal combustion engines similar to gasoline engines. For example, higher octane ratings (methanol's octane is 101.5, natural gas's is 120 to 130, versus about 87 to 93 for typical gasolines) allow higher compression ratios, raising efficiency. Other fuel characteristics such as flame speed and flammability limits affect the ability to use lean burn, a significant energy saver. And fuel energy density and character (pressurized gas, liquid, etc.) affects fuel storage volume and weight, significant factors in vehicle energy efficiency. Further, some fuels allow or require the use of completely different propulsion systems (e.g., electric motors) and drive trains, with unique energy efficiency characteristics.

5 *Vehicle longevity.* Some fuels may have a significant impact on vehicle longevity (because of effects on engine wear, materials requirements, complexity of emissions equipment, and so forth), affecting overall fuel-cycle efficiency by increasing or reducing the share of energy use attributed to vehicle manufacturing. Many analysts expect electric vehicles to have significantly greater lifetimes than gasoline-powered vehicles (although this proposition should be considered speculative until experience is gained with mass-produced vehicles). Natural gas vehicles may also have a longevity advantage over gasoline-powered vehicles.

Renewability

Fuels made from renewable resources have a significant greenhouse emissions advantage over those based on nonrenewable resources, because the regrowth of feedstocks recaptures the carbon dioxide (CO_2) released by combustion of the fuel.

Fuel Carbon Content

Gasoline and diesel fuels and their alternative fuels, as well as all energy sources used at different stages of the fuel cycle, each have unique carbon contents, and thus produce different amounts of carbon dioxide emissions *per unit of energy content* upon combustion. Consequently, even if gasoline and natural gas-fired vehicles have identical energy efficiencies, the carbon dioxide emissions from each will be different because gasoline has a higher carbon content per unit of energy than the natural gas.

(continued)

BOX 5-3: Why Does Alternative Fuel Use Affect Greenhouse Emissions? (cont'd).

When fuels are burned, most but not all of the carbon present in the fuel—95 to 99 percent—is immediately oxidized to CO_2.[1] The rest is either emitted as carbon monoxide (CO), methane (CH_4), nonmethane hydrocarbons, and carbon particulates, or remains in the combustion chamber or on the exhaust system or flue as carbon deposits. As discussed below, even though much of the non-CO_2 emissions will eventually oxidize in the atmosphere to CO_2, these emissions should be treated separately.[2]

In burning fuels directly, oil ranks between natural gas and coal in CO_2 emissions—burning 1,000 Btu's of coal produces about 20 percent more CO_2 than does burning oil, whereas burning the same amount (in energy units) of natural gas releases only about 70 percent of the amount released in oil combustion. As noted above, however, process energy is critical. Although oil refining is energy intensive, transforming natural gas into a liquid fuel like methanol can be more so—about 30 percent or so of the input energy is lost. And producing a liquid fuel from coal will likely be even more energy intensive than methanol, with the potential to lose half the input energy. The continued development of less energy-intensive processing methods can change these relationships in the future.

Non-CO_2 Gases

As noted earlier, CO_2 is not the only gas currently in the earth's atmosphere that exhibits greenhouse characteristics,[3] and is not the only such gas whose atmospheric concentration is accumulating and thus increasing its greenhouse effect. CO_2 is thought likely to cause about half of the expected greenhouse warming; the other gases will contribute the rest. Important non-CO_2 greenhouse gases include CO, CH_4, nitrogen oxides, nitrogen dioxide, and nonmethane organic compounds. The relative importance of these gases to the total greenhouse effect depends upon the time horizon being examined, because all of these gases undergo slow chemical transformation in the atmosphere—in particular, CH_4 has a short lifetime in the atmosphere but is a powerful greenhouse gas, so its relative effect is extremely sensitive to the time frame under consideration.

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[1] M A DeLuchi, Emissions of Greenhouse Gases From the Use of Transportation Fuels and Electricity,' paper prepared for Argonne National Laboratory, June 26, 1991

[2] Ibid

[3] A gas may be a direct greenhouse gas (by exhibiting relative transparency to incoming light but reflectivity to outgoing infrared radiation) or an indirect greenhouse gas (by acting to change the concentration of direct greenhouse gases)

SOURCE Office of Technology Assessment, 1994

much incentive to most automakers unless fuel economy standards are raised.

2. The Clean Air Act Amendments of 1990 (CAAA) establish three clean fuels programs: section 249 establishes a pilot-test program in California (described below); section 246 establishes a centrally fueled fleet (10 or more vehicles) program in air quality nonattainment areas; and section 227 requires gradually increasing sales of urban buses that use clean fuels. The California Air Resources Board (CARB) believes that reformulated gasolines will satisfy CAAA's clean fuels requirements, which would limit the extent to which the act will actually promote alternative fuels .[94] However, the act's Phase 11 emission standards, set

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[94] D.E. Gushee, Congressional Research Service, "Alternative Transportation Fuels: Are They Reducing Oil Imports?" CRS Issue Brief, updated Mar. 8, 1993.

[redacted]

Gasoline

A motor vehicle fuel that is a complex blend of hydrocarbons and additives, produced primarily from the products of petroleum and natural gas Typical octane (R+M/2) level is 89.

Methanol

Commonly known as wood alcohol, CH_3OH, a light volatile flammable alcohol commonly made from natural gas Energy content about half that of gasoline (implies range for the same fuel volume is about half that for gasoline, unless higher efficiency is obtained) Octane level of 101 5, allowing use in a high compression engine Much lower vapor pressure than gasoline (low evaporative emissions, but poor starting at low temperatures),

Natural gas

A gas formed naturally from buried organic material, composed of a mixture of hydrocarbons, with methane (CH_4) being the dominant component, Octane level of 120 to 130. Energy content at 3,000 psi about one-quarter that of gasoline

Liquid petroleum gas, LPG

A fuel consisting mostly of propane, derived from the liquid components of natural gas stripped out before the gas enters the pipeline, and the lightest hydrocarbons produced during petroleum refining

Ethanol

Grain alcohol, C_2H_5OH, generally produced by fermenting starch and sugar crops Energy content about two thirds of gasoline Octane level of 101 5 Much lower vapor pressure than gasoline.

Hydrogen

H_2, the lightest gas Very low energy content even as a cryogenic liquid, less than that of compressed natural gas Combustion will produce no pollution except NO_x. Can be used in a fuel cell, as well as in an internal combustion engine

Electricity

Would be used to run electric motors, with batteries as a storage medium Available batteries do not attain high energy density, creating range problems Fuel cells are an alternative to batteries, Fuel cells run on hydrogen, obtained either directly from hydrogen gas or from hydrogen “carriers” (methanol, natural gas) from which the hydrogen can be stripped

Reformulated gasoline

Gasoline that has been reblended specifically to reduce exhaust and evaporative emissions and/or to reduce the photochemical reactivity of these emissions (to avoid smog formation). Lower vapor pressure than standard gasoline (which reduces evaporative emissions), obtained by reducing quantities of the more volatile hydrocarbon components of gasoline Addition of oxygenates to reduce carbon monoxide levels,

SOURCE U S Congress, Office of Technology Assessment, *Replacing Gasoline. Alternative Fuels for Light-Duty Vehicles,* OTA-E-364 (Washington, DC U S Government Printing Off Ice, September 1990)

to begin in Model Year 2001, are very stringent (.075 gpm of non-methane organic gases with 5 yr/50,000 miles certification for vehicles under 3,750 pounds[95]), so estimates that relatively low levels of alternative fuels will be promoted by the act should be considered preliminary.

3. The State of California’s pilot-test program under the CAAA, called the Low Emission Vehicle Program (LEVP), requires minimum sales of vehicles in different emissions categories, ranging down to zero emissions. New York and Massachusetts have decided to adopt the California LEVP. As with the CAAA clean fuels requirements, CARB believes that reformulated gasoline, perhaps in conjunction with modified emission control systems, will satisfy most and perhaps all of the emission categories

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[95] U S Environmental Protection Agency, *C/can Air Act Amendments of/990: Detailed Summary of Titles* **(Washington, DC: November 1990).**

except the zero emission vehicle (ZEV) requirement,[96] which probably can be satisfied only with an electric vehicle or a fuel cell vehicle using onboard hydrogen as its fuel. The next most stringent category, for Ultra Low Emission Vehicles, may generate alternative fuel use even if reformulated gasoline can satisfy its requirements, because of cost considerations. (As above, these assessments of reformulated gasoline's ability to meet stringent emissions standards should be considered preliminary.)

4. The Energy Policy Act of 1992 establishes a national goal of 30-percent penetration of nonpetroleum fuels for light-duty vehicles by 2010, with definite requirements for alternatively fueled vehicles in Federal fleets and centrally fueled fleets operated by alternative fuel distributors, and provisions for adding requirements for centrally fueled fleets run by State and local governments and by the private sector. The Act also provides tax incentives for vehicle purchasers and for service station operators.

The Energy Information Administration has estimated that, as a result of all these initiatives. alternatively fueled light-duty vehicles will consume from 1.9 to 2.4 percent of total light-duty fuel use by 2010, with the major contribution coming from the Energy Policy Act fleet provisions.[97] This estimate assumes vehicle sales of about a million per year by 2010, with a total stock in that year of about 8.1 million vehicles, or 3.4 percent of the fleet.

There remain important outstanding policy issues regarding alternative fuel use, despite the important measures already in place. In particular, neither Federal nor State fuel tax regimes take appropriate account of alternative fuels, yielding widely different tax rates for different fuels, and in some cases taxing alternative fuels at substantially higher rates per *unit of energy* than gasoline.[98] Further, though EIA's projected market penetration of alternative fuels is substantial, it falls short of the high expectations expressed in the Energy Security Act and, as well, depends on some relatively optimistic assumptions about marketplace acceptance of electric vehicles. Consequently, there may well be continued policy suggestions for increased support of alternative fuels, especially if early penetration is disappointing. Evaluation of policy proposals for these issues requires an understanding of alternative fuels environmental characteristics, economic competitiveness, and market acceptance.

Emissions and Air Quality Impacts

Improving urban air quality was the driving force behind much of the push to move alternative fuels into the U.S. motor vehicle fleet--especially California's groundbreaking efforts. Proponents of alternative fuels believe that their physical and chemical makeup gives these fuels a substantial advantage over gasoline in controlling emissions. Electricity and hydrogen offer the most obvious benefits: electric vehicles have no harmful emissions associated with combustion or fueling;[99] and hydrogen-fueled vehicles will have no emissions if the power source is a fuel cell, and only nitrogen oxides if the power source is an ICE. In their pure form, the other alternative fuels—natural gas. methanol, ethanol, and LPG—are chemically simpler than gasoline, which should allow easier engine optimization for low emissions.

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[96] U.S. Department of Energy, Energy Information Administration, *Assumptions for the Annual Energy Outlook 1993*, DOE/EIA-0527(93) (Washington, DC: January 1993).

[97] Ibid.

[98] D.E. Gushee and S. Lazzari, Congressional Research Service, "Disparate Impacts of Federal and State Highway Taxes on Alternative Motor Fuels," Mar. 12, 1993.

[99] However, generating the electricity may create substantial emissions, though these may be far removed from the urban airsheds where air quality improvements are desired, and powerplants produce few hydrocarbon emissions, which are primary precursors of ozone.

Also, they have various attributes that appear superior to gasoline. For example, methanol:

- has a lower photochemical reactivity than gasoline. As a consequence, emissions of unburned methanol, the primary constituent of methanol vehicle exhaust and fuel evaporative emissions, have less ozone-forming potential than an equal weight of organic emissions from gasoline-fueled vehicles;
- has higher octane and wider flammability limits than gasoline. This allows a methanol engine to be operated at higher (leaner) air-fuel ratios than similar gasoline engines, promoting higher fuel efficiency and lower carbon monoxide and exhaust organic emissions;
- has lower volatility than gasoline, which should reduce evaporative emissions; and
- lacks the toxics (e. g., benzene) found in gas line, relieving some issues of carcinogenic emissions.

On the other hand, methanol emissions contain a significantly higher level of formaldehyde than do gasoline emissions, a cause for concern especially in enclosed spaces such as parking garages. Natural gas, ethanol, and LPG share similar advantages over gasoline, with each having unique characteristics. For example, natural gas has no evaporative emissions, and direct contact with ethanol is less toxic to humans than contact with either gasoline or methanol.

However, the relative emissions performance of the various alternative fuels and gasoline cannot be assessed adequately by simply comparing the physical and chemical characteristics of the fuels, or by relying on limited successful emissions testing of alternatively fueled vehicles. First, gasoline, and the gasoline vehicle, are moving targets. Under pressure from both State and Federal regulation, gasoline is being improved and new emission control technologies are nearing commercialization. As noted above, CARB believes that the combination of reformulated gasoline with new emission controls, especially the electrically heated catalytic converter, ’m will satisfy extremely strict California emission requirements,[101] and, apparently, place gasoline virtually on a par with alternative fuels. On the other hand, advocates of alternative fuels argue that emission controls depending primarily on complicated technological equipment may frequently fail with actual use. Available evidence indicates that about 10 to 20 percent of current automobiles are “gross polluters” even thought most of them are equipped with sophisticated emission controls. 02 However, this concern affects alternative fuels also; methanol vehicles, for example, will require sophisticated catalytic control to reduce formaldehyde emissions.

Second, it is not practical to use most alternative fuels in their pure form, so that some of their physical and chemical advantages will be compromised. Methanol and ethanol will most likely need to be mixed with 15-percent gasoline to promote cold starting, since the alcohols’ lack of volatility inhibits fuel vaporization in cold weather. Natural gas is largely methane, but 5 to 15 percent is a variable combination of ethane, propane, and nitrogen, thus complicating emission control.[103] Similarly, LPG is largely propane, but it contains other constituents in varying amounts. This lack of purity and uniformity complicates any attempt to optimize engine design. Also, the likelihood that the alcohol fuels will be used in flexible fuel vehicles, with varying combinations of alcohol and gasoline, further complicates emission control.

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[100] Or a similar device, e.g., a close-coupled converter (located nearer to the engine to promote rapid heating).

[101] U.S. Department of Energy, op. cit., footnote 96.

[102] D.E. Gushee, "Alternative Fuels for Automobiles: Are They Cleaner Than Gasoline?" Congressional Research Service Report for Congress 92-235 S, Feb. 27, 1992. This paper is an excellent source of information about emission and air quality implications of alternative fuel use.

[103] Ibid.

Third, tests of individual vehicles often are difficult to extrapolate to conclusions about mass-produced fleets because of variability among different vehicle models, important changes in emissions as catalysts age, and uncertainties about how vehicles will be maintained in actual use.

Fourth, the formulation of emission standards will play a major role in the actual environmental effects of alternative fuels because vehicle designers try to meet standards, not minimize emissions. Alternative fuels appear to have clear advantages over gasoline when held to the same mass emissions requirements, because their exhaust emissions are less photochemically reactive. Federal standards are based on mass emissions, preserving this advantage.[104] California, however, is moving towards emissions standards that correct for the reactivity of emissions, e.g., gasoline-fueled vehicles would have to achieve lower (mass) emissions than methanol-fueled vehicles because the gasoline exhausts produce more ozone per unit mass. Under such a regulatory system, alternative fuels might enjoy no environmental advantage over gasoline, at least so far as exhaust emissions and criteria pollutants (carbon monoxide, nitrogen oxides. hydrocarbons) are concerned.[105]

Fifth, exhaust emissions are only part of the picture. Evaporative emissions are important, and becoming increasingly so as exhaust emissions are subject to more stringent controls. Except for alcohol-gasoline mixtures, the alternative fuels have lower and less reactive evaporative emissions than gasoline.

▮ Energy Security Impacts

Switching to alternative fuels has complex effects on energy security. Development of alternative fueled systems—vehicles, supply sources, and distribution networks-is viewed by supporters as both a means to reduce dependence on oil, lowering the economic and national security impact of a disruption and/or price rise, and leverage against oil suppliers, threatening them with loss of markets if they raise prices too high or disrupt supply. The use of alternative fuels does offer the *potential* to significantly enhance U.S. energy security, but the effect depends greatly on the fuel chosen, the scale of the program, and the specific circumstances of the supply and vehicle system used. The security effects are complex and sometimes ambiguous, because some characteristics of an alternative fuels program maybe beneficial and some deleterious to energy security.

First, of course, an alternative fuels program cannot enhance energy security unless it reduces U.S. oil use. This potential benefit of alternative fuels use may be compromised by the fuel economy (CAFE) credits made available to auto manufacturers who sell alternatively fueled vehicles. In essence, these credits will allow these manufacturers to produce a less-efficient fleet than they otherwise would have produced, or else allow them to avoid paying fines because they couldn't achieve the mandated fuel economy standards. If automakers choose to produce less-efficient vehicles, alternative fuels use will save little oil and may have no positive impact on energy security.

Assuming that CAFE credits do not negate potential oil savings, the security benefit of an alternative fuels program will likely be clearest if the fuels can be domestically supplied. Fuels such as electricity, hydrogen, and ethanol are likely to be domestically produced and thus unambiguously advantageous to energy security *unless* their costs are so high as to damage the national economy.[106] Ethanol's dependence on intensive agriculture, which may suffer on occasion from drought, may make it less secure than the others; successful de-

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[104] Ibid.

[105] Note that this is not a criticism of the California proposal, which puts all fuels on an equal basis as far as allowable air quality impacts are concerned.

[106] Assuming that the fuels are used because of regulatory requirements or generous economic incentives.

velopment of economic ethanol production processes using lignocellulosic material (wood and wood wastes, waste paper) as a feedstock would significantly reduce this potential problem. Methanol *might* be domestically supplied based either on coproduction of pig iron and methanol in steel mills or on use of domestic gas resources. The potential of the former is somewhat theoretical; the latter requires a continuation of low domestic gas prices and low interest rates, with future low prices hardly assured given increasing demands on domestic gas resources (especially from power production). And natural gas would likely be supplied either domestically or with pipeline imports from Canada and Mexico, because the alternative--overseas shipment in liquefied form--would tend to be more expensive.

If alternative fuels are imported, this does not necessarily negate energy security benefits. An imported fuel's effect on energy security will depend on its physical characteristics, the characteristics of the suppliers, the type of financial arrangements made between producers and suppliers, the worldwide price relationship between the fuel and oil (that is, will a large oil price rise automatically raise the fuel prices?), and other factors.

For example, two-thirds of the world's natural gas reserve reside in the Middle East and former Eastern Bloc, leading some analysts to deny that the United States would receive any security benefit from turning to methanol (which is produced from natural gas). However, methanol use will reduce pressures on world oil supplies, and natural gas resources are more diversified than oil resources; also, the U.S. might be able to establish long-term trade pacts with secure methanol sources, which could enhance security benefits. Finally, the United States' changing relationships with the nations of the former Soviet Union and its satellites may lead to a more optimistic assessment of the energy security effects of methanol trade with these nations.

Other factors affecting energy security include scale of the program and selection of dedicated (that is, designed to use one fuel only) or multifuel vehicles. The size of the program affects the magnitude of impact on oil markets, the credibility of the program as a deterrent to intentional disruption of oil supplies, the magnitude of the financial risks, the supply source (moderate-scale natural gas and propane programs could be fueled domestically, large-scale programs probably would require imports), production costs, and so forth. The choice of multi-fueled vehicles might allow the United States to play off suppliers of oil against suppliers of alternative fuels (assuming they are different), but only if the supply and delivery infrastructure is available to allow the vehicles to be fueled exclusively with the alternative fuel if this became necessary. Concentration on dedicated vehicles. on the other hand, offers no ability to play off oil and alternative fuel suppliers, but *requires* full infrastructure development and offers important emission and performance benefits as well.

In conclusion, development of alternative fuels appears likely to offer energy security benefits if the use of CAFE credits does not eliminate oil savings, but the magnitude of these benefits could vary widely depending on the precise development scenario that unfolds, including the fuel choice, method and location of production, scale of production, and vehicle choice. There are remaining uncertainties about the direction of some of the security effects, and some of the factors that affect security are not really controllable by policymakers but will unfold over time as the fuels program develops. Consequently, estimates of the security impacts for potential alternative fuels programs should be considered tentative, especially for programs that may require importation of feedstocks or finished fuels.

Sources of Uncertainty About the Greenhouse and Energy Use Impact of Alternative Fuels

With few exceptions, there is little practical experience with large-scale use of alternative fuels in the United States, and the details and the impacts of the fuel-cycle changes necessary to support such use are uncertain.

An important source of uncertainty is the relative immaturity of much of the necessary technology to power vehicles and, in many cases, to obtain the fuel. The rapid technological change that will characterize such development implies that estimates of vehicle efficiency, emission of non-CO_2 gases, and efficiency of feedstock conversion processes are all quite uncertain. Further, many of the decisions regarding efficiency of engines and processes involve complex economic, environmental, and vehicle attribute tradeoffs that are essentially unpredictable—for example, how will engine designers trade off engine power, efficiency, and engine-out emissions in designing dedicated alcohol engines?

The energy balance of the upstream part of the fuel cycle—finding and obtaining the feedstock, processing it into fuel, and transporting the fuel to market--depends heavily on the type and location of the feedstock. In turn, this depends on the scale of worldwide development, political and trade decisions, and so forth, all unforeseeable. For example, there are multiple sources of natural gas that could prove suitable for methanol production. Most are outside of the United States, though relatively low U.S. natural gas prices and the United States' low cost of capital currently make domestic methanol production look attractive.[107] The various sites have different infrastructure and labor availability. different tax codes, and different gas prices; these translate into different tradeoffs between, for example. capital intensive high-efficiency methanol production processes and less expensive but less efficient plants. Each location requires longer or shorter travel distances to move the methanol to market, incurring higher or lower transport energy costs. As the scale of worldwide development increases, methanol will "move up the supply curve, " using more expensive feedstock natural gas sources and, perhaps, eventually move to coal as a feedstock, with negative greenhouse implications. And to complicate this issue further, methanol may be produced as a coproduct with pig-iron as an alternative to more traditional steelmaking operations involving coke ovens and blast furnaces. This form of production apparently would produce less CO_2 than a separate conventional steel mill and methanol plant.[108]

There also are a variety of straightforward technical unknowns in evaluating the fuel cycle. For example, given the importance of methane as a greenhouse gas, there is a critical uncertainty about the amount of natural gas leakage in the gas production and distribution system, As another example, both N_20 and NO_x are powerful greenhouse gases that arise, in part, from the denitrification and vitrification of fertilizers. The relative greenhouse impact of the ethanol and other biomass fuel cycles depends in large part on the rate of emission of these gases, but this is generally unknown.

Finally, there remain important uncertainties about the relative magnitude of the greenhouse forcing roles played by the non-CO_2 gases, Understanding of the role that each gas plays in global climate is still evolving.

Recent Estimates of Greenhouse Impacts of Alternative Fuel Cycles

Despite the substantial uncertainties, clear differences in likely greenhouse impacts exist among several of the alternative fuels. One of the most thorough and best-documented analyses of the fuel-cycle greenhouse emissions from alternative

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[107] D.E. Gushee, Congressional Research Service, Memorandum to the House Committee on Energy and Commerce, Subcommittee on Energy and Power, "Methanol Supply Demand Balance to 2000. " June 5, 1992.

[108] Ibid.

fuel "scenarios" is the work of Mark DeLuchi of the University of California at Davis. Table 5-6 shows DeLuchi's estimates of the fuel-cycle emissions from the use of several alternative fuels in internal combustion engine-powered light-duty vehicles, relative to the emissions from a baseline gasoline-powered automobile in the year 2000. The ranges of the estimates reflect the uncertainty discussed above.

Policy Issues

As discussed above, both Federal and State governments have initiated a number of important policy initiatives to move alternative fuels into the U.S. motor vehicle fleet, and current expectations are optimistic that significant amounts of these fuels—a few percent of total consumption-–will be consumed by 2010. Some important policy issues remain unresolved, however.

First, as noted, fuel taxation policy does not appear to take rational account of alternative fuels' unique characteristics. For example, electricity currently is charged no Federal highway tax and natural gas is charged very little, whereas LNG and methanol pay significantly higher taxes than gasoline on a dollars per unit of energy basis.[109] Although it may make sense to tax different fuels at different rates based on differential environmental or energy security impacts, current rates seem to bear no relation to energy policy or environmental goals. Two options that would take account of the properties of the fuels might be:

1. Tax each alternative fuel at the same rate in dollars per Btu delivered to the vehicle, possibly with electricity rates being adjusted to account for energy lost at the powerplant. The rate could be equal to or lower than current gasoline taxes, to reflect the government's desire to allow the market to decide or to favor alternative fuels over gasoline.
2. Tax each alternative fuel at different rates that reflect evaluations of each fuel "nonmarket" characteristics, e.g., energy security implications and environmental characteristics.

A problem with the second approach is the substantial uncertainty that underlies the likely societal impacts of the fuels, discussed above.

A second issue is closely related to the first. Federal policy currently is demanding that certain fleets-its own and those of fuel suppliers—buy alternative fuel vehicles and use these fuels. The rationale behind these requirements is to promote energy security and air quality. However, although the different fuels have very different impacts on these values, the requirements ignore these differences; fleet owners will choose fuel/vehicle combinations based only on market incentives. It is possible--even probable—that the fuel/vehicle combinations most often chosen will have significantly less favorable impacts on energy security and air quality than other choices.[110]

Congress was aware of this issue at the time of passage of the Energy Security Act and chose not to try to further influence fleet owners' market decisions. If Congress's views change, perhaps after the emergence of sales patterns for alternative fuel vehicles and the fuels, it could influence sales by using differential fuel taxes, as above, and/or by "weighting'* sales according to estimated nonmarket impacts.

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[109] Gushee and Lazzari, op. cit., footnote 98.

[110] The most popular combinations are likely to be those that involve minor adaptations from current gasoline vehicles (and thus are least costly in capital investment and most easily resold into normal markets)—primarily flex fuel vehicles. These will likely yield only modest air quality benefits (and possibly no benefits over reformulated gasoline), and their ability to use gasoline may translate into a relatively low consumption of alternative fuels.

TABLE 5-6: Fuel-Cycle CO_2-Equivalent Emissions of Greenhouse Gases

Feedstock/fuel/vehicle[a]	Fuel-cycle CO_2-equivalent emissions (grams/mile)[b]	Change with respect to reformulated gasoline[c] (in percent)
Internal-combustion-engine vehicle (ICEV)		
Coal/methanol/ICEV[d]	741	58
Coal/compressed hydrogen/ICEV[e]	713	52
Natural gas/methanol/ICEV[f]	439	-6
Natural gas/compressed natural gas/ICEV[g]	346	-26
Natural gas/compressed hydrogen/ICEV[h]	351	-25
Wood/compressed hydrogen/ICEV[i]	117	-75
Wood/methanol/ICEV[j]	80	-83
Wood/ethanol/ICEV[k]	-43	-109
Corn/ethanol/ICEV[l]	499	6
Solar electrolysis/compressed hydrogen/ICEV[m]	84	-82
Petroleum/reformulated gasoline/ICEV[n]	469	n a

[a] This analysis assumes that all vehicles would use advanced engines and drivetrains, would be optimized to run on the particular fuel shown and would meet the in-use emissions standards mandated by the 1990 amendments to the U S Clean Air Act

[b] This is the sum of ermss-ions of carbon dioxide (CO_2), methane (CH_4) nitrous oxide (N_2O), carbon monoxide (CO) nitrogen dioxide (NO_2) and nonmethane organic compounds (NMOCs) from the entire fuel-production and use cycle (excluding the manufacture of vehicles and equipment) per mile of travel All the results shown are from unpublished runs of an updated version of the greenhouse-gas emissions model developed by M A DeLuchi Emissions of gases other than CO_2 have been converted to an equivalent amount of CO_2, by multiplying mass emissions of each gas by the following "global warming potentials CH_4, 21 N_20 270 CO 2 $N0_2$ 4 NMOCs 5 The resultant CO_2 equivalents of these gases have been added to actual CO2 emissions to produce an aggregate measure of greenhouse-gas emissions

[c] The percentage changes shown are with respect to the baseline gasol[ne-vehicle gram-per-mile emissions shown at the bottom of this table

[d] The conversion of coal to methanol is assumed to be 61 8 percent efficient

[e] Hydrogen is made in centralized coal -gasification plants at 630 percent conversion efficiency, then compressed for pipeline transport using electricity generated at the biomass plant At the station hydrogen is compressed to 8400 psi for delivery to vehicles by a compressor using the national mix of power sources in the United States in the year 2000 projected by the Energy Information Administration

[f] The conversion of natural gas (NG) to methanol is assumed to be 675 percent efficient

[g] NG is compressed (CNG) to 3,000 psi for delivery to vehicles with high-pressure tanks

[h] Hydrogen is made at the refueling site from natural gas delivered by pipeline and then compressed to 8400 psi for delivery to vehicles The compressor uses electricity generated from the projected national mix of power sources in the United States in the year 2000 Reforming of NG to hydrogen is assumed to be 848 percent efficient

[i] Hydrogen is made in centralized biomass-gaslflcatlon plants at 68 6 percent efficiency, then compressed for pipeline transport using bioelectricity generated at the biomass plant At the station hydrogen is compressed to 8400 psi for delivery to vehicles by a compressor using the projected national mix of power sources in the United States in the year 2000

The conversion of wood to methanol is assumed to be 628 percent efficient

[k] An advanced conversion process is assumed in which one unit of biomass energy produces O 52 units of ethanol energy and O 068 units of electrical energy for sale Thus for every energy unit of ethanol produced, 1 9 units of biomass are required as input and O 12 units of electricity are coproduced The emissions displaced by the sale of this excess electricity are counted as a credit against actual emissions from the wood-to-ethanol fuel-cycle (The emissions credit from the sale of the excess electricity exceeds actual emissions from the rest of the fuel-cycle hence the reduction m emissions with respect to reformulated gasoline is greater than 100 percent)

[l] A relatively high productivity of **440** liters ethanol per metric tonne of corn is assumed Coal is the process fuel at the corn-to-ethanol plant and an emissions credit is taken for the production of byproducts at the plant

[m] Hydrogen is produced from water Using solar power, delivered by pipeline to the service station and then compressed to 8,400 psi for delivery to high-pressure tanks on board vehicles The hydrogen compressor at the refueling station runs off electricity generated from the projected national mix of power sources in the United States in the year 2000

[n] These are projected emissions of greenhouse **gases** from a light-duty vehicle Operating on reformulated 9a soline in the year 2000

SOURCE M A DeLuchi University of California at Daws 1993

PUBLIC TRANSPORTATION

Expanding mass transit's role in urban tripmaking has long been a key part of plans aimed at reducing transportation energy use as well as solving a number of urban problems, especially poor air quality, traffic congestion, and lack of mobility for disadvantaged groups. As discussed in chapter 2, mass transit has been fighting a generally losing battle against automobile travel throughout the United States, but its proponents believe that the proper combination of policy changes and new investment could reverse its fortunes. Proposals for transit revitalization include investment in new services (especially light rail), provision of exclusive busways, general investments in better service and improved equipment for existing systems, lower fares, and a variety of measures aimed at discouraging automobile travel (e.g., banning free parking, reduced amounts of parking, higher fuel taxes, auto-free zones). Some proponents advocate the simultaneous expansion of mass transit service and the promotion of transit-compatible land use—filling in underdeveloped areas in city centers and close-in suburbs, increasing residential densities, and promoting mixed-use development. The two strategies would then support each other. The use of urban planning as a transportation energy conservation measure is discussed in the next section.

This section focuses on the question of whether mass transit can play a major role in reducing energy use in the United States. The reader should note that this is *not* the same as asking whether transit service can be improved and thereby gain some modal share (proportion of total travel) or stop the continuing decline in modal share. It is self-evident that there are a variety of measures that can improve service, including improved maintenance, investment in new equipment, restructuring of routes, and institution of new services (including flexible paratransit services). Instead, the focus here is on the feasibility of making major shifts away from auto usage into mass transit, and the energy saving consequences of doing so.

AMERICAN PUBLIC TRANSIT ASSOCIATION

New York City transit bus, Expansion of bus and other transit services is viewed by many as a crucial part of any national strategy to save energy in transportation.

Views of Transit Proponents and Critics

Although polarization is common to policy discussions about all aspects of transportation improvement, it is most pronounced in arguments about the role of public transport in the U.S. transportation future. Opponents of expanded investment in public transportation see it as basically an expensive and ineffective failure, neither energy efficient nor capable of luring enough drivers out of their cars to make a significant dent in congestion or air pollution. Proponents of public transportation, on the other hand, often see it as the only practical solution to an inexorable rise in urban congestion, pollution, and destruction of urban amenities associated with a continuation of auto dominance in personal transportation, and they consider it to be both energy-efficient and cost-effective when *total* societal costs are considered. In slightly more detail, the opposing positions are described below.

Transit Proponents

A key to the pro-transit position is the idea that the automobile has attained its current overwhelming modal share in the United States only because its true costs are hidden from view. By one estimate, "commuters going to work in major central business districts in the United States in their own motor vehicles directly pay for only about 25 percent of the total cost of their transport. The other 75 percent is typic tiny borne by their employers (e.g., in providing "free" parking), by other users (in increased congestion or reduced safety), by fellow workers or residents (e.g., in air or noise pollution), and by governments (passed on to the taxpayers of one generation or another in ways that usually bear no relationship to auto use)."[111] Further, there are other incentives for automobile travel in addition to the hidden costs discussed above, such as the automobile-oriented land use spurred by income tax deductions for mortgage interest payments and zoning laws that force low-density development.[112]

Transit proponents point to transit's symbiotic relationship with land use[113] to argue that an increase in transit services can lead to very large reductions in energy use and pollution. They argue that even on a passenger-mile basis, transit systems are more efficient and less polluting than current automobiles with their low load factors, but that this effect is dwarfed by the ability of transit coupled with denser land use patterns to drastically reduce tripmaking. Thus, some transit proponents evaluate the energy and pollution effects of transit-oriented strategies by assuming a transit "leverage"--each passenger-mile on transit represents a reduction of four to 10 automobile miles,[114] if expansion of transit services is coupled with "densification" of the area served.

A point of reference often used as a model for the United States is Western Europe. As discussed in Chapter 3, not only do Western Europeans, with their dense, transit-oriented cities, take five times more transit trips per capita than their American counterparts, they also travel about half the total miles--creating an enormous savings in energy use and pollution production.[115]

Transit proponents also argue that the ever-increasing U.S. reliance on the automobile has left large segments of the population-the elderly, the poor, youth, the disabled—with greatly diminished mobility at the same time that the spread of auto-oriented sprawl and subsequent loss of close-by cultural, recreational, and work opportunities have made mobility all the more important. In European cities, these opportunities are often within easy walking or bicycling distance, and when longer distances must be traversed, the denser pattern of residences and destinations is highly compatible with transit service--in contrast to transit inability to efficiently serve sprawling U.S. cities.

Final i}. proponents argue that expansion of mass transit usage and reduction of auto use will yield substantial environmental benefits: reductions in auto-generated air pollution; reduction in ecosystem loss from roadbuilding and urban sprawl; fewer fatalities and injuries from transportation-related accidents; and a reduction in the loss of productivity and the pain and suffering that thes cause. An extension of the above argument about transportation's relationship to land use is that an expansion of transit service and usage is a critical element in revitalizing urban centers. Proponents believe that these potential benefits of

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[111] E.W. Johnson, "Taming the Car and Its User: Should We Do Both?" *Aspen Quarterly*, autumn 1992, based on a presentation by J. Meyer, Harvard University.

[112] J. Pucher, "Urban Travel Behavior as the Outcome of Public Policy: The Example of Modal-Split in Western Europe and North America," *American Planning Association Journal*, autumn 1988.

[113] That is, the idea that transit service encourages higher density land uses, which in turn encourages greater transit patronage.

[114] Alliance to Save Energy et al., *America's Energy Choices: Technical Appendixes* (Cambridge, MA: Union of Concerned Scientists, 1992), app. C.

[115] L. Schipper et al., "Energy Use in Passenger Transport in OECD Countries: Changes Between 1970 and 1987," *Transportation: The International Journal*, April 1992.

transit far outweigh investment costs, especially when reductions in required auto investments are taken into account.

Critics of Transit Expansion

The core of most arguments that large investments in transit in the United States are not appropriate and will not yield significant changes in auto dominance or reductions in energy use is that mass transit fits neither the development patterns of U.S. cities nor the preferences of U.S. travelers, and its pattern of failure in the United States demonstrates this lack of fit. For example, opponents of large investments in new transit systems point out that despite an investment of more than $100 billion over the past 25 years, urban mass transit systems have lost modal share (i.e., percentage of total trips) and have not succeeded in convincing significant numbers of drivers to abandon their automobiles. In fact, despite continuing growth in total passenger travel, the number of trips taken on public transit has been basically stagnant over the past decade and is lower than it was 30 years ago[116] when mass transit received no Federal subsidies.[117] Per capita transit usage has dropped in all of the metropolitan areas that initiated or expanded rail systems in the 1980s--even Washington, DC, where a showcase rail system was built at a cost of $8 billion.[118]

According to those opposed to large investments in new transit systems, even the experience in Europe (where per capita transit usage is much higher than in the United States) supports the thesis that public transportation is unlikely to succeed here even if we adopt many of the policies advocated by the environmental community—high taxes on gasoline, high parking costs, strict land use controls, and implementation of major new rail transit construction. Over the past few decades, despite the reality that Europe already has the very policies that supposedly will transform U.S. transportation, European trends have turned sharply in the U.S. direction: per capita automobile ownership has risen three times faster than in the United States; vmt per capita has grown more than twice as fast; and the modal share of transit has steadily dropped.[120]

Critics also argue with the thesis that transit systems, especially rapid rail systems, have the power to shape urban areas in ways that not only provide positive feedback to the systems themselves but also reduce total travel. They point to evaluations in the literature of transit-urban form interactions that have not found a strong linkage between new transit services and subsequent shifts in urban growth patterns.[121]

Another aspect of the critics' case against transit is the claim that it has very poor cost-effectiveness and overall efficiency, perhaps because it is heavily subsidized. For example, public transit operating costs have risen even faster than health care costs: from 1970 to 1985, operating costs per vehicle mile rose 393 percent, or twice the rate of inflation.[122] Further, 9 of 10 recent urban rail projects evaluated by the Department of Transportation exceeded their capital cost estimates; transit

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[116] U.S. Department of Transportation, Federal Transit Administration, *Public Transportation in the United States: Performance and Condition* (Washington, DC: June 1992), fig. 1.1.

[117] J. Love and W. Cox, *False Dreams and Broken Promises: The Waste/i4/ Federal Investment in Urban Mass Transit*, Policy Analysis No. *162* (Washington, DC: Cato Institute, Oct. 17, 1991).

[118] Ibid.

[119] C. Lave, "Cars and Demographics," *Access*, published by University of California at Berkeley. fall 1992.

[120] Ibid During 1965.87 "nit per capita grew 154 percent in Europe, compared to 69 Percent In the United States; and in 1987, 'he auto modal share had already grown to 82 percent.

[121] For example see G. Giuliano, School of Urban and Regional planning, University of Southern California, "Literature Synthesis: Transportation and Urban Form," report to the Federal Highway Administration, October 1989.

[122] Love and Cox, op. cit., footnote 117.

labor productivity has declined substantially over time (e.g., hours of bus service per constant dollar fell by 43 percent during 1964-85); and average annual service hours worked per employee decreased from 1,205 to 929 during the same period.[123]

Finally, and perhaps most disturbingly, some critics of expanded transit investment claim that many urban systems do not even satisfy some of the basic goals of mass transit—saving energy, reducing air pollution, or serving the urban poor and disadvantaged—at any price. They claim that whatever the *potential* energy efficiency of transit may be, the low load factors and the time spent at idle and backhaul by the average public transit bus, and the enormous amounts of energy embodied in the roadbeds, tunnels, and railcars of urban rail systems, make public transportation less energy-efficient than automobiles.[124] Similarly, given the *reduction* in transit's already very low modal share over time, it is difficult to assign significant contributions to air quality or reductions in congestion to any new transit systems. Finally, the critics point to the low usage of transit by the poor (in 1983, less than 7 percent of trips by low-income people were transit trips) and to studies of transit subsidies that show a bias in Federal operating subsidies toward the *affluent* as evidence that transit does not even serve its basic socioeconomic goal.[125]

The discussion that follows attempts to clarify these arguments and draw some conclusions about transit's potential for expansion in the United States. However, drawing firm conclusions about this potential is exceedingly difficult, because lessons that might be drawn from its past performance are compromised by the harsh environment for mass transit under which past investments were made. One conclusion should be clear, however: although there is much room for improvement in fitting appropriate transit designs into their particular physical and demographic circumstances and for improving operational methods, any *large-scale* increase in mass transit's share of passenger travel—and thus, any significant new energy savings-cannot occur simply by adding new services, no matter how efficient these may be. If there is to be any possibility of such an increase in transit modal share and new energy savings, sharp changes will have to be made in the policy and physical environment, both of which are now hostile to mass transit. There will have to be changes in urban design toward greater urban density and a better mix of commercial and residential land uses, and economic or physical restrictions will have to be placed on the automobile system. As discussed later, such changes would have sharp effects on lifestyle and would be exceedingly controversial; instituting them will require major changes in the current societal consensus about transportation and urban life.

Transit Performance in the United States

Although there may be important individual exceptions, by most standards the performance of mass transit in American cities during the past few decades has not been encouraging for those who would like to see it play a major role in a national energy conservation strategy. Virtually all measures of performance-energy intensity, ridership and modal share, cost efficiency, and so forth—have either declined outright or lag significantly behind other modes. However, some stabilization of performance has been obtained since the mid- 1980s.

It is certainly true that mass transit plays a crucial transportation role in many American cities, particularly in moving workers to and from the

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[123] Ibid.

[124] Ibid.

[125] Ibid. The affluent are benefited by a shift in emphasis toward suburb-to-downtown commuter services.

workplace. Table 5-7 lists 16 U.S. metropolitan areas whose transit modal share for commuters in 1980 was equal to or greater than 10 percent.[126] Because high percentages of commuting trips in most of these metropolitan areas are from suburb to suburb, where mass transit usage is very low, transit's share in these cities for commuting trips beginning or ending in the central city will be considerably higher than the areawide average (of at least 10 percent), and higher still for commuting trips directed at the central business district (CBD). For example, in 1980 about 15 percent of workers in the Washington, DC metropolitan area—but 38 percent of workers living in the District itself—used transit.[127] Given existing levels of congestion, there is some basis for fears that if transit service in the more transit-dependent cities is allowed to deteriorate, the CBDs of these cities will become unsupportable.

TABLE 5-7: Metropolitan Areas With Over 10 Percent of Workers Using Public Transportation

Metropolitan/metropolitan statistical area	Percent of workers using public transportation, 1980
New York, NY	49 .3%
Jersey City, NJ	258
San Francisco, CA	221
Chicago, IL	204
Washington, DC-MD-VA	148
Philadelphia, PA-NJ	140
Boston-Lawrence-Salem -Lowell Brockton, MA	126
Nassau-Suffolk, NY	125
Pittsburgh, PA	117
Oakland, CA	111
Newark, NJ	109
Iowa City, IA	107
Cleveland OH	106
New Orleans, LA	104
Baltimore, MD	102
Honolulu, HI	100

SOURCE American Public Transit Association, *Transit Fact Book* (Washington, DC September 1990), table 20, p 52 from U S Bureau of Census *State and Metropolitan Area Data Book.* 1986

The key indicators of transit performance are those that show changes in patronage. Although subsidy levels increased 14-fold in the 1970s, there was little change in total ridership. The number of workers who commute by transit actually *declined* between 1980 and 1990 by about 100,000, or from 6.4 to 5.3 percent of all workers.[128] According to the Nationwide Personal Transportation Survey, total mass transit person-trips have been relatively stagnant over the past two decades, starting at about 4.9 billion in 1969, reaching a high of about 5.5 billion in 1983, and dropping to 4.9 billion again in 1990.[129]

The relative lack of change in total transit ridership during the past 20 years hides some interesting changes in the nature of that ridership. An important change is the beginning of a shift in focus away from traditional service of central-city residents and toward suburbanites commuting to the central city. In 1970, 3.7 million workers commuted from central-city homes to central-city jobs by transit—21 percent of all such commuters.[130] By 1980, although the number of central-city to

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[126] Although the 1990 census has been completed, data on commuting have not yet been released.

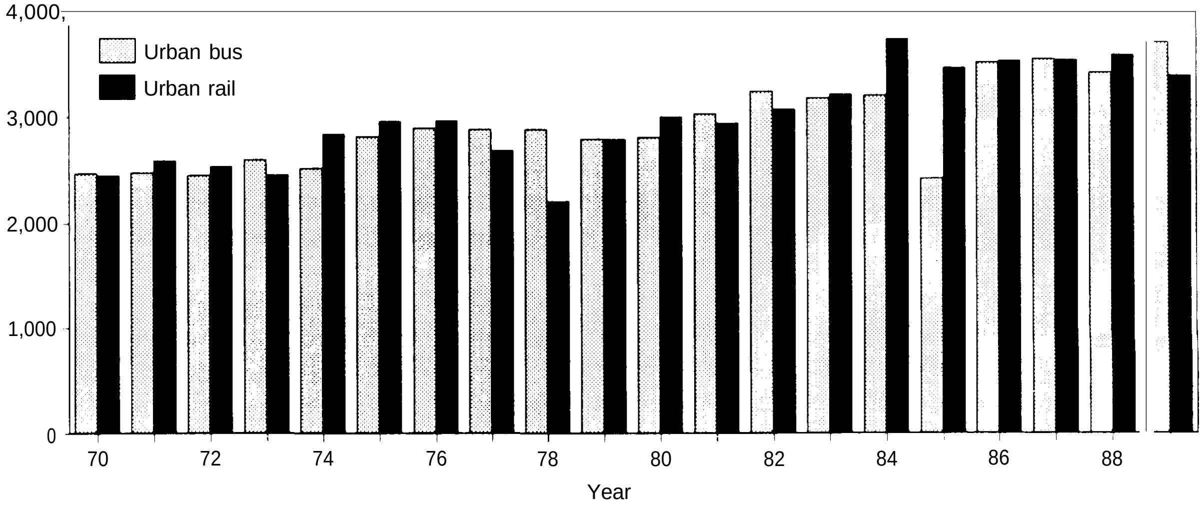
[127] American Public Transit Association, *1990 Transit Fact Book* (Washington, DC September 1990), table 21.

[128] A.E. Pisarski, *Travel Behavior Issues in the 90's* (Washington, DC: U.S. Department of Transportation, Federal Highway Administration, July 1992).

[129] P.S. Hu and J. Young, *Summary of Travel Trends: 1990 Nationwide Personal Transportation Survey*, FHWA-PL-92-027 (Washington, DC: U.S. Department of Transportation, Federal Highway Administration, March 1992), table 16. Data from the American Public Transit Association for all trip purposes, however, indicate a gradual *increase* in *unlinked* transit trips (a complete trip may include a few unlinked trip segments) from about 1975 to the present, from 7.3 billion trips to 9.1 billion (American Public Transit Association, op. cit., footnote 127, table 17), or an increase of about 1.6 percent annually. Unfortunately, interpreting this increase is difficult, because a large percentage of the added trips were on heavy rail systems, and many of these trips generate home-to-station and work-to-station bus trips that are not independent trips but inflate the selected statistic. Thus, many of the new trips are probably statistical artifacts, that is, transit users went from one long bus trip (one unlinked transit trip) to a short bus trip to the rail station and a long rail trip (two unlinked transit trips).

[130] U.S. Department of Transportation, Federal Transit Administration, *Public Transportation in the United States: Performance and Condition* (Washington, DC June 1992), fig. 1.10.

FIGURE 5-1: Energy Intensity of Urban Bus and Rail Transit



SOURCE S C Davis and M D Morris, *Transportation Data Book*, ed 12, **ORNL-671 O** (Oak Ridge, TN Oak Ridge National Laboratory March 1992) table 213

central-city commuters had increased by 29 percent, the number of these using transit had declined to 3.28 million—16 percent of all such commuters. During the same period, workers commuting from suburban homes to the central city by mass transit rose from 777,000 to 1.185 million.[131]

A key attribute of transit promoted heavily by its supporters is supposed to be its high energy efficiency. Comparing the energy intensity of alternative modes is complex and often mishandled. However, a simple measure of performance—changes in energy intensity of a mode over time—shows that both bus and rail transit have increased in energy intensity (see figure 5-1). From 1970 to 1989, bus transit increased from 2,472 British thermal units (Btu) per passenger mile (p-m) to 3,711 Btu/p-m,[132] a 70-percent increase in intensity, primarily because lower load factors and growing urban congestion overwhelmed increases in the technical efficiency of the vehicles. Similarly, urban rail transit energy intensity increased from 2,453 to 3,397 Btu/p-m during the same period, at least in part because a number of new systems were added that are faster and tend to operate at lower load factors than the earlier systems, **most** of which are in very dense older cities on the Eastern seaboard. Recently. rail transit energy intensity appears to have stabilized: the reported 1989 value of 3,397 Btu/p-m is the lowest intensity since 1983.[133]

Direct comparisons of transit and auto energy use are complicated by the need to account for several factors aside from the average energy use of the vehicles:

1. energy use in accessing transit (e.g., bus access to rail, or auto access to rail or bus);
2. differences in "trip circuity"—the relative directness of auto versus transit trips (because of

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[131] Ibid.

[132] Davis and Morris, op. **cit.**, footnote 9, table 2.13.

[133] Ibid.

limited numbers of routes, transit trips tend to be longer than auto trips with the same origin and destination);

3. appropriate vehicle load factors (e.g., because transit riders share similar socioeconomic characteristics with carpoolers, using average (low) auto load factors in transit-auto comparisons will likely be incorrect; on the other hand, some auto trips involve the driver acting primarily as chauffeur rather than active traveler, implying that basing load factors solely on occupancy may understate auto energy intensity);
4. differences in the energy embodied in system infrastructure and fuel production and delivery;
5. properly characterizing travel conditions (e.g., city or highway driving, degree of congestion; most urban transit competes with auto city driving, much of it under congested conditions); and
6. distinguishing between national averages and individual situations. Transit averages are strongly influenced by New York and a few other dense urban centers, which have very high load factors and slower, less energy-intensive rail systems. New systems will tend to have lower load factors and, for heavy rail systems, heavier, faster, more energy-intensive cars.

Thus, although simplistic measures of energy intensity show the urban modes—auto, bus, rail—to be converging,[134] individual situations require very careful and sophisticated analysis to gauge the relative energy intensity of travel alternatives.

As noted above, many measures of transit productivity have fallen substantially during the past few decades, but they have stabilized somewhat since the mid-1980s. Perhaps the most critical measures are labor productivity and cost, since wages and fringe benefits make up more than 70 percent of transit operating cost.[135] Since the inception of Federal transit subsidies in 1961, labor productivity has fallen sharply: from 1960 to 1985, transit employment rose by 67 percent, while vehicle revenue miles of service increased by less than 40 percent; vehicle-miles of service per employee fell from 14,000 to less than 11,000.[136] Recent performance has been better: between 1985 and 1989, vehicle revenue miles of service increased about 17 percent, while employment rose only 6 percent.[137]

Per-hour labor costs have risen rapidly, with public transit operators routinely earning far more than both unionized and nonunion private bus service operators.[138] primarily as a result of this labor inflation, the inflation-adjusted operating cost of transit service (dollars per vehicle-mile) rose by 80 percent between 1965 to 1983, with increases in all regions and in both bus and rail transit.[139] Again, recent results have been better: during 1984-90, the inflation-adjusted cost per revenue mile rose only 1 percent.[140]

Although part of the deterioration in transit economic efficiency is likely due to the lack of incentive for efficiency provided by heavy Federal, State, and local subsidies, part may be due to a deliberate policy of providing service to suburban

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[134] According to S.C. Davis and S.G. Strong, *Transportation Energy Data Book*, ed. 13, ORNL-6743 (Oak Ridge, TN: Oak Ridge National Laboratory, March 1993), table 2.13, 1990 energy intensities per passenger-mile of auto, urban bus, and urban rail were, respectively, 3,739, 3,735, and 3,453 Btu.

[135] M Wachs "U.S. Transit Subsidy Policy: In Need of Reform," *Science*, vol. *244*, June 30, 1989, pp. 1545-1549.

[136] Ibid.

[137] American Public Transit Association, op. cit., footnote 127.

[138] Wachs, op. cit., footnote 135, cites the total earnings of bus drivers with the Southern California Rapid Transit District at $49,777 in 1986 compared with total earnings of $34,426 at a unionized private operator nearby, and drivers at the Washington Metropolitan Area Transit Authority earning $44,014 compared to $19,418 for a Washington area nonunionized private operator.

[139] Ibid.

[140] Federal Transit Administration, op. cit., footnote 130.

workers traveling downtown or from suburb to suburb. As noted above, transit ridership for suburban to central-city commutes increased by 50 percent from 1970 to 1980. These trips often require nonrevenue backhauls and they are highly peaked; the backhauls will lower recorded worker productivity (since this counts revenue hours only), and the need to work two peaks means that unless drivers are part time or working split shifts without overtime, the result will be either substantial "dead-time" for drivers or high overtime charges. When these conditions are combined with express service—fairly common with suburban-to-downtown commutes-the cost-effectiveness of the service is particularly problematic. For example, Federal Transit Administration case studies for eight cities[141] of comparative transit costs for five types of service[142] found that Express/Limited service was the most expensive (in dollars per vehicle-hour or revenue vehicle-hour) in all eight cities.[143] In two cases (Miami, St. Louis), the cost of this service was twice (hat of other transit services.[144]

The move to serve suburbia with transit systems yields more negative impacts on over-all transit performance than just declining labor productivity and higher costs. The lower density of development has meant fewer passengers per vehicle-mile. and the highly peaked nature of the trips (mostly commutes to work) yields long periods when minimum service must be maintained but transit users are few. Further, development has shifted away from transit traditional service areas, especially within central cities, at the same time that rising auto ownership levels have drawn customers away from transit. For example, work(rips that start and finish within central cities—the trips that are easiest to serve with transit--declined as a proportion of all worktrips from 46 to 30 percent in 1960-80.[145] Trips that are very expensive to serve with transit rose dramatically: for example, the number of commuters who both live and work in the suburbs rose from 11 million in 1960 to 25 million in 1980, from 28 to 38 percent of the workforce.[146]

The service by transit of suburban commuters also presents the paradox of the general public heavily subsidizing the transportation of relatively high-income individuals. Further, a large proportion of these commuters drive to the stations and park, thus adding to pollution loads. Also, the availability of rapid rail service into the central city may actually have the perverse effect of increasing the attractiveness of suburban development, accelerating the centrifugal forces that are weakening the central city. A response to this latter concern, however, may be that these systems merely recognize the reality of suburban residential development; they follow it rather than acting as a stimulus. Also, the systems may encourage denser development than would otherwise occur.

The combination of higher labor operating costs and fewer riders per vehicle-mile has driven up operating costs per passenger and per passenger-mile. Costs per passenger rose by 50 percent (inflation adjusted) from 1975 to 1990, and costs per passenger-mile rose by 30 percent from 1980 to 1990.[147] Operating costs averaged 41 cents per passenger-mile in 1990.[148] And unlike other performance indicators, these costs have *not* stabilized recently: real operating costs per passenger

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[141] For Miami, FL; Minneapolis, MN; Los Angeles, CA; Washington, DC; St. Louis, MO; San Diego, CA; Albany, NY; and San Antonio, TX.

[142] Local/Radial, Suburban, Crosstown, Feeder, and Express/Limited.

[143] Federal Transit Administration, op. cit., footnote 130, fig. 2.7.

[144] Ibid.

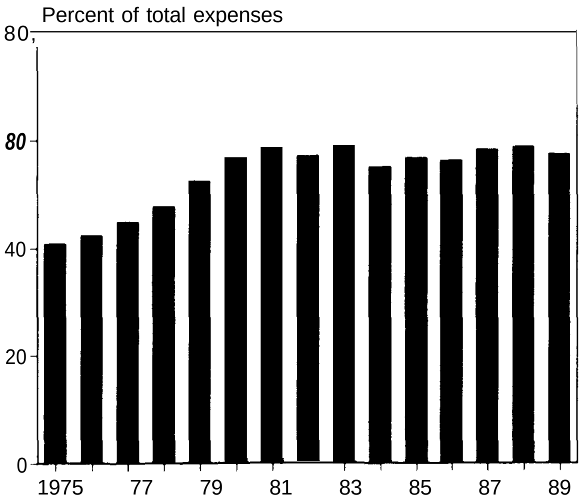
[145] Wachs, op. cit., footnote 135.

[146] Ibid.

[147] Federal Transit Administration, op. cit., footnote 130, fig. 2.3.

[148] Ibid.

FIGURE 5-2: Transit Operating Subsidies



SOURCE American Public Transit Association, *Transit Fact Book* (Washington, DC September 1990), table 8A. p 26

rose 25 percent between 1984 and 1990, and costs per passenger-mile rose 17 percent during the same period.[149] These trends result from substantial increases in transit service without a proportional increase in passengers.[150] Because transit revenues have not kept up with costs (operators have been afraid that raising fares will yield sharp declines in ridership), transit subsidies have had to rise from 41 percent of total operating costs in 1975 to 57 percent in 1989, as shown in figure 5-2.[151]

A large portion of the billions of dollars made available to U.S. transit systems (more than $100 billion over 25 years) went to build a number of new rail systems—rapid rail in Washington, DC, Atlanta, Baltimore, and Miami, and light rail in Buffalo, Pittsburgh, Portland, and Sacramento. A recent study by the Transportation Systems Center of the Department of Transportation evaluated the total (capital plus operating) cost of each of these systems.[152] These are shown in table 5-8. The rapid rail costs vary from $5,93 (1 988) per passenger trip in Atlantato$16.77 in Miami; the light-rail costs vary from $5.19 in Portland to $10.57 in Buffalo. In all of these systems, operating costs represented a relatively small fraction of total costs. If a 10-percent discount rate to pay off capital is assumed, operating costs in Washington, DC, were slightly less than 20 percent of total operating and capital costs. Among the rapid rail systems, operating costs ranged from 13 percent (Atlanta) to 21 percent (Miami) of total costs; and among the light rail, operating costs ranged from 11 percent (Pittsburgh) to 26 percent (Sacramento). As noted below, local transit agencies' focus on operating expenses in making service and fare decisions, because capital costs often are subsidized by Federal and State governments and thus are "free" to the agencies, means that decisions that save money at the local level, by reducing *operating* subsidies per rider, can lead to substantial increases in the *total* subsidy (capital plus operating) per rider.

Evaluating Costs and Benefits

The picture of U.S. transit service that emerges is a discouraging one if viewed in the context of current travel conditions and measured economic costs. However, what if emerging and future traffic problems, existing subsidies to the automobile, and environmental or other costs and benefits are included in the overall cost-benefit evaluation?

First, some proponents of mass transit argue that rapidly growing urban highway congestion will soon cause massive gridlock in many U.S. cities, with very high costs to society as well as to

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[149] Ibid.

[150] Ibid.

[151] American Public Transit Association, op. cit., footnote 127, table 8A.

[152] D H Pickrell *Urban Rail Transit Projects: Forecast Versus Actual Ridership and Costs*, DOT-T-91-04 (Cambridge, MA: Transportation Systems Center, October 1990).

TABLE 5-8: Cost Per Passenger of Recent Rail Transit Projects[a]

Rapid rail				Light rail			
Washington	**Atlanta**	**Baltimore**	**Miami**	**Buffalo**	**Pittsburgh**	**Portland**	**Sacramento**
Operating cost per passenger (1988 dollars)							
172	075	1 83	360	1 44	090	091	1 73
Total cost per passenger (1988 dollars)							
8.75	593	1292	1677	1057	794	519	653

[a] Not Including feeder bus costs

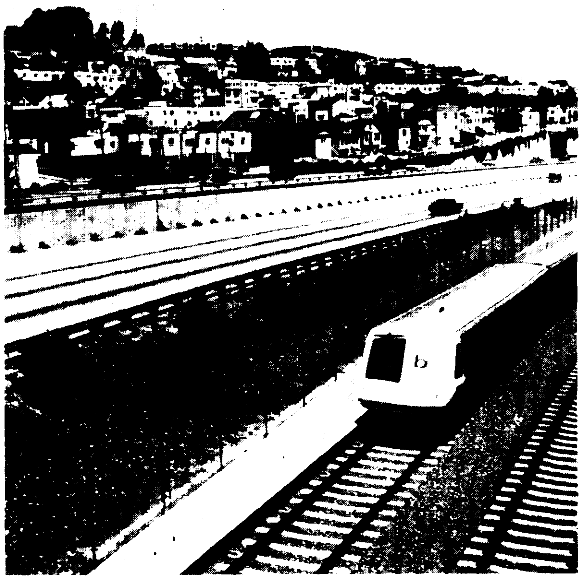
[b] Assumes a 40-year lifetime and a discount rate of 10 percent per year

SOURCE: D H. Pickrell, *Urban Rail Transit Projects: Forecast Versus Actual Ridership and Costs*, DOT-T-91-04 (Cambridge, MA: Transportation Systems Center October 1990) table 5-1

travelers. From this viewpoint, expanding transit ridership and reducing automobile usage would be a critical component of an anticongestion strategy and would generate substantial societal benefits. Also, growing congestion should encourage ridership on those transit systems that will be relatively unaffected by highway congestion (e.g., guideway systems and buses in exclusive lanes).

The validity of this argument depends on the likely magnitude of future congestion problems, the extent to which they would encourage transit ridership, and the degree of relief that increased transit ridership would provide to congestion. As discussed in chapter 4, the magnitude of future congestion problems is not easy to predict, because both travelers and traffic planners will respond to emerging problems in a variety of ways, with many of the responses (particular] y of travelers) being essentially unpredictable. Given the current travel time superiority of automobiles over mass transit, a substantial increase in transit ridership is unlikely unless a large increase occurs in congestion delay costs for autos (or a large shift in the relative monetary costs of the two modes, e.g., a substantial increase in parking costs). Recent forecasts by the Federal Highway Administration do foresee such an increase, but as noted in chapter 4, these forecasts are based on the assumption of no policy adjustments or travel reactions to growing congestion, and their reliability is questionable. Whether additional transit service will reduce congestion (or significantly reduce congestion growth) is clearly a function of the magnitude of any increase in transit ridership; most new investments in mass transit have not been able to siphon off more than a small percentage of trips, but the potential exists for a larger impact in well-chosen corridors.

Second, to the extent that the current price of auto travel does not account for its true societal cost, automobile use may be overutilized in comparison to other options (e. g., mass tran-



FEDERAL HIGHWAY ADMINISTRATION

The Bay Area Rapid Transit (BART) system serving San Francisco and its suburbs allows its riders to avoid heavily congested highways during rush hour commutes, while siphoning potential drivers off these highways.

sit).[153] As shown in chapter 4, even without accounting for societal costs such as air pollution, auto costs *are* substantially underpriced because of subsidies (payment of portions of road construction costs through general funds) and inefficient pricing (e.g., failure to charge directly for parking). The degree of underpricing appears to be less, however, than the underpricing of transit services due to direct government subsidies (U.S. transit operations are heavily subsidized; fares covered only 43 percent of operating costs in 1990,[154] with all other costs paid by local, State, and Federal governments). In other words, if a case is to be made that further subsidies to mass transit are warranted (or that further costs should be added to automobile travel) to correct an imbalance in pricing, the case will have to be based on externalities not covered in the analysis in chapter 4.

Magnification of Transit Benefits

Generally, planners assume that 10 trips on a new mass transit system will eliminate fewer than 10 auto trips, because some of the transit trips are new trips induced by building the new system and others have been captured from different transit systems (e.g., a new rail system capturing passengers from buses). Assuming that transit eliminates relatively few auto trips implies that a major portion of transit benefits (reduction of congestion, air quality improvement, etc.) will be estimated to be quite low.

Some transit proponents claim that the assumption of low auto trip reductions, critical to the cost-benefit calculations used to evaluate new transit proposals, is seriously flawed. For example, the Natural Resources Defense Council (NRDC) and the Sierra Club claim that each new transit trip can reduce four or more auto trips, because "the availability and usage of transit services also changes the location of trip origins and destinations in a way that reduces the need to travel by car, and reduces the distance of travel required by the majority of people who will continue to drive their cars,"[155] that is, instituting new transit service will change land use in ways that reduce the need to travel.

Key to claims that transit has a "magnifying effect" in reducing automobile travel is a series of analyses of different areas that show a strong relationship among the level of transit usage in an area, its land use density, and its level of auto travel. For example, the NRDC-Sierra Club analysis compares five areas in California that have similar income levels but very different levels of mass transit service and land use density.[156] These areas have marked differences in (per capita and per household) auto usage, with the highest level of transit use corresponding to the lowest level of auto use. Assuming that transit is the critical causal variable yields the relationship that 1 mile of transit replaces from 4 (Walnut Creek versus Danville-San Ramon) to 8 (San Francisco versus Danville-San Ramon) miles of auto travel.[157] The NRDC-Sierra Club analysis does make an assumption of causality: "For California conditions, we found that inducing one passenger mile of ridership on transit reduced community-wide VMT by 4-13 miles," and "in a little over 10 years, BART [Bay Area Rapid Transit], and

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[153] Other options are to forego travel altogether or to consolidate trips.

[154] Federal Transit Administration, op. cit., footnote 130.

[155] D.B. Goldstein et al., "Efficient Cars in Efficient Cities," NRCD Sierra Club testimony for conservation report hearing on transportation issues before the State of California Energy Resources Conservation and Development Commission, Apr. 23, 1990, revised Apr. 2, 1991, p. 8.

[156] Ibid., app. A.

[157] Ibid., app. A.

mixed-use densification around its stations, has given Walnut Creek a huge mobility advantage over Danville-San Ramon. "[158]

The data in the NRDC-Sierra Club analysis and similar analyses, however, do *not* show that mass transit alters land use over time, or that the introduction of transit service reduces auto travel by more than one trip for every transit trip added. For the most part, the analyses contain few historical data and do not show changes in land use over time. In discussing the above two communities, for example, the NRDC-Sierra Club analysis does not even show whether or not the differences in Walnut Creek and Danville-San Ramon that appeared in the 1988 estimates, and supposedly were caused by BART, existed 10 years earlier when BART was built. Consequently. the analysis does not even show that there *were* any changes in mobility over time that might have been caused by BART.

Further, the analysis pays only modest atten(ion to demographic differences among communities, focusing primarily on average income, despite the important role that demographics play in travel behavior. Factors such as age, household size, lifestyle choice, and so forth are important determinants of travel behavior. To the extent that denser urban areas with transit tend to attract people who would ordinarily travel less than average, the role that density and transit service *by themselves* play in reducing travel is weakened. That is, it is not just the density, transit service, and greater availability nearby of recreational, cultural, and employment opportunities that goes along with these areas, that contributes to lower travel per capita; it is also the characteristics of the people who tend to live in such areas, because many of these people would tend to travel less than average no matter where they lived.

Finally, statistical analyses cannot show cause and effect. Demonstration of a statistical relationship between transit and residential density does not, for example. imply that mass transit leads to increases in residential density, although it is clear that efficient transit makes high-density development more feasible. In fact, there is a strong possibility that much of the density-transit relationship may reflect density's influence on transit markets rather than transit influence on density; although man y factors affect transit effectiveness and economic viability, including management skills, levels of subsidy, labor relationships, and so forth, density is a key determinant of its customer base and practicality. Thus, proponents of a transit magnifier effect interpret comparisons between U.S. cities that have declined in density as their transit systems declined, and those that have maintained viable city centers with good transit, as showing that maintenance of good transit service has succeeded in keeping downtowns viable; skeptics would instead argue that in U.S. cities, many factors have contributed to downtown declines, but that one offshoot of the decline has inevitably been a concurrent drop in transit, as worsening urban economic fortunes lessened the cities' ability to subsidize transit at the same time the transit systems' customer base was decreasing. Understanding that increases in transit services may not automatically lead to land use changes, many transit proponents propose that added transit service be coupled with land use policies that yield higher densities and mixed uses. The interrelationship among transit, land use, and travel is discussed in the next section.

In conclusion, the relationships among land use, transit services, and travel behavior found in the NRDC-Sierra Club analysis and elsewhere are sufficient to call into question the assumption that an added transit trip will replace less than one auto trip, but they do not justify replacing this assumption with that of a large "magnifier" effect for transit (i.e., each transit trip replaces several auto trips). This area requires further, sophisticated analysis that examines changes in land use, travel behavior, and transportation system performance *over* ***time*** and takes careful account of differences

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[158] Ibid., p, 6 and app. A

in a variety of traveler characteristics, such as age, gender, income, and household size. Some important research into travel behavior has been conducted by Kitamura[159] and Schipper,[160] but much more needs to be done.

What Is Possible?

What could policymakers accomplish if they were willing to push for a future in which mass transit played a much greater role in the U.S. transportation system? The large gap between the reality of actual transit performance in the United States and the vision held out by strong transit proponents in the environmental community demands a hard-headed weighing of both the potential of pro-transit policies and the obstacles to progress in improving transit service and increasing ridership.

Clearly, it is fair to argue that despite high transit subsidies, the transportation environment in the United States has been skewed against high levels of transit usage. As noted above and in chapter 2, the competing public and private transportation systems evolved during a period when the private system—the automobile--enjoyed strong subsidies in the form of: low-cost or free parking; development patterns shaped by mortgage subsidies and zoning for low density that strongly favored auto over transit; freedom from payment of a variety of external costs (air pollu- (ion damages, high noise levels, ecosystem losses, and so forth): and payments of many costs (police services, portions of road construction and maintenance etc.) by government. It can be argued, of course, that U.S. mass transit also enjoys high levels of subsidy—an average 57 percent of operating costs plus much or all capital costs. Further, this could create a "level playing field" for transit in the sense that the transit subsidy, although different in form from the auto subsidy, may account for a similar or even higher percentage of the total cost to society of mass transit use. However, whatever the balance of subsidies ***now,*** the U.S. transportation system and most U.S. cities were shaped during a time when the Federal Government did *not* subsidize transit (although local governments did), and the form that the system and the cities acquired as a result—low-density development, large quantities of parking, very high levels of road density, dispersal of jobs throughout urban and suburban areas, lack of centralization—heavily favors the automobile over transit.

This argument implies that given a different set of incentives, one that established a balanced playing field from the beginning, the United States might have ended with urban environments and transportation systems quite different from those we have now. This thesis would be attacked vigorously by many analysts on the grounds that the primary forces behind the automobile's conquest of the U.S. transportation system were, quite simply, its vastly superior mobility and the growing income levels that allowed Americans to afford an auto-oriented system. However, from the standpoint of current policy choices, *the validity of either thesis is not relevant.* Rather than being interested in what might have been, policymakers addressing U.S. transportation problems must ask what is possible and desirable *given the physical system that we have--at least as a starting point.* In other words, **policy makers must take as a starting point the United States' actual auto-oriented physical infrastructure, societal attitudes, demographic balance, and interest groups, and ask what is possible from this starting point.**

The U.S. urban environment is not one that is easily served by mass transit, and over time, it is moving in a direction that will make it still less amenable to successful transit service. And the natural advantages in convenience, privacy, and travel time of automobiles over transit are enhanced considerably by an entrenched network of

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[159] See e.g., R. Kitamura, "Life-Style and Travel Demand," *A Look Ahead-Year 2020*, Transportation Research Board Special Report 220 (Washington, DC National Academy Press, 1988).

[160] See, e.g., "Linking Life-Styles and Energy Use: A Matter of Time," *Annual Review of Energy*, vol. 14, 1989, pp. 273-320.

U.S. laws and customs that reduce the cost of auto use. Thus, if policy makers hope to make mass transit a major factor in a national energy conservation initiative, they must be willing to attempt to reverse the current course of urban development (i.e., continuing suburbanization) and try to create denser, mixed-use urban environments; they must also drastically shift government expenditures and other economic incentives away from auto use. Further, they must find a way to improve the general management of mass transit systems in this country, because the recent history of transit service has been one of rapid cost escalation and declining efficiency.

Will the Political Impetus Exist?

The willingness to attempt such a course of action is likely to depend on the degree to which a national consensus can be reached that very strong actions are justified to achieve a reduction in transportation energy use. The most likely driving forces behind such a consensus are:

1. the extent to which objections to other transportation and land use-related problems—growing travel congestion, the environmental impacts of continuing suburbanization—add to the consensus for change;
2. national security issues (since the energy in virtually all U.S. transportation use, except rail transit, is oil energy) and greenhouse warming; and
3. the extent to which the public comes to recognize the linkage between urban form and transportation needs and abilities.

It is difficult to make the case that the current policy environment is "ripe" for any attempt to change the course of U.S. urban development or of auto use. For example, although both Congress and the general public are concerned about energy security and greenhouse warming, over the past several years neither has shown much interest in taking substantive measures to deal with either issue. Of course, advancing scientific knowledge about greenhouse warming and unpredictable world events could easily thrust these issues to the forefront of public consciousness and significantly increase the probability that strong initiatives will be taken.

As discussed in chapter 4, OTA believes that current forecasts of growing congestion are overstated; although the importance of congestion as a transportation problem is undisputed, there are doubts as to whether the problem will become sufficiently acute *within the next decade or so* to create the necessary impetus for drastic changes in basic transportation and land use policy. Instead, it seems more likely that pressure will be exerted for a host of more moderate measures—including congestion pricing for key routes, high-occupancy vehicle (HOV) lanes, ridesharing initiatives, and possibly an end to free parking—that may, in concert with continued suburban and exurban development patterns, limit the growth of congestion. These measures are discussed later.

Reaching a consensus that continuing suburbanization is unacceptable and that auto use must be restricted may be extremely difficult, although there are examples—Portland, Oregon, for one—where such a consensus appears to have begun.[161] The issue here is not the actual magnitude of the adverse impacts of unchecked suburban growth and increased auto use—these are large and well-documented—but their perception versus the perception of suburban benefits-that is, the relative privacy, safety, and quiet of living in a suburban environment. For example, many planners believe that suburban development is an important

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[161] However even in Portland, land use restraints have not yet prevented new low-density development from being built—though these restraints probably have affected the location of this development. The strength of the consensus will begin to be tested when residents discover that they cannot live in such developments or when restrictions on low-density building begin to drive up the prices of existing low-density developments.

cause of inner-city decline. Whatever the truth of this, however, it is not the perception of most urban residents. The current negative state of most large-city downtowns leads many urban area residents to shun the inner city as "dirty, polluted, overcrowded, decaying, and downright dangerous,"[162] and they tend to view these conditions as a *cause* of suburban flight, not an effect. The actual truth of this or other such views is not relevant to the political truth: there is little sign that voters are so unhappy with any perceived negative impacts on downtown areas, or with the energy inefficiency, capacity to absorb prime farmland, and other problems of suburban development, that they are ready to take drastic action against such development.

In other words, whatever the truth of arguments that society would benefit if large amounts of auto travel were replaced with mass transit, there is no discernible outline of a political coalition that could accomplish the changes in land use, fuel costs, capital investment, and other factors that would lead to such a replacement. Instead, areas with transportation and air pollution problems are more likely to adopt incremental improvements in transit services and relatively moderate changes in incentives for using private vehicles: in turn, these may yield small additions to transit share and small reductions in auto use, with correspondingly low impacts on energy use.

Will Ridership Be Available?

Demographic factors will play a critical role in defining potential ridership for a major expansion of transit services. Although an attempt to increase mass transit ridership would certainly aim at new constituencies, increasing transit's share among its traditional constituencies—the urban poor, women, and the old and young-would take first priority. There are substantial concerns associated with attracting additional ridership among these groups.

Transit use has dropped substantially among poor households; basically, the same travel trends that are occurring nationally are occurring among people living in poverty, particularly an increase in driving alone—from 55 to 60 percent of all trips during 1985-89.[163] This trend may be very fragile, however; virtually any increase in driving costs associated with strategies designed to shift travel away from single-occupancy vehicles or toward transit could have an especially powerful effect on the travel habits of the poor. Also, the Clean Air Act Amendments demand that cities with inspection and maintenance programs raise their" waiver limits" (the dollar amount of repairs necessary to qualify a vehicle for a waiver from emissions requirements) to $450. This change conceivably might reduce the access of lower-income households to automobiles, since presumably many of the vehicles they currently own are old and in poor repair.

Women have traditionally been more inclined than men to use transit; for example, in 1977, women used transit for about 2.7 percent of their trips versus men's 2.4 percent share. This higher share was probably due to a combination of women's lower income levels, lower access to automobiles, and lower incidence of auto licensing. These factors are changing, and women now appear to be a less inviting target for transit use.

Having a driver's license is a particularly powerful indicator of transit use: although women with driver's licenses travel much more than women without licenses (twice the number of daily trips and three times the daily travel mileage), women with licenses use mass transit for about 1 percent of their trips, whereas those without licenses use transit for more than 13 percent of their trips.[164] Over time, the percentage of adult

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[162] L.S. Bourne, "Self-Fulfilling Prophecies? Decentralization, Inner City Decline, and the Quality of Urban Life," *American Planning Association Journal*, autumn 1992, pp. 509-513.

[163] Pisarski, op. cit., footnote 128.

[164] Ibid.

women with licenses has risen rapidly, from 77 percent in 1983 to 85 percent in 1990,[165] and thus the propensity of women to use mass transit has dropped. Indeed, transit use has followed this trend. By 1990, both men's and women's transit shares had dropped substantially, to an average of 2.0 percent for both, but women's share had dropped more radically, presumably as a consequence of their increased attainment of driver licenses as well as their increased independent income and auto ownership. The difference between men's and women's transit use is now only about 0.1 percent, because women's transit share declined more than 20 percent from 1977 to 1990. whereas men's declined less than 10 percent in the same period.

Mass transit may be losing its traditional market among the old and very young, but may be gaining a market among young adults. Although transit's declining share of travel is spread broadly across age groups, it recently (1983-90) increased in share among the 20 to 29-year-old group.[166] This may be a promising indicator of future transit potential. As a guess, this rise in transit share might reflect declining prospects for high-paying jobs among this age group. Continuation of this trend may depend on the economy's ability to provide good jobs to this age cohort. Another reason for the rise in share among this group may be the increased number of singles and childless couples in the group, and their willingness to live in high-density urban areas during this stage of their lives. To the extent that this is true, the prospects for transit potential will depend on their future lifestyle decisions.

On the other hand, transit share declined markedly in the age group over 50 and the age group from 5 to 15, both traditional transit markets.[167] Among the older groups, this trend probably reflects an increasing income, as well as driving ability: many in this group grew up with automobiles, in contrast to past years. The declining share among the young may simply reflect continuing suburbanization of households with children, and perhaps also growing concerns about urban crime. Parents appear far less likely to let their children travel alone than in past years: thus they may prefer to drive them to activities rather than let them use transit.

What Are the Physical Circumstances?

The Urban Mass Transit Administration's[168] 1984 Report to Congress [169] identified four different types of urban areas that any attempt to expand transit services would have to address (note that these descriptions are of the status quo, with no major policy changes):

1. *The largest, older urban areas.* New York, Chicago, Philadelphia, Washington, and San Francisco are typical: most are in the North, but a few are in the South and West. The structure of these metropolitan areas includes a relatively dense central city with a stable or growing CBD (in terms of both floor space and economic activity, and sometimes in jobs), moderate-density older suburbs, and lower-density newer suburbs around the perimeters. Little change in this basic structure is anticipated over the next 15 years. The CBD should remain important, albeit with continued population dispersion from the central city. Annexation of new territory is often difficult.
2. *Large, older urban areas in decline.* These areas—Buffalo. Cleveland, and St. Louis are examples—have the same basic structure as the

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[165] Ibid.

[166] Ibid., fig. 16.

[167] Ibid.

[168] Now the Federal Transit Administration (FTA).

[169] Urban Mass Transit Administration, *Status of the Nation's Local Public Transportation: Conditions and Performance*, Report to Congress (Washington, DC: U.S. Department of Transportation, September 1984).

previous group but both the central city and the CBD are in marked decline, largely because of the erosion of the city's traditional industrial base. Since the ability of such places to attract compensating growth industries has frequently proved limited, continued decline is to be expected for many of them.

3. *Newer large urban areas.* Los Angeles, Denver, Houston, Phoenix, and San Diego are representative. Such cities are predominantly in the South and West, because the existing density of major cities in the North inhibits the emergence of new centers there. The rate of growth of the newer cities will probably decline from that in the 1970s. Since the major growth of these areas has occurred relatively recently, there are often substantial sections of the central cities that contain housing and commercial activity at suburban densities. Annexation by the central cities of new territory is often possible.
4. ***Smaller urban areas.*** Many urban areas in all sections of the country (with populations up to about 750,000) will experience growth, the bulk of which will be in MSAs (metropolitan statistical areas) of about half-million population in the Southeast and Mountain States, and MSAs between 50,000 and 100,000 in the Northeast and North Central areas. The reasons for the growth of each are different. In the South and West, growth results from the expansion of energy-related industries, the search for a "better lifestyle," and the process of filling out the pattern of regional centers. In the North and East, the growth is due to continued dispersion of population from the largest metropolitan areas.

New or expanded transit will have to be shaped to these individual circumstances. For the large, older cities with dense central cores and vigorous CBDs, conventional fixed-route services make sense for the downtown-oriented worktrip market, with high-capacity fixed-guideway systems (rapid rail, dedicated busway) where densities are very high and most trip distances are long enough for a high-speed system to provide some real travel time advantage. Many of these cities already have rapid rail systems, but several of these are deteriorating or losing patronage because of fare increases. As discussed below, the budgetary arguments for fare increases often ignore the huge investment in capital embodied in these systems. If the original premises upon which the systems were built remain correct, it makes little sense to let these systems deteriorate or lose patronage to avoid operating losses when the effect is to greatly ***increase*** the total (per-passenger) subsidy. On the other hand, supporters of new rapid rail systems have to recognize the extremely high per-passenger costs of such systems, which become even harder to defend when it is recognized that many of the passengers will have formerly traveled in buses or carpools.[170]

For those cities where trip distances are shorter and existing rights of way are available, light rail systems provide a more cost-effective choice than rapid rail. Express bus service also can play an important role in serving outer areas although, as noted above, this service tends to be expensive.[171]

For "cross-town" travel in larger central cities serving work and nonwork travel needs for lower income or other transit-dependent residents, conventional bus systems may be the most feasible service choice, although this type of service is expensive and will continue to require substantial subsidies.

Finally, for service in smaller central cities and trips to suburban subcenters, paratransit opera-

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[170] Ibid.

[171] Federal Transit Administration, op. cit., footnote 130.

tions (e.g., vanpools, demand-responsive services. jitneys) and ridesharing make considerably more economic sense than conventional bus services.

Bookkeeping Problems and Transit Patronage

One reason for the stagnant or declining patronage on existing rail transit systems is the combination of rising fares and declining service, fed by the reluctance of local jurisdictions to increase operating subsidies as costs rise. The cost-benefit decisions of these jurisdictions in setting fare and subsidy policies bear little relationship, however, to the overall cost-benefit calculus of the original decisions to build the systems. These original decisions offered very high subsidies per new transit passenger. both planned and actual,[172] presumably because the system planners placed a high societal value on moving trips from auto to transit. Because the Federal Government supplied most of these subsidies, however, local jurisdictions tend to ignore the sunken (already spent) costs of the systems and treat their current subsidy calculations as if the total costs of the system were operating costs. Thus, their decisions do not consider the reality that losing passengers spreads the very large capital costs of the system across fewer riders and incurs large costs to society if the original value of moving tripmakers from autos to transit, as assumed in the system construction decision, was correct. In other words, raising transit fares and/or decreasing service may decrease the per-passenger operating subsidy, but greatly increase the per-passenger *total* (operating plus capital) subsidy.

If current decisionmakers maintained the original view of the value of increasing transit ridership, they would realize, with but one possible point of dissension, that *reducing* fares and increasing maintenance and service levels, rather than increasing fares and reducing service, is the more cost-effective strategy. The dissenting point is that system efficiency may be a function of the level of the subsidy: the efficiency of heavily subsidized systems has been poor.

It is worthwhile to examine quantitatively the alternative cost-benefit choices available to transit decisionmakers--whether or not to incorporate capital costs into decisions about raising fares. Two key values are important to this issue:

1. The elasticity of transit ridership in relation to transit fares is generally thought to be about -0.3; that is, a 10 percent fare increase will decrease ridership by about 3 percent.[173]
2. In rail systems, the function of total costs associated with capital charges is quite variable, but a typical value might be 80 percent.[174]

Box 5-4 describes the effects of the alternative choices for a hypothetical rail transit system with 100,000 daily passenger trips, a total (capital plus operating) cost per trip of $10, a $1 fare, and a $1-per-trip operating subsidy. For this system, raising fares by $0.50 per trip leads to a loss of 15,000 passenger trips a day but yields a significant reduction in the total and per-trip operating subsidy: from the perspective of total costs, however, this is a situation in which society previously had been willing to subsidize each trip by $9 but will save only $1.83 for each trip lost to the system.

▮ Conclusions

Although there will be intense disagreement about the potential for success of *any* plan to greatly enlarge transit service in the United States, there would likely be general agreement with the proposition that with a few exceptions (e.g., rehabilitation of some systems in very dense cities). funnel-

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[172] As shown by Pickrell, op. cit., footnote 152, actual costs were higher and patronage was lower than originally projected, so that per-passenger subsidies were considerably higher than projected. Nevertheless, even the planned per-passenger subsidies were extremely high.

[173] Ibid., p. 28.

[174] Based on the values associated with the systems examined by Pickrell, ibid.

BOX 5-4: Capital and Operating Subsidies and Fare Decisions

In urban rail systems, capital subsidies are typically much higher than operating subsidies It is not unusual for capital charges to represent 80 percent of total system costs Despite the magnitude of these charges, however, local decisions about transit agencies' operating budgets may take little consideration of capital costs. There are several potential reasons for this the Federal Government heavily subsidizes these costs; the costs are "sunk," that is, already spent, and/or local governments accept the proposition that the costs cannot be repaid out of the fare box Where capital costs are not carefully considered in operating decisions, however, decisions about fares may be based primarily on concerns about operating subsidies This narrow focus can create inconsistencies between societal objectives and transit operating strategies

A sample case will illustrate the problem A hypothetical rail system serves 100,000 passenger trips daily and has operating costs of $2.00 per trip and capital costs of $800,000 per day The capital costs are covered by a capital subsidy of $8 per trip, and operating costs are covered by fares of $1 per trip and an operating subsidy of $1 per trip ($100,000 per day)

The transit agency, if it is concerned that the operating subsidy is too large, may examine the possibility of raising fares to $1.50 per trip. In focusing on the operating subsidy only, this looks like a reasonable move If ridership has a price sensitivity of O 3, the 50-percent fare increase might reduce passenger volume by (50 percent O 3), or 15 percent—1 5,000 passenger trips daily. The new passenger volume will generate fare revenues of $127,500 daily, reducing operating subsidies by at least $27,500 daily (and more if operating costs are reduced because of the lower volume of passengers) The operating subsidy per passenger trip is reduced to about $085

If the capital subsidy is included in the calculations, the results look somewhat different, however. The capital subsidy will rise to about $941, and the total subsidy from $9 to $1026 per passenger trip In other words, although passengers are paying more in fares, the per-passenger subsidy is actually higher than before

Another way of looking at the results is that the system has lost 15,000 passengers to save $27,500 a savings of $1 83 per passenger lost. With a focus only on operating subsidies, this seems to make sense the agency previously placed a value of $1 on having a traveler use transit presumably instead of driving, so it ended up saving more than each lost passenger was worth However, with a focus on all subsidies, society was paying $9 to have a traveler use transit. Saving only $1 83 for each passenger lost to transit looks like a bad bargain from this vantage point

The math in this example will change somewhat if the lower passenger volume allows both operating and capital savings from either or both reduced service frequency and train length, but it is unlikely that the change will be substantial enough to alter the basic conclusions

This example also provides ammunition for proposals to reduce transit fares substantially where excess capacity exists. If society really does value shifting auto riders to transit as highly as implied by the subsidies pay to rail systems, reducing fares would be an extremely cost-effective method of "buying" additional passengers Other issues that might arise in evaluating a fare reduction proposal include the desire to avoid frivolous use of the system (otherwise, there is a clear basis for arguing for elimination of fares) and the need to clearly Identify what the system's primary goals are The latter issue arises in examining questions about fares for off-peak periods If society makes no value distinction between peak and off-peak ridership, sharp fare reductions for off-peak use make excellent sense However if society values the transit system primarily as a way to ease congestion and the need for new highway capacity, off-peak ridership may be valued considerably less than peak ridership In this case. there may be less Incentive to lower off-peak fares—and increase the operating subsidy—to increase ridership

SOURCE Off Ice of Technology Assessment, 1994 ing large amounts into public transportation will not shift large numbers of trips from autos and will not save large amounts of energy unless it is coupled with intense efforts to restrain automobile travel and shift development to more transit-friendly patterns.

It is, however, unwise to point to previous (poor) experience and conclude that mass transit cannot work in the United States. The only conclusion offered by our previous experience is the one above. Whatever transit good points, it is not preferred by most travelers under the current system of incentives. Thus, any failure of previous attempts at funneling resources into transit proves only that transit cannot succeed very well within the existing system, but does not indicate what might happen with changes in the system.

For most rail transit systems, capital expenditures are subsidized 100 percent and operating expenses are subsidized partially, with authorities trying to get as much of the operating expenses as possible out of the fare box and focusing primarily or exclusively on operating expenses in trading off fares versus ridership. This funding system creates incentives to raise fares and accept lower ridership in order to reduce operating subsidies, even though capital subsidies per passenger would go up sharply'. Increasing fares 10 percent produces only about a 3-percent drop in ridership and thus seems to make sense from an operating cost standpoint.[175] The fare increase probably does not make sense from a total costs standpoint, however: minimizing the total subsidy per rider would, under most circumstances, require a fare reduction (and an increase in ridership), maybe even to the point of making the system almost free.

URBAN FORM AND TRANSPORTATION

Transportation analysts point to the structure of most American cities—the low population density, the importance of suburbs and exurbs, and the separation of residential and commercial development, as well as the enormous land area and investment given to roadways and parking facilities—as a principal cause of the very high gasoline usage, low proportion of transit trips, and low use of walking and bicycling modes characteristic of U.S. urban transportation.

The general relationship between transportation and land use is widely recognized in the transportation and urban planning community and among environmental groups, but different individuals draw widely varying conclusions from this relationship. Some view the processes of suburbanization that have dominated the development of U.S. cities for decades as being essentially unchangeable and a natural response to a confluence of interrelated factors: the mobility provided by the automobile; Americans' preference for single-family, low-density development; the lessening of the economic advantages to businesses of close proximity to each other; the desire of businesses to gain better access to a growing suburban workforce; and a continuing drive to escape growing congestion. In this view, continuing suburbanization will cause the automobile to remain the dominant mode of transportation for the foreseeable future, with travel demand continuing to grow. These individuals conclude that urban and transportation planning agencies should accept the continued dominance of the automobile and should seek to reduce adverse environmental impacts through technical and administrative improvements (improved emission controls, higher fuel economy, improved inspection and maintenance programs) while maintaining auto mobility through a combination of transportation initiatives (to increase vehicle load factors, initiate intelligent highways, including congestion pricing to rationalize highway use, and increase highway capacity) and planning flexible enough to allow land use shifts that will reduce congestion (e.g., removal of zoning constraints that artificially separate business and residential land uses).

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[175] Ron Jensen-Fisher, Federal Transit Administration, personal communication, 1993.

A second group believes that U.S. suburban growth patterns and automobile dominance are not inevitable but are instead the result of flawed public policies: that low-density development carries with it very large societal and environmental costs; and that changes in public policies, focusing on new transit services and denser land use, can shift U.S. land use and transit ridership toward European norms (i.e., higher densities and more balanced transport patterns). From their perspective. major shifts in land use toward denser urban and suburban centers can be achieved through suburban-rural development restrictions, minimum-density rules, restrictions on parking, fuel taxes, changes in income taxes, and so forth. These changes would then promote transit use as well as walking and bicycling, and would reduce overall tripmaking. At the same time, the introduction of new transit services would help to push land development patterns toward increased density, especially around the stations. In other words, the new transit services and land use controls would interact synergistically, each assisting the other-dense land use making transit work better, transit promoting denser land use.[176]

This section explores the role of urban structure in shaping, and being shaped by, the transportation system.

▮ Evidence for a Strong Relationship Between Urban Form and Transportation Energy Use

Demonstrating quantitative relationships between land use characteristics and transportation is made exceedingly difficult by our inability to examine the "control" case (what would have happened if the transit system had never been built or if the land use controls had never been applied?), the impossibility of proving cause and effect through statistical analysis, the complexity of land use and transportation interactions, and the great variability among cities that complicates cross-sectional analysis.

Although arguments favoring the ability of public policy choices to transform urban form and urban transportation patterns come from a variety of sources, one of the most prominent is a cross-sectional study of the urban structure and transportation systems of many of the world's medium and large cities performed in 1980 by Peter Newman and Jeffrey Ken worthy of Murdoch University in Perth, Australia (hereafter referred to as N& K).[177] This study concludes that there exist statistically significant relationships between transportation variables and variables describing urban structure, and highlights differences between "auto-oriented" U.S. cities and the more transit/walking/bicycling-oriented cities of Europe and Asia. This analysis cannot prove cause and effect, it does not account for some important city-to-city differences that affect transportation (e.g., differences in income levels and stage of development), and it is extremely sensitive to the manner in which boundaries are drawn defining cities' components (central business district, central city, metropolitan area, etc.). Further, it does not account for differences in the age of cities and the dominant transportation technologies present when the cities were formed. However, many of the relationships described (especially those that remain strong when the range of cities is narrowed to the subset of prosperous European, North American, and Australian cities) appear to transcend these differences and analytic problems and to express truths about transportation-urban structure relationships that should be robust over time.

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[176] See E.A. Deakin, "Jobs, Housing, and Transportation: Theory and Evidence on Interactions Between Land Use and Transportation," *Transportation, Urban Form, and the Environment*, Transportation Research Board Special Report 231 (Washington, DC: National Academy Press, 1991).

[177] P.G. Newman and J.R. Kenworthy, *Cities and Automobile Dependence: A Sourcebook* (Hants, England: Gower Publishing Co., 1989).

And despite criticisms from a number of transportation analysts, many of N&K's numerical results for U.S. and European cities agree well with other sources.[178]

Density and Job Balance

Although there are some conspicuous exceptions (e.g., New York City), N&K found that the U.S. cities in their sample could be characterized generally as low density—residential densities below 20 persons per hectare (ha, or 8 persons per acre), compared with European cities' 50/ha and Asian cities' 150/ha. Whereas European and Asian central cities tend to have balanced job and residential concentrations, U.S. central cities tend to have high job concentrations with few residents. If a few of the old U.S. cities such as New York and Chicago are excluded, the remaining U.S. inner cities in N&K's survey are one-half to one-third as dense as European inner cities, and one-tenth as dense as the Asian cities they examined. And the outer areas of the U.S. cities have very low density, perhaps one-fourth of that in Europe. Finally, despite the dedication of U.S. central cities to jobs rather than residences, these cities are less centralized in jobs than European and Asian cities; in the United States, jobs are scattered throughout the metropolitan areas.

Automobile Orientation

Along with the above differences in basic structure, the U.S. cities in N&K sample are far more automobile-oriented than their European counterparts. In 1980, the U.S. cities had three to four times the road area per capita of European cities, 80 percent more parking spaces per 1,000 workers, and considerably less public transport service—about 30 vehicle-kilometers (19 vehicle-miles) per person versus 79 vehicle-kilometers per person in Europe. Not surprisingly, measures of auto and transit use are substantially different, as well. In 1980, only about 4 percent of passenger miles in the U.S. cities were captured by public transport, versus about 25 percent in Europe (65 percent in Asia). In commuting, about 12 percent of worktrips were on mass transit in U.S. cities versus 35 percent in Europe and 60 percent in Asia. Furthermore, in U.S. cities, most of the non-transit trips were by automobile; only about 5 percent of workers walked or bicycled to their jobs, versus 21 percent in Europe and 25 percent in Asia.

Travel Volume

Besides traveling more often in private vehicles, Americans also traveled much farther than Europeans or Asians. In 1980, people in U.S. cities averaged about 13,000 kilometers of travel in highway vehicles, versus 7,400 kilometers per person in European cities and 4,900 kilometers in Asian cities. Presumably, the cause of these travel differences is a combination of the higher density and more mixed residential-employment development of European and Asian cities (i.e., less need to travel long distances to obtain services, reach jobs, or visit friends) and, perhaps, some amount of lower "mobility" in the European and Asian cities, where mobility might measure in part the opportunity to travel but might also reflect free choice to travel based on lifestyle differences.

Energy Use Per Capita

In any case, the differences in per capita annual travel distances and modal choices create a large disparity between U.S. and European or Asian cities in the amount of energy per person expended on transportation. N&K estimated that in 1980, the U.S. cities averaged nearly 59,000 megajoules (MJ; about 55 million Btu, or 450 gallons) per capita of gasoline use versus 13,000 MJ for the

[178] E.g., Pucher, Pisarski.

European cities and 5,500 MJ for Asian cities.[179] Although the European and Asian cities probably use more electricity for train transport, and the per capita energy values do not include air travel, there remain huge disparities in total energy use for transportation between the United States and Europe or Asia. For example, the Lawrence Berkeley Laboratory estimates that total per capita transportation energy use in 1987 was 57,700 MJ for the United States and only 21,200 MJ for France, 13,200 MJ for Italy, 18,300 MJ for Great Britain, and 12,400 MJ for Japan.[180]

Vehicle Efficiency

Part of the disparities in transportation energy use between U.S. and European or Asian cities reflects differences in the technical efficiencies of the vehicle fleets in these cities (e.g., the average fuel economy of the auto fleets). For example, in 1980, the U.S. light-duty vehicle fleet averaged 14.9 mpg, versus 19.6 mpg for Japan, 27.5 mpg for France, 28.7 mpg for Italy, and 22.6 mpg for Great Britain.[181] In 1987, the disparity of efficiencies had lessened somewhat: Japan's fleet averaged 21.4 mpg, France's 26.9 mpg, Italy's 29.9 mpg, and Great Britain's 25.3, that is, in general a modest increase in efficiency over 1980, whereas U.S. efficiency levels had increased 17 percent to 17.5 mpg.[182] Thus, while Italy total per capita transportation energy use in 1987 was but one-fifth that of the United States, its auto fuel efficiency was only 70 percent better. An examination of the other values indicates that most of the transportation energy differential between the United States and Europe must be accounted for by factors other than technical efficiency.

Residential Density and Gasoline Use

Urban structure, with its effect on a variety of transportation variables, appears to be a major explanatory factor in the differential energy use. N&K believe that urban population density is a key explanatory variable for per capita gasoline usage. Their plot of gasoline use versus urban density in figure 5-3 appears to show a strong relationship between population density and gasoline use. In the graph, per capita gasoline consumption rises steeply at population densities of about 30 persons per hectare (12 persons per acre); N&K consider this to be a breakpoint for the success of nonautomobile modes. N&K further assert that a strong role of density in influencing gasoline use appears *within* single urban areas as well as across different cities: according to their data, in 1980 the average resident of the New York Tri-State region used 44,000 MJ (42 million B(u); residents of the less-dense outer area of the region used 60,000 MJ; residents of New York City used 20,120 MJ; and residents of Manhattan used 11,860 MJ. For comparison sake, they cite the exurban residents of the outer Denver area, who they claim used an astonishing 137,000 MJ—more than a thousand gallons-of gasoline per year.

An examination of the curve reveals some problems with the concept of a simple density-energy use relationship, however. First, the entire right-hand side of the curve consists of only two points (for Moscow and Hong Kong), the first of which represents a city that exercises an extraordinary authority over transportation choices—an authority not possible in most of the cities in the sample. Second, for cities with annual per capita gasoline usages greater than 20,000 MJ, there ap-

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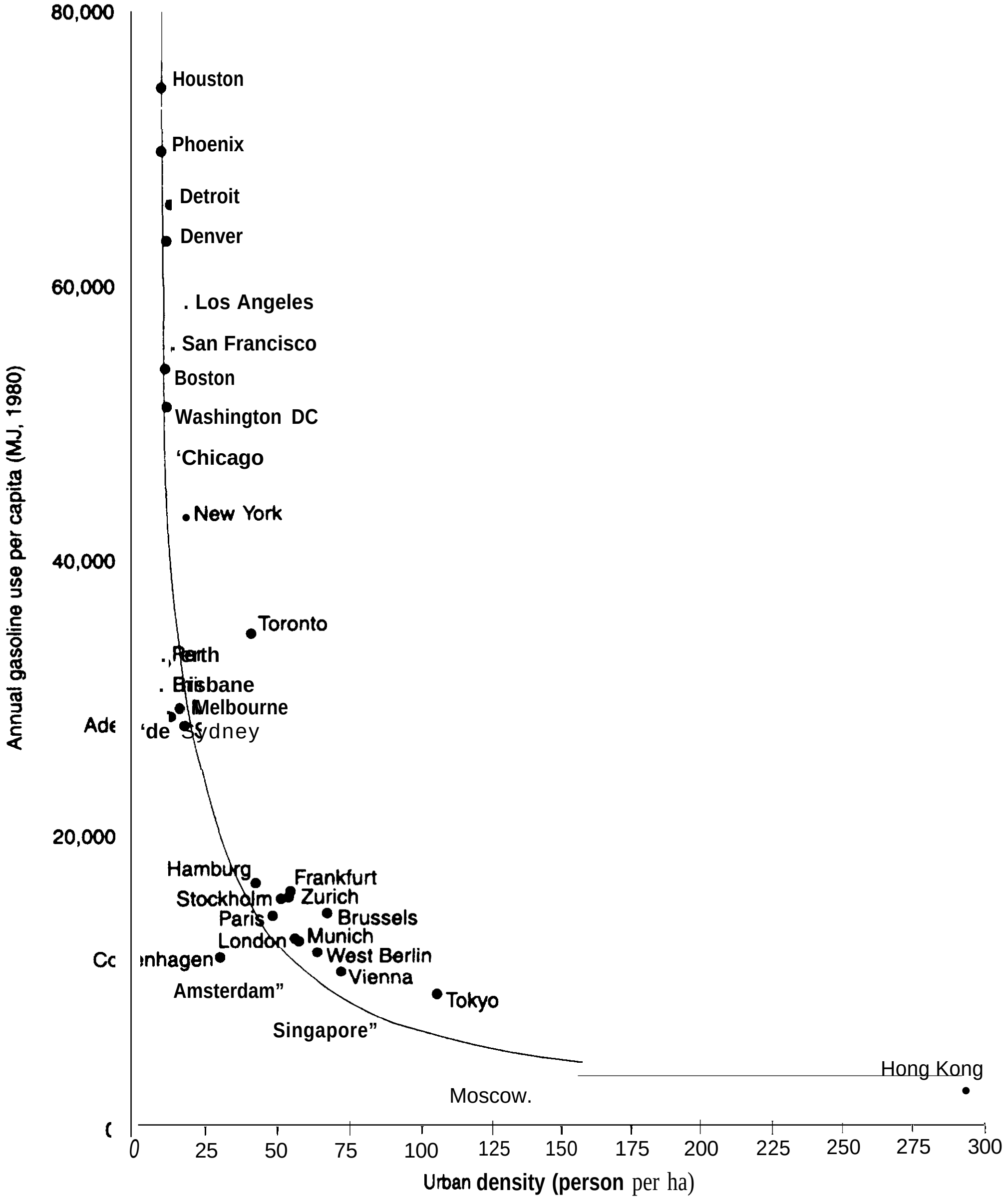
[179] These values appear to be overestimates although the relative values appear about right. Note that the LBL values for 1987 (below) for *national* per capita energy use are lower than the N&K values for gasoline {rely even though 1987 per capita energy use was higher than 1980 energy use. The LBL values include nongasoline energy. and city per capita transportation energy use seems likely to be lower than national per capita use (since, according to N&K, higher density areas such as cities are associated with less travel than lower density rural areas.

[180] L Schipper "Energy Use in Passenger Transport in OECD Countries Changes Between 1970 and 1987," *Transportation: The International Journal*, April 1992.

[181] Davis and Morris, op. cit., footnote 9. table 1.7.

[182] Ibid.

FIGURE 5-3: Gasoline Use Per Capita Versus Urban Density, 1980



SOURCE PG Newman and J R Kenworthy, *Cities and Automobile Dependence A Sourcebook* (Hants. England Gower Publishing Co 1989)

pears to be virtually no relationship between density and gasoline use; cities with very similar (low) density development have an extraordinarily wide range of gasoline usage. And between about 32,000 and 6,000 MJ per year, although there appears to be a functional relationship, the "spread" among the data points is very large. Finally, some of the data appear suspect—for example, Los Angeles is shown to have approximately the same urban density as New York. The reason presumably is that N&K have included very large geographic areas in their definition of "urban area, " thus incorporating a wide range of high-density inner-city and low-density suburban areas. It is difficult to believe that merging such areas does not weaken the reliability of the relationships uncovered.

Role of Other Variables

N&K contend that other urban and transportation attributes, some related to population density but not in lockstep with it, also influence gasoline use and overall transportation energy consumption. For example, they assert that an area's orientation to private vehicle usage impacts gasoline use. This orientation is measured by variables such as the length of road available per vehicle, the parking spaces per 1,000 vehicles, and the average speed of highway travel. Interestingly, cities with the highest average traffic speeds tend to have the highest per capita gasoline consumption even though their ability to keep traffic flowing freely leads to an efficiency advantage per vehicle-mile. One interpretation of this relationship is that travel demand is encouraged by greater ease of travel, so that providing more road space and more parking spaces encourages increases in auto trips. This, in turn, would imply that measures designed to reduce congestion by increasing capacity, which are supported by arguments that they will save time and energy, may instead increase energy use and time spent in travel by encouraging auto travel and urban sprawl. And the converse might be true: congestion may be useful in encouraging behavioral and land use changes that reduce energy use. The argument that providing more road capacity will tend to increase travel and energy use is strongly disputed by some analysts, who claim that it applies only to situations where there is unmet travel demand and that this is not now the case in the United States.[183] Further, there is an alternate explanation of the relationship between travel speed and gasoline usage: that it is low density (and the resulting separation of destinations) that is actually driving travel demand and gasoline use. The apparent speed/gasoline use relationship could be a statistical artifact caused by the strong collinearity between speed and density.

Another important variable closely associated with energy use is the degree of centralization of the city. Maintaining a strong central focus allows alternative modes, including walking and bicycling, to function, while diffusing population and employment throughout an urban area actively encourages private vehicle use and makes efficient transit difficult or impossible.

Public transport performance represents another set of variables that are strongly correlated to gasoline use and overall transportation energy consumption. In this case, gasoline usage is negatively associated with variables such as the amount of transit vehicle service, measured in vehicle-miles per capita. This relationship seems almost a tautology rather than a cause-and-effect relation, however, because the existence of an intensive transit network is most likely in those cities with high densities and centralization of activities-cities likely to have relatively low levels of both vehicular travel and gasoline usage.

The conclusion N&K draw here is that major savings in transportation energy use beyond those achievable with improvements in the technical efficiency of vehicles will require *both* improvements in mass transit systems and significant shifts in land use configurations. The land use shifts can be termed "reurbanization," designed to increase the density of residential and commercial activity, to centralize this activity, and to mix the two activities together. Specific physical shifts include in-filling vacant land that has been "leap-frogged" in the rush toward suburbanization; redevelopment of industrial and warehousing sites to more suitable uses; rezoning and rebuilding old, declining low-density districts; building intensive mixed-use developments; developing the air rights over rapid transit uses; developing un-

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[183] C.A. Lave "Future Growth Of Auto Travel in the U. S.: A Non-Problem, " paper presentedat Energy and Environment in the 21st Century, Massachusetts Institute of Technology Conference, Mar. 26-28, 1990.

used highway rights of way; physically restricting outer area growth (e.g., by preventing the subdivision of rural land); and expanding housing development in the central city.

For this report, the obvious question raised by N&K's work is, what does it imply for U.S. prospects for reducing transportation energy use? This question breaks down into three components:

1. Are the relationships described by N&K reliable?
2. Do the relationships represent cause and effect, that is, will changing urban structure lead to changes in transportation energy use, and will changing transportation systems tend to lead to changes in urban structure?
3. If the answers to question 1 and 2 are yes, can we effect the necessary changes? The latter is an issue especially when changes in urban structure are contemplated.

Reliability of the Data

As discussed above, questions can be raised about N&K's data. Anybody who has worked in transportation analysis knows that data on travel behavior are highly variable from country to country and often between different cities within the same country, including the United States. Further. most data are collected by political jurisdiction rather than by agreed-upon segments in urban structures (e.g., central business district or central city). In reality. urban analysts have no quantitative agreement about where urban boundaries should be drawn. Thus, it is difficult to know how reliable N&K's data are or whether their boundaries have been selected in a consistent analytic framework; N&K themselves take care to discuss the numerous data problems they faced. One of the more disturbing problems that N&K (and most other analyses of transportation energy use) faced was getting accurate measures of per capita gasoline consumption in cities. For the most part, consumption has been measured by using data from gasoline sales. but these sales may be poorly related to actual consumption within urban boundaries. OTA draws no conclusions about the reliability of the data and the relationships drawn from them, but notes that the latter generally agree with conventional thought about transportation and urban structure.

Cause and Effect

Cause and effect is a critical issue for the policymaker, because it clearly is important to know whether policies that tend to yield increases in urban density can be a useful part of a transportation energy conservation strategy. Also, it is useful to know whether adding a transportation system such as rapid rail will tend to increase urban density, yielding a synergistic impact—reduced travel requirements and better conditions for economic success of the new system.

Although cause and effect cannot be proved by examining statistical relationships, case studies can provide strong prima facie evidence for or against such a relationship. Unfortunately. most Western cities are reducing, not increasing, their densities, so case studies of increasing density are not readily available. It seems logical that increasing density and increasing the mix of land uses would reduce travel requirements by providing closer access to goods and services, but this must be treated as speculative (though probable).

As discussed in the previous section. studies that examine differences in transit usage, land use density, and auto travel at a single point in time[184] cannot show cause and effect or even demonstrate a relationship between land use changes and travel behavior (or between added transit services and travel behavior) over time, even though they may claim to. Further, the role of demographic differences among different land uses, and the impact of these differences on travel behavior, further complicate the issue of cause and effect; as discussed earlier, to the extent that people with" low-travel" characteristics are attracted to urban areas, part of the "cause" of low rates of travel in denser land

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[184] For example, Goldstein et al., op. cit., footnote 155.

uses will be the characteristics of the people living there, not the density per se.

Can changes in transportation systems have significant effects on urban structure, that is, can the introduction of new systems encourage development into forms that would support increased use of that system, creating positive feedback between the transport system and urban land use? Because new roads and transit systems have been added to cities, there is opportunity for obtaining better evidence about the effects of such systems on urban structure. Nevertheless, documenting a transport-created impact is difficult, because land use is affected by many factors and changes slowly. In particular, studies of past changes in transportation systems tend to suffer from a range of problems:

> . . . lack of explanatory power for observed correlations, difficulty in distinguishing cause and effect, failure to distinguish economic shifts within a region from (transportation) investment-induced growth, double counting of benefits, (scoping too narrow) to identify possible shifts in production processes and changes in economic and social organizations that might occur as a result of important new transportation investments.[185]

Recent attempts to document such impacts appear to indicate, however, that transport system shifts in the early history of U.S. cities had major impacts on urban form (e.g., the introduction of freeways greatly abetted the decentralization of U.S. cities), but that in recent times there has been less linkage between new transportation system changes and shifts in urban structure.[186] In general, the studies indicate that transportation availability and quality are only two of a number of critical factors in location and development, and by themselves, investments in transportation will do relatively little to change land use, especially if the hoped-for direction in land use is counter to general market trends.

Investigations of new rail transit investments have identified localized benefits, but regional benefits are described as "quite modest. "[187] For example, higher-density development will tend to be attracted to land around rail transit stations, but only when other conditions are right-and in some cases, such development might other-wise have occurred elsewhere in the area (e.g., at a freeway intersection). Further, some suburban-oriented rail systems have worked in ways opposite to the densification hoped for by transit proponents; by easing the difficulty of commuting to the central core from some distant suburban locations, thus spurring development at these fringe locations.[188] A key to understanding the likely impacts of transportation system changes is that in most cases, urban residents in modern U.S. cities already have very high levels of mobility; new systems cannot offer the huge increases in mobility that they might have in the early history of cities.

An important variation of the above issue is whether or not the building of new highways—or expansions of existing ones—might lead to land use changes (e.g., shifting development from high-density to low-density areas) that would tend to "use up" the new travel capacity they create. The idea that adding highway capacity to combat congestion is essentially a self-defeating exercise is a common theme of antihighway arguments. Although there is evidence to support the thesis that new highways do create land use shifts that will add to the call on their capacity, the evidence is not sufficient to support reliable estimates of the magnitude of this effect.[189]

Can We Hope To Change Land Use?

Without important shifts in land use, leading to denser, more centralized, more "European-style"

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[185] Deakin, Op. cit., footnote 176.

[186] Giuliano, Op. cit., footnote 121; and ibid.

[187] Deakin, op. cit., footnote 176.

[188] Ibid.

[189] Ibid.

urban areas, improvements in transit service are unlikely to have a major effect on transportation energy use. This automatically leads to the question, will Americans support such shifts and find the results desirable? This question, although perhaps unanswerable, can be illuminated by the following observations.

Lack of Examples

Few American cities have actually initiated a series of strong measures to focus development on the central city and restrict it in the suburbs. One is Portland, Oregon, which has established a number of planning measures to maintain compact development, including an Urban Growth Boundary to direct new development into the city rather than its suburbs, development of a light rail system, prohibition of automobiles in a key downtown corridor served by bus transit, and restrictions on parking spaces incorporated into new office development.[190] Claims for success of this effort include a constant volume of cars entering the downtown since the early 1970s, despite a 50 percent employment increase and a 43 percent transit share for commuters to downtown.[191] However, a focus on the city as a whole shows a distinctly different picture: from 1980 to 1990, the overall transit share in Portland dropped from 15.9 to 10.9 percent.[192] In addition, the number of persons driving alone increased by more than 30 percent, while the absolute number of transit users declined.[193] In fact, driving alone actually increased more than the increase in workers during this time period.[194] Further, much of the development channeled within the urban boundary has been low-density, suburban-type development; in response, Portland is now considering adopting minimum densities of development,[195] an unusual approach in a nation where zoning is virtually universally regarded as establishing ***maximum*** densities and land uses.

It maybe too early in the process to expect major improvements to show up in Portland. The Urban Growth Boundary still has within it enough developable land to allow 20 years of growth at suburban sprawl densities, and the light rail system, at this stage of its development, serves only about 15 percent of the population.[196]

What the Portland experience seems to show is that, in some cases, a reasonable local political consensus can be reached that radical and perhaps painful measures must be taken to solve transportation and land use problems; that these measures can make a positive difference in limited areas; and that it remains unproven whether these local measures will succeed on a citywide basis, but in any case success will not come swiftly. The problem with Portland and other models is that at best, they are "swimming in an automobile-oriented sea"; that is, they must overcome a national policy that seems designed to promote automobile travel by keeping gasoline cheap, encourage single-family home ownership, and build lots of roads.

Convergence of European and U.S. Transport Patterns

Although European cities, which are more oriented toward transit, bicycling, and walking than most U.S. cities, are often held up as models for the United States to emulate, in reality European

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[190] M.D. Lowe, *Shaping Cities: The Environmental and Human Dimensions*, Worldwatch Paper 105 (Washington, DC: Worldwatch Institute, October 1991).

[191] Ibid.

[192] A.E. Pisarski, *New Perspectives in Commuting* (Washington, DC: U.S. Department of Transportation, Office of Highway Information Management, July 1992).

[193] Ibid.

[194] Ibid.

[195] S. Sadler, Oregon Department of Energy, personal communication, Dec. 9 1992.

[196] Elizabeth Deakin, University of California at Berkeley, personal communication, 1992.

land use and transportation patterns are moving somewhat in the U.S. direction, with growing automobile dependency, growing transportation energy use, and increasing levels of suburbanization (this is discussed more fully in chapter 3). For example, between 1970 and 1989, U.S. light-duty vehicle (auto or light truck) ownership per capita went from 0.438 to 0.575, a 31-percent increase. In contrast, France's went from 0.242 to 0.410, an increase of 69 percent; Italy's increased by 140 percent, the United Kingdom's by 79 percent, and West Germany's by 98 percent.[197] Similarly. whereas U.S. travel energy grew only 13 percent between 1973 and 1988, European growth during that period was 55 percent, and Japanese growth was 76 percent.[198] This does not mean, however, that the United States and Europe are moving toward the same developmental and transportation future, although clearly they are converging. It seems quite likely, given their different starting points, basic transportation and urban planning policies, and geography, that European urban structures and transportation patterns will reach an equilibrium point closer to U.S. cities than they are now, but still be substantially more transit-oriented, of higher density, and lower in per capita travel.

Preferences of Residents Themselves

A critical component of a strategy to undertake the significant changes in urban form needed to make cities more transit-friendly and reduce urban tripmaking is the extent to which the goal of the changes—much denser cities with greater centralization and substantial blending of land uses—is desirable to urban residents. Americans may have serious reservations about the value of dense urban areas, but at least some of their reservations are based on false premises or on examples of inner-city life that do not accurately reflect what might be accomplished with proper planning and urban policy. For example, despite some perceptions to the contrary, there appears to be no positive relationship between population density and violent crime in cities: the less dense, automobile-oriented U.S. cities have just as much (and sometimes more) crime per capita as the old transit-oriented cities. On the other hand, the *distribution* of crime throughout a city may be as or more critical than its frequency, especially in influencing those groups most likely to wield political power. In low-density cities, high-crime neighborhoods may be well-separated from the upper- and upper middle-class neighborhoods whose residents wield the preponderance of political power; in denser cities, crime may be less easy for these residents to avoid.

There is no doubt that the quality of life in very dense, European-style cities is intensely different from that in the spread-out, automobile-oriented cities so prevalent in the United States. It may be fruitless to place some abstract value on each urban form, even though they clearly will have different travel consequences. What is important is the perception of the residents, and most important, the perception of those residents most likely to influence the political process. For example, there can be little doubt that residing in the suburbs or in the lower-density portions of auto-oriented cities such as Houston allows residents to have larger houses and often allows private open space and gardens, amenities that are impossible in a dense city except for the extremely wealthy. Similarly, residing on a cul-de-sac in a suburban neighborhood devoid of commercial enterprise allows residents to sustain a relatively “low and slow traffic”’ environment and to avoid the traffic concentration and changes in aesthetic values that often accompany commercial development. Although these amenities may come at a price—perhaps less access to cultural amenities and near-total dependence on the auto for mobility—the

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[197] Davis and Strang, op. cit., footnote 134.

[198] L Schipper et al., Lawrence Berkeley Laboratory, "Historic Trends in Transportation Energy Use An International Perspective," paper presented at the Asilomar Conference on Transportation and Global Climate Change, 1991.

majority of Americans have appeared willing to pay this price up to now. And although the price of continuing this style of development will increase in the future (e.g., with higher levels of congestion), one can only guess at the likelihood that these increased costs will greatly alter Americans' apparent preference for spreading out their cities.

Incentives for, and Time Frames of, Changes

Reductions in energy use hardly qualify as strong incentives for individuals to favor changes in their transportation choices. The cost of energy is a relatively minor part of both the monetary (quantitative) and the total personal costs of transport, and for auto travel, it is at a historic low in proportional terms.[199] Consequently, transportation choices are less likely to be based on energy than on factors such as travel time and comfort. This makes the attractiveness of different urban forms and different travel modes less easy to characterize. For example, although high urban density and concentration lead to generally shorter-length work trips, work travel *time* in these cities is often longer than in cities with lower population and employment densities because of the differential levels of congestion[200] and because sprawl "offers more diverse opportunities for faster commutes through changes of residence or jobs, the relocation of firms, or the choice of uncontested routes."[201] On the other hand, because worktrips represent only about one-quarter of all trips, the lower overall number of trips per capita in denser urban areas will likely yield significantly lower total travel time budgets for their residents than for the residents of lower-density, auto-oriented cities. As for the differential lifestyles and accessibility to alternative activities offered by different urban forms, the subjective nature of these differences prevents a fair comparison.

Because energy costs are highly visible to motorists (i.e., they see them at the gas pump every week), however, large increases in gasoline price may have an impact on travel behavior somewhat disproportionate to their impacts on total travel costs. Fuel cost is not irrelevant.

With regard to the improvement of public transport, N&K observe that only cities with extensive rail transit networks have succeeded in maintaining a high proportion of total trips on mass transit.[202] The authors relate this to the ability of trains to maintain comparatively high speeds—average speeds for urban buses are low (about 13 mph in both the United States and Europe, less than 10 mph in Asian cities), whereas train systems are much faster everywhere (typically about 25 mph).[203] In Europe and Asia, trains have substantially higher average speeds than private vehicles, although door-to-door times still suffer from time spent waiting for them and getting to and from stations, and it is likely that commuters "weigh" minutes of waiting time more heavily than minutes spent in a vehicle.[204] On the other hand, the relative success of rail transit may occur only because the majority of rail systems have been built in very densely populated cities where auto ownership is expensive, auto (and regular bus) traffic is extremely congested, and guideway transit is a particularly viable option for travel.

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[199] U.S. Congress, Office of Technology Assessment, *Improving Automobile Fuel Economy: New Standards, New Approaches*, OTA-E-504 (Washington, DC'. U. S. Government Printing office, October 1991).

[200] Giuliano, op. cit., footnote 121.

[201] P. Gordon et al., "The Commuting Paradox: Evidence From the Top Twenty," *American Planning Association Journal*, autumn 1991, pp. -116-420.

[202] Newman and Kenworthy, op. cit., footnote 177.

[203] Ibid. N&K do not say whether their values for trains apply (rely to mass transit, or to all trains in an area including commuter rail.

[204] Especially for minutes spent sitting in a car sea--if they are standing on a bus or train, vehicle time may be just as onerous as waiting time, but the point to be made here is even stronger then.

Because station waiting times and required transfers are weighted heavily in travel decisions, a bus system that allows neighborhood collection coupled with travel on exclusive rights of way might offer strong competition to trains even though top speeds are lower.

Another key question here is the time frame in which potentially significant changes in urban form could take place. Critics of transportation analyses that rely on changes in urban form to alter the transportation system note the long life of urban structures, the significant expected slowdown in U.S. population growth, and the highly developed nature of the existing auto-oriented transport system, as well as the multitude of factors aside from transportation considerations that play an important role in household and business locational decisions.[205] On the other hand, projections of growing urban congestion, with substantial increases in travel times and, presumably, with transportation considerations playing a renewed role in locating residences and offices, imply that transportation characteristics could become a major focus of locational decisions. As noted in chapter 4, the available forecasts of future congestion levels are likely to be overestimates, in part because they ignore likely changes in travel patterns.

Policy Questions

As a final point, support for changes in urban structure clearly will depend on the nature of the policy mechanisms necessary to achieve the desired changes. Although it is easy to draw up lists of measures that would contribute to denser urban forms and improved transit services, it is far from obvious how much money will have to be spent and how draconian the various taxation and zoning measures might need to be. If the differences in cities observed by N&K could be attributed to differences in urban and transportation policies among the cities, this knowledge would help quantify the measures necessary. Unfortunately, statistical analyses cannot identify cause and effect, as noted earlier.

The causes of the U.S. pattern of suburbanization are matters of considerable disagreement. One point of view holds that government policy is not the major cause—that the most powerful forces affecting urban land use in the United States and worldwide are more likely to be consumer preference, income, geography, and time (i.e. when was the city, or section of the city, developed?) than land use policies and economic incentives, although the latter are important. There are strong empirical arguments for this point of view: for example, the densest cities in the developed world are old cities whose land use patterns and densities were shaped by reliance on pedestrian travel. Portions of cities built during the era of horse-drawn carriages, trolleys, rail systems, and autos appear to reflect the availability of these new transportation systems more than they reflect the price of gasoline; in looking at the different districts of older cities, the more recently developed districts generally are substantially less dense. And residential densities, especially as reflected in the size of homes and propensity for high-rise apartments rather than townhouses, appear to reflect income as much as they reflect zoning, as implied by the extreme densities of cities in developing countries.

A contrary point of view does not necessarily deny that single-family homeownership is a widespread goal of families throughout the developed world, but considers the pattern of public policy choices to be a critical element of the extent to which this desire is satisfied and the extent to which high-density living represents a satisfactory alternative.

It is certainly true that there are substantial differences between the United States and other, more densely developed Western nations in both land use and those public policies that might potentially affect land use. Aside from obvious dif-

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[205] Giuliano, op. cit., footnote 121.

ferences in urban residential density, even the suburban developments of Europe and Canada are more densely developed and more planned than those in the United States.[206] As for policy differences, U.S. local zoning policies tend to strongly favor separation of residential from commercial uses and low densities, whereas European policies favor mixed use and compact development. In Europe, much urban land is publicly owned, so government directly controls development of this land. U.S. State and local governments often provide essential capital infrastructure and services for suburban development, whereas European governments tend to provide selective infrastructure support to channel growth into compact development. Some European authorities simply prohibit low-density, scattered development, whereas this type of prohibition is extremely rare in the United States.[207]

Some analysts also question whether market surveys that show widespread preference for low-density over high-density environment truly demonstrate anything more than the natural result of policies that have undermined central cities and transformed them into places that are intensely undesirable.[208] Because most residents of urban areas cannot afford the few places remaining in central cities that are relatively safe, physically attractive. and socially vibrant, it is not surprising that they gravitate toward the low-density alternative. The argument here is that policies to nurture central cities, including provision of excellent transit services, restrictions on freeways, parking limits, and provision of open space, would allow virtually the entire central city to duplicate what is available only in small enclaves today, and would allow these areas to be affordable enough to reverse suburbanization trends and, in consequence, substantially reduce travel requirements and auto use in urban areas.

Conclusions

Policy makers wishing to make significant changes in urban areas and their transportation systems+. g., increasing urban density and degree of centralization, and increasing the role of mass transit—are faced with substantial uncertainty about the effectiveness of various policy options. In particular, there remains substantial controversy about the role government policy can play in shaping urban structure and transportation, and about how the patterns of urban development and urban transportation systems interact with and help shape each other. This uncertainty means that policy makers will have to accept substantial risk that the results of expensive and politically difficult policies will be less than they hoped for. The available evidence does strongly imply, however, that attempts to achieve large changes in urban transportation are unlikely to be successful without policies that integrate transport changes—for example, development of new mass transit systems—with conscious efforts to direct development into patterns that will support the changes. Thus, new rail transit systems are unlikely by themselves to transform urban areas or even to make large inroads in private vehicle use. On the other hand. a strategy that combined new transit systems with strong development controls and incentives, and changes in the travel incentives that currently favor private vehicles (parking restrictions. removal of free parking incentives, congestion charges, and so forth) represents a far more credible potential for success. However, many of the necessary policy changes will be politically controversial, and the trends in urban development and travel they seek to change are long-established and accepted in this country, and indeed are beginning to take hold, albeit in modified form. in Western Europe and elsewhere. This de-

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[206] Pucher, op. cit., footnote 112.

[207] Ibid.

[208] Bourne, op. cit., footnote 162.

gree of controversy, coupled with the uncertainty about the results of the policies, will mean that elected officials may have a difficult time winning political approval for such strategies.

INTERCITY TRAVEL AND HIGH-SPEED GROUND TRANSPORTATION SYSTEMS

Although the great majority of passenger trips are local, the greater length of intercity trips means that a much larger percentage of passenger miles traveled are intercity. According to data from the 1990 National Personal Transportation Survey, only 1.2 percent of all personal trips in private vehicles are at least 75 miles in length, but these trips represent 26 percent of all *person-miles* of personal travel. Similarly, only 1.2 percent of all personal trips using *all* modes of transport are at least 75 miles in length, but these longer trips represent nearly 28 percent of all travel.

The automobile is the dominant intercity travel mode in the United States, with commercial aviation also having a strong share. The automobile's primary advantages are low cost, especially for group travel, door-to-door service, and convenience—it provides continuing transportation service after arrival. For trips less than 100 miles, the automobile is generally faster than other modes, since there is no need to reach a station or to wait for a ride. For longer trips, air travel may offer a significant time advantage and accounted for about 17 percent of intercity passenger miles in 1989;[209] it undoubtedly captured a much higher percentage of passenger-miles for trips greater than 100 or 150 miles. Bus and rail play minor roles nationally—in 1989, 1.2 and 0.6 percent, respectively[210]—but rail service is significant in some Northeast and California markets.

As discussed in chapter 2, intercity travel is expected to continue to grow strongly well into the next century. It is not clear, however, how well the road and air networks will accommodate increased travel. For example, during the past decade, road congestion has grown significantly in major metropolitan areas, especially Los Angeles, Washington, DC, San Francisco, and San Diego, and urban congestion is widely expected to increase substantially during the coming decades. Unfortunately, data on *intercity* highway travel are crude, and travel patterns and congestion severity frequency are uncertain, making projections of future congestion problems quite difficult.

Similar problems exist with forecasts of air traffic congestion. The Federal Aviation Administration indicates that the average delay time per flight increased by one-third during 1980-88, and it projects that the number of congested airports (those experiencing annual flight delays of at least 20,000 hours) will nearly double, to 41, by 1998.[211] However, these forecasts are based on rather poor data and the assumption that airlines will continue to funnel passengers into saturated airports. Much airport congestion is due to airline routing strategies rather than to an outright shortage of facilities. For example, at Chicago O'Hare, Dallas-Fort Worth, Atlanta, and Denver, the critical congestion trouble spots, most passengers are making connections rather than arriving at their final destinations. If the airlines using these airports as their hubs were to change their operating practices, they could substantially lower congestion levels.[212]

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[209] Motor Vehicle Manufacturers Association (now American Automobile Manufacturers Association), *Facts & Figures '91* (Detroit, MI 1991), p. 55.

[210] Ibid.

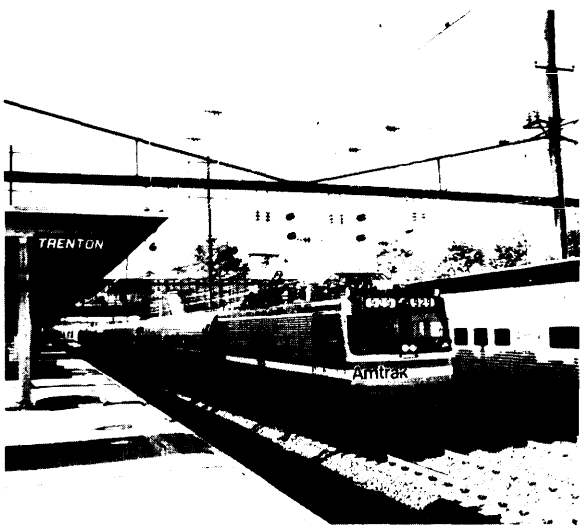
[211] U.S. Department of Transportation, Federal Aviation Administration data, reported in U.S. Congress, Office of Technology Assessment, *New Ways: Tiltrotor Aircraft and Magnetically Levitated Vehicles*, OTA-SET-507 (Washington, DC: U.S. Government Printing Office, October 1991).

[212] Ibid.

Despite these uncertainties, it is likely that both auto and air travel will experience significant increases in congestion over the coming decades. These potential problems may offer an opportunity to shift travelers to more energy-efficient modes in the denser and more congested intercity corridors. This is the thesis behind current attempts to promote HSGT (high-speed ground transportation) systems in several markets—Miami-Orlando-Tampa, Cleveland-Columbus. San Diego-Los Angeles-San Francisco-Sacramento-Reno-Las Vegas, Atlanta-Columbus/Macon-Savannah, the Northeast Corridor (Boston-New York City-Washington, DC), and others. These systems are either high-speed steel-wheel-on-steel-rail trains capable of speeds well in excess of 100 mph (the French TGV—Train a Grand Vitesse--can go about 185 mph, and speeds of 200 mph or more are anticipated soon) or magnetically y levitated (maglev) trains capable of even higher speeds (the fastest systems are expected to be able to achieve more than 300 mph). Ideally, such systems would be linked to major airports and would serve trips primarily in the 150- to 500-mile range, freeing airport capacity for longer-range trips where the superior speed of air travel is critical. These systems are described in more detail in box 5-5.

The potential of high-speed ground transportation systems for intercity trips less than 500 miles long has been studied by the Transportation Research Board[213] (TRB) and by OTA.[214] The results of the studies are quite similar.

Both OTA and TRB found that high-speed ground transportation systems were technically feasible but expensive: there are very few intercity corridors in which an HSGT system is likely to pay for itself. so government subsidies would be necessary. TRB also concluded that "considerable development and testing remain before maglev systems can be shown to operate safely and reliably in revenue service,"[215] whereas high-speed rail systems are available today. TRB found that new HSGT systems would require ridership levels between 2 million and 17 million per year to cover their capital and operating costs, with the range associated with differences in capital costs, operating costs, and fare levels.[216] **The** "most likely" break-even passenger volume for a HSR system was estimated at 6 million riders annually. At present. only one city pair in the United States—Los Angeles-San Francisco--has air ridership greater than this. By 2010, only four city pairs are expected to exceed this mark—Los Angeles-San Francisco. Boston-New' York, Washington, DC-New York, and Los Angeles-Phoenix.



NATIONAL RAILROAD PASSENGER CORP

Amtraks Metroliner is the fastest train in North America, reaching 125 mph. Proposals for new U S high speed rail systems envision much higher speeds to 200 mph or even higher

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[213] Transportation Research Board, *In Pursuit of Speed: New Options for Intercity Passenger Transport*, Special Report 233 (Washington, DC: National Research Council, 1991).

[214] Office of Technology Assessment, op. cit., footnote 211.

[215] Transportation Research Board, op. cit., footnote 213, Executive Summary.

[216] Capital costs will vary with rights-of-way costs, type of system and requirements for precision alignment, geological-topological conditions of the rights-of-way, and other factors. Operating costs will depend on speed, frequency of service, train size, and so forth. Fare levels will depend heavily on competition for ridership, especially with airlines.

BOX 5-5: High-Speed Ground Transportation Systems

The two primary candidates for high-speed ground transportation (HSGT) systems in the United States are steel-wheel-on-steel-rail trains and magnetically levitated ("maglev") systems The two systems are described below

High-speed rail (HSR) systems range from Improvements to conventional rail systems producing speeds of up to 125 mph to new train technologies operating on exclusive, grade-separated tracks that can achieve speeds close to 190 mph in actual passenger service and have achieved speeds greater than 300 mph in prototype testing Improvements to *conventional systems* include eliminating grade crossings, switching from diesel to electric motors, straightening curves and Improving track quality, improving overhead power transfer systems, introducing advanced trains that run on conventional track (e g , tilt trains with improved suspension/wheel tracking systems that allow high speeds on curves without compromising safety or discomfiting passengers), and improving signaling and train controlling systems *All-new* HSR systems demand a new track and more radical technology to achieve speeds considerably higher than the 125-mph limit for upgraded conventional systems The current state of the art is represented by the latest Japanese Shinkansen ("bullet train"), at about 170-mph top speed, and the French Train a Grande Vitesse (TGV), at about 185 mph.[1] These systems have completely grade-separated, very high-quality track dedicated to high-speed service, with rights-of-way that have minimal curvature and grades Propulsion systems are electric, cars are lightweight and aerodynamic, and signaling, communications, and train control systems are automated and very precise Although a version of the TGV has achieved more than 300 mph, the costs of speed in terms of energy use, costs, and, potentially, safety are extremely high, and many consider 200 to 220 mph a more likely goal for sustained service

Maglev systems are trains that operate suspended in air on fixed, dedicated guideways, held up by magnetic forces and propelled by linear electric motors High-speed versions are considered capable of speeds of 300 mph or greater The two most advanced high-speed systems are quite different: a German system wraps around its guideway and uses ordinary electromagnets onboard to lift the lower portion of the vehicle up toward the guideway by attraction, and a Japanese system uses onboard

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[1] Transportation Research Board, *In Pursuit of Speed New Options for Intercity Passenger Transport* Special Report 233 (Washington, DC National Research Council, 1991)

For most proposed corridors, HSGT breaks even only if costs are low compared with typical estimates, fares high compared with current air fares, and ridership at least as great as current air travel volume—all of which is unlikely.

Although maglev systems may well have lower operating costs than HSR systems (see below), capital costs are the primary components of high-speed systems, and maglev capital costs maybe as much as twice as high (per seat-mile) as high-speed rail systems. OTA found that infrastructure for a high-speed rail system in the Northeast Corridor based on the French TGV system would cost about 9 cents per seat-mile versus about 18 cents per seat-mile for a maglev system based on the German Transrapid.[217]

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[217] Office of Technology Assessment, op. cit., footnote 211, table 5-2. Assumes 20-year amortization, 6-percent interest, 3.4 billion seat-miles per year.

BOX 5-5: High-Speed Ground Transportation Systems (cont'd.)

superconducting magnets to repel the vehicle upward from the guideway The German system maintains a very small (3/8 inch) gap, which requires a very precisely built guideway and a sophisticated control system to maintain the correct gap width;[2] the Japanese system maintains a much larger (4 inch) gap and can use a guideway built to less stringent standards The Japanese system must use wheels at speeds less than 60 mph because it cannot maintain the gap below these speeds

The high speeds of maglev systems demand minimum curves and very gradual grade changes, complicating the assembly of a suitable right of way

There are no commercial high-speed maglev systems in operation The most advanced system is the German one, which has been in testing since 1989 and has reached speeds of 270 mph However, low-speed maglevs are in commercial service in Berlin, Germany and Birmingham, England

HSR and maglev systems will compete in basically the same markets and in many ways are quite similar Although maglev systems probably will be faster than HSR systems, for the faster HSRs and for most trips, the speed differential should not make much difference in total travel time Both systems will require dedicated rights-of-way with few curves both will be electrically propelled, and both will require sophisticated control systems Maglev systems may require less maintenance than HSRs because there are no moving parts, and no physical contact occurs between vehicle and guideway A potentially critical advantage of HSRs is their ability to operate on existing track, giving them easy access to urban centers Conceivably, the Japanese system might gain similar access if the wheels required for less than 60-mph travel were designed to be compatible with existing track This would however create some challenging engineering problems (e g protection of the guideway induction coils from stresses exerted by ordinary rail traffic)

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[2] A system based on attraction as is the German train is inherently unstable, because the force attracting the train to the guideway gets stronger as the train gets closer to the guideway This creates the need for the sophisticated control system

SOURCE Transportation Research Board *In Pursuit of Speed New Options for Intercity Passenger Transport* Special Report 233 (Washington DC National Research Council, 1991)

Why have high-speed rail systems been so successful in Europe and Japan but not appeared in the United States? Although proponents of these systems argue that the only reason is the failure of U.S. transportation policy to promote them, the actual reasons are more complicated (though it is true that the U.S. government has not made much of an institutional commitment to rail service). In particular, intercity corridors in the United States generally are less densely populated, with cities farther apart, than in Europe and Japan; therefore the potential ridership market in the United States is considerably smaller than in these regions. Further, both the European and the Japanese systems were built to add capacity to preexisting heavily traveled rail links, so they had a built-in baseline market. In contrast, a United States system would have to claim a huge percentage of the airlines' current market in 150- to 500-mile trips to have any chance at all of succeeding.

European HSR systems have other advantages. In particular, European and Japanese high-speed rail networks connect to well-established networks of intracity trains, enabling them to capture passengers who might be more likely to drive if (as in the United States) they needed an automobile once their destination was reached. Also, competition from autos and airlines is far less in Europe and Japan, because governments there have made a conscious policy decision to keep fuel prices very high and to limit air flights and keep air fares high,

The close spacing of European cities will provide into an even stronger advantage over the United States in the future. Completion of proposed European HSGT routes will yield a unified network, offering enormous options to train travelers throughout Europe; completion of proposed U.S. routes will connect, at most, only a few cities in any one network.[218]

Although U.S. HSGT systems maybe unlikely to break even financially, many would argue that this is scarcely a sufficient reason for ruling them out. As discussed in chapter 4, the competing highway system enjoys considerable subsidies and generates external costs (air pollution, energy security impacts of oil imports) that HSGT systems may be able to avoid. Also, although the costs of expanding highway or air networks may be quite high, their users generally pay average, not marginal, costs (except in the case of new toll roads). In contrast, a new HSGT system will rarely have any existing infrastructure with which to average costs, and its customers will face full marginal costs. For the highway and air networks, this represents a subsidy of new capacity by users of the current systems.

If governments chose to subsidize the capital costs of new HSGT systems—as is done with new urban transit projects—the financial prospects for these systems would appear attractive. Like urban rapid rail systems, the capital costs are the largest component of total costs. TRB estimated operating and maintenance (O&M) costs for an HSR and maglev system in a hypothetical corridor to be 9 cents per passenger-mile for either system; the range of estimated operating costs computed by various corridor studies is 8 to 26 cents per passenger-mile for HSR and 4 to 20 cents per passenger-mile for maglev.[219] Although all of these estimates are uncertain, if they are connect, HSGT systems with full capital subsidies would be competitive with air travel and even low-occupancy automobile travel. However, the principal competitor with an HSR or maglev system is likely to be air travel, which is essentially self-supporting; there will be substantial challenges to a complete capital subsidy for such a system.

SOCIAL COST PRICING POLICY

Key Issues

As discussed in chapter 4, motor vehicle users do not pay all the social costs of such use, nor do they fully account for the expenditures they do make in their travel decisions. In some instances, governments pay highway costs out of general funds (e.g., in the case of police and fire services) rather than from such user fees as gasoline taxes; in other instances, costs are hidden in the price of other goods (e.g., when "free" parking costs in shopping malls are hidden in the prices of the goods sold). Also, motor vehicle use creates nonmonetary costs that affect either other motorists on the road (uncompensated pain and suffering inflicted on others) or society as a whole (air pollution, global warming damages). Even when motorists pay their share as a class and account for the costs in their travel decisions, they may not be seeing the correct price (e.g., gasoline excise taxes may be meant to pay for highways, but tax charges per unit of travel bear only a modest relationship to the highway resources consumed by that travel).

The effect of motor vehicle user prices that are too low or are unaccounted for is an excess of travel; the added travel that occurs because of inadequate pricing costs society more to produce than it is worth. The effect of motorists' paying the wrong price, one that bears little relationship to costs, may be either too much or too little travel. In general, the greatest share of inefficiently priced highway expenditures identified in chapter 4 would tend to lead to excess travel, and most analyses of social costs conclude that more efficient

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[218] S.J. Thompson, *High Speed Ground Transportation (HSGT): Prospects and Public Policy*, 89-221 E (Washington. DC: Congressional Research Service, Apr. 6, 1989).

[219] Transportation Research Board, op. cit., footnote 213.

pricing of motor vehicle use would lead to lower overall use and lower energy consumption. Therefore, the concept of "full social cost accounting" for motor vehicle use is general] y viewed as an energy conservation strategy. Another potential effect of incorrect prices is the neglect of alternative travel modes that may have higher net societal value than motor vehicles, e.g., rail transit. Such neglect cannot be established, however, without careful analysis of the full social costs of *all* travel modes. This is not attempted here.

Four critical issues associated with applying social cost accounting to motor vehicle use are those of marginal versus average costs, accuracy in measuring and valuing costs, incorporation of social benefits into the accounting scheme, and identifying appropriate mechanisms for capturing the previously unaccounted for (or inefficiently accounted for) costs.

Marginal Versus Average Costs

As noted in chapter 4, the social costs calculated in this report are the total costs of all motor vehicle travel, not the marginal costs. In other words, if the estimates are accurate, we would know how much could be saved if *all* motor-vehicle travel were eliminated. Unless every increment of additional travel costs the same amount, however, it cannot be assumed that reducing motor-vehicle travel by 10 percent will save 10 percent of the total costs, even in the long run. Actually, a 10-percent reduction in travel will likely save much more than 10 percent of the total congestion costs;[220] much less of the costs of ecosystem destruction by highway building, at least in the short run; more than 10 percent of travel-related air pollution damages;[221] and so forth. Also, the marginal cost savings of a travel reduction will depend critically on what types of travel are reduced; for example, reductions in urban commuting will have cost savings implications very different from those associated with reductions in recreational travel. In other words, these estimates cannot automatically be used to calculate the cost savings associated with a policy measure that promises to reduce travel by a certain amount. On the other hand, the estimates discussed in chapter 4, and others of this kind, represent a good first step in allowing policy makers to begin to correct inefficient pricing in the transportation sector. In at least some scenarios of relatively large changes in motor vehicle use, the average costs derived from these estimates should be a serviceable approximation of the actual marginal costs.

Accuracy

Accuracy in measuring and valuing costs is particularly problematic for external costs such as air pollution damages, global warming impacts, and so forth. The only remedy for reducing existing uncertainty about these costs is continued research and analysis, which will require time and resources. However. problems with accuracy may be of less importance than meets the eye unless policymakers wish to capture all unaccounted-for social costs immediately. Given the general U.S. reluctance to raise transportation prices, it seems clear that the "universe" of politically feasible policy measures does not go beyond gradual moves to capture some of these costs. If this is so. the critical short-term need is to get a strong sense of their lower limit and a reasonable sense of the *relative* magnitude of different cost categories.

Benefits

The need to incorporate social benefits into an accounting system is obvious: the analysis of costs presented in chapter 4 indicates that motor vehicle use costs considerably more than is generally realized (i.e., the total social cost exceeds by a substantial amount the commonly recognized private cost). This is not necessarily enough information to set policy, however. Even if the estimate of unaccounted-for costs is correct, it does not mean

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[220] Because congestion costs remain zero until a threshold of [ravel is reached.

[221] Because health-related and other damages appear to have a threshold below which damage is minimal.

that motor vehicle use is underpriced to the extent implied by these costs. It is conceivable that there are large unaccounted-for *benefits*[222] in motor vehicle travel in which case the degree of underpricing is associated with the ***net*** of unaccounted-for costs and benefits. However, most analyses of the social costs of transportation assume implicitly or explicitly that the social benefits of transportation are equal to the sum of the private benefits. That is, they assume that there are no benefits of transportation that are not accounted for by the relevant decisionmakers. The FHWA, in a landmark study of highway cost allocation, stated that "the preponderance of expert opinion probably lies on the side of saying that there are no external benefits of highway consumption beyond the benefits to users."[223] However, this complex issue deserves further evaluation.

Policy Mechanisms

A final and critical issue is the selection of mechanisms for capturing the previously unaccounted-for (or inefficiently accounted for) costs. A key point is that *no* ***one measure*** can effectively incorporate all of these costs. For example, it is definitely ***not*** efficient to incorporate these costs into, say, the cost of gasoline and use a tax to capture them. In fact, as shown below, the most effective way to deal with some of these costs (e.g., parking costs in some shopping areas) is to ignore them or simply to educate travelers about them. On the other hand, it may be worthwhile to incorporate some costs into transportation services even when the match between costs and services is not strong; a weak linkage between the pattern of incurring costs and the pattern of paying for them may be better than leaving the costs entirely unpaid.

Policy prescriptions for social cost accounting

The goal of introducing social cost accounting into transportation policy is to find ways to price transportation so that a potential traveler accounts for the full marginal cost to society of transportation. The key word is *accounts;* if a user does not take a cost into account, it does not matter if the user pays it or if nonusers pay it; the nature of the inefficiency is the same, regardless of who pays. Consider the case of unpriced commercial parking, wherein the cost of parking is incorporated into the price of goods and services. Because drivers face no parking charge, they do not account for the cost of parking in their travel decisions. Hence, there is too much parking and, as a consequence, probably too many trips. Now, those who buy the goods and services pay for the parking whether or not they use it. It may turn out that those who pay for the parking indirectly are the ones who use it (this is usually the case at suburban malls, where virtually all shoppers drive and park at the mall, with the possible exception of teenagers dropped off by their parents). Yet even if the users pay, this does not eliminate the inefficiency—if the users do not face the cost and account for it, they will over consume parking.

Table 5-9 summarizes the causes of inefficient or unaccounted-for costs and prescriptions for dealing with them, based on the classification scheme introduced in table 4-1. Each class of cost has unique features and requires particular policy solutions.

Efficiently Priced But Often Overlooked Items

Several important costs of motor vehicle use are priced fairly in the market and are paid for by

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[222] That is, benefits aside from private benefits such as access, reliability and flexibility of service, and carrying capacity, which are accounted for in travel decisions.

[223] U.S. Department of Transportation Federal Highway Administration, *Final Report on the Federal Highway Cost Allocation Study* (Washington, DC: 1982), p. E-9.

TABLE 5-9: Inefficiently Priced or Unpriced Items: Causes and Prescrip

Efficiently priced items	Public infrastructure and services (government subsidies)	"Hidden" private-sector costs	"Classical" externalities
Why some items are excluded from estimates of MV ownership and operating costs	Why there is not an efficient price	Why there is not an efficient, direct, or explicit price:	Why there is no price
They are more naturally classified as medical, legal, or homeowning expenses than as transportation expenses.	Possibly indivisibility in consumption (MC = 0, e.g., defense) or decreasing long-run MC (e.g., highways); government is concerned with generating revenue, encouraging or discouraging behavior, distributing benefits, providing security and justice, and other factors besides economic efficiency.	Perceived economic benefits of free municipal parking; perceived high transaction costs (compared with benefits), institutional barriers, or tax disincentives, and presence of external benefits (parking, local roads); failure to make perpetrators liable for costs (accident costs); pecuniary effects of a price change are not seen in the sector that causes them (monopsony effects).	Impossible, too costly, or otherwise undesirable to assign and enforce property rights to the unpriced resources or effects.
What should be done economically	What should be done economically	What should be done economically	What should be done economically
Remind analysts and motor vehicle users that these are costs of MV use.	Long-run MC pricing, where possible (highway users charged optimal congestion tolls for highways; registration and license fees set at marginal administration costs; fines set so that marginal revenues equal marginal enforcement costs; parking prices at marginal cost, etc.); otherwise, allocate costs based on some measure of use; for public goods, aim for a level of output at which the marginal value summed over all consumers equals the marginal cost of supplying the quantity.	If there are no external benefits to pricing and no distorting taxes, and if transaction costs cannot be lowered and private assessments are not wrong, then do nothing (parking, unpriced roads); remove institutional barriers to private ownership and operation of roads; make those who cause accidents pay (but no direct compensation from perpetrators to victims); adjust cost accounting to attribute monopsony costs to causing sector.	Establish property rights if possible and if transaction costs do not outweigh benefits; otherwise, if few parties are involved, use collective bargaining; otherwise, set a Pigouvian tax dynamically equal to marginal external costs (i.e., damage costs not otherwise accounted for) and do not compensate victims.

KEY: MC = marginal cost; MV = motor vehicle

SOURCE: M. DeLuchi, University of California-Davis users, yet may not be accounted for in travel decisions. The more prominent are monetary accident costs not paid by insurance (generally lost productivity and some types of medical, legal, and property costs) and the costs of garages and driveways. These costs are definitely costs of motor vehicle use and generally efficiently priced, but they tend not to be considered when individuals account for their costs of travel. For example, in most jurisdictions there are sufficient housing choices that homebuyers can purchase the amount of garage space they desire[224] (or if they want, they often can convert garage to living space or add garage space), so it is likely that garages are reasonably efficiently priced. Thus, most people probably recognize an implicit cost of garages, e.g., they know their house cost $10,000 more (less) because of the presence (absence) of a two-car garage. Similarly, people will face squarely the uncompensated costs of accidents they cause. Yet, many people do not make either short- or long-term travel choices based on these costs.

No clear solution is apparent for the problem of overlooked internal costs, except education—continually reminding people of the risks they bear and the investment decisions they have made in response to their travel choices. It makes no sense to tax garages, because the problem here is not price at all, but accounting for a correct price.

Public Infrastructure and Services

Two separate factors create efficiency problems in paying for public infrastructure and services: government subsidies and inefficient pricing. According to the analyses discussed in chapter 4, in 1990, motor vehicle users paid for only 62 to 72 percent of public expenditures for highway infrastructure and services (53 to 68 percent if military expenditures are counted as motor vehicle service costs), with governments at all levels paying the rest. Further, much of the private payments are collected at rates that are poorly related to the costs incurred.

Correcting the problem of government subsidization of motor vehicle use is relatively straightforward, at least at a general conceptual level: it necessitates shifting expenditures from general revenues to some form of user fees. Establishing an appropriate form for the user fees is *not* straightforward, however. Most of the established pricing mechanisms were never meant to maximize economic efficiency because governments tend to be far more interested in other values: generating revenue; ease of collection: political feasibility, including values such as simplicity and attractive distribution of cost burden; and so forth. Unless there is widespread consensus that economic efficiency is a critical goal of transportation pricing, there will be little support for measures that correct inefficient pricing mechanisms. Further, some important costs of motor vehicle travel—the cost of protecting vulnerable oil supplies, for example—probably cannot find an efficient pricing mechanism, because small-to-moderate changes in travel demand are unlikely to affect defense expenditures at all; defense costs either are not divisible or will change only in large steps, with significant changes in gasoline consumption. Also, there is no agreement about the magnitude of these costs.

Some interest groups would like to increase taxes on gasoline to cover the subsidized costs of public infrastructure and services (as well as other items). If the total revenues collected by gasoline taxes were equal to the magnitude of the subsidized infrastructure and services, equity among transportation alternatives would be served, but not economic efficiency.[225] For example, the current Federal excise tax on gasoline is designed to raise revenue to build new Federal highways, but the costs incurred for these highways depend primarily on the capacity required during peak hours

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[224] In some jurisdictions, it is virtually impossible to purchase houses without two-car garages, but this is not the norm.

[225] Economic efficiency is a concept of how effectively the economy transforms available resources to outputs desired by members of the economy. Economic efficiency is served by prices that reflect the true marginal costs to society of the goods and services purchased.

and the types of vehicles that must be served (with heavy trucks requiring far more expensive roadways than light-duty vehicles) and secondarily on vehicle-miles traveled. The revenues collected from the excise tax do not correspond well to highway costs; they are proportional to gasoline use, which depends only mildly on miles of travel (because of the very wide range of fuel economies among road vehicles) and hardly at all on peak hour travel. Similarly, gasoline tax revenues do not track well with highway service costs such as law enforcement, which depend more on vehicle-miles traveled, level of congestion, and mix of trucks and autos than on gasoline use. Consequently, raising the price of gasoline to cover currently subsidized infrastructure and services may improve economic efficiency somewhat, by eliminating the subsidies, but it leaves much to be desired on other grounds. However, gasoline taxes remain attractive because they are extraordinarily easy to collect (the mechanism is already in place) and they are at least moderately tied to road usage.

Economic efficiency will be best served by pricing travel at the long-run marginal costs of public goods and services provided. For example, the costs of expanding highways to combat congestion might best be paid for by charging congestion tolls using electronic sensors; this should minimize transaction costs (collecting tolls mechanically exacts very high public and private costs) and focus payments on that travel most responsible for creating the costs. Congestion pricing is discussed in more detail below.

Much work remains to be done in both *defining* the marginal costs of various government services and devising pricing mechanisms that track these costs. The relative infancy of policy research on these subjects may explain the attraction of using a gasoline tax as the collection mechanism for public highway costs.

"Hidden" Private-Sector Costs

Private-sector costs that are inefficiently priced include: parking, which is usually provided free to users; local roads provided by developers and included in home prices; and monetary costs of accidents to those not responsible and not covered either by insurance or by those responsible.

Parking

Nobody forces businesses to provide free parking, and there is in fact a theoretical benefit to charging separately for parking: it would lower the price of goods and increase consumption, as well as increasing the efficiency of travel. That businesses do not charge for parking is likely due to their perception that the cost of setting up and administering a pricing system exceeds the benefits to themselves, especially if the "costs" of customer annoyance and inconvenience are thrown in. The striking preponderance of free commercial parking is evidence that this is in fact the case.

There are benefits to both businesses and consumers from charging separately for parking, but businesses count only the benefits to themselves in their decisions. Therefore there is an unaccounted-for external benefit to pricing parking. To account for this external benefit, governments could subsidize the cost of establishing a paid parking system, with the subsidy set at the marginal external benefit (not at the amount required to induce producers to price parking). With such a subsidy, businesses would institute priced parking only where the private plus external benefits exceeded the costs. Also, future widespread institution of electronic billing for other services (e. g.. for paying congestion charges or bridge tolls) would likely help achieve priced parking at low transaction costs and eliminate one of the roadblocks to unbundling parking costs from the costs of goods and services.

The provision of free parking to employees stems from a different cause than free commercial parking: the U.S. tax system counts free parking as a nontaxable employee benefit and a tax-deductible expense for employers, providing a clear incentive for businesses to substitute free employee parking for its equivalent in employee income. There are at least two ways to correct this: tax the value of free parking as income and disallow parking costs as a business deduction, or else simply force employers to offer cash in lieu of parking. California has chosen the latter approach, as discussed later.

Local roads

There may be little reason to try to "correct" the inefficiency caused by embedding some local road costs in the prices of homes. The marginal cost of an additional car or vehicle-mile on a local road is very small, because these roads are rarely congested, which implies that there is no efficient short-run price to charge users. Further, it seems unlikely that any pricing arrangement to charge for the use of local roads would be worth more than it cost. Simply leaving the cost of the roads embedded in the price of the houses served by the roads may be as good an arrangement as any.

Uncompensated accidents

The appropriate solution for uncompensated accident costs is to make those who cause accidents pay. Of course, this is easier said than done; the justice system already tries to do this, and the existence of these uncompensated costs is due less to a lack of trying than to flaws in the system that cannot be corrected easily.

A corollary to this solution is that according to economic theory, victims should not receive direct compensation from those responsible but instead should pay for insurance against the risk of accidents. This follows from the economic reasoning that a potential victim who expected to be compensated fully for any injury would not take injury risk into account when making a travel decision; paying insurance is one way of accounting for the risk.

Externalities

From the standpoint of economic efficiency, the appropriate hierarchy of treatment for externalities (nonmonetary damages that motor vehicle users impose on others without accounting for themselves) is first, if possible, to assign true property rights to the resources that are damaged by externalities (e.g., breathable air and clean water); next, if this is not possible, to try collective bargaining among the parties affected; and finally, to enact taxes that raise costs to account for the marginal external costs (but without compensating victims).

The assigning of property rights to resources such as clean air and water, if it were possible, would allow a market in these resources to be created. Polluters would have to buy the rights to use up the resources from individual sellers, in the same way that industries in some areas must buy water rights from farmers if they wish to divert water from a local river. Theoretically, individuals would measure the risks to themselves of giving up a clean air or clean water resource, and decide whether or not to accept a particular monetary offer.

Assignment of individual property rights might be possible in rural areas where the number of parties is small, but under most circumstances it would be extremely difficult to implement, especially attempting to keep track of damages to each individual allotment of clean air, clean water, or other "property." A more likely solution in most areas is collective bargaining: a would-be polluter would negotiate with a town council or citizen group about the extent to which it would accept degradation of group property rights (in clean water, in the absence of noise, etc.) in exchange for a payment. Although this is more practical than a system of individual rights, it also allows some individuals to bear costs much larger than the payment they receive (e.g., individuals with asthma would value clean air far more than the average resident and would lose more if pollution were allowed).

The third option is to collect a tax that raises the price paid by the persons creating the externalities to the marginal cost to society,[226] without compensating victims. One example of such a tax

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[226] A tax that would accomplish this is called a "Pigouvian tax.

would be an air emissions tax that exactly compensated for the damage the emissions would cause. With such a tax, polluters would seek to control emissions up to the point at which the cost of controlling the next bit of pollution was higher than the cost of the tax for that pollution; this would be the economically optimal level of pollution.

The idea of not compensating victims seems abhorrent at first glance, because they are innocent parties. The reason for avoiding compensation is that assurance of compensation theoretically would cause potential victims to fail to avoid dangerous situations and to engage in riskier behavior than they would otherwise consider (because all of the risk is borne by others). For example, even though the risk of accidents caused by others might add $10 per trip to society's cost of travel, travelers would ignore this cost if they knew they would automatically be fully compensated. If the traveler (potential victims) has to bear the "accident risk cost, " that cost would presumably be considered in travel decisions, and trips would be taken only when the benefits of the travel outweigh the full societal cost-which is socially optimum.

The clash between the above viewpoint and that generally held by social norms is the clash between strict economic efficiency and a wider view of social justice. This clash might be lessened by a more lenient view about the rule of avoiding victim compensation: that it apply only to direct participants in motor vehicle travel (e.g., other drivers and passengers), and not to victims outside the system (e. g., pedestrians).

The values for externalities estimated in chapter 4 may serve as the starting point for constructing Pigouvian taxes,[227] with the following caveats:

1. The values are preliminary and controversial, and will change as environmental restrictions change. For example, new emission regulations for automobiles should gradually reduce the level of air quality external costs, as cleaner automobiles infiltrate the fleet.
2. As pointed out in chapter 4, inclusion of externalities into travel costs should lead to more optimal levels of travel, but failure to apply external costing systems to other sectors of the economy may sabotage this. All sectors of the U.S. economy, and all economic activities competing with transportation, generate external costs; "internalizing" these costs only in the transportation sector risks overpricing transportation in relation to competing activities. The only justification for introducing Pigouvian taxes solely into the transportation sector would be if transportation generated external costs that are so much higher than those in competing sectors that ignoring the latter would not greatly affect activity levels. This may well be the case, but OTA is aware of no analytical demonstration of such a conclusion.
3. Instituting taxes on externalities should not be a question simply of computing the total external costs of motor vehicle travel and calculating a simple tax, such as a tax on gasoline and diesel fuels, that will produce revenues equal to these costs. To have travelers incorporate into their decisions the full marginal costs of their travel to society, taxes must closely track the generation of actual costs. For example, damage to roadways depends on miles traveled, type of vehicle, and type of roadway; a tax on fuels to compensate for road damage would not closely track this damage and therefore would not exert a strong influence on travelers to take actions that would minimize such damage. **The construction of a set of taxes to" internalize" the external costs of motor vehicle travel is a major analytical undertaking that goes well beyond calculating the magnitude of external costs.**

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[227] Pigouvian taxes have tax rates that just equal the marginal external costs; at this tax rate, economic efficiency is maximized.

GASOLINE TAXES[228]

This section examines the desirability of gasoline or fuel use taxes in terms of their impacts on the macroeconomy and on economic efficiency. Little attention is given to issues of distributional equity among geographic regions or income classes, since other tax and expenditure policies can more than compensate for any broad distributional impacts of gasoline taxes. Estimates of the short-run and long-run economic consequences of gasoline taxes depend on how the tax revenues are spent (or which taxes they are used to offset), the magnitude of externalities, related macroeconomic policies, and the variability of externalities from vehicle to vehicle, at different locations, and over time. One must examine each of these issues to analyze the economic impacts of increased gasoline taxes.

Impacts on unemployment and gross national product (GNP) must be central to the assessment of short-run economic impacts of a gasoline tax. Although the overall economy would be damaged by *any* tax increase in the first few years after the tax is imposed, these impacts are temporary and will disappear as the economy adjusts to the new tax regime.

The magnitude of driving-related externalities and unpriced inputs must be central to an evaluation of the long-run economic consequences of motor fuel taxes. Taxes can change the overall efficiency of the economy. The direction of this change depends on the magnitude of these externalities and unpriced inputs relative to the magnitude of the tax. And these impacts are long-term, or permanent, in nature.

In addition, even with externalities, one must examine the degree to which the instrument—gasoline taxes—is matched to the problem being addressed-externalities associated with driving. Gasoline taxes are matched well with some. but poorly with most, of the externalities associated with driving. Thus to address most of the very real externalities, gasoline taxation is not the appropriate instrument.

Impacts on Economic Variables

In addition to providing a source of Federal revenue, increasing gasoline taxes would impact the overall economy. Some impacts would show up in standard statistics published by the Federal Government, such as the national income and product accounts, whereas others will not be directly measurable based on standard statistics.

In the first few years after a gasoline tax increase, in fact, after any large tax increase, overall economic performance would decline relative to performance expected absent the increase. One central measure of overall performance is the monetary value of the total output of the economy. GNP would be reduced for several years by an amount comparable to the total additional gasoline tax revenue. During that period, unemployment and inflation would increase.

There are several pathways by which gasoline taxes influence GNP. Increases in gasoline tax directly reduce the demand for gasoline and for new cars. In addition, the gasoline tax reduces aftertax income for most people. With less income, demands for goods and services decline. This reduction in aftertax income reduces demand for new cars, gasoline, and other goods and services. These two direct effects together reduce the overall demand for goods and services in the U.S. economy. Automobile manufacturers, oil refiners, and other companies react to declines in demand by reducing production of goods and services. This reduction in output throughout the economy would translate directly into a GNP reduction.

The reduction in output also implies that U.S. companies will need fewer workers: the demand for labor will be reduced. As people are laid off and others are simply not hired, unemployment increases. The reduction in employment implies

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[228] Based on J.L. Sweeney, Stanford University, "Gasoline Taxes: An Economic Assessment," contractor report prepared for the Office of Technology Assessment, Sept. 20, 1993.

that incomes decline. Again, income reductions reduce the demand for most goods and services in the economy, which leads to even more reductions in output, further reductions in GNP, and so forth. This so-called multiplier effect thus amplifies the initial direct impacts of the gasoline tax on GNP.

A similar effect operates through corporate profits. Reductions in demand for various goods and services and associated reductions in their outputs lead to reduced corporate profits. But corporations are owned collectively by people. Thus reduced corporate profits imply reduced total aftertax income, which in turn implies reduced demand for goods and services produced in the U.S. economy and leads to further reductions in labor demand, labor incomes, and corporate profits. This "feedback loop" further amplifies the GNP reduction caused by a gasoline tax increase.

Gasoline taxes also have a direct impact on inflation, since they directly increase gas prices. Businesses whose vehicles use gasoline will find their costs increasing, and there will be pressure to increase the prices of their outputs. The net result of these price increases is increased inflation.

While the overall economy would be damaged by a gasoline tax increase taken alone, it is not meaningful to estimate short-term macroeconomic impacts of a fuel tax increase without examining impacts of the linked changes by the government and by the Federal Reserve System. Short-run macroeconomic impacts will depend on: 1) whether motor fuel tax revenues are linked to reduction of other taxes, and which other taxes; 2) whether tax revenues are linked to additional expenditure programs, and which expenditure programs: 3) whether revenues are linked to deficit reduction; and 4) the degree to which the Federal Reserve System accommodates the tax changes with monetary policy. Thus a gasoline tax increase that reduces the deficit will have a very different impact than one that allows more government spending. This in turn will have a different impact than a gasoline tax whose revenues allow a reduction in other taxes.

If motor fuel tax revenues were linked to a reduction of other taxes, then the short-run impacts of reducing these other taxes must be added to the impacts of raising gasoline taxes. Economic modeling suggests that changes in personal income taxes will normally impact the economy less than changes in corporate taxes, and that changes in general corporate taxes will impact less than changes associated with investment, such as investment tax credits. For example, the models predict that if a gasoline tax were coupled with an equal-revenue increase in investment tax credits, short-run macroeconomic losses resulting from the motor fuel tax increases would be more than offset by the short-run macroeconomic gains resulting from the investment tax credit increase. In other words, there would likely be short-run macroeconomic gains from the package of tax changes.

Monetary policy can have important impacts on GNP, employment, and inflation. Monetary policy changes may be directly coupled to changes in taxes and spending. In particular, in response to a gasoline tax increase that would increase unemployment, the Federal Reserve Bank may use accommodating monetary policy to reduce the unemployment impact, although at the expense of more inflation. With such accommodating monetary policy, the short-run impacts of a gasoline tax on GNP can be greatly reduced or even eliminated, while the short-run inflationary impacts would be amplified.

A gasoline tax, not coupled with any other tax change, would increase revenues by about $10 billion for every 1O-cent increase in the per-gallon tax rate, or about $1 billion for every 1-cent increase. But with the short-run increase in unemployment and the reduction in GNP, Federal expenditures for unemployment compensation and other "safety net" programs will increase and tax collections will decrease. Thus in the short run, the actual Federal deficit will be reduced by far less than the $10-billion increase in tax revenues. In the longer run, the reduction in the Federal deficit will be roughly equal to the increase in gasoline tax revenues, since the unemployment impacts will disappear over time.

A gasoline tax would reduce gasoline consumption through reductions in total miles driven and possibly through increased sales of fuel-efficient vehicles. Unless the reduced consumption is large enough to affect world oil prices, there would be virtually no impact on the production of oil in the United States, and thus almost all of the reduced consumption would be from imports.

A tax-encouraged increase in gasoline price of 10 percent would reduce vehicle-miles between 1 and 2.5 percent from the "no tax increase" growth path.[229] The fuel efficiency of old cars would be virtually unaffected. Under the current CAFE standards, for small tax increases there probably would be no increase in average fuel efficiency of new cars, while large enough price increases would increase average fuel efficiency.[230]

The reduction in total miles driven would imply a reduction in the environmental damages associated with driving, although emissions per mile of travel would not change substantially. Traffic accidents would decrease by a small amount. Congestion on highways could decline, very slightly, since driving during congested times would decline far less than total driving.

A second measure of the effect on the economy, one applicable particularly to the longer run, is economic efficiency. Economic efficiency is a theoretical concept of "goodness" of resource allocation, a concept designed to indicate how effective the economy is in transforming available resources to outputs desired by its members. Changes in economic efficiency include all changes that influence how well off individuals are, including their attitudes about environmental impacts and the value they place on time spent for leisure and other activities within the home. In practice, economic efficiency cannot be measured directly and one can only discuss changes in economic efficiency or economic efficiency losses associated with some policy or arrangement.

If there were no externalities or unpriced economic inputs associated with driving, and no other taxes in the economy, competitive markets would lead to the economically efficient use of gasoline. In that case, increases in gasoline taxes, taken alone, would always reduce economic efficiency.

On the other hand, with externalities or unpriced economic inputs associated with driving, competitive markets would lead to an underpricing of driving costs and thus to more driving and more gasoline use than would be economically efficient. In this case, absent distortionary income taxes or other taxes, a gasoline tax equal to the marginal value of the unpriced inputs plus the externalities would bring competitive markets back to economic efficiency by correcting the underpricing problem. Thus if the existing motor fuel tax were initially lower than the marginal externalities (measured on a basis of external costs per gallon of gasoline used) plus the marginal value of unpriced inputs, an increase in the tax could reduce economic efficiency losses. If the existing motor fuel tax were initially higher than the marginal externalities plus marginal value of unpriced inputs, then a decrease in the tax could reduce economic efficiency losses.

However, there are, in fact, income taxes and other distortionary taxes in the economy. A gasoline tax increase would raise revenue, revenue that could allow government to reduce other distortionary taxes, increase expenditures, reduce the fiscal deficit, or take some combination of these actions. Thus in assessing actual motor fuel taxes, one cannot escape assessing the effects of whatever other actions are linked to those tax revenues.

If fuel use taxes are coupled with reductions in the "typical" bundle of preexisting taxes, then economic efficiency would still increase as the gasoline tax increases, up to the level at which the

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[229] See C.A. Dahl, "Gasoline Demand Survey," *The Energy Journal*, vol. 7, No. 1, 1986, pp. 67-82.

[230] CAFE standards appear to be maintaining fleet fuel economy values at higher levels than current low gasoline prices would produce *if there were no standards*. Small gasoline price increases would be less likely to raise fuel economy levels than to allow automakers to relax their current efforts to boost market shares of small, fuel-efficient cars. See J.L. Sweeney, "Effects of Federal Policies on Gasoline Consumption," *Resources and Energy*, vol. 2, September 1979, pp. 3-26.

gasoline tax is equal to the value of the marginal externalities plus the value of unpriced inputs. Further gasoline price increases linked to the reduction of other taxes would reduce economic efficiency. Similarly, if imposition of fuel taxes were linked to Federal expenditure programs, economic efficiency would increase with gasoline tax increases (above the value of the marginal externality plus the value of unpriced inputs) if and only if the additional expenditures would be economically attractive when financed by an equally distortionary mix of taxes. However, once the gasoline tax rate is increased to equal the marginal cost of externality plus marginal value of unpriced inputs, any further tax increase would be less economically efficient than a broadly based tax that raised the same additional revenue.

In general, three key elements determine the impacts of additional gasoline taxes on economic efficiency: 1) the marginal value of externalities and unpriced inputs in motor fuel use; 2) linkages between revenues raised from motor fuel taxes and governmental expenditures, other tax reductions, or deficit reductions; and 3) the existing gasoline tax magnitude. One cannot examine the consequences of gasoline tax increases in terms of economic efficiency without examining each of these three issues.

Using Gasoline Taxes To Address Externalities

When externalities or unpriced inputs are associated with the use of motor fuel, taxes on motor fuel can motivate individual drivers to account for costs and thus increase economic efficiency. Gasoline taxes could be increased, and other distortionary taxes simultaneously decreased, so as to have minimal short-term macroeconomic losses. To strive for maximum economic efficiency, the gasoline tax rate should be made equal to the marginal value of externalities plus unpriced inputs, but to do so requires understanding of these externalities and inputs.

Unpriced Highway Services

Driving requires the use of roads and highways. In the absence of motor fuel taxes, the costs of roads and highways are typically not borne by the vehicle driver. Historically, Federal gasoline taxes have provided revenues for the Highway Trust Fund. On average, however, for trucks and cars taken together, current motor fuels taxes are lower than the unpriced costs of highway and roadway services: the current tax rates cover only part of the unpriced inputs associated with driving (see the discussion in chapter 4).

Unpriced highway services are only imperfectly linked to the fuel consumed in an automobile or truck; motor fuel taxes typically are proportional to fuel use. Although two different cars might require the same highway services per mile of driving, the old car with a fuel economy of 10 mpg faces three times the per-mile tax as the new car having a fuel efficiency of 30 mpg. The problem is even more severe when heavy trucks are compared with automobiles. Trucks probably cause the majority of highway damages yet pay the minority of fuel taxes.[231] Since average taxes cover only part of the costs, the driver of the heavy truck would be paying considerably less than costs. But automobile drivers may be paying more or less than costs, even though the average cost of all vehicles (cars and trucks) exceeds the current average tax revenues.

With this high variability across vehicles, additional Federal gasoline taxes are not particularly good instruments for addressing unpriced highway services.

Subsidized Parking

Federal tax code allows employers to provide free parking to employees as a tax-free benefit. These

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[231] U.S. Congress, Congressional Budget Office, *Paying for Highways, Airways, and Waterways: How Can Users Be Charged?* (Washington, DC: May 1992).

parking services represent unpriced inputs for employees. Free parking encourages more people to drive alone to work than would otherwise be economically efficient.

The subsidy may be larger than the cost of gasoline needed to drive to work. But this subsidy, in terms of dollars per gallon of gasoline, is highly dependent on automobile efficiency, distance between a person's home and work, and current use of the vehicle (the subsidy is available only for trips to work and does not apply for other vehicle uses).

Although the subsidy may be large, this problem would be difficult to address with a gasoline tax, since the tax would apply to all vehicles in all uses, not simply to vehicles being driven to workplaces with subsidized parking. Other instruments (e.g., changes in the Federal tax code) are more appropriate for addressing this problem. Thus although current practice implies an unpriced input, a gasoline tax would be a poor instrument to address the problem.

Congestion

Highway congestion is an important and growing externality in urban and many suburban areas. Whenever roads are congested, more driving imposes costs on other drivers and passengers. But congestion is very time and location dependent. Thus this externality leads to too much driving during periods of congestion and too little driving during off-peak periods. Optimally more people should shift their driving times from the more congested periods to the less congested.

If a gasoline tax were used for addressing problems of congestion, the tax would be zero for fuel used in noncongested times or locations, but might be $10 per gallon or more for fuel to be used in congested times. However, the motor fuel marketer has no information about whether the fuel would be consumed during highly congested times, times of no congestion, or some combination of the two. A gasoline tax cannot track the congestion variability over time and location. Thus a gasoline tax is not a useful instrument to deal with time-varying or location-varying congestion.

Environmental Harm: Air Pollution and Carbon Dioxide Emissions

A large portion of urban air pollution derives from motor vehicle evaporative and tailpipe emissions. The cost of these externalities, per gram of emissions, depends heavily on the air basin dynamics and the affected population. The amount of emissions per mile driven depends on the age of the car as well as its maintenance history. And the amount of emissions per gallon of gasoline depends on both the auto vintage and its fuel efficiency. These three factors, taken together, imply that the variation in external costs, measured on a per-gallon-of-gasoline basis, varies radically among vehicle vintages and fuel efficiencies, as well as across locations. Therefore, although these externalities are important, a national gasoline tax is not an appropriate instrument for dealing with this problem. A regionally specific State gasoline tax could be more effectively matched to the particular air basins, but even such a vocationally specific tax would not be vehicle-specific.

A second environmental externality is carbon dioxide released into the atmosphere. Carbon dioxide, working through the greenhouse effect, is expected to lead to global climate change. Each gallon of gasoline consumed releases about the same amount of carbon dioxide, independent of automobile efficiency, and each ton of carbon dioxide has the same impact, no matter where it is emitted. Therefore impacts per gallon are the same across geographic area, time, and vehicle. Thus Federal fuel taxes could readily incorporate the costs of this externality, once the appropriate cost per additional kilogram of CO_2-equivalent emissions was determined. For this purpose, fuel use taxes, differentiated by particular fuel, would be very appropriate.

Energy Security

Increases in oil use increase expected economic losses from world energy market disruptions.

First, such increases reduce worldwide spare oil extraction capacity, at least temporarily. Decreases in spare capacity exacerbate price jumps during disruptions, if the spare capacity would have been located in nondisrupted regions. Second, oil use increases magnify economic losses stemming from a given magnitude oil price jump. Thus reduced economic security is an externality associated with additional gasoline use.

In addition, if world oil prices are increased in response to increased U.S. oil imports, that increased price would apply to all oil imported into the United States. Thus, there are "terms of trade" costs to the United States associated with increases in oil use.

Each of these externalities changes over time as the "tightness" in the world oil market changes, but the rate of change is often gradual (except during oil supply disruptions). When there is little spare oil production capacity, the externality is large, and conversely, in times of much worldwide spare capacity, the externality is small. Currently. with a large worldwide excess capacity and the reasonably large U.S. Strategic Petroleum Reserve, these externalities are small.

The magnitude of this externality is the same for each gallon of gasoline used, independent of location (in the United States) and the specific vehicle in Which it is consumed. Therefore, a time-varying national gasoline tax could be an appropriate instrument for dealing with this externality.

Automobile Accidents

A significant component of driving cost is the expected cost of automobile accidents. The more a person drives, the greater is the probability of an accident. Risk and mileage ratings in automobile insurance include only part of the marginal accident costs of additional driving. To the extent that the marginal accident costs of additional driving are not reflected in increased insurance rates, there is an accident-related externality.

This externality, expressed on a per-gallon-of-gasoline basis, differs widely by automobile and by individual driver. Since there is so much variability measured on a per-mile basis, and even greater variability in the externality measured on the basis of cost per gallon of gasoline, a gasoline tax is not an efficient instrument for dealing with this problem.

Alternative Fuel Technology "Chicken-and-Egg" Problem

Recently there have been efforts to promote "alternative fuel" vehicles, vehicles fueled by methanol, compressed natural gas (CNG), ethanol. or electricity. Behind policies to promote these technologies is the idea that the unaided market will not invest sufficient funds in the development of technologies that might underlie a fundamental transformation to alternative fuels, so individuals will buy fewer alternative fuel vehicles than would be economically efficient. Part of the argument is that alternative fuels face a chicken-and-egg problem: it is not economical for individuals to purchase alternative fuels absent sufficient refueling stations, and it is not economical for fuel dealers to open stations absent sufficient alternative fuel vehicles.[232] The argument is that a large change, involving many refueling stations and vehicles would be beneficial to the overall economy. but that market forces will not move the economy past the "hump," This problem creates a type of dynamic externality. in that the history of past investment and vehicle use tends to constrain future use.

Contrary to this argument is the observation that such chicken-and-egg situations can be overcome by individual firms and people willing to take risks based on their own beliefs or guesses about the future. Examples include the transition

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[232] D. Sperling, *New Transportation Fuels: A Strategic Approach to Technological Change* (Berkeley, CA: University of California Press, 1988).

to compact discs in preference to records or musical tapes and the development of the personal computer and associated software. Although there is real disagreement about the magnitude of the externality, it could be addressed either through a subsidy for the alternative fuel vehicles or through a tax on gasoline or gasoline-fueled vehicles. These externality differentials could appropriately be addressed through differences in motor fuel taxes.

Matching the Instrument With the Externality

Fuel use taxes could motivate consumers to account for externalities associated with the use of gasoline and other motor fuels. Some externalities are fairly stable over time, location, and vehicle, and could be addressed through the use of a fuel tax. Others are highly variable, and this mechanism would be less appropriate. Although several externalities are important, only the externality components associated with unpriced road services, carbon dioxide, energy security, and the chicken-and-egg problem could appropriately be addressed with a Federal gasoline tax.

Model-Based Results

The various impacts can, in principle, be estimated by using mathematical models. Three general classes of models typically are available for such estimation: 1) partial equilibrium models of the energy sector or parts of the energy sector, 2) computable general equilibrium models of the overall economy, and 3) aggregate macroeconomic models.

Partial equilibrium models of the energy system may represent one market such as that for gasoline, many linked markets (e.g., for each of the refined petroleum products), or the entire energy supply and demand system. Partial equilibrium models generally can have the most detail about the particular energy markets being examined.

Computable general equilibrium (CGE) models represent the economy as a complete system, including each major factor of production: labor, capital, energy, materials. Such models typically allow less detail about the structure of particular energy markets.

Macroeconomic models typically represent the entire economy, focusing particular attention on determination of the overall level of economic activity as measured by GNP or gross domestic product (GDP), on employment or unemployment of labor; money supply and demand; interest rates; and inflation. Such models typically allow even less detail about particular components of the energy system, although some of the commercial macroeconomic models have incorporated extensive energy sector details.

None of the model classes is suitable for examining all of phenomena discussed above, as suggested by table 5-10, which summarizes the variables typically represented in the three classes of models. Rather, each class has its own particular strengths.

The three classes of models should be used in a complementary fashion in order to examine the relevant issues. The OTA contractor report on which this section is based provides several examples of the use of these models to examine the impacts of gasoline tax increases.[233]

TRANSPORTATION DEMAND MANAGEMENT

Transportation demand management (TDM) entails any effort to improve the efficiency of the transportation system by reducing traffic volume, especially during peak travel times, increasing vehicle occupancy, improving traffic flow, and encouraging modal shifts. Recent Federal legislation has pushed the development of TDM programs. The Clean Air Act Amendments of

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[233] Sweeney, op. cit., footnote 228.

TABLE 5-10: Variables Represented in Models

Variables	Partial equilibrium	Computable general equilibrium	Macroeconomic
GNP	No	Yes	Yes
Unemployment	No	No	Yes
Inflation	No	No	Yes
Tax revenues	Yes	Yes	Yes
Federal deficit	No	Yes	Yes
Total driving	Yes	No	No
Fuel efficiency of automobiles	Yes	No	No
Gasoline consumption	Yes	Yes	Yes
Oil Imports	Yes	Yes	Yes
Economic efficiency	Yes	Yes	No
Environmental harm	Yes	No	No
Automobile accidents	Yes	No	No
Congestion	Yes	No	No

SOURCE J L Sweeney Stanford University

1990 (Public Law 101-549) prohibit Federal agencies from approving or funding State transportation plans that do not include transportation control measures.[234] In addition, the Intermodal Surface Transportation Efficiency Act of 1991 (Public Law 102-240) established several TDM requirements and programs, including a congestion pricing pilot program; occupancy requirements for HOV lanes; State requirements for managing traffic congestion; and a six-year, $659-million intelligent vehicle-highway system program (IVHS).[235]

TDM approaches include economic incentives, regulatory mandates, and public investment and information programs. TDM measures, such as employee ridesharing programs and congestion pricing, may reduce traffic congestion, gasoline use, and vehicular emissions, but measuring these outcomes in an entire metropolitan or regional area can be extremely difficult. Because most current programs are concerned with reducing traffic congestion not gasoline use, the gasoline savings potential of many TDM options is still undetermined.

Because congestion may discourage some travel, relieving congestion through successful TDM strategies—such as parking pricing, staggered work hours, and HOV lanes—may stimulate some additional travel, thus canceling part of the potential savings. In some extreme cases, especially with IVHS programs, net travel may increase. The rapid onset of congestion on many newly constructed roads indicates that limits to the existing road supply may indeed suppress travel demand. Thus, reducing traffic congestion could in some cases lead to more trips, miles traveled, and gasoline use.

This section reviews primarily U.S. experience with various TDM efforts. The discussion is meant to be illustrative rather than comprehensive; in most cases, these, options have not been attempted on a large scale or have not been evaluated for their impact on gasoline use. Given the limited experience with TDM and the large number of factors that determine worker travel behavior (e.g., travel time, vehicle and fuel costs, parking costs, day care requirements, and travel requirements during the workday), calculations of

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[234] Public Law 101-549, 104 Stat. 2410, sec. 101(f), see 42 U.S.C. 7506(C)(2),

[235] These provisions are codified at 23 U.S.C. 102(a), 149 note, 303(c), and 307 note

congestion and travel demand reduction and gasoline savings based on theoretical calculations or extrapolations from case studies should be considered preliminary and highly uncertain.

Economic Incentives

Economic incentives are potentially powerful strategies to improve the efficiency of the road transport system. Not surprisingly, travel choices (frequency, mode, and timing) are strongly affected by prices, including those of fuel, parking, mass transit, and other transport-related costs.[236] Unlike regulatory mandates, economic incentives—including congestion and parking pricing options--allow consumers to choose their best combinations of mode choice, travel times, travel frequency, and vehicle occupancy; mandates, on the other hand, predetermine those choices.

There are several kinds of economic incentives designed to manage transportation demand: pricing parking, pricing travel (congestion and road use pricing), and other financial options related to travel demand (parking fees, automobile ownership and use fees, employee mass transit allowances). (Gasoline taxes also fit into this category, although generally they are **used** in this country to raise revenue rather than to depress demand; they are discussed in the preceding section.) Major options within each group are discussed here.

Pricing Parking

Among all TDM options, pricing parking may have one of the most significant impacts on travel demand, because parking is a valuable transport service paid only partially (if at all) by drivers. Roughly 95 million civilian commuters in the United States drive to work, and an estimated 90 percent of them do not pay for parking.[237] For commuting trips, the value of free parking often exceeds ownership and operating costs combined.[238] As a result, by substantially reducing commuting costs, free parking encourages solo driving, which increases traffic congestion and gasoline consumption.

Increasing parking costs to match prevailing market prices would reduce the incentives for solo driving. One study found that an average of 27-percent fewer auto trips were made by employees who paid for their parking at work compared with those who did not pay.[239] When a Los Angeles government agency introduced market rates for employee parking, solo driving dropped substantially (from 42 to 8 percent) and ridesharing increased substantially (from 17 to 58 percent). In Washington, DC, parking charges representing half of the local market rates were imposed briefly at several Federal buildings in 1979 and 1980, and solo driving decreased as much as 40 percent.[240]

Employers offer free parking as an employee benefit, in part because these costs are currently treated as a normal business expense, deductible from corporate income taxes, and employees are not taxed for free parking. One way to eliminate parking subsidies, therefore, is to tax employees for the value of parking; employers could be re-

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[236] M. Wachs, "'Pricing Urban Transportation **A Critique** of Current Policy," *Journal of the American Planning Association,* vol. *47,* **July 1981, pp. 24--245.**

[237] D.C. Shoup **and R. W'.** Willson, "Employer-Paid **Parking: The** Problem and Proposed Solutions," *Transportation Quarterly,* vol. *46, No.* 2, April 1992, **pp.** 169,185. This source does not clarify whether **these figures** are actual or **estimated.**

[238] Average ownership (depreciation, financing, licensing, and registration **fees)** and operations costs (gasoline **at** $1.50 **per gallon)** total about $4.90 per round trip commute, while daily **park**ing costs **in** both **urban and suburban** areas commonl**y** exceed **$5 per vehicle.** D.H. Pickrel**1,** testimony at hearings before **the** Senate Committee on Environment and **Public** Works, Subcommittee on **Water** Resources, Transportation, and Infrastructure, M**ar. 21, 199**1, **p.** 2.

[239] Shoup **and** Willson, op. cit., footnote 237, **p.** 181. The results are corrected for income, **since higher paid** employees **are both more likely** to receive **paid** parking **and** more likely to drive alone **regardless** (because of both their income **and their greater** likelihood of **having erratic** schedules).

[240] Pickrell, op. cit., footnote 238, **p.** 4.

quired to determine the value of a parking subsidy and report that value as a taxable employee benefit. Eliminating the tax exemption of free parking would be politically unpopular, but it would reduce auto travel demand and could raise between $3 billion and $4 billion in Federal revenues annually, although those revenues would decrease with time as solo driving decreased and mass transit use increased.[241]

Alternatively, employers could be required to offer their employees the cash value of their subsidized parking spaces. This option could be implemented without changing the current tax exemption on employer-subsidized parking, and it would allow employees to determine which alternative represented the greater value for them: using free parking or receiving its cash equivalent. A cash option has the advantage of being voluntary and still raising significant revenues, if the cash is taxable as income.

Shoup and Willson estimate that if 20 percent of the 85 million U.S. auto commuters who currently park free at work chose a cash option *and ceased to drive* (carpooling or using mass transit), Federal tax revenues would increase more than $1 billion,[242] and gasoline consumption would decrease by an estimated 4.5 billion gallons annually,[243] or about 4 percent of the national total.[244] However, aside from being a rough extrapolation from limited experience, the gasoline savings estimate given here is overstated to the extent that any workers with access to free parking currently commute by means other than solo auto travel (e.g., transit, walking, biking). In addition, drivers using a cash option might still drive but use their money to park on streets or less expensive lots. Better data on the availability, use, and value of subsidized parking could improve estimates of potential gasoline savings from taxing or cashing out free parking.

Pricing Travel

Congestion (or peak) pricing is designed to capture the added costs of road use during peak periods, which are generally the rush commuting hours. A basic principle behind this and other pricing strategies is that traffic congestion imposes costs not captured in existing travel prices. During peak travel periods, each marginal user imposes costs on all other users by increasing travel times. fuel use, and air emissions. These costs increase as the number of vehicles increases, but marginal users do not pay the marginal (incremental) costs of the congestion they impose on others.

A major policy concern with congestion pricing (like other transport pricing options such as gasoline taxes) is the potential for regressive impacts. As with gasoline taxes. however, the total impacts of congestion pricing depend critically on how revenues are used. According to one analysis, if revenues are used to reduce gasoline taxes and vehicle registration fees or to subsidize transit costs, a congestion pricing program may have positive economic impacts on all income groups

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[241] About 28 million U.S. commuters work in central cities with populations exceeding 500,000. Given an estimated average monthly value of $58 per parking space in those areas, the annual added tax liability per commuter totals about $167, with taxation at the marginal federal income tax rate of 24 percent (1991). If 75 percent of these commuters receive free parking, taxing this benefit would generate annual revenues of about $3.5 billion, Ibid., pp. 3, 6. Note: This source lists annual revenue gains of $4.7 billion, because the author multiplied the annual tax liability ($167) by all 28 million commuters. Here. however, the original assumption is used that only 21 million commuters (75 percent) receive free parking, which explains the discrepancy from the original source.

[242] This estimate assumes an average monthly parking value of $30 for all U.S. auto commuters, equaling an increase in total taxable income of $6.1 billion annually. With an effective marginal tax rate of 20 percent, federal revenue gains would total $1.2 billion. Ibid., pp. 179-181.

[243] Based on D.C. Shoup, "Cashing Out Employer-Paid Parking," forthcoming, as cited in J. Kessler and W. Schroeer, U.S. Environmental Protection Agency, Office of Policy Analysis, "Meeting Mobility and Air Quality Goals: Strategies That Work," draft report, Apr. 20, 1993, p. 20.

[244] In 1991, total U.S. gasoline consumption was approximately 112 billion gallons. U.S. Department of Transportation, Federal Highway Administration, *Highway Statistics 1991*, FHWA-PL-92-025 (Washington, DC: 1992), p. 6.

by reducing both travel times and other costs of using the transportation system.[245] Reducing gasoline and vehicle registration costs, however, is likely to increase travel demand, during both on- and off-peak periods, resulting in some rebound (i.e., loss) of the expected gasoline savings from congestion pricing.

Modeling studies of congestion pricing for major cities in North America and Britain have concluded that peak period travel could be reduced between 10 and 25 percent, depending on the site and the study assumptions. Such studies estimate that economically efficient charges during peak periods would range from 5 to 30 cents per mile, or about $1 to $2 per day for typical commuting distances.[246]

The studies estimate that daily congestion charges of this magnitude would reduce round-trip commute times 10 to 15 minutes on congested routes and would generate tens of billions of dollars in annual revenues nationally.[247] Estimating the impact of peak pricing schemes on gasoline consumption, however, is more difficult. largely due to expected changes in vehicle speeds and efficiencies with changes in road use. Congestion pricing would likely shift some auto use to other routes and reduce overall use and travel time, and average commute speeds could increase with mixed effects on gasoline use. The net effect on total gasoline consumption from congestion pricing is uncertain and deserves further study.

In some circumstances, such as major highway corridors, travel demand may be relatively unresponsive to price changes (price inelastic) during peak periods, particularly if travel alternatives are limited or unavailable. For example, New York City bridge and tunnel tolls doubled several years ago, but there was no major traffic reduction. For Southern California, one estimate suggests that congestion pricing of 65 cents per mile in urban areas and 21 cents per mile in suburban areas is necessary for effective demand management, a cost far higher than normal toll road rates of 2 to 4 cents per mile.[248]

Imposing high congestion fees (such as 65 cents per mile in the example above) is likely to be politically difficult. The annual added cost of driving could be almost $900 with a fee of 65 cents per mile.[249] Implementing effective suburban-based congestion pricing schemes based on the same Southern California estimate (21 cents per mile) may be difficult as well; the added cost under the same operating conditions would be about $290 per year.

A summary of the major advantages and disadvantages of congestion pricing is given in table 5-11. Although congestion pricing has been advanced by many economists since the 1960s, the strategy has not been applied on any major U.S. highway, and international experience is also very limited,[250] Several recent developments, however, have revived interest in this strategy: increasing levels of traffic congestion and associated air pollution;[251] increasing political acceptance for market-based over regulatory approaches to address public policy problems such

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[245] K.A. Small et. al., Road *Work: A New Highway Pricing and Investment Policy* (Washington, DC: The Brookings Institution, 1989), pp. 95-98.

[246] Ibid., p. 94.

[247] Ibid., p. 98.

[248] C. K. Orski, "Congestion Pricing: Promise and Limitations,'" *Transportation Quarterly,* vol. *46,* No. 2, April 1992, p. 165.

[249] Assuming an average work commute of 11 miles (the national average length of the worktrip in 1990). P.S. Hu and J. Young, *Summary of Travel Trends: 1990 Nationwide Personal Transportation Survey,* FHWA-PL-92-027 (Washington, DC: U.S. Department of Transportation, Federal Highway Administration, March 1992. p. 18). Also assuming that urban drivers travel half this distance in a peak-priced roadway for half of their trips to work and work 50 weeks per year.

[250] J A. Gomez-Ibanez, "The Political Economy of Highway Tolls and Congestion Pricing," *Transportation Quarterly,* vol. *46.* No. 3, July 1992, p. 344.

[251] Ibid., p. 345.

TABLE 5-11: Advantages and Disadvantages of Congestion Pricing

Advantages	Disadvantages
Allocating and rationing limited (congested) road space efficiently.	Due to potential price inelasticity of commuter travel demand, limited change in work travel
Capturing market externalities associated with traffic congestion	Potential scarcity or absence of alternate, less expensive routes or modes
Reduction in demand for new road construction.	
Retaining consumer flexibility in travel decisions	Reduction in competitiveness of one locality versus another by uneven application
Fixing market distortions that discourage the use of other modes	
Providing revenues for road maintenance and new construction.	Difficulty (or impossibility) of implementing effective or optimal pricing schemes politically

SOURCE Adapted from C K Orski, "Congestion Pricing Promise and Limitations," *Transportation Quarterly*, vol **46, No 2** April 1992 pp 157-167

as environmental degradation; and the development of technologies such as electronic toll collection that improve the feasibility of implementing congestion pricing by avoiding the delays imposed by stopping to make toll payments.[252]

The first congestion pricing program began in Singapore in 1975, with the imposition of a flat morning peak permit fee of $2.50 per day for autos driving to the central business district. Participants display permits in their windows. Technically, a flat fee is not the most efficient pricing scheme because there are no price adjustments for differing levels of peak travel, but the effort in Singapore led to an immediate decrease of nearly 60 percent in morning peak automobile trips. At the time the program was introduced, auto trips declined from 56 to 23 percent of total CBD work-trips. A decade later, CBD traffic levels remained lower than predicted. Congestion pricing has also been implemented in Bergen, Norway (6 to 7 percent travel reduction) and Milan, Italy (50 percent peak travel reduction in the city center) and is being developed in Hong Kong (postponed); Oslo and Trondheim, Norway (imposition of flat fees); the Netherlands (testing stage); and Cambridge, England (proposed).[253]

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) authorizes up to $25 million annually for a Congestion Pricing Pilot Program to fund a maximum of five congestion pricing projects.[254] However, the national impacts of a congestion pricing program on travel demand nationwide and gasoline use are difficult to assess, because the most effective congestion pricing schemes will vary greatly by community. depending on road volumes, patterns of auto ownership and use, job distributions, commute distances, and other factors.

Nonpeak road use pricing

The rationale for regular (nonpeak) road pricing is similar to that for congestion pricing: to reflect better the costs of building and maintaining roads, as well as the costs of vehicular emissions and other potential market externalities associated with road use. Similar to congestion pricing, tolls are commonly discussed in the context of nonpeak

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[252] Orski, op. cit., footnote 248, p. 159.

[253] Ibid., pp. 163-164.

[254] Public Law 102-240, 105 Stat. 1938, sec. 1012(b).

road pricing scenarios, including the use of private toll roads. However, there are fewer data on the impacts of nonpeak pricing. If nonpeak pricing is based on current national average toll road rates of 2 to 4 cents per mile, travel demand could be affected significant] y because these rates translate to between 40 and 80 cents per gallon of gasoline consumed (based on an average fleet efficiency of 20 mpg). The net effect of nonpeak pricing as a strategy to reduce total travel demand and gasoline consumption warrants further study.

Ridesharing Incentives

Ridesharing (or carpooling) for all trips (work, shopping, recreation) has declined for more than a decade. Between 1977 and 1990, average vehicle occupancy for all trips decreased about 16 percent (from 1.9 to 1.6 per vehicle), and occupancy for work commutes declined about the same amount (from 1.3 to 1.1, about 15 percent).[255] Ridesharing incentives to slow or reverse the recent historical decline in vehicle occupancy may apply to either peak or nonpeak travel and may take the form of subsidized van pools, free parking, or subsidized tolls. In addition, as noted above, parking charges and congestion pricing would encourage ridesharing.

The most extensive metropolitan ridesharing program stems from a regulatory program initiated in December 1987 in the Los Angeles area. The program, known as Regulation XV, requires employers of 100 or more people to develop and implement plans to increase vehicle occupancy for commute trips to their sites from 1.13 (the 1987 average) to 1.25-1.75, depending on the site, which represents an average increase in occupancy of 11 to 55 percent.[256] Bonus credits are awarded to telecommuting programs. The 8,900 affected employers are required to develop their own incentive programs and submit plans and progress reports annually. The plans commonly include economic incentives to rideshare. For example, employees of the city of Pasadena receive a monthly travel allowance of $20 but pay a $45 "trip reduction fee" each month they drive alone.[257] Employers are subject to fines if they fail to submit or implement plans, but not if they fail to achieve the ridership goals.[258]

Early results of the Regulation XV program vary greatly by work site, but there are several major trends. First, ridesharing increased significantly when parking subsidies were reduced and mass transit subsidies increased. Second, the use of onsite transportation coordinators improved performance. Third, a survey of more than 1,100 sites after the first year of the program indicated that ridesharing increased about 33 percent and solo driving decreased about 6 percent; telecommuting, walking, and biking, on the other hand, actually decreased somewhat but not significantly. Based on these early results, total daily trips in the area declined between 0.5 and 2 percent. The net impact of Regulation XV on gasoline consumption for the Los Angeles metropolitan area, however, is not known.

■ Regulatory Mandates

Regulatory mandates are enforceable provisions designed to ensure that transportation demand goals are attained. Implementing such options, however, may be politically difficult, and may reduce the amount or kinds of economic activity otherwise expected from a less restricted transportation system. Of course, where congestion is severe enough, the transport system already imposes economic costs (delays, accidents, poor air

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[255] Hu and Young, op. cit., footnote 249, p. 20.

[256] Unless noted otherwise, all information on the Regulation XV program given here is from R. Guensler and D. Sperling, "Solving the Problem Through Behavioral Change," unpublished manuscript, June 1992, pp. 6-12.

[257] C. K. Orski, "Can Management of Transportation Demand Help Solve Our Growing Traffic Congestion and Air Pollution Problems?" *Transportation Quarterly*, vol. 44, No. 4, October 1990, p. 489.

[258] Ibid., p. 492.

quality). The feasibility and efficacy of managing transportation demand by regulator-y mandates will depend on the severity or perceived severity of the traffic problem, as well as public acceptance and response to any proposed mandates.

Major TDM options in this group are discussed below. Many of these strategies are currently used in Europe and Japan, areas with high standards of living and similar but not identical traffic problems.

Restrictions on Automobile Ownership and Use

Restricting auto ownership or use can be accomplished by imposing higher age requirements for auto licenses, restricting automobile ownership in highly congested areas, limiting driving days, and restricting driving times or vehicle use in congested areas (such as central business districts). In a nation where restricted access to road travel is politically difficult to consider, imposing higher age requirements for auto licenses may accomplish little travel reduction and may offend many. The percentage of licensed drivers who are very young is low: less than 3 percent are aged 16 to 17, and only about 7 percent are 18 to 21.

One argument for restricting licenses for these first two age groups is that they account for a disproportionate share of auto deaths, about 5 and 14 percent, respectively.[259] When compared with their relative share of licensed drivers, however, auto fatalities occur disproportionately in all census age groupings up to age 34.[260] Even if younger drivers consume a disproportionate share of transportation energy, outright bans on their automobile use seem drastic as a means of saving energy in transport, especially as historical land use and transportation policies tie mobility to automobile travel. In addition, most men and women aged 16 to 19 already work[261] and presumably must travel to their job sites on a regular basis; restricting vehicle licenses for these age groups. therefore, could seriously complicate or prevent their ability to work, particularly if they live in rural areas. As an alternative, restricted licenses for young drivers that limit auto use to work-related travel may be more politically acceptable and fair, although they could create difficult enforcement problems.

Other options to reduce vehicle use are potentially inequitable and regressive, particularly if affordable and accessible transportation alternatives such as mass transit are not available or are limited. For example. uniformly increasing auto registration fees will consume a greater portion of earnings from lower-income households. Restricting driving days will have the greatest impact on one-car households, which are probably predominantly lower-income households. Another problem is that multiple-vehicle households, which will be less affected by driving restrictions, are becoming more prevalent. For example, between 1969 and 1990 the number of households with two or more vehicles more than doubled, and those with three or more vehicles increased fivefold. whereas the number of one-vehicle households increased only 1 percent.[262] Selectively raising registration fees for second and third vehicles may be a less regressive option.

Mandatory Ridesharing

Some jurisdictions may determine that ridesharing requirements are appropriate for highly congested areas or roads, but most are likely to prefer voluntary programs. Mandatory programs are likely to encounter more political resistance than voluntary ones and may not address the significant incentives (e.g., free parking) that currently encourage solo driving. In addition, mandatory

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[259] U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States: 1992*, 112th ed. (Washington, DC: 1992), p. 612.

[260] Ibid.

[261] Ibid., p. 381.

[262] Hu and Young, op. cit., footnote 249, p. 12.

programs introduce enforcement costs without raising revenues (unless monetary penalties are imposed).

In Los Angeles, an area considered to have the worst urban traffic congestion and air pollution problem in the United States, the major regulatory TDM program (Regulation XV) is substantially a voluntary incentive program. Hybrid programs such as Regulation XV may represent a more balanced mix of mandatory and voluntary elements by requiring the development and implementation of plans, while allowing employers to determine the best package of incentives for their commuting workers.

Incorporation of Parking Requirements in Zoning Ordinances

Off-street parking requirements have been a common element of zoning ordinances for new buildings since the 1920s. These requirements have several purposes, such as preventing drivers from searching surrounding areas for available parking spots and limiting parking spillover from commercial to residential areas. Nonetheless, zoning requirements that maintain a large supply of parking spaces lower parking costs and thus encourage auto travel.[263] By eliminating or modifying these mandatory requirements, the amount and cost of local parking may better match market demand and thereby reduce travel and gasoline consumption.

Efforts to limit urban parking spaces appear rare. In Munich, Germany, a gradual but aggressive effort to eliminate more than 70 percent of inner-city parking spaces was initiated in 1965. A 1988 Organization for Economic Cooperation and Development (OECD) study described this program as effective in reducing travel to the inner city.[264] To help local markets better determine the optimal allocation of parking spaces and their costs, based on market supply and demand, zoning ordinances could be written without establishing minimum parking quotas, except perhaps for handicapped spaces.

Alteration of Work Schedules

To reduce the volume of peak-hour trips for work commuters, many or most of whom have a typical business day of roughly 9 a.m. to 5 p.m., several alternative work schemes may distribute work travel more evenly across more hours: flextime, compressed work weeks, and staggered work hours. In 1988, a staggered work hour demonstration project was implemented for one month in Honolulu.[265] The goal of the program was to alter government employee work schedules to distribute peak travel over more hours in the mornings and afternoons. State, local, and county employees were required to participate in the program, which postponed the start and end of the official workday by 45 minutes each, from 7:45 a.m.-4:3O p.m. to 8:30 a.m.-5: 15 p.m. Although many exemptions were granted, about half of all government employees participated in the program, as well as about 8 percent of private employees, for a total of roughly 4,000 workers.

There appear to be no estimates of gasoline savings from the Honolulu demonstration project, but average commute times were reduced about 7 to 9 percent. Savings varied by route and time of day. Those commuting from the most distant suburbs reduced their average commute times by 15 to 25 percent, while those who started work at 7:30 or earlier actually experienced a 30-percent *increase* in their average commute time (this increase was not explained). In addition, nonpartici -

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[263] D.C. Shoup and D.H. Pickrell, "Problems with Parking Requirements in Zoning ordinances," *Traffic Quarterly,* vol. 32, October 1978, pp. 545-561.

[264] To offset the loss of inner-city parking spaces, an extensive system of park-and-ride facilities was constructed outside the center of the city. Organization for Economic Co-operation and Development, *Cities and Transport* (Paris, France: 1988), pp. 119-123.

[265] Information about the Honolulu program is from G. Giuliano, "Transportation Demand Management: Promise or Panacea?" *Journal of the American Planning Association*, vol. 58, No. 3, summer 1992, pp. 331-332.

pants enjoyed slightly greater reductions in commute times (up to 3 minutes more) than program participants. As the average indicates, however, most commuters experienced small and perhaps unnoticeable reductions in their commute times.

Gasoline savings from alternative work schedules are likely to be small. Savings from efficiency gains associated with decreased congestion may be offset somewhat by potential growth of demand. Schedules that allow workers to reduce their workweeks by a day, or by one day every two weeks, will save on the energy used for commuting, but this may be counterbalanced somewhat by non work travel during the extra day off, or even an increase in long-distance driving associated with more three-day weekends.

■ Telecommuting

Telecommuting is the practice of allowing people to work either at home or in nearby centers located closer to home during their normal working hours. The relative ease of administration and costs of implementation make telecommuting an attractive option in managing travel demand. An annual random survey estimated that 6.6 million people telecommuted[266] at least part time in 1992. or slightly more than 5 percent of the total adult workforce in the United States.[267] The 1993 survey estimates that about 7.9 million adult workers are telecommuting--a 20-percent increase over 1992.[268] If these estimates are correct. about as many workers telecommute, at least part time, as commute by mass transit.[269] However, the range of estimates of different studies differs by a factor of 3, with the lowest estimate for 1992 at 2.0 million.

Several businesses have found that along with anticipated overhead cost reductions (number of occupied offices and parking spaces), there have been increases in employee productivity and management skills. In a telecommuting project by AT&T and the State of Arizona, 80 percent of the participating supervisors reported increased employee productivity, and 67 percent indicated an increase in the overall efficiency of their departments.[270] Employee morale and productivity both improved, and telecommuting forced managers to improve their managerial skills by setting clearer objectives and managing by results rather than by overseeing. A recent survey of 100 “Fortune 1,000” companies and government organizations found that 30 percent have full-time employees who work from home part time and that 8 percent of the companies are about to begin such programs.[271]

Public policy has already played a direct role in the growth of telecommuting. Regulation XV, adopted in 1987 by the Southern California Air Quality Management District, requires the more than 4,000 district employers with 100 employees or more to develop and promote commuting options such as flexible work schedules, ridesharing, and telecommuting.[272] Several businesses have turned to telecommuting in an attempt to comply

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[266] These telecommuters do not include home-based businesses, agricultural businesses, or employees bringing home supplementary work from their offices.

[267] D. Filipowski, "Employees Who Prefer Home Work," *Personnel Journal*, vol. 71, No. 11, November 1992, p. 27. (Assumes 124.3 million workers in the United States.)

[268] P. Braus, "Homework for Grownups," *American Demographics*, vol. 15, No. 8, August 1993, p. 39.

[269] Based on 1990 census data that 5.3 percent of the total commuting population used public transit, down from 6.4 percent in 1980. American Public Transit Association, personal communication, 1993.

[270] S. Caudron, "Working at Home Pays Off," *Personnel Journal*, vol. 71, No. 11, November 1992, p. 40.

[271] A. Bellinger and H. La Van, "Telecommuting, Has Its Time Come?" *Home Office Computing*, vol. 10, No. 12, December 1992, p. 50.

[272] B. Schepp, "The Second Commute," *Home-Office Computing*, vol. 9, No. 12, December 1991, p. 45.

with the regulation's average vehicle occupancy (AVO) requirements. Regulation XV is being studied by several other areas of the United States that are out of compliance with the Federal Clean Air Act Amendments of 1990 (CAAA) standards.

Telecommuting is eligible for travel demand management funding provided by ISTEA. States and municipal planning organizations may use funds from several programs for eligible telecommuting activities. Eligible activities include the planning, development, and marketing of an area-wide telecommuting strategy designed to improve air quality and reduce congestion.[273]

The most significant barriers to telecommuting will probably be largely nontechnical factors such as lack of business and worker acceptance. Employers and workers must become familiar and comfortable with this new way of working. Employers are concerned with the cost-benefit implications. Other concerns center around remotely supervised employees and potential problems of lack of communication, extended breaks, and drug abuse. Workers are concerned with the potential lack of communication. social isolation, loss of benefits, lack of career advancement, and stress from mixing work and home life.[274] Other potential barriers to telecommuting including local zoning codes restricting home-based work and union opposition (especially the issue of employers identifying workers as independent contractors rather than employees).

Impact on Travel Behavior

Although telecommuting eliminates many commuting trips, theoretically these could be replaced by other trips or longer, unlinked trips. Some examples of new or longer trips include: shopping and/or child care trips normally made en route to work; trips by other household members due to the availability of the vehicle; [275] trips made possible due to increased flexibility of the work schedule; trips necessitated by working at home, for example, to the post office or the supply store; and relocation of residence, yielding longer commutes on office work days.

The results of some recently completed and ongoing studies suggest that many of these new trips are not occurring, and reductions in commute trips have not been offset noticeably by the generation of new trips.[276] For example, on telecommuting days, participants in the State of California Telecommunications Pilot Project made virtually no commute trips, reduced peak-period trips by 60 percent, reduced total distance traveled by 75 percent, and reduced freeway miles by 90 percent.[277]

Impacts on Energy Use

The U.S. Department of Transportation (DOT) has made tentative estimates of the future impacts on travel and energy use of a large increase in telecommuting.[278]

1. Potential telecommuters. To estimate the number of potential telecommuters, DOT focuses

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[273] U.S. Department of Transportation, Federal Highway Administration, *Transportation Implications of Telecommuting* (Washington, IX: U.S. Government Printing Office, April 1993), p. 6.

[274] These concerns have been disputed by the results of several demonstration projects and an extensive survey by the Small Business Administration.

[275] Over the long term, presumably many of the newly available vehicles would no longer be available.

[276] These studies include the Southern California Association of Governments, the State of California, the Hawaii Telework Center, the Netherlands Ministry of Transport, Puget Sound multiemployer program, Los Angeles County, the Travelers Insurance Co. in Hartford, Connecticut, AT&T in New York City, and several employers in Southern California.

[277] Federal Highway Administration, op. cit., footnote 273, pp. 64-65. There is little analysis of the effects of telecommuting on mode choice. Small-sample findings indicate that mass transit and van and carpool ridership will go down slightly. However, the built-in flexibility of paratransit service will allow most van and carpools to continue to function and thus not affect their share of vmt. See P. Mokhtarian, "Telecommuting and Travel: State of the Practice. State of the Art. " *Transportation*, vol. 18, No. 4, 1991, pp. 319-342.

[278] Federal Highway Administration, op. cit., footnote 273, pp. 53-87.

on white collar workers with a managerial and professional specialty, or workers in sales and clerical jobs.[279] These information workers, those who deal primarily with creating, distributing, or using information. are the most likely to be telecommuters in the next several years.

Approximately 50 to 60 percent of contemporary U.S. civilian jobs, or 73.3 million of the 129 million workforce, are information jobs.[280] By 2002, this number is expected to increase to 85.5 million, or 59 percent of the workforce. DOT's projected upper bound of telecommuters in 2002 is 15 million, about 10.5 percent of the workforce or 17.5 percent of information workers. This is a gain of 650 percent over the next 10 years, with half of the growth occurring in the last 3 years. The lower projection is half of the upper bound and assumes a gain of 250 percent over the same period.[281]

2. Reductions in trips and vehicle-miles traveled. According to National Personal Transportation Survey statistics for vmt, 3.7 billion vmt (or 0.7 percent of the total passenger car commuting vmt) were avoided in 1992 by the 1.6 percent of the work force that telecommuted. DOT's upper forecasts of the annual commuter passenger car vmt avoided in 1997 and 2002 are, respectively, 12.9 billion and 35.1 billion, or 0.63 and 1.4 percent of the total passenger car vmt (2.0 and 4.5 percent of total passenger car *commuting* vmt).[282] The lower bound of vmt avoided is 10 billion in 1997 and 17.6 billion in 2002, or 0.49 and 0.70 percent of total passenger car vmt (1.6 and 2.3 percent of total passenger car commuting vmt), respectively.
3. Reductions in energy use. According to the upper bound of vmt reductions presented above, telecommuting will save619 million gallons of gasoline in 1997 (14.7 million barrels), or 0.8 percent of the total used by passenger cars, and 1,679 million gallons in 2002 (40 million barrels), or 2.1 percent of the total.[283] These savings will reduce Federal and State fuel tax revenues by $57.5 million in 1992 and $540.8 million in 2002 as an upper bound ($270.3 million as a lower bound).

Policies To Stimulate Telecommuting

Although there can be substantial marketplace incentives for companies to initiate telecommuting, including enhanced access to skilled workers, increased worker satisfaction and productivity, and savings in office space, the substantial public benefits in reduced congestion, oil use, and air pollution may justify government promotional incentives. These may include changes in tax policy to allow companies to deduct some of the direct costs of the initial startup of telecommuting programs, such as worker training and telecommunication equipment costs, and to allow teleworkers to deduct computer and telecommunications equipment as a business expense on personal income taxes. Local governments can amend zoning requirements to allow a reduction in the minimum number of parking places in office buildings to

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[279] J. H. Pratt, *Myths and Realities of Working at Home: Characteristics of Homebased Business Owners and Telecommuters*, SBA-6647-OA-91 (Washington, DC Small Business Administration, March 1993), p. 26.

[280] Ashok B. Boghani et al., "Can Telecommunications Help Solve America's Transportation Problems?" (Cambridge, MA: Arthur D. Little, Inc., 1991), Reference 65740, p. 25. See also J. Nilles, "Traffic Reduction by Telecommuting: A Status Review and Selected Bibliography,'" *Transportation Research*, Part A, vol. 22A, No. 4, July 1988; and Federal Highway Administration, op. cit., footnote 273, pp. 53-55.

[281] The higher figures are derived from a forecasting model developed by Jack Nines, by using his "business as usual" nominal case. His high growth and acceptance scenario starts with 4.4 million telecommuters in 1992 and ends with 30.5 million telecommuters in 2002. See J. Nilles, Telecommuting Research Institute, Inc., "Telecommuting Forecasts,"' informational document, 1991, table 1, pp. 1, 3.

[282] Assuming an annual vmt growth rate of 3.7 percent.

[283] Assumptions fuel efficiency is held steady at 20,92 mpg, average round-trip distance avoided is also held constant at 21 .4 miles and the average distance to regional telecommuting centers is 9 miles; average price per gallon is held constant at $1.14. These are the direct savings only and do not include savings from congestion relief.

give incentives to new businesses locating in an area to implement a telecommuting program.

One of the biggest impediments to telecommuting is the lack of information on successful projects. California has a Telecommuting Advisory Council with more than 300 members, which acts as a clearing house for information and advice on telecommuting.[284] Several cities and Federal agencies have taken part in Federal- and State-sponsored telecommuting demonstration projects. An increase in the number of projects combined with a careful documentation of the economic and environmental effects of these projects could decrease employer resistance to telecommuting.

■ Public Investments, Information, and Other Efforts To Manage Transportation Demand

High-Occupancy Vehicle Lanes

HOV lanes are freeway, highway, or city arterial lanes restricted to vehicles containing two or more passengers. By providing a congestion-free alternative to normally congested traffic lanes, HOV lanes encourage ridesharing by reducing or reversing the time penalty generally incurred in picking up passengers (which often requires adding to trip length). And by encouraging ridesharing, HOV lanes may reduce the number of vehicles in use at any one time and thereby reduce gasoline consumption. This is especially important during rush hours, when congestion is at a maximum.

HOV lanes may be converted from existing highway lanes or newly constructed. All HOV lanes are likely to face enforcement problems from encroachment of nonqualifying vehicles. The benefits of newly built HOV lanes tend to be uncertain because to the extent that they relieve congestion in parallel lanes, they may encourage additional traffic. The likely magnitude of this “latent demand” for additional travel remains a source of controversy in the planning community, although experience with opening new highway lanes shows it clearly exists. Also, newly built HOV lanes introduce substantial costs for construction and maintenance. Where HOVs are developed from existing lanes, on the other hand, congestion may increase in the remaining lanes, thereby increasing fuel use (and emissions) in nonparticipating automobiles but providing a more certain incentive for carpooling and a more certain net fuel savings.

Both CAAA and ISTEA encourage construction or conversion of HOV lanes. CAAA lists HOV lanes as an allowed transportation control measure for air quality implementation plans and exempts HOV construction funds from any sanctions induced by failure to comply with the Act’s requirements. ISTEA makes HOV lanes in air quality nonattainment areas eligible for Congestion Mitigation and Air Quality funding.[285] ISTEA also permits State authorities to designate a two-passenger vehicle as a high-occupancy vehicle, a shift from previous FHWA policy limiting HOV designations to vehicles with three or more passengers.[286]

In North America, there are 40 HOV projects on freeways and other separate rights of way. These projects are dispersed among 20 metropolitan areas and cover roughly 340 miles. These projects vary by hours of operation (from 2 to 24 hours per day) and occupancy requirements (two to three or more passengers, and bus-only lanes). Under current plans, this capacity will more than double in the next decade, increasing to 880 miles by the year 2000. In addition, there are many more

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[284] Boghani et al., op. cit., footnote 280, p. 8.

[285] C.K. Leman et al., Institute for Transportation and the Environment, “Rethinking H, O. V.: High Occupancy Vehicle Lanes and the Public Interest,” discussion draft, May 1993.

[286] Ibid.

projects in off-freeway settings, such as urban arterial streets and bus-only lanes, ranging in length from several city blocks to as many as 10 miles.[287]

Two recent studies suggest both the potential of HOV lanes to reduce the growth of vehicle travel and the difficulty of accurately measuring their effectiveness. The first study examined the effectiveness of HOV lanes on Interstate 5, linking downtown Seattle with its northern suburbs. based on vehicle counts before and after HOV construction.[288] The HOV lane was available in late 1983, and vehicle counts were taken from 1978 to 1989. Adjusting for the growth in the number of households and their income, the study determined that the increase in vehicles was less than had originally been projected (with no HOV lane) for every year after the HOV became available. (As the authors stressed, HOV lanes are judged effective if vehicle counts for the corridor increase more slowly than projected. As population and auto ownership rates increase, travel volume is projected to increase even *with* effective HOV projects.)

In fact, the study determined that the reduction from expected demand levels increased over time, with a 6 percent reduction from projected levels in 1984 and a 35-percent reduction in 1989. The study concluded that based on this reduction of projected travel demand, HOV lane effectiveness in Seattle was comparable to the 10- to 25-percent reduction in congestion thought possible by using road pricing along congested routes.

Despite these encouraging results, the basic assumption of the study—that the HOV lanes were the reason for the decrease—is speculative. In particular, the study did not evaluate or consider other potential factors that may have slowed actual growth in travel demand, such as the availability and use of alternative routes, possible changes in mass transit capacity and use. and especially. shifts in the geographic distribution of employment and residential settlement over the 12-year period. Although the HOV lanes may have had a significant (if not the major) impact in reducing travel demand on Interstate 5, this example illustrates the complex challenge in evaluating precisely the impacts of TDM measures such as HOV lanes, because other factors may increase ridesharing or reduce travel demand.

Using a different measure of effectiveness, another study examined changes in carpooling rates after the construction of a 13-mile HOV lane on Route 55 in Orange County, California.[289] The HOV lane opened in 1987, and within a few years, vehicle occupancy increased between 7 and 9.5 percent. The increased occupancy was significant and greatest for workers using more than half of the 13-mile HOV lane (a 12.3-percent increase in carpooling). Other statistically significant changes in carpooling applied to workers retaining the same jobs and residences for at least two years (6.7-percent carpooling increase) and workers traveling between 6 and 9 a.m. (3.5-percent increase). Unfortunately. although the increase in ridesharing is clear in this case. the net impact on total transportation demand requires separate measurement because of the potential for increased travel demand caused by reductions in congestion and increased total road capacity. Another source of potential error in HOV lane effectiveness calculations is the potential for such lanes to pull passengers from transit: according to

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[287] K.F. Turnbull and D.L. Christiansen, "HOV Lessons," *Civil Engineering*, September 1992, p. 74; and K.F. Turnbull and D.L. Christiansen, "High-Occupancy Vehicle Facilities: An Approach to Solving Congestion and Mobility Problems," *Transportation Research News*, No. 160, May-June 1992, pp. 16-20, 35.

[288] B.S. McMullen and T. Gut, "HOV Lane Effectiveness in Controlling Traffic Congestion," *Transportation Quarterly*, vol. 46, No. 3, July 1992, pp. 429-434.

[289] G. Giuliano, "Transportation Demand Management: Promise or Panacea?" *Journal of the American Planning Association*, vol. 58, No. 3, summer 1992, pp. 329-331.

Pisarski, the socioeconomic characteristics of carpool riders and transit riders are very similar.[290] When carpools pull passengers from transit, measured increases in vehicle occupancy overstate actual declines in vehicle travel.

In conclusion, HOV lanes' effectiveness in reducing vehicle travel is difficult to measure, and the value of HOV lanes, relative to other investments, as a strategy to improve air quality, reduce congestion, and reduce energy use is being increasingly questioned by transportation planners. At the very least, each proposed use of HOV lanes should be carefully evaluated, with the potential for conflicts with transit systems and stimulation of travel fully accounted for in the analysis.

Intelligent Vehicle-Highway System

IVHS encompasses a range of technologies, many still under development, that provide one or both of two basic tools for drivers: so-called smart cars (intelligent vehicles) and smart highways (intelligent highways). These technologies taken together are designed to provide drivers with an array of real-time information, including road and traffic conditions, directions to unfamiliar or distant sites, identification of alternative routes, and determinations of optimal and safe driving speeds and automobile spacing on roads. A 1989 OTA staff paper concluded that existing IVHS technologies could increase road capacity by 10 to 20 percent but that this group of technologies alone is not sufficient to eliminate urban traffic congestion.[291]

IVHS has been presented as a means to reduce gasoline use based on the improved technical efficiency of vehicles in free-flowing traffic. However, IVHS may lead to increased travel and gasoline use by reducing congestion and travel times, so energy savings from improvements in operating conditions must be balanced by this potential travel take back. There is nothing about IVHS, per se, that would encourage ridesharing.

IVHS technologies include advanced traffic sensing and signal control technologies to improve traffic flow, as well as advanced on-board systems to help drivers interpret highway system data to reduce travel time, improve safety, or both. Although at least 60 IVHS-related technologies exist,[292] their broad functions are far less numerous, consisting of three major groups of systems: advanced traffic management (ATMS), advanced traveler information (ATIS), and automated vehicle control (AVCS). Each of these categories possesses technologies with unique roles and differing merits.

Many observers regard the ATMS as the most promising group of IVHS technologies,[293] but that perception is arguably related more to the unique nature of this technological approach than anything else about these technologies. In short, ATMS technologies are designed to monitor traffic via radar and other remote tracking systems, to analyze these data, and to alter traffic flow electronically and automatically by adjusting signal timing and freeway ramp controls, and by providing information on roadside bulletin boards. Unlike the other two major groups of IVHS technologies, therefore, ATMS bypasses direct participation and interaction with the driver and reduces the chance that drivers may not possess, understand,

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[290] Pisarski, op. cit., footnote 128.

[291] U.S. Congress, Office Of Technology Assessment, Science, Education, and Transportation Program, "Advanced Vehicle/Highway Systems and Urban Traffic problems,'" staff paper, September 1989, p. i.

[292] P.F. Rothberg, Congressional Research Service, "Intelligent Vehicle Highway Systems: Challenges, Constraints, and Federal Prt~-grams," 92-189 SPR, Feb. 18, 1992, p. 1.

[293] See, e.g., D.K. Willis, "IVHS Technologies: Promising Palliative or Popular Poppycock'?"" *Transportation Quarterly*, vol. 44, No. 1, January 1990, pp. 73-84.

or act on other on-board IVHS technologies. By acting outside the vehicle on the larger transportation system, ATMS technologies may also reduce the potential safety hazards that a complicated or distracting on-board technology could introduce by drawing the driver's attention away from the road, even if only briefly.

ATIS technologies may be used to enhance ATMS tools. ATIS technologies are on-board systems that impart information about traffic conditions and alternative routes and may include electronic maps and navigational tools. Unlike major ATMS technologies, ATIS information may be tailored to an individual driver travel plans and thus, in principle. provide complete information that assists a driver for the entire trip, from departure to final destination. These technologies, therefore, may be especially useful for drivers with multiple route options, assisting both local residents and visiting travelers seeking the best routes during a given day or time.

The third major IVHS category, AVCS technologies. is geared toward traffic safety. These on-board technologies may assist or, in the most extreme cases, replace or override drivers. Assistive AVCS technologies include adaptive cruise control, obstacle detection, and infrared sensing to improve safety for night driving. Other AVCS technologies are designed to intervene directly in driving, including automatic braking, cruise control, and maneuvering: the rationale behind these technologies is to maintain optimal but safe distances between vehicles to improve driving and traffic flow. The most ambitious AVCS technologies under development involve automated driving, where human drivers essentially become passengers until reaching their destinations.

In principle, IVHS technologies aim to make optimal use of road space, while maintaining safe distances from other vehicles and objects. By improving the efficiency of road and lane use, IVHS technologies promise to reduce traffic congestion and driving times, which could reduce vehicle emissions and fuel use per vehicle-mile of travel. but such road improvements could lead to more vehicle-miles traveled.

There are other potential drawbacks to IVHS technologies. First. absent changes in production and implementation costs, their expected expense is substantial]. According to the Federal Highway Administration, installing ATMS technologies on the more than 15.()()0 miles of U.S. urban highways will cost $30 billion to $35 billion,[294] and the costs for on-board technologies will increase this amount further, adding an estimated $1 ,500(0 $2,000 per vehicle, although these costs are expected to decline as production volumes increase.[295] However, if reported estimates of *annual* congestion costs ($30 billion to $100 billion, current dollars) and traffic accident costs ($75 billion to $100 billion, current dollars) are reasonably accurate, then a $30-billion investment in ATMS would be fairly cost-effective If congestion and accident costs were reduced as little as 5 percent per year.[296]

Second, many IVHS technologies may not work well (or at all) incrementally; that is, they require broad applications of road system and vehicular technologies. As a result, incremental investments may not be fruitful, thus limiting the chances of gradual implementation. Third, many on-board ("smart car") technologies require driver interaction and attention, which may reduce safety by distracting drivers, particularly in challenging congestion and weather conditions when they are most likely to use the technologies. Finally. concerns about legal liability in cases when AVCS technologies fail and cause accidents may limit industry interest in these tools.

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[294] "Back to the Future, Part II: Smart Cars," *The CQ Researcher*, vol. 3, No. 14, Apr. 16, 1993, p. 330.

[295] Rothberg, op. cit., footnote 292, p. 21.

[296] This would allow a simple payback within 3 to 7 years. The $30-billion annual congestion cost figure is from U.S. Congress, Office of Technology Assessment, *Delivering the Goods: Public Works Technologies, Management, and Financing*, OTA-SET-478 (Washington, DC: U.S. Government Printing Office, April 1991), Summary, pp. 1-2. The remaining congestion and accident cost figures are from ibid., pp. 16-17.

Despite these potential drawbacks, congressional interest in IVHS technologies has increased markedly in the last several years. The Intermodal Surface Transportation Efficiency Act of 1991 (Public Law 102-240) authorizes a total $659 million for IVHS research and development for fiscal years 1992 through 1997.[297] Also, at least $150 million in additional IVHS funds are authorized by 1992 Department of Transportation funding. This amount represents a major increase from earlier IVHS authorizations, which totaled about $4 million in 1990 and $24 million in 1991.[298] These projects will help determine IVHS impacts on traffic flow, congestion, and road safety, but the impacts on total vehicle travel and energy consumption (the focus of this report) are worth examining as well.

Improved traffic signaling

Although this is often discussed in the context of broader IVHS applications, changes in traffic signaling have already demonstrated their potential to reduce traffic congestion without major investments in IVHS projects. For example, urban travel times have been reduced as much as 25 percent by improved timing of traffic lights. In Los Angeles, the Smart Street project around the University of Southern California has reportedly reduced both travel time and fuel use about 13 percent.[299]

Conclusions

Some of the more optimistic evaluations of transportation demand management strategies suggest that they may reduce peak hour travel volumes by 10 to **25** percent, depending on the strategy chosen and how aggressively it is applied, and they conclude that in some cases, travel volume and congestion may be reduced even further, although the political and economic costs would likely prevent implementation.

OTA believes that estimates such as these should be treated as highly uncertain, and policymakers should recognize the large variability of TDM effectiveness, depending on location and circumstance, as well as the experimental nature of many TDM initiatives. Nevertheless, there is enough positive experience with certain types of TDM measures—moving to paid parking is an obvious example—that policy makers can expect strongly positive results with well-designed TDM programs.

Current information suggests, however, that no TDM measure by itself will eliminate traffic congestion, and no TDM measure will significantly reduce congestion in all circumstances. Moreover, some TDM strategies may increase transport energy use by improving traffic flow, thereby encouraging more and perhaps longer trips. Identifying the best TDM strategies for a city or region will depend on the nature of the major problem (congestion, air emissions, energy use) and the particular conditions of the corridor under consideration, whether city, county, or region.

Finally, transportation policy planners should appreciate several other points about current TDM strategies:

- State and local authorities generally do not pursue TDM to conserve energy.
- Most TDM strategies have not been implemented on a large scale, and most have not yet been adequately evaluated, particularly from the perspective of energy consumption.
- Most TDM strategies implemented thus far have focused on worktrips, although these represent only about one-quarter of all trips.
- Any reduction in existing transportation demand has the potential to spur latent demand. Consequently, promising results from employer-based or metropolitan-based programs should be considered tentative until the effect on total regional travel (and energy use) is understood.

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[297] Public Law 102-240, 105 Stat. 2194, sec. 6058(a)-(b),

[298] Rothberg, op. cit., footnote 292, summary page, p. 1.

[299] Willis, op. cit., footnote 293, p. 77.

- Given the variety of TDM options and the conditions that determine which will be optimal in addressing travel demand, selecting or implementing specific programs is necessarily a local exercise. Thus, Federal transportation policy planners would do well to support and encourage (rather than direct) local choices in the selection of optimal TDM strategies.

REDUCING FREIGHT ENERGY USE

Policy Context

This section offers policy options to increase the energy efficiency of the freight transport system. Several points, which are common to all policy options, provide the setting within which to consider them.

1. **Freight transport plays a key role in the economy,** and national goals for the freight transport system may not always be consistent with energy efficiency. Desirable attributes of a freight transport system include low cost, high reliability, high speed, high flexibility, minimal losses and theft, and high availability. In many cases, increased energy efficiency can reduce costs and thereby improve the freight system overall;[300] however some policy options to increase energy efficiency-such as reducing speed limits—may adversely affect other goals (in this case, speed of goods delivery). These tradeoffs must be recognized when making policy decisions.
2. **The freight transport industry itself is a significant part of the economy—for example,** about 2.1 million people are directly employed in the industry.[301] Policies affecting the energy efficiency of the industry could significantly affect the industry in other ways as well—for example, shifting freight from trucks to trains would certainly shift employment as well—and these effects must be recognized.
3. **The Federal Government has long played a role in the freight industry: 1)** The national highway system was initially rationalized in part for national defense and is now used by trucks, which are responsible for a significant fraction of the maintenance requirements of these highways.[302] 2) Navigable Waterways used by freight barges are often dredged and maintained by the Army Corps of Engineers. (3) Railroads, which operate on privately owned rail networks, were originally regulated as a response to monopoly pricing practices and an attempt to ensure appropriate pricing. At present, many freight modes are regulated and subsidized in different ways, and policy changes affecting the industry should recognize the history of regulation and the current pattern of subsidies in the industry.
4. **Evidence from past successes and failures in policies to influence automobile energy efficiency should be used to craft successful policies for truck energy efficiency.** In the last 20 years the Federal Government has tried a variety of approaches to increase the energy efficiency of the private automobile fleet, including requiring energy consumption labels, fuel economy standards, and financial incentives (e.g., the gas guzzler tax). Many of these ap-

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[300] For trains, energy is 7 percent of total operating expenses (including depreciation, from Interstate Commerce Commission, Office of Economics, *Transport Statistics of the United States* (Washington, DC: 1991), pp. 9-10). For trucks, the figure is about 8 percent (including depreciation), from U.S. Department of Commerce, *Motor Freight Transportation and Warehousing Survey: 1990*, BT/90 (Washington, DC: November 1991).

[301] Bureau of the Census, op. cit., footnote 259, p. 407.

[302] Whether or not trucks pay their "fair share" of these costs is a contentious issue; however, a Congressional Research Service analysis of Department of Transportation research states, "Most heavy trucks do not pay their fair share for use of Federal-aid highways, according to the U.S. DOT.'" Congressional Research Service, "Trucks and Public Policy," 91-15E, p. 5.

preaches could be used with freight trucks as well.

What Is the Potential?

The future potential for energy conservation in the freight sector lies largely with reducing truck energy use, because trucks consume the major part of U.S. freight energy—more than 80 percent. The technical and operational potentials for reducing truck energy use were discussed in chapter 2. As noted there, demonstration runs combining commercially available technology, highly trained drivers, and ideal operating conditions yield impressive efficiencies--50 to 70 percent greater than the existing fleet. These results may not be achievable in day-to-day operation, but they do provide an upper bound on what could be achieved with today's technologies. If all heavy trucks achieved this level of energy efficiency, energy use would drop by about 0.9 quads, or 15 percent of total freight transport energy use.[303]

Aside from these technical improvements, truck energy use can be reduced by shifting to alternative freight modes. Each freight mode has characteristics (see table 5-12) that are best suited for certain cargo. For example, trains and barges can move high volumes of goods at low cost, yet tend to be slower than trucks and are restricted to existing tracks and waterways; they are therefore best suited for long-distance transport of high-density basic commodities such as coal and grain. Trucks and air can respond quickly to new demands, can go almost anywhere, and are generally fast and reliable, but cost more as well; they are therefore best suited for distribution of higher-value-added intermediate and consumer goods.

TABLE 5-12: Attributes of Freight Transport Modes

	Rail	Truck	Barge	Air
Geographic coverage	M	H	L	H
Speed	M	H	L	H
Energy efficiency	H	M	H	L
cost	L/M	M/H	L	H

KEY H = high M = medium L = low

SOURCE Off Ice of Technology Assessment 1994

In recognition of these varied attributes, intermodal transport (use of multiple modes) has been growing rapidly. This typically involves using trucks for local pickup and delivery, and trains for long-distance hauling. The same container or trailer is used by both trucks and trains to reduce transfer delays and minimize losses and theft. Some transportation companies are investing in multiple modes: one large trucking firm, for example, recently made agreements with several railroad companies, and is investing in containers that can be carried by both trucks and trains.[304] The growth of intermodal movements--especially double-stack containers on flatcars--has led to trains taking an increasing share of these long-distance movements in corridors where train service is available.

Although each mode has markets that are best suited for it (e.g., commodities by train and barge, shorter-haul time-valued goods by truck), trains and trucks do compete in some markets. One analysis identified commodities-including motor vehicles, paper, and chemicals—that collectively account for more than one-third of both truck and train ton-miles.[305] Although data on just where trucks and trains carry these products are not available, there is general agreement that trucks and trains do sometimes compete for the same movements.

These competitive markets are not well defined, but in general, for long-distance move-

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[303] The best commercially available trucks are 62 percent more efficient than the existing fleet (see chapter 2, table 2-6, average of 72 and 51 percent. respectively), therefore replacing the fleet will reduce energy use (1-1 1.62) or 38 percent. Heavy trucks account for about 51 percent of truck energy use (chapter 2, table 2-3). trucks use 4.9 quads per year (table 2-2); therefore savings = 4.9 x 0.38 x 0.51 = 0.9 quads.

[304] "Every Problem Is an Opportunity (J. B. Hunt Transport Services)," *Fortune*, NOV. 16, 1992.

[305] In 1987 "Key Commodities in Rail Truck Competition," *Intermodal Trends*, published by the American Association of Railroads, Mar. 3, 1989.

ments of basic commodities, trains (and barges, if waterways are available) are the dominant mode. For long-distance movement of intermediate and manufactured goods, trains and trucks often compete; however the trend in recent years is toward greater use of intermodal transport (containers or trailers on trains). For intermediate movements—600 to 1,600 miles—the two modes often compete, and neither mode dominates.[306] For short-distance movements—less than about 600 miles—trucks are used almost exclusively because they offer door-to-door service and minimal loading time.

The energy savings of shifting freight from truck to rail is made uncertain by the nature of most freight energy data; they measure total energy use by mode, but the mix of products carried by different modes is quite different. For example, in 1990, the average energy intensity for intercity freight movement by truck was 3,357 Btu per ton-mile, whereas the average intensity for intercity freight movement by train was 411 Btu per ton-mile,[307] or a ratio of 8: 1. However, an examination of the energy consumption by both trucks and trains for moving *identical cargo over the same route,* for a few specific cargoes and routes, suggests that *trucks use* 1.3 to 5.1 *times as much energy as do trains to move the same cargo over the same route.*[308] *This* study found that trains generally use 150 to 310 Btu per ton-mile to move mixed freight over long distances, whereas trucks use about 770 to 980 Btu per ton-mile for the same service.[309] Many other estimates have been made of modal energy efficiency-including some that try to include not only the propulsion energy (i.e., energy required to move freight from one point to another), but also the energy associated with vehicle manufacturing, road and rail construction, maintenance, and access (getting freight to and from the terminal). A comprehensive but dated review of these estimates found that they vary widely (suggesting that such numbers be used carefully); and estimated that including all of these factors would yield about a 1.7:1 truck-to-train energy use ratio.[310] These estimates suggest that for long-distance movement of some commodities, the energy savings from shifting freight from trucks to trains could be significant, but much less than would seem to be the case from a simple examination of average energy intensities.

A second key unknown in estimating the energy savings potential of mode shifts is the amount of freight that could be shifted. One study estimated that trucks move 54 percent. and trains 46 percent, of the nonbulk, long-haul (more than 500 miles) freight traffic.[311] For an extreme case in which *all* 308-billion ton-miles of this long-distance truck traffic shifted to trains, net savings would be about 0.2 quad if only propulsion energy is considered,[312] and about 0.4 quad with propulsion, vehicle and infrastructure construction, maintenance, and access energy.[313]

Shifting *all* the competitive freight would represent a doubling of present-day king-haul nonbulk train movements, and therefore would re-

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[306] . Trends in Truck/Rail Market Share," *Intermodal Trends,* published by the American Association of Railroads, Apr. 17, 1992.

[307] Davis and Strang, op. cit, footnote 134, p. 2-25.

[308] Abacus Technology Corp. *Rail vs. Truck* Energy *Efficiency,* contractor" report for the Federal Railroad Administration, April 1991, p. 7-15. For long-haul service, including effects of circuity.

[309] Ibid., p. 7-4.

[310] Congressional Budget Office, ""Energy Use in Freight Transportation," staff working paper, February 1982. This estimate is for a trailer on flatcar train and an intercity truck.

[311] '. Trends in Truck/Rail Market Share, " op. cit., footnote 306.

[312] Assuming 875 Btu per ton-mile for trucks and 230 Btu per ton-mile for trains, as in Abacus Technology Corp., op. cit., footnote 308, p. 7-4.

[313] Assuming 3,420 Btu per ton-mile for trucks and 2,040 Btu per ton-mile for trains, as found by Congressional Budget Office, op. cit., footnote 310. This estimate is for a trailer on a flatcar train and an intercity truck.

quire expansion in the train system. Existing rail networks are not capacity-constrained, and improved information technologies would allow greater use of existing tracks. However, some new tracks would have to be built in areas not presently served, and more locomotives and freight cars would be needed. In addition, some intermodal transfer points are already heavily used and would require expansion or relocation. Such a shift would also have significant effects on the train and truck industries themselves.

Policy Options

Methods to increase freight transport energy efficiency include greater use of commercially available technologies (such as improved aerodynamics, tires, and engines), promotion of the commercial availability of new and developing technologies, operational improvements (notably reduced speed and idling), and truck-to-train mode shifts. Policy options include financial incentives such as taxes and subsidies; regulations such as fuel economy standards and speed limits; changes in Federal testing, research, and development; changes in Federal procurement; early retirement programs; and improvement of intermodal infrastructure (table 5-13).

Financial Incentives

Energy taxes

One policy option for reducing energy use is to increase the price of energy. This can be done with an energy tax. Such a tax could take many forms, including:

- Btu tax based on energy content,
- carbon tax based on carbon content,
- simple percentage tax based on current price, and
- flat tax per gallon.

Diesel fuel is already taxed by both the States and the Federal Government. The current tax is in the form of a flat tax per gallon.

Energy taxes are a contentious issue. Arguments *in favor of* using a fuel tax to promote energy efficiency include the following:

1. It is relatively easy to implement and administer. Mechanisms already exist to collect fuel

TABLE 5-13: Policy Options To Increase Freight Transport Energy Efficiency

	Increased use of technologies	More new technologies	Operational improvements	Mode shifts
Financial Incentives				
Energy taxes	P	P	P	P
Feebates	P	P	—	—
Regulation				
Fleet average requirements	P	P		—
Specific technology requirements	P	—	P	—
Increased truck size/weight limits	—	—	P	N
Enforce/reduce speed limits	—	—	P	—
Federal testing,evaluation, R&D	P	P		—
Federal procurement	P	P		—
Early retirement	P	—		—

KEY P = positive effect, — = little or no effect; N = negative effect.

SOURCE Office of Technology Assessment, 1994 taxes, and the additional administrative cost to the government of increasing the tax would be very low.

2. It can raise considerable revenue. Freight transport consumes about 27 billion gallons of diesel fuel per year,[314] therefore, a diesel tax increase of 1 cent per gallon would generate about 269 million dollars.[315] These funds could then be used to provide incentives to manufacturers and operators for research, development, and purchase of energy-efficient vehicles.
3. From the perspective of economic theory, a tax is preferable to regulation because it guides. but does not constrain, consumer choice. A tax allows users to find their own methods to conserve (e.g., by investing in energy-efficient technologies or by changing driving behavior).
4. It will affect both new vehicle purchase behavior and operation of existing vehicles.
5. U.S. diesel prices are considerably lower than those of other industrialized countries. In Germany, for example, diesel currently costs $2.81 per gallon.[316]

Arguments against using a fuel tax to promote energy efficiency include:

1. The magnitude of energy savings is uncertain. It is generally agreed that, all else being equal, a higher energy price will result in reduced energy use, but there is little agreement on the energy savings per unit of price increase. The savings will depend on the level of price increase, of course. but will also be influenced by the speed and visibility of the price increase (a sudden and widely publicized increase will result in more behavioral change than a gradual, hidden increase).
2. Some users are unaware of the opportunities for efficiency improvements. In these cases, taxes alone without improved information will have no effect on efficiency.
3. It increases the price of goods (to the extent the tax is passed on to consumers). This could have two important detrimental effects: Consumers could reduce consumption, leading to reduced economic output; and the economic competitiveness of U.S. products on world markets could be harmed. The over-all economic effects, however, will depend on how the tax is structured. A revenue-neutral tax would result in shifts, but not necessarily decreases, in economic output: and if tax revenues were used for economically productive purposes then the net effects on economic output are not clear.
4. It will affect different users differently—for example, a manufacturer located far from its market will pay more than one nearby. This is not necessarily a disadvantage, because the new price may be “correct” in the economic sense. but the differential effects may have political implications.

Feebates

These programs are discussed earlier in more detail. Feebates, or fee-rebates, combine rebates to purchasers of efficient vehicles with surcharges on purchases of inefficient vehicles. Feebates can be revenue-neutral. by having the surcharges cover the costs of the rebates and the administrative costs. Such a program provides a financial incentive for efficiency without requiring an increase in government expenditures, and is more flexible than a mandated approach such as a fuel economy standard (discussed below). The disadvantages of feebates include: 1) there is no large-scale program experience, 2) they affect only new vehicle purchases, and 3) they provide no incentive for efficient operation of vehicles. The lack of program

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[314] Davis and Strang, op. cit., footnote 134, p. 2-14.

[315] Assuming a price elasticity of demand of 0.5, and a diesel price of $1.

[316] U.S. Department of Energy, Energy Information Administration, *International Energy Annual 1991* (Washington, DC: December 1992), p. 153.

experience—specifically the lack of data on behavioral response to the combination of fees and rebates—makes it difficult to estimate the energy savings potential of such a program.

Feebate programs for trucks incur a special disadvantage because combination trucks are sold as separate trailer and engine units, and because trucks haul very disparate types of cargo. Consequently, feebate programs may have difficulty properly grouping competing vehicles. Further, defining the "average fuel economy" necessary to compute fees and rebates presents a special problem.

Regulations and Government Programs

Performance technology mandates

In 1975 Congress passed the Energy Policy and Conservation Act (Public Law 163), which sets energy efficiency requirements for automobiles and light trucks. These requirements were in the form of a minimum fleet average—the sales-weighted average efficiency of new vehicle sales was required to exceed a value set in the legislation. Although the costs and benefits of this legislation are disputed, there is general (although not unanimous) agreement that these requirements played a large part in the doubling of the average fuel economy of new automobiles—from 14 mpg in 1975 to 28 mpg in 1990.[317] More recently, legislation was passed that set energy efficiency requirements for electric motors, refrigerators, lights, and other energy-using devices. For these devices, minimum efficiency levels were set that all units must meet. An evaluation of these standards found that energy and net cost savings were significant.[318]

The precedent for mandated energy-efficiency goals suggests that such an approach be considered for trucks.[319] A mandated approach to increasing truck energy efficiency could take several forms. A fleet average requirement could be set, as it is for automobiles and light trucks, and manufacturers could determine the best mix of technologies and price incentives to meet the requirement. Such a requirement would have to be normalized to account for different truck sizes and purposes, since some manufacturers produce only full-size trucks, whereas others produce a range of trucks. Alternatively, a minimum efficiency level could be set for each class of truck (e.g., all trucks designed for pulling full-size trailers must achieve a minimum number of miles per gallon).

One complicating factor in structuring such a requirement is the interactive effects of trucks and trailers. Most heavy trucks are designed to attach to trailers, and the fuel economy of the combined truck-trailer depends in part on the aerodynamics of the trailer. There is a large existing fleet of trailers that turn over relatively slowly; therefore it would be inappropriate to require truck manufacturers to meet efficiency levels that require the use of new, aerodynamically integrated trailers.

A milder regulatory approach might involve the requirement of excess idle and/or speed warning lights, speed governors (already in use by some truck fleets), and automatic shutdown to eliminate excess idle.

Advantages of a regulatory approach include:

1. It can result in large energy savings. As noted above, regulations setting energy use for electric motors, heating and cooling equipment, lights, automobiles, and light trucks are already in place, and by most accounts have (or are expected to) resulted in large energy savings.
2. It is relatively inexpensive for the government to implement and enforce.
3. It would speed implementation of existing or near-market technologies. As discussed above,

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[317] See Office of Technology" Assessment, op. cit., footnote 7, p. 20-22, and the discussion earlier in this chapter.

[318] See discussion in U.S. Congress, Office of Technology Assessment, *Building Energy Efficiency*, OTA-E-518 (Washington, DC: U.S. Government Printing Office, May 1992), p. 111.

[319] The setting of appropriate regulations would require much better data on truck size, use, energy consumption, age, and so forth than currently exist.

technologies are available that significantly improve efficiency.

Disadvantages include:

1. It is difficult to determine the optimal level at which to set the requirement. The cost-effective level of efficiency will depend in part on fuel costs, which can fluctuate.
2. It may raise the cost of new trucks, thereby slowing fleet turnover (and reducing energy savings).
3. Regulations limit consumer choice. Some argue that consumers, not the government, are best qualified to choose their preferred efficiency level.
4. It can increase the costs of vehicle production significantly if manufacturers are forced to retool production lines.
5. It affects only new vehicles and provides no incentive for efficient operation of trucks. The very high efficiencies achieved in some trucks (see, for example, table 2-6) resulted from both efficient technologies and careful driving; it would be inappropriate to expect such results from all drivers.

Increasing allowable truck weight and size

All else being equal, larger trucks are more efficient in terms of Btu per ton-mile. However, increasing allowable truck size may encourage mode shifts from trains to trucks, reducing the net energy efficiency gains. In addition, there are safety concerns with larger trucks that are as yet unresolved.[320] These issues suggest that further study is needed before increasing size or weight limits.

Improved enforcement or reduction of speed limits

There is a considerable energy efficiency penalty from higher speeds. One generally accepted rule of thumb is a 2.2-percent mileage penalty for each mile per hour above 55.[s2]1 Despite the energy penalty, however, highway speeds have been increasing since 1974. Improving enforcement of existing speed limits, and reducing speed limits from 65 to 55 mph, are policy options to consider. Reduced speed limits will also enhance safety and, unlike many other options, affect the entire fleet and not just new vehicles. The chief disadvantage is the increased time requirement, with its attendant cost penalty.

Recent data indicate that the average speed for all traffic on rural interstate highways with a 55-mph speed limit is 60 mph. If this average applies to trucks as well, reducing average speeds from 60 to 55 mph would reduce energy use by *2.2* percent/mph x 5 mph, or 11 percent. Trucks currently consume about 5 quads of energy (table 2-2), and about two-thirds of truck miles are for nonlocal service.[322] If three-fourths of nonlocal truck-miles occur on highways, and highway truck-miles are twice as efficient as nonhighway truck-miles, reducing average truck speeds from 60 to 55 mph should save about 0.2 quad per year of freight energy.[323]

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[320] For a discussion of these issues see U.S. General Accounting Office, *The Safety of Longer Combination Vehicles Is Unknown*, GAO/RCED-92-66 (Washington, DC: March 1992).

[321] See L. Johnson et al., "Energy Contingency planning for Freight Transportation,'" ANL CNSV-34 (Argonne, IL Argonne National Laboratory, August 1982), also American Trucking Associations, The Maintenance Council, *55 vs. 65: An Equipment Operating* (*osts* (*omparison* (Alexandria, VA: 1987), p. 7.

[322] U.S. Department ~) f Commerce, Bureau of the Census, *Truck Inv* et?/or) *and Use* sir) *ey*, TC87-T-52 (Washington, DC: August 1990), p. US-6.

[323] Highway truck-miles are two-thirds times three-quarters, or one-half of total truck-miles. Assuming they are twice as efficient suggests that they consume 4.9 times (me-third. or 1.63 quads, 11 percent of [his is about 0.2 quad.

Federal procurement

The Federal Government currently has about 380,000 trucks.[324] Changes in Federal procurement to encourage or require greater energy efficiency in new trucks would save energy by itself, would demonstrate that energy-efficient technologies are available and effective, and would support markets for such products.[325] Although most of the Federal truck fleet consists of light-duty vehicles, the Federal government does purchase a significant number of medium- and heavy-duty trucks. The General Services Administration, the major purchaser of vehicles for the U.S. government, does not have energy efficiency requirements in its specifications for medium and heavy trucks. These specifications could be modified to include minimum mile-per-gallon requirements.

Federal R&D and information programs

At present, the Federal Government supports little truck energy-related R&D. Although manufacturers do considerable R&D, much of this is targeted at safety, performance, and emissions goals. In an era of flat energy prices, manufacturers see limited market demand for energy efficiency. This suggests that expanded Federal R&D support for energy efficiency may be appropriate.

Investments in energy efficiency require credible and complete information on the costs and savings of such investments. Unfortunately, data on fuel efficiency of trucks are often difficult to find and, where available, difficult to compare across models because there is no standardized testing method. Extending the existing testing and labeling program for light-duty vehicles to freight trucks would provide consumers with the information needed to make optimal energy efficiency choices. There is also a need for testing and certification of energy efficiency retrofit devices, notably aerodynamic add-ens. The effects of labeling programs are difficult to measure,[326] but there are several reasons for the government to implement them: they improve consumer information, they provide manufacturers with a marketing tool to promote highly efficient models, and a government program will probably be seen as more credible than a program run by an entity with a direct economic incentive in the outcome.

Early retirement

One barrier to rapid market penetration of energy-efficient truck technologies is the existence of a large fleet of relatively inefficient (as compared to new units) trucks. Early retirement of old trucks would improve the energy efficiency of the fleet, and offer considerable emissions and safety benefits as well. The disadvantages of such a program include possible adverse equity effects and questions about its cost-effectiveness.[327] There is insufficient experience with such programs to mount a large-scale early retirement effort; however, it may be appropriate to investigate smaller, experimental programs to see how well they work.

Promotion of intermodal freight movement

Intermodal movements have been growing rapidly, but there is room for this growth (o be accelerated. A recent survey of shippers found that the

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[324] U.S. General Service Administration, *Federal Motor Vehicle Fleet Report* (Washington, DC: September 1990), pp. 27, 35. Heating value of 122,050 Btu per gallon assumed (average of diesel and gasoline values).

[325] These issues are discussed in U.S. Congress, Office of Technology Assessment, *Energy Efficiency in the Federal Government: Government by Good Example*, OTA-E-492 (Washington, DC: U.S. Government Printing Office, May 1991).

[326] Evaluation of appliance labels is discussed in Office of Technology Assessment, op. cit., footnote 318, pp. 113-116.

[327] Early retirement ~) fears is discussed in (-1. S. Congress Office of Technology Assessment, *Retiring Old Cars: Programs To Save Gasoline and Reduce Emissions*, OTA-E-536 (Washington, DC U.S. Government Printing Office, July 1992).

major barrier to greater use of intermodal movements is the belief that intermodal transport is too slow or unreliable.[328] The causes of delay in intermodal service include excess circuity (i.e., unavailability of direct-route tracks) and, perhaps most important, excessive delays at terminals. Many terminals are located in urban areas, are too small for their volume of traffic, and are difficult for trucks to access. Infrastructure changes, such as truck-only access roads from highways to intermodal terminals, or relocating terminals outside of urban areas, could be considered. The Intermodal Surface Transportation Efficiency Act of 1991 (Public Law 102-240) established a National Commission on Intermodal Transportation (section 5005), and requires the Commission to report to Congress on barriers to greater use of intermodal service. Congress could consider the recommendations of the Commission carefully, with the recognition that improved intermodal service could have significant energy efficiency benefits.

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[328] Intermodal Association of North America and the National Industrial Transportation League, 1992 *Intermodal Index* (Riverdale, MD December 1992), p. 14. Railroads in general suffer from a reputation for unreliability and poor service; however, this is starting to change—see "'Big Rail Is Finally Rounding the Bend.'" *Business Week*, Nov. 11, 1991, pp. 128-129.