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THE FUTURE OF URBAN TRANSPORTATION

Urban transportation is likely to be increasingly dependent upon the automobile, with an accompanying decline in conventional public transit. Small, low-performance vehicles for neighborhood travel may emerge, along with some special paratransit services in moderate-density areas. Regional centers are likely to continue to develop and will be cited by future planners as a major source of urban transportation problems.

INTRODUCTION

The past decade has seen a transition in urban transportation brought about by higher energy costs, a faltering economy, and recent demographic trends. This transition is manifested in the smaller size of automobiles, increased public transit deficits, and the lack of maintenance of existing roads. Assuming that a future equilibrium will be attained, it is of interest for planning purposes and for the allocation of transportation resources to speculate on the form of that future equilibrium state and how it may be achieved.

The limited scope of this paper, which considers only the movement of people in metropolitan areas, prevents consideration of urban goods movement, an aspect of urban transportation that has been neglected too long and that appears ripe for exploitation by improved technologies and operational techniques.

CURRENT STATE OF URBAN TRANSPORTATION

Transportation Goals

People move from one location to another to achieve certain goals. In a rational sense, the cost and time devoted to this movement will be minimized, subject to some constraints on consumer preferences. Transportation planning uses this rationale to relate the cost and time of travel and certain inconveniences to a common base — for example, dollars — and then to relate these values to demand estimates and environmental and land-use considerations to compare cost benefits. Such an approach, while difficult and occasionally leading to foolish results, does present the problems in tractable terms.

However, mobility also seems to be a goal in itself. The Sunday afternoon drives, the cruising of teenagers, and the tender loving care provided the automobile are all manifestations of this phenomenon[1] and may simply reflect the high values placed on personal freedom and on the reduced anxiety associated with the availability of a personal conveyance. These individual goals bias the process of deciding on transportation policy and investment.

The process is further distorted by federal funding and regulations that have made transportation funding into a prime instrument for promoting social goals ranging from economic development to providing opportunities for the elderly and handicapped.[2]

The problem is further compounded because many of these social goals are implicit, while the justification for the investment is often based upon transportation-related issues only. In Baltimore, for example, the building of a rail transit system has been justified primarily by arguments related to improvement in mobility and to energy and environmental concerns. Little has been made of the fact that the construction of the initial 8 miles will provide about 40,000 person-years of labor — but certainly this fact had to be a major consideration in the minds of the city and state administrations, especially since 80% of the funding would come from the federal government.

Thus, many transportation programs are evaluated in terms of their success at meeting nontransportation goals, and failure to achieve these goals is likely to decrease the resources available to future transportation programs.

Transportation Policy

Over the past three decades, the public preference for the automobile has translated into public policy and programs favoring the automobile. The early programs were directed at reducing congestion, increasing travel speeds and highway capacities, and improving accessibility to urban areas. The most visible result of that policy is the Interstate Highway Program, which is the largest public works project ever undertaken.[3]

In terms of their original intent, the policies worked quite well. However, problems arose in that few people were aware of or concerned with the negative effects of these policies. Interstate commerce was improved and a vast trucking industry was built, but at the expense of the railroads. Beltways reduced congestion in the central city by diverting traffic around the city, but at the expense of inducing commerce and industry to locate away from the city. Radial highways into the city improved traffic flow and travel time, but encouraged even further dispersion and sprawl.[4] The result is a greater dependence on the automobile, more pollution and oil consumption, greater dispersion of the population, increased difficulty for mass transit to accommodate to the dispersion, and reduced mobility for the significant fraction of the public that does not have access to a car. These factors, along with the rise of the environmental movement and the disruption of neighborhoods, the displacement of people and businesses, and the high cost of urban highway construction, created a powerful deterrent to further highway construction — a deterrent sufficiently strong that the amount of new highway construction has declined rapidly.

The disillusionment with highways led to a resurgence of interest in mass transit as a cure for many urban transportation ills. The increased interest can be attributed to

1. An increasing urbanization of the population, with a concomitant increase of the cities' power in Congress and in state legislatures;
2. A perception that mobility did not improve despite the vast expenditures on highways. Most people seem to feel that improving mass transit will attract other people to its use, thereby reducing the congestion that they will face;
3. Energy, environmental, and land-use concerns;
4. An honest desire by almost everyone to believe that a mass transit system is a good idea.

This shift in attitude is a little surprising considering the state of public transit in the 1960's and 1970's. The aggressive, entrepreneurial attitude of the early trolley-line builders had disappeared by the 1920's, partly because of the regulations imposed by local governments on operations and fares. Further, ridership and revenues declined because of the automobile. This decline was arrested somewhat by World War II, but the end of the war and the increased availability of the automobile sent transit ridership into a spiraling decline — the consequent loss of revenues leading to reduced service and maintenance, this leading to a further decline in ridership,[5] and so forth.

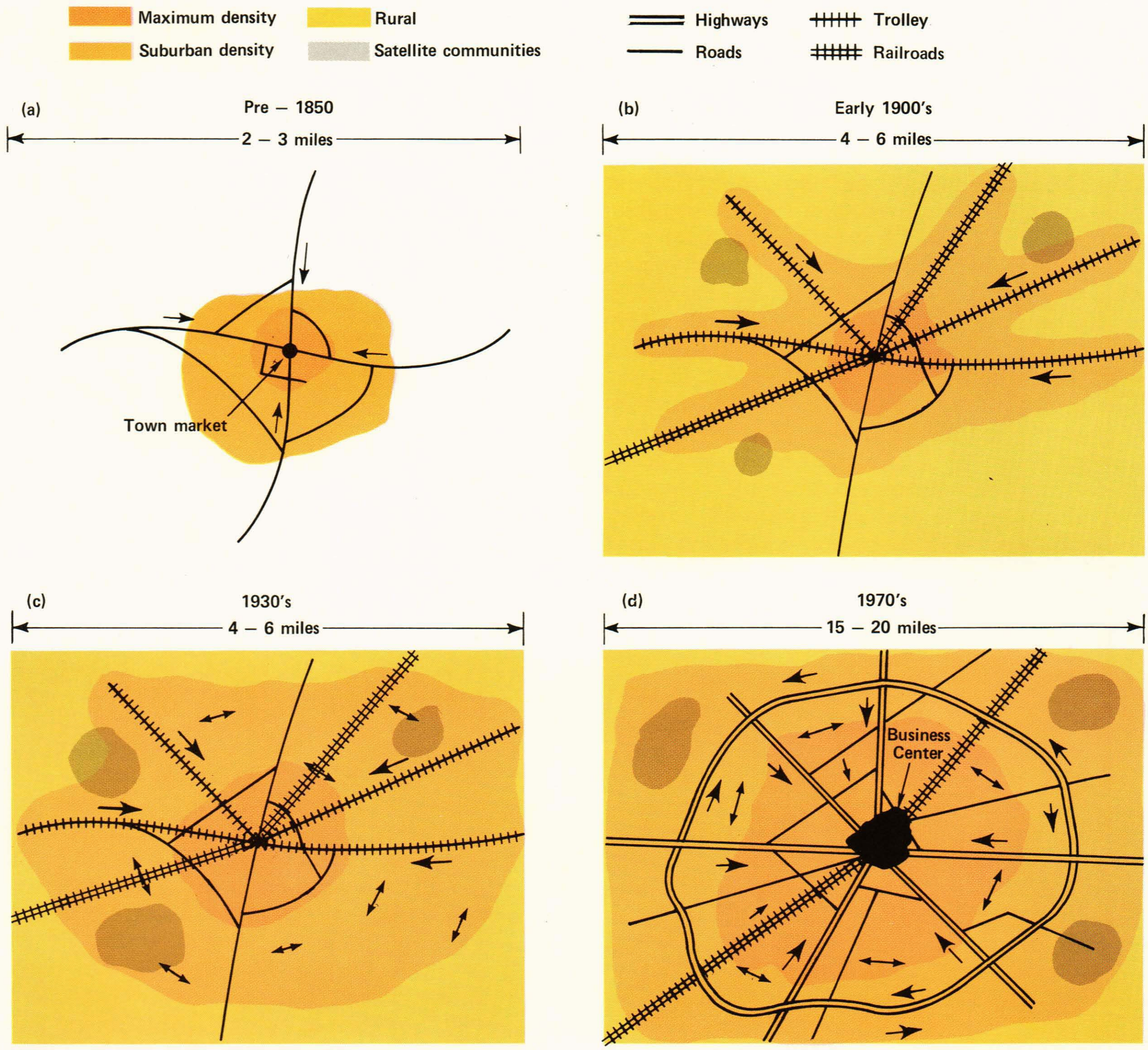
The increased attention to urban problems in the 1960's included mass transit; attempts were made to revive it, initially through subsidies from the cities to the private operators, and eventually from the federal government to the metropolitan areas to the operators. This situation was basically unstable and was finally resolved by public purchase of the systems from the private operators so that by 1970 most of the major systems were publicly owned and operated. The combination of public ownership and federal subsidies has had important consequences for mass transit, specifically:

1. The federal grants are limited to the purchase of new equipment or facilities for which the federal government would pay up to 80% of the cost. The result was a rush to buy new buses and facilities and to build rail transit systems. This movement led to a concentration on hardware rather than on improving service or increasing operational efficiency.
2. The public agencies, by virtue of federal and local regulations and political pressure, were more susceptible to the demands of labor so that transit workers went from among the lowest paid in their job categories in the mid 1960's to among the highest paid in the late 1970's. With labor representing from 60 to 80% of operating costs, this factor, along with increased fuel prices, increased operating costs drastically.
3. The acceptance of federal assistance carried with it an obligation to provide certain social services (reduced fares in off-peak hours to those over age 65, accessibility to the elderly and handicapped) and to achieve a regional consensus on transportation expenditures, all of which add to the cost. The regional consensus implies distributing the assistance to all jurisdictions in the region in order to promote acceptance.
4. The above trends, together with public pressure to maintain low fares and to retain or expand unprofitable routes and services, resulted in a growing disparity between operating costs (which have increased by 184% over the last decade) and revenues (which have increased by 44% over the same period). This burden on the transit agencies was eased somewhat by legislation in 1974 that provided federal subsidies of up to 50% of the operating deficits.

In addition to these cost-escalating factors, operating costs have continued to rise because of the service requirements associated with population dispersion and the continuing concentration of transit patronage in the AM and PM peak hours.[6] As a result, operating subsidies have increased from $0.10 per rider in 1970 to $0.40 per rider in 1978.[7] While the total transit patronage in 1978 was nearly identical to the 1970 patronage (approximately 5.9 billion passengers), the proportion of passenger-miles aboard transit has continued to decline.

Given these factors, it is not surprising that public transit systems are already facing severe financial difficulties.

The predominance of the automobile, then, is not likely to be adversely affected by current public transit and, in fact, in times of fiscal austerity, transit services are likely to deteriorate. In this regard, we should note that certain public transit routes and services do provide sufficient income to cover their



This series of sketches illustrates the growth of a community from the 1850's to the present. When everyone walked to work, shopping, church, and recreation, "urban" areas were limited by the distances one would be willing to travel on foot (a). In (b), the advent of both trolleys and steam-powered railroads permitted expansion along the routes of travel and into small, intermediate population centers. Increasing numbers of automobiles in the 1930's permitted far greater mobility, suggested by the small arrows in (c). More roads, expanding and interconnecting small centers, a growing financial and commercial centers, and the birth of industrial complexes characterized the period between 1945 and 1970.

operating expenses. These services include short radial trips along high-density corridors; inner city trips, especially in high-density, less affluent neighborhoods; and some express radial services (to Park-'N-Ride lots, for example). Any paring back in transit services would likely continue these services while reducing suburban and crosstown transit services.[8]

TRANSPORTATION AND URBAN FORM

Another factor to be considered is the relation between transportation and land-use or urban form. Historically, a strong relationship can be shown. Until the mid-19th century, the size of a city was restricted by the limitations imposed by the need to walk to daily activities. In the latter half of the 19th century, the invention of portland cement and the elevator permitted highrise buildings and higher densities, while the invention of the horse-drawn trolley and, later, the electrically propelled trolley allowed horizontal expansion. The trolleys, because they conserved human energy and were faster than walking, allowed people to separate their residences from their places of business and other activities and allowed them to purchase more living space away from the central core. The result was that the city generated radial spokes along the trolley lines from downtown. This growth was fostered by the trolley-line owners, who found it profitable to expand the line into open land, which then could be developed. Many even encouraged trolley use on Sundays and holidays by building amusement parks at the end of the line.

The subway systems built between 1890 and 1920 in New York, Boston, and Philadelphia were not as influential on urban form as the trolleys. The high cost of construction limited their placement to existing development, which permitted higher densities but had less of an impact on the eventual form of the city.

The invention of the automobile had a drastic effect on urban form. By the late 1920's, the automobile's availability and accessibility had permitted a noticeable filling-in of the area between the spokes and expansion beyond the trolley lines, had changed many of the streets served by trolleys into major arterials, and had attracted a significant number of people away from the trolleys. Although this trend was slowed by the Depression and World War II, it exploded in the later 1940's and 1950's, aided by increased affluence, public preference for low-density living, and federal and local policies that encouraged single-family, suburban housing. The result was residential sprawl, a movement of jobs to the suburban areas, and a precipitous decline in the use of public transit.

The most recent change in urban geography has been the growth of numerous regional centers of residential, commercial, and industrial activity. These centers rival the central business district in both the level of activity and spatial extent. They generally exist near the intersection of major highways on the periphery of the city and are characterized by their land-intensive nature and by their dependence on the automobile. The centers are usually embedded in areas of low-to-moderate activity. They are often too large for convenient walking and are congested. Parking and unparking to move about within the centers and access to the surrounding arterials are difficult and time consuming. While their existence is dependent upon the car, the car is not an effective mode for movement within or near the centers.

While acknowledging this historical relation between transportation and urban form, the important question for our purposes is whether this relationship still holds and will continue to hold in the future. The answer seems to be that this relationship is weakening. Two examples will be cited for illustration.

It is often claimed that the presence of a rail transit station can encourage high-density development in the vicinity of the station, with Toronto and San Francisco given as examples. Yet those[9] who have studied this phenomenon have noted the following:

1. Many areas around transit stations in the two cities have shown little or no development.
2. Those station areas having significant development were often being developed prior to the decision to build a rail system.
3. Those station areas developed after the decision to build a rail system were more affected by the favorable economic conditions and by favorable zoning, economic, and other development policies instituted by the community than by the presence of a rail system.
4. The development that did occur was not new development, *per se*, but often a shifting of development that most likely would have occurred elsewhere in the region.

In other words, the rail system acted as a catalyst for government policies favoring development near the stations. The implication is that similar development would have occurred without the rail system if similar favorable policies had been instituted. However, the magnitude or pace of the development might have been reduced without the presence of a rail system to support it.

More important to our concerns is the fact that the historical trends that have been cited are the result of the new transportation technology having a distinct advantage over the older technology in terms of speed, accessibility, and/or cost — in other words, greatly improved mobility. If this trend of transportation generating urban development is to continue, the following questions arise:

1. Is there an emerging technology that has a distinct advantage in mobility over the automobile and that eventually can replace the automobile?
2. Is the automobile, as some claim, a dinosaur whose demise is near for energy, environmental, and economic reasons? If so, what will replace it?
3. Might the automobile still predominate but be replaced by some other, substitute modes for those functions that the automobile is least effective in performing — specifically, movement in high-density areas and activity centers or along major arterials during commuting periods?

These three questions will be the basis for discussing future urban transportation.

SPECULATIONS ON THE FUTURE

In this examination of the future direction of urban transportation, two assumptions will be made:

1. The economy will remain stable or grow slowly;
2. Energy prices will continue to escalate, at least for the next decade, at a rate faster than the remainder of the economy and will then stabilize.

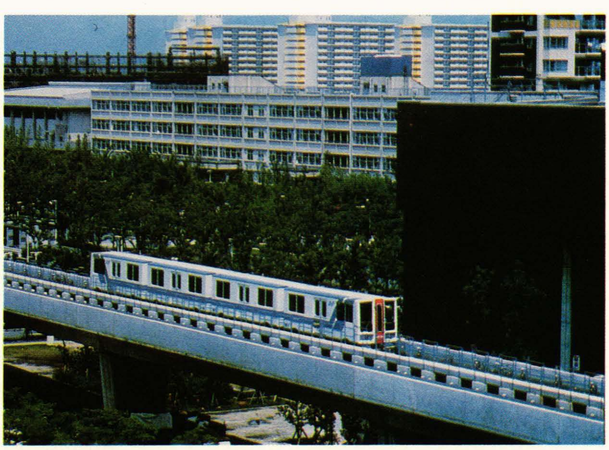
The increased price of energy and the diversion of a significant amount of the available capital into energy-related investment are expected to affect urban form. Recent demographic trends, such as smaller families where both adult members work and the increase in single-person housholds, suggest that many of these people may prefer to reduce the time devoted to home maintenance and travel by selecting smaller housing nearer their daily activities. Such a preference would be reinforced by higher energy costs for residential heating and cooling and for transportation. Although some of these people would move to the central city, the recent investment in regional centers and the increased employment in the suburban ring, especially in these centers, suggest that most of this movement would be toward the regional centers.[10]

The older, mature cities might then be characterized as having little or no spatial expansion because of the increased in-filling and the increase in size and density of the regional centers. The newer, growing cities will continue to expand spatially (although at a slower rate) with regional centers coming into existence and growing, but with the region maintaining a lower overall density than exists in the older cities.

The economic efficiency and service capability of current public transit are likely to be only marginally improved by the above development scenarios, and the reliance on the automobile is expected to continue. If new modes of transportation do appear, these will most likely be a result of the increased density of the activity centers, especially the regional centers. The form of these modes will depend upon the size of these centers, which, in turn, will depend upon the available methods for movement within the centers. An expansion of this thesis will require that we consider the future of the automobile and of current public transit and examine the attributes of recently proposed transportation innovations.

The Automobile

The automobile has undergone and will continue to undergo design changes brought about by energy, environmental, and safety concerns. These changes include downsizing, the use of lighter materials, reduced performance, improved fuel and emissions controls, safety equipment and designs, diesel engines, computerized engine management, and improvements in engine and drive-train efficiency — all resulting in higher costs. Most of these changes have been the result of federal regulation reinforced by the increased price of fuel in the late 1970's. The most notable regulation is the Energy Policy and Conservation Act of 1975, which requires the sales-weighted average fuel economy of a corporation's new car fleet to be 27.5 mpg for the 1985 model year.



Automatic guideway transit application in Osaka, Japan, connects a man-made island in Osaka harbor with the mainland. In the background are residential units on the island. (Photo courtesy of K. Morita.)

General Motors estimates that its 1985 new car fleet will average 31 mpg (EPA rating),[11] with average weights of about 2500 pounds and with about 60% of the fleet having four-cylinder engines. Diesel and six-cylinder engines will comprise most of the difference, with very few eight-cylinder automobiles being marketed.[12]

Thus, cars will continue to become smaller (about 2500 pounds) and more fuel efficient (about 25 to 28 mpg) through 1985, and the trend to greater fuel efficiency is likely to continue after 1985, possibly aided by additional federal mandates to increase fuel economy. During this latter period, we may also expect the major auto manufacturers to introduce an urban vehicle that is a low-performance, two-passenger vehicle designed specifically for use on city streets.

Less certainty exists regarding vehicle emission and safety regulations. Current regulations have contributed to a decline in emissions (especially hydrocarbon, lead, and carbon monoxide) and to increased automotive safety, but at a relatively high cost and with an accompanying decline in fuel economy.[13] Ford Motor Company, for instance, claims that emission control and safety equipment added about $700 to the base price of the 1978 intermediate size automobile, and General Motors warns that the added weight due to pollution and safety equipment could negate projected increases in gas mileage. Given the current economic and political climate and the financial state of the domestic auto industry, it is unlikely that more stringent emission or safety regulations will be imposed on the manufacturers in the next decade, although current regulations may not undergo significant change.[14] The major implication of this trend is that future efforts to improve air quality are likely to focus on measures to curtail automobile operation.

In the longer term, alternative liquid fuels for automobiles can be expected to become competitive, and partial or even complete replacement of petroleum as an automotive fuel may result. The difficulty arises in the transition stage to the alternative fuel. A rapid increase in the price of oil or a sudden, long-term shortfall in oil would have serious economic consequences that could not be accommodated by an increase in alternate fuel production since the necessary production capability could require ten or more years to achieve. A federal policy will be needed to accomplish this transition in an orderly manner. The policy must bring the alternative fuel into production in an economically feasible way and adapt the automobile fleet to the alternative fuel coincident with the fuel's availability. At least one approach is being considered to accomplish this transition: Each oil refining organization would be required to produce and market a synthetic liquid fuel at a level proportionate to its total fuel production, e.g., 5% synthetic fuel in 1990. The mandated proportion would be increased with time. The type of fuel would not be mandated, leaving that decision to the company on the basis of economics and technology. If the schedule and proportion of synthetic fuel could be chosen correctly, a smooth transition could be accomplished.[15]

Nonliquid energy sources are also of interest, with most of the current attention directed at the electric vehicle (EV) or automobile. Available battery technology has hampered the performance of EV's, especially the range. As a consequence, their use has been limited to special applications, in which this deficiency is not a major factor, such as urban delivery and service vehicles. The development of high-performance, long-life batteries could expand the EV market considerably, but, even then, the consensus of recent market studies indicates that electric vehicles are unlikely to constitute more than 5% of the automobile fleet by the year 2000.[16]

The development of EV's does provide the opportunity for the development of a low-performance, short-range, low-cost vehicle for use in local travel — essentially weather-protected souped-up golf carts. Such vehicles could be used for shopping trips, short commutes, and other trips of less than five miles along specially designated rights-of-way analogous to bicycle paths. Licensing requirements for such vehicles would be minimal, and they would be of special value to the young, the handicapped, and the elderly. With simplified rental procedures, they could also be used for circulation in major activity centers connecting, for example, the subcenters in automobile-oriented regional centers. Demonstrations of this type of vehicle in several senior citizen communities in California have met with enthusiastic response by the residents.

These minivehicles offer an opportunity to increase automobile productivity. As noted by Sparrow *et al.*,[17] about 70% of urban trips can be accomplished by these minivehicles, which could, therefore, provide the main source of transportation for urban dwellers at a considerable savings in investment and operating costs. The need for larger vehicles could be met by a shared vehicle cooperative that, with a sufficiently large membership and automotive fleet, could assure a high probability of vehicle availability to an individual member when needed. Such cooperatives are in existence in London. Alternatively, the shared vehicle arrangement could be operated by rental car agencies. These minivehicles need not be electrically powered. In fact, compressed natural gas as a fuel possesses advantages over batteries in weight and in recharging.

In effect, the automobile, unlike the dinosaur, appears to be a highly adaptable species that is likely to remain the primary mode of urban transportation if the purchase price and operating costs remain within reach of the greater part of the public. In examining these costs, it is assumed that the current transition in automobile characteristics will continue until at least the mid-1980's and will stabilize thereafter.

The operating costs consist of the costs of fuel, maintenance, parts, and tolls and parking. A recent (1980) DOE estimate using mid-range price assumptions suggests an average annual increase of about 10% between 1979 and 1985 in the price of gasoline (constant 1979 dollars) prior to state and federal taxes. The use of this rate and the current untaxed rate for gasoline (about $1.25 per gallon) suggests a gas price of $2 per gallon in 1985 (1980 dollars). Assuming that federal and state gasoline taxes are adjusted to maintain current revenues on a per automobile basis, the increase in these taxes would be about equal to the increase in the fleet fuel economy of about 36% between 1980 and 1985, i.e., from $0.13 to $0.18 per gallon. The total fuel cost would be $2.15 to $2.20 per gallon (1980 dollars). Since the fuel economy of the average new car will increase at an average rate of about 7% annually to 1985, the buyer of the average new car in 1985 will spend in the first year about $155 more for fuel (in 1980 dollars) than the buyer of the average new car in 1980 based upon a typical first-year mileage of 14,500 miles (or $110 more based upon 10,000 miles/year). The fuel costs represent about a 15% increase over the 1980 fuel costs. In addition, the costs of maintenance, parts, and accessories are projected to increase by 8% between 1980 and 1985, while the parking and toll costs are assumed to remain essentially constant.[18]

For a 1980 subcompact (EPA average of 22 mpg), fuel and oil costs and repair, maintenance, parts, and other costs represent 64% and 10% of the first-year operating costs, respectively. Assuming this ratio to be approximately valid for new 1985 cars, the total increase in operating costs between a 1980 and a 1985 model automobile will be about 11% ($165), for an average annual increase of 2.1%, a value within the projected growth in household disposable income. Even for high-mileage drivers, this difference in operating cost could be offset by reducing driving by 13% or by the purchase of a more fuel-efficient car (35.5 versus 31 mpg). Under these circumstances, the increased operating costs provide little incentive for changing driving behavior or the mode of transportation (see accompanying box).

The high-range annual average rate of increase in gasoline prices to 1985 is about 11.5%, which would result in an increase of $265 in first-year fuel costs compared to the $155 for the DOE mid-range estimates. This increase is likely to promote smaller cars, reduced driving, and some ride-sharing, but it is not likely to induce a significant change to other transportation modes. For the period beyond 1985, the DOE estimates of fuel cost increases are about 3% or less, suggesting that even modest increases in new car fuel economy will result in lower fuel costs than in 1980. The monetary costs of automobile operation,

OPERATING COSTS FOR A 1980 NEW CAR

The operating costs for the average 1980 new car are derived from estimates for a 1979 subcompact with an EPA rating of 22 mpg and with fuel costs (including taxes) of $1 per gallon. For the 1980 car, the costs of gas and oil (including taxes) were increased by 38%, taxes were unchanged, and the remaining operating costs were increased by 8%. These increases gave a total first-year operating cost of $1,476.60, compared to the 1979 value of $1,216.30, with gas and oil (including taxes) representing 64% of the total cost, and repairs, maintenance, and other costs representing 10%.

Obviously, the operating costs will increase in each subsequent year of a car's life, primarily as a result of increased fuel costs. Assumption of a fixed annual mileage of 10,000 miles with a 5% annual deterioration in fuel economy and a 10% fuel price rise yields:

Year	*Fuel Cost**	*Difference*
1980†	$ 708	—
1981	822	$114
1982	953	131
1983	1106	153
1984	1283	177
1985†	816	−467

*Constant 1980 dollars
†Purchase of average new car

As the car ages, there will be an additional incentive to reduce annual mileage and, perhaps, to increase the frequency of new car purchases. For two-car families, the trend will be to shift increased driving to the more fuel-efficient vehicle. However, the annual increment of $110 to $180 is only marginally noticeable, suggesting that the cost increase will be absorbed without significant changes in travel behavior by most drivers.

The most significant burden will fall upon the owners of cars more than five years old, which currently comprise about 45% of the auto fleet and provide about 35% of the total vehicle mileage. Many of these cars are second cars whose owners may be able to reduce the monetary burden by reduced driving. However, a large proportion of these vehicles belong to low-income one-car households. In these cases, and especially among the suburban and rural poor without access to transit, the driving costs can be large and will undoubtedly influence travel behavior.

therefore, do not appear to be a significant factor in changing driving behavior.

The increase in the purchase price of an automobile will depend primarily upon the incremental increase in the cost of capital equipment, R&D, and manufacturing, and on the new equipment added to the automobile by regulations or consumer desires. Based on industry estimates of the capital requirements to 1985, an incremental cost of about $750 per automobile (1980 dollars) is obtained. Allowing for additional equipment and accessories, a cost increment for the model year 1985 automobile of about $1000, or an increase of about 12 to 14% over the 1980 costs, is anticipated.

While insurance costs decreased in real terms in the 1960's and 1970's, the costs have increased in recent years due to the increased costs of medical care and automotive repair. Assuming stabilization in medical care costs, some increase in the probability of an individual involved in an accident having a serious or fatal injury, and an increase of 8% in automotive repair costs over the same period, suggests less than a 10% increase in insurance costs over that period. The insurance cost increase would then average about $250 to $300 (1980 dollars) over the period of ownership of an automobile.

The recent high interest rates have certainly contributed to depressing car sales and to deferring new car purchases. While continued high rates are likely to lead to longer individual car ownership, especially of the second car, and possibly to reducing car ownership for lower-income households, the incremental cost is not likely to have a significant effect on overall car ownership.[19]

The implication, then, is that the total fixed costs (purchase price, insurance, and financing) for the average 1985 new car would exceed the 1980 cost by about $1500 to $2000 (1980 dollars) or about 12 to 15%. The projected change in annual household disposable income of 2 to 3% (10 to 16% increase between 1980 and 1985) indicates that, despite the increase in automobile fixed costs, the proportion of household income devoted to these costs will remain relatively unchanged.

Automobile purchase costs beyond 1985 are likely to remain constant or decrease slightly since much of the capital investment to satisfy regulatory requirements and to improve fuel economy will have been made. Even engine adaptations to alternate fuels are not likely to require as much capital investment as the automobile design changes in the 1975 to 1985 period.

The temporal "costs" of auto transportation (those associated with how much a person values his time while traveling) are expected to increase as the total vehicle mileage in urban areas increases at a faster rate than the urban highway capacity. The Congressional Office of Technology Assessment has projected that the en route time for an average ten-mile trip will be essentially unchanged between 1985 and 1995 and will increase by 10 to 15% by the year

2000. This increase in average travel time will result primarily from the average speed reduction projected for freeways of about 30% and for principal arterials of about 12%; in the latter case, it might be as high as 20% during peak hours. These changes will increase the travel time for a ten-mile trip by two to six minutes, which is probably within the perceived threshold of travel time for most drivers and is therefore unlikely to have a significant effect on driving behavior or mode choice. More striking and significant, however, are the projected changes in the level of congestion. The ratio of the vehicle miles traveled under congested conditions (95% or more of road capacity) to the total urban vehicle miles of travel is projected to increase by a factor of about three between 1975 and 2000. The stress and frustration of driving under such conditions, and the greater likelihood of long delays due to accidents or bad weather, can contribute to relocation decisions and to some shifting in modes. More likely, the increased congestion will create a public demand for increased road capacity and alternative means of reducing congestion peaks. One can anticipate an increase in highway construction near the end of the century.

The implication of these calculations is that the automobile will remain the predominant mode of urban transportation well into the future and that transportation costs are not likely to be a significant factor in reducing population dispersion or in focusing urban growth. While improved fuel economy and reduced automobile size will aid in fuel conservation, in reducing the cost to meet specified air quality standards, and in reducing the parking space requirements per vehicle, the other problems attributable to the automobile (congestion, excessive land use in activity centers, reduced mobility for those without access to a car) are likely to remain as major urban issues.[20]

Conventional Public Transit

The continuing predominance of the automobile and the increasing scarcity of financial resources available to public transit suggest that public transit's role in urban transportation is likely to diminish or, at best, remain at current levels. The scarcity of funding suggests increased reliance on the fare box to cover operating costs, accompanied by a slow and tortuous process of reducing unprofitable suburban and crosstown routes while emphasizing the more profitable radial commuting operations and routes in the higher density, transit-oriented inner city. In addition, profitable special services such as express bus operation from the suburbs to the central business district are likely to continue.

Public transit proponents are likely to oppose such service reductions, citing the energy-conserving potential of transit as one argument for continuing service. However, these arguments do not reflect actual levels of transit patronage and operation. Assuming improvements in bus technology and in current transit use, the average fuel utilization of bus transit is about 48 passenger miles per gallon, or about 50% greater than the equivalent value projected for the average 1985 model automobile having the current average occupancy of 1.2 people. However, this conservation potential is illusory in that the conservation estimates do not reflect the extra energy consumed as a result of circuitous transit routes, deadheading, the use of the automobile to get to the transit vehicle, or the additional driving of the vehicle left at home for other members of the family. Consequently, as the automobile fleet is replaced by more fuel-efficient automobiles, little or no energy is saved under current bus operating conditions unless passenger load factors can be increased.

The potential for increasing load factors requires examination of both peak and off-peak operational conditions. During peak hours, current bus systems are operating near capacity (by design), with load factors between 35 and 45%, and are providing nationwide about 8% of the total commuting trips. Assuming that peak-hour transit patronage doubled and all of the new patrons were former automobile drivers results in a reduction of the number of vehicle trips by about 10%. Since work trips represent 30 to 40% of all trips, the decrease in vehicle trips would be no more than 3 to 4%. However, the energy savings would be even less, not only for the reasons cited in the preceding paragraph but also because most of the diversion to transit would be for the shorter work trips and would in reality include a substantial number of former automobile passengers. Further, the doubling in patronage would require a substantial addition to the bus fleet, thereby consuming construction and operating energy.[21]

A more attractive alternative is to increase patronage in off-peak hours when substantial reserve capacity is available. In examining various measures to increase off-peak patronage, Altschuler[22] concluded that only reduced or free fares during off-peak periods could attract a significant number of new patrons. Since many of these patrons are poor or elderly, such a measure may be highly desirable for social reasons but cannot be justified on the basis of energy conservation since the revenue lost per barrel of oil saved varied from $600 to $4900 per barrel.

While some rail systems are operating below capacity during peak hours and, therefore, do possess a potential for energy savings, the construction of new rail systems seldom can be justified on energy conservation grounds because of the high energy costs for construction. In examining the energy construction and operating expenditures for San Francisco's Bay Area Rapid Transit (BART), Lave[23] concluded that the initial energy investment could not be repaid in BART's projected lifetime, even if patronage were to double.

With public transit of marginal effectiveness in promoting energy conservation, financial considerations are likely to dominate transit policy, leading to fare increases and cutbacks in service along the lines previously noted.[24] Thus, a significant number of people will be further deprived of mobility unless alternatives are provided. However, the removal of transit service may provide the opportunity to attempt more effective service techniques, such as more effective integration of various paratransit services for the elderly, the handicapped, and the transportation-deprived; the legalization of jitney operations; and user-side subsidies (see accompanying box). Since these services are more flexible and adaptable to the needs of these groups, promise lower overhead costs, and may not be subject to stringent transit labor regulations, they may be capable of providing an acceptable level of service with less subsidy than conventional transit would require to serve the same groups.

Conventional transit is technically capable of connecting regional centers. The demand for service from regional centers to the central city is likely to be sufficient to justify such service, especially if the regional centers are used as the collection point for suburban trips to the central business district. However, the demand between regional centers and, therefore, the role of public transit in that area are uncertain. Economic considerations also rule against the use of conventional transit for the localized movement of people to and from the regional centers. Such service, to the extent it is provided, is likely to come from one of the paratransit modes previously discussed.[25]

In summary, it is likely that current public transit will undergo a reduction in spatial coverage and in services provided in order to focus upon the radial trip to the central business district, especially for commuting, and on service to the higher density, transit-dependent areas of the city. Public transit services in the low-to-moderate density regions and suburbs are most likely to be provided by some form of paratransit, at least at a level to satisfy the minimum needs of those without access to the automobile. Internal circulation within activity centers will become an increasingly important problem. A major consideration in the development of this scenario will be the form, method of operation, and financing of the paratransit services.

PARATRANSIT

Paratransit is defined as public-type transportation exclusive of the fixed route/fixed schedule operation characteristic of conventional mass transit and includes everything from taxis (and occasionally carpools and van pools) to more formalized dial-a-ride and subscription bus service. Such services, often operated by social service agencies, exist primarily for aid to the elderly and handicapped. In some cities, attempts are under way to integrate these operations. An integration that would combine services to the elderly and handicapped with, for example, localized circulation and feeder service to mass transit using the same vehicles and drivers could reduce the overall costs for such a system while still providing adequate service. Operation of these systems by local taxi companies, for instance, appears promising. The poor and elderly now constitute the largest groups using taxis, and expansion of these services incrementally may provide a straightforward method of evaluating and improving operation.

Jitneys are vehicles (cars to small buses) that operate unscheduled but on a fixed route, with passengers picked up by hailing or at designated locations. Jitneys were relatively common in the United States until the 1920's, when pressure from private transit operators caused them to be outlawed in all but a few locations such as Atlantic City. Illegal jitney operation is not uncommon in many inner cities today. Since jitneys are generally individually owned and operated, their overhead and labor costs are minimized, which may permit profitable operation at moderate densities.

User-side subsidies are usually in the form of vouchers, paid directly to the user rather than to the operator. As with food stamps, the user could purchase the most suitable transportation for his purpose — taxi, paratransit, or bus.

NEW TRANSPORTATION SYSTEMS AND TECHNOLOGY

Thus far, the discussion has suggested a continuing dominance of the automobile in urban transportation, with the role of conventional public transit continuing at the present level or diminishing. This situation still leaves unanswered a previous question regarding the possible displacement of the automobile by emerging technology or, alternatively, the substitution of new technology for the automobile in certain services and functions. To examine this question, we must examine the advantages provided by the automobile and the likely forms of the new technologies.

In addition to the comfort, convenience, accessibility, and capability to fulfill, as a single mode, all urban transportation functions for the user, the automobile possesses a significant public sector advantage: namely, that the vehicles are willingly purchased, maintained, and operated by private individuals. The public sector must then only provide and maintain the rights-of-way, and even these costs are primarily funded through user taxes. Any proposed replacement for the automobile is implicitly expected, therefore, to preserve the user and public sector advantages of the automobile, while mitigating the disadvantages attributed to it.

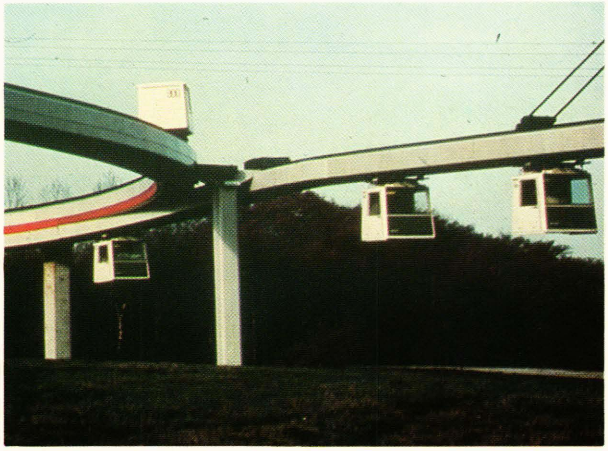
Since no new systems have been identified that can fulfill these criteria, the advocates of new transportation systems have attempted to balance the benefits of the new systems against the public sector funding constraints. These attempts have not yet been successful because of the difficulty of quantifying new system patronage and reductions in automobile use, of identifying and quantifying the potential benefits and costs, and of demonstrating that potential benefits would translate into real benefits. As a result, attempts to develop systems that might replace the automobile have been sporadic and tentative, and most efforts have turned toward the development of systems that appear to have performance and service advantages over conventional public transit.[26]

The proposed new systems fall into two general classes: (a) those that provide automobile-like operation to individuals and their companions by providing broad urban coverage and high system accessibility, together with direct origin-to-destination service at convenient trip times and at costs that are competitive with or lower than those for comparable trips by automobile; and (b) those systems that provide transit-like service along selected corridors, but with greater frequency and lower trip times than conventional transit.[27] Both classes employ extensive automation as a means of reducing operating costs (see accompanying box).

Personal Rapid Transit Systems

Personal rapid transit (PRT) systems are designed to transport individual passengers or groups of individuals traveling together by choice from an origin station directly to a destination station without intermediate stops. Such a concept implies numerous small, auto-sized vehicles (six passengers or less) operating on a relatively dense network of exclusive guideways, usually elevated, with a highly sophisticated vehicle and system control that would automatically route the vehicles through the guideway network to minimize travel time. Functionally, PRT systems are automated versions of taxis.[28]

The attractiveness of the PRT concept to the user lies in its ability to provide individual service at travel times and operating costs comparable to those for the automobile. To the community, the advantages are the reduction in congestion (each PRT lane is equivalent to about five street lanes), parking, and vehicle emissions, and the accessibility of the system to those without access to an automobile. On the other hand, the high cost of development, the high capital cost, the lack of a proven demonstration, and the resistance of rail transit advocates mitigate against the adoption of these systems. More important, the dense right-of-way infrastructure overlaying existing streets (a PRT guideway about every fifth block) and the need for even an initial application to have broad areal coverage in order to satisfy the diverse trip patterns will continue to hinder PRT applications. Although PRT's could be used within corridors and for circulation in activity centers, the economics of such applications generally dictate larger vehicles and multiple party occupancy. It would appear that the eventual application of PRT's is dependent upon their ability to evolve from less complex and sophisticated transit modes.



MBB Cabinentaxi®, one example of a personal rapid transit system in operation. (Photo courtesy of the U.S. Department of Transportation.)

Automated Transit Systems

Although the term "automated systems" encompasses all automatically controlled systems from PATCO and BART to PRT's, the emphasis here is on fully automated systems operating on exclusive and usually elevated guideways and using vehicles with capacities of from 10 to 60 passengers. These systems are designed to provide service along corridors and circulation within large activity centers such as central business districts. The larger vehicles would stop at all stations, or perhaps only at stations requiring discharge or boarding of a passenger, along the route in the same manner as conventional rail transit or buses. The smaller vehicles could provide set-to-set service, i.e., boarding passengers from one or a few stations in one subarea and delivering them without enroute stops to one or a few stations in another subarea. These systems, therefore, provide a conventional transit service, albeit at a capital cost advantage compared to rail transit (from 20 to 50% of rail) and an operating cost advantage compared to

Automatic guideway transit application in France, connecting Lille to the new town of Villeneuve d'Ascq. (Photo courtesy of P. Smith.)

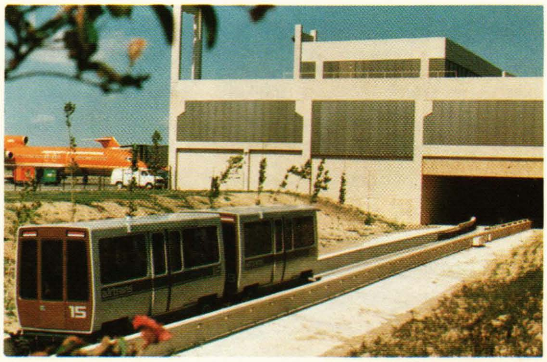
AUTOMATION

The introduction of increased automation into rail transit and the subsequent problems that have evolved have raised questions regarding the value of automation in transit. The rationale for automation includes increased safety, reduced operating costs, and, to a lesser degree, improved performance. The Congressional Office of Technology Assessment (OTA) has examined this rationale for automation in rail transit ("Automatic Train Control in Rail Rapid Transit," May 1976), with the following conclusions:

1. Certain aspects of automation (Automatic Train Protection) can indeed enhance safety of rail transit, which, by the way, is currently the safest mode of transportation.
2. Automation can reduce operating personnel requirements but at the expense of increasing the number of higher paid maintenance personnel. However, overall operating costs are reduced by 3 to 6%.
3. Automation can increase capacity by allowing shorter spacings between trains, but since most rail systems operate with some capacity reserve, this advantage is seldom realized.
4. Automation increases the system capital cost by 2 to 5%, depending upon the level of automation.
5. Automation reduces reliability of the system simply because of the increased number of components. There is no conclusive evidence that automatic equipment is more prone to failure than other components once the initial break-in period is passed.

The OTA report does not fully examine additional benefits in automation that may be achieved if accompanied by institutional changes. These include:

1. Minimal train crew requirements are determined by union agreements and work rules and by perceptions regarding passenger security for established transit systems. These limit the reduction in operating personnel achievable by automation. For example, BART operates at 0.9 operating employee per vehicle (train crew, dispatchers, towerman, central control, and yard) while the fully automated AIRTRANS system at Dallas-Fort Worth employs 0.3 operating personnel per vehicle. Using these values, a fully automated BART system would save 270 operating positions. On the other hand, additional maintenance personnel would be required. For BART, the maintenance personnel per vehicle is 1.7, 16% of whom maintain automated equipment aboard the vehicle. Since BART is already highly automated, an increase of 25% in car automation maintenance personnel is thought to be conservative for full automation. This provides a value of 1.76 maintenance people per vehicle. Assuming a 20% higher pay differential for maintenance employees, as in the OTA report, would mean a savings of 20% in operating and maintenance labor costs or, since labor costs represent about 75% of total operating costs, an overall savings of about 15%. A similar calculation of PATCO, another highly automated system, suggests a similar savings of 15% in total operating costs by employing full automation. Similar results are obtained if car-miles are used as the normalizing parameters. While these results may be optimistic, they are suggestive of the savings to be gained from full automation. It is estimated that full automation would increase PATCO or BART capital costs by no more than 1 to 2%.
2. The reduced marginal cost of operation achieved through automation would permit either higher levels of service or longer service hours for the same operating costs.
3. The current maintenance costs could be reduced by improved maintenance techniques, personnel training, and improved diagnostic equipment. AIRTRANS employs 1.5 maintenance personnel per vehicle compared to the 1.7 for BART and PATCO. While these remarks would also apply to all maintenance activities, the productivity increase is likely to be higher for the automated equipment.



LTV Airtrans® at the Dallas-Fort Worth Airport, moving people between gate areas at the airport and to the airport hotel. (Photo courtesy of LTV, Inc.)

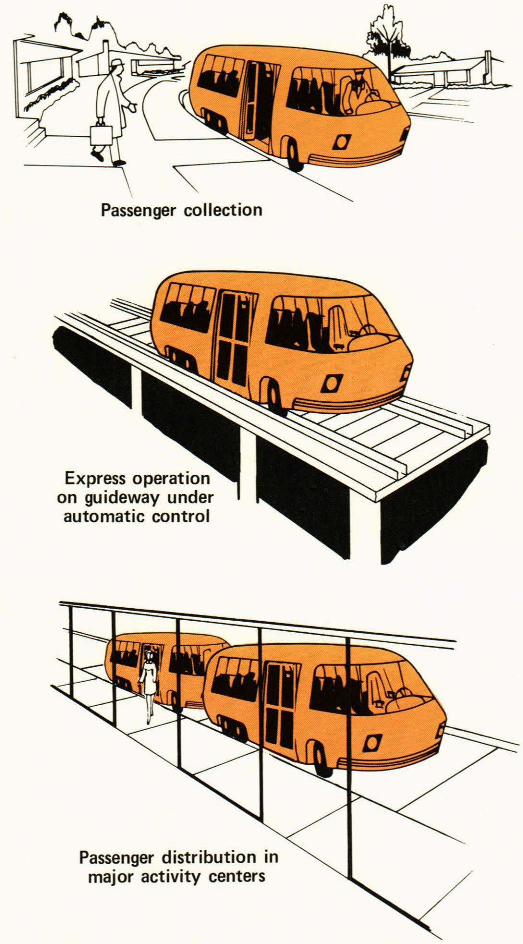
buses (from 30 to 50% of buses). The line capacities of 15,000 passengers per hour per lane will satisfy the corridor transit needs of most U.S. cities.[29] Since the average speeds are about equivalent to rail and about 30 to 100% faster than buses, an increase in patronage compared to buses is expected.[30]

Despite these apparent advantages,[31] such automated systems are not competitive with the automobile except along congested corridors and in activity centers. Therefore, the systems are not a replacement for the automobile but rather a substitute for it in those areas in which the automobile is least effective. In the United States, current applications have focused on circulation in major activity centers such as airports and universities. Foreign applications such as those in Kobe, Osaka, and Lille have used these systems as connectors to new towns.[32] An eventual role for the systems may be the opportunity they provide to assist in restructuring major activity centers by, for example, encouraging peripheral parking and auto-free zones.

Dual-Mode Transit Systems

Dual-mode systems are characterized by their ability to provide both fully automated operation on exclusive rights-of-way and manual operation on city streets using automobile- to bus-size vehicles. Such systems are an obvious attempt to combine the flexibility and accessibility of the automobile and bus with the advantages attributed to the fully automated systems. The exclusive right-of-way then needs to be constructed only in those areas where such operation would be clearly advantageous. Since the vehicles are likely to require dual propulsion and control systems, the advantages are gained at the expense of vehicles that are more complex, more expensive, heavier, and probably have higher maintenance requirements than the vehicles being replaced.

Dual-mode buses would operate in an automatic mode along corridors and in high-density areas and manually in low-density and suburban areas. For example, the bus would circulate in suburban areas collecting passengers and be driven to the closest access point to enter the guideway. The driver would leave the bus at this point to drive a bus leaving the guideway while the original bus would proceed along the automated guideway, boarding and discharging passengers. The higher speeds attainable along the guideway, as compared with those of conventional buses, suggest reduced travel time for passengers (and, thereby, increased patronage) and more rapid bus turnaround times (thereby reducing requirements for both fleet and drivers), which, along with the automated operation, should reduce operating costs. However, these savings are at least partially offset by the time and cost (and additional facilities) to inspect the bus prior to automated operation and by the idle time of drivers waiting for a bus (or of passengers waiting for a driver). A more effective approach might be the use of conventional buses to feed the stations of automated transit systems, thereby eliminating the need for inspection and for driver exchange.



Dual-mode bus systems that can operate both manually and under automatic control provide a potential for improving transit service. Such systems would operate as conventional buses in outlying, lower density areas and then in the automated mode as they enter higher density congested areas.

The introduction of dual-mode automobiles, which in effect represents the introduction of automated highways, does suggest benefits in reduced congestion, accident rates, vehicle emissions, and parking or, at least, the transference of parking to peripheral areas. These benefits are probably outweighed by the higher cost of vehicles; the cost of guideways; the cost, delays, and congestion of inspection facilities; and institutional problems such as liability and user charges. Furthermore, the introduction of these systems will probably be hampered by the highly visible costs to the public and private sectors, whereas the benefits are neither immediate nor visible.

The technological development requirements for dual-mode buses and automobiles include and extend beyond the requirements for automated transit systems and PRT's, so that the development in the latter systems will influence the development of the dual-mode systems. Furthermore, the most likely avenue for the evolution of dual-mode automobiles is through public acceptance and wider use of electric automobiles, which are more easily adapted to automation and guideway use than the internal combustion engine. One can then envision that the application of automated transit and the growing use of electric vehicles will combine and evolve toward automated highways and dual-mode vehicles. However, as already noted, neither of these precursor systems is likely to be an important element in urban transportation prior to the year 2000 and, consequently, the likelihood of dual-mode systems evolving into an important element is even further off.

In summary, there does not appear to be an emerging technology that is likely to effect any significant displacement of the automobile or, given the assumed economic conditions, even to threaten the growing predominance of the automobile. However, one of the technologies — automated transit systems — can have an influence on the restructuring of activity centers and on the development of regional centers and new towns.

URBAN VILLAGES

Urban villages are described as several residential neighborhoods containing a variety of housing types that are organized about a concentration of diverse employment opportunities such as a regional center. These villages are seen as a means of more closely linking housing and jobs, of conserving energy and infrastructure costs, and, especially, of fostering a sense of identity of the residents and employers with their community. As noted earlier, demographic trends, higher energy costs, and public policy are expected to encourage a movement toward such villages or centers, which would contain a mixture of residential, commercial, and industrial activity. This hypothesis can be examined for the assumed scenario conditions.

The monetary costs of transportation, as already discussed, are not expected to increase significantly — at least for the owners of new automobiles. The temporal costs of transport will show some increase as the population increases, with little additional highway construction and with reduced road maintenance. Neither of these increases appears to be sufficiently large to significantly influence coalescence about regional centers or, if coalescence occurs, to favor heterogeneous centers over homogeneous centers (centers primarily involving a single activity — residential/retail, commercial, or industrial). Formation of the latter centers is not likely to have a major effect on reducing total automobile travel, although ride sharing and mass transit may be aided by this form of coalescence.

Furthermore, retrofitting of existing housing to conserve energy can also discourage a trend to regional centers if the cost differential between new and existing housing continues to increase.[33] In addition, the introduction of such dispersed energy sources as wind, geothermal, small-scale hydroelectric, and solar could further contribute to dispersion and to increases in trip length. The scale of production for such technologies is generally small, and, since consumption is integrated with production, small clusters of settlement and activity are encouraged in the vicinity of the resource. Since these resources are spatially dispersed, their use implies homogeneous clusters with dispersed travel demand between the clusters and the remainder of the metropolitan area.[34]

For the present scenario, then, energy costs are not likely to be the paramount parameter in the development of regional centers. However, demographic trends, environmental and infrastructure considerations, perceptions regarding energy availability and price, and the uncertainty of energy projections are likely to foster land-use policies that encourage the development of urban villages. For our purposes, then, we need to consider the transportation requirements of these centers.

While high-density urban villages such as the new island towns in Kobe and Osaka are economically viable for mass transit and prime candidates for automated systems, most urban villages will remain automobile-oriented, supplemented, perhaps, by paratransit services. However, the increased activity and spatial expansion of the regional centers will result in increased congestion and additional transportation requirements.

To examine these requirements, consider the evolution of a regional center from existing shopping centers, apartment complexes, industrial parks, etc. Such initial centers use a considerable portion of the space for parking and automobile accessibility, and eventual growth can be limited by this factor and by the length of walk from parking and within the center. At this point, nearby subcenters will emerge and eventually experience similar problems. Furthermore, the new subcenters are likely to be homogeneous in character so that movement between subcenters will be highly desirable. Given the attractiveness and marketability of the center, growth of this form will continue until internal congestion and other transport costs approach the costs of transport into the center from the surrounding region or, for those people living outside the center, the cost of transport to other centers. Although land constraints, market saturation, and other economic factors may limit growth prior to this point, internal mobility appears to provide an upper bound on the size and level of activity within a center. Given a continuing attractiveness of such an automobile-saturated center, further growth will require the introduction of a transportation mode that will improve internal mobility. Of the available modes, the following candidates appear promising:

1. Rental of low-performance vehicles: A simplified rental scheme to provide low-performance vehicles that could circulate within the center and village either on dedicated rights-of-way or

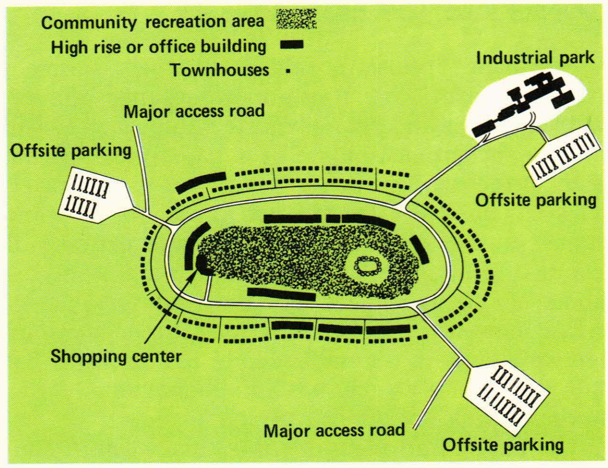
on the streets may improve circulation and reduce parking requirements. The difficulties in such an approach are limited capacity, vehicle maldistribution, and vandalism.

2. Minibuses: Minibuses would operate within the village and between subcenters, with some circulation within centers, probably using the available streets and rights-of-way. However, the high operating costs may limit the level of service. With relatively slow speeds and poor service, the patronage is likely to be limited, with the car still predominant and concomitant street congestion resulting in even poorer service for the bus patron.

3. Automated transit system: The automated systems operating on dedicated rights-of-way could connect and circulate within the subcenters, providing a high level of service at moderate operating costs. The major difficulty is the capital investment, which might be partially covered by charges against the businesses within the center at a rate inversely proportional to their distance from the system in a manner similar to elevator charges.

The main benefit of such systems is a reduction in parking requirements, since patrons would be expected to park their cars and use the circulation system for internal movement, and the potential of locating parking on the periphery, thereby diverting core space to more productive purposes. However, a center evolving in this manner would still consume considerable land, and the new internal modes are not likely to be used efficiently. Furthermore, some existing businesses may oppose new circulation modes because of the additional cost and the accessibility it would provide to competitors.

Some of these objections may be removed if the growth of the center and village is planned and guided from its initial stages. The most efficient method of operation for the transit modes is either in a shuttle or a loop configuration. Consider a loop configuration with spurs to the interior of the loop and to selected locations outside the loop. The eventual configuration of the center might then consist of the high-demand activities being located adjacent to the loop, with the interior consisting of either high-rise commercial and residential facilities or, alternatively, of open space, and the outer regions of lower density commercial and residential use. Industrial facilities and parking would be located at the outer peripheries, connected to the loop by spur lines. Automated transit systems would appear to be the primary candidates for such centers and might eventually be expanded to the central city and the central business district. Such centers could start as automobile-oriented centers, with construction in accord with the eventual configuration and with core parking. As the center grows, the automated system could be constructed in stages and the parking moved to the periphery.



Widely separated and self-contained regional centers like the one illustrated here are likely to be increasingly common in the decades ahead. Minibuses or other transit systems on frequent schedules will move people from the offsite parking areas to homes, shopping areas, and centers of industry and business.

The above discussion suggests the following considerations:

1. Without planning and guidance in the initial stages of a center's development, the center will develop along the lines of the first model, resulting in considerable horizontal expanse and remaining automobile oriented. Alternatives for internal circulation are likely to develop only as a consequence of land-use and geographical constraints or extremely high economic activity. Further, there are no identifiable forces sufficiently strong to differentiate between heterogeneous and homogeneous centers. Centers developing in this manner are unlikely to provide the expected benefits or to result in substantial improvements in land use, energy, or the environment.

2. While further analysis is needed, the guided development of centers appears to provide the opportunity for improved land use, reduced infrastructure costs, and energy and environmental conservation. Furthermore, the alternative circulation modes may be less costly because of improved operation and reduced capital requirements. For example, 60% or more of the capital cost of automated systems is in the cost of the elevated guideways and stations. The ability to place these systems at grade and to integrate the construction with other facilities should provide substantial cost savings compared to constructing such systems in existing centers.

CONCLUDING REMARKS

The main conclusion of this qualitative assessment of the future of urban transportation is that the automobile, while undergoing considerable change, will remain the primary mode of urban transportation and, in fact, will increase its share of urban travel. This conclusion is based upon a scenario that assumes an average annual energy price increase of about 10% in an economy that is growing, stably, at about 2% annually.[35] Under these conditions, the increase in energy prices is in the long run balanced by improvements in automobile fuel economy so that the individual consumer has little economic incentive to change travel behavior.

The analysis also suggests that, inasmuch as conventional public transit is not a significant energy conservation measure, economic conditions are likely to dictate increased fares and reduced coverage and service, especially for suburban and crosstown routes and in other low-density areas. The major impact will be on the poor, the elderly, and the handicapped who reside in these low-density areas and who, in addition to being deprived of transit service, are also likely to own older automobiles with higher fuel consumption. To some extent, this impact may be mitigated by the emergence of very small, low-performance vehicles for use in local travel and by the integration of paratransit services in these low-density areas.

The major impact of technology is likely to be through an improvement to the automobile and in the development of low-performance vehicles for neighborhood use. While new transportation systems are being developed, they are less likely to replace the automobile than to replace conventional transit or to substitute for the automobile in those locations where the automobile is least effective, i.e., movement in activity centers or along radial corridors. Even then, the high capital cost of these systems will be a major deterrent to their initial implementation. The one possible exception is the use of automated transit systems to guide the growth and improve the effectiveness of new towns, regional centers, and other high-activity areas.

However, the emergence of regional centers is not as clear as is often hypothesized. Certainly, energy costs do not appear as influential. Furthermore, while demographic trends and public policy may encourage the development of such centers, their form and structure are not likely to be as desirable as is often perceived by public planners unless actions are taken to constrain the location and form of the growth.

While these conclusions are based on a nominal scenario, consideration of reasonable alternatives suggests that the conclusions are not likely to change significantly. A rapid economic growth, with energy prices keeping pace or declining with respect to the growth, suggests a return to the 1950's and 1960's and a continuation of dispersion. There is an increased likelihood that new technology may replace conventional public transit, but the use of the automobile would continue to increase. A declining economy would reduce auto travel and have a severely disruptive effect on any form of public transit. On the other hand, a rapid rise in energy prices compared to economic growth and conservation would be highly disruptive, with the main impact being the reduction of auto travel, acceleration of the shift to more fuel-efficient cars, and an increase in ride sharing. Such an occurrence is not likely to improve the position of public transit.

REFERENCES and NOTES

1 The recent spate of articles on "the end of the American love affair with the automobile" is premature. The articles would have been more accurate if the process were considered to be a change from an overweight, gluttonous, extravagant mistress to a lighter, diet-conscious, if still extravagant, model.

2 Witness the requirements to use transit funding to make bus and rail transit fully accessible to the severely handicapped despite the negligible patronage by this group and evidence that alternative services would be more effective and considerably less costly.

3 The Interstate Highway and Defense Act initially provided for about 31,000 miles of interstate highway at an estimated cost of $27 billion (1956). Costs were revised to $44 billion in 1958 and to $89 billion in 1977. Mileage was increased to about 41,000, with about 8000 miles to be built in urban areas. The funding is provided by a federal gasoline tax and a tax on tires and motor oil.

4 A good summary of these effects is provided in A. A. Altschuler, *The Urban Transportation System,* MIT Press (1979), and J. R. Meyer and J. A. Gomez-Ibanez, "Urban Transportation Problems and Policy" (unpublished manuscript, 1980).

The primary cause of dispersion is a public preference for low-density living. This preference has been visible in the United States for at least 100 years and is visible in all developed countries. Since in most cities the maximum space per unit cost is at the periphery of the city, suburbanization and sprawl result. Residential location theory employs this public preference to suggest that the consumer attempts to maximize his "space" subject to constraints on the total housing and transportation "costs." Since the transportation "costs" included in this calculation appear to be "marginal costs," their influence on residential location has been relatively small.

Commerce and industry followed this population shift both for access to customers and the labor force and because of the lower land cost. Furthermore, the increased dependence on trucking and the availability of interstate highways reduce transport costs for facilities near these highways. In Baltimore between 1960 and 1970, the suburban population increased by 34%, while the central city decreased by 3.5%. In the same period the number of suburban jobs increased by 154,000, while the employment in the central city decreased by 22,000. The percentage of metropolitan residents working in the central city decreased from 66 to 51%.

It should be noted that a 20- to 30-minute commuting trip has been considered acceptable for several centuries, and it has been suggested that many people find this period of transition valuable. Since average travel speeds during peak hours have increased by 10 to 20% in most cities in the past two decades, the area opened to development has increased by about 30%.

5 Transit revenue passengers totaled 6.5 billion in 1905 and about 13 billion in 1927 (an increase faster than the growth of urban population). The Depression resulted in a drop to about 8.5 billion in 1934, with a sharp increase to a peak of 19 billion in 1945 as a result of wartime shortages in gasoline, automobile production, etc. Since 1945, the decline has been rapid, with transit revenue patronage in the late 1970's less than 6 billion — a number comparable to the patronage in 1905.

6 Although less than 40% of all urban trips occur during the AM and PM peak hours, more than 50% of transit passenger trips (60 to 80% in some smaller cities) occur during this period. The concentration of transit trips in the four to six hours that comprise the AM and PM peak periods provides the transit operator with a business manager's nightmare, since he cannot defer this service. He serves it or loses it. The operator must size his facilities, equipment, and labor force to meet these commuting demands and then is faced with available capacity that exceeds demand by a factor of three to ten, depending upon the time of day and the city.

7 Meyer and Gomez-Ibanez, "Urban Transportation Problems and Policy."

8 Meyer and Gomez-Ibanez note that the short radial and inner-city trips represent about 50% of a transit agency's operating costs, while the express service accounts for another 20%. The remaining 30% of the

operating cost is represented by suburban and crosstown trips that do not generate sufficient revenues to pay their costs. Although reduction in these latter services may be justified economically, such changes may have difficulty in gaining political acceptance. Many of the less productive services are in place as a means of providing something for everyone, and reductions in these services are likely to be opposed by the affected jurisdictions.

It is worth noting that the economically self-sufficient services are those that provide a travel time competitive with the automobile.

[9]See DeLeuw, Cather and Co., "Land Use Impacts of Rapid Transit," U.S. DOT Report (Aug 1977); M. Webber, "The BART Experience," *The Public Interest* (Fall 1976); and M. Webber, "Effects of BART on Urban Development," ASCE Convention (Oct 1977).

[10]The movement toward the regional centers can be supported qualitatively by residential location theory under the assumption that the total costs of housing and transportation will become an increasing and recognizable portion of the household budget. The consumer will tend to minimize these costs while still attempting to maximize the space purchased. Since the unit spatial costs are likely to remain lower in the outer urban rings, these locations should be preferred. If "energy costs" represent a significant portion of the housing cost, then cluster development with implied energy saving should also be preferred — permitting more space for a given housing cost.

If transportation costs rise more rapidly than housing costs, movement nearer to the daily activities will be encouraged. Since many of these activities could be found in regional centers, all of the conditions for movement to regional centers seem to be satisfied. Moreover, if the regional centers become sufficiently large to support a wide spectrum of activities and demands, the transportation costs may decline, encouraging even more concentration.

[11]The EPA fuel economy test procedures provide notoriously high estimates compared to in-use measurements — between 10 and 20% on most models but as high as 30% on certain models. See B. D. McNatt, H. T. MacAdams, and R. Dullan, "Comparison of EPA and In-Use Fuel Economy of 1974-78 Automobiles," DOE Report, Office of Transportation Programs (Oct 1979). The bias is greatest for the most fuel-efficient cars, suggesting that the 58% increase in new car fuel economy between 1974 and 1980 (14.2 mpg versus 22.4 mpg) is significantly lower, say 40 to 50%. Consequently, the EPA values will be discounted by 15% for calculations in this paper.

[12]C. Agnew, GMC, speech given at 1981 Transportation Research Board Annual Meeting, Washington, D.C. (Jan 1981).

[13]The imposition of emission control regulations has had a major impact on automobile emissions. In Baltimore, for example, the current Federal Motor Vehicle Control Program is estimated to reduce motor vehicle hydrocarbon emissions by 44% (52.7 to 29.5 metric tons) and carbon monoxide by 33% (450.7 to 300 metric tons) for the 6 to 9 AM period on a Friday in July 1982. These reductions represent 77% of the estimated hydrocarbon emission reduction needed to attain an oxidant standard of 0.08 ppm.

[14]The domestic automobile manufacturers can make the case that a part of their financial problem is attributable to federal regulations that forced massive investment at the same time that market forces were moving toward smaller cars and that the economy was declining. A brief overview of the history of the industry during this period is given in "Corporate Strategies of Automobile Manufacturers," by The Futures Group (DOT Contract HS-7-01784, Nov 1978).

[15]The approach has been proposed by J. Maroni, an economist with the Ford Motor Co. The coincidence of synthetic fuel production with automotive fleet capabilities could be accomplished through consultation between the oil and automotive industries in the same manner that leaded/ unleaded gasoline allocations are made.

[16]The development rationale for EV's has centered on the conservation of oil by expanding the use of EV's in areas where electricity is generated by coal or nuclear plants and on the reduction in automobile-source emissions. GMC has announced plans to market a small EV commuter car and Ford is likely to follow the GM lead.

The market estimates cited in the text assume a relatively slow increase in oil prices and continuing availability of oil. A series of rapid price increases or oil shortfalls could expand the EV market since the public may accept the lower performance and higher cost in order to maintain their desired mobility.

[17]F. T. Sparrow, J. D. Fricker, and R. K. Whitford, "Mobility Enterprise: Improving Automobile Productivity," Transportation Research Board Annual Meeting, Washington, D. C. (Jan 1982).

[18]The EPA mandates are 20 mpg in 1980 and 27.5 in 1985, or a 6.7% average annual increase. The 1980 EPA rating based upon actual sales was 22.4 mpg (J. D. Murrell, J. A. Foster, and D. M. Bristor, "Passenger Car and Light Truck Fuel Economy Trends through 1980," Society of Automotive Engineers, Technical Paper No. 800853). Using the GMC 1985 estimate of 31 mpg, the average annual increase would be 6.7%.

[19]The effect of the high interest rate on the consumer may be illustrated by the following calculation. Assuming a 15% annual rate of interest applied to 80% of the purchase price of the automobile over three years would increase the finance charges for the 1985 car by about 17% over the finance charges for the 1980 car at the same interest rate.

[20]Even air quality, energy consumption, and parking space requirements are likely to continue as major problems because of the increase in the number of automobiles. The U.S. Census Bureau estimates that the number of households will increase by about 2% annually to 1990. Kain and Fauth (May 1976) estimate that the number of cars per household will increase by about 0.57% annually to 1990. Using these values to the year 2000 suggests an increase from 118 million autos in 1980 to 148 million in 1990 and 190 million in 2000, most of this increase taking place in urban areas.

[21]The energy savings may be negative. A substantial increase in bus trips implies service into low-density, low-patronage areas so that substantial additional bus mileage would be required for each additional passenger. An increase in Washington Metropolitan Area Transit Authority bus mileage of 16% in 1974 attracted 5% more patronage. Extrapolating these numbers nationwide implies that doubling patronage would require quadrupling mileage.

[22]A. A. Altschuler, "The Urban Transportation System."

[23]C. Lave, "Rail Rapid Transit: The Modern Way to Waste Energy," Univ. of California at Irvine, Report No. W122 (Mar 1977). An advantage of rail transit is that it can use electricity generated by nonpetroleum sources. The argument presupposes a reserve of electrical generating capacity that is not likely to continue given the delays in building nuclear and coal-fired generating plants. Even if this argument is credible, the high cost of rail transit suggests that the trolley bus would be a more cost-effective alternative for corridors within its capacity limits.

[24]An argument often offered for promoting public transit is that of emergency service during a fuel shortage. However, most actions that might be taken during such an emergency are not strongly dependent upon normal bus operation but upon effective prior planning and on the reserve capacity of buses, drivers, and maintenance personnel. Current bus production is about 3000 buses annually, although domestic suppliers attained levels of 6000 in the early 1970's. Since the current bus stock exceeds 50,000 vehicles, emergencies will have to be handled with few new buses entering the fleet unless a reserve stockpile of buses exists. New buses imply new drivers and mechanics and an emergency training course.

It is more likely that most cities will have to make do with what is available. For some midwestern and western cities of between 250,000 and 750,000 population that now operate with a slight peak hour reserve capacity, the problems may be manageable, but for most cities without a peak hour excess capacity, the problems will be severe. The situation will require placing older buses back into service, accelerating or deferring maintenance, and increasing overtime for driver and maintenance personnel. Furthermore, the new demand will come primarily from suburban locations, thus increasing trip length and bus mileage — the very routes now requiring the greatest subsidy and providing the least energy conservation potential.

[25]Paratransit applications have been a mixed bag of successes and failures, but all have required public subsidy. However, those operated by local agencies, especially private taxi firms, have required the lowest subsidization, primarily because of the lower driver wage rates and greater flexibility in vehicle type and operation. The primary justification for inclusion of these services in the above scenario is the desire to provide mobility to those without access to the automobile on the grounds of equity of public funding and services. While the cost per passenger for paratransit services is likely to remain high, the total subsidy required may be below the current subsidy to public transit for similar services.

[26]The current decision process for selecting new technological developments can hinder the introduction and diffusion of new technology. Historically, a new transportation technology has been introduced on a limited scale, and operational experience has led to modifications and improvements that have in turn led to further applications. In this way, the new technology has had the opportunity to develop until it could be clearly shown to be superior to competing technologies, which it then began to displace. This process, from initial introduction to eventual domination, took a generation or more. In this manner, the railroads displaced canals, the electric trolley displaced horse- and cable-drawn conveyances, the airplane and truck displaced the railroad, and the automobile displaced the electric trolley. In contrast, present procedures require that the new technology demonstrate clear superiority (on paper) before major development and applications are authorized. This requirement leads to exaggerated claims for the new technology that are not achievable when the technology is initially implemented. The apparent failure of the technology is then used to deter further development or applications.

[27]A basic tenet of transportation theory supported by available data is that the fundamental parameter in the traveler's choice of mode is travel time. The emphasis of the new systems on quick trips or higher average speeds reflects an attempt to divert people from the competing mode to the new system.

[28]The primary technological feature of PRT systems is that, in order to obtain the required line capacities, the vehicles must be capable of operating

at spacings between vehicles less than standard transit industry practice, i.e., less than safe stopping distance. The implications of this concept appear revolutionary. A sacred tenet of the rail industry is the requirement that a failure shall result in a safe condition. In practice, this is achieved by establishing block boundaries so that there is always a safe braking distance between trains. Since PRT systems are to operate at spacings less than the safe stopping distance, one can postulate failures that will result in collisions between vehicles. PRT advocates claim that, although standard practice is violated, the basic principle of a failure resulting in a safe condition is not violated since the vehicle can be designed to withstand collision and to protect the passengers.

[29]Rail transit capacities range up to 60,000 passengers per hour per lane and buses provide values to 3000 on city streets and about 10,000 on freeway bus lanes.

[30]The projected capital costs (1980) for the automated systems range from $10 million to $40 million per mile (the latter figure for a proposed Los Angeles system), with operating costs of $1 to $1.50 per vehicle-mile. In local service, the systems average about 16 to 18 mph while set-to-set service averages 18 to 24 mph. Bus average speeds are 10 to 12 mph in urban areas and about 5 to 6 mph in the central business district.

[31]The introduction of the automated systems is hampered by the capital costs, the aesthetic concerns about and acceptance of elevated structures, and the opposition from conventional transit interests. The front end costs (development, engineering, production tooling) for the initial application are quite high and tend to discourage first applications. Further, the economic calculations of net present value favor buses because of the high discount rates currently employed. Although the reduction in operating subsidies may change these attitudes, the capital funding limitations counterbalance any widespread attempts to construct these systems. Since few system construction starts are likely without federal funds, the prospects for an expanding market for these systems in the United States appear dim. The exception may be in privately developed centers, in central business districts where the automated systems, in the role of "horizontal elevators," may possess a cost advantage, or in new towns, where the image of space-age technology is desirable.

[32]In the applications cited, the image of high technology appeared to be as influential in the choice of the automated system as did transportation and economic considerations. Foreign governments have viewed these systems as a potentially exportable technology. In the United States, the history of the development of these systems provides a case study of the ambivalent attitude toward the federal role in developing civilian public-sector technology and public transportation, and in guiding urban development.

[33]R. Stobaugh and D. Yergin, eds., *Energy Future; Report of the Energy Project at the Harvard Business School,* Ballantine Books (1979). In this work, energy savings from 25 to 65% are quoted, noting a Standard Oil of California study that "concluded that 50% energy savings are possible as economically attractive investments in a substantial part of the nation's housing stock." The cost of these simple and effective retrofit improvements ranged from $20 to about $1000. Based on DOE mid-range cost estimates and the 50% savings, the energy costs in a retrofitted home in 1985 would be equivalent to the 1978 costs without retrofit, and energy cost savings would accrue after that date.

[34]J. W. Dyckman and J. C. Fisher, "A Summary Report of the Tenth International Fellows Conference, The Changing Metropolitan Economics of the Eighties: Public and Private Opportunities," Johns Hopkins University Center for Metropolitan Planning and Research (1981).

[35]The impact of travel behavior on total energy consumption, and therefore on price, has not been considered since urban transportation is only one of many factors that would influence price. The effect of increased price would be considered through analysis of another scenario.

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