Chapter IV

TRANSPORTATION OPTIONS

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Currently Available Options

Available transportation options can be divialed into two classes— those operating in mixed traffic (i. e., on public roadways) and those operating on their own exclusive rights-of-way or guideways. A few options, such as streetcars and dual-mode vehicles, can operate either in mixed traffic or on exclusive guideways.

Mixed Traffic Modes

There are several distinct categories of passenger transportation now operating on public streets in mixed traffic:

- automobiles,
- taxis,
- vanpools,
- buses, and
- streetcars (or *light-rail vehicles).*

Automobiles—Over 90 percent of urban trips are made with the automobile, which attests to the fact that its advantages heavily outweigh its disadvantages. The automobile's advantages over other forms of transportation include: [1]

- **a** direct ride from origin to destination,
- available for use at all times,
- travel in any direction at the whim of the driver,
- no need to stop and pick up other passengers,
- privacy and reasonable safeguards against annoyance of other people,
- constant cost for any group size,
- a seat for each rider, and
- freedom to choose individual taste and comfort preferences.

The disadvantages of the automobile to the *user* include:

- cost of operation and maintenance ineluding insurance,
- high depreciation rate,
- cost of parking,

[1]Richard Willow, "Factors Influencing Consumer Choice in Urban Transportation, " paper presented at the *international Symposium on Traffic and Transportation Technologies*. Hamburg, West Germany, June **18-20, 1979.**

- congestion on nonexclusive rights-of-way,
- risk of accidents and reliance on driving skills of others, and
- poor dependability under adverse weather conditions.

The automobile is most frequently cited for its negative impacts on the community and on society:

- the internal combustion engine consumes dwindling petroleum supplies;
- emissions contribute substantially to urban air quality problems;
- space is wasted because of unoccupied seats and because most autos are larger than their function requires;
- garaging costs must be added to costs of land, homes, and buildings;
- major urban core highway improvements are very costly and bring additional traffic into downtown streets;
- major improvements in roads and parking facilities require valuable urban land and add to urban environmental blight;
- accidents resulting in injuries and death impose high public costs for police, rescue squads, hospitals, and rehabilitation facilities;
- onstreet parking adds to urban roadway costs and visual blight; and
- the automobile is not a satisfactory mode for the transportation disadvantaged who must be provided with public systems to ensure their mobility and accessibility to urban services.

Despite its negative features, the automobile has become the dominant urban mode and it sets the standard against which other travel options are measured.

Taxis—Like the private auto, taxis can travel everywhere in the city and are available at virtually all times of day. They are not immediately available like one's own car but are much more convenient than scheduled transit service. To some, the lack of privacy may seem undesirable. Shared-ride taxis can be significantly more productive in costs per mile and line capacity than private automobiles. They can also provide a high level of service to the transportation disadvantaged, especially if used in conjunction with a subsidy program. Shared riding may be somewhat more time consuming because of the need to serve other riders at the same time.

Vanpools—Vanpools operate at speeds comparable to those of private automobiles or taxis. In terms of energy and economic efficiency they are superior to most other surface modes.[2] However, vanpools must take more roundabout routes to pick up and drop off all riders and are therefore not well-suited to short trips. Vanpool riders usually have to share a common destination or origin in addition to a shared schedule.

Buses—The greatest benefits of buses on mixed streets are their low capital costs and high lane capacities. But the low average speeds and the limitations imposed by fixed schedules and fixed routes are disadvantages compared to more personal transportation forms, Buses can also be uncomfortable. They lack privacy and do not offer assured seating. Unlike the automobile, the price of travel increases with group size.

Photo credit U S Department of Transportation

Buses in mixed traffic

Streetcars—Streetcars have larger capacities than most buses but are less maneuverable. When a rail vehicle becomes disabled, following vehicles are delayed, creating a nuisance to the flow of all traffic. Energy-wise, streetcars may

[1]Richard L. Gustafson, H. N. Curd, and T. F. Golob, "Survey Data: Measurement of User Preferences for a Demand-Responsive Transportation System," General Motors Research Publication GMR-1057, 1971.

be advantageous where low-cost electricity is available. Maintenance costs are also higher because of the added burden of track and power-line upkeep.

All transportation options operating in mixed traffic experience a severe decline in service levels as congestion increases. Exclusive guideway alternatives, on the other hand, move faster and more reliably.

Exclusive Guideway Modes

There are six broad categories of systems that operate on exclusive guideways (or rights-of-way):

- busways,
- heavy-rail transit (HRT),
- light-rail transit (LRT),
- shuttle-loop transit (SLT),
- group rapid transit (GRT), and
- personal rapid transit (PRT).

These six types of systems can be designed, installed, and operated to suit a broad range of transit requirements. Major system characteristics include vehicle and line capacity, number of transfers, flexibility of routes, station spacing, number of stations, degree of automation, and frequency of service.

The six broad categories of systems distribute themselves along a common continuum for several of these characteristics (see figure 4). Some of these characteristics are of maximum value at the PRT end of the continuum. Others are of maximum value in the reverse direction. That is, any given characteristic of maximum value for HRT will be of minimum value for PRT, and vice versa. Busways should perform similar to LRT lines.

Systems at the HRT end of the continuum offer high-capacity line-haul service in high-density corridors. Large distances can be covered because the average speed is high enough to make trip times acceptably short. However, station spacings are quite large, and transfers from line to line maybe required.

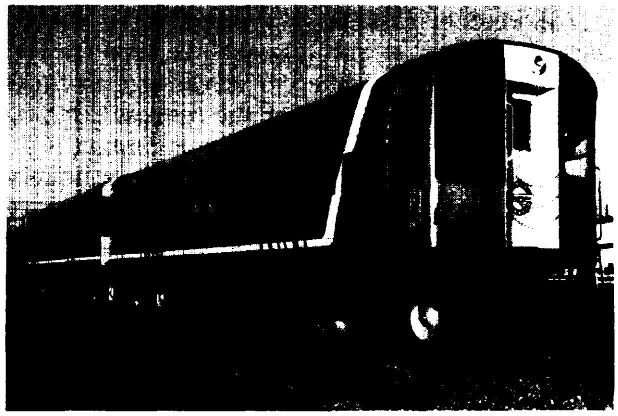

Photo credit Chicago Transit Authority

Heavy-rail transit vehicle serving Chicago

At the PRT end of the continuum the line-haul capacity is lower, but shorter station spacing and direct origin-to-destination service is possible. Currently, vehicles at this end of the– spectrum are incapable of achieving the higher average speeds of the larger vehicle but such capabilities could be developed. At the present time practical maximum trip distances for these

Figure 4.–Characteristics of Exclusive Guideway Systems

HRT • LRT • Busway		SLT • GRT • PRT
larger	[illegible]	smaller
larger	[illegible]	smaller
more	[illegible]	less
less	[illegible]	more
longer	[illegible]	shorter
less	[illegible]	more
less	[illegible]	more
scheduled	[illegible]	On demand

SOURCE Office of Technology Assessment

systems are shorter than for rail systems. Travel time comparisons between PRT and HRT are analogous to the fabled race between the tortoise and the hare. Like the hare, HRT achieves high top speeds but is slowed by many stops along the way. PRT systems, operating with offline stations that eliminate intermediate stops, proceed more slowly but, like the tortoise, they achieve average speeds that are very close to their line speed. Thus, HRT and PRT could achieve comparable trip times, despite large differences in top speed.

All-weather capability is sensitive to vehicle size, as well as to running surface type (rail v. road). Rail has an inherent advantage in snow because of the elevation of the narrow running surfaces and because the very high contact pressures at the wheel-rail interface crush or liquefy ice and snow. Special care is generally necessary only at switches where heaters may be needed to melt ice and snow accumulations. Power rails and wires are susceptible to ice build-up, which must be removed with heaters, chemical solutions, or special scrapers.

Because good adhesion is critical to achieving safe stopping distances, snow build-up on close-headway rubber-tired automated systems cannot be tolerated. The current practice for preventing snow accumulation is to heat the guideway surfaces with imbedded electrical heaters or fluid-carrying pipes. To control ice on power rails, special scrapers, heated glycol sprays, and heated power rails are currently used.

To date PRT, GRT, SLT, and HRT have achieved the highest degree of automation. LRT is not currently at that level, but there is no inherent reason that LRT on a dedicated right-of-way could not be fully automated. Automation is independent of vehicle form, as long as the longitudinal control is properly matched to performance characteristics.

Buses on busways are still totally nonautomated in the United States. With the driver on the vehicle, there is little incentive to automate the busway portion of the trip, However, there is no inherent reason to prevent buses from running manually in mixed traffic and automatically on a guideway. This concept, known as the dual model bus, has been studied at the Urban Mass Transportation Administration (UMTA).

Comparison of Mode Classes

Modes in the mixed-traffic class offer several advantages:

- utilization of existing roadway system;
- freedom of route selection;
- high level of direct routing (for auto, vanpools, and taxis); and
- easy access for user-owned vehicles.

The exclusive-guideway modes sacrifice some of these advantages and must absorb the cost of the guideway. But their inherent advantages make them very desirable:

- less subject to congestion delays,
- more predictable travel time,
- more easily understood routes,
- better potential for automation, and
- less need for land.

It is interesting to note that streetcars (and trolley buses) are limited in route selection like guideway vehicles and also are subject to traffic delays. Thus, they suffer from the disadvantages of both classes. This strongly suggests that light-rail vehicles should be provided with their own right-of-way whenever possible.

Each of these categories has evolved to suit a market need. The size range of conventional systems extends from large-capacity HRT systems through buses, with a conspicuous gap, to auto-like transportation. A need exists to provide transportation service that provides more of the social, psychological, and convenience needs satisfied by the auto, but without the drawbacks of congestion and parking. A part of the motivation for the development of small-vehicle automated guideway systems derives from this need.

Desirable Future Service Options

The decline in market share for transit over the past several decades indicates that currently deployed transit services do not satisfy the mobility needs of most people. Although it is still not entirely clear which service attributes are most important to consumers, recent studies suggest that in addition to cost and trip time many factors such as assured seating, privacy, reliability, safety, and availability weigh heavily in the choice of travel mode. -3 [4]5 '

An important goal of transit R&D is to identify important service attributes and improve technology so that it can better satisfy travel, psychological, and social needs at a reasonable cost. Development and validation of these new forms of transit service will give transit operators a wider range of options and more flexibility to satisfy locally defined urban transportation needs.

Transit service could become more competitive with the automobile if improvements were achieved in the following areas:

- reduction of wait time and travel time by providing service with limited transfers and with few or no intermediate stops,
- areawide 24-hour service,
- group fares,
- high dependability and a minimum of service interruptions,
- guaranteed seating and a sense of privacy, and
- guaranteed service through commitment to a guideway.

Reduction of wait time and travel time.—The automobile provides service on demand and with relatively short travel times. Future transit options should more closely approximate these service levels. Trip time on transit can be reduced by providing a vehicle on demand and origin-to-destination service with few or no intermediate stops. Conventional systems could provide these service levels but the costs would be prohibitive.

Areawide 24-hour service.—Because of cost, transit service does not operate at the same level at all times of day. Some locations are served in the peak periods only. At other times of day, service is much less frequent. As a result, it is very difficult in many cases to make transfer connections or even reach a desired destination. Late-night service, if it does exist, may be perceived as unsafe to use because of the extended waiting time and because of the walking distance from the system station or stop to the user's origin or destination. Guideway systems are usually limited in extent because of the high installation costs of conventional designs. Automation enables 24-hour service to be on call without having large numbers of operators on duty during slack periods.

Group fares.—For a family or a medium-sized group, round trip fares by conventional transit could cost significantly more than by auto, even when parking charges are included. Transit service charge could be by the vehicle instead of by the rider. PRT and AGRT operating in the demand-responsive mode could offer this benefit.

High service dependability .—The reliability of the system and the ability to recover quickly from failures are very important service attributes. Because the most reliable of equipment still fails occasionally, an effective failure recovery strategy is mandatory to contain the effects of failures. Dependability also reduces maintenance costs.

Guaranteed seating and privacy .—Studies sponsored by UMTA and others show that users place a high value on privacy and being assured of a seat. The desire for adequate personal space is also related to the need for security. Some individuals may prefer a vehicle in which they are guaranteed to be alone (PRT); others may prefer large groups; still others may like a small group.

[3]Willow, op. cit.

[4]Gustafson, op. cit.

[5]Richard L. Gustafson and F. P. D. Navin, "User Preferences for Dial-A-Bus: A Comparison of Two Cities" (prepared for presentation at the Third *Annual Demand Responsive Transit Conference*, Ann Arbor, Mich., June 1972).

[6]Joel Miller, "Identification and Definition of the Mobility Requirements of the Handicapped and the Elderly" (unpublished doctor's dissertation, Northwestern University, 1975).

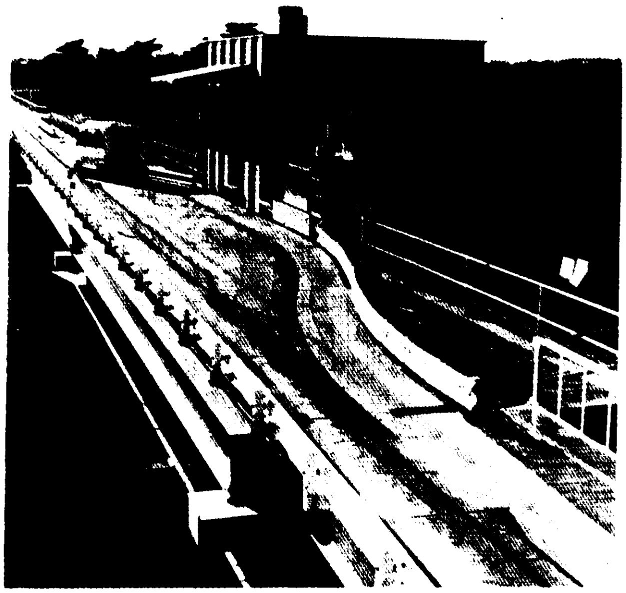

Photo credit Japanese Ministry of International Trade and Industry

Automobile-sized transit vehicles offer privacy and assured seating

System operational policies ultimately determine whether or not seating and adequate space are provided. New options will need to be developed that offer privacy, security, and guaranteed seating at a reasonable cost.

Guaranteed service through commitment to a guideway.—Both developers and consumers are more likely to make locational decisions based on a committed fixed guideway transit system than on bus service which could be here today and gone tomorrow. Consumer choice of work, shopping, and housing location can, in turn, influence the density of an urban area, although these changes will come about slowly.

If a decision is made to deploy a heavy-rail system (HRT), development will tend to concentrate around the relatively few stations on the system. If AGT is deployed widely throughout a metropolitan area, development nodes will tend to be smaller and more dispersed than for HRT due to the larger number of stations. But either form of exclusive guideway transit should encourage higher density development than would systems that operate in mixed traffic.

Future Technology Options

The research on exclusive guideway transit systems could lead to many technological improvements common to all AGT, including AGRT. Improvements include:

- reducing headways (thus increasing lane capacity) via modernized controls, collision avoidance systems, and improved braking;
- minimizing guideway intrusion and assuring all-weather operation through innovative design;
- improving emergency evacuation;
- integrating stations into existing commercial buildings to allow easy access, reduce construction costs, and stimulate business;
- increasing system capacity and efficiency through automatic vehicle coupling and bidirectional capability;
- reducing travel and wait time and providing point-to-point service by means of computerized vehicle management, offline stations, and high-speed switching; and
- using levitation principles to lift the vehicle off the guideway for more efficient propulsion.

Reduction of headways.—Traditional transit systems use fixed-block controls to maintain vehicle separation. This scheme evolved from the railroads, where a stretch of track is divided into sections (blocks) with a minimum of at least one open block between trains.

Modern technology allows the block to move with the vehicle. The size of the moving block varies in relation to vehicle acceleration speed and braking capability. These moving blocks can be adjusted automatically to shorten unnecessary vehicle separations and to achieve higher guideway occupancy without compromising safety.

Such a system appears to offer a level of reliability equal to that of the fixed-block system; however, the initial application of moving-block controls may raise questions of institutional liability. Improved braking is also necessary at closer headways. An early validation of this technology is warranted.

Guideway design.—While exclusive guideways allow vehicles to move unhampered by other traffic, they are perceived by some as an intrusion into the urban environment. Recently proposed guideways use lighter materials to reduce their bulky appearance and to offer more eye-pleasing architectural designs that will blend better into the surrounding cityscape. In general, narrow deep-beam guideways should cost less per unit length. Further study is needed to determine which guideway designs offer the most cost-effective operation in ice and snow conditions.

Emergency evacuation.—New systems must allow for safe evacuation in cases such as collision, fire, and snowbound vehicles. This problem presents special difficulties in the case of narrow guideways and suspended vehicles which prevent the user from escaping on foot.

Station/building integration.—It is expected that future AGT stations can be integrated into new or existing buildings. The degree to which merchants and developers will cooperate in achieving this integration, however, has not been established.

Automatic vehicle coupling.—Operations of fixed guideway systems could be made more efficient if vehicles could be automatically coupled into trains during periods of peak demand and uncoupled when the demand is light. Joining two or more cars togetherhile in motion involves a controlled collision similar in principle to the docking procedure in spacecraft.

Reducing trip time.—Other promising technological evolutions in control systems will further enhance and expand the capability of automated guideway systems. The forecasted improvements include higher average speeds **(30** to 60 mph), computerized vehicle management for possible point-to-point service without transfers, and high-speed switching.

Track design for conventional railroads requires that a section of rail several feet long change positions to direct trains onto alternative paths. High-speed switches are usually constructed by having a small component move on the vehicle rather than in the guideway. This feature allows vehicles to pass through switches at very close spacing and facilitates the use of offline stations. These improvements can help achieve assured seating, ride comfort, and privacy. Comparable improvements are possible for conventional systems but the cost of this service has inhibited its introduction.

Levitation.—Some automated guideway system designs now use air or magnetic vehicle levitation in place of wheels for vehicle support. An advantage of contactless support is less wear on both the guideway and vehicle components. Although the guideways for levitated systems must initially be fabricated as accurately as for rolling vehicles, it is expected that reduced mechanical wear will lead to savings in guideway maintenance. Even more significant is the potential total savings in maintenance of solid-state electronics in magnetic levitated systems versus mechanical parts in wheeled systems. Levitated systems may also generate less noise than mechanically suspended systems.

Both air and magnetic levitated vehicles require energy for levitation in addition to the energy required for propulsion. The longitudinal resistance of levitated vehicles, however, is lower than that of wheeled vehicles. Development work is needed to improve sensing and control to maintain the correct amount of levitation.

Implementing Technologies for Service Improvements

Development and introduction of improved transit systems and services are difficult and painstaking processes. Unlike some applications of advanced technology such as the Apollo space program where a mission of short duration is carried out in a controlled environment, transit technology must perform its mission for several years in a complex institutional, physical, and social environment. Facile comparisons between a successful space program and continuing urban transportation problems have tended to overlook the complex operating and institutional environment confronting urban transit.

In order to become viable transit options, new transit technologies, such as AGRT, must be able to demonstrate high reliability in a real environment that is acceptable to operators.

The service and technology options presented in this chapter, although desirable, may not be achieved or implemented in a single action. These advanced technologies could be introduced through a technology evolution process whereby a staged implementation would be carried out emphasizing the following steps:

- implementing automated guideway technology in short segments to accumulate operating experience, leading to design improvements in subsequent deployments,
- implementing automation to increase productivity,
- introducing system or subsystem technologies where short wait time, travel time, and other service options may be provided at reasonable cost by modern control techniques, and
- introducing network technologies for providing a full range of service options desired by users.

Unresolved Issues

- acceptability of integrating stations into privately owned structures,
- maintenance of correct air gap in levitated systems,
- emergency evacuation procedures,
- all-weather operation, and
- liability questions concerning the use of moving-block controls.