Impact of Advanced Group Rapid Transit Technology

January 1980

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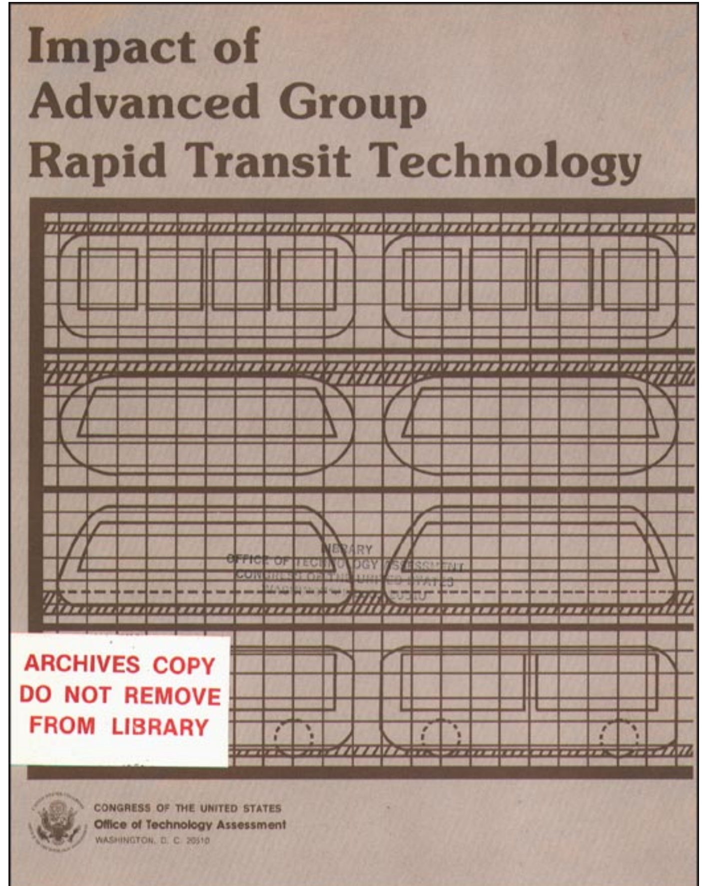

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Foreword

This assessment of advanced group rapid transit (AGRT) was made in response to a request of the House Committee on Appropriations to evaluate the need for this technology and its relationship to national mass transportation goals

In 1975, OTA published a major study, *Automated Guideway Transit, An Assessment of PRT and Other New Systems.* This current study of AGRT represents a partial update of the earlier report.

Increases in traffic congestion, petroleum shortages, and decreasing mobility for the transit-dependent reflect a growing need for more efficient and effective transportation options. This report examines the need for further advances in automated guideway transit (AGT) technology and evaluates their potential impacts on various stakeholder groups.

Members of the advisory panel and public participation working group contributed a great deal of valuable information and guidance throughout the course of this assessment. In addition, OTA is grateful for the assistance of numerous Department of Transportation officials representing both the Office of the Secretary and the Urban Mass Transportation Administration. Several cities were visited to evaluate the operation of existing AGT systems and to obtain the views of transit operators, planners, system suppliers, and consumers. Additional documents and data obtained from various domestic and foreign sources are referenced in this report.

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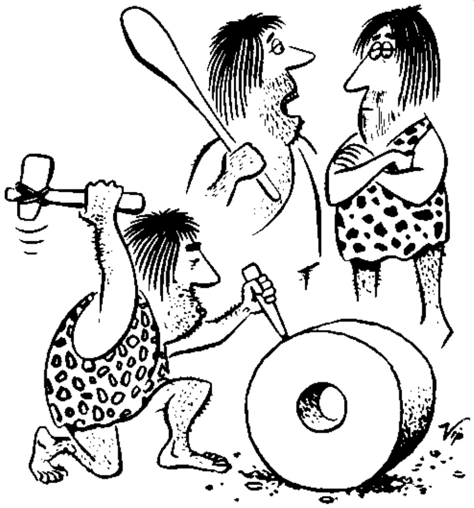
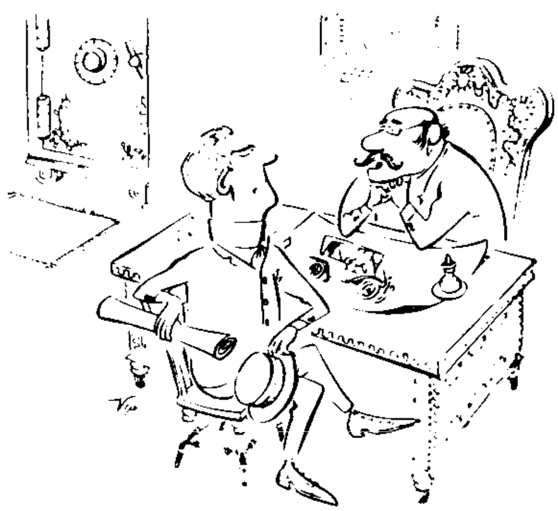


' 'As a matter of fact, one of our tribe conceived the Idea of the wheel quite some time ago, but we reasoned that the speed of the outer circumference would be so much greater than the speed of the Inner circumference that the whole thing would fly apart. so we abandoned It "

Chapter I

Summary— Issues and Options



"Do you realize. sir, that If your invention should gain popular acceptance–which I do not for one moment believe it will–we should have to provide paved roads, throughout the length and breadth of the country, thousands of pumping stations to supply ready access to fuel, and innumerable vacant lots In every city In which to park the vehicles? Take my advice and forget this folly, Henry "

''The whole business is economically unsound, gentlemen. With a train of this length and 40 miles of track. we find that only .0568 percent of the track will be in use at any given time. representing a constant idle investment of 99.9432 percent.''

Credit. Illustrations by Virgil Partch
SOURCE U S Steel Pub ADUSS No. 87-1811. December 1965

Photo credit: U.S. Environmental Protection Agency

Congestion: possible doubling by year 2000

Projected Daily Urban Travel and Congestion

	1975		1985		2000	
	Daily auto VMT (millions)	Percent occurring under congested conditions	Daily auto VMT (millions)	Percent occurring under congested conditions	Daily auto VMT (millions)	Percent occurring under congested conditions
Interstate	288	10	[illegible]	18	[illegible]	[illegible]
Other freeways and expressways	170	11	[illegible]	15	[illegible]	[illegible]
Other principal arterials	465	16	[illegible]	21	[illegible]	[illegible]
Minor arterials	331	9	[illegible]	[illegible]	[illegible]	[illegible]
Collectors	150	5	[illegible]	7	[illegible]	10
Local	230	N/A	[illegible]	N.A.	[illegible]	N.A.
Total	1,634	10	[illegible]	14	[illegible]	[illegible]

VMT = vehicle miles traveled
Congested conditions occur when the ratio of traffic volume to road capacity is greater than [illegible].
Source: [illegible], p. [illegible]

Chapter I

SUMMARY–ISSUES AND OPTIONS

Overview

Unless cities adopt forms of transportation that require less energy and space, they face a future of greatly increased traffic congestion and reduced mobility. Barring major policy changes, traffic congestion in cities is expected to double between 1975 and 2000. In addition, people dependent on public transportation will find it increasingly difficult to travel, particularly to dispersed suburban job centers where most of the employment growth is occurring.

Current transit options, conceived 50 or more years ago, are unable to serve efficiently the dispersed travel patterns in today's low-density urban areas. This growing mismatch between available transit services and trip demands largely explains why transit serves only 12 percent of the work trips and 2.5 percent of total urban trips (see table below). Transit's market share would need to increase dramatically to bring about a major reduction in traffic congestion and energy consumption.

Urban transportation problems do not lend themselves to a single all-encompassing solution. Several near- and long-term options have been identified, however, which offer the reasonable prospect of making these problems more manageable. These options include expanded use of carpools and vanpools, transportation system management techniques, land use policies, near-term transit product improvements, and new transit technologies offering service levels more competitive with the automobile.

Major Mode of Transportation to Work for 21 Standard Metropolitan Statistical Areas: 1975

Mode	Number (thousands)	Percent[a]
Workers using vehicles	*11,650*	100
Auto or truck	10,040	86
Drives alone	7,877	68
Carpool	2,100	18
Public transportation	1,432	12
Bus or streetcar	1,018	9
Subway or elevated	177	2
Railroad	224	2
Other (motorcycles and bicycles)	179	2

[a]Percent of workers using vehicles
NOTE Figures do not add due to rounding
SOURCE Data from the Travel to Work Supplement to the Annual Housing Survey

Automated guideway transit (AGT)—consisting of driverless vehicles operating on their own guideway—is widely regarded as a promising new option that cities should have the opportunity to select in addition to buses, subways, and trolleys. A wide variety of automated transit systems are undergoing development in the United States, Europe, and Japan. The simplest form, called shuttle-loop transit (SLT), has operated successfully for several years in shopping centers, airports, and amusement parks. SLT systems typically consist of single vehicles or vehicles in trains operating on short segments of linear or circular guideways with few stations, little or no vehicle switching, and at least 1-minute spacing or "headway" between vehicles. Most installations have been on elevated guideways, but some also operate at ground level or in tunnels. These types of systems are commonly referred to as horizontal elevators. The Urban Mass Transportation Administration (UMTA) has provided some research and development funding for SLT systems over the past decade and is now supporting planning activities in 10 cities for the installation of SLT systems in the downtown areas. This downtown people mover (DPM) program was created to test the viability of existing AGT systems as circulators in city centers.

A second generation of AGT systems called group rapid transit (GRT) is operating in Morgantown, W.Va., and at the Dallas-Fort Worth, Tex., airport. Both of these systems received Federal support. Compared to SLT systems, GRTs can operate at shorter headways (down to 3 seconds) on more extensive guideway networks and make much more extensive use of switching. GRT stations can be located on sidings called offline stations, which permit vehicles to bypass other vehicles that have stopped to accept or discharge passengers.

The most complex form of guideway transit is called personal rapid transit (PRT). These systems are characterized by small, one- to six-passenger vehicles, capable of operating at one-half to 3-second headways and offering nonstop origin-to-destination service on extensive, narrow guideways. As in the private automobile, PRT riders would not be required to share their vehicle with strangers. PRT has been under development in France, West Germany, and Japan, but no system has been deployed in cities.

A federally funded program is currently underway to develop a third generation of automated systems called advanced group rapid transit (AGRT). The largely arbitrary system specifications, as defined by UMTA, place AGRT on the dividing line between GRT and PRT systems. These specifications call for 40-mph, 12-passenger, all-seated vehicles operating with 3-second headways and offline stations. Three designs were selected including a rubber-tired vehicle with propulsion through the wheels, and two systems propelled by linear induction motors, one supported by an air cushion and the other magnetically levitated, The technologies under development in the AGRT program could be applied to all forms of exclusive guideway transit ranging from large-vehicle urban rail systems to small-vehicle PRT systems.

OTA was asked by the Transportation Subcommittee of the House Appropriations Committee to evaluate recently proposed changes in the scope and cost of the AGRT program. This assessment addressed three major issues.

Issue 1: The Need For More Advanced Automated Systems

Will AGRT offer significantly lower cost and superior service than other types of urban transit?

There is considerable support at the local level for continuing work on AGT technologies, both among transit users and public officials. Users and nonusers alike are critical of the amenities, frequency of service, reliability, crowding, and inconvenience characteristic of transit services currently available in most cities. Technological innovations encompassed in the AGRT program include new electronic control systems, linear induction motors, magnetic levitation systems, high-speed switching, and emergency braking for short headway operations. These advances in technology offer several potential benefits to transit operators and users:

- service flexibility comparable to vans or taxis coupled with the carrying capacity of a trolley car system or a multilane freeway,

Photo credit U S Department of Energy

Old technology—changing needs

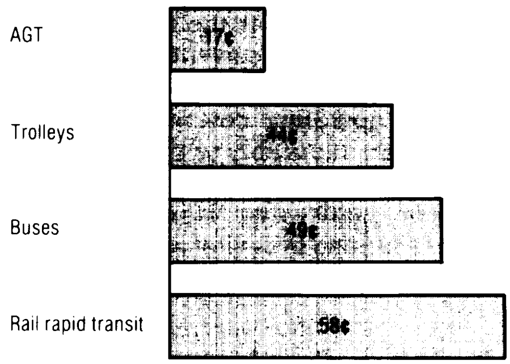
- lower cost per mile of guideway than for heavy-rail transit systems thus permitting the construction of more extensive guideway networks for a fixed capital investment,
- rapid origin-to-destination service with few or no intermediate stops and no transfers, and
- substantially increased frequency of non-rush hour service.

Systems incorporating these technologies could transport people and goods into activity centers as well as provide circulation within downtown and suburban activity centers. While there is widespread agreement that these changes in service levels would be beneficial, several potential problems have been identified that need to be more fully addressed:

- reliability of new technology;
- community acceptance of elevated guideway designs;
- evacuation of passengers stranded on narrow elevated guideways;
- operating problems in ice and snow;
- public resistance to riding small, automated vehicles in the company of strangers; and
- verification of lifecycle cost estimates.

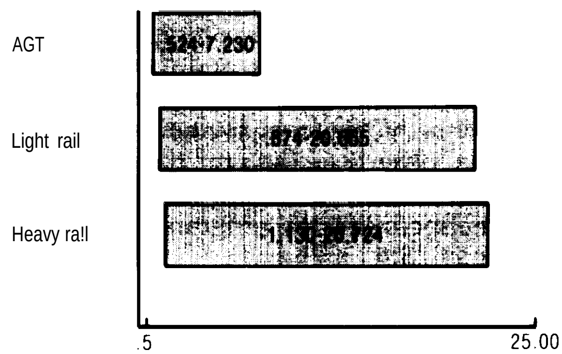
UMTA has sponsored studies that compare the capital and operating costs of AGRT with other transit options. The results show that there are great variations in cost from system to system which make generalized cost comparisons virtually meaningless. For example, operations and maintenance (O&M) costs per vehicle-mile for the **10** existing AGT systems range from $0.49 to $6.55. Average O&M costs per passenger-mile for AGT ($0.17) compare very favorably with trolleys ($0.44), buses ($0.49), and rail rapid transit ($0.58). However, the O&M costs per passenger-mile for AGT ranges from $0.09 to $1.01. Consequently, comparisons of average costs across broad categories of systems tend to be misleading. There are also wide variations in the capital costs of these systems which reflect site-specific differences in topography, guideway design, local labor rates, and system design requirements. More reliable comparisons need to be made through analysis of individual community requirements.

Average Operating and Maintenance Costs Per Passenger-Mile



SOURCE N D Lea & Associates Inc , Washington D C

Guideway Construction Costs, $/Lane-Mile (in millions of 1976 dollars)



SOURCES Thomas K Dyer Inc *Rail Rapid Transit Cost Study* March 1977 N D Lea & Associates Inc Summary of Capital and Operating and Maintenance Cost Experience of Automated Guideway Transit Systems June 1978

No reliable techniques exist for estimating ridership on such systems because they embody service characteristics presently unavailable on public transit. Until some actual operating experience is accumulated, claims about costs per passenger-mile on AGRT systems cannot be verified. Surveys show that the service attributes made possible by AGRT technologies are regarded favorably by the public. However, survey data is not always a reliable indication of future behavior. A limited test of these new service levels will be required to verify the survey findings.

In summary, we find that:

- AGRT technologies appear capable of providing service levels that the public wants but cannot get with currently available transit technologies.
- Capital and operating cost estimates for AGRT compare favorably with the costs of installing and operating heavy-rail systems on exclusive guideways. However, there are large variations in capital and operating costs among the 10 operational automated guideway systems. Precise comparisons with other transit technologies will require further testing of AGRT systems and real-world experience.
- Additional system optimization studies are needed to determine the preferred vehicle size, seating capacity, guideway configuration, headway; and line speed of future AGT systems. The views of transit operators and the public should play a central role in this analysis.

Issue 2: Prototype Development

Do the benefits to be gained from building more than one prototype technology justify the additional cost?

The original AGRT project plan called for three manufacturers to submit competing designs, followed by the selection of a single system for prototype development. This plan was later changed to provide for prototype development of both the air-cushion and the wheeled-vehicle systems. In the revised plan, work was also to continue on magnetic levitation technology, but at a lower level than for the other two systems. These changes, together with inflation adjustments, increased the program costs from $43.5 million to $111 million.

AGT technology is currently at a stage of development analogous to automobile technology shortly after the turn of the century. In the early years automobile technology was very diverse and a single-design concept did not emerge until after an extended period of testing in the marketplace. AGT is still in the early stages of its development cycle and it is too soon to predict which technology will prove superior in most applications.

In summary, we find that:

- Money invested in alternative AGRT technologies during the early phases of the R&D program can provide relatively inexpensive insurance against the risk of picking an inferior design.
- At this early stage in the development cycle, there is no sound technical basis for discontinuing work or providing any promising technology with significantly less funding. Magnetic levitation is a particularly promising option because of its low noise and high reliability potential.

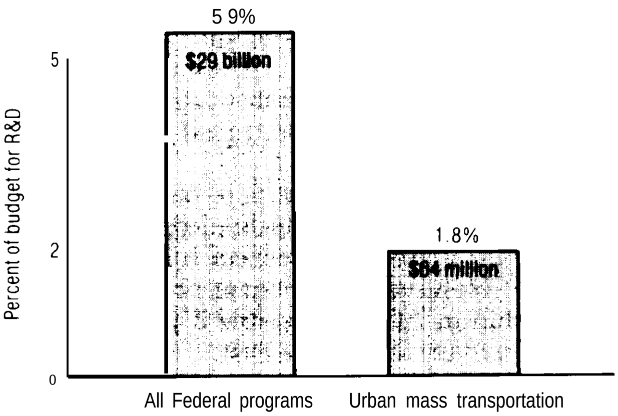
Issue 3: Government/Industry Relationships

What role should Government and industry play in the development of advanced AGT?

Federal programs established to foster the introduction of new transit technologies have consistently underestimated the complex institutional, economic, and technical barriers to innovation. Neither transit operators nor local public officials are anxious to volunteer their communities as laboratories for transit experiments unless the Federal Government is prepared to underwrite the financial risks of failure.

Potential transit system suppliers find it increasingly difficult to justify major corporate investments in transit innovation, given a history of uncertain Federal support, unrealistically tight development timetables, complex institutional barriers, and the lack of established stable markets. Unlike the automotive industry which caters to millions of customers, or the aircraft manufacturers who have established long-term relationships with scores of airlines worldwide,

Federal Government Spending Allocated to Research and Development–1979



SOURCES Office of Management and Budget U S Department of Transportation Urban Mass Transportation Admfmstral(on

the fate of would-be transit equipment suppliers is increasingly bound up with one customer—the Federal Government. Suppliers regard this as an inherently unstable and risky arrangement.

The transit procurement process continues to be administered at the local level. However, the amount of funding available to each city, the kinds of equipment that are eligible for purchase, and the procurement procedures themselves are largely determined at the Federal level. The supplier industry is generally skeptical that the Federal Government will either decontrol the transit procurement process or provide what they regard as sufficient funding to create a stable market for innovative transit technologies. Several firms are willing to participate in federally funded R&D programs that require no major corporate investments, but it is unlikely that production commitments will be made unless industry is reasonably confident of a favorable return on investment, even if Government agencies promise support for such a market.

Transit operators and local public officials are expressing growing concern that the products of these federally sponsored R&D programs fail to satisfy their transportation needs at reasonable costs. Denver, Cleveland, Houston, and St. Paul were all selected by the Federal Government as demonstration sites for an AGT system. All four cities have reportedly withdrawn from the program even though UMTA had agreed to pay 80 percent of the system acquisition costs. While many other cities have expressed an interest in deploying AGT, it remains to be seen how many will decide to implement their plans.

In West Germany and Japan the development of advanced AGT technologies has been supported through special agencies established to promote the development of products that are competitive in international markets. In this country, the transit R&D function is managed by the same agency that regulates and funds urban transportation systems. Although foreign countries lack the depth of operating experience with AGT that has been accumulated in the United States, they have been more successful in resisting pressures to rush new technologies into service before they are thoroughly tested, and they have followed a more orderly development process.

The West German Cabintaxi system, with characteristics very similar to the current AGRT design goals, is expected to be carrying passengers in a Hamburg demonstration by 1981. The current development timetable for U.S. AGRT systems suggest that they will not begin to carry passengers before 1990 even if development and deployment hurdles are overcome. If the Cabintaxi demonstration is successful, it would be a clear signal that technological leadership has shifted overseas. The trade implications of such a development will depend on future U.S. Government policy toward advanced transit development and deployment.

In summary, we find that:

- Introduction of innovative transit systems is constrained not only by the need to more adequately develop the technology, but by major institutional and economic barriers as well.
- Recent experience suggests that the promise of 80-percent Federal funding is no longer sufficient inducement for cities to accept transit technologies if there is a question relative to whether they will meet local needs at a reasonable cost.

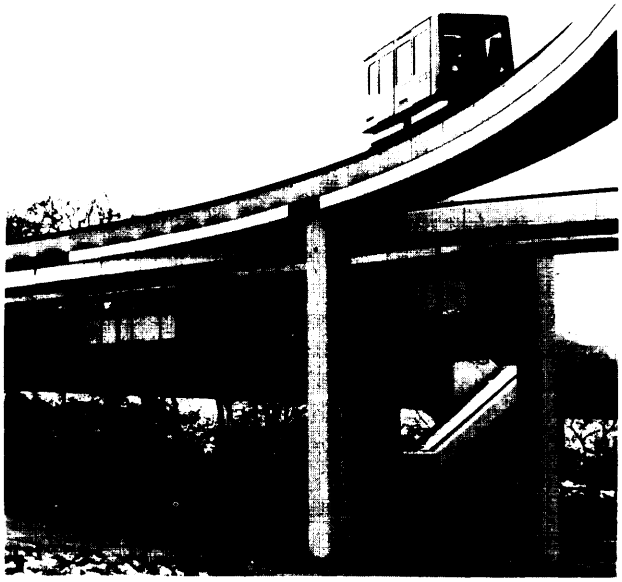


Photo credit DEMAG Fordertechnik

West German AGRT to enter service in 1981—9 years ahead of U.S. version

- Both West Germany and Japan have fostered a cooperative relationship between Government and industry that has helped ensure an orderly program of long-range transit innovation. Further consideration is needed of alternative institutional arrangements for managing transit R&D in the United States.
- The potential of broad international leadership in the transit technology field is no longer a credible prospect for U.S. industry. However, component or system leadership in AGT is possible if pursued more effectively than in the past.

Policy Options

Four options for continued research on AGT have been identified. These options are as follows:

1. **emphasize short= run product improvements in operating shuttle-loop and group rapid transit systems;**
2. **continue long-range development of critical new subsystems capable of providing major cost and service improvements;**
3. **validate new subsystems in a system environment to ensure that they perform acceptably as part of an integrated package; and**
4. **develop prototype systems that incorporate major new technologies leading to early deployment in cities.**

These options could be adopted either singly or in combination. For example, the first option emphasizes incremental improvements in shuttle-loop and group rapid transit systems that are already in operation. Examples of product improvements might include higher line speeds, larger motors, and more reliable door mechanisms. This upgrading of operational systems could be pursued as a short-range R&D objective alongside longer range transit innovations such as those encompassed in the AGRT program. Depending on the scope of a given product improvement program, the cost for each system could be expected to fall in the range of $2 million to $7 million. The major advantage of this option is that improvements are available to cities in the near-term. But if short-term objectives are pursued to the exclusion of long-range R&D options, major cost and service level improvements would be indefinitely postponed and the AGRT contractors would discontinue work on advanced systems.

Options 2 and 3 would continue development of technologies associated with the AGRT program but incorporate more flexibility in the selection of system design and performance specifications. To achieve the advances in service levels specified in the AGRT program each of the new subsystems needs to be developed in parallel and tested in a systems environment. It would be of little value, for example, to increase a vehicle's line speed to 40 mph unless it could be simultaneously demonstrated that the vehicle can be safely switched at these speeds, that the emergency braking systems are effective, and that the control systems are capable of maintaining safe stopping distances. It is not necessary, however to build full production prototypes to verify that the technology meets its design goals. Deferring development of production prototypes, however, will delay the deployment of these new technologies. Pursuing both Options 2 and 3 would cost in the range of $60 million to $80 million.

Option 4 would proceed immediately with the design and development of production prototypes. This was essentially the AGRT program as requested by UMTA in the FY 1979 budget at a cost of $111 million. Early in 1979, UMTA scaled down these plans. While work is to continue on the wheeled vehicle and air suspension systems together with a lower level effort on magnetic levitation, a decision to develop prototypes has been deferred. This option involves the highest cost and technological risk. Its major strength is that it aims at achieving the AGRT program goals in less time than it will take under Options 2 and 3.

In summary, we find that:

- Updating existing technologies (Option 1) should be a continuing objective of short-range transit R&D programs. But a short-range program is not a substitute for a long-range program aimed at achieving significant improvements in performance, cost , and service levels—beyond those achievable through incremental improvements in existing transit systems.
- Continued work on critical AGRT subsystems and their validation in a systems environment (Options 2 and 3) should help ensure the orderly development of new transit systems with improved operating characteristics. Emphasis on these two options appears to be most appropriate at this time.
- A decision to proceed immediately to develop one or more production prototype systems (Option 4) presupposes a base of knowledge about the relative merits of the technological options and their marketability which does not currently exist, Selecting specific prototype designs at this time would appear to be premature.

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Chapter II

INTRODUCTION

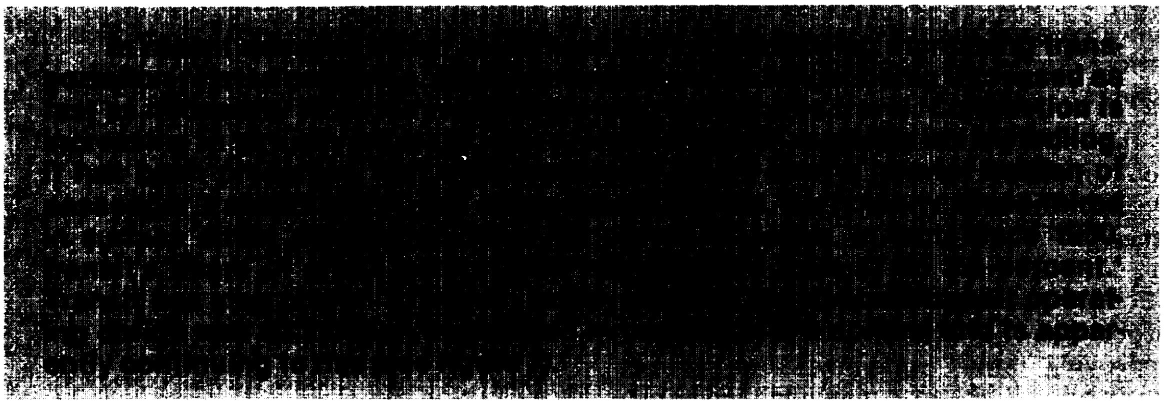
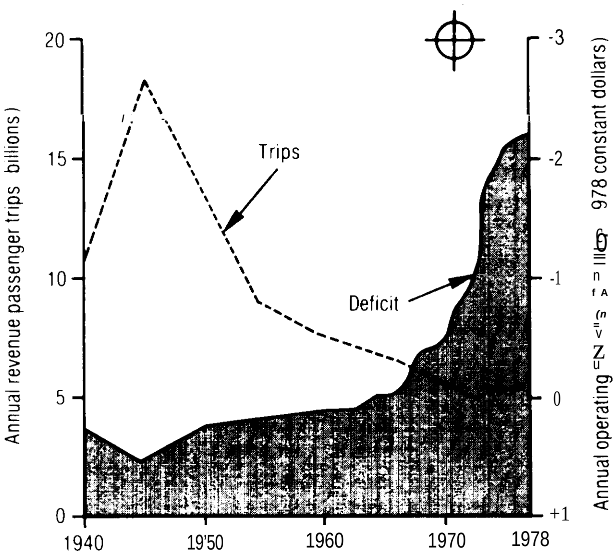


Figure 1.—U.S. Urban Mass Transit Trends (1940-78)



SOURCE American Public Transit Association

In hindsight, decline in the use of public transit is not only understandable but appears to have been an inevitable consequence of the changing growth patterns of U.S. cities. Since World War II, suburban areas have been growing nearly four times faster than central cities. Jobs and activities have followed people to these suburbs, decentralizing the functions once largely confined to a single central business district.

[1]Alan Altschuler, *The Changing Institutional Environment of Urban Transportation* (Cambridge, Mass.: MIT Center for Transportation Studies), March 1976.

Conventional transit—fixed-route bus, trolley, elevated, or subway—was introduced 80 or more years ago when most of the urban population lived in the high-density central city, where nearly all employment, shopping, and other activities were carried on. This basic fixed-route transit, running to and from the central business district, is becoming less compatible with the spatial distributions of modern cities with large multicentered suburbs and diffuse trip patterns.

Transit systems show very marked economies of scale. As the number of riders per mile decreases, the cost per rider increases—very rapidly. As cities have changed, the automobile has replaced transit as the basic urban transportation system. Although the decline in the total transit ridership bottomed out in 1972 and some growth has occurred since, costs have risen inexorably.

The goal of improved urban transportation is to make the urban area a better place to live; transportation attributes per se are important only as they contribute to this larger goal. The automobile is not space-efficient. Downtown areas, high-density suburban developments, and the principal arterials connecting them are choked throughout large parts of the day with automobile traffic. If existing cities are to become more pleasing places in which to work and live, more space-efficient modes of transportation must be developed both for circulation within high-density areas and along arterials. This may require a combination of some restrictions on automobile use at certain times or in certain areas and sufficiently attractive transportation alternatives to make such restrictions acceptable to the public.

By the early 1960's it became apparent that without immediate Federal intervention, a great many transit systems would have been unable to renew their equipment or maintain service levels. To deal with this rapidly deteriorating situation, Congress enacted the Urban Mass Transportation Act of 1964 for the purpose of: 1) improving transit equipment and services, 2) encouraging long-range planning, and 3) providing funds to acquire and preserve services.

Two of the three goals of the 1964 Act have been largely achieved. Federal funds have enabled local public agencies to provide support to troubled transit systems, thus preserving at least a minimum level of service for the captive rider. In addition, the quality of local transportation planning has improved significantly as a result of Federal support. Since 1964 a Federal investment of over $12 billion has gone into the purchase of equipment and extension of services. Although ridership continued to decline after 1964, it bottomed in 1972 and has shown an increase in each year since then. Ridership today is roughly equivalent to **1970** levels. Although the 1973-74 energy crisis is identified as having caused this reversal, other factors have undoubtedly contributed as well—the better service and equipment coming online as a result of the Urban Mass Transportation Administration's (UMTA) programs, subsidized fares, increasing urban congestion, and the decline in urban freeway construction, overall urban area growth, and central area rejuvenation. Transit's share of total urban travel, however, has not kept pace with the growth in urban population and person-trips.

Over the past 18 years, Federal funding for urban mass transportation has totaled $16.7 billion. As shown in table 1, 96 percent of these funds have been spent in the past 10 years.

Barring a major energy crisis which would dramatically curtail automobile usage, transit's market share is likely to drop further over the next 20 years. By the year 2000, urban auto-

Table 1.–Administrative Commitments by Fiscal Year and UMTA Activity (in millions of dollars)

Fiscal year	Capital facilities grants	Formula grants	RD&D	Technical studies grants	Managerial tralnlng grants	Unlverslty research & trainng grants	Interstate and urban systems grants	i x free demon-strations	Commuter rail operaflng subsidies	Non-urbanized formula . grants	Total
1962	$ 10 5	—	$ 02	—	—		—	—	—		$ 107
1963	—		193	—			—	—	—	—	193
1964	—		3 9	—		—	—	—	—		3 9
1 9 6 5	507	—	8 9	—		—	—	—			596
1966	1092	—	4 7				—	—	—		1139
1 9 6 7	1210	—	5 5	$ 31	$01	—	—	—	—		1297
1968	1220	—	6 5	36	—	—		—	—		132 1
1969	1483		183	50	—	$1.7	—	—		—	1733
1970	1327	—	163	80	—	3.0	—		—	—	1600
1971	3407	—	3 9 5	144	0 4	3 0	—	—			3980
1972	5100		6 1 4	250	0.5	2 5		—	—	—	5994
1 9 7 3	8637	—	71 5	335	0 4	2 5	—		—	—	9716
1974	8703	—	6 6 7	376	0 3	2.3	$ 95.6			—	1,0728
1975	1,1966	$ 1516	4 6 8	371	0 5	2.2	814		—	—	1,5162
1976	1,092.2	390.3	4 7 7	38 t	0,4	0 7	3376	—		—	1,9070
TQ	2470	521	177	9 6	0 3	14	2154	$03	$ 234		5672
1977	1,2500	6216	5 8 9	432	0 5	2 0	4094	0 7	5 5	—	2,3918
1978	1,3988	7424	681	550	0 3	2 0	6667	—	806		3,0139
1979	1,2250	1,3000	6 4 0	550	0 5	2 0	7000	0 5	750	$750	3,4970
Total	'~~,{8~i	$3,2580	$6259	$3682	$42	$253	$2,5061	$15	$1845	$750	$16,7374

NOTE FY 1962 through FY 1977 reflect ad-m! nistrative commitments FY 1978 and FY 1979 reflect obligations

SOURCE Department of Transportation Urban Mass Transportation Administration Jan 22 1979 mobile vehicle-miles are expected to increase by over 80 percent, which would mean a more than twofold increase in traffic congestion and reduced mobility. ' Meanwhile, transit operating deficits may soon exceed **$3** billion annually, and could continue to c1imb.[3]

[2]U.S. Congress, Office of Technology Assessment, *Changes in the Future Use and Characteristics of the Automobile Transportation System: Summary and Findings*, OTA-T-83 (Washington, D.C.: U.S. Government Printing Office, February 1979).

[3]U.S. Congress, Congressional Budget Office, *Urban Mass Transportation: Options for Federal Assistance* (Washington, D.C.: U.S. Government Printing Office, February 1977).

Clearly, the vast majority of the traveling public prefers the amenities offered by the automobile, and they are prepared to pay a heavy premium to retain these features. Continued deployment of bus and rail systems meeting current service standards shows little promise of being able to persuade significant numbers to abandon their automobiles in favor of public transit.

R&D: The Search for More Competitive Transit Options

Section 6 of the Urban Mass Transportation Act of 1964 authorized a program of research, development, and demons ration projects to pursue three goals:

1. assist in the reduction of urban transportation needs,
2. improve mass transit service, and
3. minimize cost.

The proportion of the UMTA budget devoted to the search for more competitive transit systems and services remains low in relation to the overall rate of Federal R&D spending. In FY 1979, 5.9 percent of the total Federal budget was allocated to R&D while only 1.8 percent of the UMTA budget was earmarked for the development of new and improved transit systems. In the defense sector, where the development of competitive products is given a high priority, 10 percent of the budget is set aside for R&D. Between 1975 and 1979, the total UMTA budget increased 133 percent while funding for R&D grew only 37 percent.

Currently UMTA devotes roughly two-thirds of its R&D funds to near-term product improvements and one-third to new systems development. Virtually all of the work on new systems is focused on the development of automated guideway transit. Almost no attention has been paid to one of the three objectives of R&D as spelled out in the authorizing legislation which is to explore ways to reduce the need to travel, such as through the use of telecommunications or land use policy changes.

Automated Guideway Transit

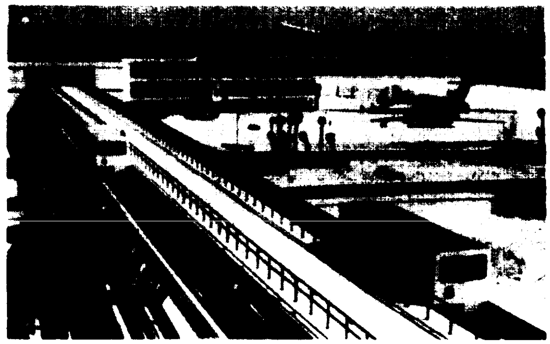
Automated guideway transit (AGT) is a class of transportation systems in which unmanned vehicles are operated on fixed guideways along a fixed right-of-way. About **20** such systems exist in the United States today, almost all of them in airports, zoos, or amusement parks. The various AGT classes are described more fully in OTA'S previous report on AGT[4] and are illustrated in figure 2. While the different types of AGT often are regarded as being distinct systems, they should be regarded as only discrete points in a multidimensional option space of system characteristics. UMTA is currently in the process of deploying demonstration automated guideway systems in the downtown sector of several cities to determine their public acceptability in general urban transit service.

Concurrently with the downtown people mover (DPM) demonstrations, UMTA is funding the development of a new AGT technology known as advanced group rapid transit (AGRT). The AGRT program, as defined by UMTA, encompasses several advances in technology including magnetic levitation, high-speed switching, and new command and control capabilities to permit short-headway operations

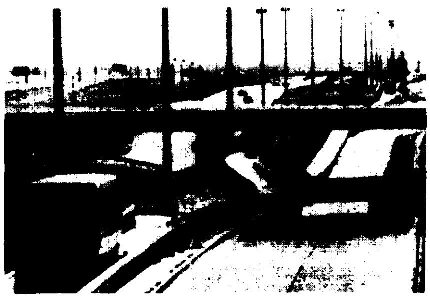
[4]U. S. Congress, Ott ice of Technology Assessmen t, *Al/ tomated Guideway Transit*, OTA-T-8 (Washington, D. C.: U.S. Government Printing Office, lune 1975).

Figure 2.–Classes of Automated Guideway Transit

Shuttle-Loop Transit
- simplest technology
- vehicle size varies
- little or no switching
- long headway—60 seconds or more



Passenger Shuttle–Tampa International Airport



Airtrans—Dallas/Ft. Worth Airport

Group Rapid Transit
- more than six riders
- switching to shorten en route delays
- Intermediate headway—3 to 60 seconds

Personal Rapid Transit
- one to six riders
- no en route delays or transfers
- short headway—less than 3 seconds

Cabintaxl–Hagen, W, Germany

SOURCE Off Ice of Technology Assessment, *Automated Guideway Transit*, June 1975

in complex networks. The design goals established by UMTA[5] specify the following features:

- automated driverless vehicles,
- guaranteed seating,
- full climate-control,
- 5-minute maximum wait time for vehicles,
- no transfers necessary on the system,
- limit of two or three intermediate stops,
- 40-mph top speed,
- 12-passenger vehicles,
- single- or two-car trains,
- elevated guideway,
- 3-second headway,
- 14,400 seats/hour/lane (theoretical), and
- electrical power.

It should be noted that these are UMTA'S design goals and should be subject to modifica-

[5]U.S. Department of Transportation, Urban Mass Transportation Administration, "Request tor Proposal (RFP) DOT-UT-30014 High performance Personal Rapid Transit (HPPRT) System, " Feb. 20, 1974.

tion to meet the specific needs of particular applications. A city could, as an example, conclude that its needs are best met by an AGRT system with lower line speeds, longer headways, and smaller vehicles, These kinds of modifications would not involve major changes in technology. Potential applications for systems incorporating AGRT capabilities include activity center circulation, radial trunklines, outlying collection/distribution, and regional networks.

History of AGRT

The AGRT program was conceived in the wake of TRANSPO '72, a Department of Transportation (DOT) sponsored transportation exhibition held at Dunes Airport. Promoted as a showcase for new transportation technology, four AGT concepts were displayed under UMTA sponsorship. The AGRT program, as announced in February 1974, was to consist of two phases—a 7-month preliminary design phase followed by a 36- to 40-month prototype development phase. The entire project was scheduled to be completed in 1978.

Three contractors, Boeing, Otis, and Rohr were selected during the Phase I competition to prepare preliminary designs. Proposals for Phase 11 work *were* submitted in September 1975 following completion of the preliminary designs. Figure 3 lists the technologies that each of the contractors proposed to meet the system specifications.

At this juncture, the program underwent the first of several major modifications. Responding to recommendations contained in the FY 1976 DOT Appropriations Conference Report, UMTA restructured the program. Instead of selecting one of the three contractors to proceed with a test track development, a decision was made to split Phase II into two parts, thus extending the completion date to the first part of 1981.

All three contractors were invited to continue design refinements and laboratory testing of key components during an 18-month Phase 11A. This work got underway in June 1976. As a part of Phase IIB, a single design was to be chosen for full-scale prototype testing at the DOT test center near Pueblo, Colo. During the fall of 1977, as Phase 11A was nearing completion, a task force was formed within DOT's Office of the Secretary, once again to review the AGRT program and to chart a course of further activity. The DOT review led to the following recommended program redirection:

- maintain competition by funding both the Otis air-cushion and Boeing wheeled-vehicle technologies in Phase IIB;
- continue technology development on the Romag magnetic levitation system but at a lower level than the other two systems;
- fund Boeing and Otis to conduct a facility commonality study with the aim of achieving a common test track at Pueblo;
- continue study and development of operating vehicles in trains; and
- conduct a departmental review of proposals for construction of the test facility at Pueblo following the detailed design activity period.

As a result of these recommended changes and adjustments for inflation, the total cost of the AGRT program increased from $43.5 million to $110.9 million. Tables 2 and 3 provide a

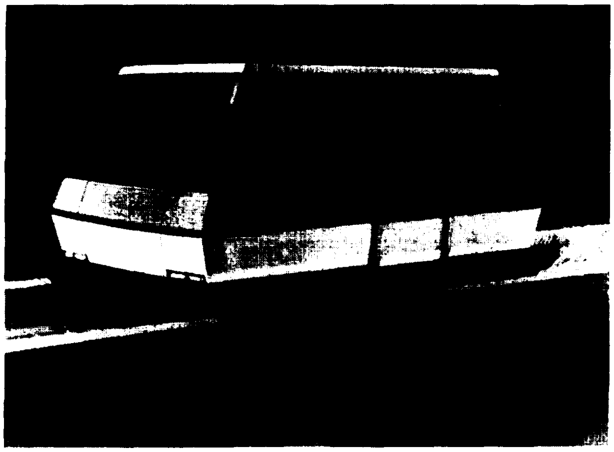
Table 2.–AGRT Funding (in millions of dollars)

Budget proposal. Submission to Congress– FY 1979	cost
Prime contractors	
AGRT development?	$800
Trained system design	40
Romag development	50
Prime contractor tolal	890
Technical support	79
Total	969– “
Prior expenditures	
Phase I planning	9
Phase I	
Prime contractors	15
Support	4
Total Phase I	2.8
Phase 11A Planning	.4
Phase 11A	
Prime contractors	6.3
Support	1.7
Total Phase 11A	8.4
Phase IIB Inltlatlon	
Prime contractors	2.0
Support	.8
Total Phase IIB	28
Total expenditures (through 3/31 /79)	140
GRAND TOTAL	$110.9

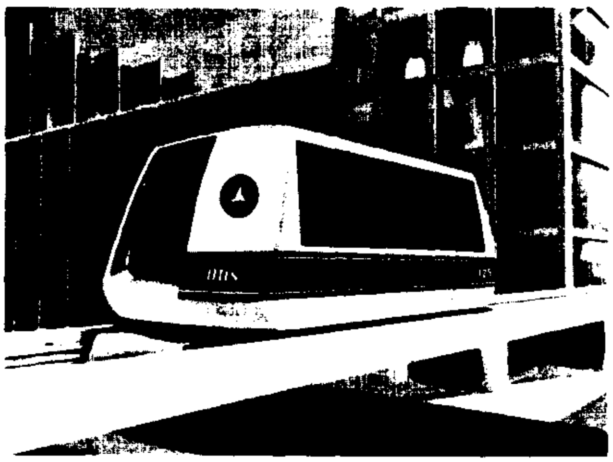
ªSee table 3 for breakdown

SOURCE Urban Mass Transportation Administration

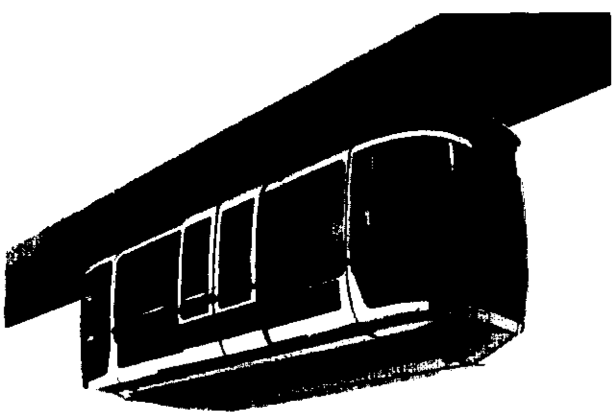
Figure 3.–Summary of AGRT Technology Options



Contractor:	Boeing.
Suspension:	Wheeled, rubber tires.
Propulsion:	d,c. electric motors
Guideway:	8-ft. wide, bottom-supported U channel,
Command & control:	Moving block, colllslon avoidance radar,
Switching.	High speed, on vehicle,



Contractor:	Otis.
Suspension:	Alr levltatlon,
Propulsion.	Linear Induction motors.
Guldeway:	8-ft. wide, bottom-supported channel guldeway
Command & control:	Mowng block.
Switching.	High speed, on vehicle



Contractor,	Boeing (formerly Rohr),
Suspension.	Magnetic lewtatlon,
Propulsion	Linear Inductlon motors
Guldeway	4-ft. wide, top-supported monorail beam
Command & control:	Moving block.
Swdchlng	High speed, on vehicle

Pholo credits U S Department 01 Transportation

Table 3.–AGRT Engineering Prototype Development (cost per contractor in millions of dollars)

	Vehicles	Command & control	Gu!deway stations	Total
Englneenng design	$3	$ 6	$4	$13
Fabricatlon	3	5	4	12
Integration	—	3	–	3
Test	—	4	—	4
Totals	$6	$18	$8	32
Englneerlng prototype upgrading	—	—	—	8
Total	—	—	—	$40

SOURCE Urban Mass TransportationAdministration

listing of projected program costs broken down by category of activity. The program then took another turn, when in early 1979 UMTA scaled down the scope of Phase IIB work. Instead of testing prototypes of the Boeing wheeled-vehicle and Otis air-cushion system at the DOT test facility near Pueblo, Colo., the test is now to be carried out at each of the contractor's plants, using engineering vehicles. Program costs through Phase IIB now total approximately $73 mill ion.

Following completion of the Phase 11A contract, Rohr decided to abandon work on urban transit systems and on February **3, 1978,** signed a licensing agreement with Boeing for rights to the Romag technology. Numerous Phase IIB proposals were being submitted by the two remaining contractors in response to changing UMTA requirements, but contracts were not signed until June 1979. A lapse of 18 months occurred between the time Phase 11A work was completed and Phase IIB contracts were signed. These frequent alterations in the program, coupled with the lack of continuity in funding, have led the contractors to question the depth of UMTA commitment to advanced systems development.

Issues Addressed in the Assessment of AGRT

The House Appropriations Committee report on the FY 1979 Department of Transportation Appropriations Bill states in part:

> . . . as a result of a departmental reevaluation, the number of (AGRT) systems to be developed has been increased from one to two or more and the total estimated cost of the project has increased from **$43,.500,000** to approximately $110,000,000. In view of this substantial cost increase, the committee intends to request an Office of Technology Assessment review of the project.

In a letter dated July 17, 1978, the Committee requested that the Technology Assessment Board authorize an assessment of this project to "determine the project's feasibility as well as its relationship to the overall goals of the Department's mass transportation program. " In November 1978, OTA initiated a preliminary issue analysis pending Board approval to proceed with technology assessment.

Three principal issues were addressed in this report:

1. Will AGRT offer significantly lower cost and superior service than other types of urban transit?
2. Do the benefits to be gained from building more than one prototype technology justify the additional costs?
3. What role should Government and industry play in the development of advanced AGT?

This study partially updates a major assessment of "Automated Guideway Transit" published by OTA in June 1975. During the course of the current study, OTA staff members visited

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the Otis and Boeing test facilities as well as AGT systems at the Miami, Seattle-Tacoma, Houston, and Dallas-Fort Worth airports and the Wedway system at Disneyland. Public participation meetings were held in eight cities: Baltimore, Dallas, Denver, Houston, Jacksonville, Los Angeles, Miami, and Seattle. Meetings were also held with transportation planners in several cities where AGT deployments have been or are currently under consideration. An advisory panel and a separate public participation working group have met throughout the course of this project to assist in the study design and to comment ori the work in progress.

Both the AGRT contractors and numerous officials in DOT cooperated fully in providing useful background information.

In succeeding chapters the potential impacts of AGRT are examined in the light of urban transportation needs and currently available transit options. Alternative patterns of Government/ industry relations are explored, with particular attention paid to practices in Europe and Japan. The concluding chapter outlines several options for future AGT development, analyzes the pros and cons of each option, and provides a range of costs for each approach.

Chapter III

URBAN TRANSPORTATION NEEDS

Transit R&D programs should [illegible] select [illegible]

Some of the [illegible] rapid transit ([illegible]) [illegible] 24-hour service are [illegible] using conventional bus [illegible]

[illegible] to jobs, [illegible] friends and [illegible] of life is cor- [illegible]

There would be a basic logic in saying that providing access is the purpose of a city; it aggregates individuals and activities so that mutual access is possible. The specific spatial arrangement of this aggregation depends on the characterof the transportation available. Acenturyago when urban travel was largely on foot, effective access depended heavily on proximity. Homes had to be near work, and stores near homes. Densities were high, streets were narrow, and travel distances short. This pattern is preserved and observable in those parts of our cities that grew up before introduction of trolley cars and proliferation of the automobile.

The mobility provided by the automobile has been a major factor permitting the majority of the U.S. population to achieve personally desired housing and lifestyle goals. It has also become for most the preferred means of travel. Yet, it has become increasingly apparent that there are substantial problems in reliance on the automobile as the predominant urban travel mode. These problems include increasing congestion, pollution, and energy consumpt ion. While some of the problems can, in the long run, be cured or greatly alleviated, there are a t least two that cannot.

First, the automobile is unavailable to many urban residents—the poor, elderly, young, and handicapped. The dispersed development engendered by the automobile makes it difficult to provide efficient public transit service to meet the travel needs of these groups.

Second, the car is very inefficient in its use of space. The transportation capacity needed in the higher density portions of the city cannot be provided by automobiles; a more space-efficient mode of travel is needed.

Transportation does influence the way cities evolve and function. We would like to be able to match transportation to the needs of the city. It becomes, therefore, appropriate to directly consider the alternate, and sometimes conflicting, goals that cities might choose to adopt.

Goals for Our Cities

Transportation systems not only provide for personal mobility, but also influence the long-term spatial evolution of cities. Therefore, these facilities should be designed to meet social and economic objectives such as:

- housing for all residents offering choices of price, location, and lifestyle;
- jobs for all residents wishing to work;
- services—social, medical, cultural, recreational, and commercial; and

- a transportation system that permits citizens of urban areas to reach housing, jobs, medical, cultural, and recreational facilities with a minimum expenditure of time, money, and energy resources.

Little progress has been made toward fashioning strategies for physical development to achieve these goals.

For most of this century, metropolitan area growth has tended toward lower density residential development based first on streetcar and then on automobile transportation. While some signs of a trend toward reurbanization have been noted recently, a return to the highly concentrated turn-of-the-century city is not foreseen. Change in urbanization occurs very slowly. Were a concerted effort toward reurbanization to be undertaken today, significant and visible change would not appear until the next century.

A step toward higher densities is often viewed as desirable by urban planners since concentration permits greater use of transit or walking to satisfy activity needs. Yet, the same high levels of concentration that promote transit use also attract high levels of auto traffic to activity centers. So long as increased activity density is limited to only one end of the trip (e.g., the location of jobs or shopping facilities) the auto will remain the desired and most convenient mode for most trips. If cities are to be pleasant places to live and work, an easy and convenient transfer from the auto to the mode serving inside the high-density area will be absolutely essential.

The economics of urban activities also play a major role in the shaping of cities. While many functions can be efficiently conducted in high-rise, high-density structures, it is unlikely that industrial processes will ever again be conducted in multistory inner city buildings. The economics of transportation, industrial, and warehousing processes dictate that land-intensive structures be located in low-density areas where space can be obtained cheaply.

Central business districts may, in some cases, evolve into high-density centers encompassing a mixture of activities and dwellings catering to those who prefer the metropolitan life. Other dwelling and activity center nodes are likely to be located throughout the suburban region, sometimes in conjunction with major retail centers. Residential areas of somewhat higher density may evolve but the mature, low-density, suburban residential areas will remain and new, low-density, exurban development may continue to be developed. Many factors will influence these trends including land cost / travel cost tradeoffs and tax and fiscal /monetary policy.

There is no unanimity of tastes and preferences as to what cities should look 1ike, and not all cities will evolve the same way. Some urban areas may choose to revitalize and encourage high-density growth. Some may choose to shrink their central business districts and encourage the growth of suburban activity centers, Others may leave development programs entirely to market forces. Transit R&D programs should expand the options that cities can select to support locally determined urban forms.

Goals for Urban Transportation

Although current experience in urban areas shows that people will tolerate many inconveniences in traveling, the desired system for persona] transport is one that:

- permits the traveler to make trips at convenient times, rather than on the schedule of a specific vehicle;
- provides a comfortable trip—not overly crowded, seats available, few transfers, little waiting, and a place to store packages;
- **allows** travelers to reach activities within a reasonable time (e. g., no more than 30 to 40 minutes for work travel);
- permits travel at a cost commensurate with the value of the trip and the quality of service provided; and
- is compatible with the structure of the area being served.

The automobile meets these goals for many types of travel in urban areas, but it is unsatisfactory in high-density areas and on arterials leading to them. Here, mtore space-efficient transportation is needed. AGRT systems are claimed to reduce congestion-related problems by providing the following features to attract people out of their cars:

- extensive coverage —stops within walking distance of large numbers of central city residents;
- frequent service—service headways sufficiently short so that it is not necessary to

Photo credit DEMAG Fördertechnik

Assured seating important to consumer

consult a schedule in order to avoid long waits;
- service to major activity locations in the metropolitan area-Central business district work places, work and retaill activity nodes, and lower density industrial workplaces;
- r-eliable and dependable service;
- climate controlled vehicles
- assured wating for all users;
- perception of safety and security;
- direct service between most or all stations to minimize transfers; and
- rivacy.

Features such as climate control and security can be provided with conventional systems. Other features such as no transfers, 24-hour service, and assured seating are either technologically infeasible or uneconomical using conventional bus or rail hardware,

It is technologically feasible to provide a service with the characteristics stated above. Automation may be a key factor in making small-vehicle large-network systems, offering improved service levels, more economically feasible.

As service and economic considerations warrant attention, so too does architectural and esthetic acceptability. In only rare instances have facilities for automobile transportation been adequately blended into the urban environment. The bulky, smelly, noisy, diesel bus, does little better. Subways remove often obtrusive vehicle systems from the cityscape, but also deprive the rider of the enjoyment of light and air and the excitement of observing city activity. Small-vehicle transit systems, even if elevated, will be less obtrusive and more amenable to integration into the city structure. The small, lighter weight guideways should provide more opportunities for architectural creativity, and could also be enclosed within new or existing structures, much like the Minneapolis skyway system.

The Urban Mass Transportation Administration's AGRT development program should be evaluated in comparison with other technological and operational options that could be developed for the future. It is not certain at this time what solutions will be needed in the future. Just as the changing character of cities and lifestyles was often a primary factor in the decline of conventional public transportation, so are future changes going to be key determinants of future transportation choices.

Chapter IV

TRANSPORTATION OPTIONS

> *A need exists [illegible] reasonable cost that [illegible] needs sup- [illegible] petroleum con- [illegible]*
>
> *[illegible] studies which suggest [illegible] such as assured [illegible] in the choice of [illegible]*
>
> *[illegible] basis to [illegible] This [illegible] public [illegible] ble.*

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

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[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 powerline 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.

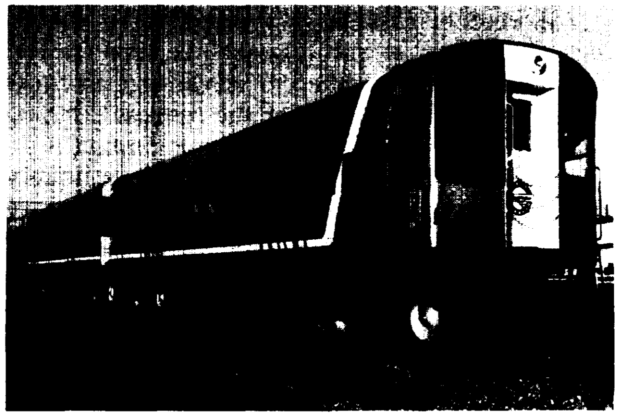

Photo credit Chicago Transit Authority

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 s Busway		SLT • GRT • PRT
larger	[illegible]	smal ler
larger	[illegible]	smal ler
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, van-pools, 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.

‘WI11OW, op.cit

[4]Gustafson, op.cit.

[5]Richa ret L. Gustafson and F. P. D. Nav in, “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).

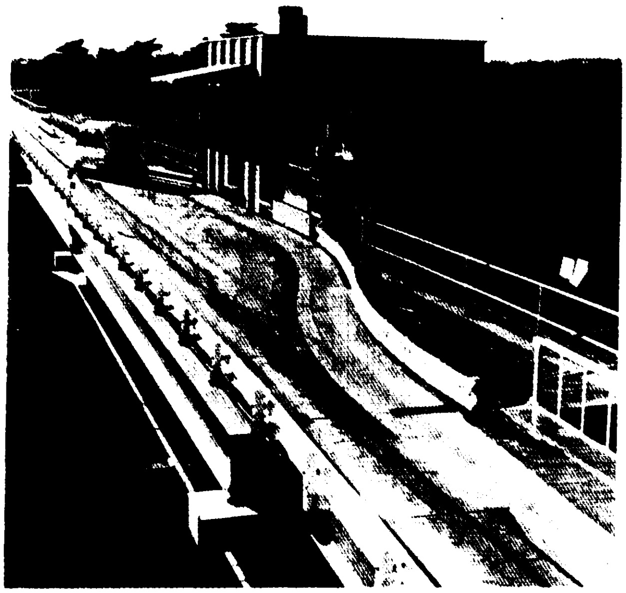

Photo credit Japanese Ministry of International Trade and Industry

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.

Chapter V

IMPACTS OF ADVANCED GROUP RAPID TRANSIT TECHNOLOGY

Systems derived from advanced [illegible] (AGT) technology have the potential to [illegible] and quality of urban [illegible]

The first of the [illegible] group rapid transit (AGRT) [illegible] This issue has been [illegible] vanced AGT [illegible] modes. The [illegible]

- quality of service [illegible]
- the auto user [illegible]
- ridership [illegible]
- urban development [illegible]
- [illegible] employment and productivity

Quality of Service

The advantages of AGRT over other transit modes are due to:

1. its unique ability to provide station-to-station service with no transfers and few stops on its own right-of-way, and
2. its high availability at all times of day due to automation.

It can also provide high-capacity service by running multicar trains over fixed routes on fixed schedules.

The Urban Mass Transportation Administration (UMTA) has yet to perform important computer simulations and other studies that would indicate the congestion impacts caused by large numbers of people trying to use the system and that would indicate the tradeoffs among vehicle size, system configuration, trip patterns, and other design and operating decisions.

The quality of service offered by a transportation mode is measured by such variables as time, cost, comfort, convenience, reliability y, availability y, and coverage. Assuming that AGRT would be operated and managed as well as existing transit systems, its inherent advantages are its potential for station-to-station service with no transfers and few stops and its availability at all times of day. While it could only provide the same amount of coverage as a bus system at appreciable cost, it would provide superior service on all other variables (assuming the security and emergency evacuation questions can be adequately addressed). The guarantee of a seat, the possibility of on-demand service, and the prospect of fewer transfers could give AGRT a distinct advantage over other grade-separated modes as well.

The flexibility of AGRT will allow it to respond to changing demand levels. At periods of low utilization, the service would be "demand-responsive, " with vehicles being routed to stations as service requests are generated. Such trips would involve minimal stops and no transfers. During periods of higher demand, the vehicles can be operated in trains on fixed schedules, over prescribed routes, serving small clusters of stations. In this latter case, service would be similar to that of a conventional rail system. *

* In this manner it has been claimed that AGRT could be adaptable to share the transit burden in relieving a "fuel crisis, " being able to offer the same line-haul capacity as heavy-rail systems. While existing guideways would be adequate within a given coverage area, stations would have to be enlarged and additional vehicles and attendant facilities acquired.

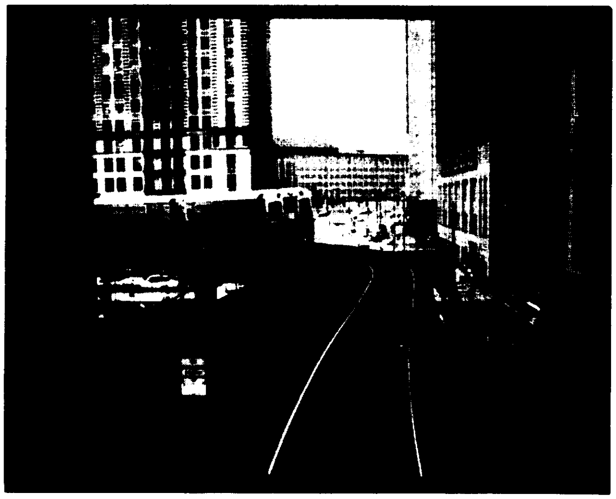

Photo credit OTA staff photo

Wide-elevated guideways create visual blight but easier emergency evacuation

There are other amenities that can be provided to make transit travel comfortable and convenient. Some of these, such as air-conditioning, barrier-free access, seat comfort, sound deadening, and simplified fare collection, are not inherently unique to AGRT. Decisions to implement AGRT rather than other options should not be based on these factors.

UMTA material indicates that AGRT has a capacity of 14,400 persons per lane per hour for its AGRT systems.[1] In practice it is virtually impossible to achieve these capacities with single 12-passenger vehicles operating individually at 3-second headways. Guideways and stations, like highways, are subject to congestion that would severely impair service levels, i.e., time, convenience, comfort, reliability. AGRT vehicles operated in tandem could actually achieve much higher capacities. Detailed computer simulations to show the various tradeoffs of cost, travel time, capacity, and other factors are needed to shed more light on this critical issue.

Unresolved issue:

- the relationship between service levels, passenger trip demands, and other factors.

[1] U. S. Department of Transportation, Urban Mass Transportation Administration, Request for Proposal (RFP) DOT-UT-300 14, High Performance Personal Rapid Transit (HPPRT) System," Feb. 20, 1974.

The Auto User

If provided with sufficient capacity, and if available at all times, AGRT should be a more attractive alternative to the automobile than conventional transit modes.

The major rationale for AGRT is that it will help to reduce auto usage and all the attendant negative impacts the auto has on the urban environment and on national energy policy. In many areas auto disincentives are being proposed to help deter people from driving, particularly when they drive alone, in congested city districts, or during peak periods. However, for these disincentives (such as auto-restricted zones or increased tolls or parking charges) to be effective at instigating a shift to a transit alternative, the transit systems must possess two important attributes:

1. capacity (to handle the influx) and
2. a level of service close to that of the automobile.

For AGRT to truly be an effective alternative to the auto, sufficient capacity must be provided to serve the new riders abandoning their automobiles. In this respect AGRT is no different than any other transit mode. But where AGRT can truly be an advantage over automobile usage is with some of the service attributes discussed above under "Quality of Service. " AGRT would certainly be more attractive than buses in mixed traffic. Because of its ability to provide more stations at a fixed cost than light- and heavy-rail guideway systems and to offer non-stop non-transfer service, AGRT should, in most instances, appear at least as attractive as conventional fixed guideway systems. Another very important factor is that AGRT would be available at all times of day, 7 days a week, a feature absent from most transit systems today. Thus, for those auto users who would wish to travel by transit or who might otherwise be deterred from continuing to drive, AGRT should be more attractive than conventional modes if capacity can be provided to meet demand.

Ridership

The service attributes of AGRT should enable it to attract significantly more riders than ordinary bus service and at least as many riders as other guideway modes. But additional studies are needed to determine consumer reactions and the magnitude of ridership impacts.

The service potential for an AGRT system is similar to an automated shared-ride taxi taking a rider from origin to destination with only a small number of stops. In theory, any system could be operated in this manner. In practice, only a small-vehicle system can efficiently provide point-to-point (or, in this case, station-to-station) service without having either excess capacity or a large number of stops.

On an overall basis when AGRT is compared with transit modes operating in mixed traffic, it will attract higher ridership in the general areas covered because of its superior speed, comfort, and reliability. It will also benefit from allowing most passengers to complete the AGRT portion of their trip without transferring. *

AGRT has no inherent speed advantage over conventional rail systems, but could attract higher ridership due to its better coverage (for a given construction budget) and reduced transfer potential. Not enough is known about how consumers would react toward UMTA's AGRT concept, versus a well-managed modern rail system with guaranteed seating. It is likely that the choice between these two options would be based on local factors in addition to ridership forecasts, although AGRT should prove relatively more cost-effective for lower volume grade-separated installations. As noted in the previous section, AGRT could be spoiled by its own success—with higher volumes congesting the system, lowering service levels, and necessitating additional capital facilities.

Unresolved issues:

- consumer reaction to advanced automated systems versus other grade-separated technology and
- the congestion impacts caused by a large number of people trying to use the system.

*With heavy ridership preliminary analysis has Indicated that it may be more efficaceous to operate AGRT with a series of overlapping fixed routes on fixed frequencies. In this manner some passengers may have to transfer. For on-demand service, it appears that all riders would receive a direct ride

Special User Groups

Because of its potential for providing broad geographic coverage and station-to-station nontransfer service, AGRT can provide significant service improvements for special user groups.

In every urban area there are large numbers of people whose mobility needs require special attention in planning and designing public transportation services. For the poor, the cost and availability of public transportation are critical variables; for the handicapped and elderly, physical accessibility to vehicles and stations is of utmost importance if they are to have a P1ace in the mainstream of American life. Other groups requiring special attention are women and the young.

As a new mode, AGRT vehicles and stations would be designed to be in compliance with accessibility regulations of section 16(b)2 of the Urban Mass Transportation Act of 1964 (as amended)[2] and section 504 of the Rehabilitation Act of 1974.[3] However, any other federally assisted new mode or new facilities (fixed or rolling) must also meet these requirements. The inherent characteristics of AGRT do appear to offer some advantages to these special user groups.

For all user groups, automated guideway systems would be superior to nonautomated transit modes because of their availability at all times of day and night. Because of automation, service levels do not have to be sharply lowered in offpeak hours to save the costs of operators or attendants. The transit-dependent, particularly low-income shift workers, would benefit from this. Women, in particular, would benefit from the absence of long waits at isolated unprotected bus stops after dark. The handicapped and elderly would benefit from shorter waits for service, in contrast to long waits and unreliable service frequently experienced with buses operating on local streets, The absence of transfers on fixed guideway systems (whether automated or not) would also make travel easier. (On an all-bus system many of the handicapped are realistically limited to traveling to destinations ly - ing along only those bus routes passing very close to their residences.)

If AGRT can meet its construction cost goals, then more extensive coverage can be provided than with other fixed guideway systems (for similar construction budgets). If such coverage was provided in suburban areas, inner city workers would have better accessibility to outlying job opportunities than they would have with conventional fixed-rail systems.

There are two potential disadvantages to AGRT. First, if AGRT is provided in place of local bus service there will be fewer access points to the system. Second, satisfactory solutions for emergency evacuation need to be found that meet the requirements for the handicapped and elderly, particularly when suspended or narrow guideway systems are being considered.

Wider doorways to stations and vehicles as well as escalators and/or elevators for level changes would be an asset for all transit riders. But most particularly they would benefit the handicapped and elderly in comparison to what conventional alternatives provide. However, there is little reason to believe that the same accommodations cannot be provided on conventional systems. Thus, decisions to proceed with AGRT development to aid special user groups should consider the aspects of geographic coverage and transfers.

‘Urban Mass Transportation Act of 1964, Public Law 88-365, 78 Stat. 302, U.S. C. vol. 49, sec. 1601 et seq. (as amended), sec. 16(b) 2.

‘Rehabilitation Act of 1974.

Safety and Security

Automation enhances the safety (collision avoidance) of guideway transit systems.

Passenger security is perceived as a problem when the ride must be shared with strangers, particularly on small vehicles with infrequent stops.

Methods to provide security in unattended vehicles and user response to such methods, remain as unresolved issues.

Wide= guideway bottom-supported systems offer the most satisfactory opportunities for emergency evacuation procedures. Narrow guideway systerns are potentially less costly, less obtrusive, and less subject to winter weather operating problems; but no satisfactory emergency evacuation strategy has been developed for them.

Automation can enhance safety by eliminating accidents due to human error and equipment failure. Those AGT systems already in operation have exhibited superior safety performance since they first began operation in 1971. ~

Security issues arise from uncertainties regarding public acceptance of unattended stations and vehicles. Unattended platforms are common in many transit systems and all bus stops are, in fact unattended stations. The more limited number of waiting points in AGRT would appear easier to monitor and control. (Similarly, a heavy-rail system with yet fewer stations might offer a further advantage.) Research has shown that crime rates at transit stations parallel those of adjacent neighborhoods. [s] Design guidelines are being prepared which stress adequate lighting and unobstructed visibility. Such treatment should reduce station security problems for AGRT and other systems to a minimum.

Photo credit L TVAC PR&A

Automated systems have proven safe in nonurban settings

[4]The MITRE Corporation, *Urban Applications of Advanced Group RapidTransit A) l Alternatives Analysis* Study, September **1978, p. 140.**

'Ib]d., p. 144.

There is little experience from which to assess security in unattended vehicles. Currently deployed systems in Morgantown, W. Va.; in the Dallas-Fort Worth Airport; and in numerous other airports, theme parks, and zoos have had few problems; but none of these systems operate in a typical urban environment.

Fire presents a very difficult problem for all transit modes. Vehicles are vulnerable to fire in the passenger compartments, in undervehicle equipment, and on nearby property. In-vehicle fires can be controlled with a more judicious choice of materials, a solution available to all modes. However, should fire occur on or under a vehicle, the location of the vehicle will be crucial. Vehicles on the surface have the best chance of being evacuated; passengers can walk away from fires in tunnels if they are not overcome by smoke. Vehicles supported on wide guideway elevated structures can utilize the built-in walkways; however, no generally acceptable solutions are yet available for narrow guideways and suspended vehicles. Conventionally powered AGRT, with a proliferation of traction and control units, has a greater probability of failure and delay than larger vehicle systems. On existing elevated systems it is also common practice to close sections of guideway when fire occurs on adjacent property. Most of the concerns over fire also apply to the need for emergency evacuation of accident victims.

Unresolved issues:

- methods to provide security in unattended vehicles (and user response to such systems) and
- emergency evacuation procedures.

Urban Development

Fixed guideway systems that provide not only line=haul service but also circulation and distribution within activity centers may enhance urban development potentials of the area served.

Urban development tends to occur in areas having high accessibility. Transit systems enhance accessibility in station areas and thus support development and redevelopment when carried out in conjunction with other positive development policies such as zoning changes and economic incentives.

AGRT systems, by providing many small stations rather than a few large stations, should encourage medium-density development at many nodes, as opposed to higher densities at a few concentrated points. By combining line-haul and distribution service, AGRT systems should be able to effectively serve dispersed activity centers designed for automobile access. This latter attribute suggests that AGRT systems may prove more effective than existing transit modes in enabling central-city residents to obtain access to jobs in lower density suburban locations.

Many existing Federal programs influence urban development patterns: housing, highways, water supply, waste treatment, and economic development to name a few. The AGRT program goals should be made consistent with a common set of Federal policy goals.

Unresolved issues:

- the effects of AGRT systems on land use development patterns and
- the relationship of AGRT and its potential urban applications to the programs and policies of the Department of Housing and Urban Development, the Environmental Protection Agency, and other relevant agencies.

Energy and Environment

To the degree that the service characteristics of AGRT systems attract travelers to use transit rather than the private low-occupancy auto, electrically powered systems should make a positive contribution to petroleum con= servation and maintenance of environmental quality.

For highly concentrated large travel demands, large-vehicle systems will be more energy-efficient. For periods of low demand, small vehicles operated as needed, without the requirement to provide scheduled service, will permit energy savings by tailoring supply to demand. Selection of an optimum vehicle size would have to follow an analysis of local 24-hour service needs.

Noise impacts of guideway systems will depend partially on the technology utilized. Rubber-tired vehicles would probably be similar to vans or panel trucks in noise impact. Air cushion systems, as in the proposed Otis vehicle, appear to be fairly quiet. Magnetic levitation and linear motor technology with no moving parts for propulsion or suspension should be very quiet.

The visual impacts of elevated guideways are a very localized and subjective matter. In the city of Miami, for example, both the rapid rail and downtown people mover (DPM) systems will be elevated. This form is apparently acceptable to the public in both residential areas and scenic areas such as Biscayne Boulevard. Miami Beach, however, rejected the area's elevated rapid rail alternative because of the elevated profile. In Denver the elevated guideway issue was also polarizing. From the rider's point of view, elevated travel may be more pleasing than at-grade or underground service.

Electrically powered transit systems can help reduce air pollution to the extent that persons can be attracted out of private autos. However, the overall effect of any benefits will depend on the environmental characteristics of the power source.

Snow and ice present particularly perplexing problems for transit. Elevated guideway systems could cause an environmental nuisance if snow and ice fall or drip on passers-by. Removing them can entail great costs in energy and manpower, if a complete shutdown is not forced altogether. During the harsh winter of 1976-77, more money was spent on the Morgantown system for natural gas to heat the guideway than for electricity during the full 12-month period. '

'N. D. Lea & Associates, Inc., *Summary of Capital and Operations and Maintenance Cost Experience of Automated Guideway Transit Systems*, June 1978, pp. 17-18.

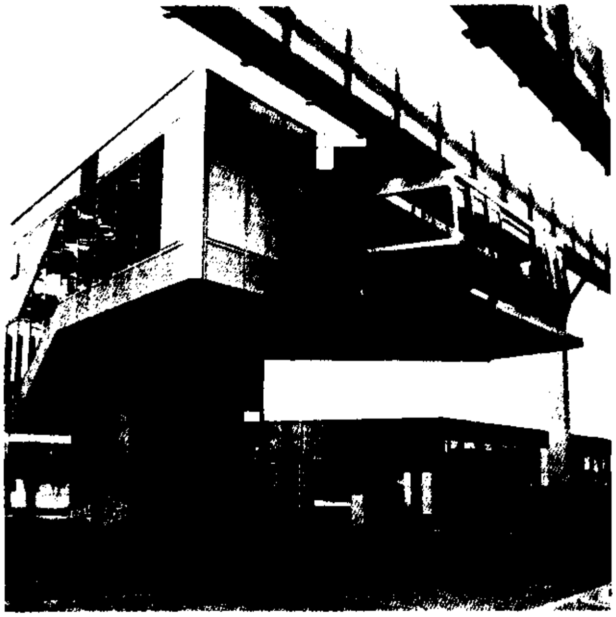

Photo credit Siemens

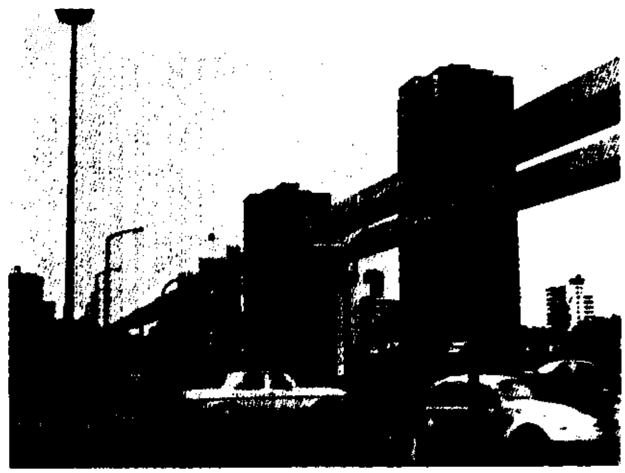

Photo credit DEMAG Fördertechnik

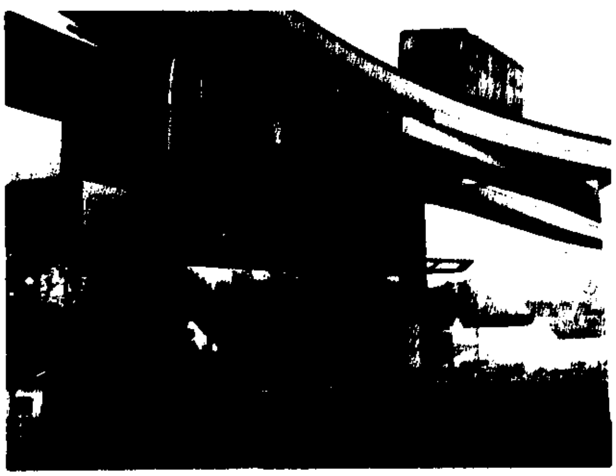

Photo credit Siemens

Suspended vehicles are less bothered by ice and snow. Narrow guideways are less obtrusive, but emergency evacuation is a problem

An I-beam (monorail) .design would accumulate less snow than some proposed U-shaped designs that actually trap it. (The latter probably would permit less dripping.) Keeping the power rails free from ice, snow, and frost is also an important consideration in assuring service dependability.

Unresolved issues:

- esthetics of elevated guideways,
- an energy-efficient solution to maintaining operations during ice and snow conditions, and
- optimum vehicle size and speed for energy efficiency.

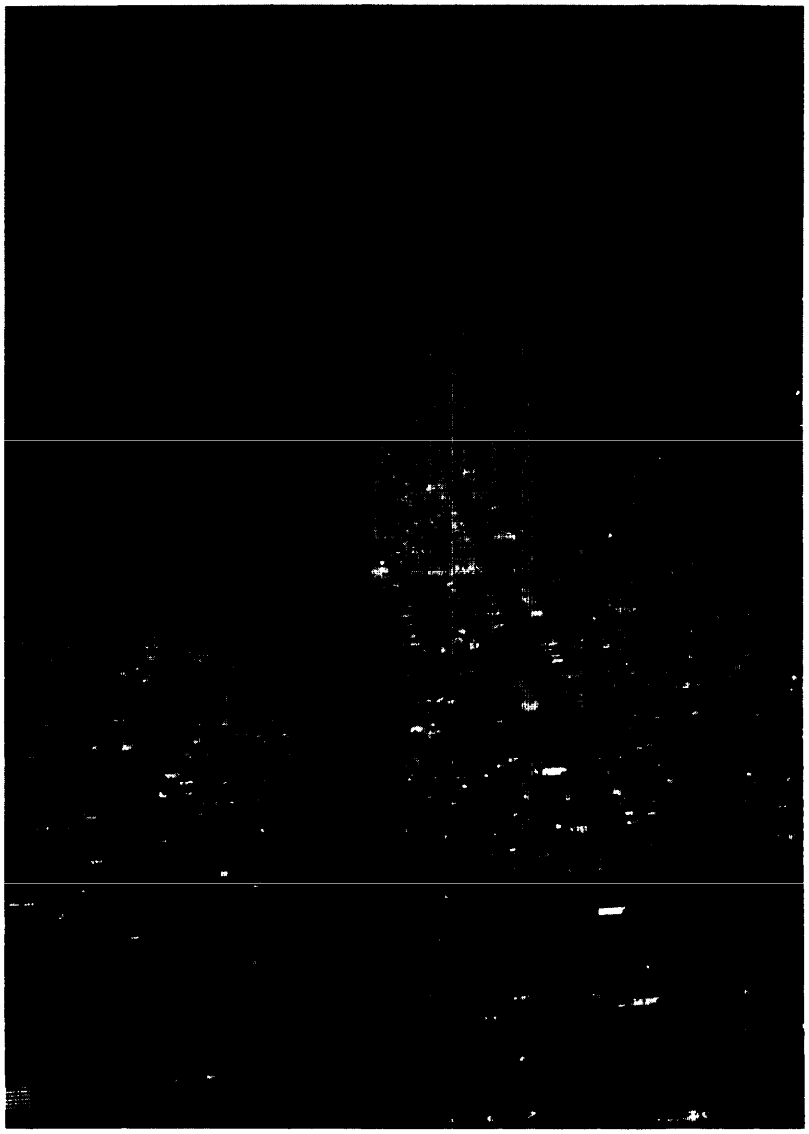

Photo credit: OTA staff photo

Electric-powered transit can help reduce air pollution

Economics

Advanced AGT systems offer the potential to reduce the cost of public transit. However, wide variations in estimates of capital and operating costs, for both automated guideway and existing systems, do not permit definitive cost comparisons to be made at this time.

Local site conditions and preferences may be more important factors in system selection than the inherent economic characteristics of AGRT.

Although claims have been made that AGRT can reduce the costs of urban transit operation, the data are not available to substantiate these generalized claims. As recommended in OTA's 1975 report on AGT, UMTA undertook a program of socioeconomic research in conjunction with the new systems development program. Two studies on this topic have been completed, and two more are underway.

- The MITRE Corporation, *Urban Application* of *Advanced Group Rapid Transit: An Alternative Analysis Study,* September 1978.
- N. D. Lea & Associates, Inc., *Summary* of *Capital and Operations and Maintenance Cost Experience* of *Automated Guideway Transit Systems,* June 1978.
- Cambridge Systematic, Inc., "AGT Markets Study" (in progress).
- Barton-Aschman Associates, Inc., "Generic Alternatives Study" (in progress).

The MITRE study indicated that AGRT could improve transit ridership but the findings on system economics cannot be generalized. The N. D. Lea study summarized the cost experience of 10 existing systems, mostly in airports and theme parks. Generally, these systems are very limited in mileage and the results of their operating experience are not directly applicable to AGRT. Cambridge Systematic and Barton-Aschman are doing further research on AGT markets with added emphasis on the "image" of these systems. The first study is investigating AGT in general; the second is comparing AGRT with 28 other modes or modal combinations.

One of the major decisions in urban transit is whether or not to invest in the high costs of exclusive rights-of-way and grade separations for transit vehicles, be they bus, light rail, heavy rail, or AGT. Such guideways free transit from the constraints and problems of mixed traffic operations and provide significantly better levels of service. However, it is not clear that certain operating economies made possible by an exclusive right-of-way will lower operating costs sufficiently to recover fully the investment in guideway and stations.

When AGRT is compared to conventional transportation modes on a lifecycle-cost' basis there is too much variability and uncertainty in the available data to come to any generalized findings. There are many tradeoffs involved and wide ranges of parameter values within any given mode. When the AGRT technology is available for urban deployments, local site conditions and preferences may be more important factors in system selection than the inherent economic characteristics of AGRT.

Because UMTA's program has centered on a discrete set of AGRT specifications, data are not available on other size vehicles or other system configurations. It may be desirable to conduct system optimization studies to determine the attributes of a broad range of AGT configurations for different applications before prototype systems are designed.

A critical element of AGT costs is the design of the guideway. Narrow deep cross-sections are most efficient from a structural point of view and may also be less obtrusive. Suspended systems, such as Romag, are usually of such a design, but supported systems can also be designed as efficiently. U-shaped cross-sections are

'U. S Congress, Office of Technology Assessment *Automated Guideway Transit* OTA-T-8 (Washington, D. C.: U.S. Government Printing Office, February 1975).

*Lifecycle costs include operating and maintenance costs together with the cost of capital structures and equipment over the life of the facility.

much less efficient and in addition collect more snow and ice in adverse weather environments.

Unresolved issues:

- the attainability of operating and maintenance cost goals,
- the uncertainty of capital costs for various configurations and the extent to which these may be reduced by improved guideway design, and
- optimum vehicle and operating procedures for various applications.

Employment and Productivity

The data are not available to determine the extent to which AGRT might be more labor-productive than other transit modes. UMTA should investigate the potential reduction of jobs for unskilled persons brought about by sub= stituting automated systems for manually operated systems.

Several questions have arisen concerning the size and mix of labor skills required to operate and maintain AGT systems:

1. Will deployment of automated systems significantly increase or decrease the total size of the transit labor force?
2. What skill mix of workers will be required?
3. Over what time frame would any changes occur?

There are no clear-cut answers to these questions.

Impact of AGRT on size of labor force

Automated guideway vehicles will operate without attendants and it is presumed stations would be unattended. However, automated guideway systems have a long list of labor categories to fill: mechanics, machinists, electricians, cleaners, maintainers for all major systems (guideway, power distribution, substations), technicians (for fare-collection machinery, elevators, escalators, and communications equipment), and police, as well as engineers, planners, and administrative personnel. In its study of 10 existing systems N. D. Lea stated, "... labor is generally the largest single (operations and maintenance) cost component ... "~

If an advanced automated guideway system were compared with a modern rail system with the same size vehicles, requirements for maintenance personnel would appear to be similar. Although the automated system might require additional programmers and control room personnel, the large savings in vehicle operators (and stations) should yield it a large labor advantage. However, if the automated vehicle is small and a large number of vehicles are necessary (as with the proposed AGRT vehicle) maintenance requirements could be considerably larger than for a conventional system. When an automated system is compared with a bus system of comparable size, the labor tradeoff is in the number of bus operators versus the number of persons required to maintain vehicles and guideways. OTA has found no definitive studies on this issue and finds that further study is necessary.

Labor skill mix

Many of the jobs in a bus operation are regarded as "unskilled' '-drivers, cleaners, and many of the shop functions. Were an automated system to replace all or a portion of a bus fleet, it is possible that many of these unskilled jobs would disappear. While a few more highly trained technicians would be required for vehicle and system maintenance, the required skill mix for new systems is not well-understood.

Timing of labor impacts

UMTA's scenario for automated guideway systems envisions small deployments in a few cities beginning with the DPM demonstrations. "Advanced" technologies would then be implemented starting in the late-1980's. If current capital funding policies are followed, these advanced systems would be implemented in "oper-

*N. D. Lea & Associates, Inc., *Summary of Capital and Operations and Maintenance Cost Experience of Automated Guideway Transit Systems*, June 1978, p. 16.

able segments."[9] Under such circumstances it is unlikely that any single urban area could have a substantial automated guideway network in operation before the mid-1990's. At that time societal attitudes toward the substitution of automation may have changed. In any case the rate of implementation would be gradual and existing Federal law would ensure that no existing employees were displaced.[10] Provisions of existing labor agreements also need review and revision where necessary to be consonant with the nature of AGRT operations.

[9] U.S. Department of Transportation, Urban Mass Transportation Administration, "Major Urban Mass Transportation Investments: Statement of Policy," *Federal Register* 41 (Sept. 22, 1976).
[10] *Urban Mass Transportation Act of 1964*, sec. 13(c).41513.

Although it has been argued that AGRT would be more labor-productive than other transit modes, supporting data are not available. However, labor relations and the potential reduction of unskilled labor positions are important social issues deserving serious consideration by UMTA.

Unresolved issues:

- the size and nature of the labor force required for advanced AGT systems,
- the impact of existing labor agreements on the deployment of regional automated systems, and
- social impacts from the potential reduction in transit jobs for unskilled persons.

Summary

AGRT possesses several inherent advantages which give it great potential as an urban transit mode:

- a less costly guideway that allows coverage to be increased (beyond that of conventional designs) for each dollar invested,
- a guaranteed seat,
- station-to-station service without the necessit y to transfer, and
- a high level of service at all times of day.

These characteristics can be provided on any mode. However, i t is the technological advances of AGRT that make them more economically feasible. In addition, the lighter less-obtrusive guideway should make AGRT more esthetically acceptable to the community.

Although AGRT appears to be a strong candidate in local alternatives analysis, its suitability will largely be determined by local site-specific conditions. The purpose of UMTA's AGRT program is not to develop a universally best-suited mode, but to make available to cities a new set of options, which, with adequate funding, will be preferred in many applications.

The most serious deficiency of AGRT planning is a satisfactory procedure for evacuating passengers in a hurry. The best approach is to design in such a way as to minimize the number of instances in which evacuation is required. Failure to resolve this issue will severely limit the range of opportunities for AGRT deployment. Two other areas need more serious considerations by UMTA: labor issues and the system optimization studies.

Chapter VI

GOVERNMENT/INDUSTRY RELATIONSHIPS IN ADVANCED GROUP RAPID TRANSIT TECHNOLOGY DEVELOPMENT

[illegible]

Results of these investigations show:

- that there are substantial national differences in R&D policies,
- that Government should become involved in only those specific technologies which support national policy objectives,
- that there are major policy options between promoting R&D or supporting Government procurement of innovative technologies, and
- that technology development and technology demonstration ought not to be confused when moving innovation through the difficult transitions from concept to deployment.

They further indicate a growing concern in the United States and several other mature industrialized societies that industrial productivity is declining or stagnating and that incentives for stimulating innovations which might reverse this trend are either lacking or not working properly. Much of the emphasis in some countries, most notably Japan, has been on innovation that would make those nation's industrial base more competitive in international markets.

[1] U.S. Congress, Office of Technology Assessment, *Government Involvement in the Innovation Process* OTA-R-73 (Washington, D.C.: U.S. Government Printing Office, August 1978).

[2] U.S. Congress, Office of Technology Assessment, *The Role of Demonstrations in Federal R&D Policy* OTA-R-70 (Washington, D.C.: U.S. Government Printing Office, July 1978).

[3] U. S. Department of Commerce, "Domestic Policy Review of Industrial Innovation," Work Plan, Sept. 18, 1978, Washington, D.C.

[4] Advisory Subcommittee on Economic and Trade Policy of the Advisory Committee on Industrial Innovation, "Draft Report on Economic and Trade Policy, Dec 20, 1978, Washington, D.C. – An advisory committee convened by and reporting to the Secretary of Commerce.

[5] Advisory Subcommittee on Procurement and Direct Support of Research and Development of the Advisory Committee on Industrial Innovation, "Draft Report on Federal Procurement Policy," Dec. **22, 1978,** Washington, D.C. —An advisory committee convened by and reporting to the Secretary of Commerce.

[6] Organization for Economic Cooperation and Development, *Policies for the Stimulation of Industrial Innovation*, Volume 1—Analytical Report; Volume 11- 1—Country Reports Canada-France-West Germany -Italy-Japan-United States-United Kingdom; Volume 11-2—Country Reports Australia-Austria-Denmark-Finland-Ireland-Netherlands-Norway-Spain-Sweden, Paris, 1978. Available in English or French versions.

Photo credit Japan Ministry of International Trade and Industry

Japan develops advanced transportation technologies to penetrate international markets

Among the reasons that the question of Government/ industry relations is important is the near demise of the U.S. transit vehicle industry* at a time when "Buy America" is a stated policy of the Urban Mass Transportation Administration (UMTA) and other Federal agencies. As of this writing there are no American-owned manufacturers of light- and heavy-rail passenger cars and only two reluctant domestic manufacturers of full-size transit buses. The factors that influenced this decline need to be identified to ensure that advanced group rapid transit (AGRT) does not suffer a similar fate. The disintegration of U.S. industrial capability in the transit industry has coincided with an era of substantially increased Federal involvement in the planning, funding, and management of transit. Shifting Government procurement policies, with unrealistic design standards and leadtime, have accounted in part for the demise of the transit supplier industry. Future policies on development of AGRT and other advanced technologies in urban transit should be looked at with these industry impacts in mind.

● At least that segment of the industry willing to market vehicles which meet the criteria for Federal assistance.

Each of the remaining three sections of this chapter considers an important justification for Government involvement in developing public transit technologies. The three justifications are:

- to reduce barriers to innovation caused by unique problems of developing technologies for public sector clients,
- to deal with issues of foreign competition and trade, and
- to support other long-range national policy objectives.

Barriers to Innovation

The complex institutional and regulatory process surrounding the procurement of urban transit systems inhibits private suppliers from developing the innovative technologies necessary to meet today's transit needs.

The complexity of the public institutional arrangements and decisionmaking processes that influence deployment of new technologies in urban settings is perhaps the biggest barrier to innovation which the private sector faces in developing new technologies. Since established systems, procedures, and expectations are difficult to change, incremental improvements are often preferred to significant departures from tradition. System suppliers are reluctant to develop unique innovative systems when competition is required for governmental procurement. And problem-solving technologies aimed at a future, rather than a current problem, often find no potential client agency present at all to deal with the long-range future.

For these reasons private sector firms often fail to show interest in developing products for such difficult and uncertain markets. One major response that Government could take would be to guarantee a market for innovative products, rather than to provide R&D grants to get the technology developed. Market guarantees are considered further in chapter VIII.

Another barrier to innovation comes from a reluctance on the part of major corporations to become involved in potentially risky ventures. Unsuccessful attempts to meet rigid performance and reliability requirements serve to discredit the supplier more often than those responsible for creating unrealistic specifications. The high visibility of transit systems contributes to an atmosphere of confrontation between suppliers and their public clients, making resolution of problems more difficult than in private sector commercial transactions.

The lack of markets for publicly supported new technology also limits involvement. Boeing was awarded the Morgan town contract in 1970, but has yet to garner another automated guideway deployment contract. Otis, the other AGRT contractor, still has only its single deployment at Duke University, a nonpublic client. Boeing-Vertol, with UMTA assistance, designed and built the standard light-rail vehicle, a technology which will probably not see service beyond Boston and San Francisco. Three domestic bus manufacturers (General Motors, AM General, and Grumman Flexible) have also claimed that the brief run of recently developed full-size transit buses will not allow them to recoup their investment in design and tooling. All declined to submit bids for the first attempt at a transbus procurement on May 2, 1979.

While local governments supposedly have control over technology selection through the alternatives analysis process, automated guideway systems are rarely given serious consideration. Federal regulations for capital grants restrict system considerations to "operable segments"[7] whereas the strongest market for AGRT appears to be in regional or multicorridor deployments.

If the institutional structure itself is not enough to constrain the enthusiasm of system suppliers, then the lack of enthusiasm on the part of system purchasers may be the telling blow. Transit operators, conservative by nature, and a cautious public are reluctant to take a chance on unproven systems given the adverse publicity generated by recent Federal demonstrations and deployments of new technologies. In several cities visited by the OTA staff for this assessment, the main operator reaction was a desire for additional buses to relieve current overcrowded conditions. Pressed with such immediate problems, they show little interest in solutions that will not be available for another 10 years.

Government involvement is no guarantee of success in developing new technologies. Aside from the controversy surrounding several new U.S. technologies, two important foreign ventures were also unsuccessful. The transurban technology of Kraus-Maffei sponsored by the Province of Ontario was abandoned after severe technical problems developed. Japan's CVS system, although successfully demonstrated on an extensive test track, has not yet been deployed. Moving a complex public technology from laboratory to deployment is a difficult process with the potential for great financial risk and political embarrassment.

[7]U.S. Department of Transportation, Urban Mass Transportation Administration, "Major Urban Mass Transportation Investments: Statement of Policy," *Federal Register*, vol. 41, No. 185, Sept. 22, 1976, p. 41513.

Foreign Competition and Trade

The potential of broad international leadership in the transit technology field is not a credible prospect for U.S. industry. However, the possibility of component or system leadership in automated guideway transit remains if pursued more deliberately than in the past.

While the United States is carrying out its own programs of advancing transit technology through development of downtown people mover (DPM) and AGRT system development, foreign industries are making progress on systems that may enter the international market perhaps well ahead of U.S. technology. A more immediate concern to those interested in questions of technological leadership and trade balances, however, is the near demise of U.S. productive capacity in more traditional transit technology. Both in the areas of light- and heavy-rail car production, U.S. firms have left the field after losing out to foreign suppliers on the limited procurement activities in this country. The potential of broad international leadership in the transit technology field is not a credible prospect for U.S. industry given both the makeup of the existing supply industry and the geographic dispersion of the transit system replacement demand concentrated in European countries. However, the possibilities of component, product, or system leadership may remain in certain niches of the transit spectrum if they are aggressively pursued in a more systematic manner. Whether or not the rewards of such a restricted development strategy are worth the costs is a major question, however, given both the softness of the U.S. market for such advanced technologies and the foreign competition under development.

The status of various forms of group rapid transit and personal rapid transit abroad as of 1975 was well-documented in the previous OTA assessment, *Automated Guideway Transit,*[8] The programs which are proceeding abroad that seem to have relevance to the AGRT program here in the United States are the Cabintaxi and H-Bahn systems in West Germany, two Japanese systems under development in the Kobe and Osaka port districts, and the French Aramis system. The Cabintaxi system which has had test track demonstrations in Hagen, West Germany is now being deployed in an outlying suburban portion of Hamburg. The system, under the sponsorship of the industrial consortium of Messerschmidt-Bolkow-Blohm and DEMAG and the Federal Ministry of Science and Technology, has performance characteristics very close to the specifications UMTA has set for AGRT. The initial development costs are shared 80 percent by the West German Federal Government and 20 percent by industry, although the system originated as an industrial initiative. As it enters the demonstration stage, local government and the Federal transportation ministry will begin cost-sharing with the system developer.

Japanese systems under development are perhaps more modest technologically than the West German system, but they are proceeding with considerable active support by local governments in Kobe and Osaka.

In France, the Aramis system, under development by Engins MATRA, has gone through several test track demonstrations near Paris, but has not emerged to a point of major development. The VAL shuttle-loop system is being installed in Line. Studies involving the RATP, or Paris Metro Authority, have been done for suburban installations linking the regional transportation system, but no final decision on a deployment has been made.

A summary of prospective foreign competition indicates an interesting contrast. Technologically, foreign developers appear to be on a par with accomplishments in the United States. A limited number of systems have been deployed in the benign operating environments of amusement and activity centers, and more advanced technologies have been investigated on test tracks. However, only the West German Cabintaxi system appears technologically advanced over anything tested to date in this country. On the other hand, only the U.S. systems have operating experience akin to what might be encountered in real urban settings. The Morgantown and Airtrans systems are the two most complex and extensive systems in daily operation anywhere in the world today. Foreign competitors, therefore, would appear to trail in that important step of technology and service demonstration. However, if the Hamburg Cabintaxi demonstration succeeds, technological leadership could shift overseas.

[8] U.S. Congress, Office of Technology Assessment, *Automated Guideway Transit*, OTA-T-8 (Washington, D. C.: U.S. Government Printing Office, February 1975).

Long-Range Objectives—An Intermediate Recipient

To overcome the absence of interest in long-range solutions by public agencies, an intermediate recipient for technological innovation could be created similar to those developed in West Germany and Japan to stimulate industry over the long term.

AGRT technology and even more advanced performance system concepts might continue to be funded and programed by UMTA or they might find a better institutional home elsewhere in Government. *One* of the critical issues raised in the OTA report on Government involvement in the innovation process[9] is whether or not Congress should provide direct support for non-mission-oriented technology. Mission-oriented technology is that directly relevant to the mission of the agency conducting the research or technological development. It appears that UMTA's involvement with AGRT might be a direct mission-oriented portion of its urban transit role. But the foreign experiences leading to development of advanced forms of transit technology have almost all been examples of non-mission-oriented agencies taking the lead.

In Japan, the Ministry of International Trade and Industry took the lead in encouraging the development of CVS, not for the express purpose of improving urban transit, but instead for the promotion of numerous facets of Japan's steel, electronics, computer, and other industries seeking new product developments and new markets. The Ministries of Transportation and of Construction did not take an active role in this now dormant program. In West Germany, the lead in supporting the development and demonstration of the Cabintaxi system is again in the Federal Ministry of Research and Technology and not the Ministry of Transportation. Similar cases exist in the United Kingdom, France, and Canada where the initial efforts aimed at creating a small-vehicle automated transit system were championed by special non-mission agencies interested in technological innovation for industry's sake and incidentally for transportation mission outputs.

In the United States no such agency exists with the exception of the Federal laboratories and the National Science Foundation. However, as stated in a recent OTA report, the concept may be advantageous:

> This policy [of having only mission-oriented technology] differs markedly from the practices and procedures of other technologically advanced nations, notably Japan, in which the Governments support technological innovation with no other goal than the general economic one of helping particular sectors of industry to grow and to compete in international markets.
>
> Increased attention has recently been focused within the Government on ways in which, in cooperation with the private sector, it might seek to stimulate and encourage technological innovation through programs of direct support of some kind. There are three basic reasons for the heightened interest in such programs. First, the United States is facing increasingly stiff competition in technology-based products from other nations that have programs for the domestic support of technological innovation for purely economic purposes.
>
> In addition, the social returns on technological innovation are often greater than any reasonable expected private return, due to the inappropriability of some of the benefits, which make a Federal sponsorship role appropriate. Lastly, there are purely social reasons for supporting innovation. An example of these is the general desirability of creating employment. [10]

Other such R&D programs exist, albeit with different missions and host mission-oriented agencies. They may face the same troubles of timing, lack of constituencies, and risk-sharing that AGRT does. Perhaps out of the Presidential initiatives on industrial innovation or out of the congressional oversight and review of them, some multiagency approach to improved Government/industry relations could be developed that would benefit the long-range prospects for AGRT and other urban or institutionally complex public technologies.

[9] *Government Involvement in the Innovation Process*, op. cit., p. 52.

[10] Ibid.

Summary

AGRT technology should be viewed in the context of broad national policy with regard to Government/industry relations and to the demonstration of public technologies in real-world settings. Much experience has been accumulated in recent years on both of these subjects, experience that is highly relevant to the questions of timing, cost, and fundamental approach to the development, demonstration, and ultimate deployment of technologically advanced forms of public transit.

Significant barriers inhibit transit innovation in American cities:

- the complexity of the local transit decision-making process;
- insufficient markets, which are too limited for the competition;
- Government-subsidized foreign competition;
- risks of technological failure and poor system management;
- risk of adverse publicity, cost overrun, and political embarrassment;
- the cautious approach to innovation of local operators and decisionmakers;
- the overriding concern at the local level for solving immediate problems versus long-run planning;
- adverse procurement regulations that discourage innovation; and
- frequent changes in Federal regulations that may not give suppliers large enough production runs to justify their investment in design and tooling.

The examination of foreign competition in automated guideway technology reveals that practical operating experience rather than technological issues should maintain a domestic preference for American systems over the next few years. However, this may change as claims for the West German Cabintaxi become verified in actual operations.

Rather than have UMTA justify to its constituency of transit operators, urban mayors, and current users the long-range benefits of developing AGRT or of the related technologies, it may be more advantageous for an agency such as the National Science Foundation, or other high-technology agency, to make the arguments for financial support and bear the responsibility for failure or success. A second option would be to decentralize responsibility for transit R&D. These and other options deserve further study.

Chapter VII

MARKET SCENARIOS–INNOVATION IN THE PUBLIC SECTOR

Realistic market development [illegible] group rapid transit (AGRT) suggest a cautious approach [illegible] with careful attention to the development of techn[illegible] incremental deployments of proven systems.

AGRT Implementation Scenarios

Introduction of a public technology into the real world is a complex and poorly understood process. Innovative urban transit technologies such as AGRT share much in common with that class of technologies found most likely to fail in OTA's recent study of Federal demonstrations. These failures result from: 1) technology that is not operationally reliable and 2) the complexity of the urban institutional environment.[2] These factors should be thoroughly evaluated before a decision is made to deploy AGRT systems.

Chapter V contains an assessment of how well AGRT might function in daily urban transit service. But it is also necessary to sketch out implementation scenarios that trace the path of the technology from development through prototypes to demonstration, deployment, and consumer acceptance. Major transit investments such as the downtown people mover (DPM) proposals or possible AGRT installations are regarded as demonstrations by the Urban Mass Transportation Administration (UMTA), but are expected by local authorities to be proven systems capable of reliable daily operation. Thus, all automated guideway transit (AGT) deployments over the next few years will be subject to intense international scrutiny of their reliability, cost, and service characteristics. In this country the institutional complexity of the transit implementation process will ensure that these paths are not trouble-free.

While large-sized cities already committed to light- or heavy-rail systems might be in a position to accept new automated guideway technologies only in limited applications as distributor systems, more modest-sized communities without existing rail systems might prefer modest scale applications that could be expanded incrementally into corridor or regional systems. This is quite likely to be the reaction of transit operators, elected officials, and the community-at-large, as well as being pragmatic for capital spending purposes. This incremental approach of applying proven technology in measured doses is suggested by recent literature on demonstration programs.[3]

[1] Catherine Burke, *Innovation in Public Policy The Case of Personal Rapid Transit* (Lexington, Mass. : D. C. Heath & Co., 1979).

[2] U S Congress, Office of Technology Assessment, *The Role of Demonstrations in Federal R& D Policy*, OTA-R-70 (Washington, D C. U S Government Printing Office, July 1978), pp. 31-41.

[3] Ibid., p. 48.

Downtown People Mover Deployments

OTA's 1975 report on AGT systems recommended that UMTA undertake an urban demonstration of shuttle-loop transit (SLT) technology.[1] UMTA chose central business districts as the application site for these demonstrations, and opened up the eligibility criteria to include any proven AGT technology, be it SLT, group rapid transit, or personal rapid transit. * In fact,

[1] U S. Congress, Office of Technology Assessment, *Automated Guideway Transit* OTA-T-8 (Washington, D. C,: U. S, Government Printing Office, February 1975), p. 7.

*Descriptions and definitions of these technologies can be found in ch. I.

UMTA has called for the first three deployments to use different technologies. To direct primary focus on the social and economic impacts, UMTA decided that technological risk should be minimized.

While UMTA regards these ventures as demonstrations, the cities themselves are treating them as deployments. Because the impacts are real and long-lasting, the local decisionmaking process reflects the concerns of the various interest groups. Thus, the implementation process as well as the actual system operations are worth observing and monitoring to guide the AGRT development and implementation program. As several of the R&D options discussed in the next chapter indicate, AGRT technology development could continue during this process, but with a goal toward subsystems development rather than toward the completion of production prototypes.

Summary

The scenario for implementation of advanced AGT technologies is one of gradual technical improvement and deployment of systems in short operable segments. The DPM program and the foreign deployments will provide valuable information that will be useful in guiding further automated guideway technology development.

Chapter VIII

OPTIONS FOR AUTOMATED GUIDEWAY TRANSIT RESEARCH AND DEVELOPMENT

Innovation in automated guideway [illegible] (AGT) development can be stimulated by the Federal Government [illegible] the supply or the demand sides of the market. Stimulation of the [illegible] current time is premature due to the state of [illegible] development.

Four alternative supply-side [illegible] to the development of production-ready advanced AGT system[illegible] in this chapter. They tradeoff the advantages of a [illegible] allows for the market testing of less sophisticated technical [illegible] the potential benefits of proceeding more directly to [illegible] prototype development.

Introduction

The Federal Government can bring about advances in AGT technology by supporting efforts to improve existing technologies or by guaranteeing eventual procurements to motivate technical discoveries.

The approach of market guarantees raises a range of issues touched on in several of the reports cited in chapter VI. In particular, OTA's report on industrial innovation stated:

> Most Federal programs intended to affect technological innovation have historically been concerned with the supply of new technologies. Accordingly, they have attempted to increase this supply by, for example, reducing the cost of development, undertaking research in publicly supported laboratories, increasing the rewards of innovation, etc. This policy emphasis has resulted in part from a widely held, but overly simple, view of the innovation process which sees R&D as the overridingly important aspect. In contrast, recent research emphasizes the complex interconnectedness of various stages in the innovation process and recognizes that market demands are often a more important motivator of innovation than technical discoveries.
>
> Evidence suggests that policies which work through influences on demand may often be more effective than those which concentrate on increasing supply. One way of influencing demand is by Government procurement. Evidence presented earlier in the report shows that an assured Government market for new products can be an effective stimulus co innovation. This conclusion is strongly supported by the foreign experience.

The downtown people mover (DPM) program sought to provide that assured market, but the apparent withdrawal of Cleveland, St.

Photo credit Of Is Elevator

Downtown People Movers being planned in several U.S. cities

[1] U.S. Congress, Office of Technology Assessment, *Government Involvement in the Innovation Process*, OTA-R-73 (Washington, D.C.: U.S. Government Printing Office, August 1978), p. 66.

Paul, and Houston from the program demonstrates how difficult it is to guarantee a market. Even when the Urban Mass Transportation Administration (UMTA) offers to pay 80 percent of the capital cost there is no assurance that cities will cooperate, if they conclude the risks outweigh the benefits. The cities must be convinced that new technologies will help solve significant transportation problems at reasonable cost. There is growing doubt at the local level that federally sponsored transit R&D will provide workable solutions at an affordable cost.

Program Options for Advanced Technology Development

This section describes four specific supply side options that would lead to the availability of advanced automated guideway technologies in the late 1980's. The first two options would focus on laboratory improvements. The latter two would proceed to test track settings for validation of the existing advanced group rapid transit (AGRT) technology as an integrated system.

Option 1: Emphasize the Upgrading of Existing Technologies

The first objective of this option is to upgrade existing AGT technologies to the point where they will be able to provide viable urban transit service. None of the existing AGT systems have been subjected to the rigors and high expectations of the urban travel market. They are operating in much more benign environments—amusement parks, shopping centers, and airports. To become more viable options for urban development, they need improvements in reliability, durability, speed, capacity, security, and cold weather availability. The lack of a stable market for urban automated guideway technology precludes existing suppliers from upgrading their own technologies for such a market. At the present time UMTA is supporting a limited amount of such development with four system suppliers.

The second objective of this option would be to put improved systems into service as early as possible. For example, these technologies, as improved, could be used in the DPM demonstrations, or existing AGT installations could be retrofitted. This approach will provide more near-term results than the more advanced technology options that will not be production ready following current schedules before the late 1980's at the earliest.

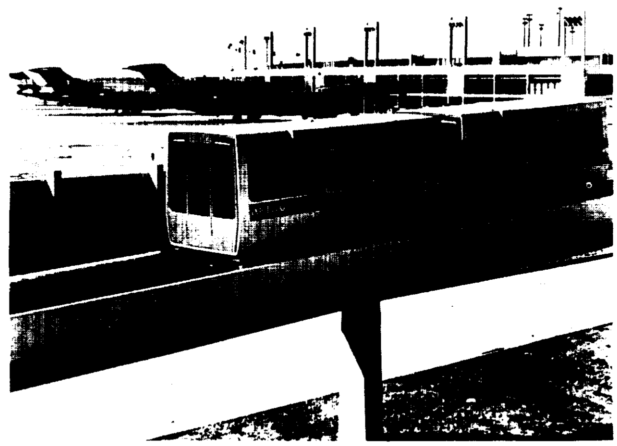

Photo credit L TVAC PR&A

Near-term option—upgrade airport systems for use in cities

The third objective of this approach, if pursued to the exclusion of other options, is to delay work on advanced technologies until many of the unresolved issues identified in chapter V (see table 4) are further analyzed.

Table 4.–issues Requiring Further Analysis*

- Guldeway and station congestion Impacts
- Consumer reaction to advanced automated guideway systems
- Methods to provide security in unattended vehicles
- Emergency evacuation procedures
- Effects on land use development patterns
- Relationship to other Federal programs and policles
- Acceptability of the esthetic Impacts of elevated guldeways
- Impacts of snow accumulation and options for solutlon
- Optimum vehicle size and speed for energy efficiency
- Attainabllity of AGRT operating and maintenance cost goals
- Optimum guldeway shape
- Optimum vehicle and operating procedures for various appilcatlons
- Size and nature of required labor force
- Potential reduction In jobs for unskilled persons
- Impact of existing labor agreements

'This list is a summary of the unresolved issues listed at the end 01 each of the sections m ch V
SOURCE Off Ice of Technology Assessment

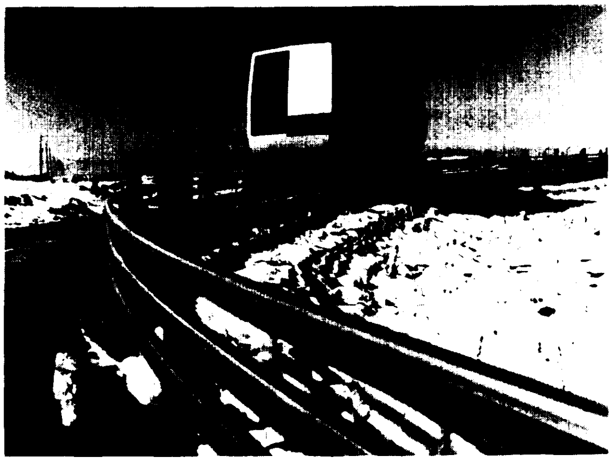

Photo credit Otis Elevator

AGRT must be able to operate in ice and snow

Option 2: Emphasize Critical Subsystems Development

The Federal Government would support activities related to the development of subsystems or components that comprise the new technologies in AGRT (see table 5). The eventual goal of this form of the program would be to combine these subsystems into a working system (or family of systems). This program would then differ from UMTA’s automated guideway transit technology (AGTT) program which is working on more general problems such as safety and security and cold weather reliability. As with Option 1, the results of this program as they come online could also be applied to existing new systems. In some cases they could also be applied to conventional bus and rail as well as to automated technologies. Decisions on the final shape(s) of AGRT would be deferred.

A shortcoming of this approach is that a realistic systems environment is needed to verify integrated component operations.

Table 5.–Typical Features of Advanced AGT Systems

• Linear induction motors	• Automatic training
• Air-cushion suspension	• High-speed swltchlng
. Magnetic levitatlon	c Goods handllng
• Mowng-block controls	• All-weather operation
• Colllslon avoidance radar	• Safety and security systems
c Minimum guldeway cross-section	Emergency braking

SOURCE Off Ice 01 Technology Assessment

Option 3: Validate Subsystems in a Systems Environment

This option would provide the realistic systems environment necessary to test the interacting relationships of components but defer the additional costs of full-scale prototype development. A sample test configuration would include a small number of breadboard vehicles, a modest amount of guideway, and perhaps two or three switches. The validation program would be designed: 1) to verify that the tested components perform as expected (command and control, vehicle operations) and 2) to produce reliable cost estimates for decisions on further program direction.

Option 4: Develop and Validate Technology on Prototype Systems

Complete prototype systems would be developed for one, two, or three of the technologies and engineering validation completed yielding production-ready systems. The prototypes would adhere to the UMTA AGRT specifications, although actual urban deployments need not adhere in all respects to the same design. As an example, a complete prototype validation would include multiple vehicles and sufficient guideway to test high-speed operation and switching. This testing would verify such functions as merging, longitudinal control, headway maintenance, and collision avoidance. Those functions that cannot be verified on the test track would be simulated in the laboratory, using computer analysis as required. UMTA has estimated this process as taking about 60 months.

The advantages and disadvantages of these four options are summarized in table 6. These options are not necessarily mutually exclusive. Option I could be carried out along with any of the other three. And OTA does not imply that there are clear-cut distinctions between Options 2, 3, and 4. In fact, there is a natural evolutionary process. The real distinctions among the options are in the amount of commitment that Congress wishes to make at this time given budget considerations and the need for further information.

Table 6.–R&D Options for Achieving AGT Technologies–Pros and Cons

Option	Pros	Cons
1. Emphasize the upgrading of existing AGT technology (Ie., DPM)	• Much to offer from existing AGTs, • Improves marketability of exlstlng AGTs, • Lowest level of technological risk • Allows time for other studies, • Defers major technological commitments, • Benefits many suppliers and technologies. • Incremental Innovation widely supported, • Does not outpace market for urban AGTs. • Least costly in short run.	• Slowest option for achieving deployable advanced technologies. • Yields modest AGT technology and service improvements. • Risk of Boeing and Otis leaving program. • Increasing technology gap with foreign systems.
2. Emphasize critical subsystems development	• New subsystems immediately deployable, c Low technological risk, • Allows time for other studies. • Defers major technological commitments, • Benefits other suppllers, • Supports Incremental Innovation. • Low short-run costs, • Can also Include Option 1,	• Slow option for achieving deployable technologies. • Major subsystems require a systems environment for engineering verlflcatlon • Risk of Boeing and Otis leawng program,
3 Validate subsystems in a systems environment	• Avoids costs of full prototypes. • Provides a realistlc environment for subsystems verlflcatlon • Provides cost estimates. • Malntalns supplier interest (Boeing and Otis), • Includes Option 2, can Include Option 1.	• Involves a technological commitment, • Forecloses other technologies,
4. Develop and validate technology on prototype systems	• Fastest option to achieve program goals. • Maintains continuity and stability of program, • Maintains suppller interest (Boeing and Otis), • Includes Optlons 2 and 3; can Include Optlon 1. • Reduces technology gap with foreign systems	• Highest technological risk, • Forecloses other technologies, • Marketabdity unsure, • Highest cost In short run.

SOURCE OTA staff analysıs

Number of Prototypes

Competition would create incentives to encourage economy and austerity in both system design and development and satisfy local requirements for competitive bidding.

Money spent on the development of alternative systems can be relatively inexpensive insurance against the possibility of picking an inferior alter= native.

A subsidiary question related to Options 3 and 4 concerns the number of prototype systems to be funded at this time should either of these options be selected. The OTA findings in this regard are derived from the conceptual stance outlined in chapter 111 that AGRT is but one potential configuration within a multidimensional option space. Other developmental programs within UMTA are more broadly based. The AGTT program, for example, is working on a number of problems (i. e., safety and security, cold-weather operation, guideway configuration) with wide applicability to automated systems, both existing and advanced. The DPM program, designed to demonstrate off-the-shelf automated guideway technologies, is open to a wide variety of offerings including various size vehicles, monorails, and suspended technologies.

Evaluation of R&D program options should consider the recommendations of the Commission on Government Procurement and the guidelines on procurement subsequently issued by the Office of Management and Budget as spelled out in Circular A-109. The essence of this policy is to maintain competition between similar or differing designs as long as maintenance of such competition is economically feasible. Some of the principal arguments in favor of retaining competition are listed in table 7.

There is a substantial degree of technological diversity offered by the three AGRT system concepts, particularly with respect to command and control, suspension, and propulsion systems. The cost of preserving these options, at least through the technology verification stage, is small in comparison with the cost of a single deployment. The retention of multiple suppliers is also consistent with Federal and local procurement requirements which favor a competitive bidding process. Critics of this approach claim UMTA is paying twice to solve the same mission and that ‘other missions or other appreaches to the urban transit dilemma should also be considered.

Table 7.–Principal Arguments in Favor of Retaining Competition

Arguments In favor of competition	Tradttlonal procurement process	Competltwe acquisition process
Provides flexibility for dealing with technological uncertainty	There IS no hedge against tallure	Money spent on the development of alternative systems can be relatively inexpensive Insurance against the posslblllty that a premature choice of one approach may later prove to be a poor and costly one
Allows for greater Innovation	Since Government has made the design declslons about the best approach to meet a need, private sector contractors compete for the development and production of a ‘ ‘required system’ and do not offer their own best solutions at thew lowest costs. Consequently, there IS llmlted opportunity for contractor Innovation and technical competition, contractors find it easier to promise the customer what he wants, rather than to Innovate and demonstrate new products	
	Large firms tend to acquire a technical base based on their experience with successful products and their customers’ tastes Although smaller firms are likely to have more mltla-twe and to be more Innovative, they are usually discouraged from competing because the competition begins late In the process, when the costs are highest	
Provides for greater control over costs	With only a single organized effort underway to meet a need, system performance and scheduling sllppages have to be accommodated by additional funding. As a result of this monopoly sltuatlon, costly and burdensome controls and regulations must be applled to a greater extent than In competitive procurement to prowde public accountability.	Competltlon would reinstate a challenge to Industry to use a wider span of technologies for system solutions that are of lower cost and simpler design Competition would create Incentwes to encourage economy and austerity In both system design and development
Allows for performance as as well as price comparisons	There are no standards to measure the efficiency of a single undertaking and no competition to ald In choosing the best system. Source selections have depended less on technical differences between proposals and more on contractor predicted costs at a time of great technical uncertainty about the chosen system In relying on these cost predictions for Inltlal system procurement, Insufficlent weight has been given to system performance and to the costs that are eventually to be paid for operating, supporting, and maintaining the system	Competitve exploration of technical approaches should produce dlstlngulshably different system performance characteristics Technical differences would then become more Important crlterla for choosing systems and contractors than In the past when differences mainly Involved design detail and an uncertain cost

SOURCE *Report of the Commission on* Government *Procurement* vol 2 1972

Magnetic Levitation Technology

At this early stage in the development cycle there is no sound technical basis for discontinuing work or providing any promising technology with significantly less funding. Magnetic levitation is a particularly promising option because of its low noise and high reliability potential.

The suspended Romag technology (see figure 3), originally developed by Rohr, and licensed to Boeing in 1978, has several features of particular merit:

- it is believed more suitable for winter operations;
- the guideway shape is closer to a structural optimum, reducing costs and guideway obtrusiveness; and
- through the use of 1inear induction motors and magnetic levitation, the propulsion and suspension systems have no moving parts and hence, more reliable operating characteristics.

Although its development is currently receiving less funding than the other two AGRT technologies, Romag exhibits highly desirable characteristics as an alternative.

Funding

The program proposed by the Department of Transportation in early 1978 raised the total cost of the AGRT development program to $111 million (see table 2) which included the estimated effect of inflation through to an anticipated completion date in early 1984. This plan would spend $40 million each on the Boeing (wheeled) and Otis (air cushion) technologies with $5 million being devoted to Romag. This level of effort corresponds to Option 4. According to data from UMTA, $14 million of the $111 million had been spent through April 1979.

Early in 1979 UMTA scaled down these plans, Contracts recently negotiated with Boeing and Otis provide approximately $25 million to each contractor for further work on the wheeled-vehicle and air-cushioned systems. Boeing will also receive $9 million to continue development of magnetic levitation technology. Cost of the revised plan including prior expenditures totals $73 million. A decision to develop production prototypes has been deferred.

Possible funding levels for Options 1, 2, or 3 (table 8) acknowledge that the optimum development course to advanced AGT systems is not clear at this time and that technological options should be kept open as long as possible. Using a recent grant to upgrade Airtrans as a guide, the first option could entail costs of up to $5 million to $7 million per technology. As a guide to costs for Option 2, UMTA proposes to spend $13 million on engineering alone for the Boeing (wheeled) and Otis (air cushion) technologies, were complete prototypes to be planned for at this time (table 3). Additional manufacturers could be included adding to costs or some synergism introduced among the AGRT technologies to reduce costs.

Table 8.–Estimated Funding Levels for Advanced AGT Options

Optlon	Near-term program cost (millions)
1 Emphasize upgrad!ng of exlstlng AGT technology	$15-30”
2 Emphasize crltlcal subsystems development	$20-40”
3 Validate subsystems In a system environment	$60-80”
4, Develop and valldate technology on prototype systems (UMTAFY 1979 proposal)	$97

"OTA siafl estimates
SOURCE Olfice of technology Assessment

Creation of a limited systems environment (Option 3) would have to include most of the full-system engineering costs, but only a portion of the fabrication costs. Savings could thus amount to up to $8 million to $10 million per technology. Assuming the two Boeing technologies would use a common command and control system, the requirements for Option 3 would be on the order of $60 million to $80 million.

Table 8 shows $97 million as the cost-to-complete of Option 4, based on the current plan of two full prototypes, and about $5 million for Romag. It is possible, however, to reduce the amount of prototype guideway and structures for system validation so that additional resources could be diverted to accelerate the development of magnetic levitation technology.

Goods Movement

A study should be undertaken to determine the extent to which automated systems could be used to transport some kinds of goods in urban areas, thus reducing road congestion and spreading the cost of automated guideway system construction.

Joint use of transportation facilities to move both people and goods is a historic practice, permitting the required capital investment to be spread over a greater number of users. The predominance of trucks for urban goods movement is a result of the ubiquity of the highway system, the ability of users to operate trucks sized to their specific needs, and the control of the industry over the timing of shipments.

The possibility that an automated system could be used for shipment t~f a substantial portion of goods in urban areas deserves consideration. Not all commodities could realistically be served. The most likely applications would be for goods moving in large volume to or from common supply or collection points such as mail or waste. Retail outlets might be included if enough of them are close enough to guideways

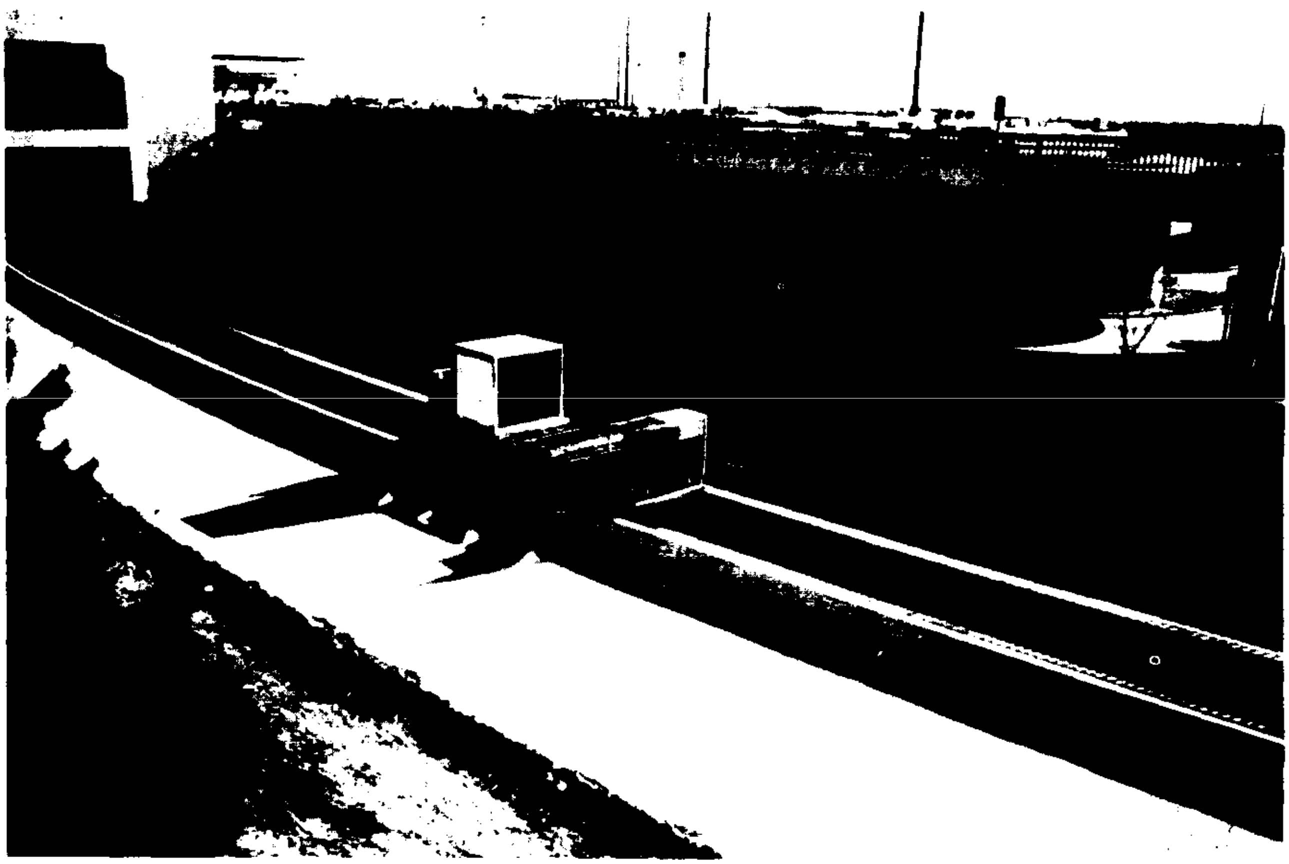

Photo credit OTA staff photo

An AGRT system capable of carrying goods as well as people could reduce costs to provide short inexpensive sidings. In any urban application the type and volume of goods-handling potential will depend on the characteristics of the local economy and the locations of the system.

Unresolved **issue:**

- the potential markets that could use AGT facilities for goods movement.

Nonautomated Guideway Transit Options

AGRT is but one option to improve urban transportation. Its development should not preclude continuing investigations into a number of other promising areas for the future:

- transportation systems management for better utilization of existing passenger vehicles and rights-of-way;
- dual-mode buses or cars that can operate in mixed traffic under manual control and in an automated mode on a guideway;
- automated roadways to free the motorist of the responsibilities of vehicle control and to provide safer operation free of human error and erratic behavior;
- personal rapid transit, an automated guideway mode (see figure 2) with separate small vehicles for each traveler or group of persons traveling together;
- telecommunications research to find ways to reduce the need to travel; and
- alternative land use policies which, in the long run, could affect the need to travel, the length of travel, and the mode of travel by changing the relative proximities and densities of activity centers.

Summary

AGRT is being developed as an additional technology to help cities meet their needs for public transportation. As an alternative to AGRT, Option 1 would upgrade and deploy existing automated guideway technologies for urban use in the near term. The second option would continue further studies while also beginning work on those subsystems that would ultimately be required for an advanced AGT technology. The third option would add to the second by providing a realistic systems environment in which to test these subsystems in integrated operations. The fourth option, representing essentially the program proposed by UMTA in 1978 and subsequently revised would proceed directly with the construction and testing of prototype systems leading to a production-ready technology by the mid-1980's.

This assessment has identified several critical information gaps. The selection of one or more of the first three options would allow more time for analysis of these issues, which could impact many of the design decisions for advanced automated guideway systems. There is also a need to determine further what significant differences exist among the AGRT technologies. For this reason and for reasons of system competition it would seem desirable that development should continue on all technologies until better information becomes available on which to base the selection of preferred alternatives.

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