REPORT OF THE PANEL ON CURRENT DEVELOPMENTS IN THE UNITED STATES

Prepared for
the Office of Technology Assessment

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CONTENTS

Introduction

The Panel on Current Developments in the United States was asked to examine the background and current status of automatic guideway transit in the United States. Attention was devoted to each of the following questions:

- Why AGT? How do the advocates of AGT argue their case?
- What are the AGT system types? How do personal rapid transit, group rapid transit, and shuttle-loop transit differ from one another?
- Who owns AGT systems? What systems are in service and in construction?
- Who wants AGT? What agencies have studied possible applications? What do they have in mind?
- Who supplies AGT? What are the problems of suppliers?
- What have Federal agencies done?
- What are the obstacles to progress? What actions would encourage early, effective and general exploitation of AGT?

The panel includes five individuals with extensive experience in the field of urban public transportation. Brief biographies of the panel members are included in Appendix A. The panel members have performed this work for OTA within a period of three months while attending to their regular jobs. Only one meeting of the entire panel was held—in Washington, D.C. on February 18 and 19, 1975. Four panel members attended a meeting with UMTA officials on February 14. Some six or eight additional meetings were held when two members of the panel could et together.

Many sources of data have been used by the panel. Formal documentation of the field is not yet well established. Much of the data contained in the report was gathered by correspondence, telephone interviews, and conferences with specialists and leaders in the field. Although some information expresses the considered positions of these specialists and their firms the panel has attempted to compile and report on as factual a basis as possible.

The panel has had valuable assistance from many individuals, firms, and agencies. The assistance of the following individuals was especially valuable:

Dennis Elliott, Dallas-Fort Worth Airport.
Phillip E. Gillespie, Westinghouse Electric Co.
James G. Harlow, West Virginia University.
Charles Hickox, LTV Aerospace Corporation.
Arthur E. Hitsman, Boeing Aerospace Co.
Eino Latvalla and Richard Donlon, Otis—Transportation Technology Division.
Hendrik Pater, Universal Mobility Inc.
Farrel L. Schell, Kaiser Engineers.
A. J. Sobey, General Motors.
Russell Thielman, Ford Motor Company.
W. J. Holt, Rohr Industries, Inc.

Chapter 1: Why AGT?

NEED FOR MOBILITY

People congregate in cities to obtain access to opportunities for housing, jobs, education, recreation, purchase of goods and services, medical care and so on. Mobility is the principal means of gaining access to such opportunities. The means for achieving mobility are far from ideal, and consequently there are strong incentives to improve transportation services. A review of the characteristics of existing modes reveals limitations and deficiencies that cannot be easily removed. Therefore the promises of improvements made by advocates of entirely new automated guideway transit systems warrant careful study.

WALKING

Walking is the most nearly universal means of achieving mobility and is used to some extent by all but the severely handicapped. Measures are being taken in some communities to increase the effectiveness and the usage of walking as a mode of urban travel. Among these are land use patterns that promote closer spatial rouping of urban structures; better walking surfaces and shelters; eYimination of barriers; installation of mechanical aids such as elevators, escalators and conveyors; and the elimination of competition between pedestrians and vehicular traffic. Howeve~, even if all possible encouragement and assistance is given to pedestrian travel, most urban residents will remain heavily dependent upon vehicles and other mechanical aids.

PRIVATE VEHICLES

Automobiles, motorcycles, and bicycles provide the greater part of urban transportation and will continue to do so for a long time. However, the automobile is too costly for the poor and is not directly usable by many, including the more affluent, who are unable to drive because of youth, old age, physical limitations and lack of skill.

Even those who own and operate automobiles are being pressed by circumstances to re-evaluate their customary practice and to consider alternatives. The main forces at work are all too familiar:

- Environmental programs.
- Energy shortage.
- Traffic safety.
- Congestion.
- Resistance to urban sprawl.
- Desire for transportation efficiency.

Today urban sprawl and the lack of public transit forces many families to own and operate two or more automobiles at considerable expense. Future growth in urban population and in affluence will aggravate present auto-related problems and will accentuate the need for alternatives.

Bicycles are extensively used, especially by the young, and their use should be encouraged. However, like walking, bicycling will not be used enough to make everyone mobile. Motorcycles are probably a negligible factor although they offer advantages over the automobile in most respects other than safety and comfort.

CONVENTIONAL URBAN PUBLIC TRANSPORTATION

The conventional public transportation modes now serving urban America are:

- Transit:
  - Scheduled Buses.
  - Rail Rapid Transit—Subways.
  - Street Cars—Light Rail Vehicles.
  - Trolley Coaches—Electric Buses.
- Commuter Rail Trains.
- School Buses.
- Taxis.

These systems provided about 12.5 billion rides in 1971 for outlays totaling about $5 billion. These outlays were about 5 percent as great as the amount spent on the private automobile in the same year. Transit in typical urban areas provides 3–10 percent of all trips, 15–30 percent of all peak-hour tmps and 30–50 percent of peak-hour trips to the central area.

The programs of UMTA and earlier agencies have focused on the four transit modes and commuter rail. These programs began modestly in the early 1960's and have increased greatly both in scope and in funding levels. Yet a decade of federal support passed before the decline of transit patronage was stopped and regrowth has been small.

The characteristics of the two principal conventional modes of transit are ill-suited for universal application in all urban situations.

- Rail systems are capital-intensive and are difficult to justify except where their high capacities can be utilized.
- Buses are labor intensive and, in most cases, slow. Frequent service is usually provided only on heavily traveled routes and only during peak hours of travel.

Rail and bus systems appear incapable of providing service of good quality throughout metropolitan areas at all times of day and at acceptable costs. Even 100 percent or 200 percent increases in outlays for rail and bus service would leave most of the problem of urban mobility unsolved.

The level of public expenditure necessary to extend rail and bus service to all urban areas and to raise the quality of transit services to the level enjo~-ed by auto travelers would almost certainly be unacceptable. Therefore, compelling reasons exist for a search for new modes of transportation that will be more effective and less costly.

Both public and private agencies are making innovative uses of conventional vehicles in providing para-transit services. Among these are:

- Dial-a-Bus.
- Shared ride taxis.
- Employer or developer supplied van pools.
- Subscription bus pools.
- Matching schemes for car pools.

These systems undoubtedly provide valuable services and may enjoy considerable growth. However, some are costly and others are mainly suitable for work trips to major employers. They offer aid but are not full solutions.

ADVANCED SYSTEMS

Since the early 1960's there has been growing interest in the possibility that advanced urban public transportation systems can be explolted to overcome existing deficiencies and to satisfy other broadly defined urban goals. Advanced systems include accelerating pedestrian conveyors, continuous capacity or moving way vehicle systems, fast urban transit links, and dual-mode transit as well as several types of automated guideway transit systems (AGT).[1] The latter class is the subject assigned to this panel.

A major incentive for U.S. development of AGT systems was provided in 1966 by the Reuss-Tydings Amendments to the Urban Mass Transportation Act of 1964. These amendments required the Secretary of Housing and Urban Development to:

> ". . . undertake a project to study and prepare a program of research, development, and demonstration of new systems of urban transportation that will carry people and goods within metropolitan areas speedily, safely, without polluting the air, and in a manner that will contribute to sound city planning. The program shall (1) concern itself with all aspects of new systems of urban transportation for metropolitan areas of various sizes, including technological, financial, economic, governmental, and social aspects; (2) take into account the most advanced available technologies and materials; and (3) provide national leadership to efforts of States, localities, private industry, universities, and foundations. "

The resulting report, *Tomorrow's Transportation, New Systems for the Urban Future,* was submitted by the President to the Congress in May, 1968. This report and the related backup stuclies are credited with prompting interest in government and industrial development of AGT systems in the U.S. and abroad.

Various types of AGT systems have been envisioned for use in conjunction with one another and as complements and supplements to conventional modes. A single, all-purpose AGT system is not likely to emerge in the foreseeable future. hfore likelJ", multi-modal mixes of conventional and advanced systems till be used.

Automated guidewa~r s~wtems are used and have been studied in a variety of settings. Among these are relativel~' small applications in major activity centers such as airports and business district?, large networks to serve entire metropolitan areas, and installations in heavily traveled corridors. If AGT systems can be widely exploited, as many authorities envision, they may prove to be the most valuable of all urban public transportation modes in terms of the amount and qualit~r of service rendered, the economy of capital and operational costs, and in contributions to social goals. However, widespread use will also require enormous capital outlays.

Automated guidewa~r transit systems have a remarkable ability to capture the imagination, and a considerable number of advocates has

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[1] See p. 129 for definitions of AGT types and settings.

emerged. Included are scientists, engineers, transportation specialists from various fields, university professors, public officials, inventors, consultants, manufacturers and citizens-at-large.

The advantages claimed for automated guideway transit are summarized below. Some of the advantages are available, to varyin degrees, from other modes. Also, various AGT system types wi 1 undoubtedly differ from one another in their abilities to dehver the advantages claimed.

More Routes and Stations.—It is argued that AGT systems can economically serve a 1arge number of routes and many closely spaced stations, thus they can make service more nearly universally accessible than is possible with conventional modes and para-transit. This attribute is especially valuable to travelers with limited mobility via automobile.

Travel Tirne.—AGT will allow passengers to save travel time. They will board vehicles with shorter waiting times and proceed to their destination at higher average speeds than with conventional modes.

Ofl-Peak Service.—Furthermore, it is claimed that AGT systems can maintain a uniformly high level of service at all times of the day and night whereas conventional modes almost universally cut back service to save on labor.

&'ajety.-It is claimed that automated guideway systems will be safer than manually controlled vehicles to passengers and non-travelers as well.

Costs *to Operators. -It* is argued that certain types of AGT systems can provide a high level of service with less capital cost than is required for rail systems, especially on routes requiring intermediate or low capacities. Current costs of entire rail rapid transit systems are in the range of $20-$50 million per mile for capacities of about 30,000 passengers per hour per direction. Underground lines cost as much as $100 million er mile.

It is also c'laimed that AGT can provide more service per unit of labor cost than buses and taxis. Relying on these claims, it is argued that the life-cycle costs of AGT systems can be lower than conventional systems for prescribed conditions and levels of service, and that AGT systems can have superior cost-effectiveness characteristics on many routes.

Resources.—For a given set of conditions it is claimed that AGT systems will save land, material, energy and the time and effort of travelers. Furthermore, urban development plans geared to the use of AGT s~stems will enlarge those savin s.

Enmronment.— It is claimed that AGT systems will reduce air and water pollution, noise, aesthetic offenses, and damage to biotic communities while providing an improved environment to users in terms of ride quality, comfor~, visual impact and convenience.

Employers.—It is clalmed that employers—public and private-will gain from an enlarged labor market, more regular attendance and less need for employee parking lots.

Merchants.-It 1s claimed that some merchants will gain from an enlarged market and from less need for parking lots.

S'chools.-It is claimed that AGT systems can relieve school districts of a substantial part of the burden of transporting students.

Luhor.-It is claimed that the construction and operation of AGT systems will create employment opportunities of value to labor.

Suppliers.—It is claimed that the development, manufacture and installation of AGT systems will provide valuable business o portunities, will exploit United States developed technology, an will promote a favorable balance of trade.

Land Owners.-It is claimed that AGT systems will increase the value of land and floor space, reduce the total cost of land develo men~, and speed the development of land in areas near stations. A us, lt would contribute toward im roved efficiency of operations.

Land *Use Patterns and Urban Form.—It* is clalmed that new fixed guideway systems will encourage clustered development in land use rather than continued costly development of urban sprawl where costs of public service are exceptionally high.

Tazpayers.—It is claimed that AGT systems will enjoy higher patronage and lower unit costs than conventional modes and that the need for subsidies will be less per passenger served. Where subsidies are required they will be amply rewarded by savings in travel time, increased productivity, and the like.

NEED FOR VALIDATION

The claims made by the advocates of AGT systems require close study and evaluation. It is natural to expect that results will differ greatly among system types and application sites; thus requiring detailed analyses and comparisons of life-cycle costs, revenues, operating and service attributes, environmental impacts, and contributions to social goals.

Chapter 2: What are the AGT Systems Types?

Terms for automated guideway transit systems and related subjects have not yet been completely standardized. Consequentl~', the vocabulary of this report contains a number of new terms. The names of system types and other specialized terminology are italicized where defined or explained.

The following names and acronyms are used:

Automtited Guideway Transit (AGT).
Personal Rapid Transit (PRT).
Group Rapid Transit (GRT).
Shuttle-Loop Transit (SLT).

Automated guideway transit systems have two distinguishing features:

- The?" have their own roadwa~w which are usually called ex-*clwnve guideways.* Guideways may be elevated, at or near ground level, or underground.
- *Vehicles are* automafed—Thatt is, they can carry passengers without a driver on board although a staff of employees is used to monitor operations, assist and provide security for passengers, collect fares, maintain and service equipment, and perform administration. Attendants may be assigned to vehicles or trains on occasion.

AGT SYSTEMS

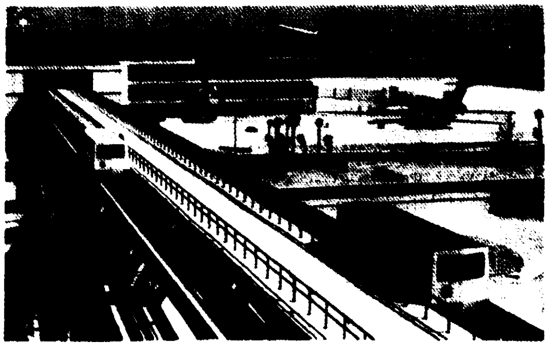
AGT systems can differ from one another in ~ great many ways and any scheme of sub-classification is necessarily somewhat arbitrary.

~1'hrec sub-classes are defined below. 'rhe~~ differ with respect to technical sophistication, service attributes, operations and availability or readiness for applications by local transit agencies. These differences are summarized in the tabulation entitled Attributes of AGT Systems. A representative concept of each is shown on the next page. Further pictures and diagrams of AGT are contained in Chapter 3 of of this report.

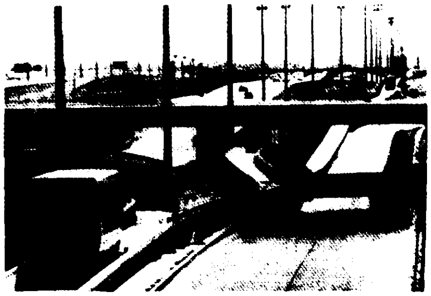
CLASSES OF AUTOMATED GUIDEWAY TRANSIT

Shuttle-Loop Transit

- simplest technology
- little or no switching
- vehicle size varies
- long headway-60 seconds or more



Passenger Shuttle-Tampa International Airport



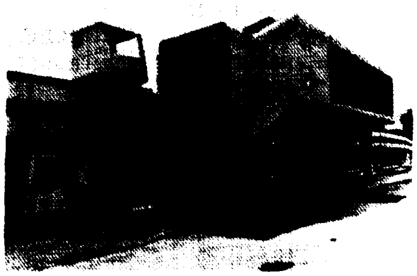
AIRTRANS-Dallas/Fort Worth Airport

Group Rapid Transit

- switching to shorten en route delays
- more than six riders
- intermediate headway-three to 60 seconds

Personal Rapid Transit

- one to six riders
- no en route delays or transfers
- short headway—less than two seconds



Cabinentaxi—Hagen, W. Germany

Attributes of AGT Systems

	PRT	GRT	SLT
Availability for use___ -----	Future: No revenue system, no system in construction, no systems planned.	Emerging: 1 revenue system exists and 1 system is in construction. Others are in the planning **stage.**	Current: Many systems are in service, in construction, and in planning stage.
Operations.. - _ __________	Vehicles follow paths tailored to personal needs of traveler.	Vehicles or trains follow multiple paths.	Vehicles or trains follow unvarying paths.
Service- _ _ --- _ _ -- _ _ _ -----	Traveler will ride alone or with his own travel party in one vehicle from origin to destination with minimum en route delays and no transfers.	Traveler must wait for right vehicle and ride with group. Traveler will bypass some or all en route stations and will make few transfers.	Traveler will board first vehicle, will be delayed at en ~ route stations, if any, and @ will transfer from route to route.
Guideway configuration----	Network of single or double gu:;;;a::rv~;rm;;~a@ ~ decelerating and accelerating guideways at off-line stations—switching extensively used.	Single and double guideway, trunk, and branching lines, stations on-line or off-line, switching commonly used.	Single and double guideway shuttles and loops, on-line stations, switching used sparingly.
Technical sophistication----	Complex. Only partly demonstrated.	Intermediate. Not yet perfected in application.	Simple. Requires refinement.

It is not always easy to draw sharp boundaries between classes and efforts to do so are tedious and impractical. Consequently, the following definitions deal with middle-of-class examples.

PRT SYSTEMS

The term *personal rapid transit* or PRT entered the technical vocabulary in 1968 when It was used in "Tomorrow's Transportation" to identify a conceptual system that would use automobile scale vehicles (two to six seats). Each vehicle would carry one person or a small group traveling together by choice—a *single travel party.* Vehicles would operate over a network or grid of guideways having many stations and intersecting lines. The intersections of lines would provide each vehicle with alternative paths. *Switches* (or the equivalent) would allow vehicles to make turns or to continue in the original direction of travel just like autos at street intersections and freeway interchanges. These intersections of routes are called *nodes,* and the ability of vehicles to continue or to change directions at nodes is called *coupling.* PRT systems are *fully coupled* at the nodes.

Nothing would prevent strangers from riding together in a PRT vehicle if they chose to do so. However, in a PRT network containing dozens or hundreds of stations, there will be few occasions when opportunities for ride sharing occur by chance. For example, one traveler about to board a vehicle at station number 1 bound for station number 99 is unlikely to encounter a stranger going to the same place. Furthermore, it can be shown that the first rider would usually suffer an intolerable delay if he were required to wait for another person going to the same place.

PRT vehicles will carry loads comparable to private automobiles and therefore must follow one another very. closely to achieve acceptable line capacities. The time interval between vehicles is called *headway.* Transit experts agree that close spacing or short headway is necessary to make PRT systems attractive for metropolitan networks. For example, an average headway of about two seconds will be needed to give a PRT line a capacity equal to one lane of auto traffic on a freeway—about 1800 vehicles carrying average loads of 1.4 passengers, or 2,500 passengers per hour per direction. An average headway of about one-half second will be needed to give a PRT line the same capacity as auto traffic on a four-lane freeway-—about 10,000 passengers per hour per direction.

PRT systems must have stations located on sidings rather than on the main line--i.e. *off-line platforms.* This feature allows some vehicles to pass a station while others stop. The most severe technological challenges that face developers of PRT systems are to achieve close headways safely, reliably, and economically, and to manage thee empty vehicle fleet. No PRT system exists, and no urban application is m early prospect.

While some PRT proponents feel the social benefits of private party service will provide superior public transit, others feel the environmental issues far surpass the severity of the technological issues mentioned above. Aerial guideways in residential areas; the large number of lines (both main lines and sidings) ; the size and number of stations needed in downtown areas; and large number of vehicles in motion represent visual intrusion issues yet to be considered.

GRT SYSTEMS

Group rapid transit systems are designed to serve travel groups having similar origins and destinations rather than single travel parties. GRT vehicles may be of any size although van-scale and bus-scale vehicles (ten to fifty passengers) are likely to be most common. Trains may be used.

GRT systems may have on-line stations on lightly traveled route and off-line stations on main routes. GRT routes may divide into *branching-lines* and may remerge, but they do not have fully coupled 3-way or 4-way nodes. The combination of branches and off-line stations allows the system to provide service on a variety of routes, thus the traveler using a GRT system must be careful to board the correct car and may have to wait while other cars pass. (See Figure 3 below). Also, GRT passengers making relatively long trips in a metropolitan-scale system will probably find it necessary to make one or a few transfers from one vehicle to another.

GRT headways can be relatively long in comparison with PRT. For example, a 'line with average headways of about 15 seconds—vs. 2—and average vehicle loads of about 10 persons—vs. 1.4—would carry as many passengers as one freeway land devoted to auto traffic—2,500 passengers per hour per direction. Vehicle loads of 40 would increase line capacity to 10,000 passengers per hour per direction with single vehicles or 20,000 passengers per hour per direction with two-vehicle trains.

Group rapid transit systems exist at Dallas/Ft. Worth Airport. Texas, and in Morgantown, West Virginia and on the West Virginia University campus. These systems represent two quite different technical approaches. The Dallas/Ft. Worth system has been in service for more than a year. The Morgantown system is scheduled for operational testing by mid-1975. 130th have experienced considerable difficulty but offer valuable opportunities for learning. Substantial effort can be profitably expended on the perfection of those two systems and on the design of alternatives suitable for other applications.

SLT SYSTEMS

Shuttle-loop transit systems are the simplest of the three sub-systems and by far the best understood. SLT systems have a single essential characteristic: their vehicles follow unvarying paths and make little or no use of switches. Vehicles may be of any size, and trains may be used.

The vehicles of a shuttle system move back and forth on a simple guideway—the horizontal equivalent of an automated elevator. Shuttles have stations at both ends of the run and may have intermediate stations as well. (See Figure 1 below).

The vehicles of a loop system move round and round a closed path which may include any number of stations. Stations are on the main line. Headways are limited to about 60 seconds. (See Figure 2, below.)

Variations of the SLT make limited use of switches. Double guideway lines may use crossover switches rather than turnaround tracks at the ends. Single guideway lines use switches to allow two cars or trains to bypass near the midpoint of the line.

Capacity and speeds of SLT systems can vary over a wide range. For example, one application has two shuttles on parallel guideways in each route. The run is 1,000 feet long, the vehicle capacity is 100 passengers, the maximum speed is 30-35 mph, and the capacity of each shuttle is 2,500 passengers per hour per direction—equal to the capacit of one freeway land devoted to auto traffic.

1LT systems are becoming relatively common in the United States. There are 15 installations, counting those in construction, from four suppliers.

Chapter 3: Who Owns AGT Systems?

The panel has identified and obtained data on seventeen AGT installations presently in existence in the United States. Fifteen are of the shuttle and loop transit type: of these, nine are operating and six are in construction with completion scheduled for mid-1975. There are no personal rapid transit systems in service or in construction. The installations are:

SHUTTLE AND LOOP TRANSIT

Operating

1. Tampa International Airport, Florida, 8 Shuttles.
2. Houston Intercontinental Airport, Texas, 1 Loop.
3. Seattle-Tacoma International Airport, Washington, 2 Loops, 1 Shuttle.
4. Love Field, Dallas, Texas, 1 Loop.
5. California Exposition and State Fair, Sacramento, 1 Loop.
6. Hershey Amusement Park, Hershey, Pa., 1 Loop.
7. Magic Mountain, Valencia, Calif., 1 Loop.
8. Carowinds, Charlotte, N'. C., 1 Loop.
9. Kings Island, Kings Mill, Ohio, 1 Loop.

In Construction

10. Kings Dominion, Ashland, Va., 1 Loop.
11. Pearl Ridge, Honolulu, Hawaii, 1 Shuttle.
12. Bradley International Airport, Hartford, Corm., 1 Shuttle, by-ass.
13. Fairlane Town Center, Dearborn, Mich., 1 Shuttle, bypass.
14. Miami International Airport, Florida, 2 Shuttles.
15. Busch Garden, Williamsburg, Va., 1 Loop.

GROUP RAPID TRANSIT

Operating (partial)

16. Dallas/Ft. Worth Regional Airport, Texas, 17 Overlapping Loops.

In Construction

17. Morgantown, West Virginia, 3 Stations with demand responsive routing and scheduling.

TAMPA AIRPORT COMPLEX

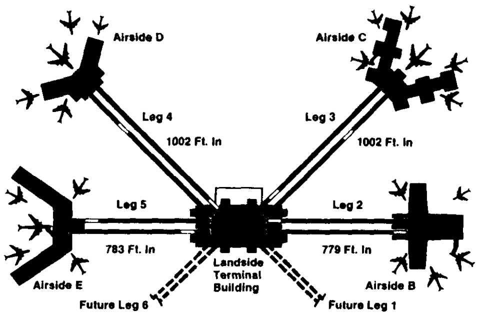


Figure I.—Shuttle System Layout

(a) Passengers Boarding

(b) Vehicles on Double Guideway

TAMPA INTERNATIONAL AIRPORT

In April, 1971 the Hillsborough County Aviation Authority, after a nine-year program of study and construction, opened a new air terminal of pioneering design. Among other features it included eight guideways and driverless shuttle vehicles. This installation is the largest and most not able example of the use of shuttles.

The design objective for the new terminal complex was to limit the walking distances of air travelers to a maximum of 700 feet—a distance considered tolerable to virtually everyone. The same terminal design without the shuttles would have imposed walks in the range of about 1,500 to 2,500 feet. Although the designers observed the imposition of much longer walks at other airports they considered distances greater than 1,300 feet to be burdensome to almost all travelers and unacceptable to some.

The terminal complex includes a central building and four satellites. Space is reserved for two more satellites (See Fig. 1). Each satellite is linked to the central building by an elevated structure about 1,000 feet long containing two guideways and a walkway for emergency use. Each guideway carries a single passenger vehicle which operates as a shuttle between two stations. (See Fig. lb). The system is the horizontal equivalent of an automated express elevator.

Each ~-chicle carries 100 passengers normally (125 with crowding). The \-chicle dwells-stands idle to unload and reload—about so seconds at each station. Travel time is about 40 seconds at a maximum commanded speed of so to 35 mph, Each vehicle can make about 25 round trips per hour. Thus the capacity of each shuttle is about 2,500 passengers per hour both to and from the central building. Each two-shuttle route can carry about 5,000 passengers per hour in both directions—about the same as a four-lane freeway devoted to auto traffic.

The average trip time, counting waiting and riding, is about 1.25 minutes for a l,000-foot trip. This is equivalent to a constant speed of about 9 miles per hour, or about three times as fast as walking.

The equipment w-as produced b?- Westinghouse Electric Corporation. It is the second in a series of five installations by that firm. The first was the Port Authority of Alleghany County Demonstration Project at South Park, Pa. The airport estimates that the total cost of the system was $8.25 million; $4.5 million for engineering and transit hardware; and $3.75 million for structures, stations, utilities and the like. operating costs are now about $275,000 per year-only $6,000 of that is for electric power. A work force of 6 is required to keep the 8-car system in 24-hour service.

The Tampa shuttles have carried about 50,000,000 passengers in slightly less than four years of operation. At present the system averages about 37,000 passengers per day.

No fare is collected. The cost of supplying the service is about 7 cents a ride, including capital and interest as well as operations.

The system is able to provide service on each route almost constantly-99.96 percent of the time in 1973. When stoppages occur, the system fails gracefully'. Individual vehicles arc stopped involuntarily about once every 20 hours on the average—usually for very minor incidents. They are restored to service with an average delay of less than 7 minutes. The stoppage of one vehicle does not impede the vehicle on the parallel path and passengers are usually able to change cars after a brief delay. In the rare case when both vehicles are out of service—about once a week on each line—travelers simply leave the stopped car—which is always possible—and finish the trip on foot on the walkway. The walk requires less than 4 minutes.

There have been no accidents in which vehicles were damaged. In one case power was reversed on a moving car, and two passengers suffered significant injuries. There have been reports of minor injuries and a few claims. As a whole, the injuries and claims have been substantially lower, on a comparable basis, than those encountered on the facility's elevators and escalators.

Each vehicle runs about 48,000 miles per year-comparable to a New York City subway car. Vehicle travel totals about 1,500,000 miles to date.

HOUSTON INTERCONTINENTAL AIRPORT

In 1969, the City of Houston opened up one of the largest commercial airports that had ever been planned and built from bare ground. The program had started in 1960. The terminal design was innovative in arrangement and in its dependence upon driverless vehicles operating on a simple closed loop.

Monotrain at Houston—Rohr Industries

The objective was to limit walking distances to about 600 feet for most air 'travelers. The terminal c;mplex is being built in stages and when complete, will include four terminal buildings and a hotel complex. The units stand in a straight line and are separated from one another by more than M mile. The entire complex will be longer than one mile. Two terminals were built in the initial phase and the hotel was recently completed.

The guideway and a median walkway are underground in tunnels beneath parking lots and in the basements of buildings. The route is about 3,oOO feet long with 6,20(I feet of guideway. There are eight stations: one in the hotel, two in the terminals and five in the parking lots. There is also a separate maintenance and storage area and switches for moving trains to and from passenger service.

Each train includes three cars and has a total capacity of up to 36 passengers—half seated and half standing. At present average headwa~'s can be as low as 3 minutes, when all 6 trains are used, and the highest capacit~" is about 72o passengers per hour per direction. With a larger fleet-18 trains in service—the system would reach its limiting headways of 60 seconds and its maximum capacity of about 2,160 passengers per hour per direction.

Vehicles operate at a maximum speed of 8 mph but stop at every station and slow for short-radius turns. Average speed of travel is about 400 ft. per minute—only about 50 percent better than walking. Average waiting time for a vehicle is now about 2 minutes but may eventually be as low as 30 seconds. While the system does not save much time for the average traveler it is a basic convenience. It is usually agreed that time spent riding is more tolerable than equal time spent walking, for most travelers, and also that the ability to ride is especiall~~ valuable for travelers encumbered with luggage, parcels or small chddren. Thus the system provides valuable services without greatly shortening travel time.

The system originally installed was replaced in 1972 by *a* system purchased from Westinghouse Air Brake Corporation (WABCO). That product line was later sold to Rohr Industries, and Rohr has provided aid in perfecting the design and maintaining the system. The Houston installation is the first of two revenue systems of this design. (See *Pearl I{idge* below.) A test track was established at Cape May, New Jersey during product development and remains in service.

Total capital cost of the system has not been estimated. Cost of the replacement hardware was reported to be $815,000. Total operating costs are not available. A fare is not charged and data on patronage are not available.

The system is reported to have experienced many technical difficulties that caused frequent interruption of services at the outset. Many of these problems are reported to have been worked out. However, data are not available on the mean time between failures and mean time to restore service,

The layout of the Houston airport system does not lend itself to partial operation when trouble develops—it does not fail gracefully. A defect on one train or at one point on the guideway will block the loop and stop the entire system within a short time. h-o provision has been made to reverse trains so that serviceable trains can provide a shuttle service. Neither is it possible to cross over to the other track or to turn back at an intermediate point to maintain partial service.

'I'he s~'stem has an excellent safet~' record. There has been one case of damage to a vehicle while under manual control but no accident of consequence involving passengers.

The six trains in this s~wtem accumulate more than 34,000 miles of travel each year.

SEATTLE-TACOMA INTERNATIONAL AIRPORT

In mid-1973 the Port of Seattle opened two major new satellite facilities at Sea-Tac and began operation of an SLT system. It includes about 8,800 feet of route in three elements: one shuttle and two loops (See below). A single vehicle type is used. Cars are shifted from one element to another and to the storage and maintenance area by three transfer tables.

All routes are below ground level and the loops are located beneath aircraft taxiways and aprons over much of their length. The objective of this system was to provide the sole means of passenger access for the two satellites that are several hundred feet away from the buildings of the central terminal complex. This design eliminated the need for finger piers or other connections above ground and conserved scarce land for the movement and parking of aircraft.

The shuttle is located beneath the main terminal complex. It has a single track ancl operates one vehicle between two stations almost 1,000 feet apart. Each of the two loops has a single track and three stations: one in the new satellite terminal, one interfacing with a shuttle station and one at the outer end of a concourse which is an extremity of the central terminal complex. The loops are about 3,700 and 4,1OO feet long.

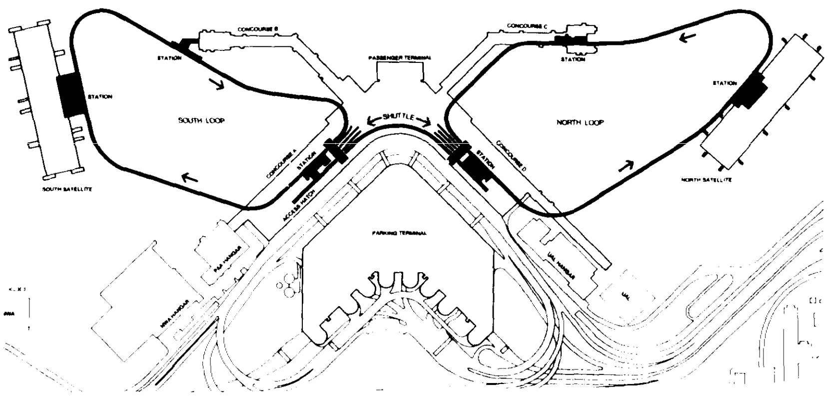


Figure 2.—Sea-Tac Satellite Transit System Layout

The vehicles normally carry 102 passengers with 12 seated and 90 standing (see below). When fully equipped the system will have 25 vehicles. At present there are 9 vehic]es in service and 3 on order. When 9 vehicles are in use four are assigned to each loop and one to the shuttle. Capacities are about 1,800 passengers per hour per direction on the shuttle and about 4,800 passengers per hour in the one direction of travel on the loops. Loop capacities can be increased to 14,400 passengers per hour. Vehicles receive ma~inllln~ spe~d~ con~man.d of 27 mph. Average trip times, including both the wmt and the ride, me about 1.8 mmutes on the shuttle and about 3,3 minutes on the loop.

The Sea-Tac system was supplied by Westinghouse Electric Corporation and is the second revenue system from that source. The capital cost of the initial 9-vehicle system has been estimated by the airport to be $14 million including $5.3 mi lion for the transit hardware and its installation and $8.7 million for tunnels, stations and other elements. The annual operating cost has been estimated at $540.000 per }-ear. Total cost pe~ airline"passenger is estimated at almost 274: about 9# for operation and about 18f for capital recovery with interest.

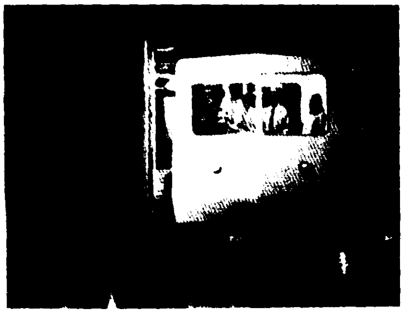
No fare is collected. Patronage has been estimated to be about 6,000,000 riders per ~'ear.

The system enjo~-s a high degree of reliability. The mean time between failures for a vehicle is almost a week, The mean time to restore service is 6 minutes. Service is available within two minutes at all stations 99.9~o of the time.

The system is designed to limit the consequences of failures when they occur. Personnel at a console in a central control room can use remote controls to restart vehicles, push or pull defective vehicles, form and separate trains, and operate transfer tables to add or remove vehicles from service. When a vehicle is stalled between stations on one of the loops, all other vehicles on the loop can be operated in a shuttle mode and all stations can be served. Passengers in a stalled vehicle can always evacuate to a parallel walkway and walk to the next station.

There have been no accidents of consequence.

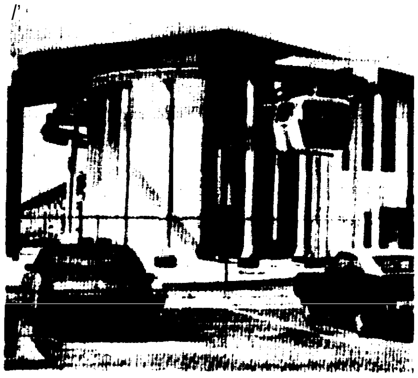
It is estimated that each vehicle will average 47,000 miles of travel per year.



Vehicle in Tunnel

Vehicle Interior

Westinghouse Electric Satellite Transit System
Seattle-Tacoma Airport



Loop System Designed for Braniff International Airline at Love Field, Dallas, Texas-now idle due to Braniff service shut down.

BRANIFF- STANRAY CORPORATION

LOVE FIELD

Early in 1970, Braniff International inaugurated a new transit service at Love Field, Dallas, Texas. It connected their portion of the air terminal and a parking lot located some 4,200 feet away from the terminal. The objective was to exploit parking space far beyond tolerable walking distance and also to make access to Braniff more attractive than other air lines. The system has been idle since Braniff ended commercial services at Love Field.

The system employs a single closed loop. Switches and sidings are incorporated at both ends of the loop for empty vehicle storage and at one end for maintenance and cleaning. One terminal of the route is at a building in the pinking lot and the other is in the terminal near the aircraft loading gates. A single intermediate station is located on the line to the parking lot at a point near the former baggage retrieval urea. The .guideway is mn overhead monorail about 8,400 feet in length located some 20 feet above grade in double guideway configuration with loops at each end.

Vehicles normall~ carry up to 10 passengers with six seated and four standing md up to 14 with crowding. Minimum headway was reported to be 20 seconds and maximum capacity was said to be 2,000 passengers per hour per direction. However, the fleet contained only 10 vehicles (rather than a full complement of 20) and it appears likely that actual capacity was about 600 passengers per hour per direction.

Maximum speed is about 15-17 mph with an average near 13 mph. Waiting was usually brief and total travel time is about 4–5 minutes. The overall speed is at least equivalent to three times walking speed.

The system was tailored to the needs of the owner—Braniff International. It was developed and installed by a team including the airline, Stanray Corporation, and American Crane Corporation. The system at Love Field is the only one of its type. It is reported to be usable and available for sale. At present the monorails and one vehicle are being used by PRT Systems, Inc. as a test facility for an advanced version of the system.

The cost of stations is not known but costs of equipment and structures have been reported to be about $925,000 including losses born by the contractors. Annual operating costs have been reported to be about $240,000 per year including about $10,000 for power. Operating costs were reported to be 45¢ per vehicle mile.

Fares were not charged but it was estimated that patronage was at least 1.5 million riders in the last year of service and at least 5,000,000 in the entire period of service.

Estimates have not been prepared of the mean time between failures or of the mean time to restore service. However, the owner expressed pleasure regarding the reliability of the system during the last half of the 4-year service period. Five employees were required to maintain the system. Two employees were always available for emergencies but they- performed other duties unless called.

Evacuation of stalled vehicles presented a difficult problem since the passengers were some 15 feet above ground level. Fortunately, evacuations became infrequent as reliability improved and did not pose a severe problem.

The safety record of the system was very good. One accident occurred under manual control and caused damage to an empty car. there were no accidents of consequence involving passengers.

Based on data reported from the project, it can be inferred that the entire fleet accumullated about 500,000 vehicle miles per year and that individual vehicles traveled about 50,000 miles per year.

This system is considered successful by the owners.

CALIFORNIA EXPOSITION AND SIMIL.4R SYSTEMS

,Six loop systems from one supplier-Universal mobility, Inc.—have been installed in recreational facilities in the U.S. T'hree installations of the same type were used at EXPO 67 in Montreal, Quebec, Canada, and others are used abroad. Some of these systems serve transportation purposes primarily and some have only an entertainment purpose. Some use open vehicles while others are enclosed and air conditioned. All are automated but some, carry attendants, observers or narrators. The system are included in this discussion because they are undoubtedly~ applicable in a variety of non-recreational uses. Experience gamed in their use is valuable

The California *Exposition system* was first installed in about 1968 but was removed for a time and then replaced for the 1974 Exposition and Fair. It ranı~ under automatic control in 1974 but with a monitor on board. It is expected to operate unattended in 1975.

The main purposes of the system is to transport passengers between the main gate and a major attraction on the opposite side of the grounds. The entertainment value of the ride is secondary'. The route is 1.7 miles long and links two stations. A plan has been made to add 4 miles of dual guideway to serve a second recreation park some distance from the fair grounds.

The system employs four trains. Each train includes 8 vehicles and carries 50 to 60 passengers. Trains are reported to have maximum speeds of about 10 mph nnd make about 4 or 5 round trips per hour. Capacity is about 1,500 to 2,000 passengers per hour per direction.

The capital cost of the system is not known although one report places it at about $2.5 million. operating cost is estimated to be $40,000 per year with most costs incurred during a 23-day season. operating cost is about 27¢ per ride. A 50¢ fare is charged. In 1974, revenue of $75,000 was received from 150,000 riders. The 1975 season's patronage is expected to be higher.

Safety has not been a problem. Reliability statistics are not available. However. significant delays are rare.

The other U. S."insta]lations "of this type are listed here:

- Hershey Amusement Park
  Hershey, Pennsylvania
  In service since 1969.
- Magic Mountain
  Valencia, California
  In service since 1971
- Carowinds
  Charlotte, N,C.
  In service since 1972.
- Kings Island
  Kings Mill, Ohio
  In service since 1974
- Kings Dominion
  Ash~and, Virginia
  To0 enter service in 1975.

A representative of the supplier reports that 6 U.S. and 3 Canadian installations represent a total capital cost of about $30 million and that the systems have carried 125 million passengers wthout serious injuries or fatalities.

PEARL RIDGE

During 1975 a shuttle system will be installed in Pearl Ridge, Honolulu, Hawaii, by private interests to link two shopping centers separated by about 1,000 feet. Service is scheduled to begin in September. The elevated route contains a single guideway and two stations plus track for storage and maintenance of vehicles. The system will employ one train made up of four vehicles.

The supplier is Rohr Industries and the car design is a derivative of the design used at the Houston airport. Capital cost is reported to be $1.1 million. Operating cost is not available.

Normal train capacity is 48 passengers with half seated and half standing. The train will make about 25–30 round trips per hour. Maximum capacity will be about 1,200–1 ,500 passengers per hour per direction.

The service will be free. Estimates of patronage are not available.
Specifications call for the system to be out of service no more than 60 hours per year and no longer than 12 hours at any one time.

BRADLEY INTERNATIONAL AIRPORT

In November, 1975, the Connecticut Department of Transportation is scheduled to begin demonstrating a new shuttle transit system at Bradley Field near Hartforcl, Connecticut. The system will link the air terminal with a parking lot and serve a motel at an intermediate station. The primary purpose of the .systcm is to improve the airport with respect to appearance, congestion, comfort and convenience. A second purpose is to demonstrate automated guideway transit for the benefit of other potential users in Connecticut.

The end-to-end length is 3,700 feet with 3 stations: one at each end and one near the center. The guiclew~~~- is a single path shuttle except for a 700-foot b~-pass section ne~~r tl~e mid-point. This cJ1ows the guidewa~' to accommodate two vehicles without incurring the full cost of a clouble path.

J"ehicle speed is 30 mph. Nominal capacity is 24 (six seated and 18 stancling) or 30 with crowding (See below). Each vehicle will make about 11 round trips per hour. Without crowding the total capacity of the 2-vehicle system is ubout 545 passengers per hour per direction.

VEHICLE FOR BRADLEY INTERNATIONAL AIRPORT

(Ford Motor Company)

Exterior View

Interior View

Average time for the longest trip—waiting, riding, and dwell—is 3.5 minutes. From the traveler's view this is equivalent to a constant speed of 12 miles per hour or 4 times walking speed.

Ford Motor Company is the supplier. This will be their first revenue system. However, an earlier model was demonstrated successfully at TRANSPO 72, and the current model is being tested extensively at the company's test track near Dearborn, Michigan, and at Bradley before the start of passenger service.

Capital cost of the system is reported to be $4.5 million. Operating costs are estimated to be $250,000 per year. Patronage is estimated at one million passengers per year.

Safety features, reliability, availability and maintainability are specified in detail but experience data remain to be generated. Portions of the guideway will be heated to avoid problems from snow and ice. The system can operate at half capacity with one vehicle out of service provided it is not stalled somewhere on the single path guideway. Disabled vehicles can be towed to the shop.

There are no firm plans to extend the Bradley installation but the design permits expansion if that should become desirable.

FAIRLANE TOWN CENTER

In March, 1976, the Ford .Motor Land Development Corporation. in partnership with other private interests, plans to begin public operation of a shuttle system at Fairlane Town Center. Opening the transit system has been delayed by other conditions. The purposes of the system are to serve as a major attraction and transportation service in a multi-purpose commercial development, The system will operate between the Hyatt Regency Hotel and the Shopping Center.

The end-to-end length is 2,600 feet and is a single path except for an 800-foot by-pass section near the mid-point. There are two stations at the ends of the line. Vehicles are similar to those described for Bradley except that 10 passengers can be seated while 14 will stand. Each vehicle can make up to 18 round trips per hour. With two vehicles in service maximum capacity is about 860 passengers per hour per direction.

Total trip time will average about 2 minutes including waiting. Equivalent constant speed, for the traveler, is about 15 mph or five times walking speed.

Ford Motor Corn any is the sup lier. This will be the second revenue installation [or their second AGT model. The capital cost is reported to be $4.5 million and operating cost is reported at $250,000 per year.

The service will be free. Patronage has been estimated at 3 million riders per year. The system will operate 11 hours per day. The comments on safety and reliability for Bradley a ply here.

Fairlane Town Center is the initial phase of a much larger development called the Fairlane NTew Town. The SLT system has been designed with a view toward expansion to serve other parts of the project.

hlAlll INTERNATIONAL AIRPORT

Metropolitan Dade County Aviation Authority is presently engaged in the installation of two shuttles at .Miami International Airport. The start of services is scheduled for 1976 having been delayed by other construction. The purpose of the system is to exploit otherwise unusable land. The shuttles will connect the main air terminal structure with a new international terminal located in a satellite beyond acceptable walking distance.

The installation will employ an elevated structure containing two guidewa~w. Each guidewa~' will carr~" a two-vehicle train. The system is comphcated by the fact that one vehicle must be "free" and the other '[sterile" in the vernacular of customs officials. That is, one vehicle must be reserved for the exclusive use of international passengers who have not yet completed entry procedures.

The two guideways will be parallel and about 1,400 feet long. Each will carry a two-vehicle train and each train will accommodate 200 passengers, all standing, during peak periods.

Train speeds commanded are 28 mph, maximum. Dwell time is 15 to 20 seconds and travel time is 62 seconds. Each train will make about 22 round trips per hour and the entire system will carry about 9,000 passengers per hour per direction. overall trip time is about 80 seconds on the average. Equivalent speed is about 10.5 miles per hour or 3.5 times walking speed.

Transit hardware is being supplied by Westinghouse Electric Corporation under a $3.5 million contract. This will be their fourth revenue system and also represents the fourth model of their design. Construction is being procured locally. Total capital cost of the system is estimated at $6.7 million. Operating costs have been forecast at $300,000 per year.

Patronage is forecast to be 5.1 million in 1980. A fare will not be charged. Operating cost will average about 6¢ per ride. Total costs of capital, interest and operation are not available but would probably be about 15¢ per ride.

Safety and reliability specifications exist but experience with this design "is lacking. The commendable record achieved by Sea-Tac should be equalled or surpassed.

BUSCH GARDENS

Anheuser-Busch is installing *a* loop transit system at Busch Gardens, Williamsburg, Va., with a planned opening in June 1975. The system will provide transportation services as well as an overview of the park. The single loop will be 7,000 feet long and will contain two stations.

Westinghouse Electric Corporation is the supplier. This is their third revenue system. The system will employ a single two-vehicle train similar to those at Miami International. Normal capacity will be 180 passengers per train—24 seated and 156 standing. Maximum commanded train speed will be 30 mph. With one train, system capacities will be 2,000 passengers per hour in the one direction served, Seven vehicles could be added to increase capacity to 9,000 passengers per hour per direction.

The cost has been reported to be $4 million.

DALLAS/FT. WORTH AIRPORT

In January 1974, the Dallas/Ft. Worth Regional Airport Board opened an entirely new airport which is the largest and most innovative ever developed. The Airtrans intra-airport transit system is an integral part of the *aiport* design and operations. It links the numerous widely separateT elements of the airport to transport passengers and material of various types.

The Urban Mass Transportation Administration has made important financial contributions to the project. In 1970 a grant of about $1 million was made to the airport to support studies and to finance test tracks by the two competing suppliers who were then favored: Dashaveyer and Varo. Later, in 1972, UMTA made a capital grant of $7.6 million to the airport to aid in the installation of Airtrans by LTV Aerospace Corporation.

Airtrans employs vehicles of two types—passenger and utility. When fully operational passenger vehicles will be used to serve airport employees separately from air travelers and airport visitors. The utility vehicles will provide several material transport functions using containers of various types.

Vehicles will operate over 17 distinctly different service loops as follows :

- 5 passenger loops:
  - 2 between terminals and remote parking.
  - 3 among terminals.
- 2 employee loops between terminals and remote parking lots.

2 Air Mail Facility loops.
4 interline baggage and mail transfer loops.
4 supply and solid waste loops which will operate only on slack period.

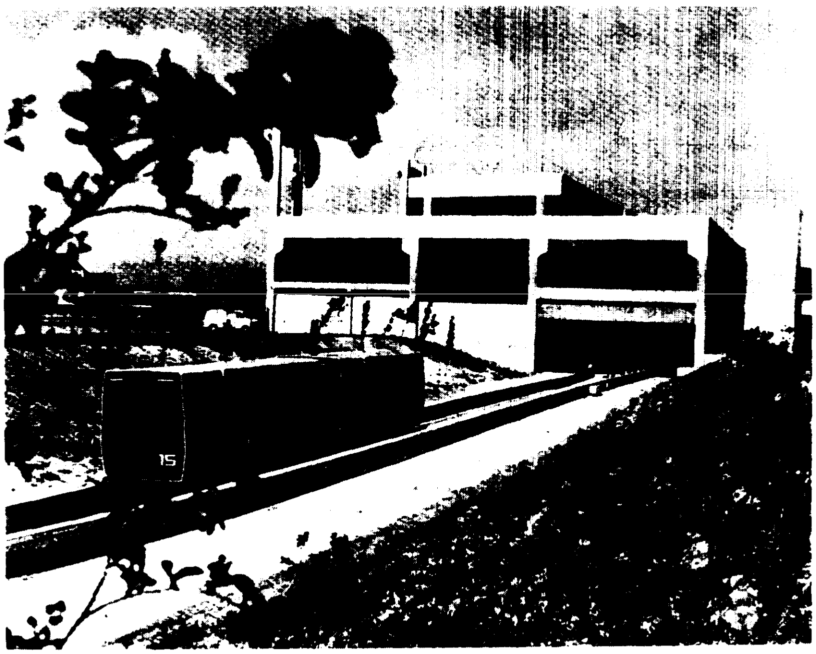
The Airtrans system includes the following major elements:

13 miles of one-way guideway (65,000 feet).
55 station stops:
  14 passenger.
  14 employee.
  27 material and other.
68 vehicles:
  51 passenger.
  17 utility.
74 switches.

Airtrans exploits switches for two purposes: to direct vehicles from the main line to off-line stations and to branch and remerge the main lines, These features allow the vehicles of various service loops to share a common guldeway network and allow some vehicles to by-pass en route stations while others stop to discharge and reload. Passengers must wait to board the correct vehicle but they proceed to their

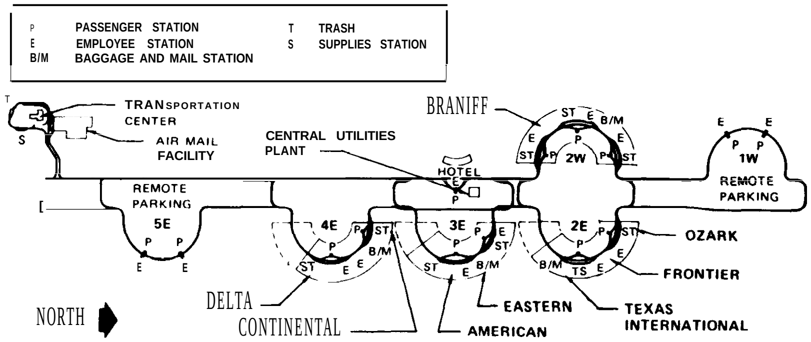
AIRTRANS SYSTEM DALLAS/FT. WORTH AIRPORT

(LTV Aerospace Corporation)

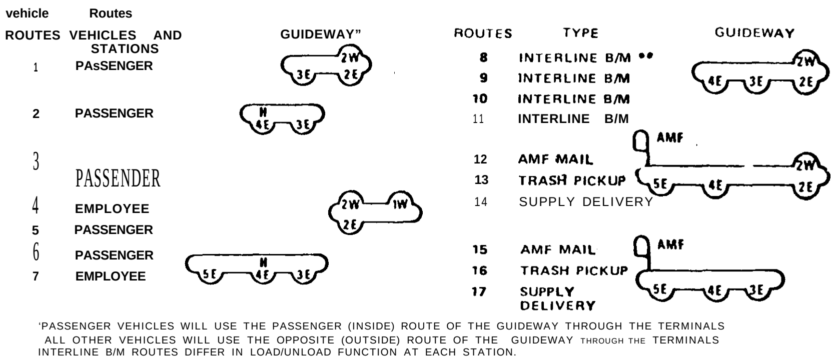


Vehicle Train on Passenger Service Route destination without transfers, in almost all cases, and with few station delays. These technical and operating features make Airtrans outstanding in size and complexity in comparison with all systems discussed above.

A schematic diagram of the guideway and the system's 17 distinct service loops is shown below.



Schematic Guideway Layout at Dallas/Ft. Worth



Distinct Service Routes at Dallas/Ft. Worth

Figure 3.—Schematic Guideway Layout of AIRTRANS, Dallas/Ft. Worth Airport, LTV Aerospace Corporation

The design of the airport makes walking distances short enough to be satisfactory for most air travelers and airport visitors. However, distances for trips to remote parking lots and to other airlines are so great that walking is not feasible and walkways have not even been provided. Vehicular service is, therefore, essential for some intra-airport travel as well as for all goods movements. When Airtrans is out of service, it is necessary to use buses, trucks, and other automotive vehicles.

Airtrans passenger vehicles are designed to accommodate 40 passengers—16 seated and 24 standing. Utility vehicles carry 3 containers. Vehicles operate singly and in 2-vehicle trains according to need.

The capacity of the entire system (all routes combined) is specified as 9,000 passengers, 6,000 pieces of luggage and 70,000 pounds of mail per hour. However, no single link would have to carry the full load. Specifications call for maximum speeds of about 18 mph. Average travel times should not exceed either 10 or 20 minutes depending upon the destination. Maximum travel times should not exceed 20 or 30 minutes.

Unexpected difficulties have been experienced both with the Airtrans system and with materials handling systems and procedures. Also, times available for interline connections were reduced by the airlines after Airtrans was designed and in operation. The time now allowed for baggage and mail transfers is beyond Airtrans capability. As a result only the five passenger services remained in regular use through the first year of operations. Buses have been kept on standby to provide service whenever stoppages exceed about 15 minutes. At the start of the second year buses were seldom needed. Automotive vehicles were used throughout the first year to transport employees and at times for all of the materials services. The airport has made plans to initiate all of the specified services except interline baggage and mail transfers in 1975. However, difficulties between the airlines, the airport board and LTV resulted in a crisis on March 6, 1975 and the system was shut down. Service was restored on March 17 under a new agreement.

The Airtrans system was designed, fabricated and installed by LTV Aerospace Corporation under a $35.3 million contract. The company has reported that costs have exceeded the contract amount by more than $18 million. LTV also has a contract to maintain the system for three years after it has been "conditionally accepted. " That period has not yet started to run because of the inability of the principal parties to agree upon the system status relative to the original specifications.

Total operating costs of the system are not available. However, there are indications that the costs of operating and maintaining Alrtrans plus the costs of providing stand by and alternative services are great enough to cause serious concern to the airport's major tenants, the airlines, and to the airport board.

Patronage was about 3 million during the first year, A fare of 25¢# is charged. Therefore, passenger revenue is now about $750,000 per year.

Reliability was an extremely serious problem for Airtrans at the outset. Statistical data are not available but considerable improvement has been achieved. The design of Airtrans with numerous overlapping service loops makes the operation of the entire system vulnerable to stoppage if a single vehicle or wayside element fails. All routes are one-way and there are few opportunitys for vehicles to by-pass one that is stalled. One vehicle cannot push or pull another. When mobile repair teams cannot restore a vehicle to service, a tow vehicle must enter the guideway and remove the disabled vehicle to an exit.

Safety has not been a problem for Airtrans. There have been no accidents or injuries of consequence to passengers.

The system accumulated more than three million vehicle miles in the first year of operation.

MORGANTOWN, WEST VIRGINIA UNIVERSITY

The Morgantown project is scheduled to reach operational status in mid-1975 with all features needed to support normal passenger service but without elevators needed for some handicapped travelers. The project has a long and complex history that can only be sketched here.

The project was initiated by West Virginia University" in 1967 and funds for a study were obtained from UMTA in 1969. In August, 1970, the University proposed a project to design and construct a system containing 3.6 miles of double guideway, six stations and 90 vehicles.

The umversity had two purposes:

- To establish a national demonstration facility for the study of technical, behavioral, social, economic, urban design and other aspects of automated guideway transit.
- To transport 17,000 students, 5,000 faculty and staff members, to better utilize facilities and staff, and to transport the people of Morgantown.

In August, 1970, UMTA took charge of the management and funding of the project as a demonstration. The physical scale of the initial phase of the project has since been considerably reduced. The route is now 2.2 miles in length, there are three stations, and a 3-way interchange has been eliminated. The design of the initial phase would allow for later completions of the full project.

The objectives reported by UMTA in 1974 were:

- To dimension the service benefits of systems of this type.
- To assess the institutional problems encountered in building such a system in the urban environment.
- To determine the costs to build, maintain and operate the system.
- To determine the impact of the system on congestion.

In October, 1972, the prototype version of the systym was successfully demonstrated to the public and press in a dedication ceremony conducted by Secretary Volpe. In the next few months tests were run using a fleet of five vehicles. As can be expected in R&D programs considerable redesign was found necessary and that work has been done. Fort}' -five new vehicles are being produced and are in various stages of testing. The entire system is to be tested in the spring of 1975. Successful completion of those tests plus minor tasks will end the contractors' present obligations. UXITA and the University have agreed on the conditions for accepting the present installation and for completing the system with capital grant assistance.

The Morgantown system now contains 2.2 miles of double guideway, three stations and a maintenance and operations facility. Vehicles can operate non-stop between any pair of stations. The intermediate station contains multiple paths and sidings arranged so that vehicles can pass without stopping or stop to discharge and reload. Some vehicles will stop and then continue in the same direction while others will stop and turn back.

The sy-stem will operate in both *scheduled* and *demand* modes. The *scheduled* mode is like other transit systems: that is, each vehicle will have a pre-determined destination. However, travelers will be advised by computer controlled graphic displays which vehicle to board. The *demand* mode is unique. The traveler will push a button or otherwise indicate his desired destination at the boarding point. The control system will make available a vehicle either by recognizing that an empty vehicle is already in the station load berth or by dispatching a vehicle from another source to provide the needed service. The value of the demand mode is relatively small with the three stations presently provided but will be considerable if and when the network is increased to include five or six stations as desired by the University

Vehicles carry 21 passengers—8 seated and 13 standing—with crush loading.

Morgantown Vehicle Gets Finishing Touches—wing Aerospace Company

The minimum headway is 15 seconds, which is equivalent to 240 vehicles per hour per direction. The maximum theoretical capacity is 5,040 pphpd. However, in practice, average headways will be longer than 15 seconds and average loads will be less than 21 passengers.

Actual loads imposed on the system will have to be determined by operating in revenue service. Peak loads are expected to occur during class change intervals at the University. Consequently, the maximum loads experienced will depend on the way classes are scheduled as well as on the number of passengers seeking to use the system. Present indications are that peak loads will be in the range of 50 to 80 percent of the theoretical maximum capacity-that is, 2,500 to 4,000 pphpd.

Vehicle speed is 30 mph maximum. Waiting time will not exceed 5 minutes in slack periods and 2 minutes in peak operations. Riding time from one end of the system to the other will be about 7 minutes for 2.2 miles or about 19 mph.

The Morgantown system was supplied by the Boeing Company with support from sub-contractors. UMTA's outlays to contractors and others are reported to total $64.2 million through June of 1975. Costs of administration are not known. The University has made cash outlays of about $1 million and has furnished or accumulated land from other public agencies for much of the right-of-way. Boeing has expended additional funds from company sources in an amount not announced to develop certain essential proprietary components and for all other work necessary to complete the tests. Operating costs have been estimated by the University and their consultants at an average level of $850,000 per year over a 10-year period based on 1972 prices. (Another source indicates costs of $970,000 per year, presumably in 1975 prices). This includes the cost of a work force of about 40 persons at labor rates supplied by the University. These cost estimates will have to be updated during the initial operation period.

Recent estimates prepared for UMTA indicate that patronage may be about 29,500 rides per day. Students would pay $5 per month for a transit pass along withother university fees, Other riders would pay 25# per ride. The University has expressed concern that operation costs for the 3-station system will exceed revenue by at least $500,000 per year.

hluch of the redesign accomplished in 1973 and 1974 has been devoted to reliability and safety assurance. Service availability is now specified at 96 percent. Components have been selected and redundant elements have been included as needed to satisfy that goal.

The system will not fail gracefully and few physical features have been provided to deal with vehicle stoppages. Vehicles are not designed to push or pull one another. There are limited sidings to hold defective vehicles. Cross-over switches are not provided to allow routing of traffic around a stalled vehicle. Stalled vehicles will be removed to the yard by a maintenance vehicle. With these features a 30-minute period of time will be needed to restore service. The physical design accentuates the need for high reliability. On the other hand, automatic software reactions have been included in the system design to minimize recovery time of a stopped vehicle and to reduce the system impact of a vehicle stoppage.

Guideways are heated to insure operating capabilities when it is precipitating below freezing temperatures, This feature is reported to have added $4 million to capital costs and $17,000 per year to operating costs.

Safety has received detailed attention in the design of the system. operational testing with multiple vehicles is scheduled to begin in May, 1975.

The Morgantown system has been developed only to about half of the scale orginally planned. Provisions have been made for expansion to the original design.

It appears that the cost of expansion of the Morgantown program will be in the vicinity of $40 to $50 million for a route extension of about 1.3 to 1.4 miles (15,650 feet of single lane guideway), 30 new vehicles, 2 new stations, expansion of one station, and associated software, power supply and other ancillary equipment.

Chapter 4: Who Wants AGT?

The panel has attempted to identify and question all of the publi" agencies and private interests that have given serious study and consideration to the purchase and use of AGT systems. In the time available it has not been possible to do a thorough and complete job, and consequently the information presented below is only a sample of a larger universe. However, data have been obtained regarding 36 agencies and firms who have shown interest in application of AGT systems. of these, six deal with metropolitan scale applications and 29 deal with major activity center applications.

The panel recognizes several deficiencies in the abbreviated presentation of interests in AGT systems. The list is incomplete. A showing of interest today does not mean genuine demand tomorrow—some agencies many never decide to make AGT installations. It was not possible, in the time available, to write descriptions of a number of projects for which data were obtained.

METROPOLITAN SCALE APPLICATIONS OF AGT

At least a dozen public agencies and a few private interests have studied the possible employment of AGT systems to serve major parts of a metropolitan region. The panel has obtained data from six such studies: four deal with metropolitan networks and two deal with corridors. The sponsors and locations are:

Metropolitan Networks

1. Regional Transportation District, Denver, Colorado.
2. Twin Cities Area Metropolitan Transit Commission, St. Paul, Minneapolis, Minnesota.
3. Comprehensive Planning Organization of the San Diego Region, San Diego, California.
4. Transportation Commission of Santa Clara County, San Jose, California.

Corridors

5. Port Authority of Allegheny County, Pittsburgh, Pennsylvania (TERL) project.
6. Private interests, El Paso/Juarez international link.

These projects, if executed, would require a capital investment of almost $7 billion: $6.7 billion for the four networks and $250 million for the two corridors. A more thorough canvass might easily turn up additional studies that would require a similar amount.

REGIONAL TRANSPORTATION DISTRICT, DENVER, COLORADO

Organization of the RTD was authorized in July 1969. It became a working entity in 1970 and launched an innovative transportation study in February, 1971. In January, 1972, a report was issued summarizing the year's work and making certain recommendations.

In March, 1973, a Summary Report was issued in which the installation of an automated guideway system was recommended together with improvements in conventional modes. mₑ term PRT was used in the Summary Report but in to today's vocabulary the system would be classified as group rapid transit or GRT. The technology was, in fact, quite similar to that employed at Morgantown, The system envisioned in 1973 would have included about 100 route miles of double guideway, 67 stations and a fleet of about 800 12-passenger vehicles. The total capital cost of the AGT system was estimated at almost $1.1 billion at 1973 price levels.

In September, 1973, the Region's voters approved a bond issue of $425 million to cover the local share-then one-third-of the AGT system plus buses and other improvements. The bonds are backed by a one-half cent sales tax which started in 1974. Under current legislation the local share is one-fifth rather than one-third, and the Federal Government might be called upon to supply capital grants up to $1.7 billion for a total program costing just over $2.1 billion,

Early in 1974 RTD contracted with a consultant to serve as system manager for the AGT program and other work, However, detailed work on the 1973 plan is not going forward because of concerns expressed by UMTA. Instead, RTD and its consultants are engaged in a restudy of five alternatives, including bus, light rail transit, conventional rail rapid transit, GRT and PRT. A report is being issued in the spring of 1975. As this report is written, it is impossible to say what the RTD will recommend.

TWIN CITIES AREA METROPOLITAN TRANSIT COMMISSION, ST.PAUL/MINNEAPOLIS

The Commission was created by the Minnesota Legislature in 1967 and was directed to develop a plan for a complete, integrated mass transit system for the Twin Cities area. Numerous studies have been made during the past 8 years dealing with short term and conventional transit modes as well as AGT systems. Since the early 1970's exploitation of AGT systems in some fashion appears to have been widely accepted by officials and citizens of the Twin Cities. However, controversy has raged over the level of technological sophistication to be sought, the extent of networks and location of routes and other matters.

The most recent study effort is now approaching completion and several reports and drafts have been released. The study has treated four system types which represent the entire spectrum of AGT technologj-.

Terms used by Twin Cities	*Equivalent OTA terminology*
Intermediate Capacity Rapid Transit -- ICRT	Shuttle and Loop Transit-SLT.
Group Rapid Transit - GRT ------- .._- -----	Group Rapid Transit (low technology level)—GRT-I.[1]
High Performance Personal Rapid Transit HPPRT.	Group Rapid Transit (high technology level)—GRT-II.[1]
High Capacity Personal Rapid Transit-HCPRT.	Personal Rapid Transit--PRT.

1 See the report of the Panel on Operations and Technology for definitions of GRT–I and GRT–II.

The Commission conducted its Second Technology Conference in November 1974 to solicit the advice of outside experts. Consensus of opinion of that group tended to discourage reliance on the PRT alternative (the system UMTA calls High Capacity PRT) on the grounds that it is not a viable option without a long-term development period and because of serious uncertainties regarding the end results. For example, it was estimated that 7 to 12 years would be required for research and testing at a cost exceeding $200 million.

Similar, if less serious, reservations were expressed regarding the high-technology GRT II system (called HPPRT by UMTA).

Attention was focused on a Base Network exploiting low-technology GRT I technology. The system would employ 16-seat vehicles and would have minimum headways of 12 to 15 seconds. These characteristics are similar to those of Morgantown and to Denver's 1973 concept. The most extensive network would include 81 miles of dual guideway, 114 stations and 2,100 vehicles. Capital cost would be almost $1.7 billion and annual operating costs would be about $94 million.

A system of the shuttle and loop type was also studied. It would use 40-seat cars and 60-second headways. A 60-mile system with 47 stations would have a capital cost of $1.3 billion and operating costs of almost $58 million per year. Because of its dependence upon well-proven technology, this system could begin operation in 1981, 2 to 4 years earlier than the most sophisticated alternative.

The Twin Cities study will not reach a final decision until an alternative analysis satisfactory to UMTA has been completed. It seems evident that the actual operating experiences of the Morgantown and Dallas-Ft. Worth Airport GRT systems during 1975 are likely to have a strong influence on the decision in Twin Cities. Serious difficulties with either GRT systems may tend to build support for the SLT alternative.

03[PREHENSIVE PL.4NNIN"G ORG.4NIZATIOh' OF THE SAN DIEGO REGION , CALIFORNIA

In December, 1974, CPO received a report from consultants outlining a transit development program for the period 1975 to 1995. The report treated buses in various applications, rail rapid transit, light rail vehicle transit and automated guideway transit. It outlined a number of staging strategies which would allow early action but would postpone technical choices until appropriate stages of the program. The concept would also allow for exploitation of technical advances as they evolve in the future.

The study treated an automated guideway transit system of the shuttle and loop type but indicated that provisions would be made for later upgrading to include off-line stations and other GRT features. The network included 59 miles of dual guideway, 57 stations and a vehicle fleet containing 17,500 seats (vehicle size was not specified.) The total capital cost was estimated at about $1.6 billion, including $50 million of development cost that would be avoidable if San Diego were not the first or pioneer user of the particular technology selected.

Under the consultant's recommended programs, choice of technology would be made at the end of 1976. The initial AGT capital grant from UMTA would be needed at the end of 1978. The first stage of the system would begin operation at the end of 1986, and the last stage would be completed sometime after 1995.

TRAN'SPORTATION COMM1SS1ON OF SANTA CLARA COUNTY, SAN JOSE, CALIFORNIA

The Commission was created to plan a county-wide rapid transit system. Consultants were hired in March, 1974, for a three-phase, study. A Preliminary Phase Report was submitted in October 1974, for review and discussion. The panel does not have the results of the review.

The Commission stated that one goal was to provide a transit system capable of attracting a major share of all travel in the county. More specifically, the Commissioners called for:

- Thirty percent transit ridership.
- Streets and highways carrying a number of cars no higher than there were in 1967.
- Encouragement of transit ridership by persons having a second family car.

This mandate is in sharp contrast with the current low level of transit usage and posed an unparalleled challenge to the staff and consultants, In fact, it would require transit to carry 1.8 million passengers daily in 1990 if popdation and employment grow as projected.

The consultants considered a variety of alternatives, including BART extension, extensive use of buses and bus ways, and two kinds of automated guideway transit.

The consultants' Medium Capacity Rapid Transit system was not specified in detail. It might turn out of be a member of the shuttle and loop class or a low-technology example of the group rapid transit class. It would employ' 20 to 30 passenger vehicles operating singly or in trains. Maximum speeds would be 40 to 50 mph and line capacities would be 10,000 to 15,000 pphpd. Headways are not specified and other features are open.

The consultants also studied PRT systems with characteristics that conform to the definition used by OTA in this report. This technology was treated in case studies but was not recommended—in part because of the long lead time needed for development.

Four cases were studied. The one which appears to be most appropriate would employ 140 miles of dual guideway, and about 140 stations. Capital costs would total $2.35 billion at 1974 price levels. Operating costs would be $160 million per year. It was estimated that manual controls could be substituted for automatic controls for am additional cost of $15 million per. year.

The consultants called attention to the urgent need for entirely new transportation systems to transport travelers short distances to and from transit stations and for other short trips. Neither scheduled buses nor dial-a-bus systems appear capable of supplying the needed service.

PITTSBURGH TERL PROJECT

In 1969, a plan was initiated by the Port Authority of Allegheny County for construction of a fully automated rubber-tired vehicle system in Pittsburgh, Pa. This system would operate as a double guideway shuttle with turn-back switches at the ends of the lines. The purpose is to provide line-haul service in a radial corridor focused on the rental business district. The proposed route is 10.5 miles long and includes 11 stations and one yard.

The vehicles envisioned are similar to the Westinghouse Transit Expressway vehicles used at Tampa and Sea-Tac but would not necessarily be from that source. Vehicles will run in pairs up to trains of 10 vehicles.

Each vehicle will be 35 feet long, about the same as a city bus, and will normally carry up to 66 passengers with 28 seated and 38 standing. Headway will be 2 minutes at the outset but reducible to 1.5 minutes. Theoretical capacity will be 19,800 passengers per hour per direction at the outset. Peak loads are estimated to be 15,000 pphpd.

Vehicles will have maximum speeds of 60 mph but will average 28 mph. With an average of one-minute waiting during peak hours a passenger would spend about 12 minutes on a 5-mile trip—the equivalent of 25 mph overall.

The system would operate 20 hours per day. The frequency of service would drop to 15 minutes in slack periods. That is more frequent service than is usually provided by manned systems, and even longer hours of service and closer headways might prove to be attractivc and economically' justifiable with automatic controls.

The cost of the system would he determined by competitive bidding. In 1974, the Authoritty's consultant estimated that all costs and contingencics would total about $232 million on about, $22 million per mile. operating costs were estimated at $5.7 million per year including $3.6 for labor and $1.2 for power. Patronage was estimated at 12.5 million riders per year. The fare would be 40¢ and would provide revenue of $5 million per year.

Detailed specifications were drafted for safety and reliability.

The plan envisions future projects to extend lines, add routes, add stations and shorten headways.

The TERL project has been the subject of political conflict almost from the start and has suffered a, number of delays. Its fate is uncertain at this time.

EL PASO/'JUAREZ

An international application of AGT has been planned between El Paso, Texas and Juarez, Mexico, by two privately financed organizations-International Monorail (corporation of the U.S. and Moncrriel Intelnational, S.A. of Mexico. In January, 1974, the firms selected Ford Motor Company" as their supplier.

The sponsors hope to operate the system as a business enterprise for profit and without public aid. Other stated purposes me to encourage tourism and commercial activity to aid in revitalizing the central business districts; to provide efficient, safe, economical and attractive service, and to relieve congestion.

The route would be 1.5 miles long and would be a single guideway except for by pass near the midpoint. The system will employ. four 70-passenger vehicles. Waiting time will average about 1 minute and travel time at a cruise speed of **40 mph will** be about 2.5 minutes. Overall speed will be equivalent to about 25 mph.

Patronage was estimated at 25,000 to 30,000 riders per day although frees were only specified as 25¢ to 50¢. The capital cost of the system was estimated to be about $15 million. Operating costs are not known. This project has been delayed indefinitely by financial difficulties.

MAJOR ACTIVITY CENTER STUDIES

The panel obtained information regarding some 30 possible applications of AGT systems in major activity centers. These have been grouped under the following headings:

. Airports.
. Central Business Districts/Center City.
. Multiple Purpose Developments.
. Medical Centers.

There has not been time enough to describe all of the studies. Some examples are presented for each type of application-others are only listed.

Capital costs of the group of prospective AGT applications cannot be estimated precisely but are in the order of $1 billion.

AIRPORTS

The panel has obtained information regarding AGT studies at airports in these nine cities:

1. Atlanta, Georgia,
2. Boston, Massachusetts.
3. Chicago, Illinois (O'Hare).
4. Detroit, Michigan (Metropolitan).
5. Los Angeles, California (Internatioal).
6. Oakland, California.
7. San Francisco, California.
8. New York, New York (JFK International).
9. Newark, New ,Jersey (Newark International).

The study for Newark is described here as all example of the class.

NEWARK INTERNATIONAL AIRPORT

Since 1966, the Port Authority of New York and New Jersey has planned to include a transit system in the terminal and grounds at Newark International Airport in New Jersey. Space for guideways and stations has been reserved. The primary purpose is to link the terminal complex with a station on a proposed extension of the PATH rail rapid transit line. Other purposes are to link three major terminal buildings with one another and to serve remote parking lots.

During 1971 and 1972 planning became specific and m 1973 technical proposals were solicited. The respondents were Westinghouse Electric Corporation, Rohr Industries, Inc., LTV Aerospace Corporation, and the Dashaveyor Company, a Bendix subsidiary.

The route would include a double guideway about 9,000 feet in length and seven stations. Vehicles would operate as shuttles but would use switches to change tracks at the ends of lines. Cross-over tracks at intermediate points would allow vehicles to turn back or operate around a stalled vehicle, A walkway would parallel the guideway to allow easy evacuation of stalled vehicles.

The terminal buildings were planned at a time when only the South Park prototype of the Westinghouse Transit Expressway system was in existence. Consequently, space was reserved for vehicles of about that size. Specifications call for vehicles to carry 36 passengers normally with 24 seated and 12 standing and up to 50 or 60 with crowding. The specifications called for 15 vehicles and 1 minute headways. Peak loads could be accommodated with headways of about 2 minutes and without crowding.

Vehicles would have maximum speeds of 35 mph and average speeds of 30 mph. Total trip time from the rail station to the first terminal would average 5.5 minutes-4.5 minutes in the vehicle and 1 minute waiting to board. The distance is 1.3 miles and the equivalent constant speed is almost 15 mph or five times walking speed.

In 1974 the project was held up indefinitely because PATH was delayed and because of the decline in air travel. Consequently, there was no call for priced bids. The Port Authority had estimated a cost of $35 to $40 million for transit hardware, guideways and other elements that had not already been incorporated in the terminal. Total cost was not estimated.

It was planned that the winning contractor would also maintain the system for 5 years. The cost of operations was not determined.

Patronage was estimated at 5 million trips per year, 16,000 trips per day and 1,000 trips in the peak hour. Capacity could be increased to about 4,0OO pphpd by- using two-car trains and by shortening headways to 50 seconds. Service would be provided 24 hours each day. A fare would be charged but the amount was not set.

Specifications covered numerous safety and reliability features. Requirements included:

- Operation in snow and ice storms.
- Walkways for evacuations.
- Non-combustible and fire retardant materials.
- Crash worthy' vehicle design.
- Cross-overs to allow operation around stalled vehicles.

CBD/CENTRAL CITY STUDIES

The panel obtained information on 9 studies dealing with AGT application in and near central business districts. The cities are:

Ann Arbor, Michigan.
Detroit, Michigan.
3. Las Vegas, Nevada.
4. Long Beach, California.
5. Minneapolis, Minnesota.
6. Mid-NIanhattan, New York, N.Y.
7. Lower Manhattan, New York, N.Y.
Norfolk, Virginia.
San Diego, California.

Descriptions for Los Vegas, Ann Arbor and San Diego are presented below.

LAS VEGAS, NEVADA

Efforts to install an automatesd guideway system in Las Vegas and Clark County, Nevada began at least as early as 1968. The purpose of the system was to improve transportation services among the CBD, the world-famous "strip", a convention center and the airport. It was considered desirable to relieve congestion on the streets, to make travel fast and pleasant, to achieve a degree of privacy by using small cars, and to enhance the image of Las Vegas.

The project has an extremely complex history that cannot be recited here. In the most recent episode proposals were submitted in February, 1973 by three firms:

- Aerial Transit Systems of Nevada, Inc., a venture of Pullman, Inc. and Bendix.
- Monocab, Inc., a subsidiary of Rohr Industries, Inc.
- LTV Aerospace Corporation.

LTV withdrew their proposal. Rohr Monocab was selected as the supplier in November, 1973. However, delays occurred and both the cost of the project and the availability of funds changed for the worse. A revised proposal was submitted in February, 1974, at which time the total cost was estimated at $103 million. In September, 1974, the county withdrew and other changes in participants occurred, leaving only Rohr and the City as parties to the negotiations. A reduced project was proposed and rejected by the City in December, 1974. The resolution under which the negotiations had been authorized was then rescinded.

This was an extremely expensive adventure for all parties involved, both public and private. For example, Rohr conducted promotional and engineering efforts over a period of about 5 years and spent something in the order of $1 million. other contractors must also have incurred substantial costs. Local agencies incurred considerable administrative expense.

In 1973 it was expected that patronage would be in the range of 18 to 20 million per year with an average fare of $1.40. The project was to be financed by sale of revenue bonds. A public trust was to be set up to facilitate the financing. None of this was realized.

According to Rohr's proposal, the route was to be 8.5 miles long with 24 miles of guideway. It included 18 stations, 140 vehicles and one yard. Stations would have been off-line and vehicles would have seated SIX passengers—many travel parties would have enjoyed a private ride without stops enroute. Privacy could be ensured by paying a special fare.

Vehicle maximum speed was 35 mph. The longest trip would have required about 16 minutes riding and less than 2 minutes waiting. Minimum headway was planned for 10 seconds. Maximum link capacity was 2,160 passengers per hour per direction. Practicable capacity would probably have been 20 to 40 percent less.

This would have been the first revenue system by Monocab. However, the company demonstrated a system successfully at TRANSPO 72 and also had extensive experience with a 2,20O foot test track at Garland, Texas.

ANN ARBOR TRANSPORTATION AUTHORITY [1]

This system would link the central business district of Ann Arbor with the University of Michigan's Central, Medical and North

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1 This study was one of the five concluded under a State of Michigan program called New Transit for Michigan Communities or New-TRAN for short.

Campuses, Dial-a-Ride stations, remote parking, and the AMTRAK station.

Phase I of the program would include 13,160 feet of guideway, 8 stations, a yard and shops, and four vehicles. The system study included provision for extension. The vehicles would have nominal capacities of 50 passengers including standees, top speeds of 37 mph and average speeds of 15 mph. Minimum headways would be about 2.5 minutes.

Patronage was estimated at 2,300 passengers per hour in the peak period, 20,000" passengers on an average work day, and 6.6 million passengers per year.

Estimated costs, in 1973 price, were $14.3 million for capital investment and less than $300,000 per year for operations. operating costs would average 4.4 cents per trip. Service would be free.

The project has not been carried forward by state and local agencies

CENTRE CITY, SAN" DIEGO

During the past two years the City of San Diego, California has conducted a series of urban design and transportation studies of the central city area, An urban design concept was developed; then, transportation systems linking the activity nodes were defined and alternative analyses and evaluations were made. The objective wm to enhance the urban design concept-make it happen-by providing efficient transit access/circulation services including service to peripheral parking garages and interfaces with regional transit services. Future objectives include a link to Lindbergh Field and options to extend the centre cit~' system to serve the region.

Four alternatives were considered: two using buses of different sizes and two using AGT s~stems. One AGT s~'stem was of the PRT t~-pc and the other represented the GRT t~'pe. The GRT s~'stenl was recommended.

The s~'stenl, with an airport link, would include 7.6 miles of double guidewa)', mostlj elevated, 20 stations, 75 vehicles and a yard. Vehicles would have top speeds of 35 mph. Enroute stops would reduce the average speed to about]4 mph. ~Tchicles would operate - singl~~ or in trains. Each unit would carr~~ 44 passengers with 22 seated and 22 standing. Headwa~" would be about 60 seconds,

Peak patronage in 1986 would be 31,000 passengers per hour distribllted o~~er all lines of the network. Patronage would be 256,000 riders for an average work da?' and 78.6 million riders per ~'car.

Costs, estimated in 1974 prices, were $74 million for capital investment and $2 million for operations in the first year. Cost of operations would avemge 3.3 cents per ride.

This project is active ancl is likel~: to be carried forward. There are, howe~er, differences between the clt~ plan and the overall regional])Ian in~ol~"ing the location of peri])heml parking but not the center city transit project per se. Resolution of the parking philosoph~~ can be achie~-ed. This transit project provides an excellent opportunity for the first phase of a multi-l) hased regional s~rstem. Viewed in this light, tile l)robabilitj- for implementation is high.

MULTIPLE PURPOSE DEVELOPMENTS

The panel obtained information on 8 studies dealing with possible applications of AGT systems in newly developed multiple purpose centers.

Their locations are:

1. Crown City, Kansas City, Missouri.
2. Echelon, New Jersey.
3. Cameron, Alexandria, Virginia.
4. Plaza del Ore, Houston, Texas.
5. Post Oak, Houston, Texas.
6. Southfield, Michigan.
7. Crystal City, Arlington, Virginia.
8. Interama, Dade County, Florida.

The latter project is described here.

INTERAMA

In 1972, the Inter-American Center Authority and other agencies began planning a new Cultural and Trade Center north of Miami, Florida on the mainland side of Biscayne Bay and near the northeast corner of Dade County. The center was to occupy about 300 acres of a 1,700 acre parcel of land. In 1973, an automated guideway transit system was incorporated in the plan,

The purpose of the system was to connect the Center with the Dade County Regional Transit System and other modes of public transportation, to serve remote parking lots, to provide circulation among the elements of the Center and to provide passengers with an overview of the area.

The route was to be 7,350 feet long and was to employ a double guideway. Vehicles would either operate as shuttles and use switches to turn back at the ends or would operate in closed loops. Seven stations were planned: two in the south parking area, two in the Center and three in the north parking area. One of the latter would also interface with a station of the regional transportation system. A Yard and maintenance area were included in the layout.

Technical specifications were issued in March, 1974, and bids were received in May. Proposals were received from Bendix, Ford, Rohr, Westinghouse Electric and Arrow Development. The proposed systems differed in many respects and consequently: the data presented here are drawn from a baseline system estabhshed by BRH Mobility ,Services Co., a consultant to Interama.

The baseline system would employ 31 vehicles, each with a capacity for 52 passengers. Vehicles would operate single or in trains of two or three cars. Vehicles were limited to maximum speeds of 28 mph. Dwell times were 40 seconds. Average speed for a typical trip was just over 9 miles per hour. Minimum headway was about 90 seconds. With three-car trains maximum capacity was about 6,200 pphpd. Peak loads were estimated at 10,800 passengers per hour m both directions. Patronage on an average weekday was about 69,000. Annual patronage was estimated to be 16 million.

Safety was specified in terms of automatic train control systems and fail safe principles. Suppliers were requested to state mean times between failures for major components.

Capacity could be expanded by adding cars and the route could be extended to serve other areas. Evaluation of bids was completed in August, 1974. However, by that time the Authority had encountered severe problems in raising funds and in the fall of 1974 the transit project was aborted.

MEDICAL CENTERS

A number of medical centers have conducted studies of automated guideway transit systems. Brief descriptions of four studies are included below. The locations are:

1. Detroit Medical Center Corporation, Detroit, Michigan.
2. Duke University- Medical Center, Durham, North Carolina.
3. The University' Health Center of Pittsburgh, Pittsburgh, Pennsylvnnia.
4. Texas Medical Center, Inc., Houston, Texas,

The objectives of these studies are similar in many respects and include the following:

- To transport passengers, patients and cargo within the complex and thereby make circulation easier and faster.
- To transport passengers to and from transit routes and remote parking thereby making access easier.
- To link the medical center with other nearby centers of activity.
- To reduce traffic congestion in and near the medical complex.
- To reduce the need for parking lots **and** garages especially within the densely developed areas of the medical complex.

DETROIT MEDICAL CENTER

The Center occupies a 97-acre site and is one of the nation's largest centers for medical services, education and research. It contains five major hospital and plans exist for expansion. Alternative AGT systems studied included two shuttle configurations and two loop configurations. One alternative single guideways and bypasses, and included one branch line. That system would have a route length of 1.8 miles, 10 stations of three types, 7 vehicles, a yard and a control center. Capital cost was estimated at $12 million. Operating cost was estimated at $185,000 per year. Patronage was estimated to be in the range of 58,000 to 69,000 riders per week in 1976 or about 3.0 to 3.5 million riders per year. Operation cost per trip would average about 5 to 6¢. A fare would not be charged.

DUKE UNIVERSITY MEDICAL CENTER

A study conducted in 1973 and 1974 described an AGT system to carry passengers and cargo. Initially the system would link the existing hospital and a planned 900-bed facility. It would be expandable to serve remote parking, transit stations, a V.A. hospital, and other facilities.

It would include guideways in tunnels, at grade and on elevated structures. Two intersecting loops were planned. A north-south loop would be developee in three stages and would eventually include 8 stations, An east-west loop to be developed at some later tim would include 7 stations.

Passenger vehicles would accommodate up to 35 riders and would be able to carry patients on stretchers. Five passenger vehicles and two cargo vehicles would be required on the north-south loop.

Vehicle top speed would be 31.6 mph. Average speed would be 8.5 mph. Minimum headway would be about 2 minutes.

Patronage was estimated at 2,200 passengers per hour in peak periods, 18,000 passengers on the average day, and 5.6 million per year. Average operating cost would be 3¢ per trip. A fare would not be charged.

Decisions are forthcoming relative to the construction of the hospital expansion and connecting transit link, pending the development of an acceptable financing program. Under the present rules, private financing would be necessary if the University acts alone. Sponsorship by a public agency may emerge at some later time.

THE UNIVERSITY HEALTH CENTER OF PITTSBURGH

A study conducted in 1971 and 1972 described an SLT system employing 2,400 feet of double guideway on elevated structures, three stations, three vehicles and a yard. The system was expandable to include five stations and could be extended further to serve other facilities and transit stations.

Vehicles would have top speeds of 35 mph and would carry 35 passengers.

The system would carry 2,000 passengers in the peak hour, 14,000 on an average work day and 4.2 million riders per year.

Cost estimates in 1972 prices were $7.7 million for capital investment and $190,000 per year for operations. The average operating costs would be 4.4¢-per trip.

TEXAS MEDICAL CENTER

Texas medical Center contains 28 member institutions and attracts tens of thousands of visitors and staff members daily. A study conducted in 1972 and 1973 considered installation of an automatic guideway transit system of the loop type. dual guideway and 10 stations would be placed on elevated structures. Passenger vehicles would carry 16 seated passengers and up to 19 standees. Patients on stretchers could be carried and cargo vehicles would be provided. l'chicle speeds would reach a maximum of 35 mph and would average 15 mph. Headways would be 90 seconds.

The system would carry- 5,500 passengers in the peak hour mnd 26,400 passengers on the average work day. Annual patronage would be almost 8 million riders.

Capital cost of the transit system would have been almost $12.5 million in 1972 prices. Operating costs would have been almost $380,000 per year. operating cost per rider would be 4.8¢.

The plan contemplated extension to connect the medical center with other major activity centers.

Inability to finance the project has prevented construction.

Chapter 5: Who Supplies AGT?

The 17 AGT sytems now in existence in the United States have been supplied by SIX firms who remain in the business and one group formed for a single project (Braniff International and others). The firms and number of installations are:

1. Westinghouse Electric Corporation, Pittsburgh, Pa., 4.
2. Universal Mobility, Inc., Salt Lake City, Utah, 6.
3. Rohr Industries, Inc. (Monotrain), Chula Vista, Calif., 2,
4. Ford Motor Company, Dearborn, Mich., 2.
5. LTV Aerospace Corporation, Dallas, Tex., 1.
6. Boeing Aerospace Company. Seattle. Wash.. 1.

Other firms have spent considerable time, effort, and money on the development of full-scale test tracks and vehicles, prototype systems, and temporary demonstration projects (such as TRANSPO '72). Some of the firms are believed to have stopped their programs or to have withdrawn entirely. None have yet been rewarded by sales of revenue passenger systems in the United States. Prominent members of this class are:

7. Otis Elevator Company, Inc., Transportation Technology Division, Denver, Colo.

   Rohr Industries, Inc. (Monocab), Chula Vista, Calif.

9. Alden Self-Transit Systems Corporation, Bedford, Mass.
10. Bendix Corporation (Dashaveyor), Ann Arbor, Mich.
11. Pullman, Inc. (Aerial Transit), Las Vegas, Nev.
12. Uniflo Systems Company, Minneapolis, Minn.
13. Mobility Systems and Equipment Company, LOS Angeles, Calif.
14. PRT Systems Corporation, Chicago, Ill.
15. General Motors Corporation, Transportation Systems Division, Warren, Mich.
16. McDonnell Douglas. Redondo Beach. Calif.

In other parts of the would, AGT development has proceeded in Europe, Japan, and Canada. Progress in these countries is the subject covered by another panel report in this study for the Office of Technology Assessment. The remainder of this chapter is devoted to the current situation for the United States suppliers and their appraisal of the AGT market.

WESTINGHOUSE ELECTRIC

The Westinghouse Electric Corporation of Pittsburgh, Pennsylvania has been a supplier to electric rail and traction companies for more than 85 years. It entered the AGT field in about 1961 when the Transit Expressway' system concept was announced. In 1963 Westinghouse entered into a contract with the Port Authority of Allegheny County and an agency later incorporated in the United States Department of Housing and Urban Development for the demonstration of the

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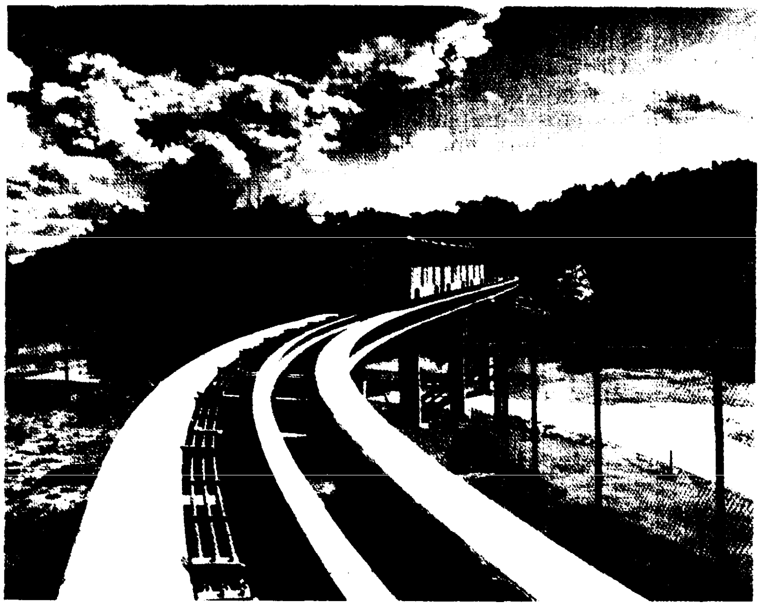
Transit Expressway system at South Park in Allegheny County. That demonstration opened successfully in 1965 and remains intact and operable.

The South Park Test Track is a closed loop 9,360 feet long, mostly elevated with a 1,000-ft. spur line at grade. It contains one switch, two stations and a maintenance and control facility. Vehicles are 30.5 feet long and normally accommodate up to 54 passengers—28 seated and 26 standing-or up to 70 passengers with crowding (See below). Vehicles run at speeds up to 55 mph on straight sections and at 2-minute headways. Vehicles can operate singly or in trains of up to 10 cars. Theoretical capacity of this system could be increased to 21,000 pphpd.

The system as used primarly for demonstration tests but on many occasions it was opened to visitors and for the Allegheny County Fair. A 10-cent fare was charged during Fair operations. In one 2-month period almost 41,000 passengers were carried without accidents of any kind. In one 10-month period the system logged more than 21,000 vehicle miles.

The total budget for the demonstrations between 1963 and 1973 was $7.4 million. The U.S. Government paid about $4.5 million, state and local agencies supplied about $1.7 million and Westinghouse and other contributing companies paid about $1.2 million.



Transit Expressway System Vehicle-Westinghouse Electric

Substantial amounts were spent by Westinghouse to develop a switch and to develop second, third and fourth generation models of Transit Expressway. The company is a major supplier of transit components and has established two new manufacturing facilities and a new Transit Expressway test track near Pittsburgh.

The company reports that it has spent a total of $35 million on the development of Transit Expresswau and related transit technologies. Development funded by government agencies has been about $6.2 million.

The Transit Expressway at South Park was the prototype for four revenue systems described elsewhere in this report:

1. Tampa International Airport, Florida.
2. Seattle-Tacoma Internatioal Airport, Washington.
3. Miami International Airport, Florida.
4. Busch Gardens, Williamsburg, Virginia.

Company representatives indicate that this work has not all been profitable but specific data are proprietary.

Westinghouse has competed for a number of jobs that were not awarded or that were won by other firms. Among these are:

Interama (aborted by client just short of selection of supplier).
Bradley International Airport (won by Ford).
Morgantown (won by Boeing).
Dallas-Ft. Worth (won by LTV).
Newark International Airport (delayed by client).

The company will be able to compete for the Pittsburgh TERL project if it is ever carried forward.

Bid and proposal costs have ranged from $25,000 to $250,000 per project. A total figure was not supplied.

Westinghouse representatives call attention to the fact that the company has invested a significant amount of its own funds to meet the predicted demands for new transit markets. An AGT system of the loop type-the first Transit Expressway-was originated by Westinghouse in response to requests by Pittsburgh planners, the City of Pittsburgh and Allegheny County and was designed for medium density rapid transit corridors. Automatic train control (ATC) was seen as a vital subsystem for Transit Expressway.

The market for conventional rail has developed much more slowly than projected. In Los Angeles, Seattle, Houston and New York State it lost out on voter referendums. AGT systems using rubber tires have been proposed for metropolitan application, such as in Pittsburgh, Honolulu, San Juan, Miami and Baltimore but have also been used as the scapegoat of political in-fighting among vested interests. Those who object to the innovation of AGT systems do not face up to the fact that Westinghouse can point to outstanding successes wit h such systems.

The overall business atmosphere for AGT marketing has been troubled. There has been shifting emphasis and lack of clear policy at tile federal level, lack of knowledgeable leadership at the federal and local level, continual project postponement, irresponsible political squabbling, uncontrolled project delays, ambiguous specifications, lack of standards in general and particularly regarding safety performance and measurement, one-sided contract terms and conditions, inflation, lack of funds, high interest rates and public apathy. To make matters even worse, the Federal government has used its funding power to bring forth more potential suppliers into the market place than the market has been able to provide with business opportunities.

The number of companies that have left the transit industry after long histories or that have entered and abandoned the field within the past few years attest to this.

The transportation business has not produced the profit or the return on investment for Westinghouse that could be achieved in other businesses. Consequently, there are periodic corporate reviews to determine whether to stay in or get out of the business. Westinghouse has made a special study of the market and marketplace over the past four years. So far the results have indicated that a definite shift of emphasis is necessary if government and industry are to serve the needs of the people.

Company representatives feel that the needs for transit have been incorrectly assessed by extremists on both ends of the technological spectrum: the case has not been made for revolutionary transit concepts like PRT nor will it be sufficient just to spend billions of dollars of government money to modernize transit cars and buses with air conditioning and the like, They favor a moderate course, one which will utilize new concepts while at the same time improving existing facilities.

The immediate problem really boils down to the ills of urbanization. The transit industry can aid in improving the quality of urban life by using good innovative transportation methodology and proven transit technology. This does not mean that the development of new technology should be neglected but rather that the realistic market needs of today, and in the near term, can be addressed without quantum leaps into unknown technologies. Westinghouse is against standing still, as is evidenced by the fact that it is first in the field of AGT. But the company also favors orderly, well thought out, evolutionary improvements with proper emphasis on real market needs and several application methods.

Specifically the quality of urban life needs to be improved first in the major centers of urban activity, such as the central business districts, suburban centers, air terminals, medical centers and universities. Such centers have pressing needs and warrant particular attention.

Westinghouse representatives suggest that AGT applications must start with the major activity centers and expand outward, rather than concentrate on regional urban mass transit networks while ignoring the dire need for urban center mobility. AGT vehicle systems in major activity centers can intercept automobile, bus and train passengers at convenient transfer points and prevent the stuffing of major activity centers with street vehicles. This shows promise of capturing a much larger share of the passenger-trip market and continuing to utilize the automobile and commuter buses and trains for the functions they are presently performing satisfactorily. AGT must be planned and integrated with parking, street uses, pedestrian-ways, buildings, commerce and security systems for it to make a significant impact on urban life styles.

Westinghouse is optimistic about many aspects of this business. More than the people of an~~ other nation, the American people are quick to adjust and to support a good product or service where they are free to make a choice. However, an alternative to the automobile must be given urban residents that is a good *competitive* choice, not just a new item of hardware or a repainted vehicle.

Westinghouse is optimistic about the technology that is available today. Automated guideway systems of the shuttle ancl loop types and modest extensions of that technology will perform most of the functions that can be foreseen for urban centers. Higher speed versions of the same system types can perform the functions of rapid transit as well.

Westinghouse is pessimistic about the viability of the whole "PRT" concept. The necessary automatic control system alone to control a short-headwa~r small car PRT system, as proposed by the PRT purists, is not going to be available in the foreseeable future without seriously degrading our safety philosophy for operating public system-

Even at that, the cost of developing and supplying such a system looks prohibitive. The signs that a realistic market for PRT exists are not evident and, as a matter of fact, it seems to be an ill-conceived solution, looking for a problem to solve.

Westinghouse believes it is reasonable and proper to expect a stable and non-hostile environment in which to do business. It expects good and fair competition—the lack of competition can be worse than too much because public bodies will not ordinarily buy a one-of-a-kind product or deal with a single source. Westinghouse expects to work to competently written specifications and to meet well defined standards. Ambiguity makes the risks of doing business unpredictable and uncontrollable for a, supplier. Finally, Westinghouse expects to meet its corporate business objectives or to find another business in which to invest its limited resources,

Westinghouse representatives express concern about the employment and productivity aspects of the AGT business. Transportation is a labor-intensive industry both from the standpoint of the system owners and the supplier. Westinghouse is working hard at standardization and cost reduction to increase productivity and offset the impact of inflation. Westinghouse employment, like that of its innumerable suppliers required to support its manufacturing operation, fluctuates with the workload.

Dollar volumes traditionally fluctuate widely in this industry, For example, they may be $15 million one year and $60 million the next. This has a serious effect on employment, employee morale, retention of seasoned, experienced professionals, and, of course, development funding and limits. Present plant facilities could support a substantial increase in direct employmlcnt. Westinghouse has mapped out growth to broaden its product base and to reduce severe fluctuations. Political and economic influences have thwarted this effort time and time again.

With regard to changes in Federal programs, Westinghouse representatives have expresse these views: the conpany believes that much of the R&TD monies spent so far have been spent on projects which have overlapped previous efforts, demonstrated concepts of questionable values and marketability or have had as their main objective putting new' suppliers into the business. It is highly questionable to use MD funds to create new competitors to established suppliers.

Prior to undertaking development programs, Westinghouse suggests that the responsible federal agency or department evaluate the pro-

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gram with a sufficient cross-section of industry to insure the marketability of the results. Significant influences in the transportation market include:

Users—the consumer.
Transit properties, both private and public.
Labor.
Suppliers.
Land developers and redevelopers—both private and public.
Property owners.
Municipalities.
States.
Federal.

The program must define what is needed and the procedure to be followed to insure meaningful results. Long-term and short-term programs should be clearly identified with the markets they are intended to serve.

The federal level should provide national standards for transportation, particularly on matters of safety. In conjunction with these standards, formalized procedures must be provided to determine whether or not they have been met. "Certification" is not recommended because it would have a detrimental effect on the marketability of valid new ideas.

The federal level should continuously and realistically monitor and document the state-of-the-art in the transit industry. It should estimate and publish the amounts of time and the costs needed to develop new systems or subsystems. This would allow planners, consultants, transit properties and governmental interests to be more objective in assessing technology.

Westinghouse representatives feel that R&D should be directed to solving real, near-term consumer problems. The HPPRT is viewed as a program to develop a system which may have no realistic, economic application. Further, they feel that the "Standard Light Rail Vehicle" (SLRV) has been endorsed by UMTA as a favored rapid transit alternative for the United States. In view of the fact that the "Transit Expressway" vehicle system has logged a considerable number of revenue passenger miles at Tampa and Seattle, they feel it would be reasonable for UNITA also to endorse Transit Expressway as an equally viable alternative.

UNIVERSAL hfOBILITY

Since 1963, Universal Mobility, Inc., Salt Lake City, Utah, has been associated with Habegger, I.tcl., Thul], Switzerland, in the development, fabrication and sale of the Minirail AGT systems in North America. The first three systems of this type were installed at EXPO Lausanne in Switzerland in 1964. Additional systems were installed at Munich, Federal Republic of Germany, in 1965 and at Blackpool, England in 1966. Three systems were installed at EXPO '67 in Montreal, Canada, and two are used in Japan. Six systems have been installed in the United States between 1969 and 1975 (See list in Chapter 3). Proposals were made and lost for the Sea-Tac airport il~stallation and for a TRANSPO 72 demonstration.

The development of this system hm been accomplished by Universal Mobility and Habegger without UMTA assistance. Owners of the United States systerns iuclude one state government and five private firms. None of the instillations received capital grants from UMTA. Approximately 10 percent of the cost of each system is used to purchase imported components while the remainder is for United States goods and services-much of which is from local sources.

The company's experience has been mainly with fairs, expositions and recreation parks. However, these automated systems are suitable for use in urban public transportation services and such applications are under study. Vehicle bodies have been designed to meet the needs of the buyer-some are open and some are enclosed and air conditioned.

A representative of the company has estimated that the capital cost of the American systems (United States and Canada) totals $30 million. Patronage totals 125 million rides. He reported that there have been no accidents of consequence to passengers.

FORD

Ford Motor Company, Dearborn, Michigan, began a development program in AGT systems in 1970 with a decision to construct 650 feet of test guideway. During 1971 and 1972 they supplied one of the TRANSPO '72 demonstration systems and operated it successfully, carrying 25,000 riders, That system included two stations (one on-line and one off-line), 750 feet of guideway, and two 24-passenger vehicles. The company received partial reimbursement from UMTA for the construction and operation of the TRANSPO '72 demonstration; however, all AGT development work by Ford has been privately financed.

In February, 1974, the company completed its Cherry Hill Test Facility on a 230-acre parcel of land near Dearborn. It includes an 0.8 mile loop, a 600-foot off-line station lane and a maintenance control building. These facilities allow testing vehicles at speeds up to 35 mph. With expansion of the facility the track will be able to test vehicles at speeds of up to 60 mph. The vehicles for revenue installations will be tested at Cherry Hill. The facility. has been in continuous operation since February 1974 at levels of manning ranging from one to three shifts.

The company is now installing two systems for passenger service-one at the Fairlane Town Center near Dearborn and another at Bradley International Airport near Hartford, Connecticut. (See discussions above.) These systems are a second generation model of the TRANSPO 72 design and have incorporated many improvements. The total capital cost of these two projects is about $9 million.

Ford has competed for two jobs that have not been executed. They were selected for the El Paso Juarez job, which would have cost about $15 million. However, the project has been delayed by difficulties in financing and may be aborted. Ford competed against three other firms for the Interama project. The proposals were evaluated but no award was made because of the inability of the client to finance the project. Some $500,000 has been expended on bids and proposals.

Ford has guarded optimism regarding the future market for automated transportation systems. There is a need for new systems offering increased mobility in congested areas. However, there is no present mechanism by which the federal government is effectively stimulating the development of this market. The future of the public sector market depends almost entirely on the leadership and direction which must be supplied by the federal government.

There is a latent need which has been estimated by a number of published sources as between $2 and $5 billion over the next twenty years. Exactly how and if the market develops will be largely the result of responsive federal policy.

There are some indications that the automated transportation system market is beginning to develop. During 1974 approximately $400 million in new business opportunities were under active consideration. It is significant, however, that only $1 to $2 million in new systems was awarded.

Government must provide leadership and direction in solving national transportation needs. Industry will respond if the risks and returns are favorable compared to alternative investment opportunities. It is not enough for the federal government to sponsor prototype development and to expect industry and transit authorities to shoulder the remaining risks and expenses. The uncertainties regarding additional development expense and eventual product marketability represent an unacceptable risk to industry.

The deployment of urban AGT demonstration programs must be encouraged and sponsored by the government. Only when the social and economic consequences of meaningful deployments are known will the marketability of AGT be established. The government can encourage demonstration programs by offering capital grants to communities with suitable applications. The present cost-effectiveness criteria governing capital grants should be relaxed in recognition of the high costs associated with early installations and in view of such factors as economy of scale and relative product maturity.

ROHR I$IONORAIL

Facilities of the Monorail System Division of Rohr Industries are located in New Jersey near Wildwood and Cape May. The product line of this division was acquired from Westinghouse Air Brake (WABCO) in 1972, and WABCO had acquired the product line from Universal Design, Ltd. in 1968. The entire history of the product line goes back to about 1960. Facilities include a manufacturing plant and office and three test tracks in New Jersej-. Each track includes an operating switch. The test tracks accommodate the three models in the product line. Rohr Industries has expended $850,000 on system development including product rights.

The Division has produced two full~' automated passenger carrying systems: Houston International Airport, Texas, and Pearl Ridge, Honolulu, Hawaii, both described elsewhere in this report. Two other s~*stems were designed for manual operation with automatic control features as a back Up: the San Diego Animal Park in California and the Bronx Zoo in New l"ork. In addition the Division and its earlier entities have produced 10 passenger carr~'ing s~wtenls that depend entirel~' or almost entirel~r on manual controls.

The Division has bid and lost two projects: Dallas-Ft. Worth Regional Airport and Bradley International Airport. They have also bid two jobs that have been delayed or aborted: Newark International Airport and Interama. Costs of bids and proposals were not disclosed.

Representatives of the company have a guarded outlook for the future. The current Rohr Monorail products, now in passenger service, are of the shuttle and loop type and are suitable for major activity centers where modest speeds are acceptable. There are many potential urban sites where systems costing $1 to $2 million could produce valuable services. Examples are central business districts, airports, medical centers, universities and government installations, Lead time for design and installation is short-about 18 months. The company could supply 3 to 4 systems per year now and could increase output as sustained demand Increases. From the supply side, there would be few problems in delivering several dozen small systems with a total value of $50 to $100 million within 5 years. The difficulty is that potential buyers must overcome complex institutional problems and raise money before the latent demand becomes effective.

The Monorail products do not require research and development for urban applications although better components and improved designs are possible. It would also be useful to have advanced approval of the designs by UMTA in anticipation of receipt of applications for capital grants but that problem has not yet been encountered.

LTV

LTV Aerospace Corporation, Dallas, Texas has been active in the AGT field since about 1970 but their main endeavors have been associated with the Airtrans installation at the Dallas/Ft. Worth Airport. (That installation is described above.)

LTV received authority to proceed with the Airtrans project on August, 2, 1971 and began providing services on some routes less than 30 months later on January 13, 1974, in time for the airport opening. The speed with which this project was conducted borders on the amazing and reflects great credit on the firm. This can be put in perspective by reciting some of the milestones of the project:

- August 1971—Authorized to proceed.
- February 1972—Broke ground for guideway.
- May 1972—Ran prototype vehicle on guideway.
- September 1972—Conpleted first production vehicle.
- February 1973—Operated vehicle in a closed loop.
- March 1973—Conducted first completely automatic route operation.
- September 1973—Completed the 13-mile guideway.
- January 1974—Started inter-terminal passenger service 15 hours per day when airport opened.
- February 1974—Extended passenger service to remote parking.
- March 1974—Inaugurated services to Air Mail Facility.
- May 1974—Logged millionth vehicle mile.
- June 1974—Began 24-hour service.
- December 1974—Logged three-millionth vehicle mile.

The time limitations for the project and the need to make decisions quickly and to act upon them at once left many problems unsolved when the airport opened. Only a miracle of technical achievements could have avoided such troubles.

LTV has conducted a large and costly program to redesign and retrofit troublesome elements and to maintain the system. In its 1974 annual report the company indicated that it had written off just over $18 million in Airtrans costs over and above current contract coverage.

Although great progress has been made in the 15 months since opening, Airtrans has not provided a number of the services for which it was designed. Some of the deficiencies can be attributed to difficulties still experienced by Airtrans equipment but others are the result of external forces. For example, Airtrans met the airport's specifications regarding timely movements of mail and baggage among terminals but the airlines shortened the time available for interline transfers after Airtrans was designed and operating. It appears that a considerable revision of the Airtrans routes and other features will be necessary to meet the new requirements. Also, the equipment and procedures used with the utility vehicles to discharge and reload containers carrying mail, baggage and other material have not always been prompt and effective, Resultant delays disrupt other schedules and cause further delays throughout the system. Because of various technical and operating difficulties and disagreements regarding financial matters, relations among LTV, the airport and the airlines have become increasingly strained, A breakdown of relations occurred on March 6, 1975 and LTV discontinued maintenance of the system. This made it necessary for the airport to shutdown operations. Operations were resumed on March 17 under a new agreement.

There is considerable danger that an opportunity of very substantial general value to the Nation will be lost in this situation. LTV has undoubtedly learned many valuable lessons and is in the best position to carry the learning process forward. However, institutional sponsorship does not exist and funds are not available to do additional work directed at both local and national objectives or to publish and disseminate such information, The local situation makes it almost certain that initiative for a program aimed at national interest and needs will not come from the parties on the scene.

UMTA might provide such a service. UMTA has participated in the Airtrans project at three stages. A grant was made in the late 1960's for technical work and testing by two firms other than LTV. In 1972, a capital grant in the amount of about $7.5 million was made to aid construction. Recently, UMTA has opened discussion with the airport and others with a view toward conducting a technical and operative assessment of the project. This is envisioned as a limited effort involving UMTA staff and support from Transportation Systems Center and others,

In the view of panel members it would be worthwhile to consider the possibility of greatly increasing UMTA participation in Airtrans beyond that originally envisioned. Assistance could bc of three kinds:

- Technical studies to more accurately specify the needs for service in light of a year's experience.
- **R & D** projects to improve the system design and to introduce second-generation components.
- Capital grants for alterations, improvements and enlargements of the physical system and studies of user and public acceptance.

The results of a successful program along these lines together with full documentation and display of results would be of value to many other potential users of AGT systems and to other suppliers as well.

LTV has been involved in other AGT work. The firm proposed in competition with three others on the Newark International Airport project described above. A selection was not made and action on the project has been postponed indefinitely. The company also proposed on the Las Vegas project but withdrew from the competition before a selection was made, The firm has affiliations with French and Japanese firms. LTV has expended almost **$30** million in company funds on ground transportation developments of all types, mostly on Airtrans.

Company representatives express the view that the money spent by the Department of Transportation on R & D is too low in relation to the money spent for capital assets. They are of the opinion that industry should bear a part of the costs of R & D but there is not much incentive under present market conditions.

Representatives of the company feel that UMTA should support development of components to achieve much higher reliability than now available. This was identified as a critical deficiency since many shelf components do not have known or predictable mean times between failure, and vendors have little incentive to subject them to the costly tests that would be needed to make the estimates. “Certification” at the component level might be undertaken by UMTA. The company endorses estimates of others that the cost of developing a GRT system suitable for regional-scale deployment till be at least $50 million and that. developing high technology PRT systems may require 10 years and cost $250 million.

Spokespersons indicate that the lack of a well established and dependable procurement process is a serious limitation. There is a need to examine various alternatives, including those used in defense and aerospace procurement, ordinary commercial transactions, commercial aircraft procurement and the earlier practices of the transit industry such as the cooperative drafting of specifications for the President’s Conference car.

BOEING

The Boeing Aerospace Company, Seattle, Washington, made in-house studies of AGT systems as early as 1962, but Morgantown has been their main effort. In February 1971, Boeing bid on two elements of the project: the vehicle contract, which they won in May, and the command and control systems, which they lost to Bendix. In August, 1971, they contracted with UMTA to add the system management function which had previously been assigned to Jet Propulsion Laboratories, California Institute of Technology, Pasadena, California. The Morgantown project is described elsewhere in this report.

The cost of the entire project to UMTA is reported to be $64.2 million. major Boeing subcontractors received $25 million for guideways and stations and $7.5 million for command and control. One element of the Morgantown system—the vehicle command and control system-was developed by Boeing with company funds and remains proprietary.

The end date of Boeing's current contract is June 30, 1975. They are now training University personnel to maintain and operate the system. When all of the company's obligations are discharged—which could be later than June—Boeing plans to relocate the staff to Seattle.

Members of the panel have expressed the view that Boeing has learned much that would be of value to the Nation and specifically to prospective buyers and suppliers of GRT systems. The firm is well situated to learn far more by continuing work at Morgantown through the initial operating stages. Early withdrawal would be wasteful of experience and detrimental to the R & D purposes of the project. It would be in the national interest for Boeing to be retained under contract at Morgantown to operate the system until it is thoroughly debugged and until maintenance and operation become routine. It would also be appropriate for UMTA to finance Boeing in the conduct, of redesign and retrofit programs which are certain to be needed at least in some degree. These activities might profitably extend over a period of 2 or 3 years. During that period technical, operating and economic information regarding the project should be documented in reports and otherwise made available to outsiders including competent professional personnel, prospective buyers of AGT systems and suppliers of components and systems.

Other than Morgantown, Boeing has constructed a test track at the Boeing Space Center in Kent, Washington. Its purposes include functional test and checkout of the Morgantown vehicles as well as evaluation of application developments and technology advancements, and display of operating vehicles to visitors. The track contains a simulated station, a variety of geometric sect sections and a number of switches.

Boeing bid and lost the Toronto Zoo project and the Bradley International Airport project. The company is affiliated with Japanese interests and is participating in the EXPO 75 transportation system on Okinawa. That system is based on Morgantown technology and represents a $10 millon return on Morgantown investment in the form of positive balance of payments. Boeing-Vertol was recently awarded one of three UMTA contracts for High Performance PRT studies.

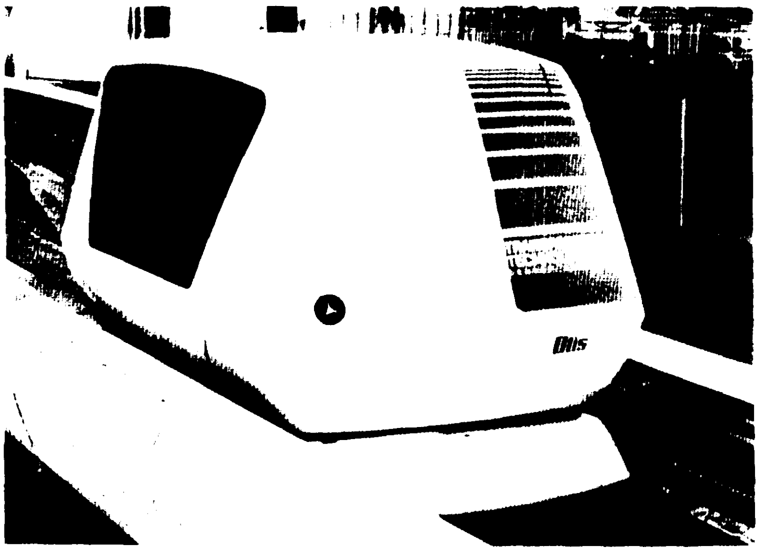
Boeing spokesmen indicate that the firm does not have a clear picture of where the market is going. There is no national policy —no long-term plan or direction. UMTA has confused industry about opportunities. Boeing, like other firms, is always prepared to do work on a cost-plus-fixed-fee basis but does not want to put up large "front end" investments for A GT systems under prevailing market conditions. After the market has been verified the company would consider private funding of system development if it were coupled with a "certification" procedure by which products could pre-qualify for capital grants. UMTA-funded research on components, theory, etc-–the NACA/NASA role in civil aviation--would be welcome. Efforts to establish configuration standards would be premature at this time.

OTIS-TTD

The Transportation Technology Division of Otis Elevator Company is located in Aurora and Denver, Colorado. The Division and its earlier entities have been engaged in the AGT business since 1968 and founders of the firm had done related work at General Motors for several years. Two test facilities were built near Detroit, Michigan, in 1969, and a third exists near Denver, built in 1971. An Otis-TTD system was demonstrated at TRANSPO 72 (see below) and was subsequently' tested there. Four test vehicles have been built.

Otis-TTD systems have exploited two advanced subsystems —-air cushion suspension and linear electric propulsion. Recent work has considered rubber tires and rotary electric motors as alternatives. Their designs have also featured a unique station apparatus-a *dock-which slides* the vehicle clear of the track to its loading position. Otis-TTD has spent more than $10 million on proprietary development and about $1.6 million on government funded demonstrations.

Otis-TTD was one of three contractors engaged by UMTA in 1973 for a preliminary study of dual-mode transit. They now have one of three contracts with UMTA to study HPPRT. The company has an association] with a French concern and has had negotiations regarding licenses with two ,Japanese firms. The company bid and lost two projects currently underway by others: Miami International Airport (Westinghouse Electric) and Bradley International Airport (Ford). They also proposed a system for Centaworld, Jacksonville, Florida which was not executed for lack of funds. Two other bids were made and withdrawn: Toronto Zoo, Ontario, Canada; and El Paso,/Juarez. The company has spent in excess of $600,000 on bid and proposal work.



Otis Linear Induction Motor (LIM) Vehicle at Transpo '72, Dunes Airport, Otis Elevator Company, Transportation Technology Division

Representatives of otis-TTD are optimistic regarding the future of AGT systems. They feel that economics will ultimately dictate driverless operation of transit vehicles. AGT will become a major business within the next 10 years after the current emphasis on buses has subsided. Private corporations have spent tens of millions of dollars on development but none has produced a system with sufficient reliability and sophistication to meet the needs of an urban area installation, It is clear that industry will not spend its own money to develop systems for a market which does not yet exist and for which no standards or specifications are set for capital grant support.

In their view it is appropriately that the Federal Government sponsor the development of systems at least through the engineering prototype level. Such development would establish a market for which industry could compete. Industry would fund development to bridge the gap between engineering prototype and production status. Such fundin g would be amortized by competing firms over a number of systems and installations in much the same way as developments for many commercial markets are presently handled (e.g., computer systems and other forms of automation such as material handling).

The federal Government should set standards for various classes of systems, particularly as they relate to passenger safety. The government should also maintain a continuing R&D effort to provide improvements in system and component areas. Such development would be available as public information to the industry and transit authorities.

Otis-TTD representatives believe that Congressional support of the proposed UMTA programs for Fiscal Year 1976 is especially crucial. Automated guideway transit systems can provide significant help in solving the congestion problems of our cities as wel as providing a means of transport dependent upon electrical energy which can be derived from other than petroleum fuel sources to assist in achievement of our national self-sufficiency goal. These systems can have stable operating cost characteristics and lower life cycle costs than labor intensive conventional systems or heavy rail systems. These judgments are obviously shared by other industrialized countries in the western world (Germany, France, England and Japan) where development of advanced guideway transit systems are well underway with government sponsorship. If our cities are to have the option to install automated guideway systems, it is essential that the U.S. Government support the development.

If such support is not forthcoming from the Federal Government in fisca] Year 1976, company representatives predict that the U.S. industry efforts will serlously" recede or disappear and that nothing constructive will be accomplished in the United States in terms of development over the next five years. At the end of such period we would probably find ourselves incapable of competing with foreign development and would end up importing foreign technology to satisfy our urban transport needs in order to keep pace with advancements in the rest of the western world. This would further exacerbate our problems with balance of payments and deprive U.S. industry of its rightful role in leading, at least in the United States, in automated urban transit.

ROHR MONOCAB

Monocab, Inc., of National City, California has been a subsidiary of Rohr Industries, Inc. since July, 1971. The firm's history goes back to 1968 when activities started as the transportation System Division of Varo, Inc., in Garland, Texas. Two test tracks were constructed at Garland. The longest was a 2,200-foot loop with one off-line station.

The conmpany installed a 1 ,900-foot loop and one off-line station at TRANSPO '72 (See below) and successfully operated two, 6-passenger vehicles during the exposition demonstrating lo-second headway operations. For the demonstration and subsequent test program Monocab received about $1.8 million from UMTA and put in about $1 million of their own money. The conmpany has recently developed a 500-foot test track at Chula Vista, California for an advaced vehicle. The vehicle employs a new electrical subsystem which provides propulsion, braking and switching.

Monocab was one of the two suppliers originally favored for the Dallas-Ft. Worth project and received support from UMTA via the airport borad for design studies and tests. They competed for the Morgantown project at an early stage. They were selected for the Las Vegas project but that project was aborted. They were one of the competitors for the Interama project, which was also aborted. They were recently awarded one of the three HPPRT contracts by UMTA.

Rohr Monocab representatives anticipate sales of small systems for special purpose applica t ions such as shopping centers, universities, medical centers, airports and recreational parks. However, high interest rates and other financing difficulties are the main limitation. their outlook for larger installations to serve more general urban needs depends upon action of the Federal Government. They expect the HPPRT program to be the pacing item and to lead to the deployment of the first such system. HPPRT is viewed as a medium capacity transit system potentially usable in Denver, Miami, the Twin Cities, Honolulu, San Juan, San Diego, Los Angeles, Trenton, and Detroit.

Monocab Vehicle at Transpo '72, Dunes Airport, Rohr Industries

The company favors larger expenditures by UMTA on component and subsystem development and on improvement of analytical techniques, as well as the development of a GRT system suitable for near-term use and deployment. They do not feel that companies are going to cost-share R&D programs. They feel that the government should move promptly toward a usable, small-scale demonstration at the end of the 4-year HPPRT development and test program.

Representatives of Rohr Monocab express the view that UMTA research and development must serve as a catalyst, expediting the availability of new systems for the American urban public. New systems must capture the imagination and support of all the players or stake holders in public transit—the rider, the non-rider, the operator, the installer, the equipment suppliers, and the political institutions. The new systems "movement" needs a clear-cut operational success. Automation, for all of the potential good it can provide, has not been proven conclusively to be worth the investment.

Therefore, to bring about urban applications of new systems, the following course is recommended by the company:

1. Implement a two-pronged program which will address the deployment of automated systems both near-term and long-term.

   a. On a component and subsystem basis, upgrade the technology, as required, to bring automated shuttle and loop transit to urban revenue operations status.

   b. On a system basis, proceed with the development of group rapid transit technology emphasizing the critical areas of switching, system reliability, safety, systems management (i.e., vehicle management, maintenance management, scheduling, fare collecting, etc.).

2. Recognize that reluctance for AGT system deployments is related to asthetic and safety issues which must be resolved along with technical and economic questions.

3. Recognize the need for staged urban system deployments in which technical sophistication would increase with each successive phase. Each phase must be self-sufficient and able to satisfy a legitimate transit function. Initial deployment should make use of improved versions of the automated shuttle and loop systems. As demand builds, the system would expand in both area coverage and operational sophistication. Direct link-up of guideway at all nodes is not a mandatory requirement at the outset. Transfers are tolerable. As more sophisticated systems become available, lines could be coupled at transfer points.

The panel has obtained data from a number of other suppliers who have had significant experience with AGT systems. Lack of time has made it impossible to do more than comment briefly on the roles of 8 such firms.

ALDEN SELF TRANSIT SYSTEMS CORPORATION, BEDFORD, MASSACHUSETTS

Alden was one of the pioneers in the PRT field and did much to promote the concept, including development of test vehicles and tracks. Alden was a subcontractor to Boeing in the Morgantown project as a supplier of components. The firm does not have a fully developed system.

THE BENDIX CORPORATION, ANN ARBOR, MICHIGAN

The Bendix Corporation acquired the Dashaveyor Company and its AGT product line in 1971. At least two test tracks have been developed, and the system was one of four demonstrated at TRANSPO '72. One test track and the demonstration received financial support from UMTA totaling about $2 million. The company appears to have withdrawn from the business of supplying AGT systems but remains a supplier of control subsystems. Its Canadian affiliate continues to supply small transit systems for recreation parks.

PULLMAN, INC., CHICAGO, ILLINOIS

Aerial Transit Systems of Nevada, Inc. was formed by Pullman and others with the primary objective of competing for the Las Vegas, Nevada project which has been aborted. A test track and vehicles were developed at Hammond, Indiana. Apparently, the firm is no longer active in the AGT field.

UNIFLO SYSTENS COMPANY, MINNEAPOLIS, MINNESOTA

The Uniflo Systems Company traces its history to 1967. Financial support totaling $2 million has come from Rosemount, Inc., and UMTA supplied $400,000 for component R & D work. The firm has developed test tracks and vehicles and has conducted extensive tests and demonstrations for visitors. They have competed on a number of jobs without success. They submitted a proposal in the HPPRT competition and lost. The company is reported to have stopped AGT business activities.

MOBILITY SYSTEMS AND EQUIPMENT COMPANY, LOS ANGELES, CALIFORNIA

This firm was founded by one of the engineers responsible for the Braniff AGT installation at Love Field. It received a contract in the amount of $225,000 funded by UMTA for work on an AGT propulsion subsystem, Other information is not available.

PRT SYSTEMS CORPORATION, CHICAGO HEIGHTS, ILLINOIS

This firm is presently using the Braniff Love Field AGT installation as a test track for a new vechicle of advanced design. One vehicle is being tested. It employs a new electrical device to achieve magnetic levitation and propulsion. Negotiations are being conducted with several prospective buyers, but no systems are in service.

GENERAL MOTORS CORP., TRANSPORTATION' SYSTEMS DIVISION. WARREN, MICH.

General Motors did work on automated controls for highway vehicles in the late 1950's and began work on AGT systems in the early 1960's. A 4-seat vehicle employing air cushion suspension and linear electric motors was operated on a 20()-foot test track in 1962. A substantial program was conducted during the period until 1966. Total cost was reported to be $4 to $5 million. In 1968, General Motors gave licenses to Transportation Technology, Inc., which later became Otis-

General Motors established a new Transportation Department in the Engineering Staff in 1973 and elevated it to division level in 1975. The Transportation Systems Division was one of three contractors who received $500,000 contracts from UMTA for work on dual-mode buses. That program was aborted by UMTA for lack of funds. The Division is now making a broad study of-public transportation systems but has made no announcements regarding AGT plans, lf any exist.

31CDONNELL DOUGLAS, HUNTINGTON BEACH, CALIF.

The firm has monitored the development of AGT sytems for a numn ber of years. In 1974, McDonnell Douglas announced its interest in joining the Ontario Transportation Development Coporation and the West German firm of Krauss-Maffei in a joint venture to bring the KM magnetic-levitated system to this country. However, extreme difficulties in developing the system for the Toronto Exposition and the resulting cancellation of the project caused McDonnell Douglas to reconsider its position. The firm was prepared to invest up to $20 million in the project. However, the cancellation became effective before McDonnell Douglas invested any funds.

Chapter 6: Summary and Views of Respondents

SYSTEMS IN EXISTENCE

Seventeen AGT systems exist in the United States. Fifteen are relatively simple shuttle and loop transit (SLT) systems. Two are of the group rapid transit (GRT) type. Ten are currently providing service, one is idle, and six are in advanced stages of construction. Six industrial firms and one consortium have supplied the 17 systems. The installations are tabulated on the next page by type of system, supplier, type of application, present status, and location.

Existing AGT Systems

	Airports	Parks	Commercial developments	University communities	Total	Locations
SLT Systems:						
Westinghouse Electric.	2+1[1]	11			4	TamI>a, Fla., Seattle-T:~conq l~"ush., Miami, Fla., Williamsburg, Va.
Universal mobility	,;	+ 1 1			6	Hershey, Pa., Valencia, Calif., Charlotte, N, C., Kings hlill, Ohio, Ashland, Va., Sacramento. ~ Uahf.
Ford.	; [1]	~	11		2	Hartford. Corm.. Dearborn. Mich.
Rohr Monotrain			1 I		2	Houston; Tex., Honolulu, H:lwnii.
Braniff	12				1	l)allas (Love Field), Tex.
GRT Systems:						
Boeing				11	1	Morgantovvr\, W. Va.
LTV	1				1	Dallas/Ft. M orth, Tex.
Total	7	7	2	1	17	

1 In construction. 2 Idle.

S'cate.-These systems employ approximately- 200 automated vehicles or permanently linked trains. They operate over some 35 miles of single-lane, automated guideways or the equivalent of about 17 miles of double guideway route.

Performance.-Speeds are in the range of 8 mph to 35 mph. Capacities are in the range of 600 passengers per hour per direction to 9,000 pphpd.

Patronuge.-Total patronage of AGT systems is believed to be in the range of 120 to 150 million riders to date. When the 17 systems are all fully operational, patronage will be in the order of 50 million riders per year.

Costs of installations.—The cost of AGT installations to their owners and the United States Government plus losses suffered by contractors, where known, totals about $200 million. Of this amount about $75 million is associated with 15 shuttle and loop transit systems and $125 million is associated with the two existing group rapid transit systems—both in the low-technology band of the GRT spectrum. The federal government has made no contributions to the capital costs of the 15 SLT systems. It has contributed about $7.5 million toward the capita] costs of the GRT system at Dallas/Ft. Worth and about $64.2 million on the Morgantown GRT installation including both R & D and capital outlays.

Costs of operations.—Information regarding operating costs is incomplete and of poor quality; however, available data indicate that operation of the 17 systems will require outlays of about $6.5 million per year after shake-downs.

Safety.-The systems in existence have experienced few accidents and only one in which a passenger suffered serious injury. This performance is remarkable when one considers that there are no uniform standards governing the design or operation of the systems.

Availability of Service/Reliability .—The systems differ markedly in their abilities to provide service at all times. Panel members agree that both the Tampa and Sea-Tac systems should be regarded as successful]] in this respect. The systems display these attributes:

- The mean times between failures are only moderately long. For example, at Sea-Tac vehicles experience involuntary stoppages at intervals of about 150 hours on the average.
- The time to restore service is short: about 6 or 7 minutes on the avearge.
- Service is available about 99.9 percent of the time.
- Both systems ems fail gracefully. At Tampa, stoppage of one vehicle has no effect on others. At Sea-Tac failure of one vehicle on a loop has a limited effect on the operation of other vehicles but does not stop service on the loop. Failure of a vehicle on the Sea-Tac shuttle stops service on that link until repaired. An emergency walkway is provided on all Tampa and Sea-Tac routes to guard against immobilizing passengers when a general stoppage occurs as during a power failure. Passengers can always evacuate the vehicle and proceed on the walkway. This evacuation procedure is quite satisfactory for a simple system; however, for a fully developed urban transit system this may not be the best alternative-allowing passengers to proceed on a walkway adjacent to the guideway over the complete length.

It should be noted that neither of the two GRT systems in existence fails as gracefully', and restoration after some failures cannot be accomplished as quickly. Consequently, both system designers found it necessary to seek highly reliable components, For example, vehicles need to achieve mean times between failures of about 1,500 hours-10 times as long as at Sea-Tac-to achieve established standards of service availability. In both systems the need for highly reliable components could have been reduced, to some degree, by design changes. Some opportunities of this type may have been overlooked through haste or inexperience. Others appear to have been omitted in the interest of capital cost savings. For example, neither system provides an emergency walkway.

STUDIES OF POSSIBLE FUTURE APPLICATIONS

The panel identified and obtained data for 36 cases in which public agencies and private interests made studies of AGT applications. A more thorough search would turn up additional cases—perhaps a total of 75 to 100. The capital cost estimates cited in the 36 studies total about $8 billion. A complete survey of the field might double or triple that figure.

Interest exhibited today does not mean that purchases will necessarily be made tomorrow. The panel found no way of estimating the number of projects that will be undertaken, their size or their timing. Inquiries at UMTA yielded no such estimates.

It is clear that the possible exploitation of AGT systems has captured the interest of a great many possible buyers even though information available to officials and planners at the local level has been limited. Almost all of the studies settle on systems at the low end of the technological] scale--SLT or simple GRT systems. The uncertainties regarding availability, cost, and other characteristics of PRT systems account for their exclusion.

METROPOLITAN NETWORKS

The largest systems in prospect would include extensive networks designed to serve entire metropolitan areas. Four studies dealing with the initial stages of such networks describe possible future systems containing about 380 miles of dual guideway and almost 380 stations. Full development would be staged over several decades. Capital cost estimates for the four installations total $6.7 billion. To provide perspective, it may be useful to note that rail rapid transit routes in the United States total about 500 miles and that the WMATA system will add 100 miles to that total at a cost of about $4.5 billion.

The studies display serious concern with the economic, service and other limitations of conventional transit modes—bus and rail rapid transit—and indicate the hope or expectation, based on analysis, that AGT systems will have superior characteristics. The studies show varying degrees of awareness of the differences among system types-–such as SLT, GRT, and PRT in the vocabulary of this report. All appear to recognize that PRT systems involve exploitation of high technology and will not be available for many years until large-scale development and test projects are completed. Some express concern over the economics of PRT. These beliefs tend to focus attention on SLT systems of the types now available and on lower technology systems of the GRT type that could be installed in the near-term.

It is not clear that local agencies concerned with metropolitan networks use objective approaches in choosing between SLT and GRT systems, or in selecting a multi-modal mix of systems most suitable for a particular community.

Natural conservatism coupled with the desire for early action tends to encourage adoption of SLT designs which have records of successful use. However, if decisions must be delayed a few years, as is likely in some cases, the technical risks of GRT systems real' appear lower and the service advantages and other features promised by GRT technology may lead to their adoption.

Corridor applications of AGT systems may be regarded as the initial stage of a metropolitan network. Two cases were examined: the Pittsburgh TERL project and the El Paso/Juarez international link. Their costs would have totalled about $250 million. Neither seems likely to be built. However, the decisions apparently turned on financial and political rather than technical issues. The SLT hardware proposed in each study involves little or no technical risk or uncertainty.

MAJOR ACTIVITY CENTERS

Studies dealing with AGT applications in major activity centers have been conducted in profusion. The panel obtained data from 30 studies:

Type of application:	Number of studies
Airports	9
Central city /CBD.	9
Multiple-purpose developments	8
Medical centers	4
Total	30

These studies dealt almost entirely with low technology systems of the SLT type. This is explained in part by factors of uncertainty discussed above but also by the simplicity of the route structures envisioned which make sophisticated hardware unnecessary,

Again, the panel's search was not exhaustive—several dozen studies of AGT ssstems for major activity centers could probably be added to the list. Estimates are not available for all of the 30 studies but it appears that total capital costs would be on the order of $1 billion.

Many of these studies have been frustrated by financial difficulties, objectives that differ significtintly from those of UMTA, and institutional relationships. Many of these projects serve special functions, i.e., airport circulation, CBD or institutional circulation, etc., and when measured against UMTA objectives for serving the commuters and the disadvantaged, these projects have relatively low priorities. A respondent with considerable experience in the AGT field feels this market should start with the development of AGT systems in major activity centers, and such systems should be expandable outward in such a way that ultimately they can serve both the local and express functions of the transit system. This concept could appear to have substantial merit and could fit nicely with the new UMTA philosophy' of starting with a basic element and adding to it "useable segments".

A PROPER MATCH OF PRODUCT LINES AND MARKETS

There is now considerable evidence that the application of PRT in an established large urban area is a decade or more away. Furthermore, PRT may, be environmentally undesirable in established urban areas. Early applications of SLT or GRT on appropriate routes would forestall further excessive urban sprawl by the encouragement of clustered development in areas ready for urban renewal. Thus, if a major goal for urban transit is to forestall further urban sprawl and its accompanying increased petroleum consumption, then technology efforts should be directed to match SLT and GRT to the needs of existing urbanization and focus any further R & D efforts in PRT on furture new towns where its application can be simplified. The allocation of investments in these technologies should be proportionate to the urban potentials identified above.

SUPPLIERS OF AGT SYSTEMS

The community of suppliers of AGT systems in the United States is headed by six firms that have systems m revenue service and that remain in the business.

	Number of *installations*
1. Westinghouse Electric Corp., Pittsburgh, Pa	4
2. Universal Mobility, Inc., Salt Lake City, Utah	6
3. Rohr Industries, Inc. (Monotrain), Chula Vista. Calif	
4. Ford Motor Co., Dearborn, Mich.	2
5. LTV Aerospace Corp., Dallas, Tex	1
6. Boeing Aerospace Co., Seattle, Wash	1

Other firms with aspirations to be system suppliers but without a record of actual sales of revenue systems are:

1. Otis Elevator Company, Inc. Transportation Technology Division, Denver, Colo.
2. Rohr Industries, Inc. (Monocab), Chula Vista, Calif.
3. Alden Self-Transit Systems Corporation, Bedford, Massachusetts.
4. Bendix Corporation (Dashaveyor), Ann Arbor, Mich.
5. Pullman, Inc. (Aerial Transit,), Las Vegas, Nevada.
6. Uniflo Systems Company, Minneapolis, Minn.
7. Mobility Systems and Equipment Company, Los Angeles, Calif.
8. PRT Systems Corportition (associated with Braniff), Chicago,
9. General Motors Corporation, Transportation Systems Div., Warren, Mich.
10. .McDonnell Douglas, Redondo Beach, California.

Close observers of the industry estimate that privately financed development costs incurred by the entire group total at least $100 million. These companies are suffering severe frustrations in their efforts to do business. Some firms have withdrawn from the field after large expenditures of private funds and years of effort by dedicated staff members. Others appear to be on the verge of withdrawing. Some suppliers observe that there are more AGT suppliers than justified by the market, and complain that UMTA has encouraged firms without transit experience to enter the field while established transit suppliers are finding it necessary to withdraw.

DEFINITION' OF PRODUCT LINES

There is a need for stability and common definitions in the product lines being offered for sale, and for dependable data on costs. This deficiency" leaves suppliers without guidance or reference points in designing new- products and handicaps buyers in making comparisons among products. Suppliers of systems are at a disadvantage because competing products proposed for a particular application often differ in so many respects that buyers find comparisons of products impossible or meaningless. Sellers also complain that they spend substantial amounts on proposals that do not lead to sales by any one.

UNREALISTIC PROCUREMENTS

Local agencies have a record of initiating procurements that are unrealistic with respect to the costs and availability of hardware and that are not supported by a financial plan. Such procurements are often aborted after considerable time and effort has been expended by suppliers and local agencies as well.

.4 CC EPTANCE CRITERIA AND PROCEDURES

There is a need for national level standards, criteria and procedures that can be used to demonstrate that a product has reached "market ready" status. There should be a wa-y to determine with confidence that UMTA will not reject an otherwise sound capital grant application for an AGT system on grounds of technical inadequacy of the project. The same framework needs to be extended to cover final test and buyer acceptance of completed AGT systems. Suppliers cannot write specifications for competitive procurements. Local agencies and consultants often lack experience in the field and are likely to write specifications that are incomplete and ambiguous. Such specifications are costly to satisfy and often prove to be unenforceable in the end.

FEDERAL CONTRIBUTIONS

Federal agencies—mainly UMTA—have aided several of the installations and development programs surveyed by the panel. Instances that came to light are recapitulated here:

- Grants of almost $4.5 million were made to the Port Authorit.~' of Allegheny County to aid in demonstrating the Transit Expressway.
- A grant of $1.0 million was made to the Dallas/Ft. Worth Regional Airport Board in 1970 to support studies and test track developments by two prospective vendors—both of whom were unsuccessful bidders in the end.
- A capital grant of $7.6 million was made to the same Board in 1972 to aid in paying for the Airtrans system.

- R & D studies were funded in the amount of $1.8 million for component developments by four prospective suppliers—Mobility Systems, Uniflo, Pullman and Alden—and related work.
- Approximately $9.7 million was expended by UMTA for demonstrations of four AGT prototype systems at Transpo 72 and for tests conducted thereafter. A second generation design of one of those systems-developed with private funds by Ford-is now being installed at two sites.
- UMTA has contributed about $64 million to the Morgan town project at all stages from technical studies through final deployments and test.

This listing may not include all minor items. The activities identified involve expenditures of about $95 million.

I. ELDERSHIP AND DIRECTION

Suppliers and prospective buyers complain that there is a lack of leadership or direction at the national level regarding the development and deployment of AGT systems. This deficiency is charged most often against agencies of the federal government including the Urban Mass Transportation Administration and other parts of DOT, the Office of Management and Budget, the White House and Congress. The same charge could be lodged against national level professional and trade organizations. Recent formation of a special task force on AGT systems by the American Public Transit Association (APTA) is an encouraging development. Initiative is in long supply at the regional and local level but is not yet focused.

ALTERNATIVE STRATEGIES

There is a need for clear, complete, explicit statements of the strategies to be followed in developing and deploying AGT systems and for definitions of the roles of industry, transit operators, federal, state and !ocal governments and others. Suggestions on these subjects were solicited from system buyers and suppliers and from panel members. Most of the responses can be summarized under four headings:

- The transit industry's "PCC" precedent.
- The industrial standardization process.
- The airworthiness certification procedure.
- The DOD/NASA approach.

THE PCC PRECEDENT

The transit industry has had one outstandingly successful experience in establishing% standards for streetcars. In the mid-1930's readers of the industry met and, with technical aid, established standards for what was called the President's Conference Committee Car. Vehicles of that design are still in use and are known by the acronym "PCC Car". One panel member has suggested that representatives of transit properties in eight or nine cities now studying AGT applications might be able and willing to initiate a new version of that program. The primary objective would be to achieve low costs while obtaining desired systems. Sponsorship and financial support would be needed from agencies such as UMTA, APTA, the Conference of Mayors, the National League of Cities, and the Transportation Research Board. This technique would be workable for relatively simple systems or for the subsystems of more advanced systems. Such systems could be developed by UMTA contractors but if costs are low and markets are assured, might more appropriately be developed by private industry.

STANDARDIZATION

Industrial standardization procedures provide a second approach that has been used with great success in many fields for 50 years. This would be accomplished with the aid of the American National Standards Institute. Their procedures are well established and require the cooperation of all interested parties such as the American Public Transit Association, the Transit Development Corporation, the Transportation Research Board, prospective buyers and suppliers, professional societies and UMTA. Again, this procedure is most suitable for relatively simple systems and for subsystems and components. UMTA could pay the cost of development; but development by industrj' would be feasible, and a mixed approach could be used.

CERT[FICATION

Certification of the airworthiness of new aircraft, as is done by the Federal Aviation Administration, suggests a third alternative. This procedure would place a heavy burden on UMTA to establish standards and to devise acceptance testing procedures. Doubts were expressed by various respondents regarding UMTA'S ability to obtain staff and develo competence to do the job. If aircraft industry practices were forlowed, the procedure would require the supplier to produce a testable prototype system and to operate it in tests specified and monitored by UMTA. The costs of the prototype sj"stem and most of the cost~ of the tests would be borne b~' the supplier.

Bringing a high-technology s~wtem to the point of certification would probabl~' require expenditures comparable to those for a large commercla] aircraft. This burden would probabl~r be unacceptable to all suppliers, at least until a large market is assured, tind could force man~- firms to abandon the field. However, the costs of bringing simple systems and evolutionarjr improvements to the point of certification would be acceptable to several firms. UMTA might encourage evolutionary advances by paying for R&D on advanced subsystems or might share costs in other ways provided that industry would be willing to accept cost-sharing. Industry, however, has become disenchanted with cost-sharing to expedite development of AGT.

NASA AND DOD APPROACH

NASA and DOD procurement practices in developing space exploration systems and weapons systems provide a fourth alternative. Specifications would be prepared and the costs of development and testing would be paid by the government. contractors would do the work under cost-plus, fixed fee contracts but would acquire no formal proprietary rights in products developed entirely under the contract. At the end of a successful development program all suppliers would be allowed to produce the system.

This approach would be attractive if the development of a technically advanced GRT system or a high-technology PRT were given a high national priority. One of the main disadvantages of the approach is that the supplier of the prototype system inevitably achieves a great competitive advantage from experience gained at government expense even though the firm obtains no proprietary rights. Newcomers find it necessary to spend private funds on in-house development or to underprice proposals to catch up.

It appears that UMTA'S HPPRT program will follow this path at least during the four years required to develop and test a prototype. 1f that wort proves satisfactory, the problems of going into production and of establishing multiple sources of supply will remain. The cost of production design, tooling, manufacturing plants and product-testing facilities will be considerable–-perhaps several hundred million dollars. The panel found no well founded estimate of these costs.

It appears that UMTA expects industry to pay the costs needed to carry the HPPRT program forward through production and deployment beyond the end of the four-year prototype development and test program. If present government practices regarding competitive procurements continue to be followed the deployment of the first HPPRT system cannot begin until there are in existence at least two sources of supply. It is hardly conceivable that two or more U.S. firms would make private investments of the magnitude required to produce HPPRT systems without assurances that their products will enjoy large-scale and continuing sales. At present there is no way that UMTA or the potential buyers of such systems can give assurances. Thus, it appears that the UMTA plan for HPPRT is not complete. Something must be added to bridge the gap between final testing of a successful prototype and approval of capital grant applications from local agencies for actual installations of the HPPRT systems.

cLOSURE

Respondents held different view-s regarding the merits of the four alternative development strategies and other matters. Generally, those interested in low-technology systems of the SLT class tended to favor private funding of development and reliance on professional and industrial practices in establishing acceptance standards. Respondents interested in PRT systems and relatively sophisticated GRT systems agree that government financing is needed at least through prototype development and testing.

Statements made by seven respondents are repeated here, with some editorial license, to indicate the diversity of opinions.

1. One school of thought is to encourage only the early exploitation of low-risk technology systems, the development of software and standards, and the development of hardware at the component and subsystem level. It is argued that this evolutionary process will progressively determine the needs for AGT systems and bring forth mlprovements.

2. Another respondent indicates that, to date, AGT systems have been successfully applied to targets of opportunist]", such as an airport, zoo, or an educational institution. The big market is the urban scene where AGT applications should curtail urban sprawl and its resulting increases in gasoline consumption. AGT should encourage clustered development, shorten the length of vehicle trips, and even encourage more walk trips. Ultimately, it should produce transportation with relatively lower operating costs. There is a need to continue developing relatively simple systems. The research and development thrust should be sufficient to carry AGT rapidly into larger urban markets with 'add-on" degrees of sophistication as the technology evolves and is proven suitable for urban deployment.

3. One respondent states that automated guideway transit technology represents UMTA's only investment to date in developing viable alternatives to the conventional modes of urban public transportation. Transit operating losses require government subsidy of $1 for. evey $2 of revenue, yet this problem receives minimal attention in guiding a search for alternatives to conventional transit. In view of todays urban economic, energy and environmental situation the requirement for accelerated UMTA R&D spending is critical. UMTA'S R&D budget size is inadequate in the face of its task and in relation to its overall expenditures.

4. A fourth respondent is quoted as follows: "Based on the results of planning studies of several urban areas, prototypical of the majority of the urban areas in the United States, there has been stated the need for transit options that bridge the gap between traditional rail transit and bus. This transit option would be particularly attractive for the medium density type urban areas and would offer a service level to attract riders from the automobile. The HPPRT project provides an option for this transit need. combined with a well structured technology development program, which could address the total spectrum of AGT technology, UMTA permently has the sole opportunity to guide and stimulate this technological option. "

5. Another respondent, commenting on UMTA's HPPRT program, has suggested that the problem of assuring competition might be overcome by carrying development through the engineering prototype level on two or three different approaches. If the cost for each approach is on the order of $30 million, then three approaches could be execised in prototype form for around $100 million.

6. Others have taken the opposite positiom-that f(lnds for R&D for the HPPRT system should have vcry low priority, and that funds should rather be allocated in greater amounts to Improving systems at Morgantown and Dallas~ Ft. Worth. The same respondents state the view that it would appear that the greatest benefits of the AGT system are in the city, where automobile congestion has become a serious problem and will eventually be nearly' intolerable. This is especially' significant at this time because of the emphasis on energy conservation. With $200" million invested in AGT installations, it is unfortunate that there is no such installation in a city to ascertain feasibility. There should be a concerted effort by the Federal Government, municipalities, and the transportation industry to initiate a first urban application promptly.

7. Still another respondent suggests that the government's role must be to provide leadership and direction in national transportation matters. Industry will respond if the risks and returns are favorable compared to alternative investment opportunities, It is not enough for the federal government to sponsor prototype development and to expect industry. and transit authorities to shoulder the remaining risks and expenses. The uncertainties regarding additional (Development expense and eventual product marketability represent an unacceptable risk to industry'. The deployment of urban people mover (Demonstration programs must be encouraged and sponsored by the government. Only when the social and economic consequences of meaningful deployments are known will the marketability of people movers be established. The government can encourage demonstration programs by offering capital grants to communities with suitable applications. The present cost effectiveness criteria governing capital grants should be relaxed in recognition of the high costs associate(l with early installations and because of such factors as economy of scale andl relative product maturity.

Among the panel members and respondent,s there appears to be considerable agreement that UMTA should indicate clearly what conditions must be met by a supplier and a product to quality for capital grants. There was also wide agreement that the government's role and contributions should be defined regarding research and development on components, subsystems, and systems. Finally, a need is felt for the government to specify what financial aid or assurances of markets it will provide to industry to encourage investments needed to get technically advanced systems into production.

UMTA's authorltly to act on the suggestions made in this report needs to be ascertained. However, it appears that UMTA now has tiuthority. to establish conditions for the qualification of new products for capita] grants and needs only. to act if it chooses to do so. I t appears that the government's role and contributions to the process of selecting and developing hardware-components, subsystems and systems-can be redefined over broad limits by administrative action backed by the appropriation of funds. It appears that the problem of providing financial aid to bring advanced systems into production or of tiss[lring markets for such systems to encourage private investments may be beyond Uhl TA's authority an(l, if such tictions are desired, new legislation nla~~ be reqllired.

APPENDIX

APPENDIX

BIOGRAPHIEX

Members of the Panel on **Current** Developments in the United States

Clark Henderson, Chairman
Staff Scientist
Stanford Research Institute
Menlo Park, California

Mr. Henderson has conducted research on transportation since 1953 and has specialized in urban public transportation systems during the past decade. He was the principal author of *Future* Urban Transportation System prepared for the federal government in 1968. He has conducted studies for local and regional transit agencies and for suplliers of transit systems.

John K. Howell
Transportation Consultant
Gerald D. Hines Interests
Houston, Texas

Mr. Howell was project manager of the Westinghouse Electric Transit Expressway Demonstration Project and directed the Tampa and Sea-Tac Transit Expressway projects. In consulting practice since 1970, he has completed more than 50 transit projects involving planning, engineering, specifications and proposals, economic estimates and evaluations.

John R. Jamieson
Director of Transit Development
Twin Cities Area Metropolitan Transit Commission
St. Paul, Minnesota

Mr. Jamieson has occupied his present position for five years. He has conducted a number of long-range planning studies including technology assessment, optimum systems, and most recently a detailed study of small vehicle fixed guideway systems. Previous experiences included Deputy Federal Highway Administrator, Minnesota Commissioner of Highways and fifteen years in industry in various assignments ranging from field engineering to product development.

Thomas A. Lancaster
Manager of Market Analysis
Rohr Industries, Inc.
Chula Vista, California

Mr. Lancaster is responsible for long-range forecasting, planning and detailed analysis of transit trends at Rohr. Earlier, he was engaged in product development and engineering work with the Bendix Corporation. In 197 1–72 he participated in the President's Commission on Personnel Interchange and served as Deputy Director—Special Projects in UMTA. He is a professional engineer.

Roy Lobosco
Supervisor, Facilities Planning
Port Authority of New York and New Jersey
New York, New York

Mr. Lobosco has been responsible since 196.5 for the program aimed at installation and operation of an AGT system serving Newark International Airport and connecting the terminal with a proposed PATH extension. He has supervised internal planning and the work" of consultants and has negotiated with four potential suppliers regarding all technical and operational features of their proposed systems.

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